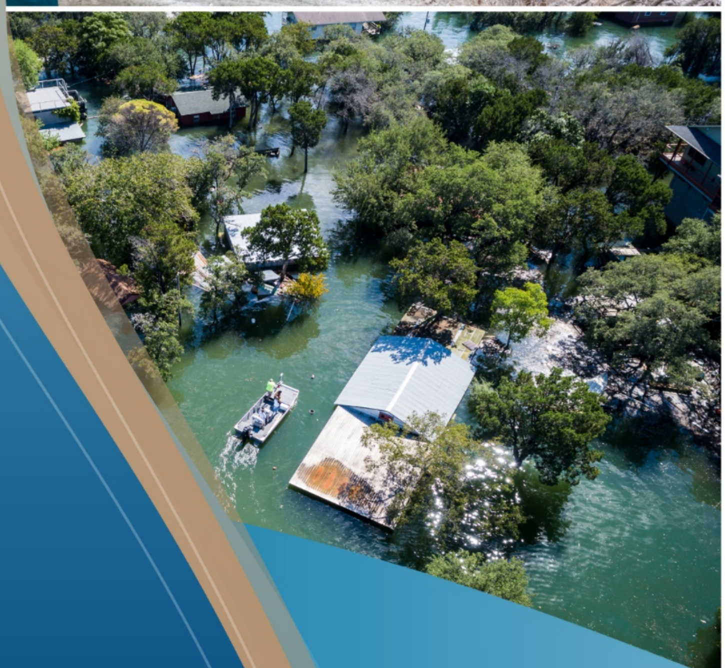
MARCH 2023



WASHINGTON COUNTY, OREGON

NATURAL HAZARD MITIGATION PLAN

U.S. Department of Homeland Security
FEMA Region 10
130 228th Street, SW
Bothell, WA 98021-8627

FEMA

December 4, 2023

The Honorable Kathryn Harrington
At-Large Chair, Washington County Board of Commissioners
155 N. First Avenue
Hillsboro, Oregon 97124

Dear Commissioner Harrington:

On April 18, 2023, the United States Department of Homeland Security's Federal Emergency Management Agency (FEMA) Region 10, approved the Washington County Natural Hazard Mitigation Plan as a multi-jurisdictional local plan as outlined in Code of Federal Regulations Title 44 Part 201. This approval provides the below jurisdictions eligibility to apply for the Robert T. Stafford Disaster Relief and Emergency Assistance Act's Hazard Mitigation Assistance grants projects through April 17, 2028, through your state:

Washington County	City of Hillsboro	City of Tigard
Tualatin Valley Water District	City of North Plains	City of Sherwood
Clean Water Services	Tualatin Hills Park and Recreation District	City of Beaverton
City of Cornelius	City of Forest Grove	

The updated list of approved jurisdictions includes the City of North Plains, City of Sherwood, Clean Water Services, Tualatin Hills Park and Recreation District, and the City of Beaverton that recently adopted the Washington County Natural Hazard Mitigation Plan. FEMA individually evaluates all application requests for funding according to the specific eligibility requirements of the applicable program. Though a specific mitigation activity or project identified in the plan may meet the eligibility requirements, it may not automatically receive approval for FEMA funding under any of the programs.

Approved mitigation plans may be eligible for points under the National Flood Insurance Program's Community Rating System. For additional information regarding the Community Rating System, please visit: www.fema.gov/national-flood-insurance-program-community-rating-system or contact your local floodplain manager.

Over the next five years, we encourage your communities to follow the plan's schedule for monitoring and updating, and to develop further mitigation actions. To continue eligibility, jurisdictions must review, revise as appropriate, and resubmit the plan within five years of the original approval date.

If you have questions regarding your plan's approval or FEMA's mitigation grant programs, please contact Joseph Murray, Planner with Oregon Office of Emergency Management, at (503) 378-2911, who coordinates and administers these efforts for local entities.

Sincerely,

Kristen Meyers, Director
Mitigation Division

Enclosures

cc: Anna Feigum, Oregon Office of Emergency Management

EC:vl

Release Statement

Upon approval by Federal Emergency Management Agency (FEMA) Region 10 and adoption by the participating jurisdictions and special districts within the planning area, the entire document, or any specific part, may be released to the agencies or organizations determined by the Washington County, Oregon, Natural Hazard Mitigation Plan (NHMP) Steering Committee.

Release to the public of the entirety or any part of this document will follow current state and local public information statutes and practices.

Record of Plan Distribution

Table 1: Record of Plan Distribution

Number	Agency	Contact Name	Position/Title	Date

Record of Changes

The 2023 Washington County, Oregon, Multi-Jurisdiction Natural Hazard Mitigation Plan (NHMP) is a dynamic document that is under continual review. The document may be changed administratively under the authority of Washington County Emergency Management, the administrative agency responsible for the update, in coordination with the Steering Committee.

Administrative changes may include:

- Corrections or revisions that clarify context and readability;
- Updates that reflect adopted policy and/or procedures;
- Hazard data and risk information that enhances the current plan; and
- Other authorized changes granted to the administrative agency by the Steering Committee.

It shall be the responsibility of the administrative agency's point of contact (POC) or their designee to maintain this record of changes throughout the current planning cycle.

Table 2: Description of Changes

Section/Page	Description of Change	Authorized by	Date

Executive Summary

Hazard mitigation is any sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects.

The impact of anticipated yet unpredictable natural events can be reduced through holistic planning and implementation of cost-effective, preventive mitigation efforts.

Washington County and its cities and special districts understand that it is not only less costly to reduce vulnerability to disasters than to repeatedly repair damage, but that proactive steps should be taken where possible to protect the economy, environment, and most vulnerable citizens from inevitable natural hazard events.

This NHMP recognizes that local jurisdictions and special districts have the opportunity to address their vulnerability more comprehensively by identifying mitigation strategies during all phases of emergency management (preparedness, mitigation, response, and recovery). Though hazards cannot be eliminated, vulnerability to hazards can be reduced by improving understanding of the natural hazards faced and their potential impacts and by implementing mitigation strategies.

The 2023 NHMP presents the hazard impacts most likely to affect Washington County, including its cities and special districts, and mitigation strategies to reduce or eliminate the most significant vulnerabilities. This update to the 2017 Washington County NHMP adds eight new plan participants and the hazards of dam failure and extreme heat. It also provides updated hazard and risk data and analyses, mitigation strategies, and plan implementation details. The plan provides strategic direction to mitigate hazards and protect people, property, and the environment and increase resilience.

The plan fulfills the requirements of the Federal Disaster Mitigation Act of 2000 (DMA 2000) as administered by the Oregon Department of Emergency Management and FEMA. The project was funded by the Fiscal Year 2019 FEMA Pre-Disaster Mitigation Grant (PDMC-PL-10-OR-2019-002). An Emergency Management Coordinator at the Washington County Department of Land Use and Transportation administered the grant and led the project.

The planning area for this plan is for Washington County, Oregon, and the planning participants include the following jurisdictions and special districts:

- City of Beaverton[1]
- City of Cornelius[2, 3]
- City of Forest Grove[2, 3]
- City of Hillsboro
- City of North Plains[2]
- City of Sherwood[2]

[1] The City of Beaverton NHMP was adopted in 2020. This plan was updated and incorporated into the 2023 Washington County plan as the City's annex.
[2] Did not participate in the 2017 Washington County NHMP.
[3] The cities of Cornelius and Forest Grove had a joint NHMP that was adopted in September 2011. The 2011 plan was updated and incorporated into this plan as separate annexes for the cities.

- City of Tigard
- Clean Water Services[2]
- Tualatin Hills Park & Recreation District[2]
- Tualatin Valley Water District[2]
- Washington County

Figure 1 shows the locations of all participating jurisdictions and the service areas of participating special districts. The unincorporated areas of the county fall under Washington County's purview.

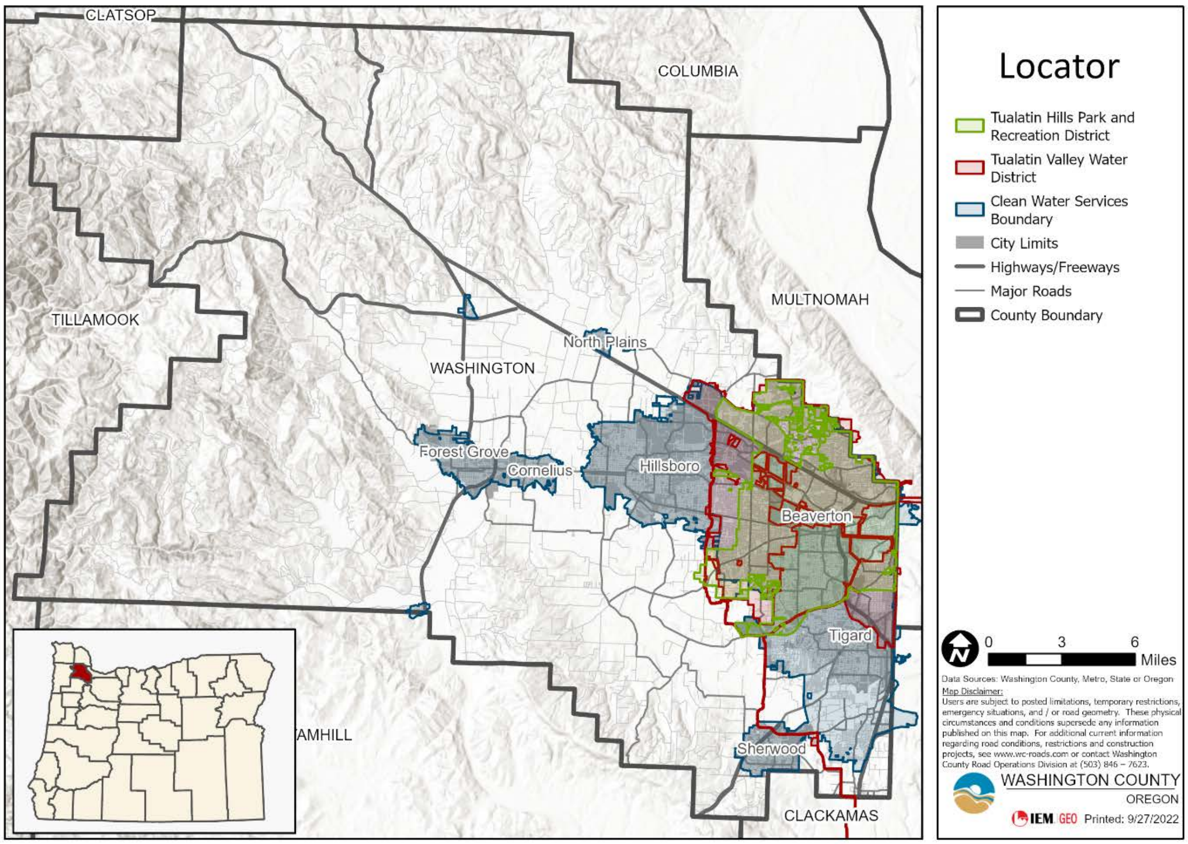


Figure 1: Washington County Natural Hazards Mitigation Plan Planning Area

The NHMP Steering Committee identified the following hazards as impacting the planning area. These hazards are profiled in Volume 1, Section 2 of this plan, and specific hazard risk and vulnerability information unique to each participant is presented in the respective participant annexes. These hazards are shown in alphabetical order and do not represent the probability, vulnerability, or hazard risk rank identified during the planning process.

- Dam failure[4]
- Drought
- Earthquake

[4] New hazard for the 2023 NHMP update

- Extreme heat[5]
- Flooding
- Landslide
- Volcanic ash
- Wildland fire
- Windstorm, including tornado
- Winter storm

Data collection periods during the planning process varied for planning participants, depending on their previous NHMP participation, and are shown in Table 3.

Table 3: Data Collection Periods for Planning Participants

Participant	Data Collection Period	
	From	To
Washington County and the cities of Tigard and Hillsboro	11/1/2016	2/22/2022
City of Beaverton	1/1/2020	2/22/2022
Cities of Cornelius and Forest Grove	9/1/2011	2/22/2022
All other participants	As far back as was available	2/22/2022

The format of this plan is designed to provide a user-friendly source for all hazard information for participants.

- Release Statement
- Record of Plan Distribution
- Record of Changes
- Executive Summary
- Abbreviations and Acronyms
- Table of Contents
- Volume I: Natural Hazards Base Plan
  - Section 1: Introduction
  - Section 2: Hazard Identification and Risk Assessment
  - Section 3: Mitigation Strategy
  - Section 4: Plan Execution, Maintenance, and Adoption
- Volume II: Planning Participant Annexes
  - Annex A: City of Beaverton
  - Annex B: City of Cornelius

[5] New hazard for the 2023 NHMP update

- Annex C: City of Forest Grove
- Annex D: City of Hillsboro
- Annex E: City of North Plains
- Annex F: City of Sherwood
- Annex G: City of Tigard
- Annex H: Clean Water Services
- Annex I: Tualatin Hills Park & Recreation District
- Annex J: Tualatin Valley Water District
- Annex K: Washington County

- Volume III: Appendices
  - Appendix A: Planning Area Profile
  - Appendix B: Planning Process and Public Engagement
  - Appendix C: Implementation Resources and Funding Opportunities

The Washington County 2023 NHMP will be a useful tool for all participants, communities, and their stakeholders for increasing public awareness about local hazards and risks while providing information about options and resources available to reduce those risks. Informing the public about potential hazards will enable informed decision making on where to live, purchase property, or locate businesses and will help each of the jurisdictions and special districts protect themselves against the effects of the identified hazards.

Abbreviations and Acronyms

AEBM	Hazus Advanced Engineering Building Module
APA	Approved Pending Adoption
ARPA	American Rescue Plan Act
ASOS	automated surface observing systems
AWIA	America's Water Infrastructure Act of 2018
BCD	Oregon Building Codes Division
BFE	base flood elevation
BRIC	Building Resilient Infrastructure and Communities Grant Program
CARES	Coronavirus Aid, Relief, and Economic Security Act
CDBG	Community Development Block Grant
CDC	Centers for Disease Control and Prevention
CDC	Community Development Code
CERT	Community Emergency Response Team
CFR	Code of Federal Regulations
CIG	Conservation Innovation Grants
CPAWC	Cooperative Public Agencies of Washington County
CSZ	Cascadia Subduction Zone
CVO	United States Geological Survey-Cascades Volcano Observatory
CWPP	community wildfire protection plan
CWS	Clean Water Services
DLCD	Oregon Department of Land Conservation and Development
DMA 2000	Disaster Mitigation Act of 2000
DOGAMI	Oregon Department of Geology and Mineral Industries
DOT	Department of Transportation
DR	Major federal disaster declaration
DSCI	Drought Severity and Coverage Index
EAP	emergency action plan
EM	Federal emergency declaration
EMC	Washington County Emergency Management Cooperative
EMPG	Emergency Management Performance Grant
ENSO	El Niño Southern Oscillation
ERP	Emergency Response Plan

ERT Emergency Response Team

EO Executive Order

EPA Environmental Protection Agency

FEMA Federal Emergency Management Agency

FIRM Flood Insurance Rate Map

FM Federal fire management assistance declaration

FMA Flood Mitigation Assistance

FPA floodplain administrator

FWS Fish and Wildlife Service

G acceleration due to gravity

GIS geographic information system

HAZMAT hazardous materials

Hazus-MH Hazards U.S. Multi-Hazard software

HMA Hazard Mitigation Assistance

HMPG Hazard Mitigation Grant Program

HOA Home Owners Association

HUD Housing and Urban Development (Department of)

HVAC heating, ventilation, and air conditioning system

ISO Insurance Services Office

JWC Joint Water Commission

MGD million gallons per day

MM Modified Mercalli Intensity Scale

MPH miles per hour

NEHRP National Earthquake Hazards Reduction Program

NEPA National Environmental Policy Act

NFP National Fire Plan

NFIA National Flood Insurance Act

NFIP National Flood Insurance Program

NHMP Natural Hazard Mitigation Plan, Washington County, Oregon Multi-Jurisdiction Natural Hazard Mitigation Plan

NID National Inventory of Dams

NOAA National Oceanic and Atmospheric Administration

NPS National Park Service

NRCS National Resources Conservation Service

NSF National Science Foundation

NWS National Weather Service

ODF Oregon Department of Forestry

OEM	Oregon Department of Emergency Management
ORWARN	Oregon Water/Wastewater Agency Response Network
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
P	primary seismic waves
PA	Public Assistance
PDM	Pre-Disaster Mitigation Grant Program
PGA	peak ground acceleration
PG&E	Pacific Gas and Electric Company
PNW	Pacific Northwest region of the United States, which includes Washington County
POC	**p**oint of contact
RDPO	Regional Disaster Preparedness Organization
RFO	Regulatory Floodplain Overlay
RL	repetitive loss property
RWPC	Regional Water Providers Consortium
S	secondary seismic waves
SBA	Small Business Administration
SBA EIDL	Small Business Administration Economic Injury Disaster Loan
SCADA	supervisory control and data acquisition software
SFHA	Special Flood Hazard Area
SFIP	Standard Flood Insurance Policy
SHMO	state hazard mitigation officer
SRL	severe repetitive loss property
SWSI	Surface Water Supply Index from the Natural Resources Conservation Service
TMDL	total maximum daily load
THPRD	Tualatin Hills Park & Recreation District
TVF&R	Tualatin Valley Fire and Rescue
TVWD	Tualatin Valley Water District
URM	unreinforced masonry structures
USACE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
VEI	Volcanic Explosivity Index
WUI	Wildland-urban interface
WWSP	Willamette Water Supply Program
WWSS	Willamette Water Supply System
°F	Degrees Fahrenheit

Table of Contents

MARCH 2023

Volume I: Natural Hazards Base Plan

1. Introduction

Code of Federal Regulations (CFR) Title 44, Part 201.6 (44 CFR §201.6) Requirements

- **§201.6(c)(3)(i):** [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.
- **§201.6(c)(4)(i):** [The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.

What is Hazard Mitigation?

- Mitigation is commonly defined as sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. Hazard mitigation focuses attention and resources on policies and actions that will produce benefits over time.
- A mitigation plan states the specific courses of action that participants intend to follow to reduce vulnerability and exposure to future hazard events. These plans are formulated through a systematic process centered on the participation of individuals, businesses, public officials, and other stakeholders.
- A local hazard mitigation plan documents the jurisdiction’s commitment to reduce risks from natural hazards. Local officials can refer to the plan in their day-to-day activities and in decisions regarding regulations and ordinances, granting permits, and funding capital improvements and other community initiatives. Additionally, local plans serve as the basis for states to prioritize grant funding.

To reduce the nation’s mounting natural disaster losses, the United States Congress passed the Disaster Mitigation Act of 2000 (DMA 2000) to amend the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) of 1988. Section 322 of DMA 2000 emphasizes the need for state and local government entities to closely coordinate mitigation planning activities and makes the development of a hazard mitigation plan a specific eligibility requirement for any local government applying for federal mitigation grant funds. These funds include the Hazard Mitigation Grant Program, and the Building Resilient Infrastructure and Communities grant program (formerly known as the Pre-Disaster Mitigation grant program) administered by the Federal Emergency Management Agency (FEMA) under the Department of Homeland Security. Communities with an adopted and federally approved hazard mitigation plan thereby become pre-positioned and more apt to receive available mitigation funds before and after the next disaster strikes.

1.1. Overview

Local hazard mitigation planning is the process of organizing community resources, identifying and assessing hazard risks, and determining how to best minimize or manage those risks. This process results in a hazard mitigation plan that identifies specific mitigation actions, each designed to achieve both short-term planning objectives and a long-term risk reduction. To ensure the functionality of each mitigation action, responsibility is assigned to a specific individual, department, or agency along with a schedule for its implementation. The plan maintenance process and procedures are established with an eye toward developing an ongoing assessment and monitoring of implementation progress, as well as the evaluation and enhancement of the mitigation plan itself. These plan maintenance procedures ensure the plan remains a current, dynamic, and effective planning document over time.

Mitigation planning offers many benefits, including the following:

- Awareness of risks and vulnerabilities for decision makers, planners, and the public.
- Saving lives, property, environments, and money.
- Reduction of hazard impacts and faster recovery following disasters, which enhances resilience.
- Creation of strong community partnerships across sectors and with the public.
- Reduction of future vulnerability through wise development and post-disaster recovery and reconstruction.
- Expediting the receipt of pre-disaster and post-disaster grant funding.
- Integration of mitigation actions into other local planning efforts, goals, and initiatives.

The 2023 NHMP has been prepared in coordination with the offices of FEMA Region 10 and the Oregon Department of Emergency Management (OEM) to ensure that it meets all applicable DMA 2000 and state requirements. A Local Mitigation Plan Review Tool, found in Volume III, Appendix B, provides a summary of federal minimum planning standards, and notes the location in this plan where each requirement is met.

1.2. Background

The most recent update of the Washington County NHMP was adopted in 2017. The 2017 Washington County NHMP participants included the cities of Hillsboro and Tigard. and was adopted by the Washington County Board of County Commissioners on November 22, 2016. The city of Beaverton updated its NHMP in 2020, and it was adopted by the Beaverton City Council on April 28, 2020. The city of Beaverton opted to join the 2023 Washington County NHMP update as did seven other new participants, for a total of eight new participants. This update adds dam failure and extreme heat as hazards that impact the planning area.

1.3. Purpose

Hazard mitigation plans are prepared and adopted by communities with the primary purpose of identifying, assessing, and reducing long-term risk to life and property from hazard events. Effective mitigation planning can break the cycle of disaster damage, reconstruction, and repeated damage by natural hazards in the following ways:

- Identifying how a community will work together to reduce risks which will protect life, safety, and property by reducing the potential for future damages and economic losses that result from all hazards.
- Improve public awareness of the need for individual preparedness and building safer, more disaster-resilient communities.
- Make communities safer places to live, work, and play.
- Qualify for grant funding in both the pre-disaster and post-disaster environments.
- Develop strategies for long-term community sustainability during community disasters, which will speed recovery and redevelopment following future disaster events.
- Demonstrate a firm local commitment to hazard mitigation principles.
- Comply with state and federal requirements for local multi-jurisdictional hazard mitigation plans.

1.4. Authority and Guidance

This plan was prepared in compliance with Section 322 of the Stafford Act, 42 U.S.C. 5165, as amended by Section 104 of the DMA 2000. Local mitigation planning requirements are codified in the Code of Federal Regulations (CFR) Title 44, Part 201.6 (44 CFR §201.6), Local Mitigation Plans. DMA 2000 specifies requirements for local governments to undertake a risk-based approach to reducing the impacts and consequences from natural hazards through mitigation planning. In addition, DMA 2000 requires that local plans be updated every five years, with each planning cycle requiring a complete review, revision, and approval of the plan by the state and FEMA.

The plan shall be routinely monitored, evaluated, and revised to maintain compliance with the following provisions, rules, and legislation:

- Section 322, Mitigation Planning, of the Stafford Act, as enacted by Section 104 of the DMA 2000 (Public Law 106-390); and
- FEMA's Interim Final Rule published in the Federal Register on February 26, 2002, 44 CFR §201.

The method and schedule for plan maintenance is provided in additional detail in Volume I, Section 4.

1.5. Applicability and Scope

The scope of this NHMP encompasses all participating entities in Washington County, as noted in the Executive Summary. This plan identifies natural hazards that could threaten life, property, and the environment throughout the County. The scope of this plan includes both short- and long-term mitigation strategies, implementation strategies, and possible sources of project funding to mitigate identified hazards. This plan complements and is consistent with the 2020 State of Oregon Natural Hazard Mitigation Plan (2020 Oregon NHMP) and builds on and updates the 2017 Washington County NHMP.

The information provided in the Hazard Identification and Risk Assessment (Volume I, Section 2) reflects the impact of the hazards on all of Washington County, not solely the participating entities. Additionally, the historical events documented in Volume I, Section 2 reflect the events that impacted the entire county, not solely the unincorporated areas of the County. Participant-specific vulnerability analyses, risk assessments, and historical events are in the individual participant annexes.

1.6. Policy Framework for Natural Hazards Planning in Oregon

Planning for natural hazards is an integral element of Oregon's statewide land use planning program, which began in 1973. All Oregon cities and counties have comprehensive plans and implementing ordinances that are required to comply with the statewide planning goals. The challenge faced by state and local governments is to keep this network of local plans coordinated in response to the changing conditions and needs of Oregon communities.

The Oregon Statewide Land Use Planning Goal 7, Areas Subject to Natural Hazards, calls for local plans to include inventories, policies, and ordinances to guide development in hazard areas. Planning Goal 7, along with other land use planning goals, has helped reduce losses from natural hazards. Through risk identification and the recommendation of risk reduction actions, the 2023 NHMP aligns with the goals of the comprehensive plans for Washington County and all participating cities, and the Tualatin Valley Water District Master Plan, and helps all participants meet the requirements of Planning Goal 7.

The primary responsibility for the development and implementation of risk reduction strategies and policies lies with local jurisdictions. However, resources exist at the state and federal levels. Some of the key agencies at these levels include OEM, Oregon Building Codes Division, Oregon Department of

Forestry (ODF), Oregon Department of Geology and Mineral Industries (DOGAMI), and the Department of Land Conservation and Development.

1.7. Plan Development and Update Process

This plan update was facilitated, written, and completed in collaboration with the contracting firm IEM. The project was funded by Fiscal Year 2019 FEMA Pre-Disaster Mitigation Grant (PDMC-PL-10-OR-2019-002). The grant was administered, and the project led by, an Emergency Management Coordinator at the Washington County Department of Land Use and Transportation. Additional information about the plan development and update process, including public engagement opportunities and outcomes, is in Volume III, Appendix B.

1.8. Mitigation Goals

The Steering Committee reviewed and evaluated goals from the 2017 Washington County NHMP, 2020 city of Beaverton NHMP, 2011 NHMP for the cities of Cornelius and Forest Grove, and 2020 Oregon NHMP. The goals from each plan were grouped by topic and then synthesized to create the seven goals below. These goals are the basis of this plan and summarize what the Steering Committee will accomplish by implementing this plan.

1. Develop and implement strategies to minimize loss of life, public and private property damage, and damage and disruption of essential infrastructure from the impact of natural hazards while protecting and restoring the environment.
2. Ensure effective implementation of mitigation strategies and increased success in receiving funding. This includes:
    a. Develop and maintain partnerships and promote mitigation leadership within local and regional public agencies; the public; non-profit organizations; and businesses.
    b. Ensure consistency between city, county, regional, and state mitigation strategies.
    c. Consistently seek diverse funding and resource partnerships for future mitigation efforts.
3. Develop and implement natural hazard education and outreach programs to increase awareness, engagement, and partnership among the public; local, city, and regional agencies; nonprofit organizations; and businesses. Includes:
    a. Engage and motivate the public to invest in natural hazard risk reduction policies and projects.
    b. Motivate the “whole community” to build resilience and mitigate against the effects of natural hazards through engagement, listening, learning, information-sharing, and funding opportunities.
4. Support the adoption and application of development policies and standards that address the potential impacts of natural disasters and prevent development within mapped hazardous areas where risks to people and property cannot be practicably mitigated.
5. Enhance communication, collaboration, and coordination among agencies at all levels of government and the private sector to mitigate natural hazard risks.
6. Integrate and align hazard mitigation strategies with local comprehensive plans, climate adaptation efforts, and emergency operations plans and procedures, when possible.
7. Enhance the ability of the economies of Washington County and its jurisdiction to rebound quickly from natural hazard events, by strengthening emergency operations including increasing communication, collaboration, and coordination among public agencies, non-profit organizations, and businesses. Includes mitigating the inequitable impacts of natural hazards by prioritizing and directing resources and investments to build resilience in the most vulnerable populations and the communities least able to respond and recover.

1.9. Plan Organization, Format, and Content

The NHMP is organized into three volumes that satisfy the mitigation requirements in 44 CFR §201.6. Volume I has four sections, each participant annex in Volume II has six sections, and Volume III has three appendices containing supporting documentation.

Volume I

The following sections are included in Volume I:

- Section 1: Introduction
  - Describes the purpose of the NHMP and introduces the mitigation planning process.
- Section 2: Hazard Identification and Risk Assessment
  - Describes the hazards identified, location of hazards, previous events, and jurisdictional profiles, satisfying the requirements under 44 CFR Parts 201.6(c)(2)(i) and 201.6(c)(2)(ii).
- Section 3: Mitigation Strategy
  - Reflects on the mitigation actions previously identified and examines the ability of participating entities to implement and manage a comprehensive mitigation strategy, satisfying the requirements under 44 CFR Parts 201.6(b)(3), 201.6(c)(1), 201.6(c)(3)(i), 201.6(c)(3)(ii), 201.6(c)(3)(iii), 201.6(c)(3)(iv), and 201.6(c)(4)(ii), and
- Section 4: Plan Execution, Maintenance, and Adoption
  - Describes strategies for monitoring, evaluating, and updating plans; NHMP incorporation into other plans and policies; and future public updates for each participating jurisdiction, satisfying the requirements under 44 CFR Parts 201.6(c)(4)(i), 201.6(c)(4)(ii), and 201.6(c)(4)(iii).

Volume II

Volume II includes eleven participant annexes. Each participant annex contains six sections that satisfy the requirements under 44 CFR Parts 201.6(b)(1), 201.6(b)(2), 201.6(b)(3), 201.6(c)(1), 201.6(c)(2)(i), 201.6(c)(2)(ii), 201.6(c)(4)(i), and 201.6(c)(4)(iii).

- Section 1: Introduction
- Section 2: Planning Process
- Section 3: Hazard Identification and Risk Assessment
- Section 4: Capability Assessment
- Section 5: Mitigation Strategy
- Section 6: Action Items

Volume III

Volume III comprises the following three appendices:

- Appendix A: Planning Area Profile
- Appendix B: Planning Process and Public Engagement

  - Describes the planning process and organization for each participating jurisdiction, satisfying the requirements of 44 CFR Parts 201.6(b)(1), 201.6(b)(2), 201.6(b)(3), 201.6(c)(1), 201.6(c)(4)(i), and 201.6(c)(4)(iii).

- Appendix C: Implementation Resources and Funding Opportunities

1.10. Maintenance Process

The Steering Committee, consisting of a representative from each participating jurisdiction and special district, will continue to collaborate as a planning group in coordination with the Washington County NHMP Project Manager. Primary contact will be through emails and conference calls, with strategy meetings occurring at least annually and following a disaster declaration for natural hazards covered in this plan for any planning participants. The Steering Committee points of contact for the participants will jointly lead the plan maintenance and update process by:

- Discussing methods for continued public involvement and education;
- Documenting successes and lessons learned;
- Researching new or updated data, laws, policies, regulations, or initiatives that can contribute to hazard histories, risk assessments, loss estimates, vulnerabilities of assets, or action items for plan participants;
- Reviewing potential funding availability, including state and federal grant program Notices of Funding Opportunities;
- Assessing the progress of previously implemented actions that reduce vulnerability and losses, and any new opportunities for mitigation actions; and
- Maintaining and completing documentation of the NHMP maintenance process.

Each Steering Committee member is responsible for monitoring and tracking the progress of action items identified by their jurisdiction or special district in this NHMP and submitting a status summary to the County's project manager biannually using the action item planning document.

Additionally, each Steering Committee member will work with their Technical Committee and other jurisdictional or special district representatives to:

- Review existing action items to determine appropriateness for local funding;
- Prioritize potential mitigation projects; and
- Update decision makers on progress of the plan.

1.11. Plan Approval and Adoption Process

Once the NHMP has received FEMA Approvable Pending Adoption (APA) status, each participating jurisdiction or special district will take the plan to their governing body for final public comment and adoption. A copy of each adoption resolution will be inserted into Volume III, Appendix B and held on file at FEMA, OEM, and the Washington County Emergency Management Office.

2. Hazard Identification and Risk Assessment

Significant Changes

- Detailed information on the OEM hazard analysis methodology included.
- Dam failure, extreme heat, and wildfire smoke added as hazards impacting the planning area.
- Disaster declarations expanded to include federal, state, and local declarations.
- Summary table of participant hazard risk scores for all hazards added.
- Information on characteristics, location, extent, history, probability of future events, vulnerabilities, and how climate change may impact frequency and or intensity added for all natural hazards in the planning area.
- Updated all tables and figures to reflect current information.
- Inclusion of additional maps and graphics showing hazard information.
- Drought hazard profile expanded to include ecological drought, cascading hazards and impacts, and measure of drought extent.
- Earthquake hazard profile expanded to include information about liquefaction and coseismic landslides. Information about the Portland Hills, Gales Creek, and Beaverton fault zones and Hazus®-MH event scenarios with damage data for these faults added to the hazard profile.
- Flooding hazard profile expanded to include streambank and riverbed erosion and channel migration.
- Volcano hazard profile streamlined to focus on volcanic ash.
- Wildfire smoke impacts included in wildfire hazard profile.
- Enhanced Fujita scale added to illustrate extent of tornadoes in windstorm, including tornado hazard profile.

CFR 44 §201.6 Requirements

- **§201.6(c)(2)(i):** [The risk assessment shall include a] description of the type, location, and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.
- **§201.6(c)(2)(ii):** [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008, must also address NFIP [National Flood Insurance Program] insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of:
  - **§201.6(c)(2)(ii)(A):** The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas.
  - **§201.6(c)(2)(ii)(B):** An estimate of the potential dollar losses to vulnerable structures identified in…this section and a description of the methodology used to prepare the estimate.
  - **§201.6(c)(2)(ii)(C):** Providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.
- **§201.6(d)(3):** A local jurisdiction must review and revise its plan to reflect changes in development, progress in local mitigation efforts, and changes in priorities, and resubmit it for approval within 5 years in order to continue to be eligible for mitigation project grant funding.

2.1. Risk Assessment Overview

Completing a natural hazard mitigation risk assessment allows planning participants to identify and characterize hazards that can impact them and determine what populations, built environment infrastructure, and systems are most vulnerable to each hazard. The risk assessment provides the factual basis for the mitigation strategy, including the mitigation action items, identified by each plan participant that will reduce losses from identified hazards. The assessment process consisted of three phases conducted sequentially, as each phase builds on data from prior phases.

- **Phase 1:** Phase 1 includes identification of natural hazards that can impact the jurisdiction. This includes an evaluation of potential hazard impacts, including type, location, and extent.
- **Phase 2:** Phase 2 includes identification of important community assets and system vulnerabilities. Example vulnerabilities include populations, economies, existing and future structures, agriculture land and property, critical facilities and infrastructure, natural environment, and changes due to climate change.
- **Phase 3:** Phase 3 includes evaluation of the extent to which the identified hazards overlap with, or impact, the important assets identified by the community.

Each hazard profile in this section contains an analysis of hazard characteristics, hazard history, probability of future events, vulnerability assessment, and a Hazard Risk Score Summary.

This risk assessment applies to all plan participants. Relevant participant-specific risk information is in the participant annexes. This section supports the Oregon Statewide Planning Goal 7, Areas Subject to Natural Disasters and Hazards by evaluating the risk to people and property from natural hazards.

The information presented below, along with information presented in Volume III, Appendix A: Planning Area Profile, is used to inform the risk reduction actions identified in Volume I, Section 3: Mitigation Strategy.

2.2. Hazard Analysis Methodology

OEM created a hazard analysis methodology to examine hazard vulnerability and probability by collecting information about the four rating criteria of history, vulnerability, maximum threat, and probability for each hazard that impacts the communities in the planning area.

The 2017 NHMP used the OEM methodology, and for this 2023 update, the Steering Committee chose to use this methodology again to provide consistency and continuity from plan to plan. The vast majority of local NHMPs and the Oregon NHMP use this methodology, which allows comparison of the same hazard across jurisdictions statewide. This methodology does not compare hazards to each other or rank hazards against one another. Instead, this process provides a sense of hazard priorities or relative risk and allows comparison of the same hazard across participants. It provides planning participants with a sense of hazard priorities, or relative risk. By doing this analysis, mitigation can focus on the greatest risk. While hazards occur together or as a consequence of others (e.g., dam failure may cause flooding and earthquakes may cause landslides), participants considered hazards as a singular event for the purposes of rating.

This hazard analysis methodology can:

- Help establish priorities for planning, capability development, and hazard mitigation;
- Serve as a tool in the identification of hazard mitigation measures;
- Be one tool in conducting a hazard-based needs analysis;
- Serve to educate the public and public officials about hazards and vulnerabilities; and

- Help communities make objective judgments about acceptable risk.

Each of the hazards examined by this analysis was scored using a formula that incorporates the four rating criteria, a weight factor, and three levels of severity: low, medium, and high. For every hazard, scores for the four rating criteria are determined by multiplying each criterion's severity rating by its weight factor. The rating criteria scores for the hazard are then summed to provide a total score for that hazard. The methodology produces scores that range from 24 (lowest possible) to 240 (highest possible).

Vulnerability and probability are the two key components of the methodology. Vulnerability examines both typical and maximum credible events and accounts for approximately 60% of the total score. Probability endeavors to reflect how physical changes in the jurisdiction and scientific research modify the historical record for each hazard and accounts for approximately 40% of the total score.

Definitions and values for the ratings and severity criteria and weight factors are explained below.

2.2.1. Severity Ratings

Severity ratings are applied to the four categories of history, vulnerability, maximum threat, and probability. The severity rating scales are unique to each category and are provided below.

- **Low:** Choose the most appropriate number between 1 and 3 points.
- **Medium:** Choose the most appropriate number between 4 and 7 points.
- **High:** Choose the most appropriate number between 8 and 10 points.

2.2.2. History

History is the record of previous occurrences and has a weight factor of two. Events to include in assessing the history of a hazard are events for which the following types of activities were required:

- The emergency operations center (EOC) or alternate EOC was activated.
- Three or more emergency operations plan functions were implemented.
- An extraordinary multijurisdictional response was required.
- A local emergency was declared.

A severity rating is applied based on the following:

- **Low:** 0–1 event in the past 100 years scores between 1 and 3 points.
- **Medium:** 2–3 events in the past 100 years scores between 4 and 7 points.
- **High:** 2–3 events in the past 100 years scores between 8 and 10 points.

2.2.3. Vulnerability

Vulnerability is the percentage of population and property likely to be affected under an average occurrence of the hazard. It has a weight factor of five. A severity rating is applied based on the following:

- **Low:** < 1% affected scores between 1 and 3 points.
- **Medium:** 1% to 10% affected scores between 4 and 7 points.
- **High:** > 10% affected scores between 8 and 10 points.

2.2.4. Maximum Threat

Maximum threat is the highest percentage of population and property that could be impacted under a worst-case scenario. It has a weight factor of 10. A severity rating is applied based on the following:

- **Low:** < 5% affected scores between 1 and 3 points.
- **Medium:** 5% to 25% affected scores between 4 and 7 points.
- **High:** > 25% affected scores between 8 and 10 points.

2.2.5. Probability

Probability is the likelihood of future occurrence within a specified period of time and has a weight factor of seven. A severity rating is applied based on the following:

- **Low:** One incident likely within 75 to 100 years scores between 1 and 3 points.
- **Medium:** One incident likely within 35 to 75 years scores between 4 and 7 points.
- **High:** One incident likely within 10 to 35 years scores between 8 and 10 points.

2.3. Hazards Identified

Through an assessment of previous federally declared disasters in Washington County, historical events and potential events in the County, and a review of available local mitigation action plans, the NHMP Steering Committee determined this plan will address the risks associated with the following 10 natural hazards:

- Dam failure[6]
- Drought
- Earthquake
- Extreme heat[6]
- Flooding
- Landslide
- Volcanic ash
- Wildland fire
- Windstorm, including tornado
- Winter storm

Summary information and risk assessments for each of these hazards is presented in Volume I, Section 2.7. Specific hazard risk and vulnerability information unique to each participant is presented in the participant annexes. These hazards are shown in alphabetical order and do not represent the probability, vulnerability, or hazard risk rank identified during the planning process.

The timeframe of the data collected during the planning process varied for planning participants depending on their previous NHMP participation and is reflected in Table 4 below.

[6] New hazard for the 2023 NHMP update

Table 4: Timeframe of Data Collected for Planning Participants

Participant	Timeframe of Data Collected	
	From	To
Washington County and the cities of Tigard and Hillsboro	11/1/2016	2/22/2022
City of Beaverton	1/1/2020	2/22/2022
Cities of Cornelius and Forest Grove	9/1/2011	2/22/2022
All other participants	As far back as was available	2/22/2022

The timeframe for county-level data and information, including disaster declarations, demographics, and hazard event history, is from November 1, 2016 to February 22, 2022.

2.4. Disaster Declaration History

Since the adoption of the most recent NHMP, Washington County has been a part of four federal disaster declarations, eight Oregon disaster declarations, and two local disaster declarations. A review of federal and local disaster declarations and emergency executive orders issued by the Oregon governor since November 1, 2016, shows that wildfire, winter storm, and extreme heat events are the main hazards that significantly impacted the County.

Table 5: Federal Disaster Declarations Including Washington County Since November 1, 2016[7]

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories*
		From	To			
Major Federal Disaster Declarations (DR) Including Washington County Since November 1, 2016						
DR-4562	9/15/2020	9/7/2020	11/3/2020	Wildfire and Straight-line Winds	No	B
Federal Fire Management Assistance Declarations (FM) Including Washington County Since November 1, 2016						
FM-5371	9/10/2020	9/8/2020	9/15/2020	Wildfire	None	B
FM-5358	9/8/2020	9/8/2020	9/14/2020	Wildfire	None	B
Federal Emergency Declarations (EM) Including Washington County Since November 1, 2016						
EM-3542	9/10/2020	9/8/2020	9/15/2020	Wildfires	None	B

* Eligible work in Public Assistance Category B is emergency protective measures that must be completed within six months. Eligible work must be required as a result of the declared incident, be located in the designated area, be the legal responsibility of the applicant, and be undertaken at a reasonable cost.

[7] Federal Emergency Management Agency. (2022). Declared Disasters. https://www.fema.gov/disaster/declarations

Table 6: Governor Executive Orders Declaring State of Emergency Including Washington County Since November 1, 2016[8]

Declaration Number	Declaration Date(s)	Incident Period		Incident	Individual Assistance	Public Assistance
		From	To			
EO-21-37	12/23/2021	12/23/2021	1/3/2022	Severe Winter Storm	Statewide	No
EO-21-27	8/10/2021	8/10/2021	8/20/2021	Extreme Heat	Statewide	No
EO-21-26	7/29/2021	7/29/2021	8/5/2021	Extreme Heat	No	No
EO-21-02	2/13/2021	2/11/2021	2/18/2021	Severe Winter Storm, High Winds, Flooding, and Landslides	No	No
EO-20-43	9/14/2020	9/8/2020	9/14/2020	Invocation of Emergency Conflagration Act for the Powerline Fire	No	No
EO-20-41	9/9/2020	9/8/2020	11/1/2020	Invocation of Emergency Conflagration Act	Statewide	No
EO-17-06	4/13/2017	1/11/2017	3/20/2017	Severe Winter Storm, High Winds, Flooding, and Landslides	No	No
EO-17-02	4/13/2017	1/11/2017	2/1/2017	Severe Winter Storm, High Winds, Flooding, and Landslides	Statewide	No

Table 7: Local Disaster Declarations and Resolutions in Washington County Since November 1, 2016[9]

Participants	Declaration Date	Incident Period		Incident
		From	To	
Washington County	2/13/2021	2/12/2021	2/13/2021	Severe Winter Storm
Washington County	9/11/2020	9/8/2020	9/29/2020	Two concurrent wildfires: Powerline–Henry Hagg Lake–Cherry Grove wildfire (Powerline wildfire) and Chehalem Mountain–Bald Peak wildfire

[8] Office of Oregon Governor. (n.d.). Executive Orders. https://www.oregon.gov/gov/Pages/executive-orders.aspx
[9] 2023 NHMP Participant Planning Documentation

2.5. Vulnerability Assessments

A detailed community profile, which includes information on the vulnerabilities below, is in Volume III, Appendix A. Participant-specific information and vulnerabilities are identified in the annexes, as appropriate, and include:

- Populations
- Economies
- Structures (existing and future)
- Improved property
- Critical facilities and infrastructure
- Natural environment

Changes in development for participants with previous mitigation plans are described in participant annexes, as applicable. This includes information about increases and decreases in vulnerability and changes in priorities, as appropriate.

2.6. Summary of Participant Hazard Risk Scores

Based on the risk assessment methodology outlined in Section 2.2, each NHMP participant assigned a risk score to each of the hazards identified in this plan. Each of the hazards examined by this analysis was scored using a formula that incorporates the four rating criteria, a weight factor, and three levels of severity: low, medium, and high. The score range for this methodology is 24 (lowest possible) to 240 (highest possible).

Table 8: Summary of Participant Hazard Risk Scores

Participant	Hazard Risk Score										
	Dam Failure	Drought	Earthquake: Cascadia (3–5-minute event)	Earthquake: Crustal (1-minute event)	Extreme Heat	Flooding	Landslide	Volcanic Ash	Wildland Fire	Windstorm, Including Tornado	Winter Storm
City of Beaverton	–	198	196	196	212	188	86	178	–	208	203
City of Cornelius	83	186	201	201	148	48	118	99	240	240	240
City of Forest Grove	83	186	201	201	148	48	118	99	240	240	240
City of Hillsboro	81	184	201	201	179	159	34	126	177	205	205
City of North Plains	56	170	201	71	177	181	24	124	201	132	187
City of Sherwood	74	175	186	158	162	79	61	119	142	178	208
City of Tigard	95	167	203	203	162	162	73	137	168	205	205
Clean Water Services	78	165	148	155	152	189	96	86	127	147	142
Tualatin Hills Park & Recreation District	24	166	161	161	199	143	72	152	143	198	208
Tualatin Valley Water District	133	186	201	159	177	67	88	119	161	169	206
Washington County	83	186	201	201	177	173	102	124	191	132	211

2.7. Hazard Profiles

The following natural hazard profiles are listed in alphabetical order and do not represent their rank, as each jurisdiction prioritized the hazards independently. The information provided in this section reflects the impact of the hazards on all of Washington County, not solely the participating jurisdictions and special districts.

Each profile provides a hazard description, significant events since the adoption of the 2017 NHMP, if applicable, and potential impacts and vulnerabilities. The potential impacts for each hazard are presented in the same order, as applicable: populations, economies, structures, improved property, critical facilities and infrastructure, historical properties and cultural resources, and natural environments.

The timeframe of data collected during the planning process for Washington County was November 1, 2016 to February 22, 2022.

Participant-specific hazard and vulnerability information is identified in the annexes, as appropriate.

2.7.1. Dam Failure

Significant Changes
- Created standalone hazard profile.
- Additional information on vulnerabilities and how climate change may impact the frequency and severity of dam failure added.

2.7.1.1. Characteristics

Dams protect water resources used for drinking, agriculture, and recreation and protect downstream development from inundation. Dams may be multi-functional, serving two or more of these purposes. Human-made dams may be classified according to the type of construction material used, construction methods, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage and, occasionally, the purpose of the dam.[10]

Embankment dams are the most common type of dam in use today. Materials used for embankment dams include natural soil or rock, or waste materials obtained from mining or milling operations. An embankment dam is called an “earthfill” or “rockfill” dam depending on whether it is comprised of compacted earth or mostly compacted or dumped rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type, and strength of the materials from which the dam is made.[11]

The National Inventory of Dams assigns classification categories to dams as a measure of the probable impacts of failure. A dam classified as high hazard does not indicate it is unsafe or likely to fail. The level of risk or probability of failure of a given dam is not a factor in this classification scheme. Instead, the high hazard classification means if the dam were to fail, people in the inundation area downstream from the dam are at risk of loss of life.

Dams assigned to the significant hazard potential classification are those where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities. Such dams are often located in predominantly rural or agricultural areas.

Dams assigned to the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life. Failure of dams in the high hazard classification will generally also result in economic, environmental, or lifeline losses, but the classification is based solely on probable loss of life.

Dam failures can occur at any time in a dam’s life; however, failures are most common when water storage for the dam is at or near design capacity. At high water levels, the water force on the dam is higher, and several of the most common failure modes are more likely to occur. Correspondingly, for any dam, the probability of failure is much lower when water levels are substantially below the design capacity for the reservoir.

For embankment dams, the most common failure mode is erosion of the dam during prolonged periods of rainfall and flooding. When dams are full and water inflow rates exceed the capacity of the controlled release mechanisms, overtopping may occur. When overtopping occurs, scour and erosion of the dam and/or of the abutments may lead to partial or complete failure of the dam. Internal erosion, piping, or seepage through the dam, foundation, or abutments can also lead to failure of this type of dam.

[10] Association of State Dam Safety Officials. (2020). Dams 101. https://damsafety.org/dams101
[11] Association of State Dam Safety Officials. (2020). Dams 101. https://damsafety.org/dams101

Earthquake ground motions may cause dams to settle or spread laterally. Such settlement does not generally lead, by itself, to immediate failure. However, if the dam is full, relatively minor amounts of settling may cause overtopping to occur, with resulting scour and erosion that may progress to failure. Landslides into the reservoir, which may occur on their own or be triggered by earthquakes, may lead to surge waves that overtop dams or hydrodynamic forces that cause dams to fail under the unexpected load. In rare cases, high winds may also cause waves that overtop or overload dam structures.

Concrete dams are also subject to failure due to seepage of water through foundations or abutments. For waterways with a series of dams, downstream dams are also subject to failure induced by the failure of an upstream dam. If an upstream dam fails, then downstream dams also fail due to overtopping or hydrodynamic forces.

For smaller dams, the erosion and weakening of dam structures by growth of vegetation and burrowing animals is a common cause of failure.

Any dam is susceptible to failure due to improper design or construction, improper operation, and unusual hydrodynamic forces.

Dam failures can occur rapidly and with little warning. Fortunately, most failures result in minor damage and pose little or no risk to life safety. However, the potential for severe damage still exists.

Where a dam's failure is expected to result in loss of life downstream of the dam, an emergency action plan (EAP) must be developed. The EAP contains a map showing the area that could be inundated by floodwaters from the failed dam. These dams are often monitored so that conditions that pose a potential for dam failure are identified to allow for emergency evacuations.

2.7.1.2. Location and Extent

Oregon follows FEMA's guidance for assigning hazard ratings to dams and for the contents of EAPs, which are now required for all dams rated as high hazard. Each dam is rated according to the anticipated impacts of its potential failure. The state has adopted the following definitions for state-regulated dams:

- **High Hazard:** This rating is assigned when loss of life is expected if the dam fails.
- **Significant Hazard:** This rating is assigned when loss of life is not expected if the dam fails, but extensive damage to property or public infrastructure is.
- **Low Hazard:** This rating is assigned to all other state-regulated dams.

There are 3 high hazard, 15 significant hazard, and 59 low hazard dams in Washington County. Although there are high hazard dams in the County, none of them meet all FEMA High Hazard Potential Dam eligibility requirements.[12]

Table 9: High Hazard and Significant Hazard Dams Located in Washington County[13]

Name	State Classification	Regulator
Scoggins Dam	High	Federal
Barney Dam	High	State
Kay Lake Dam	High	State

[12] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[13] U.S. Army Corps of Engineers. (2022). National Inventory of Dams. https://nid.sec.usace.army.mil/#/

Name	State Classification	Regulator
Burkhalter #2 Dam	Significant	State
Cook Reservoir Dam	Significant	State
Raymond Dierickx Dam	Significant	State
Dober Reservoir Dam	Significant	State
Ettinger Pond Dam	Significant	State
Hoefer–Pierson Reservoir Dam	Significant	State
Jesse Enlargement Dam	Significant	State
Lind Reservoir Dam	Significant	State
Maple Headquarters Reservoir Dam	Significant	State
Paul Chobin Dam	Significant	State
Pierson–Upper Dam	Significant	State
Tualatin Park Dam	Significant	State
Unger–Bill Dam	Significant	State
Walters, Glenn #1 - Large Dam	Significant	State
Walters, Glenn #5 Dam	Significant	State

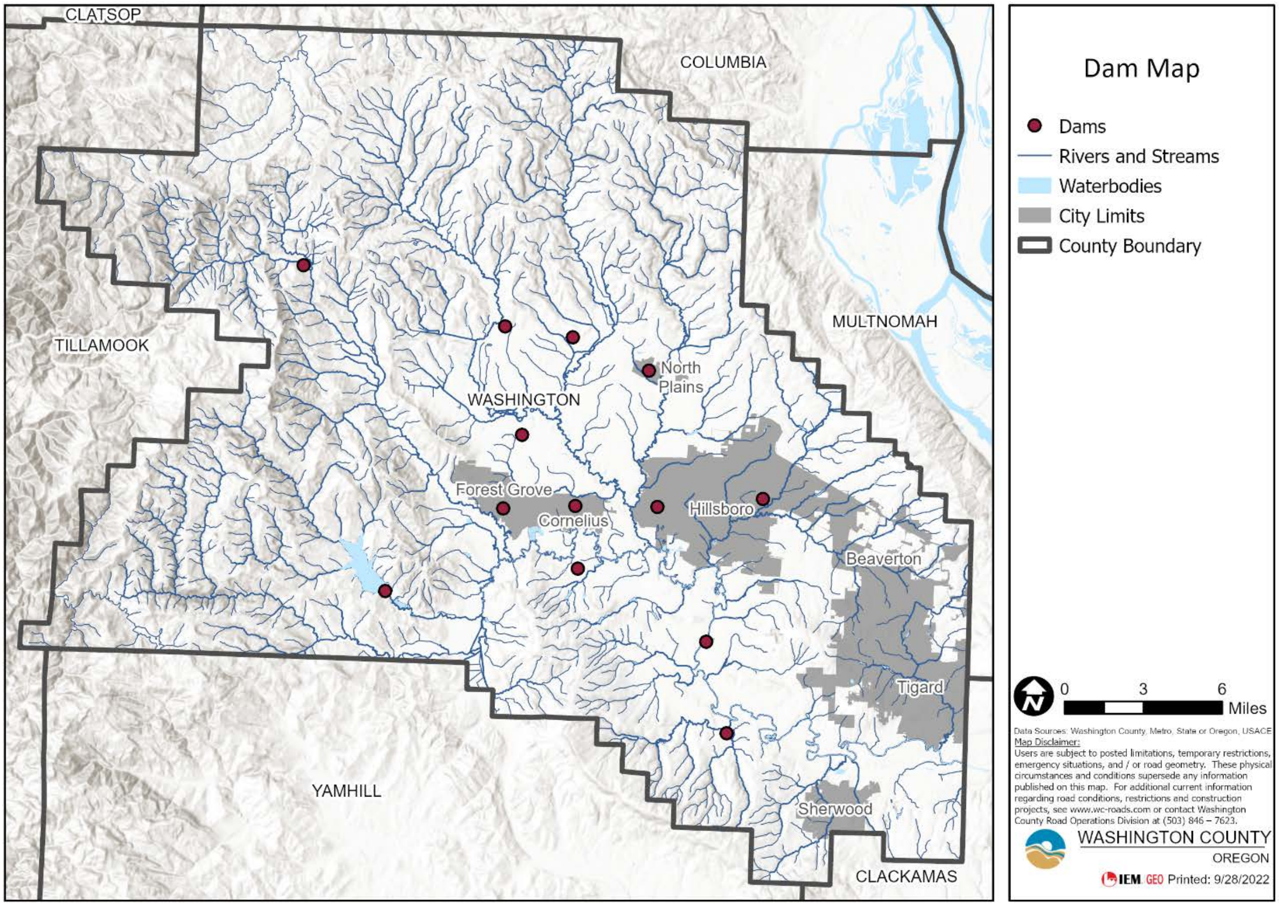


Figure 2: High and Significant Hazard Dams in Washington County

2.7.1.3. History

There have been no recorded dam failure events in the history of the planning area.

2.7.1.4. Probability of Future Events

An engineering risk assessment and analysis of a dam is the best indicator of the probability of failure. Without that, the condition of a dam as determined by Oregon Water Resources Department (OWRD) engineering staff is a helpful indicator of the failure potential of a dam.

Dam safety regulators determine the condition of dams rated as high hazard. A dam's condition is considered public information for state-regulated dams, but the conditions of federally regulated dams are generally not subject to disclosure. State-regulated dams rated as significant hazard do not yet have condition ratings.

Oregon uses FEMA's condition classifications. These classifications are subject to change, and revisions are being considered at the national level. Barney and Kay Lake dams are both classified as satisfactory by OWRD.[14] This means no existing or potential dam safety deficiencies are recognized. Acceptable

[14] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.

Although the condition of Scoggins Dam is not public information because it is federally regulated, the dam has an EAP that was last updated in January 2020 and last inspected in July 2020.[15] This dam is located directly over the Gales Creek Fault and is potentially at risk of damage or failure if an earthquake were to occur. However, because of these recent planning and evaluation activities it is expected that the dam is in good condition and performing as expected.

2.7.1.4.1. Climate Change

Most climate change models indicate there may be more extreme precipitation events in the future. One of the main concerns for dams is the potential for larger floods than experienced in the past. If a flood that is larger than the dam design occurs, spillway capacity may be exceeded and the dam may overtop, or the spillway may erode, causing the reservoir to empty rapidly. This scenario can present real risks to the dams in Washington County; however, the exact degree of risk is currently unknown.

2.7.1.5. Vulnerability Assessment

Failures of some dams can result in loss of life and damage to property, infrastructure, and the natural environment. The impacts of dam failures range from local impacts to the dam owner's property and waters below the dam, to community destruction with mass fatalities.

Barney and Kay Lake dams currently meet state regulations and safety standards, reducing the risk of a dam failure event occurring and vulnerability. Dams in the planning area can face risks from earthquakes, landslides, and wildfire, including the buildup of large woody debris behind dams. Per the 2020 Oregon NHMP, no plan participants are considered "most vulnerable jurisdictions" to dam failure because the County does not have any high hazard dams in poor or unsatisfactory condition.[16]

The Tualatin River and Fanno Creek are susceptible not only to heavy rain but also to the potential failure of Scoggins Dam. At times of heavy rain these rivers, creeks, and lakes can overflow. Fanno Creek is the most susceptible to flooding in these instances, with many bridges vulnerable to high water. There is also the potential for property damage along the river and creek in the event of high water or dam failure.

OWRD is working to complete more in-depth analyses of potential impacts from failure of state-regulated dams. This evaluation will explore more specific impacts to hospitals, major roads, and other critical infrastructure. OWRD's dam safety program personnel do not have specific expertise on the environmental effects of dam breach events, but it is likely failure of a large dam will include serious environmental effects. Failure of the dams undergoing risk analysis could cause extensive local damage to property and infrastructure. Information from OWRD's risk analyses will be included in the 2025 update of the Oregon NHMP.[17]

Impacts from dam failure can vary greatly based on magnitude and extent and can include both direct and indirect consequences.

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[15] Army Corps of Engineers. (n.d.). National Inventory of Dams. https://nid.usace.army.mil/#/

[16] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[17] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

The potential direct consequences of dam failure include[18]:

- Injuries and/or loss of life;
- Damage to commercial structures and/or their contents; residential structures and/or their contents; equipment and supplies at industrial sites; and facilities that provide services;
- Flooding of transportation, water, electrical, and communication infrastructure;
- Loss of livestock and agricultural crops;
- Reduction in agricultural output due to loss of irrigation;
- Loss of recreation opportunities;
- Debris and sediment removal; and
- Cost to repair or rebuild dam.

The potential indirect consequences of dam failure include[19]:

- Increased traffic congestion while repairs occur;
- Increased occupancy in nursing homes to accommodate patients from nursing homes in the inundation area;
- Prolonged operations of temporary shelters for residents of the inundation area;
- Closure of industries due to lack of water or wastewater treatment; and
- Loss of tourism.

2.7.1.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of dam failure. Additional information is in the participant annexes.

Table 10: Participant Overall Risk of Dam Failure[20]

Participant	Overall Risk of Dam Failure
City of Beaverton	–
City of Cornelius	83
City of Forest Grove	83
City of Hillsboro	81
City of North Plains	56
City of Sherwood	74
City of Tigard	95
Clean Water Services	78

[18] Federal Emergency Management Agency. (2012, March). Assessing the Consequences of Dam Failure. https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

[19] Federal Emergency Management Agency. (2012, March). *Assessing the Consequences of Dam Failure.* https://damsafety.org/sites/default/files/files/FEMA%20TM%20AssessingtheConsequencesofDamFailure%20March2012.pdf

[20] 2023 NHMP Participant Planning Documentation

Participant	Overall Risk of Dam Failure
Tualatin Hills Park & Recreation District	–
Tualatin Valley Water District	133
Washington County	83

2.7.2. Drought

Significant Changes

- Hazard profile expanded to include ecological drought, cascading hazards and impacts, and measure of drought extent.
- Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency of drought added.

2.7.2.1. Characteristics

A drought is a period of drier than normal conditions creating hydrologic imbalance, shortage of precipitation adversely affecting crops, or a period of below-average water in streams and lakes, reservoirs, aquifers, and soils. Because drought is defined relative to normal conditions for an area, there is no universal measure of precipitation or dryness that signifies drought.

Drought occurs in virtually every climatic zone. Drought is a temporary condition, and the extent of drought events depends on the degree of moisture deficiency and the duration and size of the affected area. Typically, droughts occur as regional events and often affect more than one city and county simultaneously. Other climatic factors, such as high temperature, high wind, and low relative humidity, are often associated with drought and can significantly affect its severity.

There are five types of drought[21]:

- **Meteorological:** This type of drought occurs when the degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. This type of drought usually takes at least three months to develop and can last for years.
- **Hydrological:** This type of drought occurs when precipitation shortfalls, including snowfall, affect subsurface water supplies like stream flows and reservoir, lake, and groundwater levels. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with, or lag the occurrence of, meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system. such as soil moisture, stream flow, and groundwater and reservoir levels.
- **Ecological:** This type of drought occurs when “a prolonged and widespread deficit in naturally available water supplies, including changes in natural and managed hydrology, that create multiple stresses across ecosystems.”[22] Recent drought mitigation efforts have focused on ecological drought to fully address the ecological dimensions of the hazard, including impacts on vegetation and ecosystems.[23]
- **Agriculture:** This type of drought occurs when various characteristics of meteorological or hydrological drought are linked to agricultural impacts. These characteristics include precipitation shortages, differences between actual and potential evapotranspiration (evaporation combined

[21] National Drought Mitigation Center. (2022). Types of Drought: Fiscal Year 2022. https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx
[22] National Drought Mitigation Center. (2022). Types of Drought: Fiscal Year 2022. https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx
[23] Crausbay, S.D.; Ramirex, A.R.; Carter, S. L; Cross, M.S; Hall, K.R.; Bathke, D.J; Betancourt, J. L; Colt, S.; Cravens, A.E.; Dalton, M.S.; Dunham, J.B.; Hay, L.E.; Hayes, M.J.; McEvoy, J.; McNutt, C.A.; Moritz, M.A.; Nislow, K.H.; Raheem, N.; & Sanford, T. (2017, December 1). *Defining Ecological Drought for the Twenty-First Century.* https://journals.ametsoc.org/view/journals/bams/98/12/bams-d-16-0292.1.xml

with transpiration), soil water deficits, and reduced groundwater or reservoir levels. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. This type of drought should account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity.

- **Socioeconomic:** This type of drought occurs when the demand for water exceeds the supply as a result of a weather-related supply shortfall, affecting the population individually and collectively. Most definitions of socioeconomic drought associate it with supply, demand, and economic good, as the supply of many goods, such as water, food grains, fish, and hydroelectric power, depends on the availability of water.

There is a link between the different types of drought.

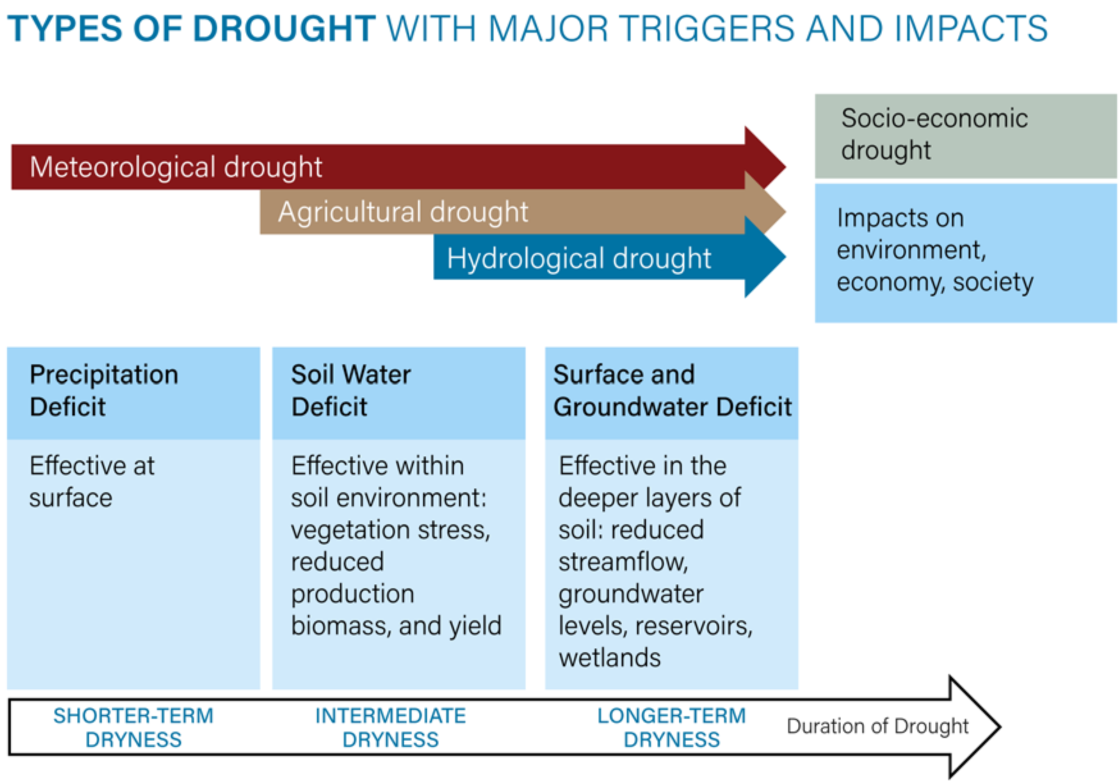

Figure 3: Types of Drought with Major Triggers and Impacts

Drought can also be an institutional phenomenon, resulting from poor management of water supply and reserves—an imbalance in supply and demand—and is often due to a combination of metrological, hydrologic, agricultural, and socioeconomic factors.

2.7.2.2. Location and Extent

Drought may affect the entire Washington County planning area equally. Drought is difficult to measure, due to its diverse geographical and temporal nature and its operation on many scales. Despite that difficulty, various indices for measuring and characterizing drought can be useful to rank event severity. Most federal agencies use the Palmer Method, which incorporates precipitation, runoff, evaporation, and soil moisture. However, the Palmer Method does not incorporate snowpack as a variable. Therefore, it is not believed to provide a fully accurate indication of drought conditions in Oregon and the Pacific

Northwest, although it can be very useful because of its a long-term historical record of wet and dry conditions. Figure 4 shows the Palmer Drought Severity Index (PDSI) for the County as of September 28, 2022.

The Surface Water Supply Index (SWSI) from the Natural Resources Conservation Service is an index of current water conditions throughout the state. The index utilizes parameters derived from snow, precipitation, reservoir, and stream flow data. The data is gathered each month from key stations in each basin. The lowest SWSI value, -4.2, indicates extreme drought conditions (Low Surface Water Supply ranges from -1.6 to -4.2). The highest SWSI value, +4.2, indicates extreme wet conditions (High Surface Water Supply ranges from +1.6 to +4.2). The midpoint is 0.0, which indicates an average water supply (Average Water Supply ranges from +1.5 to -1.5).

El Niño-Southern Oscillation (ENSO) weather patterns can increase the frequency and severity of drought. During El Niño periods, alterations in atmospheric pressure in equatorial regions yield an increase in the surface temperature off the west coast of North America.

This gradual warming sets off a chain reaction affecting major air and water currents throughout the Pacific Ocean. In the North Pacific, the jet stream is pushed north, carrying moisture-laden air up and away from its normal landfall along the Pacific Northwest coast. In Oregon, this shift results in reduced precipitation and warmer temperatures, normally experienced several months after the initial onset of the El Niño phase. These periods tend to last nine to twelve months, after which surface temperatures begin to trend back toward the long-term average. El Niño periods tend to develop between March and June, and peak from December to April. ENSO generally follows a two- to seven-year cycle, with El Niño or La Niña periods occurring every three to five years. However, the cycle is highly irregular, and no set pattern exists.

According to the National Weather Service (NWS) Climate Prediction Center, 22 El Niño episodes have occurred since 1950, with the two most recent strong El Niño episodes occurring in 1997–98 and 2015–16.[24] An El Niño episode occurred in 2019; however, it was classified as “weak” and did not create drought conditions in the County.[25]

2.7.2.2.1. Measuring Drought Extent

The Drought Severity and Coverage Index (DSCI) has possible values from 0 to 500. Zero indicates none of the area is abnormally dry or in drought, and 500 indicates the entire area is exceptionally dry (in D4, exceptional drought).[26]

Drought classifications by category, and corresponding descriptions and potential impacts, are provided in Table 11.

[24] Climate Prediction Center Internet Team. (n.d.). Cold & Warm Episodes by Season*.* National Weather Service Climate Prediction Center. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

[25] Donegan, B. (2019, March 14). *El Niño* El Nino Conditions Strengthen, Could Last Through Summer. The Weather Channel. https://weather.com/news/weather/news/2019-03-14-el-nino-conditions-strengthen-could-last-through-summer

[26] Akyuz, F.A. (2017). Drought Severity and Coverage Index. United States Drought Monitor. https://droughtmonitor.unl.edu/About/AbouttheData/DSCI.aspx

Table 11: Drought Severity and Coverage Index Categories and Potential Impacts[27]

Category	Description	Potential Impacts
D0	Abnormally dry	• Going into drought: short-term dryness slowing planting, growth of crops, or pastures • Coming out of drought: some lingering water deficits and pastures or crops not fully recovered
D1	Moderate drought	• Some damage to crops and pastures • Streams, reservoirs, or wells low and some water shortages are developing or imminent • Voluntary water-use restrictions requested
D2	Severe drought	• Crops or pasture losses likely • Water shortages common • Water restrictions imposed
D3	Extreme drought	• Major crop or pasture losses • Widespread water shortages or restrictions
D4	Exceptional drought	• Exceptional and widespread crop and pasture losses • Shortages of water in reservoirs, streams, and wells are creating water emergencies

[27] National Drought Mitigation Center, University of Nebraska–Lincoln. (2022). Drought Classification. https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx

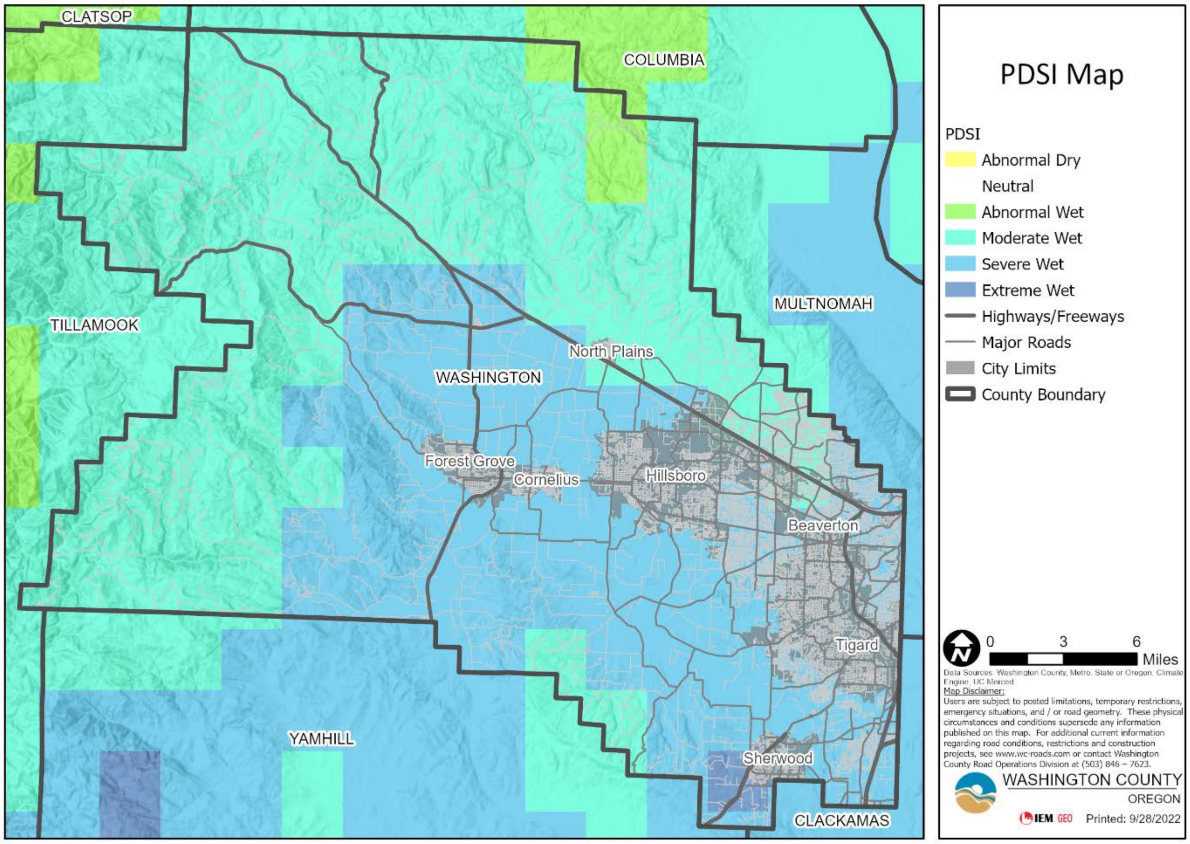

Figure 4: Drought Conditions in Washington County as of September 28, 2022

2.7.2.3. History

Precipitation in Oregon follows a distinct spatial and temporal pattern; it tends to fall mostly in the cool season, from October to April. The Cascades block rain-producing weather patterns, creating a very arid and dry environment east of these mountains. Moist air masses originating from the Pacific Ocean cool and condense when they encounter the mountain range, depositing precipitation primarily on the inland valleys and coastal areas. Because of this weather pattern, significant droughts are typically uncommon in Washington County; however, agriculture drought can occur with relative frequency.

Table 12: Historic Drought Events in Washington County Since November 1, 2016

Date	Declaration
Beginning May 11, 2021	Agricultural drought declaration with corresponding Small Business Association Economic Injury Disaster Loan (SBA EIDL) program implementation. During the week of May 11, the County had a DSCI of 300. The DSCI did not reach 0 until the week of March 22, 2022.
Beginning April 18, 2020	Agricultural drought declaration with corresponding SBA EIDL program implementation. During the week of April 24, the County had a DSCI of 185 and was 220 from the week of May 5 to June 2. The DSCI did not reach 0 until the week of February 2, 2021.

Date	Declaration
Beginning July 24, 2018	Agricultural drought declaration with corresponding SBA EIDL program implementation. During the week of July 24, the County had a DSCI of 300 that was sustained until the week of December 18, 2018. The DSCI did not reach 0 until the week of October 22, 2019.

2.7.2.4. Probability of Future Events

Drought is currently a cyclic part of the climate of Oregon, occurring in both summer and winter, with an average recurrence interval between 8 and 12 years. Short-term, seasonal events are more frequent, while long-term events are less frequent. Although there have been advancements in climatology, estimating drought probability and frequency continues to be difficult. This is because of the many variables that contribute to weather behavior, climate change, and the absence of historical information. Understanding drought as a recurring climate cycle is a first step toward creating management practices that effectively mitigate its effects.

2.7.2.4.1. Climate Change

Climate change forecasts highlight an increased risk for drought conditions in the Pacific Northwest. The U.S. Climate Assessment notes that "changes in the timing of streamflow related to changing snowmelt are already observed and will continue, reducing the supply of water for many competing demands and causing far-reaching ecological and socioeconomic consequences."[28]

Climate models project warmer, drier summers for Oregon. These summer conditions, coupled with projected decreases in mid- to low-elevation mountain snowpack due to warmer winter temperatures, increases the likelihood the County will experience increased frequency of one or more types of drought under future climate change.[29]

Climate change may result in increased frequency of drought due to low spring snowpack (likely, >90%), low summer runoff (likely, >66%), and low summer precipitation and low summer soil moisture (more likely than not, >50%).[30]

In addition, an increase in the frequency of summer drought conditions is predicted due largely to projected decreases in summer precipitation and increases in potential evapotranspiration.[31]

With climate change, snow droughts, the type of drought in which snowpack is low but precipitation is near normal, are expected to occur more often. The 2015 drought in Oregon was a snow drought and serves as a good example of what future climate projections indicate may become commonplace by the mid-twenty-first century.[32]

The 2021 Pacific Northwest Water Year Impacts Assessment shows that the Pacific Northwest region, which includes the planning area, was drier than predicted during the year. The 2021 water year in the

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[28] Melillo, J.M., Richmond, T.C., & Yohe, G.W. (Eds.). (2014). *Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment.* U.S. Global Change Research Program, pg. 148 http://s3.amazonaws.com/nca2014/low/NCA3_Highlights_LowRes.pdf?download

[29] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[30] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[31] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[32] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

Pacific Northwest tied as the fifth warmest and seventeenth driest since documentation of records began in 1895.[33]

2.7.2.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County have the potential to be exposed to and impacted by drought. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

When a drought occurs, it may affect all areas of the County. Historically, urban areas of the County fare much better during a drought than rural, less populated areas of the County. By encouraging or invoking water conservation measures during a drought, public municipal water systems can reduce residential and industrial demand for water. Rural areas are much more dependent on water for irrigation for agricultural production. Landowners in rural or less-populated areas are often reliant on individual, privately owned wells as a drinking water source.[34]

A drought event can cause widespread impacts, depending on its severity.[35]

- **Water:** Ground and surface water quality can be impacted when water is not regularly replenished, and water may not be available for farming, manufacturing, or use in everyday activities like bathing, cooking, and washing dishes.
- **Health:** Negative effects on the quantity and quality of drinking water can occur, and sources of food and nutrition can be compromised, leading to increased incidents of illness and disease. Drought is linked to increased heat-related, waterborne, and cardiorespiratory illnesses, as well as mental health conditions. Decreases in water during drought can lead to reduced availability of electricity and hospitalized and elderly people can be at increased risk for injury or death.
- **Environmental:** In addition to water quality issues, low water levels resulting from drought have a significant impact on ecosystems. When water levels are low in lakes, rivers, and other water bodies, their ability to flush out contaminants diminishes, causing an increase in waterborne pollutants. Reduced plant growth, local species reduction or extinction, and landscape-level transitions, such as forest conversion to non-forested vegetation, which may in turn reduce water retention in soils, may occur. Additionally, freshwater ecosystems may change flow regimes, increase water temperature, and deteriorate water quality, which may result in fish kills, reduced opportunities for recreation, and decreased hydropower production.[36]
- **Built environment:** While impacts to the built environment aren't as dramatic as those from other hazards, drought has a significant effect on buildings and infrastructure. When buildings are located on expansive soils, for example, the foundation can be compromised as soil moisture decreases and clay-based soils contract. The study of expansive soils in the County is extremely

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[33] Bumbaco, K.A., Rogers, M.H., O'Neill, L.W., Hoekema, D.J., & Raymond, C.L. (2022). 2021 Pacific Northwest Water Year Impacts Assessment. A collaboration between the Office of the Washington State Climatologist, Climate Impacts Group, Oregon State Climatologist, Idaho Department of Water Resources, and NOAA National Integrated Drought Information System. https://www.drought.gov/sites/default/files/2022-02/PNW-Water-Year-Impacts-Assessment-2021.pdf
[34] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[35] American Planning Association. (2019). Falling Dominoes: A Planner's Guide to Drought and Cascading Impacts. https://planning-org-uploaded-media.s3.amazonaws.com/publication/download_pdf/Falling-Dominoes-Planners-Guide-to-Drought-and-Cascading-Impacts.pdf
[36] National Oceanic and Atmospheric Administration–National Integrated Drought Information System. (n.d.). Ecological Drought. https://www.drought.gov/what-is-drought/ecological-drought#:~:text=%20Examples%20of%20drought%20impacts%20to%20ecological%20systems,water%20temperature%2C%20and%20deteriorate%20water%20quality%2C...%20More%20

limited. A 1967 DOGAMI study mentions the presence of high plasticity and high groundwater, which are the factors needed to cause shrink swell in expansive soils.[37] Municipal water supply and delivery, municipal wastewater, transportation systems, and parks and recreational facilities are also impacted by drought. There may even be situations where water-intensive industries relocate and agricultural production shifts to different locations due to lack of water.

- **Economic:** Water is essential to the production of goods and services, and when the water supply is depleted or disrupted, reduced productivity or closures can impact supply chains. Industries that are directly affected by drought include agriculture, recreation, energy, tourism, agriculture, timber, and fisheries, among others. Drought can have wide-ranging impacts that include job losses, business failures, and lost investments.

Even though drought may not be declared often in Washington County, when drought conditions do develop, the impacts can be widespread and severe. Reasons for potential broad and significant impacts include the following[38]:

- Higher population density and growing population in the County.
- Dependence on surface water supplies for many municipalities, agriculture, and industries from large flood control reservoirs in the Willamette River system.
- Agriculture is a major industry becoming increasingly dependent on irrigation.
- Increased frequency of toxic algal blooms in the Willamette system reservoirs, resulting in restrictions on use of water from reservoirs for drinking (i.e., for human and animals). Affected waters may not be safe for agricultural irrigation and other uses, necessitating purchasing and transporting water from alternative sources.
- Since drought is typically accompanied by earlier onset of snowmelt (e.g., during flood control or early storage season), little or no snowmelt runoff is stored until later.
- An earlier start to growing season, before the start of the irrigation season, means that crops may not be irrigated until the irrigation season begins.
- Insufficient number of farm workers available because the growing season began before the workers were scheduled to arrive.

When natural hazard events overlap or occur in quick succession, the events can compound and cause detrimental effects. Drought is particularly likely to be part of a cascading hazard because it can cover a large area and go on for a long time.[39]

- **Drought and extreme heat:** Drought and extreme heat often occur simultaneously, and drought can make a hot day hotter, while a heat wave can make dry conditions even drier. Periods of extreme heat increase evaporation, leading to reduced water availability in soils and surface water supplies. Periods of drought can cause extreme heat due to lack of water in the atmosphere, soils, and rivers, where decreased water availability in the system reduces the amount of evaporation happening at the surface, quickly increasing temperatures. Extreme heat can also increase water demands, in which human activities can reduce water supplies, leading to human-caused drought. These hazards occurring together can compound health impacts, reduce energy production, cause loss of aquatic life due to reduced stream and reservoir levels and increased water temperatures, kill vegetation, and create dangerous air quality issues.

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[37] Department of Geology and Mineral Industries. (1967). Engineering Geology of the Tualatin Valley Region, Oregon. https://www.oregongeology.org/pubs/B/B-060.pdf
[38] Oregon Natural Hazards Mitigation Plan. (2020, September 24). https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[39] American Planning Association. (2019). Falling Dominoes: A Planner's Guide to Drought and Cascading Impacts. https://planning-org-uploaded-media.s3.amazonaws.com/publication/download_pdf/Falling-Dominoes-Planners-Guide-to-Drought-and-Cascading-Impacts.pdf

- **Drought and wildfire:** Decreased soil moisture and increased temperatures stress vegetation and increase plant mortality, providing fuel for fires. Reduced ponds, streams, and reservoir levels can also limit withdrawal sources for fighting wildfires. The extreme conditions can also increase the likelihood of shrub and tree mortality by wildfire in previously fire-adapted ecosystems, in addition to habitat and infrastructure losses and threats to animal and human life. Wildfires, whether located in or outside the County, may also create dangerous air quality issues for residents.
- **Drought and flooding:** Drought, along with wildfires that can stem from drought, increase flood risk. Extended drought and wildfire can stress and reduce the amount of vegetation. When it does rain, the reduction of vegetation can increase flooding due to faster runoff rates, compared to normal conditions when abundant vegetation slows runoff and increases water absorption into the ground. Drought or wildfire conditions prior to flooding can also cause water quality deterioration from the increased soil and ash particles in the runoff. On farmlands, drought conditions prior to flooding may also cause a surge of farm chemicals applied to crops to enter streams through runoff. These factors can affect the water quality for aquatic life, animals, and humans, who are all dependent on the water source. Increased instances of flash flooding may also occur.
- **Drought and landslides:** Droughts can indirectly cause landslides through a cascade of natural hazards. For example, drought can cause dry conditions and increased fuel loads for wildfires that, in turn, can increase the likelihood of flooding. The ash-infused topsoil, which is water repellent, and loss of vegetation can increase runoff and take large amounts of earthen material with them, causing devastating impacts to populations in the path of the landslide event. These Such events could cause the loss of infrastructure and life. From an environmental standpoint, they may also affect the water quality of downstream rivers and streams and the habitat for animals, flora, and fauna. The landslides can also alter the topography of the landscape, which can modify surface and groundwater flow patterns.

2.7.2.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of drought. Additional information is in the participant annexes.

Table 13: Participant Overall Risk of Drought[40]

Participant	Overall Risk of Drought
City of Beaverton	198
City of Cornelius	186
City of Forest Grove	186
City of Hillsboro	184
City of North Plains	170
City of Sherwood	175
City of Tigard	172
Clean Water Services	165
Tualatin Hills Park & Recreation District	166
Tualatin Valley Water District	186
Washington County	186

[40] 2023 NHMP Participant Planning Documentation

2.7.3. Earthquake

Significant Changes

- Hazard profile expanded to include information about liquefaction and coseismic landslides.
- Information about the Portland Hills, Gales Creek, and Beaverton fault zones and Hazus®-MH event scenarios with damage data for these faults added to the hazard profile.
- Additional information on vulnerabilities and how climate change may impact the frequency and severity of earthquakes added.

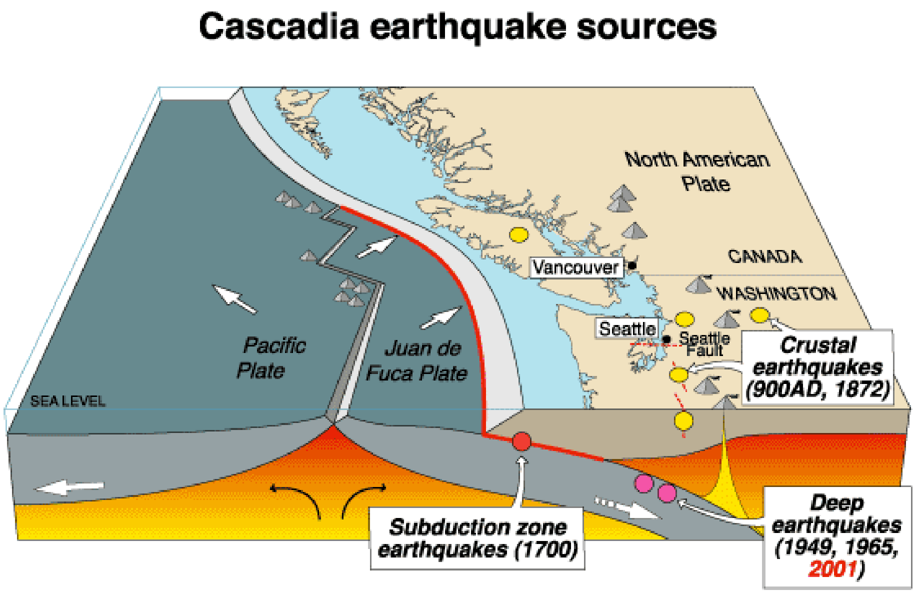
2.7.3.1. Characteristics

An earthquake is a sudden movement of rock on each side of a fault in the earth's crust that abruptly releases strain that has accumulated. The movement along the fault produces waves of shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause casualties, economic disruption, and extensive property damage.[41]

The effects of an earthquake can be felt far beyond the site of its occurrence. Earthquakes usually occur without warning, and after just a few seconds, can cause massive damage and extensive casualties. The most common effect of earthquakes is ground motion, usually felt as shaking and vibrations.

The severity of ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. Ground motion causes waves in the earth's interior, known as seismic waves, and along the earth's surface, known as surface waves. There are two kinds of seismic waves. Primary waves are longitudinal or compression waves similar in character to sound waves, which cause back-and-forth oscillation along the direction of travel, creating a vertical motion. Secondary waves, also known as shear waves, are slower than primary waves and cause structures to vibrate from side to side in a horizontal motion. When primary and secondary waves hit the surface of the earth, they generate surface waves. Slower than seismic waves, and therefore later to hit, surface waves are responsible for most of the damage during an earthquake.

[41] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm



	Source	Affected area	Max. Size	Recurrence
●	Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
●	Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
●	Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Figure 5: Cascadia Earthquake Sources

Earthquakes from four sources threaten Washington County:

- **Crustal** earthquakes are the most common. They typically occur along faults, or breaks in the earth's crust, at shallow depths of 6 to 12 miles below the surface. When these events occur on faults in or near populated areas, they are a major hazard. All damaging historic earthquakes in the state have been crustal earthquakes.[42] One of the largest events in recent years in Oregon, the magnitude 5.6 Scotts Mills earthquake of 1993 was a crustal earthquake. The epicenter was approximately 30 miles south of the planning area. The incident resulted in a federal disaster declaration; however, it caused limited damage in Washington County.
- **Subduction zone** earthquakes occur in places where the tectonic plates that make up the surface of the earth collide. When these plates collide, one plate slides beneath the other, where it is reabsorbed into the mantle of the earth. This dipping interface between the two plates is the site of some of the most powerful earthquakes ever recorded, often having magnitudes of 8.0 to 9.0 or larger. The greatest earthquake threat to Washington County is the hazard posed by infrequent megathrust earthquakes on the Cascadia Subduction Zone (CSZ) located off the Oregon coast.

[42] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

- **Deeper intraplate** earthquakes occur within the remains of the ocean floor that is being subducted beneath the North American Plate. This type of earthquake could occur beneath much of the Northwest at depths of 25 to 37 miles. Deeper intraplate events may have a higher magnitude but tend to result in less damage than a crustal earthquake of the same caliber, due to the depth at which it occurs.
- **Volcanic** earthquakes can be caused by a slip on a fault near a volcano or by vibrations generated by the movement of magma or other fluids within the volcano.[43] The largest felt volcanic earthquake near the County was a magnitude 5.5 in 1981, under Mount St. Helens. These earthquakes are typically smaller than earthquakes caused by non-volcanic sources, but they have the potential to cause cracks, ground deformation, and damage to structures and infrastructure.[44] These events are an indication of magmatic activity and may be a precursor to a volcanic eruption.[45]

Two earthquake-induced hazards, also called coseismic hazards, also have the potential to impact Washington County:

- **Liquefaction** occurs when saturated soils substantially lose bearing capacity due to ground shaking, causing the soil to behave like a liquid. Liquefied soil will force open ground cracks to escape to the surface. The ejected material often results in flooding and may leave cavities in the soil.[46] This action can be a source of tremendous damage, especially to buildings and underground infrastructure.[47]
- **Coseismic landslides** are mass movement of rock, debris, or soil induced by ground shaking.[48] They may be scattered across a broad area extending tens or more of kilometers from the earthquake epicenter, causing widespread impacts over and above the damage caused by strong ground shaking of the earthquake itself.[49]

2.7.3.2. Location and Extent

Earthquakes are typically measured in terms of magnitude and intensity. Magnitude is related to the amount of energy released during an event, while intensity refers to the effects on people and structures at a specific place. Small to moderate earthquake magnitude is usually reported according to the standard Richter scale. Larger earthquakes are reported according to the moment magnitude scale because the standard Richter scale does not adequately represent the energy released by these large events.

Intensity is usually reported using the Modified Mercalli (MM) Intensity Scale. This scale has 12 categories ranging from “not felt” to “total destruction.” Different values can be recorded at different locations for the same event depending on local circumstances, such as distance from the epicenter or building construction practices. Peak ground acceleration (PGA) is also used to measure earthquake intensity. It measures the earthquake’s intensity by quantifying how hard the earth shakes in each location. PGA can be measured as a percentage of acceleration due to gravity, noted by “% g.” Table 14 identifies corresponding intensity and magnitude ratings as well as effects associated with each rating.

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[43] Pacific Northwest Seismic Network. (n.d.). Volcanic Earthquakes. https://pnsn.org/outreach/earthquakesources/volcanic
[44] Pacific Northwest Seismic Network. (n.d.). Volcanic Earthquakes. https://pnsn.org/outreach/earthquakesources/volcanic
[45] Pacific Northwest Seismic Network. (n.d.). Volcanic Earthquakes. https://pnsn.org/outreach/earthquakesources/volcanic
[46] Pacific Northwest Seismic Network. (n.d.). Liquefaction. https://pnsn.org/outreach/earthquakehazards/liquifaction
[47] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[48] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[49] U.S. Geological Survey. (n.d.). Coseismic Landslides. https://www.usgs.gov/special-topics/big-sur-landslides/science/earthquake-hazards

Table 14: Effects of Intensity and Magnitude Ratings

Magnitude	MM Intensity	PGA (% g)	Perceived Shaking
0-4.3	I	<0.17	Not Felt
	II-III	0.17–1.4	Weak
4.3-4.8	IV	1.4–3.9	Light
	V	3.9–9.2	Moderate
4.8-6.2	VI	9.2–18	Strong
	VII	18–34	Very Strong
6.2-7.3	VIII	34–65	Severe
	IX	65–124	Violent
	X	124+	Extreme

Washington County is at risk from several fault systems, including the CSZ, Portland Hills Fault, and Gales Creek Fault.

2.7.3.2.1. Cascadia Subduction Zone

The CSZ is the boundary between two of the earth's crustal plates. These continent-sized plates are in constant slow motion, and the boundaries between plates are the site of most earthquake activity around the globe. At the CSZ, the Juan de Fuca Plate, located offshore of Oregon and Washington, slides to the northeast and under the North American Plate, which extends from the Oregon coast to the middle of the Atlantic Ocean. The Juan de Fuca Plate slides beneath the continent (subducts) at about 1.5 inches per year, a speed that has been directly measured using high-accuracy GPS. The fault that separates the plates extends from Cape Mendocino in Northern California to Vancouver Island in British Columbia, and slopes down to the east from the seafloor. The fault is usually locked, so that rather than sliding slowly and continuously, the 1.5 inches per year of subduction motion builds tremendous stress along the fault. This stress is periodically released in a megathrust earthquake, which can have a magnitude from 8.3 to 9.3.[50]

2.7.3.2.2. Portland Hills Fault Zone

The Portland Hills Fault Zone lies just east of Washington County. This zone is comprised of three crustal faults that trend roughly northwest to southeast and are about two miles apart: the Oatfield Fault, which runs along and just west of the spine of the Portland Hills; the Portland Hills Fault, which runs directly under downtown Portland; and the East Bank Fault, which runs along the east bank of the Willamette River. Several lines of indirect evidence have led to the conclusion that the Portland Hills Fault Zone appears to be capable of generating a large-magnitude earthquake. These faults are believed to be capable of generating an earthquake of magnitude 6.8 to 7.2 on average, once every 1,000 years.[51]

[50] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[51] Washington County, Oregon. (n.d.). Local Earthquakes. https://www.co.washington.or.us/EmergencyManagement/Hazards/Earthquake/local.cfm

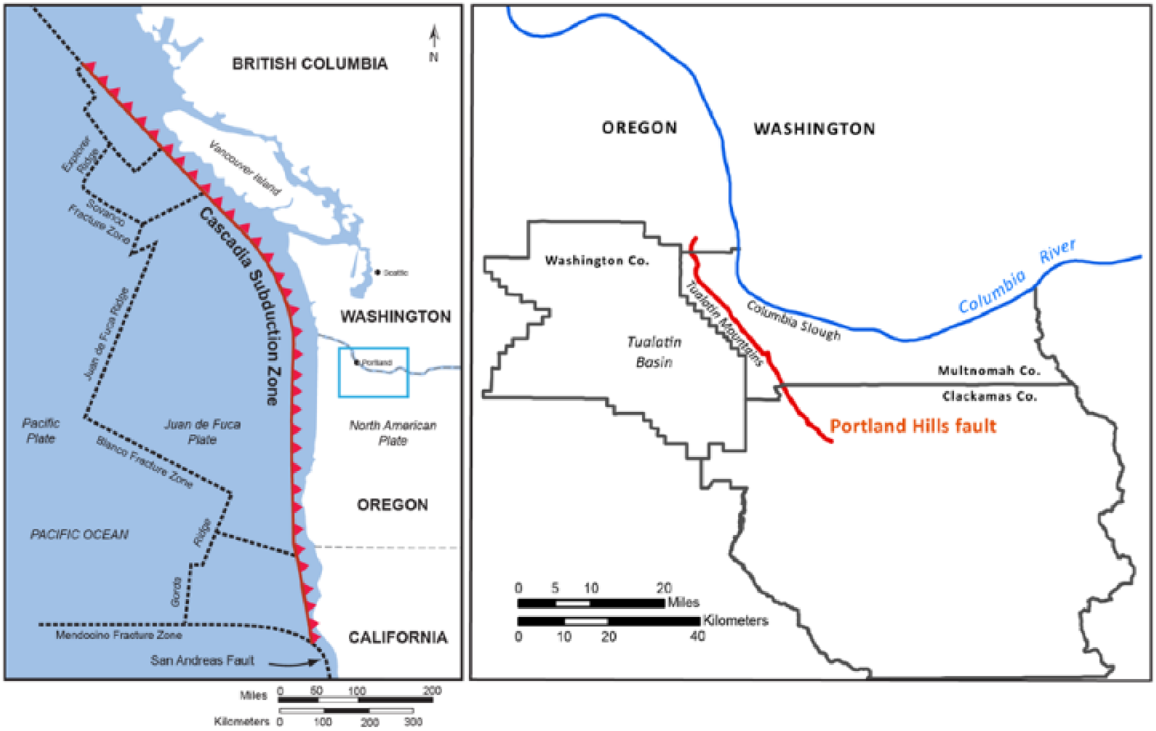

Figure 6: Cascadia Subduction Zone Fault (left) and Portland Hills Fault (right) Locations. Blue Rectangle in Left Figure is Shown in Right Figure.[52]

2.7.3.2.3. Gales Creek Fault Zone

The Gales Creek Fault Zone is in western Washington County and is approximately 45 miles long. If the full length of the fault were to rupture, it would result in a magnitude 7.1 to 7.4 earthquake. It is believed that the fault has the capability of producing an event every 4,000 years. The most recent earthquake along this fault occurred 1,000 years ago.[53]

[52] Bauer, J.M., Burns, W.J., & Madin, I.P. (2018). Open-File Report 0-18-02: Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon. *Oregon Department of Geology and Mineral Industries.* https://www.oregongeology.org/pubs/ofr/O-18-02/O-18-02_report.pdf

[53] Horst, A.E., Streig, A.R., Wells, R.E., & Bershaw, J. (2021). Multiple Holocene Earthquakes on the Gales Creek Fault, Northwest Oregon Fore-Arc. *GeoScience World. 111*(1), 476–489. https://doi.org/10.1785/0120190291

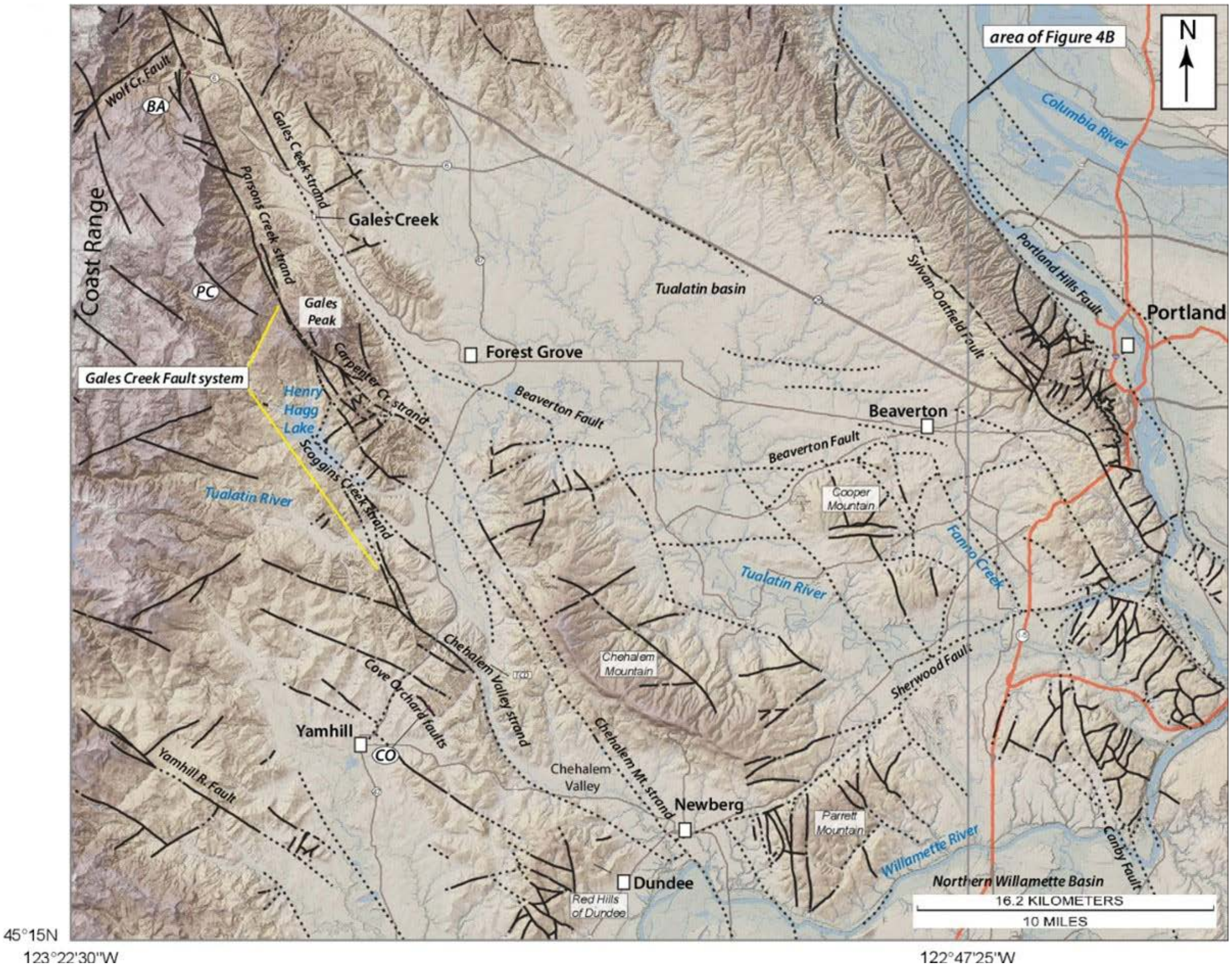

Figure 7: Gales Creek Fault[54]

2.7.3.2.4. Liquefaction and Coseismic Landslides

Whether and where liquefaction will take place depends on many factors. These include the degree of saturation, the grain size distribution and consistency at a site, the strength, duration, and frequency content of the shaking and even the grain shape and depth of soil. Figure 8 shows the areas of Washington County that are susceptible to liquefaction.

Site amplification is the degree to which soil types weaken or strengthen seismic waves produced from an earthquake. The National Earthquake Hazards Reduction Program (NEHRP) classifies these geologic units into soft rock, dense soil or soft rock, stiff soil, and soft clay or soil. NEHRP soils can significantly affect the level of shaking and amount of damage that occurs at a specific location during an earthquake. Figure 9 shows site amplification classes present in Washington County.

[54] Semantic Scholar. (n.d.). *Northwest Migration of the Oregon Forearc on the Gales Creek Fault.* https://www.semanticscholar.org/paper/Northward-migration-of-the-Oregon-forearc-on-the-Wells-Blakely/b7485394d7ed09a7dec3b1e433f5a47e8c157d39/figure/5

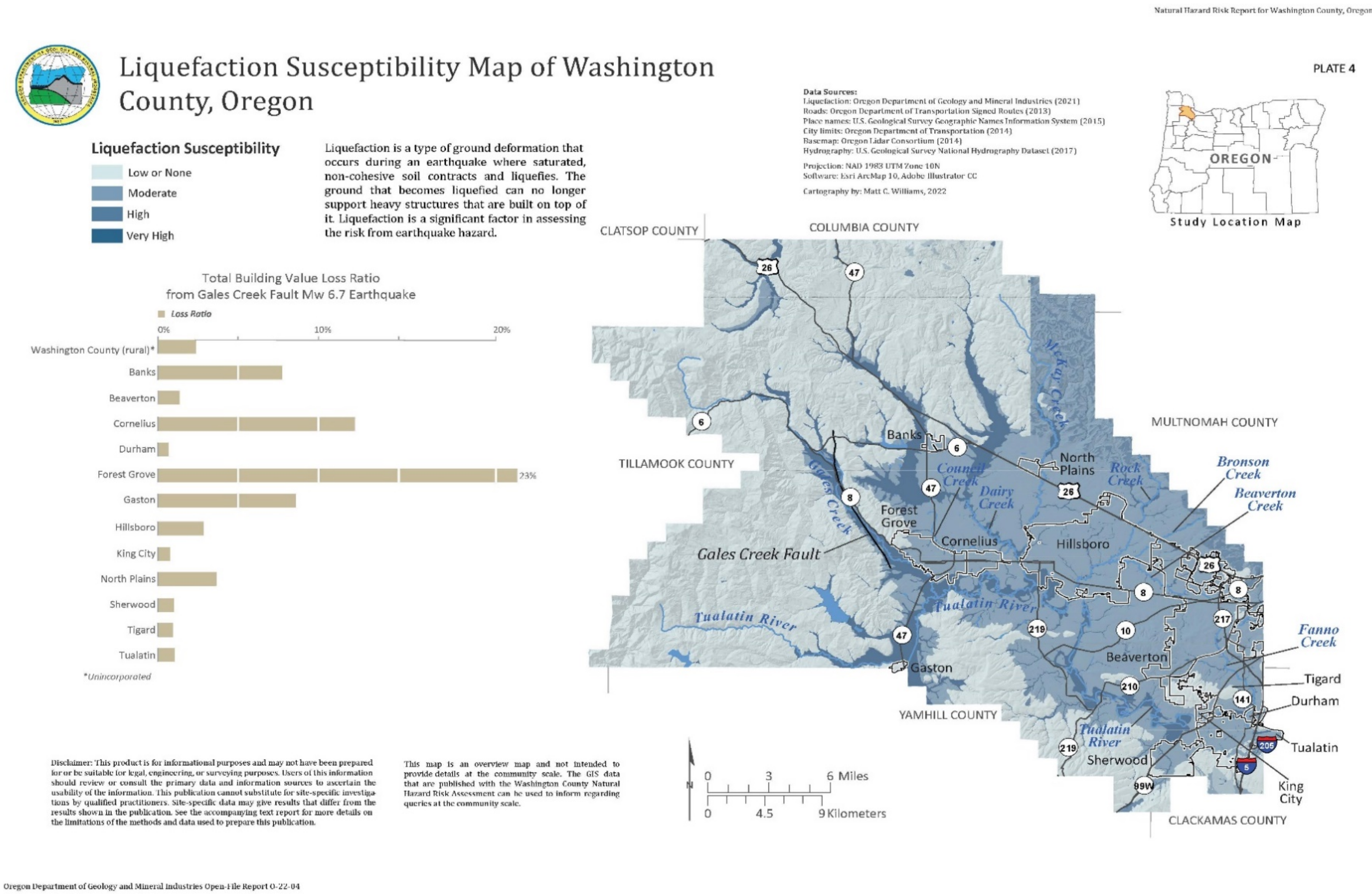

Figure 8: Liquefaction Susceptibility Map of Washington County, Oregon[55]

[55] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

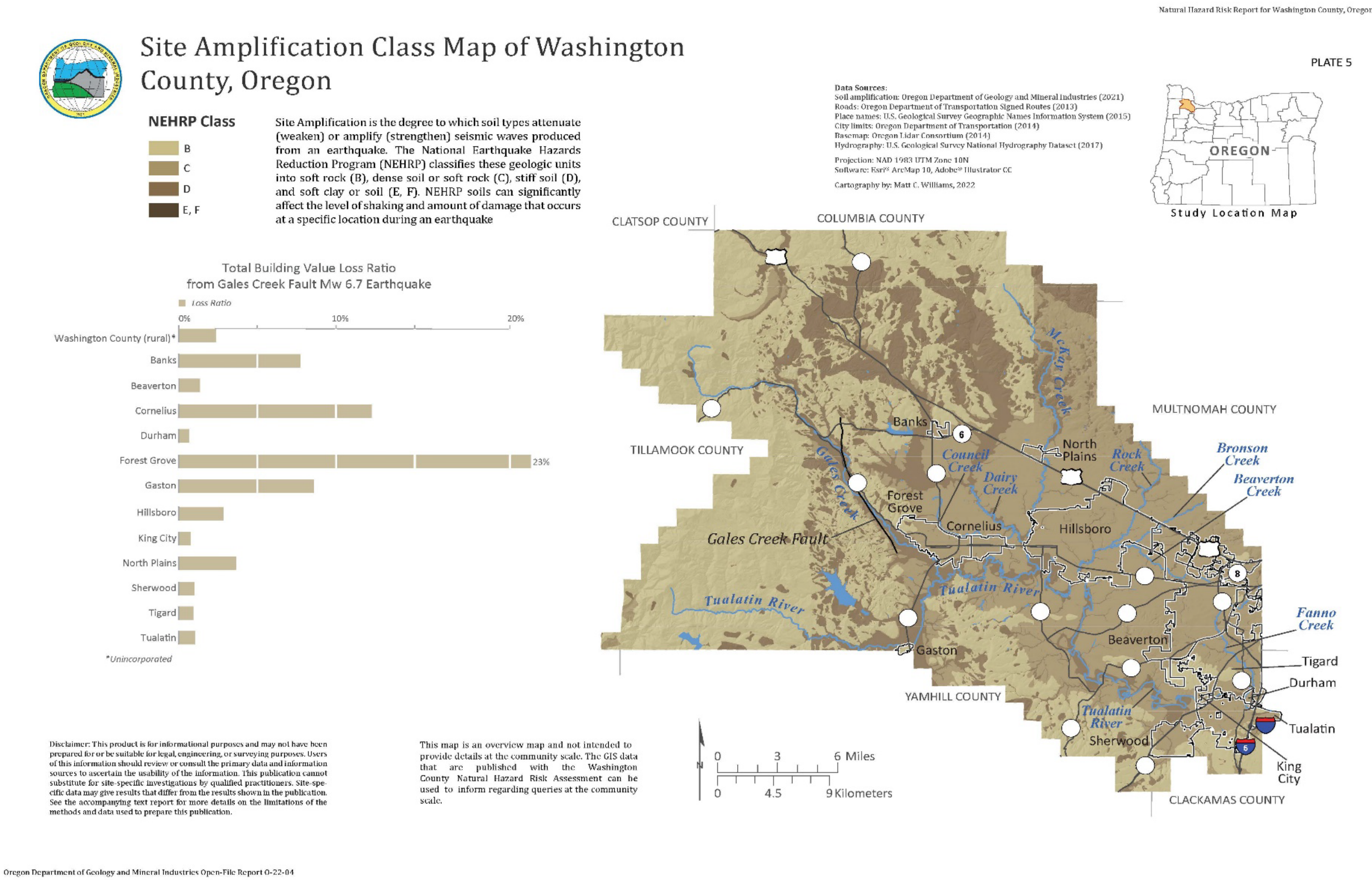

Figure 9: Site Amplification Class Map of Washington County, Oregon[56]

[56] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

Strong ground shaking can also cause new landslides and reactivate dormant landslides. Commonly, slopes that are marginally stable prior to an earthquake can become unstable and fail. Some coseismic landslides result from liquefaction that causes lateral movement of soil, or lateral spread.[57] Coseismic landslides are more likely to occur in the northern portion of Washington County where a threat of non-coseismic landslides also exists.[58] Figure 10 below shows the areas of Washington County that are susceptible to coseismic landslides.

[57] Oregon Department of Geology and Mineral Industries. (n.d.). Open-File Report O-19-09: Coseismic Landslide Susceptibility, Liquefaction Susceptibility, and Soil Amplification Class Maps, Clackamas, Columbia, Multnomah, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-19-09/O-19-09_report.pdf

[58] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

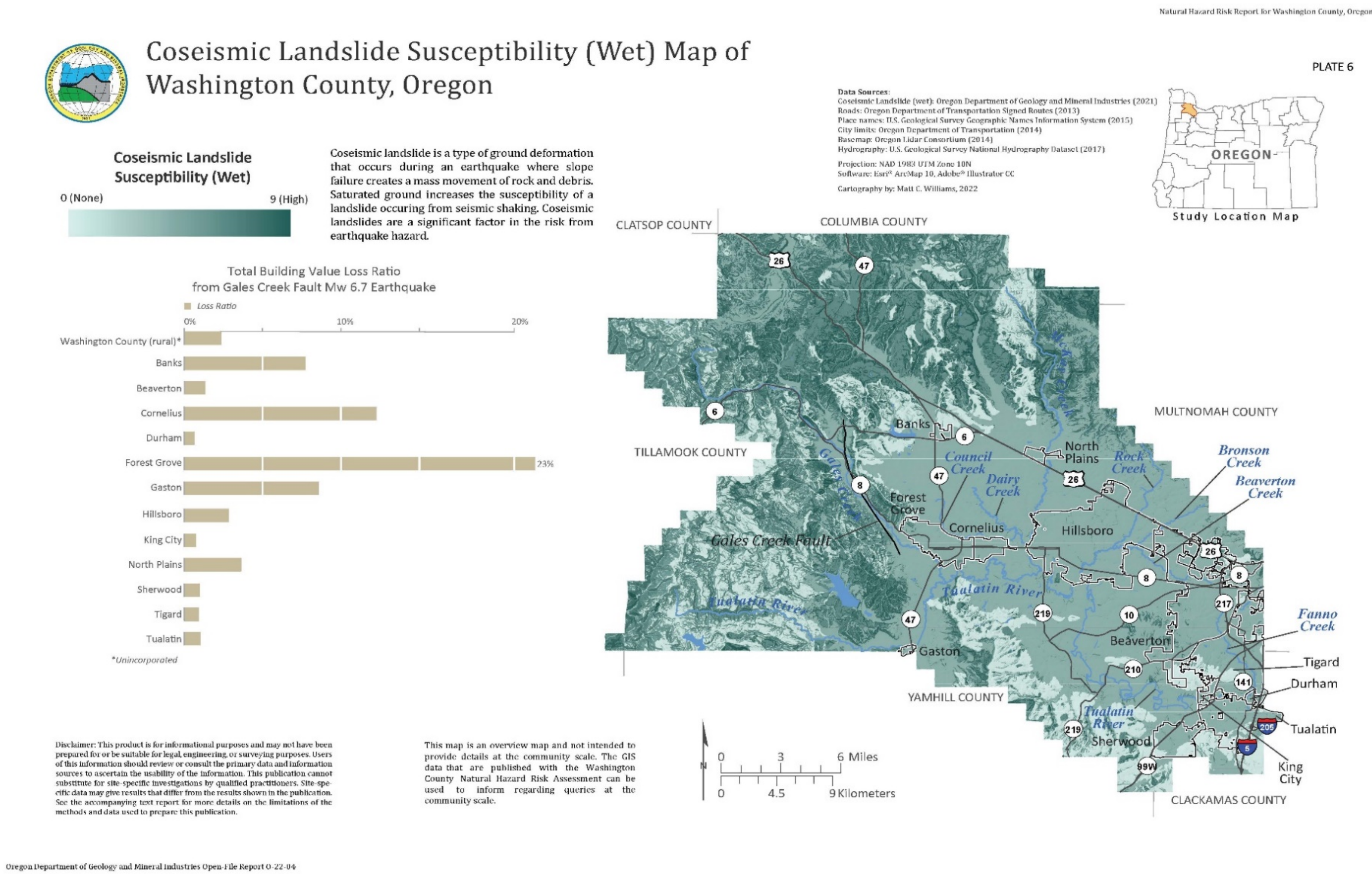

Figure 10: Coseismic Landslide Susceptibility (Wet) Map of Washington County, Oregon[59]

[59] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

2.7.3.3. History

There have been no significant recorded occurrences of earthquakes since the adoption of the 2017 NHMP.

The 2020 Oregon NHMP shows that Region 2, which includes Washington County, has had at least seven crustal earthquakes of magnitude 4.0 or greater since 1877. The region's largest earthquakes were the 1877 magnitude 5.3 and the 1962 magnitude 5.2 earthquakes. In addition, the region has been shaken historically by crustal and intraplate earthquakes and prehistorically by subduction zone earthquakes centered outside the area.[60]

Earthquakes that have been felt in the planning area, including the city of Beaverton, have originated in other areas. The Scotts Mills earthquake on March 25, 1993, was the first significant earthquake in recorded history to originate close enough to the city to be felt. Beaverton experienced only minor damage, but surrounding counties, including Clackamas, incurred significant damage and received a federal disaster declaration. The Nisqually earthquake on February 28, 2001, was felt in the city of Beaverton but did little damage. Numerous small quakes occurred in the Portland Metro area, which is geographically adjacent to Washington County, in 2013, 2014, and 2015. Most of these earthquakes were not strong enough to be felt. In 2003, though too small to be felt, a small quake was detected under Cooper Mountain, in the southern part of the city of Beaverton, on a fault that had been previously designated by geologists as "inactive." The Beaverton fault zone is not shown on most published geologic maps of the area because it is currently minimally active. It is unknown how active it may be in the future. The central part of the Beaverton fault zone is mapped along the northern base of Cooper Mountain in the south-central part of the Tualatin Basin, but the rest of the fault zone has no apparent geomorphic expression.[61]

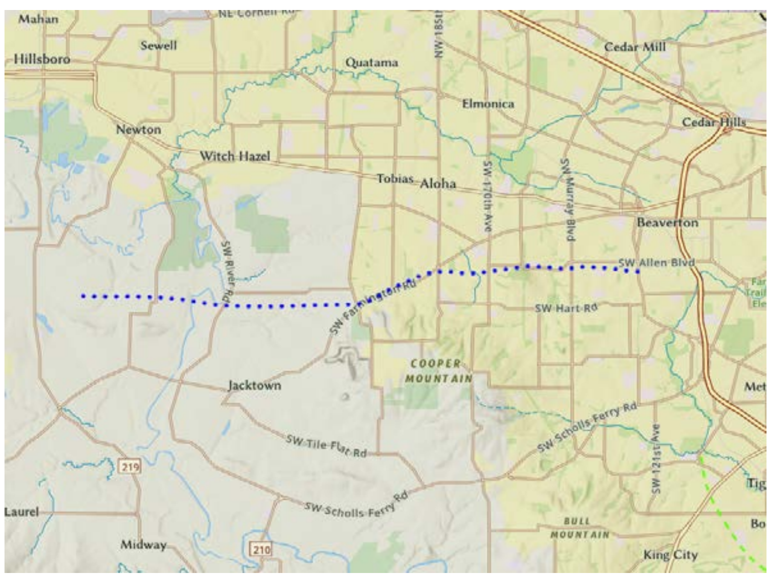

Figure 11: Beaverton Fault[62]

[60] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[61] Personius, S.F. (Compiler). (2002). Fault number 715, Beaverton Fault Zone, in Quaternary fault and fold database of the United States: U.S. Geological Survey website. https://earthquake.usgs.gov/cfusion/qfault/show_report_AB_archive.cfm?fault_id=715&section_id=

[62] U.S. Geological Survey. (n.d.). U.S. Quaternary Faults. https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=5a6038b3a1684561a9b0aadf88412fcf

2.7.3.4. Probability of Future Events

As indicated by plan participants, there is a medium probability of an earthquake occurring in Washington County, representing that one incident is likely to occur within 35 to 75 years. There is a higher than 45% probability the County will experience damaging shaking during the next 100 years, which is the highest level of probability possible.[63]

There are different types of earthquakes that could impact the County. The probability of a damaging earthquake, however, is harder to determine. Establishing a probability for crustal earthquakes is difficult given the small number of historic events in the region. Earthquakes generated by volcanic activity in Oregon's Cascade Range are possible, but likewise unpredictable.

The greatest earthquake threat to the County is posed by the CSZ. Although earthquakes can be a highly variable natural phenomenon, the CSZ has a well-understood recurrence history, which makes calculating potential future events easier and highlights the importance of increased mitigation efforts. Washington County is susceptible to deep intraplate events within the CSZ, ruptures of the CSZ, and shallow crustal events within the North American Plate.

The paleoseismic record includes 18 magnitude 8.8–9.1 megathrust earthquakes in the last 10,000 years that affected the entire subduction zone, including the County. The return period for the largest earthquakes is 530 years, and the probability of the next such event occurring in the next 50 years ranges from 7% to 12%. An additional 10 to 20 smaller, magnitude 8.3–8.5, earthquakes affected only the southern half of Oregon and northern California. The average return period for these is about 240 years, and the probability of a small or large subduction earthquake occurring in the next 50 years is 37%–43%.[64]

Although a CSZ event could cause more widespread and catastrophic damage to the planning area, the County is more likely to experience a crustal earthquake event than a CSZ event. Crustal earthquakes are likely to occur more frequently and be smaller events with low to medium impacts compared to CSZ events.

2.7.3.4.1. Climate Change

There is currently insufficient research on potential impacts climate change may have on the frequency, magnitude, and extent of earthquakes.[65]

2.7.3.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County have the potential to be exposed to and impacted by earthquakes. Due to the natural variability in how earthquake events can occur, it is not likely that all shaking, liquefaction, and coseismic landslides will occur simultaneously or to the same degree. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

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[63] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[64] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[65] National Aeronautics and Space Administration. (2019, October 29). *Can Climate Affect Earthquakes, Or Are the Connections Shaky?* Global Climate Change. https://climate.nasa.gov/news/2926/can-climate-affect-earthquakes-or-are-the-connections-shaky/

The Oregon DOGAMI has completed in-depth studies to determine potential impacts of various earthquake scenarios. Scenario-specific vulnerabilities are detailed below. Impacts from earthquakes can vary greatly based on event location, magnitude, and extent. Generally, an earthquake can:

- Cause injury or death;
- Create a need for widespread search and rescue operations;
- Produce mental health impacts, including post-traumatic stress disorder;
- Result in widespread public health issues stemming from failing or damaged infrastructure, such as lack of clean water and sanitation;
- Impact governments economically by reducing future revenues, increasing current costs resulting from response activities, and increasing future costs resulting from recovery and reconstruction activities;
- Interrupt business operations;
- Affect personal and household economics through loss of income, increased medical costs, and property damage that may not be covered by insurance;
- Damage and destroy the built environment, including above- and belowground utility lines, residential, public, and private buildings, and transportation systems;
  - There are many unreinforced masonry (URM) structures throughout the state; however, the currently available default building data does not include any URM structures. Thus, the reported damage and loss estimates may seriously under-represent the actual threat.[66]
- Cause hazardous material releases due to infrastructure and facility damage;
- Harm ecosystems by causing loss of habitat, death and destruction of vegetation and animals, and erosion;
- Change water flows, including paths of rivers and streams; and
- Trigger other hazard events, such as fires, tsunamis, floods, landslides, and sinkholes.

2.7.3.5.1. Cascadia Subduction Zone Magnitude 9.0 Scenario and Portland Hills Fault Magnitude 6.8 Scenarios

DOGAMI completed an analysis of potential impacts that could occur in the County as a result of a CSZ magnitude 9.0 scenario and a Portland Hills Fault magnitude 6.8 scenario. This study provides information that can inform mitigation actions and assist planners in estimating sheltering and public assistance needs in the aftermath of an event.

The study was published in 2018 and covers the counties of Washington, Clackamas, and Multnomah. Because Washington County has experienced population and built-environment growth since the report was created, some data used may not be the most recent information available. Additionally, some data is comprehensive for all three counties; however, the study provides a strong baseline for the planning area and plan participants to utilize.

A magnitude 9.0 CSZ earthquake will result in significant damage to buildings, with collateral casualties, in the tri-county area. Transportation networks may be severely impaired, compromising emergency response. Millions of tons of debris will need to be removed to staging areas for sorting and eventual permanent disposal. Hundreds of thousands of buildings will need timely safety inspections, and thousands to tens of thousands of people will need to find other permanent housing arrangements. In comparison, a magnitude 6.8 Portland Hills Fault earthquake will be devastating to the tri-county area,

[66]Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

primarily due to its position relative to the study area's major assets and population centers, with losses more than double those from a magnitude 9.0 CSZ earthquake.

Scenarios in the report use the best scientific information available on fault placement, rupture frequency, and earthquake magnitude. Because the loss estimate data is used for planning purposes, scenarios incorporate the upper end of predicted magnitude when modeling a specific earthquake. The study focuses on damage to buildings and the people that occupy them and the two key infrastructure sectors of electric power transmission and transportation routes.

Each earthquake scenario was modeled with a wet (saturated) and a dry soil condition, and each earthquake was modeled at two different times of the day, at 2 a.m. and at 2 p.m. In western Oregon, soil moisture conditions vary widely throughout the calendar year. Soil moisture conditions influence the likelihood of an earthquake-triggered landslide or liquefaction. An earthquake occurring during wet (saturated) soil conditions is much more likely to induce landslides and liquefaction. Some earthquake-induced landslides may occur in dry soil conditions, but liquefaction is much less likely. Throughout a typical day, people move between various buildings, such as residences, schools, work facilities, and commercial facilities. Some buildings, due to their basic structural system, are more likely to sustain significant damage from an earthquake and, thus, depending on how many people are occupying the building at the time of the earthquake, cause more casualties.

The Hazus Advanced Engineering Building Module model estimate used in the study identifies each building's probability of being in one of five damage states: None, Slight, Moderate, Extensive, and Complete.[67] Damage state descriptions are provided below.

- **None:** No damage.
- **Slight:** Small plaster cracks at corners of door and window openings and wall and ceiling intersections; small cracks in masonry chimneys and masonry veneers. Small cracks are assumed to be visible, with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as large cracks).
- **Moderate:** Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
- **Extensive:** Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
- **Complete:** Structures may have large permanent lateral displacement or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with a damage state of Complete is expected to be collapsed, on average.

[67] Federal Emergency Management Agency. (2020). Earthquake Loss Estimation Methodology. Hazus-MH 2.1 Advanced Engineering Building Module (AEBM) Technical and User's Manual. https://www.fema.gov/sites/default/files/2020-09/fema_hazus_advanced-engineering-building-module_user-manual.pdf

2.7.3.5.2. Study Results[68]

2.7.3.5.2.1. Cascadia Subduction Zone Magnitude 9.0 Scenario

Table 15: Number of Buildings Per Damage State and Soil Moisture Conditions for Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario

Building Damage State	"Dry" Soil	Building Percent	"Wet" Saturated Soil	Building Percent
Slight	44,673	25%	41,807	23%
Moderate	20,381	11%	19,012	11%
Extensive	6,303	3%	5,892	3%
Complete	2,784	2%	14,026	8%
Total Damaged Buildings	**74,141**	**41%**	**80,737**	**45%**

Table 16: Buildings Per Damage Category, "Dry" Soil Moisture Conditions for Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario

Building Category	Total Number of Buildings	Building Square Footage	Building Value	Building Repair Costs	Building Loss Ratio
Agriculture	10,753	26,823,000	$2,855,000,000	$368,000,000	13%
Commercial	5,863	104,377,000	$15,815,000,000	$2,310,000,000	15%
Industrial	1,399	50,567,000	$8,548,000,000	$1,350,000,000	16%
Institutional	1,931	28,098,000	$4,856,000,000	$790,000,000	16%
Multi-Family Residential	18,475	98,385,000	$15,671,000,000	$1,155,000,000	7%
Single-Family Residential	138,117	289,198,000	$34,755,000,000	$990,000,000	3%
Manufactured Housing	4,573	5,523,000	$232,000,000	$49,000,000	21%

68 Oregon Department of Geology and Mineral Industries. (2018). Open-File Report O-18-02: *Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon.* https://www.oregongeology.org/pubs/ofr/O-18-02/O-18-02_report.pdf

Table 17: Buildings Per Damage Category, “Wet” Soil Moisture Conditions for Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario

Building Category	Total Number of Buildings	Building Square Footage	Building Value	Building Repair Costs	Building Loss Ratio
Agriculture	10,753	26,823,000	$2,855,000,000	$558,000,000	20%
Commercial	5,863	104,377,000	$15,815,000,000	$3,031,000,000	19%
Industrial	1,399	50,567,000	$8,548,000,000	$1,799,000,000	21%
Institutional	1,931	28,098,000	$4,856,000,000	$1,039,000,000	21%
Multi-Family Residential	18,475	98,385,000	$15,671,000,000	$2,016,000,000	13%
Single-Family Residential	138,117	289,198,000	$34,755,000,000	$3,144,000,000	9%
Manufactured Housing	4,573	5,523,000	$232,000,000	$61,000,000	26%

Table 18: Collapsed Buildings by Soil Moisture Conditions for Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario

Total Number of Buildings	“Dry” Soil	“Wet” Saturated Soil
181,111	158	313

Table 19: Number of Permanent Residents Buildings Per Damage Category and Soil Moisture Conditions for Cascadia Subduction Zone Magnitude 9.0 Earthquake Scenario

Building Damage State	“Dry” Soil	“Wet” Saturated Soil
Slight	133,418	125,169
Moderate	66,488	62,313
Extensive	16,055	15,165
Complete	5,185	37,657
Total Permanent Residents	**221,146**	**240,304**

2.7.3.5.2.2. Portland Hills Fault Magnitude 6.8 Scenario

Table 20: Number of Buildings Per Damage Category and Soil Moisture Conditions for Portland Hills Fault Magnitude 6.8 Earthquake Scenario

Building Damage State	"Dry" Soil	Building Percent	"Wet" Saturated Soil	Building Percent
Slight	57,184	32%	49,602	27%
Moderate	44,766	25%	38,807	21%
Extensive	15,892	9%	14,519	8%
Complete	6,492	4%	28,194	16%
Total Damaged Buildings	**124,334**	**70%**	**131,122**	**72%**

Table 21: Buildings Per Damage Category, "Dry" Soil Moisture Conditions for Portland Hills Fault Magnitude 6.8 Earthquake Scenario

Building Category	Total Number of Buildings	Building Square Footage	Building Value	Building Repair Costs	Building Loss Ratio
Agriculture	10,753	26,823,000	$2,855,000,000	$309,000,000	11%
Commercial	5,863	104,377,000	$15,815,000,000	$4,917,000,000	31%
Industrial	1,399	50,567,000	$8,548,000,000	$2,412,000,000	28%
Institutional	1,931	28,098,000	$4,856,000,000	$1,258,000,000	26%
Multi-Family Residential	18,475	98,385,000	$15,671,000,000	$2,831,000,000	18%
Single-Family Residential	138,117	289,198,000	$34,755,000,000	$3,582,000,000	10%
Manufactured Housing	4,573	5,523,000	$232,000,000	$52,000,000	23%

Table 22: Buildings Per Damage Category, "Wet" Soil Moisture Conditions for Portland Hills Fault Magnitude 6.8 Earthquake Scenario

Building Category	Total Number of Buildings	Building Square Footage	Building Value	Building Repair Costs	Building Loss Ratio
Agriculture	10,753	26,823,000	$2,855,000,000	$525,000,000	18%
Commercial	5,863	104,377,000	$15,815,000,000	$6,424,000,000	41%
Industrial	1,399	50,567,000	$8,548,000,000	$3,270,000,000	38%
Institutional	1,931	28,098,000	$4,856,000,000	$1,707,000,000	35%
Multi-Family Residential	18,475	98,385,000	$15,671,000,000	$4,687,000,000	30%

Building Category	Total Number of Buildings	Building Square Footage	Building Value	Building Repair Costs	Building Loss Ratio
Single-Family Residential	138,117	289,198,000	$34,755,000,000	$7,614,000,000	22%
Manufactured Housing	4,573	5,523,000	$232,000,000	$70,000,000	26%

Table 23: Collapsed Buildings by Soil Moisture Conditions for Portland Hills Fault Magnitude 6.8 Earthquake Scenario

Total Number of Buildings	"Dry" Soil	"Wet" Saturated Soil
181,111	387	1,155

Table 24: Number of Permanent Residents Per Building Damage Category and Soil Moisture Conditions for Portland Hills Fault Magnitude 6.8 Earthquake Scenario

Building Damage State	"Dry" Soil	"Wet" Saturated Soil
Slight	168,428	145,320
Moderate	137,364	118,446
Extensive	48,269	43,868
Complete	19,582	86,010
Total of Permanent Residents	**373,643**	**393,644**

2.7.3.5.2.3. Gales Creek Fault Magnitude 6.7 Scenario

DOGAMI ran a Gales Creek Fault deterministic scenario with a magnitude of 6.7 using the Hazus®-MH database. This report provides specific potential impacts and vulnerabilities for this scenario.[69]

The results indicate that Washington County will incur losses of approximately $2 billion or 2.7% of total building assets due to a Gales Creek Fault magnitude 6.7 earthquake. These results are strongly influenced by proximity to the Gales Creek Fault and ground deformation from liquefaction. Moderate to high liquefaction susceptibility exists throughout the County, which increases the risk of earthquake. There are some developed areas in the cities of Forest Grove and Hillsboro that are built on highly liquefiable soils and have higher estimates of damage from this earthquake scenario than other communities in the study area. Loss estimates from an earthquake scenario described in this report vary widely by community in Washington County.

[69] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

The results of the Washington County Gales Creek Fault magnitude 6.7 earthquake scenario are as follows:

- Number of red-tagged buildings: 1,807
- Number of yellow-tagged buildings: 6,049
- Loss estimate: $2,018,269,000
- Loss ratio: 2.7%
- Non-functioning critical facilities: 31
- Potentially displaced population: 6,160

Red-tagged buildings correspond to a Hazus®-MH damage state of "complete," which means the building is uninhabitable. Yellow-tagged buildings are in the "extensive" damage state, indicating limited habitability. These damage states are correlated to loss ratios that are then multiplied by the building dollar value to obtain a loss estimate.

Although the impacts of coseismic landslides were included in the Hazus®-MH earthquake results, DOGAMI did not perform an analysis that specifically isolated damage caused by coseismic landslides. These landslides likely contribute to a small percentage of the overall estimated damage from the earthquake hazard in Washington County. Landslides exist in the northern portion of Washington County where coseismic landslides are more likely to occur.

Building vulnerabilities, such as the age of the building stock and occupancy type, are also contributing factors in damage estimates. The first seismic buildings codes were implemented in Oregon in the 1970s, and by the 1990s, modern seismic building codes were being enforced. Nearly 70% of Washington County's buildings were built before this time. Certain building types are known to be more vulnerable than others in earthquakes, such as the manufactured homes. In Hazus®-MH , manufactured homes are one occupancy type that performs poorly in earthquake damage modeling. Communities that are composed of an older building stock and more vulnerable occupancy types are expected to experience more damage from earthquake than communities with fewer of these vulnerabilities.

The report identifies the following locations within the study area that are comparatively at greater risk of earthquake hazard[70]:

- Areas near the epicenter of the simulated earthquake scenario are likely to incur a significant amount of damage. The communities of Banks, Cornelius, Forest Grove, and Gaston have higher estimated loss ratios compared to other communities in the study due to the level of shaking likely to occur.
- Buildings in areas with relatively high liquefaction susceptibility along Dairy Creek, Gales Creek, and the Tualatin River are at higher risk of damage from coseismic liquefaction induced ground deformation.
- Unreinforced masonry buildings in the older downtown portions of Forest Grove and Hillsboro are more vulnerable to potentially substantial damage during an earthquake compared to other nearby structures built to modern standards.
- Twenty-eight of the 269 critical facilities in the study area are estimated to be non-functioning due to an earthquake like the one simulated in this study.[71]

[70] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[71] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

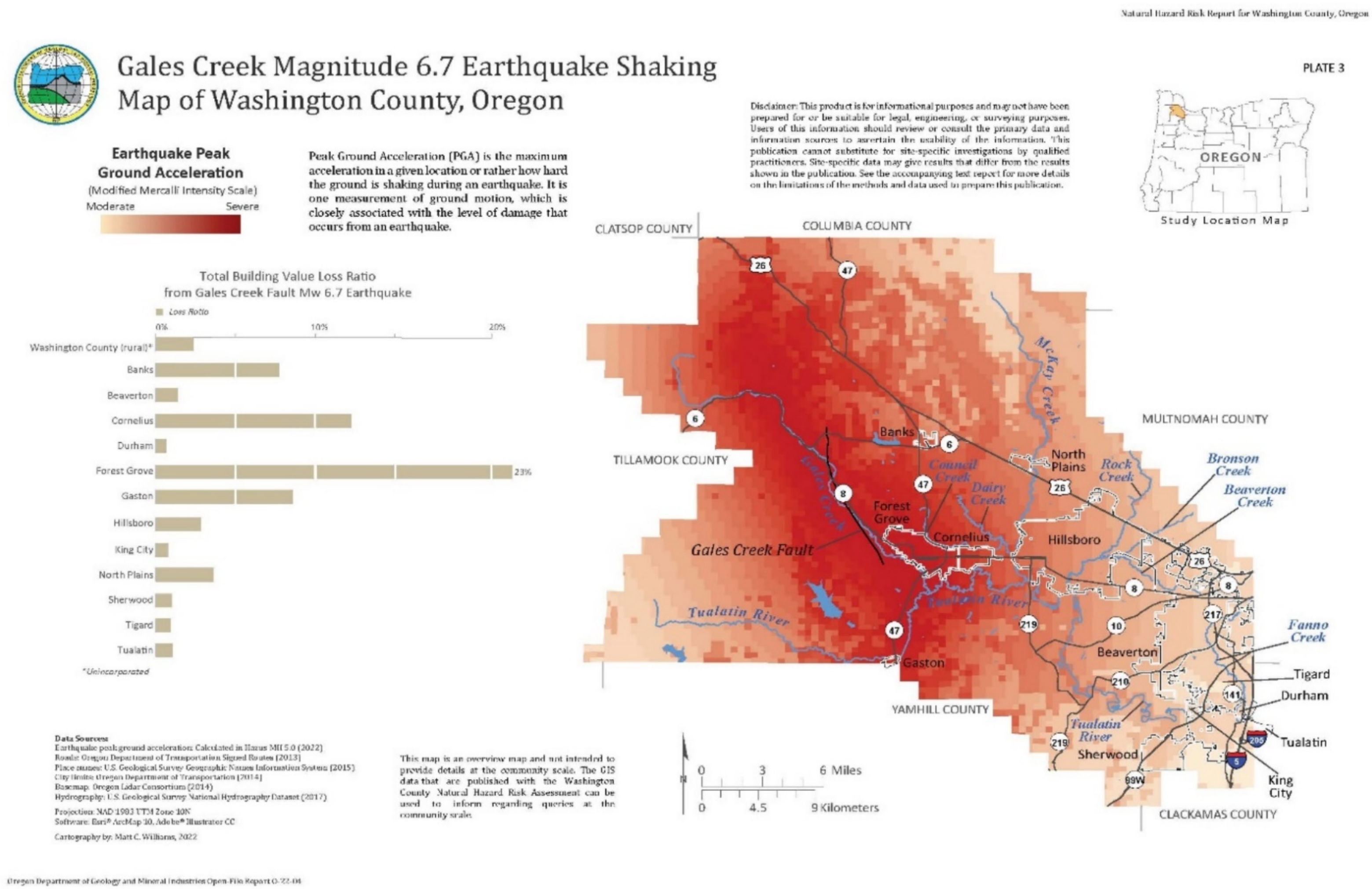

Figure 12: Gales Creek Magnitude 6.7 Earthquake Shaking Map of Washington County, Oregon[72]

[72] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

2.7.3.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of a 3- to 5-minute Cascadia earthquake event and 1-minute crustal earthquake event. Additional information is in the participant annexes.

Table 25: Participant Overall Risk of Earthquake[73]

Participant	Risk of Earthquake: Cascadia (3–5-minute event)	Risk of Earthquake: Crustal (1-minute event)
City of Beaverton	196	196
City of Cornelius	173	159
City of Forest Grove	173	159
City of Hillsboro	201	201
City of North Plains	201	71
City of Sherwood	186	158
City of Tigard	203	203
Clean Water Services	148	155
Tualatin Hills Park & Recreation District	161	161
Tualatin Valley Water District	201	159
Washington County	201	201

[73] 2023 NHMP Participant Planning Documentation

2.7.4. Extreme Heat

Significant Changes

- Added as a hazard that impacts the planning area. Not included in previous versions of the NHMP.

2.7.4.1. Characteristics

Extreme heat events occur from time to time as a result of natural variability, and Washington County usually experiences warm, dry summers. Historically, extreme heat and heat waves have not been common, but days above 90 degrees Fahrenheit (°F) occur nearly every year.[74]

There are several ways to measure extreme heat, and it is typically defined relative to normal conditions for an area. Per the 2020 Oregon NHMP, one common way to measure extreme heat is to count the number of days with temperatures above a certain threshold, such as days with temperatures above 90 °F.

Due to a rise in frequency, severity, and impacts from extreme heat events, the Steering Committee chose to include this hazard for the first time in the 2023 Washington County NHMP. Extreme heat events are expected to increase in frequency, duration, and intensity in the County due to continued warming temperatures, so it is important to continue and enhance current mitigation efforts and prepare for the implementation of enhanced mitigation actions as future conditions change.

2.7.4.2. Location and Extent

Recent extremely hot temperatures have impacted the entire planning area. Although the temperatures experienced among NHMP participants may vary slightly due to geographic, vegetation, and built environment variations, the entire County will experience extreme heat simultaneously.

The NWS office that covers Washington County issues heat warnings based on the National Oceanic and Atmospheric Administration (NOAA) NWS Experimental HeatRisk forecast categories.

Figure 13 shows the NOAA NWS Experimental HeatRisk forecast categories, which are used as a guide for the issuance of excessive heat advisories, watches, and warnings.

The Experimental HeatRisk forecast provides a color and numeric value that places forecast heat for a specific location into an appropriate level of heat concern, along with identifying groups potentially most at risk at that level. The HeatRisk is accompanied by recommendations for heat protection and is a useful tool for planning for upcoming heat and its associated potential risk.[75]

Based on the high-resolution NWS national gridded forecast database, a daily HeatRisk value is calculated for each location from the current date through seven days in the future. Currently, HeatRisk is adopted for use in the NWS Western Region and is being introduced and tested in other NWS regions. Once it is nationally adopted, "experimental" will be removed from the product's name. It is anticipated this will occur in one to two years. It has been available in the western United States since 2014.

Heat watches, advisories, and warnings remain the official nationally recognized heat products from the NWS. The HeatRisk represents additional information that can be used to better identify those days of the year when heat may be at levels that pose a risk to certain populations or economic sectors.[76] HeatRisk

[74] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[75] National Weather Service. (n.d.). HeatRisk-Overview. https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=pqr
[76] National Weather Service. (n.d.). HeatRisk-Overview. https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=pqr

ensures communities have the right information at the right time to be better prepared for upcoming heat events.

The biggest difference between the HeatRisk approach and other approaches is that it identifies unusual heat specifically for that date and location, rather than only using a single threshold value applied across a large area. This allows the approach to better account for acclimation and the variation in climatology that we know exists across most regions. To do this, the NWS uses high-resolution gridded climatology to put the forecast into context. HeatRisk also incorporates heat-health data from the Centers for Disease Control and Prevention into the thresholds, essentially applying direct impact information into the approach.[77]

Category	Level	Meaning
GREEN	0	No Elevated Risk
YELLOW	1	Low Risk for those extremely sensitive to heat, especially those without effective cooling and/or adequate hydration
ORANGE	2	Moderate Risk for those who are sensitive to heat, especially those without effective cooling and/or adequate hydration
RED	3	High Risk for much of the population, especially those who are heat-sensitive and those without effective cooling and/or adequate hydration
MAGENTA	4	Very High Risk for entire population due to long duration heat, with little to no relief overnight

Figure 13: National Weather Service Experimental HeatRisk Categories[78]

The Portland office of the NWS, which covers Washington County, issues a range of watches and advisories associated with extreme heat. These NWS products are supplemented by the Experimental HeatRisk forecast, shown in Figure 14.[79, 80]

- **Excessive Heat Outlook—Be Aware!** The potential exists for an excessive heat event in the next three to seven days. An outlook is used to provide information to those who need considerable lead time to prepare for the event, such as public utilities, emergency management, and public health officials.
- **Excessive Heat Watch—Be Prepared!** Conditions are favorable for an excessive heat event in the next 24 to 72 hours. A watch is used when the risk of a heat wave has increased, but its occurrence and timing is still uncertain. It is intended to provide enough lead time so those who

[77] National Weather Service. (n.d.). NWS Experimental HeatRisk. https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=pqr
[78] National Weather Service. (n.d.). NWS Experimental HeatRisk. https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=pqr
[79] National Weather Service. (n.d.). Heat Watch vs. Warning. https://www.weather.gov/safety/heat-ww
[80] National Oceanic and Atmospheric Administration National Weather Service, Portland Oregon Office. (2022, July 14). Personal communication with Treena Jensen, Warning Coordination Meteorologist.

need to set preparation plans in motion can do so, such as established local excessive heat event plans.

- This heat watch is issued when there is a HeatRisk of 2.66–3.9 (red) to 4 (magenta). A watch is issued 12–48 hours ahead of the anticipated event, when there is a more than 50% chance of warning criteria being met.

- **Excessive Heat Warning—Take Action!** This warning is issued within 12 hours of the onset of extremely dangerous heat conditions. The warning is used when the HeatRisk is 2.66–3.9 (red) to 4 (magenta). A warning is issued up to 36 hours ahead of the event when imminent threat or there is a more than 80% chance of warning criteria being met.
- **Heat Advisory—Take Action!** This advisory is issued within 12 hours of the onset of extremely dangerous heat conditions, when the HeatRisk is 2–2.38 (low orange) to 2–2.65 (high orange). A warning is issued up to 36 hours ahead of the anticipated event when there is an 80% chance of advisory criteria being met.

NWS Watch Heat Warning and Advisories

Product	*Timeframe*	*Threat/Action*	*NWS Heat Threshold*	*EAS/WEA/ NAWAS?**
Excessive Heat Warning	• Up to 36 hours ahead of event. • When imminent threat or >80% chance of warning criteria being met.	• Threat to life—much of the population. • Take protective action.	• HeatRisk 4 (Magenta) • HeatRisk 2.66–3.9 (Red)	No
Heat Watch	• 12–48 hours ahead of event. • When >50% chance of warning criteria being met.	• Threat to life—much of the population. • Have a plan for action.	• HeatRisk 4 (Magenta) • HeatRisk 2.66–3.9 (Red)	No
Heat Advisory	• Up to 36 hours ahead of event. • When 80% chance of advisory criteria being met.	• Moderate risk to vulnerable. • Take protective action/message to vulnerable communities.	• HeatRisk 2.4–2.65 (High Orange) • Consider for 2–2.38 (Low Orange)	No

* Emergency Alert System (EAS); Wireless Emergency Alert (WEA); and National Warning System (NAWAS)

Figure 14: National Weather Service Portland Heat Warnings and Advisory Thresholds[81]

[81] National Oceanic and Atmospheric Administration National Weather Service, Portland Oregon Office. (2022, July 14). Personal communication with Treena Jensen, Warning Coordination Meteorologist.

2.7.4.3. History

Historically, Washington County does not have a record of consistent extreme heat events. However, as can be seen in the detailed history below, the frequency, duration, and intensity of events has been increasing rapidly. Typical average temperatures range from 65 °F to 71 °F in May; 71 °F to 78 °F in June, 78 °F to 84 °F in July, and 81 °F to 84 °F in August.[82]

The heat index is a measure of how hot it feels, combining temperature and relative humidity. As relative humidity increases, a given temperature can feel even hotter. The body cools itself through the evaporation of perspiration or sweat. However, when the relative humidity is high, the increased moisture content in the air decreases the evaporation of perspiration or sweat. Therefore, the body feels warmer when it is humid. This is why the combination of temperature and relative humidity is used to determine the heat index and likelihood of heat disorders with prolonged exposure or strenuous activity.[83]

Table 26: Historic Extreme Heat Events in Washington County[84]

Date	Event
May 22–23, 2017	A ridge of high pressure brought a couple of days of warm weather. Temperatures climbed up into the upper 80s to low 90s, with a heat index of 88 °F in many locations across the area. Early season heat led people to seek relief in local rivers and lakes. While air temperatures were warm, river and lake temperatures were still cold, leading to two drownings across the area.
June 2017	June brought high heat of sufficient duration to warrant activation of cooling shelters. Temperatures at Hillsboro Airport reached 99 °F with a heat index of 98 °F on June 25.
August 1–4, 2017	**Excessive Heat Event:** Strong high pressure brought record-breaking heat to many parts of northwest Oregon. The heat led people to seek relief at local rivers. Two people drowned while swimming. Cooling shelters were opened in the County. The maximum temperature reached 104 °F with a heat index of 109 °F.
July 12–17, 2018	High pressure over the region led to a stretch of hot days, and hot temperatures led people to cool off in local rivers. There were two drownings recorded. Cooling shelters were opened in the County. The maximum temperature reached 96 °F with a heat index of 95 °F.
August 2019	August brought high heat of sufficient duration to warrant activation of cooling shelters. Temperatures at Hillsboro Airport reached 97 °F with a heat index of 99 °F on August 28.

[82] Weather Spark. (n.d.). August Weather at Portland-Hillsboro Airport. https://weatherspark.com/m/145224/8/Average-Weather-in-August-at-Portland-Hillsboro-Airport-Oregon-United-States
[83] National Weather Service. (n.d.) Excessive Heat. https://www.weather.gov/phi/heat
[84] National Centers for Environmental Information Storm Events Database, Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx;
Washington County Planning Documentation; Weather Spark. (n.d.). August Weather at Portland-Hillsboro Airport. https://weatherspark.com/m/145224/8/Average-Weather-in-August-at-Portland-Hillsboro-Airport-Oregon-United-States

Date	Event
June 26–29, 2021	A high-pressure heat dome over the region led to stretch of extreme heat, shattering records from June 26 through June 29. All-time maximum temperatures were broken by 8 °F to 10 °F. The maximum temperature reached 108 °F with a heat index of 115 °F. Widespread fatalities (123 total) occurred due to the heat, as many were without air-conditioning, and there was an increase in the number of drownings. Widespread closures and postponements of businesses and events, respectively, also occurred. There were reports of roads buckling due to heat, and cooling shelters were opened.
August 11–14, 2021	Hot weather began to develop August 9, peaking August 11–12, and temperatures continued above normal for several days. The high temperature at Hillsboro Airport was 103 °F with a heat index of 109 °F on August 11 and August 12. Peak afternoon temperatures of 100 °F to 105 °F drove people to seek relief in or near bodies of water. A 61-year-old man drowned while swimming. Some businesses closed due to the heat, and cooling shelters were opened.

2.7.4.4. Probability of Future Events

Washington County does not have a consistent history of extreme heat events; however, the area has recently experienced unprecedentedly hot summers. It is anticipated that the County will continue to experience more frequent and more intense extreme heat events in the future due to warming temperatures. Washington County is anticipated to experience fewer days with extreme heat than other areas of the state; however, it is expected the County will experience at least an additional 30 hot days per year.[85]

Extreme heat events can often lead to or be accompanied by drought and wildfire. Washington County is expected to experience increased frequency of extreme heat, drought, and wildfire events, and these events may occur independent of each other or concurrently.

- Extreme heat and drought often occur simultaneously, and drought can make a hot day hotter, while a heat wave can make dry conditions even drier. Periods of drought can quickly increase temperatures. Extreme heat can also increase water demands, in which human activities can reduce water supplies, leading to human-caused drought.[86]
- Extreme heat can also intensify wildfire occurrences and impacts. Research has found that a 1.8 °F increase in mean summer temperature increased the risk of a fire starting on a given day—either by human activity or a lightning strike—by 19% to 22% and increased the burned area by 22% to 25%.[87]

2.7.4.4.1. Climate Change

The frequency, duration, and intensity of extreme heat events is expected to increase, with days becoming hotter and overnight lows becoming warmer. If greenhouse gas emissions continue at current

[85] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[86] American Planning Association. (2019). Falling Dominoes: A Planner's Guide to Drought and Cascading Impacts. https://planning-org-uploaded-media.s3.amazonaws.com/publication/download_pdf/Falling-Dominoes-Planners-Guide-to-Drought-and-Cascading-Impacts.pdf
[87] Fountain, H. (2021, November 17). Hotter Summer Days Mean More Sierra Nevada Wildfires, Study Finds. *The New York Times.* https://www.nytimes.com/2021/11/17/climate/climate-change-wildfire-risk.html#:~:text=Over%20the%20past%2020%20years,by%2022%20to%2025%20percent. (login required)

levels, temperatures in Oregon is projected to increase on average by 5 °F by the 2050s and 8.2 °F by the 2080s, with the greatest seasonal increases in summer.[88]

Extreme heat can include days with maximum temperatures over a threshold, seasons with temperatures well above average, and heat waves, or multiple days with temperature above a threshold. An increase in the frequency and magnitude of extreme heat events could significantly impact the planning area, as most infrastructure, critical facilities, and structures are not currently built to operate or withstand sustained higher temperatures. Additionally, the population in the planning area is not acclimated to higher temperatures and not adequately prepared to live and work in such conditions.

The degree to which future changes in warm temperature extremes in Oregon will be affected by changes in weather patterns is still an active area of research.[89]

2.7.4.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County have the potential to be exposed to and impacted by extreme heat. When extreme heat occurs, the impacts are typically population heavy.[90]

Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

2.7.4.5.1. Populations

Extreme heat is associated with more fatalities than any other severe weather event in the United States.[91] Heat-related deaths increased by 74% from 1980 to 2016 worldwide,[92] and heat-related mortality is expected to increase as the severity and duration of extreme heat events increase. Increases in the frequency of extreme heat events, and even small increases in average summer temperatures, are expected to increase the incidence of heat-related illnesses and deaths.[93]

With respect to extreme heat, vulnerability is defined as the combination of the probability of extreme heat events, sensitivity to extreme heat, and level of adaptive capacity in response to extreme heat.[94]

Sensitivity is the degree to which people or communities are negatively affected by extreme heat exposures. Certain populations are more sensitive than others. Older adults, infants and children, pregnant women, people with preexisting diseases, and those who take certain medications that affect thermoregulation or block nerve impulses are some of the populations with higher sensitivity.

Heat exposure can lead to heat rashes, heat cramps, heat exhaustion, and heat stroke. Although all these illnesses can cause issues, the two most deadly are heat stroke and heat exhaustion. Indirect

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88 Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf
89 Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf
90 United States Environmental Protection Agency. (2006). Excessive Heat Events. https://www.epa.gov/heatislands/excessive-heat-events-guidebook
91 Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
92 Fernandez, M. (2021, August 20). Study: Extreme Heat is Becoming an Unignorable Global Health Issue. (https://www.axios.com/extreme-heat-killed-nearly-400000-people-globally-e498118e-ca29-4360-b7c9-9d2080e09240.html)
93 Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf
94 Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

impacts include the exacerbation of existing renal, cardiovascular, and respiratory conditions. Heat waves can result in increased deaths and illness among vulnerable human populations. Older adults, children, infants, people with existing medical conditions or disabilities, low-income communities, and outdoor workers are among the groups most threatened by heat waves.[95] People who work outside (including construction workers, farmworkers, and foresters), as well as outdoor athletes face higher exposures to extreme heat. People who live in social isolation, including linguistic isolation or those living alone with few social relationships, are also at higher risk. Social factors, including race and ethnicity, income, and educational attainment, are correlated to numerous health outcomes, including heat-related illness.

Young children and infants are particularly vulnerable to heat-related illness and death, as their bodies are less able to adapt to heat than are adults' bodies. Older adults who are exposed to extreme heat, particularly those who have preexisting diseases, take certain medications, live alone, or have limited mobility, can experience multiple adverse effects. People with chronic medical conditions are more likely to have a serious health problem during a heat wave than healthy people. Pregnant women are also at higher risk. Extreme heat events have been associated with adverse birth outcomes, such as low birth weight, preterm birth, and infant mortality, as well as congenital cataracts.[96]

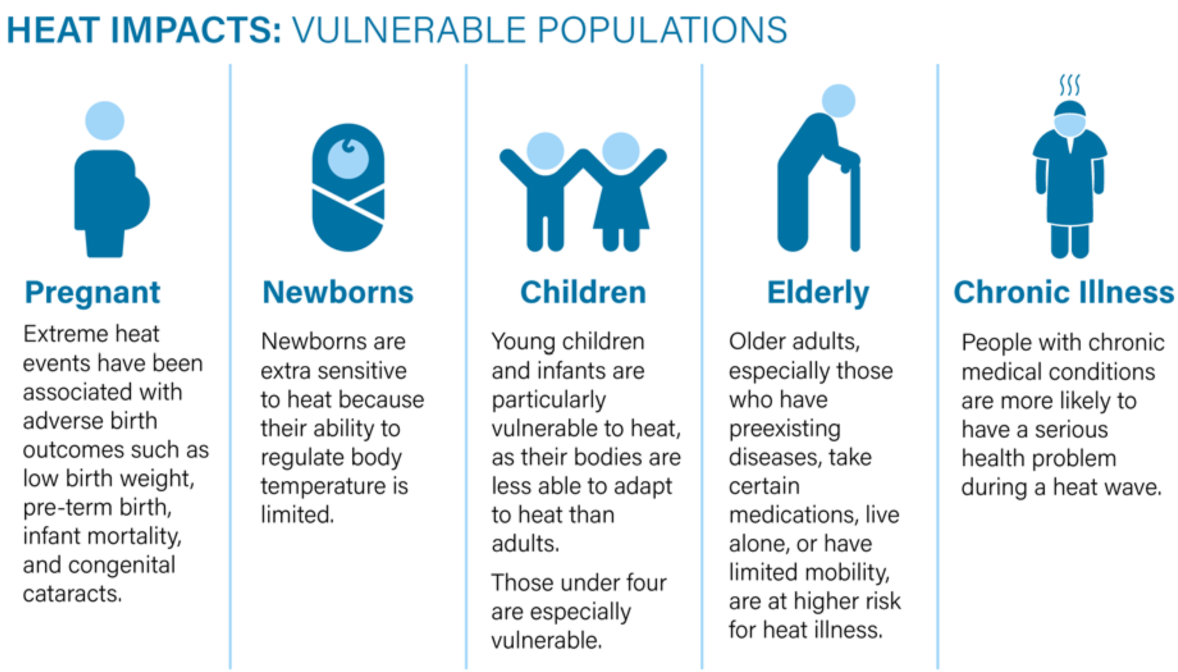

Figure 15: Heat Impacts on Vulnerable Populations[97]

Mental health can also be affected by extreme heat.[98] There is evidence that extreme heat is associated with higher levels of aggression, violence, and suicidal behavior. Heat-related impacts on health may be immediate or delayed. Even small increases in average summer temperatures can lead to increases in heat-related deaths, especially among those with underlying medical conditions. A threefold increase in

[95] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[96] National Weather Service. (n.d.). Heat Safety Tips and Resources. https://www.weather.gov/safety/heat
[97] National Weather Service. (n.d.). Heat Safety Tips and Resources. https://www.weather.gov/safety/heat
[98] Thompson, R., Hornigold, R., Page, L., & Waite, T. (2018, July 12). *Associations Between High Ambient Temperatures and Heat Waves with Mental Health Outcomes: A Systematic Review.* https://www.ncbi.nlm.nih.gov/pubmed/30007545

heat-related illness with each 10 °F rise in daily maximum temperature has been documented in Oregon.[99]

Adaptive capacity is the ability of communities, institutions, or people to adjust to potential hazards, to take advantage of opportunities, or to respond to consequences in ways that reduce harmful exposures (i.e., the ability to prepare for, respond to, and cope with heat events). Health outcomes are strongly influenced by adaptive capacity factors, including those related to the natural and built environments, government regulations, and response. Increasing access to air-conditioning often is touted as a means of increasing resilience to extreme heat events. At present, about 68% of single-family homes and manufactured homes in Oregon have cooling systems, and about 25% of multi-family residences have cooling systems.[100] However, air-conditioning also can increase emissions of greenhouse gases that contribute to climate change, and not all populations, especially the most vulnerable, have access to air-conditioning. Therefore, more comprehensive mitigation actions should be taken to reduce population vulnerability to extreme heat.[101, 102, 103]

2.7.4.5.2. Economy

Extreme heat events can have negative impacts on worker productivity across all economic sectors. This includes time lost on the job when people need to take more frequent or longer breaks to avoid overheating, less overall worker efficiency and effectiveness, and time lost when it is too hot for people to work at all. Workers who spend significant time outside, including agriculture and construction workers, are more likely to suffer impacts.[104] Oregon Occupational Safety and Health instituted a heat illness prevention program on June 15, 2022, to mitigate the health impacts of this emerging hazard. This program applies to outdoor and indoor work activities, where the heat index equals or exceeds 80 °F.[105] The rules of the program include making shade immediately and readily available to outdoor employees, providing an adequate supply of drinking water for exposed employees, implementing a rest-break schedule for preventive cool-down periods, and creating a heat illness prevention plan, including supervisor and employee training.[106]

Additionally, extreme heat can affect crops and livestock health and yields, although these impacts are limited in Washington County because there are not high numbers of agriculture areas or activities. Because it is anticipated the entire United States is likely to experience a rise in extreme heat occurrences, impacts to agriculture in other sectors may impact the County's population via more expensive food, goods, and services, including energy and healthcare costs. Tourism can also be impacted.

2.7.4.5.3. Structures, Improved Property, Critical Facilities, and Infrastructure

Heat waves can damage transportation infrastructure and pose challenges for maintenance and construction. Higher temperatures can put stress on bridge infrastructure through thermal expansion of

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[99] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[100] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf

[101] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf

[102] Hawkins, M., McMahon, K., Nagele, D., & Pearce, V. (2020, November 18). Heat Workshop. https://www.weather.gov/media/safety/heat/Heat%20Workshop%20Day%202%20PDF.pdf

[103] National Weather Service. (n.d.). Social Media: Heat (Summer). https://www.weather.gov/wrn/summer-heat-sm

[104] McLeod K.B. (2021, September 7). Heat is Killing Us—and the Economy Too. https://www.atlanticcouncil.org/content-series/the-big-story/heat-is-killing-us-and-the-economy-too/#:~:text=The%20economic%20costs%20of%20extreme%20heat%20are%20already%20huge.&text=The%20losses%20will%20increase%20as,and%20%24500%20billion%20by%202050

[105] Oregon Occupational Safety and Health. (n.d.). Heat and Wildfire Smoke Rules—Summary. https://osha.oregon.gov/OSHARules/adopted/2022/heat-wildfire-smoke-rule-summary-2022.pdf

[106] Oregon Occupational Safety and Health. (n.d.). Heat and Wildfire Smoke Rules—Summary. https://osha.oregon.gov/OSHARules/adopted/2022/heat-wildfire-smoke-rule-summary-2022.pdf

bridge joints and paved surfaces, and deterioration of steel, asphalt, protective cladding, coats, and sealants. Extreme heat can accelerate the deterioration or threaten the integrity of some types of asphalt pavement through softening, rutting, and migration of liquid asphalt. Hotter summer days can pose risks to the health and safety of maintenance and construction crews, limiting working hours. Vehicle overheating and tire deterioration can also occur during extreme heat events.[107]

Additionally, buildings can incur such damage as cracked foundations, broken or melted siding, and overheated air-conditioning units sparking, potentially causing fires. Infrastructure impacts can include overheated and damaged utilities, including power, water, and communication systems.

During the 2021 extreme heat events, the city of Portland, which is located directly northeast from Washington County, experienced power outages, street buckling, and melted streetcar cables.[108] TriMet had to temporarily suspend all MAX Light Rail services due to temperatures over 100 °F causing the overhead copper wires to expand and sag, forcing the trains to slow.[109] Although the system is designed to operate up to 110 °F, overhead wires reached 120 °F, and the rail was at 140 °F.[110]

Extreme heat in urban areas poses risk to human health and safety, especially for those living and working in urban heat islands. People living outdoors or in the upper floors of multifamily housing units may be particularly vulnerable. In cities, non-white populations are more likely to live in urban heat islands, neighborhoods with impervious surfaces and low tree coverage, and areas with limited access to green space. Urban areas also may face increased energy and water demand and increased risk of disruption to civic and economic activity.[111]

Urban heat islands are defined by the average difference between the temperatures of a city and its more rural surroundings. Urban heat islands are created by the concentration of heavy, dense materials in cities that absorb heat well and become warmer themselves in response, primarily the asphalt and concrete of roadways and rooftops and the brick, stone, and concrete of buildings. Solar radiation accounts for much of the energy these materials absorb, but the heat emitted by vehicles, air conditioners, refrigeration equipment, and industrial machinery also contributes substantially. Once warm, buildings and roadways slowly re-emit this energy, causing densely built and paved areas to remain many degrees warmer than their surroundings, even during cool nights.[112]

Urban heat effects tend to be concentrated in certain areas. The cities in Washington County tend to experience surface urban heat island effect of one to more than three degrees hotter than other areas of the County on a summer day.[113] This temperature difference represents the difference in surface temperature between the built-up and non-built-up urbanized areas.[114] Such areas are typically occupied by communities in which education is limited, income is low, and the proportion of children and elderly residents is high. Urban heat island effects therefore are greatest in neighborhoods where people are

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[107] The American Association of State Highway and Transportation Officials. (n.d.). Extreme Weather & the Transportation System.
http://climatechange.transportation.org/pdf/extreme_weather_briefings/AASHTO_Heat_Waves.pdf

[108] Parks, B.W. (2021, July 1). Oregon's Built Environment Faces New Tests with Extreme Heat.
https://www.opb.org/article/2021/07/01/heat-oregon-air-conditioning-infrastructure/

[109] Singer, M. (2021, June 27). TriMet is Temporarily Suspending All MAX Service Due to Extreme Heat.
https://www.wweek.com/news/city/2021/06/27/trimet-is-temporarily-suspending-all-max-service-due-to-extreme-heat/

[110] Singer, M. (2021, June 27). TriMet is Temporarily Suspending All MAX Service Due to Extreme Heat.
https://www.wweek.com/news/city/2021/06/27/trimet-is-temporarily-suspending-all-max-service-due-to-extreme-heat/

[111] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[112] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf

[113] Chakraborty, T., Hsu, A., Manya, D., & Sheriff, G. (2020). A spatially explicit surface urban heat island database for the United States: Characterization, uncertainties, and possible applications. *ISPRS Journal of Photogrammetry and Remote Sensing.* https://doi.org/10.1016/j.isprsjprs.2020.07.021

[114] Chakraborty, T., Hsu, A., Manya, D., & Sheriff, G. (2020). A spatially explicit surface urban heat island database for the United States: Characterization, uncertainties, and possible applications. *ISPRS Journal of Photogrammetry and Remote Sensing.* https://doi.org/10.1016/j.isprsjprs.2020.07.021

most susceptible to heat stress. Compounding urban heat island effects, homes in low-income neighborhoods often are less able to manage excessive heat, with less-insulated roofs, limited access to cross-ventilation, and inability to afford air-conditioning. Urban heat island effects can be addressed through strategies that focus on materials, vegetation, transportation, or buildings.[115]

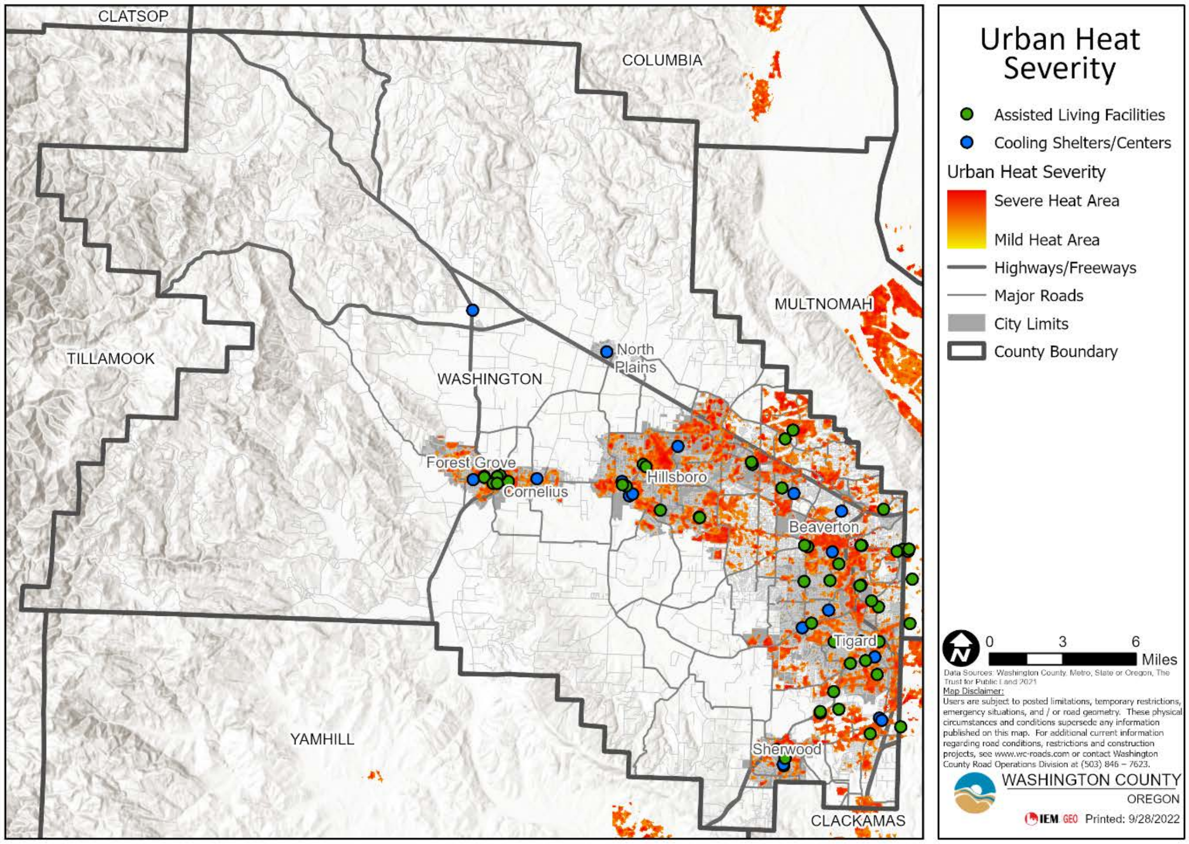

Figure 16: Urban Heat Severity in Washington County

2.7.4.5.4. Natural Environments

Plants, animals, ecosystems, and natural environments have experienced increased negative impacts and mortality during extreme heat events of the early twenty-first century. Summer heat-wave mortality of animal populations is making summer a season of stress and survival, altering populations and ecosystems.[116]

Extreme heat can kill organisms outright, especially if they are also exposed to intense sunlight. Dehydration sets in and organs fail as enzymes stop working and proteins sustain damage. The trauma can make survivors more susceptible to disease and predation and reduce or delay reproduction. Hot weather can also cost animals by discouraging them from foraging or hunting. During the 2021 “heat dome” experienced by the Pacific Northwest, a billion shellfish and other intertidal animals baked to death, scores of hawks became sick or injured, tens of thousands of bottom-dwelling fish died, and trees

[115] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://www.cakex.org/sites/default/files/documents/OCAR5.pdf
[116] Stillman, J.H. (2019, February 6). *Heat Waves, the New Normal: Summertime Temperature Extremes Will Impact Animals, Ecosystems, and Human Communities.* https://journals.physiology.org/doi/full/10.1152/physiol.00040.2018

suffered root and vascular system damage, leading to scorched leaves, and prematurely dropped needles. The overall impacts of these losses are yet to be seen and may take years to develop.[117]

Droughts and wildfires that can occur independent of extreme heat or concurrently can also have detrimental impacts on natural environments.

2.7.4.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of extreme heat. Additional information is in the participant annexes.

Table 27: Participant Overall Risk of Extreme Heat[118]

Participant	Overall Risk of Extreme Heat
City of Beaverton	212
City of Cornelius	148
City of Forest Grove	148
City of Hillsboro	179
City of North Plains	177
City of Sherwood	162
City of Tigard	162
Clean Water Services	152
Tualatin Hills Park & Recreation District	199
Tualatin Valley Water District	177
Washington County	177

[117] Rosen, J. (2021, November 22). *How Heat Waves Warp Ecosystems.* https://www.hcn.org/issues/53.12/north-climate-change-how-heat-waves-warp-ecosystems
[118] 2023 NHMP Participant Planning Documentation

2.7.5. Flooding

Significant Changes

- Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency of flooding added.
- Hazard profile expanded to include streambank and riverbed erosion and channel migration.

2.7.5.1. Characteristics

Flooding results when rain and snowmelt create water flow that exceeds the carrying capacity of rivers, streams, channels, ditches, and other watercourses. The primary types of flooding that occur in Washington County are riverine floods and urban floods. In addition, any low-lying area has the potential to flood, and dam failure can cause flooding in inundation zones.

Urban flooding occurs in developed areas where the amount of water generated from rainfall and runoff exceeds the storm water systems' capacity. Urbanization of the watershed changes the hydrologic systems of the basin. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb and slowly release rainfall. Rain flows over impervious surfaces such as concrete and asphalt and into nearby storm sewers and streams. This runoff can result in the rapid rise of flood waters because the water moves from the ground and in to streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in flood waters that rise very rapidly and peak with violent force. The resulting high water volume and turbidity contribute to erosion of streambanks.

Riverine flooding occurs when rivers and streams flow over their banks. Flooding in large river systems typically happens due to large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers. A common Willamette Valley phenomenon involves tributary stream backup during periods of high water. When tributary streams cannot enter swollen main stem rivers during periods of high water, tributary streams are forced out of their banks.[119]

The most severe flooding conditions occur, however, when heavy rainfall is augmented by rapid snowmelt. These events make more water available for runoff than does precipitation alone by melting the snowpack and by adding a small amount of condensate to the snowpack. If the ground is frozen, stream flow can be increased even more by the inability of the soil to absorb additional runoff. Significant rain-on-snow events occur in years that are colder and wetter than normal because snow accumulates at lower elevations, and then is melted off during subsequent rain events.[120]

2.7.5.1.1. Channel Migration in Association with Flooding

Channel migration is the process by which streams move laterally over time. It is typically a gradual phenomenon that takes place over many years due to natural processes of erosion and deposition. In some cases, usually associated with flood events, significant channel migration can happen rapidly. In high- flow flood events, stream channels can avulse and shift to occupy a completely new channel.

Areas most susceptible to channel migration are transitional zones where steep channels flow from foothills into broad, flat floodplains. The most common physiographic characteristics of a landscape prone to channel migration include moderate channel steepness, moderate to low channel confinement (i.e., valley broadness), and erodible geology. Channel migration is not a standard consideration of the NFIP.

[119] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[120] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

The Oregon DOGAMI completed a study on channel migration zones for 225 river miles in Washington County in 2021.[121] The study area included the main stem of the Tualatin River, seven tributaries to the Tualatin River (Beaver Creek, Beaverton Creek, Dairy Creek, Fanno Creek, Gales Creek, McKay Creek, and Rock Creek) and two tributaries to Dairy Creek (East Fork Dairy Creek and West Fork Dairy Creek). These streams originate in the forested Tualatin Mountains and Oregon Coastal Range. They collectively flow towards the center of Washington County, eventually joining the Tualatin River, which flows east into the Willamette River. These rivers flow through wetlands and forested, agricultural, and urbanized lands, including the communities of Gaston, Forest Grove, Hillsboro, Beaverton, Tigard, and Tualatin. Figure 17 through Figure 22 show the river and creek segments and channel migration zones for the study area.

[121] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

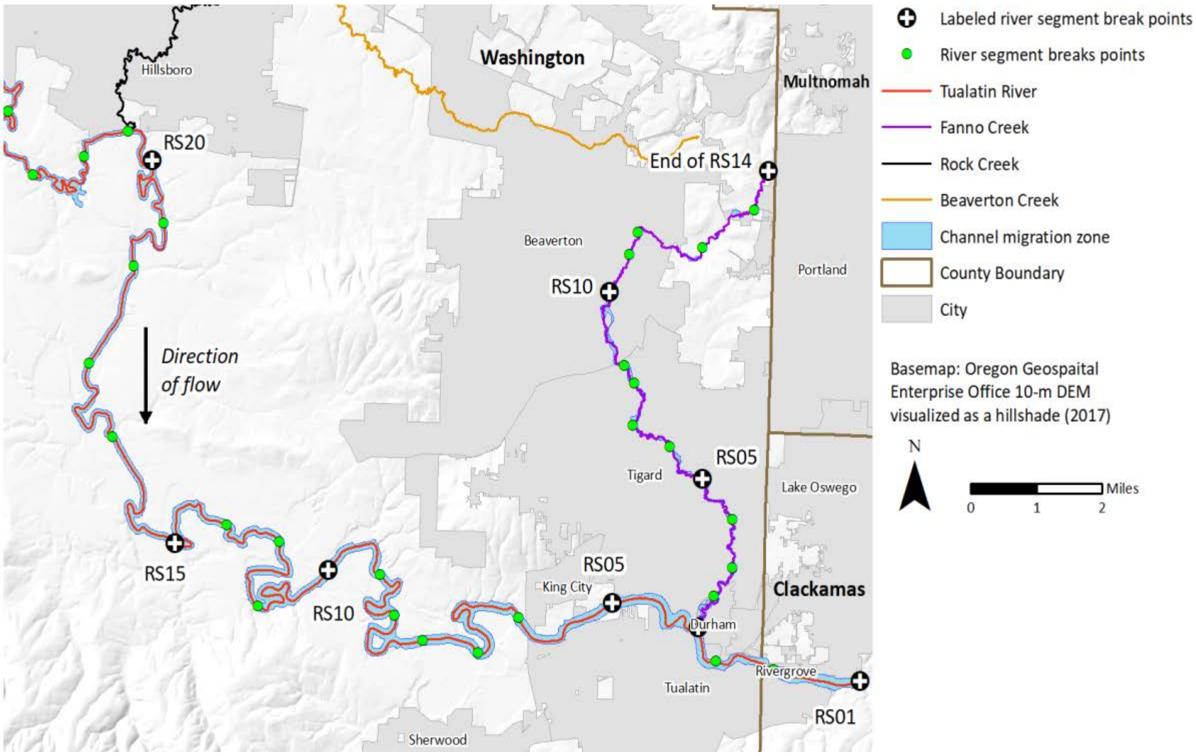

Figure 17: Tualatin River and Fanno Creek Segments and Channel Migration Area[122]

[122] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

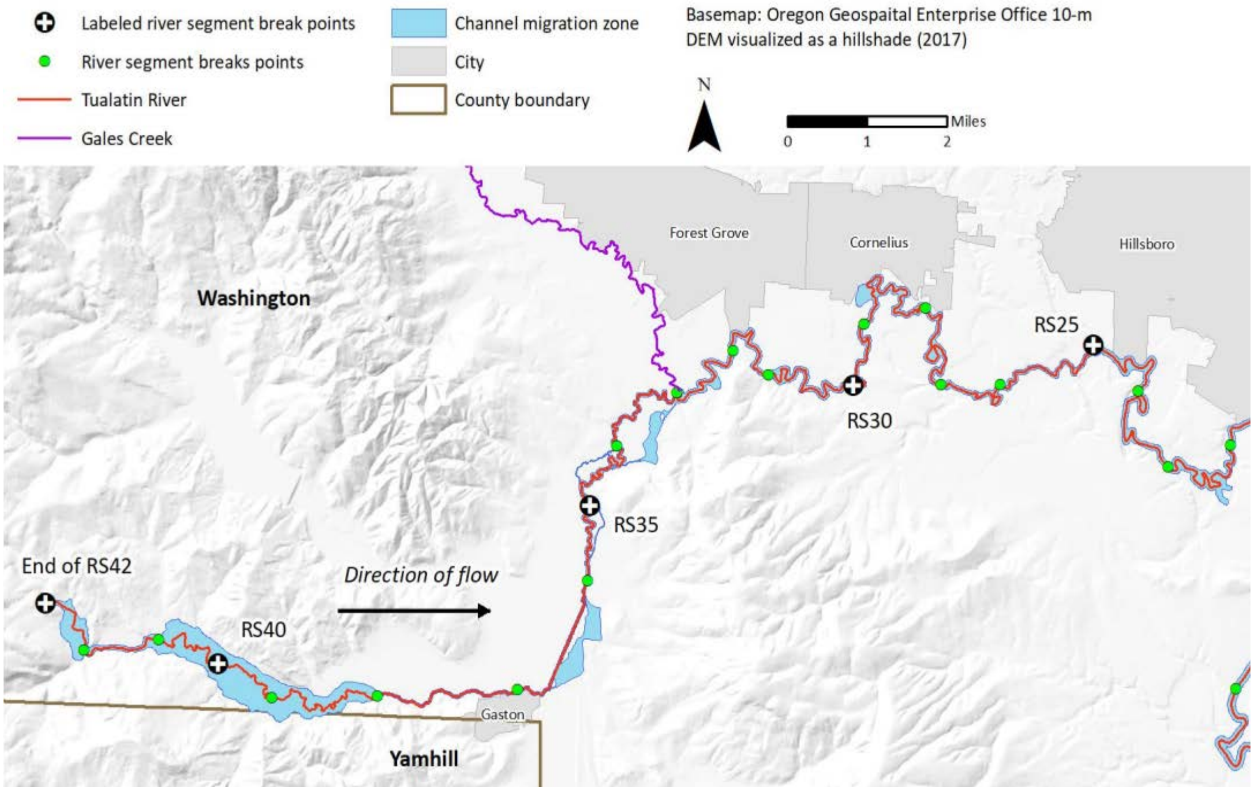

Figure 18: Tualatin River Segments, Channel Migration Zone Area, and Labeled Counties[123]

[123] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

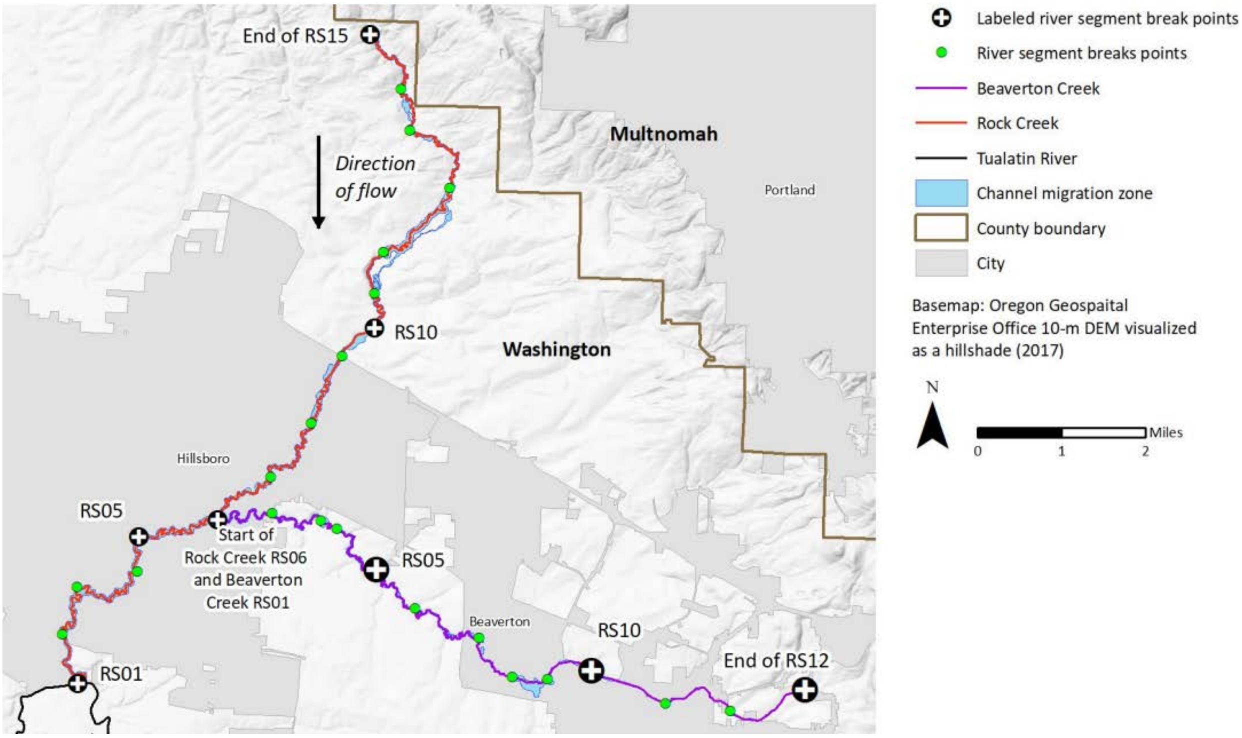

Figure 19: Beaverton and Rock Creek Segments, Channel Migration Zone Area, and Labeled Counties[124]

[124] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

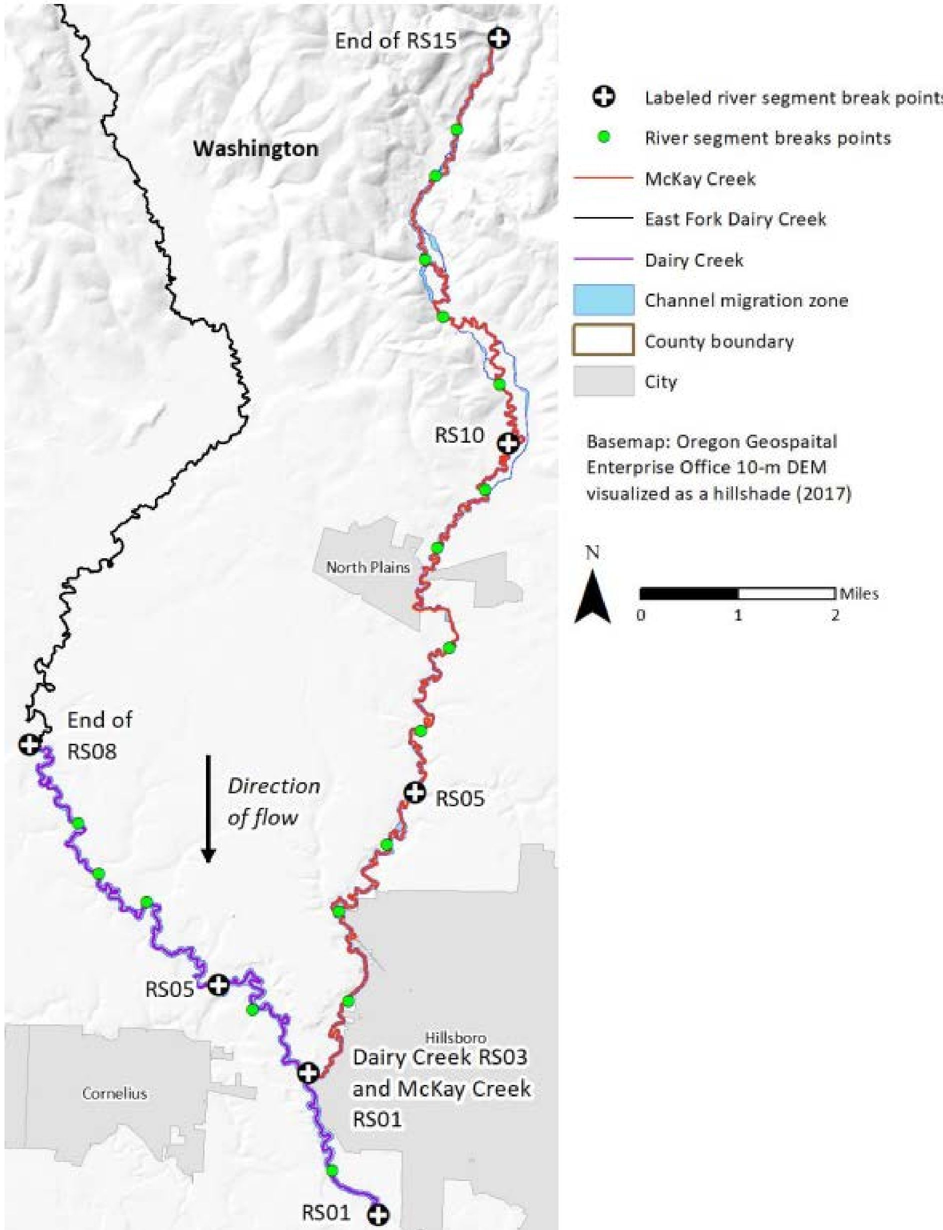

Figure 20: McKay Creek, Dairy Creek, Channel Migration Zone Area, and Labeled Counties[125]

[125] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

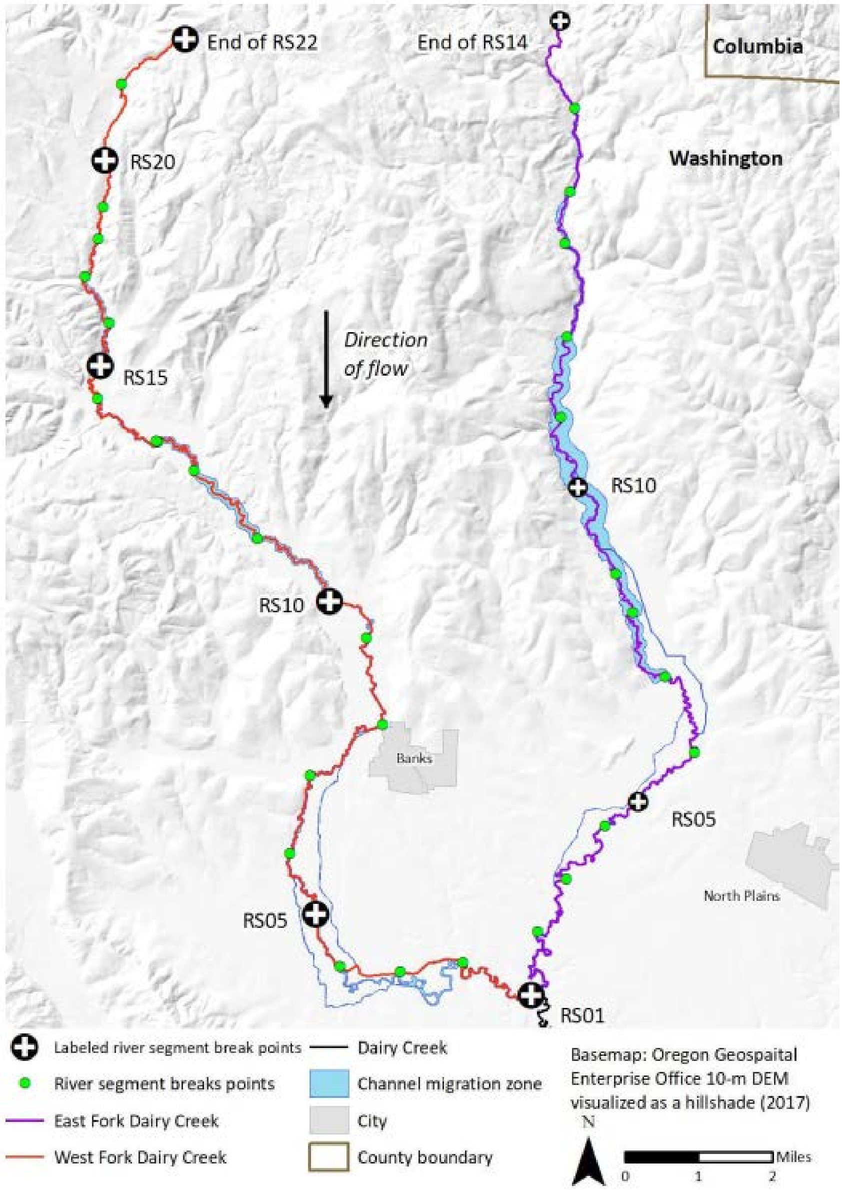

Figure 21: East and West Fork Dairy Creek Segments, Channel Migration Zone Areas, and Labeled Counties[126]

[126] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

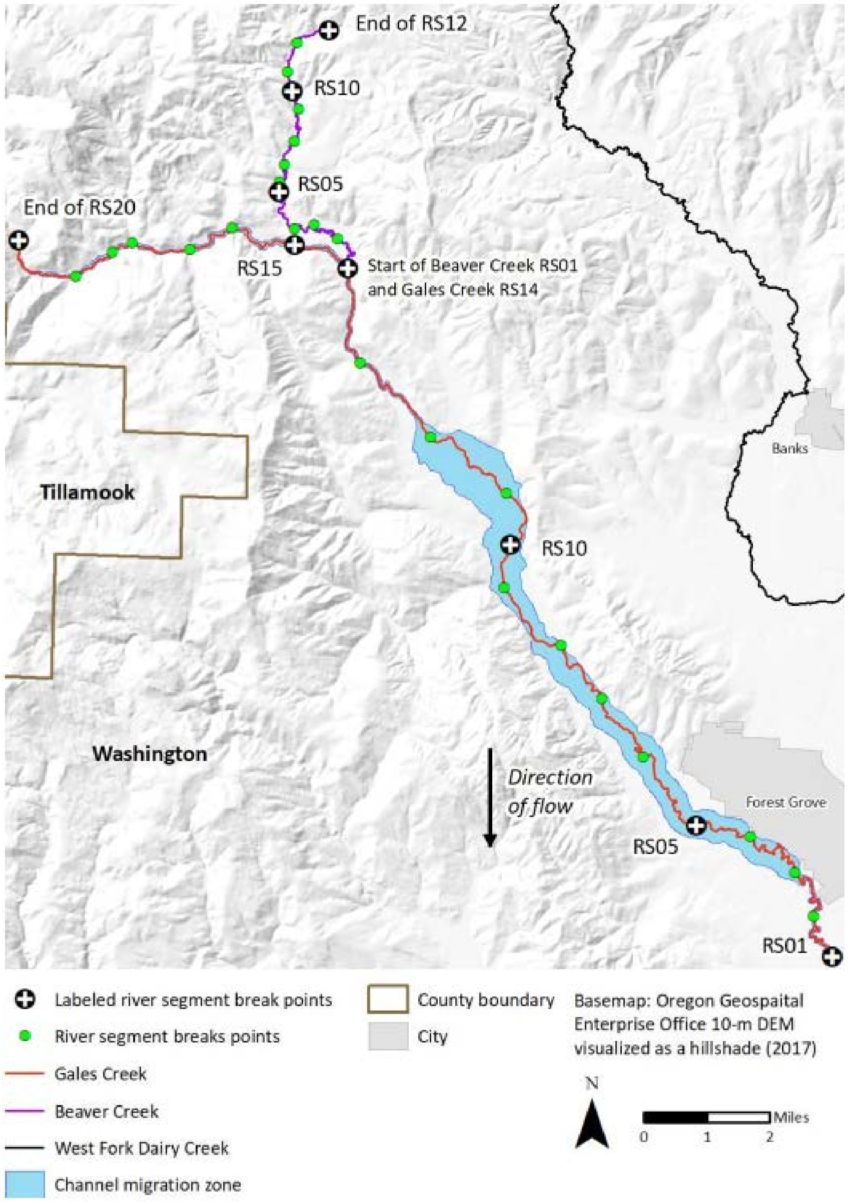

Figure 22: Beaver and Gales Creek Segments, Channel Migration Zone Area, and Labeled Counties[127]

[127] Oregon Department of Geology and Mineral Industries. (2015). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Marrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

Channel migration is a geomorphic process by which a stream moves laterally across its floodplain over time. This process includes bed and bank erosion, sediment deposition, and channel avulsion, a process in which the stream abruptly moves to an entirely new location on the floodplain.[128] Channel migration can undermine buildings, roads, levees, and other infrastructure; it can rapidly redirect flooding to new areas, erode land, cut off evacuation routes during a flood, and, in rare cases, endanger lives.[129]

Channels migrate and change as a function of sediment supply, discharge, channel bed and bank geology, climate, riparian vegetation, basin physiography, and human modifications.[130] While bedrock-controlled channels migrate very gradually across centuries, alluvial channels with braided, meandering, and anastomosing channel forms commonly migrate across the landscape over years or decades.[131] Channel morphology may change in both horizontal and vertical directions. Horizontal movement is often observed as lateral migration, avulsions, widening, or narrowing. Vertical movement includes channel bed incision and sediment aggradation, both of which can trigger lateral migration.

Channel migration zone mapping seeks to identify the area the channel is most likely to occupy in the future based on historical channel behavior and current geomorphic conditions. These maps include the areas on the floodplain previously occupied by the channel, as these areas create a high potential for channel reoccupation. Areas susceptible to future erosion are mapped based on the past rate of erosion observed in historical aerial photographs. Potential avulsion areas are also included in the maps and are based on interpretations of lidar topography, with a focus on low-lying areas near the active channel. Maps define the area in which a given stream is likely to move laterally and change its channel course within the next 30 and 100 years.

[128] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

[129] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

[130] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

[131] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

Table 28: Streams Studied in Washington County for Channel Migration Zone Mapping[132, 133]

River Name	Drainage Area (sq. miles)	Average Slope (%)	Average Active Channel Width (feet)	Studied Stream Length (miles)	Total Stream Length (miles) from National Hydrography Dataset, U.S. Geological Survey, 2020	50-Year Annual Exceedance Probability (2-year flood), Stream Stats (Cooper, 2005) (cubic feet per second)
Beaver Creek	10	0.57%	24	7.5	11.4	541
Beaverton Creek	38	0.20%	25	11	11.4	735
Dairy Creek	20	0.04%	50	11.2	15	5,890
East Fork Dairy Creek	64	0.64%	35	22.2	35.8	2,110
Fanno Creek	32	0.18%	28	14	21.1	669
Gales Creek	75	0.67%	66	25.9	42.7	3,400
McKay Creek	67	0.33%	33	20.8	36.6	1,740
Rock Creek	76	0.16%	35	17.1	28.7	1,490
Tualatin River	694	0.05%	88	68.6	121.3	16,000
West Fork Dairy Creek	80	0.89%	25	26.5	40	2,480

The results of this study should be used to identify people, places, buildings, and infrastructure most vulnerable to floods and channel migration at a neighborhood scale. The information can be used by local emergency managers, planners, community leaders, residents, and other stakeholders to make informed decisions about flood hazards, including their mitigation, land use, and environmental management.

2.7.5.1.2. Streambank and Riverbank Erosion

Streambank erosion naturally occurs when the forces exerted by flowing water exceed the resisting forces of bank materials and vegetation. Erosion occurs in many natural streams that have vegetated banks. However, land use changes or natural disturbances can cause the frequency and magnitude of water forces to increase. Loss of streamside vegetation can reduce resisting forces, thus streambanks become more susceptible to erosion. Channel realignment often increases stream power and may cause streambeds and banks to erode. Streambank erosion is an important source of the sediment and pollutants that enter area lakes, ponds, and stream channels.

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[132] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

[133] Oregon Department of Geology and Mineral Industries. (2021). Open File Report O-21-15: Flood Depth and Channel Migration Zone Maps, Benton, Marion, Morrow, and Washington Counties, Oregon. https://www.oregongeology.org/pubs/ofr/O-21-15/DOGAMI%20Open-File%20Report%20O-21-15,%20Flood%20depth%20and%20channel%20migration%20zone%20maps,%20Benton,%20Marion,%20Morrow,%20and%20Washington%20Counties,%20Oregon.pdf

The principal causes of streambank erosion may be classed as geologic, climatic, vegetative, and hydraulic. These causes may act independently, but normally work in an interrelated manner. Direct human activities, such as channel confinement or realignment and damage to or removal of vegetation, are major factors in streambank erosion.

Protective measures for streambanks can be grouped into three categories and are often used in combination[134]:

- **Vegetative plantings:** Conventional vegetation may be used to stabilize streambanks.
- **Soil bioengineering systems:** These systems use living plant materials as structural components. Adapted types of woody vegetation, such as trees and shrubs, are installed in configurations that offer immediate soil protection and reinforcement.
- **Structural measures:** These measures include rock riprap and other relatively permanent measures to protect streambanks.

The method of streambank stabilization chosen depends on site conditions, cost, and materials and labor availability.

Riverbank erosion often occurs during flood events. The level and severity of bank erosion depends on flow velocity, the soil profile, vegetation type, and whether there are blockages in the river, such as large fallen trees and other debris. Bed lowering can move in both an upstream and/or downstream direction, influencing channel stability over an extensive length of the river or stream system.

Bed lowering can initiate extensive bank erosion because the height of the banks relative to the bed are effectively increased, leaving them more susceptible to collapse. Riverbed lowering can[135]:

- Undermine riverbanks, resulting in overall channel enlargement with all the associated adverse impacts of bank erosion on economic and environmental values.
- Cause lowering of river water level. This may deny water to pumps for irrigation and/or domestic supplies. It may also decrease the viability of in-stream habitats.
- Cause lowering of groundwater level in the adjacent floodplain. This may deny water to bore wells and adversely affect the aquifer.
- Cause downstream siltation, which can destroy aquatic habitats and adversely impact water quality, water availability, flooding, and navigation and recreational pursuits.
- Result in damage to infrastructure, including bridge sand pumps.

Most waterways experience sediment movement during floods. The quantity of sediment usually increases with the size of the catchment and is influenced by surrounding land use. Sediment appears as murky, muddy water flowing through the water during floods. When sediment moves downstream, it can increase erosion and settle on the lower banks of the creek. As sediment is typically high in nutrients, this can result in rapid weed growth, which in turn stabilizes the sediment and changes the shape of the creek bed. This can create a narrower flow channel that can lead to bank undercutting and potential slumping. If slumping occurs, this can result in the bank being washed away, creating a near vertical wall, which can further increase the effects of shading and make it difficult for vegetation to establish.[136]

[134] Klausmeyer, K. J. (n.d.). Streambank Erosion. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ks/newsroom/features/?cid=nrcs142p2_033508
[135] Queensland Government Department of Environment and Resource Management. (2009, May). What Causes Streambed Erosion? https://www.qld.gov.au/__data/assets/pdf_file/0033/67677/what-causes-stream-bed-erosion.pdf
[136] Land for Wildlife. (n.d.). Creek and Riverbed Erosion. https://www.lfwseq.org.au/creek-and-riverbed-erosion/

Four main processes contribute to bed erosion[137]:

- **Decrease in sediment supply:** This can occur when the natural passage of sediment through the system is interrupted by upstream dams, catchment erosion control works, or excavations in the streambed.
- **Increase in bed slope:** This can be a result of straightening the river, removing a bed control such as rock riprap, or excavating the bed of the river for extractive industries or recreation reasons.
- **Increase in velocity, not associated with an increase in slope:** This can be a result of a channel constriction such as debris, fill, vegetation on the riverbed, or bridge abutments.
- **Increase in discharge:** This can be a result of increased urban runoff, catchment clearing, or increases in rainfall.

2.7.5.2. Location and Extent

The extent of flood events is described in terms of the horizontal area affected, the vertical depth of flood waters, and related probability of occurrence. Flood studies often use historical records, such as streamflow gages, to determine the probability of occurrence for floods of different magnitudes. The probability of occurrence is expressed in percentages as the chance of a flood of a specific extent occurring in any given year. Probability of flooding is measured as the average recurrence interval of a flood of a given size and place. It is stated as the percent chance that a flood of a certain magnitude or greater will occur at a particular location in any given year.

The annual probabilities calculated for flood hazard fall into the following categories[138]:

- A **10-year flood** has a 10% chance of occurring in any given year.
- A **50-year flood** has a 2% chance of occurring in any given year.
- A **100-year flood** has a 1% chance of occurring in any given year. This category is used as the standard for floodplain management in the United States and is referred to as a base flood.
- A **500-year flood** has a 0.2% chance of occurring in any given year.

The areas most at risk of flooding within Washington County are within Tualatin floodplain areas in the unincorporated county; in many commercial areas in Beaverton along Beaverton Creek and Fanno Creek; and in a significant portion of commercial areas in the city of Tualatin. Many other communities in Washington County have little to no risk of flooding. There are few areas of concentrated flood damage; however, the small amount of damage that is estimated is scattered across the County at various places along streams.

Per DOGAMI, areas in the County at significant flooding risk include[139]:

- Commercial areas in the city of Tualatin along Hedges Creek are at risk of flooding.
- Commercial areas in the city of Tigard along Fanno Creek are at risk of flooding.
- Commercial areas in the city of Beaverton along Beaverton Creek are at risk of flooding.

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[137] Queensland Government Department of Environment and Resource Management. (2009, May). What Causes Streambed Erosion? https://www.qld.gov.au/__data/assets/pdf_file/0033/67677/what-causes-stream-bed-erosion.pdf
[138] U.S. Geological Survey Water Science School. (2018, June 7). The 100-Year Flood. https://www.usgs.gov/special-topics/water-science-school/science/100-year-flood
[139] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

- Residential and commercial buildings along tributaries to Beaverton Creek throughout the city of Beaverton are at risk of flooding from a 100-year flood.
- Several residences and businesses in the city of North Plains along a tributary to McKay Creek are at risk of flooding.
- Many residential structures are exposed to flooding in the vicinity of Highway 26 and Cedar Mill Creek and Johnston Creek.

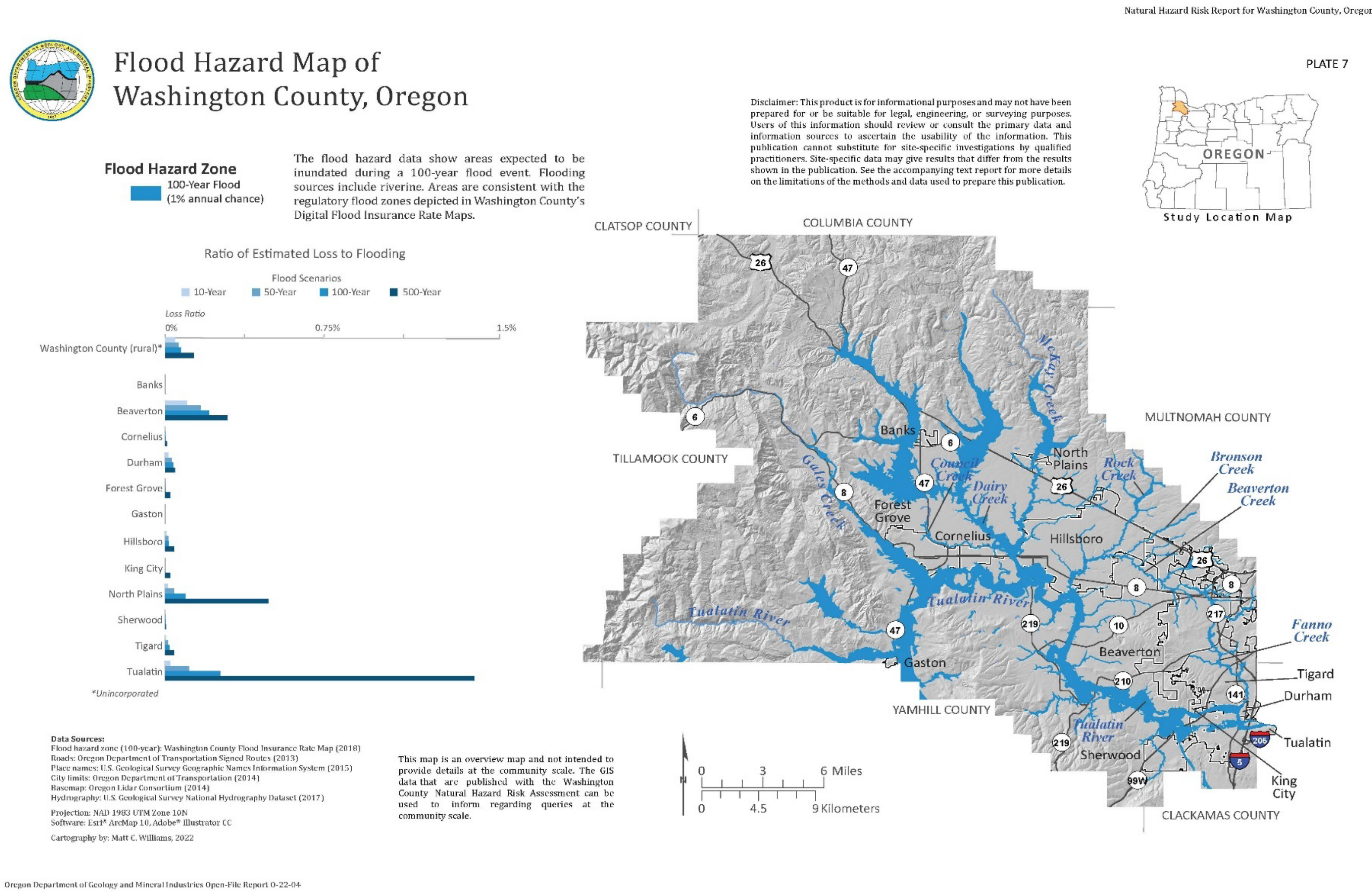

Figure 23: Flood Hazard Map of Washington County, Oregon[140]

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[140] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

Increased development accelerates the risk of flooding in urban areas. Impervious surfaces, such as concrete and asphalt, collect water at a faster rate than undeveloped landscape, and the resulting runoff can collect in streets, ditches, and basements and impact county residents. Mitigation efforts must also consider localized areas of high flood risk or repetitive flooding that lie outside mapped floodplains. These areas are identified in participant annexes.

2.7.5.3. History

Flooding is most common from October through April in Washington County. There have been six significant flooding events in the planning area since the adoption of the 2017 NHMP.

The northern Willamette Valley, which includes Washington County, has a lengthy flood history, with significant floods occurring about every 7 to 15 years.[141] The Willamette River has produced numerous floods, and these floods typically occur in the winter. The common pattern includes the accumulation of heavy wet snow in higher elevations followed by a mild, rainy weather system. The resulting snowmelt on saturated or frozen ground sometimes produces devastating flood conditions. These conditions would be worse were it not for many dams on the upper reaches of the Willamette and some of its tributaries.[142]

Table 29: Historic Flooding Events in Washington County[143]

Date	Event
November 2016	A moist Pacific front moving slowly across the area produced heavy rainfall, resulting in flooding of several rivers across northwest Oregon and at least two landslides. Heavy rain resulted in flooding of the Tualatin River at Dilley in unincorporated Washington County. The Tualatin River reached flood stage at 7:30 a.m. on November 25 and crested at 17.7 feet at 12:15 p.m. on November 25. The river dropped below flood stage at 6:40 p.m. on November 25.
February 2017	Heavy rain caused the Tualatin River near Dilley in unincorporated Washington County to flood. The river crested at 17.77 feet, which is 0.27 feet above flood stage. A series of fronts brought moderate to heavy rainfall across northwest Oregon, resulting in flooding on many rivers across the area over the next several days.
February–March 2019	Back-to-back low-pressure systems dropping south along the coast of British Columbia and Washington brought cold air south as well as plenty of moisture into northwest Oregon. A Washington County official reported that 40 county roads were covered with water due to heavy rains and snowmelt. In the city of Tigard, emergency transportation routes were disrupted, and there were multiple outfall and stream bank damage impacts during the event.

[141] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[142] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[143] National Centers for Environmental Information Storm Events Database, Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx, 2023 NHMP Participant Planning Documentation

Date	Event
January 2021	January 12: Road closure at SW 149th Ave. and SW Division St. near South Johnson Creek in Beaverton. A series of slow-moving fronts brought periods of heavy rain along with strong winds. This resulted in river and urban flooding, landslides, and debris flows. The front brought a burst of 35–50 mph winds to the Willamette Valley and southwest Washington interior, resulting in over 100,000 customers without power across southwest Washington and northwest Oregon. The Tualatin River at Dilley in unincorporated Washington County rose above flood stage at 11:30 p.m. on January 12, crested at 18.09 feet, then fell below flood stage at 3:30 a.m. on January 14. Flood stage is 17.5 feet. January 13: Fanno Creek flooding occurred at SW North Dakota Street in the city of Tigard. January 14: The Tualatin River near Farmington in unincorporated Washington County rose above flood stage around 2 p.m., crested at 32.6 feet, then fell below flood stage at 10:15 a.m. on January 16. Flood stage is 32.0 feet.
February 2022	Minor flooding occurred in the County and resulted in road closures. In the city of Tigard, emergency transportation routes were disrupted, and there were multiple outfall and stream bank damage impacts during the event.

2.7.5.4. Probability of Future Events

History, probability, and vulnerability data is used to determine the probability of future flooding events. The probability of occurrence is expressed as a percentage indicating the probability of a specific flood event occurring in any given year. The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability that FEMA uses for regulatory purposes. There is a high probability a flooding event will occur in Washington County within the next five years.

2.7.5.4.1. Climate Change

Flood magnitudes in the planning area are likely to increase due to climate change. Heavy precipitation events are expected to become more intense because a warmer atmosphere can carry more moisture. Also, in a warmer climate, the relatively contribution of rainfall to floods will be greater than that of snowmelt. The consequence is larger flood peaks because, for a given amount of precipitation, the peaks of rainfall-driven floods tend to be larger than those of snowmelt-driven floods. Projected increases in wet-season precipitation also are likely to increase winter flood magnitude. Increases in regulated flows from the main stem of the Columbia River during winter appear likely to increase flood risk throughout the Columbia River reservoir system, which includes Washington County.[144]

Along the Willamette River and its tributaries within the County, the largest increases in extreme river flows are more likely to be upstream toward Cascade Range headwaters, and less likely downstream. Along the Lower Columbia Basin, large increases in extreme flows are least likely. Overall, it is more likely than not (>50%) that increases in extreme river flows will lead to an increase in the incidence and magnitude of damaging floods, although this is a low confidence projection.[145] These potential increases are also dependent on local conditions like site-dependent river channel and floodplain hydraulics, soil

[144] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/.
[145] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

moisture, and water table height. Increases in extreme river flows leading to damaging floods will be less likely in urban areas with strong stormwater management infrastructure and/or river reservoir operations, as these measures have the capacity to offset increases in flood peak.

La Niña events are associated with heavy rain from the western tropical Pacific, where ocean temperatures are well above normal, causing greater evaporation, more extensive clouds, and a greater push of clouds across the Pacific toward Oregon. These events typically occur naturally every three to five years and can last up to two years. Climate change could impact the severity and frequency of La Niña; however, the specific effects are not yet known.

2.7.5.5. Vulnerability Assessment

The vulnerabilities and impacts of flooding can vary widely depending on the size, extent, and magnitude of the event. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

2.7.5.5.1. Populations

Flood waters can create significant public health concerns, such as the spread of infectious diseases, exposure to chemicals, hazardous materials, and debris, and water quality issues. Toxins and pathogens, such as viruses and bacteria, are transported along with contaminated sediments and floating debris. Sediments can be deposited on streets and in residential neighborhoods and parks, causing potential health concerns related to lead, arsenic, and other pollutants stored in the sediments. Water from flooded commercial and industrial facilities, storage tanks, grounded vessels, and common household chemicals are swept up and spread with the flood waters. Flooding can often cause sewage treatment systems to fail, releasing untreated sewage into flood waters. Intestinal bacteria such as E. coli, salmonella, shigella; hepatitis A virus; and agents of typhoid, paratyphoid, and tetanus are often found in flood waters. People exposed to these infectious agents can develop intestinal distress and debilitating disease symptoms. Other flood waterborne pathogens, such as flesh-eating bacteria, can cause severe forms of illness, such as necrotizing fasciitis and sepsis.[146] Water for consumption and daily use may need to be boiled or bottled water purchased for safety reasons, but not all populations have equitable access to these resources.

Injury or death can also occur as people evacuate through flood waters, including individuals who drive through flood waters. DOGAMI's evaluation estimates 4,161 residents might have mobility or access issues due to surrounding water.[147] Additionally, emergency routes may be limited or eliminated, and emergency services may not be able to access portions of the planning area to assist vulnerable populations. Since the adoption of the 2017 NHMP update, Tualatin Valley Fire & Rescue has performed 16 water rescues in Washington County. These rescues included swift-water rescues and searches for a person in water, in addition to watercraft rescue, surf rescue, water- and ice-related rescue, and swimming rescue.[148] Rescues completed by city-specific fire departments are included in their respective annexes.

2.7.5.5.2. Economy

Floods can impact governmental, private, and personal economics. These hazards are also associated with significantly lower local revenues. Floods can lead to a drop in property values, which decreases property taxes, and can disrupt local government spending and sources of intergovernmental revenues,

[146] Greater Houston Flood Mitigation Consortium. (2018, May 15). Fact Sheet 9: How Do Floods Impact Environment? https://www.houstonconsortium.com/graphics/FS9-Environment.pdf
[147] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[148] Tualatin Valley Fire & Rescue. (2022, May 9). Personal communication with Brian Smith, Captain.

causing municipalities to incur more debt. A consequence of flooding is that local governments increase their outstanding debt to fund recovery and maintain public services in their communities.[149]

Recovery efforts can provide temporary increases in revenue for the private sector, including cleaning, hauling, and construction services. However, overall, flooding has a negative economic impact due to suspended economic activity, loss of wages and revenues, and repair or replacement costs that may not be covered by insurance. Flooding can also have an enormous impact on agriculture through damage to crops, land, livestock, and equipment.

2.7.5.5.3. Structures, Improved Property, Critical Facilities, and Infrastructure

Properties within flooded areas may experience major impacts or be destroyed. The level of damage is dependent on the structure type, proximity to the flooding source, the velocity of the inundation water, amounts of debris in the flood water, longevity of the flood, and total depth of the flood.

Increased development accelerates the risk of urban flooding. Impervious surfaces, such as concrete and asphalt, collect water at a faster rate than an undeveloped landscape, and the resulting runoff can collect in streets, ditches, and basements, impacting residents on a regular basis. Storm drains often back up because of the volume of water and become blocked by vegetative debris like yard waste, which can cause additional flooding. Development in the floodplain can raise the base flood elevation, decrease vegetation, and cause flood waters to expand past their historic floodplains.

Infrastructure can also be seriously damaged or destroyed. Water and wastewater systems can become contaminated, electrical systems and communication equipment can be damaged, and transportation routes, including road and rail segments and bridges, are at risk for inundation and damage. Repairs or reconstruction efforts are typically delayed until water levels recede.

The 100-year flood has traditionally been used as a reference level for flooding and is the standard probability measure FEMA uses for regulatory purposes. An analysis completed by DOGAMI using Hazus®-MH shows the 100-year flood loss countywide as[150]:

- Number of buildings: 1,323
- Value of exposed buildings: $60,414,000
- Loss ratio: 0.08%
- Damaged critical facilities: 2

In addition to the Hazus®-MH flood analysis, DOGAMI completed an exposure analysis by overlaying building locations on the 100-year flood extent. This estimates the number of buildings elevated above the level of flooding. This was done by comparing the number of non-damaged buildings from Hazus®-MH with the number of exposed buildings in the flood zone. Of the 1,625 buildings that are exposed to flooding, it is estimated that 302 are above the height of the 100-year flood.

Table 30 through Table 34 provide flood loss estimates and flood exposures for 10-year, 50-year, 100-year, and 500-year flood events in unincorporated Washington County and participating cities.[151]

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[149] Sarmiento, C. & Miller, T.R. (2006, October). Costs and Consequences of flooding and the Impact of the National Flood Insurance Program. American Institutes for Research. https://www.fema.gov/sites/default/files/2020-07/fema_nfip_eval-costs-and-consequences.pdf
[150] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[151] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

Table 30: Flood Loss Estimates for 10-Year Flood Scenario

Plan Participant	Total Number of Buildings	Total Estimated Building Value	Number of Buildings	Loss Estimate	Loss Ratio
Unincorporated Washington County	100,745	$28,760,104,000	398	$13,022,000	0%
City of Beaverton	26,405	$11,283,939,000	203	$11,197,000	0.1%
City of Cornelius	3,807	$954,752,000	1	$2,000	0%
City of Forest Grove	8,199	$2,525,502,000	1	$0	0%
City of Hillsboro	37,513	$15,487,612,000	39	$922,000	0%
City of North Plains	1,333	$414,606,000	1	$51,000	0%
City of Sherwood	6,109	$2,194,018,000	1	$10,000	0%
City of Tigard	18,731	$7,526,469,000	15	$213,000	0%

Table 31: Flood Loss Estimates for 50-Year Flood Scenario

Plan Participant	Total Number of Buildings	Total Estimated Building Value	Number of Buildings	Loss Estimate	Loss Ratio
Unincorporated Washington County	100,745	$28,760,104,000	558	$17,547,000	0.1%
City of Beaverton	26,405	$11,283,939,000	310	$18,191,000	0.2%
City of Cornelius	3,807	$954,752,000	1	$7,000	0%
City of Forest Grove	8,199	$2,525,502,000	2	$2,000	0%
City of Hillsboro	37,513	$15,487,612,000	66	$1,995,000	0%
City of North Plains	1,333	$414,606,000	4	$162,000	0%
City of Sherwood	6,109	$2,194,018,000	1	$20,000	0%
City of Tigard	18,731	$7,526,469,000	37	$889,000	0%

Table 32: Flood Loss Estimates for 100-Year Flood Scenario

Plan Participant	Total Number of Buildings	Total Estimated Building Value	Number of Buildings Exposed	Loss Estimate	Loss Ratio
Unincorporated Washington County	100,745	$28,760,104,000	651	$20,649,000	0.1%
City of Beaverton	26,405	$11,283,939,000	355	$22,809,000	0.2%
City of Cornelius	3,807	$954,752,000	1	$8,000	0%

Plan Participant	Total Number of Buildings	Total Estimated Building Value	Number of Buildings Exposed	Loss Estimate	Loss Ratio
City of Forest Grove	8,199	$2,525,502,000	2	$3,000	0%
City of Hillsboro	37,513	$15,487,612,000	74	$2,547,000	0%
City of North Plains	1,333	$414,606,000	9	$383,000	0.1%
City of Sherwood	6,109	$2,194,018,000	1	$30,000	0%
City of Tigard	18,731	$7,526,469,000	45	$1,392,000	0%

Table 33: Flood Loss Estimates for 500-Year Flood Scenario

Plan Participant	Total Number of Buildings	Total Estimated Building Value (in thousands)	Number of Buildings	Loss Estimate (in thousands)	Loss Ratio
Unincorporated Washington County	100,745	$28,760,104,000	1,080	$37,428,000	0.1%
City of Beaverton	26,405	$11,283,939,000	429	$32,268,000	0.3%
City of Cornelius	3,807	$954,752,000	5	$64,000	0%
City of Forest Grove	8,199	$2,525,502,000	20	$579,000	0%
City of Hillsboro	37,513	$15,487,612,000	141	$6,173,000	0%
City of North Plains	1,333	$414,606,000	58	$1,963,000	0.5%
City of Sherwood	6,109	$2,194,018,000	1	$50,000	0%
City of Tigard	18,731	$7,526,469,000	78	$2,959,000	0%

Table 34: Flood Exposure Estimates for 100-Year Flood Scenario

Plan Participant	Total Number of Buildings	Total Population	Potentially Displaced Residents from Flood Exposure	% Potentially Displaced Residents from Flood Exposure	Number of Flood Exposed Buildings	% of Flood Exposed Buildings	Number of Flood Exposed Buildings Without Damage
Unincorporated Washington County	100,745	252,626	1,969	0.8%	865	0.9%	214
City of Beaverton	26,405	98,738	1,376	1.4%	384	1.5%	29
City of Cornelius	3,807	12,674	6	0%	3	0.1%	2
City of Forest Grove	8,199	25,132	0	0%	2	0%	0
City of Hillsboro	37,513	104,041	203	0.2%	99	0.3%	25
City of North Plains	1,333	3,341	22	0.7%	15	1.1%	6
City of Sherwood	6,109	21,315	0	0%	1	0%	0
City of Tigard	18,731	54,729	173	0.3%	59	0.3%	14

2.7.5.5.4. Natural Environments

The impacts of flooding on the environment can be wide-ranging, from the dispersion of low-level household wastes into water systems to contamination of community water supplies and wildlife habitats with extremely toxic substances. Industrial or agricultural chemicals and wastes, solid wastes, raw sewage, and common household chemicals comprise most hazardous materials spread by flood waters that pollute the environment.

Flooding can help spread organic material, nutrients, and sediments, which enrich floodplain soils. Flooding can also replenish water resources and trigger life processes, such as bird breeding events, migration, and seed dispersal in flora and fauna adapted to these cycles. Additionally, good soil moisture can allow crops and pastures to be established. However, a massive flood event can result in widespread injury or death to plants and animals and drastically change nesting and feeding habitats for bird, reptile, and mammal species.[152]

Flooding can have secondary effects of causing stream bank erosion and channel migration, or precipitating landslides that can cause further damage, impacts to the natural environment, and change ecosystems.

2.7.5.6. National Flood Insurance Program

The Flood Insurance and Mitigation Administration, a component of FEMA, manages the NFIP. The three components of the NFIP are:

1. Flood insurance;
2. Floodplain management; and
3. Flood hazard mapping.

Jurisdictions in Washington County participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes federally backed flood insurance available to homeowners, renters, and business owners in these communities.

Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods. Residents and business owners who own property in high-risk areas, sometimes referred to as Special Flood Hazard Areas, are required to purchase flood insurance if they have a mortgage from a federally regulated or insured lender. They also must carry the insurance for the life of the mortgage. Residents and business owners with a mortgage on a building outside high-risk areas can also purchase flood insurance and may be eligible for lower cost preferred risk policies.

In addition to providing flood insurance and reducing flood damages through floodplain management regulations, the NFIP identifies and maps floodplains. Mapping flood hazards creates broad-based awareness and provides the data needed for floodplain management programs and to actuarially rate new construction for flood insurance.

Flood insurance rate maps (FIRMs) provide the most readily available source of information for 100-year floods, and these maps are used to support the NFIP. FIRMs delineate 100- and 500-year floodplain boundaries for identified flood hazards. These FIRMs provide the basis for flood insurance and floodplain management requirements. The most recent FIRM map of Washington County was created November 4, 2016.

[152] Ocean Watch Australia. (n.d.). What are the negative and positive impacts of flooding on the environment? https://www.oceanwatch.org.au/latest-news/coastal-marine/what-are-the-negative-and-positive-impacts-of-flooding-on-the-environment/

In April 2021, FEMA launched Risk Mapping, Assessment, and Planning (Risk MAP) 2.0, an update to the NFIP insurance rate pricing methodology. Risk Rating 2.0 enables FEMA to set rates that are fairer and ensures that both rate increases and decreases are equitable. The new methodology builds on years of investment in flood hazard information by incorporating private sector data sets, catastrophe models, and evolving actuarial science.

With Risk MAP 2.0, FEMA has the capability and tools to address rating disparities by incorporating more flood risk variables. These include flood frequency, multiple flood types—river overflow, storm surge, coastal erosion, and heavy rainfall—and distance to a water source, along with such property characteristics as elevation and the cost to rebuild. Previously, pricing was predominantly based on relatively static measurements, emphasizing a property's elevation within a zone on a FIRM.

Currently, policyholders with lower-valued homes are paying more than their share of the risk while policyholders with higher-valued homes are paying less than their share of the risk. Because Risk Rating 2.0 considers rebuilding costs, it equitably distributes premiums across all policyholders based on home value and a property's unique flood risk.[153]

Floodplain management regulations are the cornerstone of NFIP participation. Communities that participate in the NFIP are expected to adopt and enforce floodplain management regulations that apply to all types of floodplain development and ensure that development activities will not cause an increase in future flood damages. Buildings in floodplains are required to be elevated at or above the base flood elevation as established by the local regulations. Additional details about each participant's involvement in the NFIP are in participant annexes, as applicable.

2.7.5.6.1. Repetitive Loss Properties and Severe Repetitive Loss Properties

A repetitive loss (RL) property is a property insured under the NFIP that the program has paid at least two claims of more than $1,000 in any 10-year period since 1978, regardless of any change(s) of ownership during that period. Nationwide, RL properties constitute 2% of all NFIP-insured properties but are responsible for 40% of all NFIP claims. Mitigation for RL properties is a high priority for FEMA, and the areas in which these properties are located typically represent the most flood-prone areas of a community.

Severe repetitive loss (SRL) properties are properties that have sustained the highest levels of damages and claims. SRL properties are defined as any building that is covered under a Standard Flood Insurance Policy (SFIP) and has sustained flood damage for which:

- Four or more separate claim payments have been made under an SFIP, with the amount of each claim exceeding $5,000 and the cumulative amount of such claims exceeding $20,000; or
- At least two separate claims payments have been made under an SFIP, with the cumulative amount of those payments exceeding the fair market value of the insured structure as of the day before the loss.

The identification of RL properties is an important element to conducting a local flood risk assessment, as the inherent characteristics of properties with multiple flood losses strongly suggest that they will be threatened by continual losses. RL properties are also important to the NFIP, since structures that flood frequently put a strain on the National Flood Insurance Fund.

A primary goal of FEMA is to reduce the number of structures that meet these criteria, whether through elevation, acquisition, relocation, or a flood-control project that lessens the potential for continual losses.

There are 51 RL properties in Washington County as of September 30, 2021. Unincorporated Washington County has seven SRL properties and is the only plan participant with SRL properties. The

[153] Federal Emergency Management Agency. (n.d.). Risk Rating 2.0: Equity in Action. https://www.fema.gov/flood-insurance/risk-rating

specific addresses of the properties are maintained by FEMA, Washington County, and local jurisdictions, but are deliberately not included in this plan as required by law.

Table 35: Number of Repetitive Loss Properties in Washington County as of September 30, 2021[154]

Jurisdiction	Number of RL Properties
City of Beaverton	6*
City of Forest Grove	1
City of Hillsboro	1
City of Tigard	2
City of Tualatin**	4
Unincorporated Washington County	36, including 7 SRL properties
Total	**51**

*FEMA sources show 7 properties, but one is outside city limits.
**Not a 2023 NHMP participant.

Neither the County nor the participating cities are members of the Community Rating System (CRS).

2.7.5.7. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of flooding. Additional information is in the participant annexes.

Table 36: Participant Overall Risk of Flooding[155]

Participant	Overall Risk of Flooding
City of Beaverton	188
City of Cornelius	48
City of Forest Grove	48
City of Hillsboro	159
City of North Plains	181
City of Sherwood	79
City of Tigard	162
Clean Water Services	189
Tualatin Hills Park & Recreation District	143
Tualatin Valley Water District	67
Washington County	173

[154] Personal communication with Washington County Land Use and Transportation Department personnel
[155] 2023 NHMP Participant Planning Documentation

2.7.6. Landslide

Significant Changes
• Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency of landslide added.

2.7.6.1. Characteristics

Landslides are downhill or lateral movements of rock, debris, or soil mass. The term is used for varying phenomena, including mudflows, mudslides, debris flows, rock falls, rockslides, debris avalanches, debris slides, and slump-earth flows. The size of a landslide usually will depend on the geology and the triggering mechanism. Landslides initiated by rainfall tend to be smaller, while those initiated by earthquakes may be large.

Landslides can be rapid or slow moving. The velocity of landslides varies from imperceptible to over 35 miles per hour. Some volcanic induced landslides have been known to travel between 50 to 150 miles per hour. On less steep slopes, landslides tend to move slowly and cause damage gradually.

Rapidly moving landslides, including debris flows and earth flows, present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Rapidly moving landslides have also caused most of the recent landslide-related injuries and deaths in Oregon. Slow-moving landslides can cause significant property damage but are less likely to result in serious human injuries.

Debris flows typically start on steep hillsides as shallow landslides, enter a channel, then liquefy and accelerate. Canyon bottoms, stream channels, and outlets of canyons can be particularly hazardous. Landslides can move long distances, sometimes as much as several miles.

The susceptibility of hillside and mountainous areas to landslides depends on variations in geology, topography, vegetation, and weather. Certain geologic formations are more susceptible to landslides than others. In general, locations with steep slopes are most susceptible to landslides, and the landslides occurring on steep slopes tend to move more rapidly and therefore may pose life safety risks.

Four primary types of landslides can impact Washington County:

- **Slides** move in contact with the underlying surface. These movements include rotational slides, where sliding material moves along a curved surface, and translational slides, where movement occurs along a flat surface. These slides are generally slow moving and can be deep. Slumps are small rotational slides that are generally shallow. Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage but are far less likely to result in serious injuries than rapidly moving landslides.
  - Slides associated with volcanic eruptions are typically large and can include as much as one cubic mile of material.
  - Slides caused by erosion occur when ditches or culverts beneath hillside roads become blocked with debris.
  - Slides caused by erosion are the most common type of landslide in Washington County. Many recent landslides in the County primarily have been slow moving and have caused the greatest impact to roads and culverts.
- **Rock falls** occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations, such as those along highways where the road has been cut through bedrock, can cause rock falls. These landslides are fast moving, with the materials free falling or bouncing

down the slope. The total volume of material involved is generally small, but individually the boulders or blocks of rock can be large and can cause significant damage.

- **Flows** are landslides in which soil and rock breaks up and flows like a plastic or liquid. Debris flows normally occur when a landslide moves downslope as a semifluid mass, scouring or partially scouring soils from the slope along its path. Flows often occur during heavy rainfall, can occur on gentle slopes, and can move rapidly for large distances, traveling at speeds of more than 35 miles per hour for several miles. Earthquakes often trigger flows as well. Other types of flows include debris avalanches, mudflows, creeps, earthflows, debris flows, and lahars.
- **Complex landslides** are any combination of landslide types. Most slope failures are complex combinations of the above distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard associated with landslides, landslide characteristics, identification methods, and potential mitigation alternatives.

In Washington County, the most common landslides are debris flows and shallow and deep landslides.[156]

Due to their general nature, landslides on steep slopes are typically more dangerous because they can occur with little warning and their movements can be very rapid. Locations at risk from landslides or debris flows include areas with one or more of the following conditions:

- On or close to steep hills.
- Steep roadcuts or excavations into steep slopes.
- Existing landslides or places of known historic landslides; such sites often have tilted power lines, trees tilted in various directions, cracks in the ground, and irregular ground surfaces.
- Steep areas where surface runoff is channeled, such as below ground in culverts, V-shaped valleys, canyon bottoms, and steep stream channels.
- Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons, and large boulders (2 to 20 feet in diameter) perched on soil near fans or adjacent to creeks.
- Occurrences of logjams in streams.

Landslides often occur together with other natural hazards, thereby exacerbating conditions, as described below:

- Shaking due to earthquakes or seismic tremors can trigger events ranging from rockfalls and topples to massive slides.
- Volcanic activity, especially eruptions, can cause large slides that include as much as one cubic mile of material.
- Intense or prolonged precipitation or large amounts of melting snow can cause flooding and can also saturate slopes and cause failures leading to landslides.
- Extreme precipitation events can occur at all phases of the ENSO cycle, but the largest fraction of these events occur during La Niña episodes and during ENSO-neutral winters. During La Niña episodes, much of the Pacific Northwest experiences increased storminess, increased precipitation, and more overall days with measurable precipitation. The risk of flooding and rain-induced landslides and debris flows can be related to La Niña episodes.
- Erosion can cause slides when ditches or culverts beneath hillside roads become blocked with debris and precipitation runoff is constrained. Runoff water can collect in soil and in some cases cause a slide. Usually the slides are small (100–1,000 cubic yards), but some have been known to be quite large.

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[156] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

- Landslides into a reservoir can indirectly compromise dam safety, and a landslide can even affect the dam itself.
- Wildfires can remove vegetation from hillsides, significantly increasing runoff and landslide potential.

2.7.6.2. Location and Extent

Portions of the cities of Beaverton, Tigard, Hillsboro, Forest Grove, and the unincorporated area of Washington County are exposed to landslide hazards. Areas in terrain with moderate to steep slopes or at the base of steep hillsides may be exposed to landslides. While these areas are highly prone to landslides, most of the populated areas are outside these zones because most of the buildings are on the relatively flat ground towards the center of the Tualatin Valley. However, in these areas, even moderate slopes can become unstable and trigger a landslide if rain or runoff oversaturates the soil.

Per DOGAMI, areas of significant landslide risk include the following:

- Residential structures along the west side of the Portland Hills are generally at a higher risk from landslides.
- The southern, western, and northern rural areas of Washington County with steep slopes have an increased risk of landslides.
- Many areas in the southwestern portions of the cities of Beaverton and Tigard are highly susceptible to landslides.
- Buildings built along Rock Creek in the city of Hillsboro are at higher risk of landslides than other adjacent areas.

Approximately 40% of the County has high or very high susceptibility to landslides, while the cities generally have less susceptibility. About 40% of the land in the City of Tigard lies within the category of being moderately susceptible to the landslide hazard. Cities in Washington County have very low percentages of high and very high landslide exposure susceptibility.

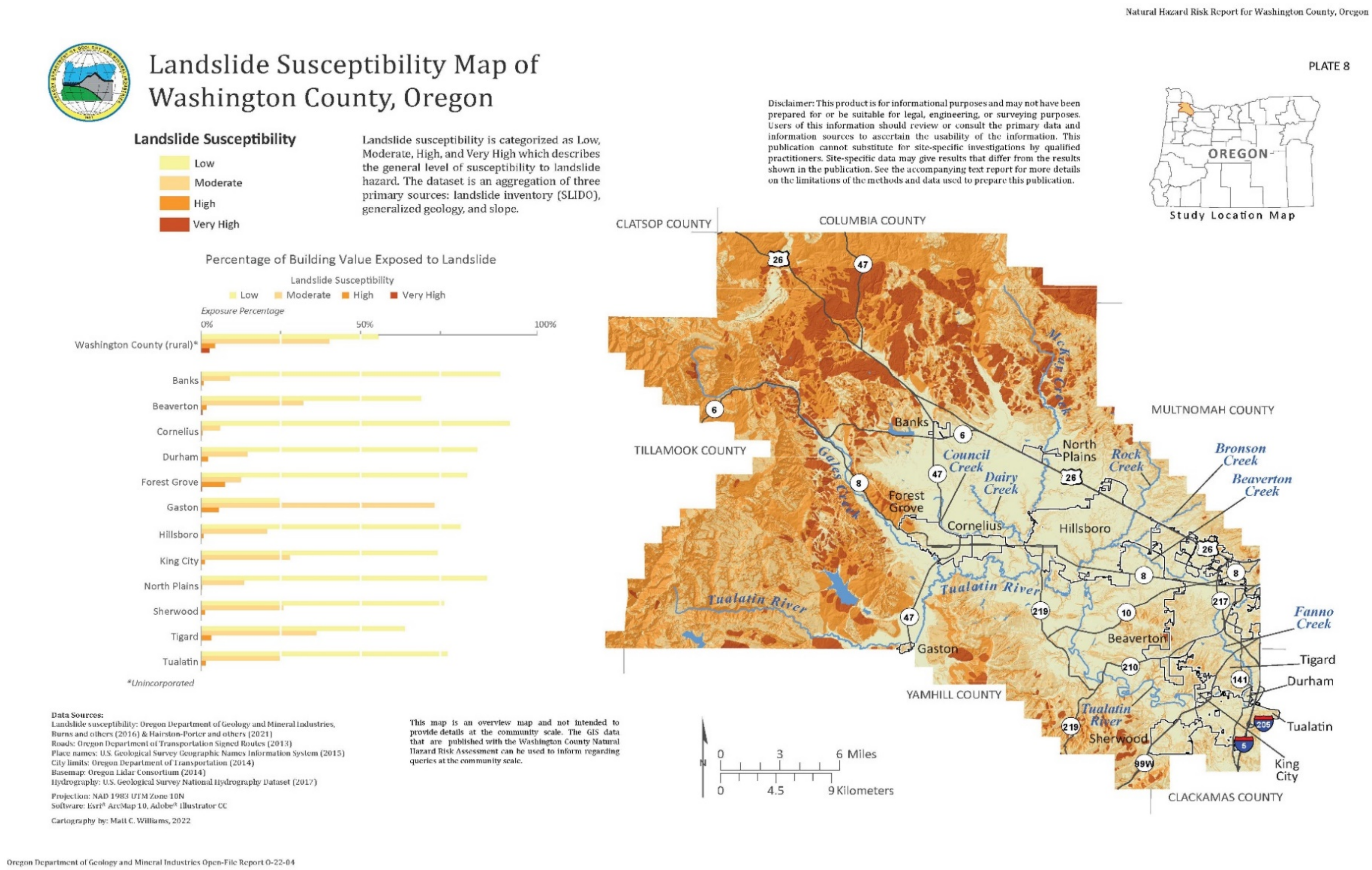

Figure 24: Landslide Susceptibility Map of Washington County, Oregon[157]

[157] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

The geographic extent of landslide events is essentially the same as slide location, while the effects depend on what infrastructure is in the way of a slide and the magnitude and force of the slide itself. The extent of effects could be as limited as one building or property, to regionwide effects, as in the case of a major transportation disruption, slide-induced dam failure, or utility outage.

Rapidly moving landslides have the greatest potential to endanger human life or inflict serious injury, especially to those living in or traveling through rapidly moving slide-prone areas. Slow moving slides are less likely to inflict serious human injuries but can cause property damage.

As population growth continues to expand and development into landslide susceptible terrain occurs, greater losses are likely to result. Landslide hazards are pervasive in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas that are susceptible to landslides is beneficial to reducing risk for every community and rural area of Washington County.

2.7.6.3. History

The likelihood of a landslide in any given slide-prone location is largely dependent on the water content of the soil or rock fill. Landslides may happen at any time of the year, especially during rainy months when soils become saturated with water.

A landslide on December 7, 2021, resulted in an emergency, long-term closure of Dixie Mountain Road from the quarry to the end of the road. The root cause is still under investigation. The road remains closed, and an alternate access to the quarry was opened up. The response cost to the County as of June 2022 is approximately $3,000. No other significant landslide events have occurred in the planning area since the adoption of the 2017 NHMP.[158]

2.7.6.4. Probability of Future Events

The landslide recurrence interval is highly variable. Some large landslides move continuously at slow rates. Others move periodically during wet periods. Very steeply sloped areas can have relatively high landslide recurrence intervals ranging from 10 to 500 years.

Because debris flows can be initiated at many sites over a watershed, in some cases recurrence intervals can be less than 10 years. Slope alterations can greatly affect recurrence intervals for all types of landslides and also cause landslides in areas otherwise not susceptible. Most slopes in Western Oregon steeper than 30 degrees (about 60%) have a risk of rapidly moving landslide activity regardless of geologic conditions. Areas directly below these slopes in the paths of potential landslides are at risk as well.[159]

Areas that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. This commonly leads to distinctive geomorphology that can be used to identify landslide areas, although over time the geomorphic expression may become subtle, making the landslide difficult to identify. Other types of landslides tend to occur in the same locations and produce distinctive geomorphology, such as channelized debris flows, which form a fan at the mouth of the channel after repeated events.

Geologic, terrain, and climatic conditions that led to landslides in the past are good predictors of future landslides. Therefore, data and maps can provide critical information to guide site-specific investigations for future developments and to assist in planning and mitigation in existing landslide-prone areas in the County. However, the location of existing landslides alone is not enough to predict the future. The

[158] 2023 NHMP Planning Documentation
[159] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

geology, slope, and triggering factors, such as water, earthquakes, volcanic eruptions, and human activity, also must be considered. All of these factors combined result in landslide susceptibility, that is, whether a location is more or less likely to experience landslides.

The probability of rapidly moving landslides occurring depends on a number of factors, including steepness of slope, slope materials, local geology, vegetative cover, human activity, and water. There is a strong correlation between intensive winter rainstorms and the occurrence of rapidly moving debris flows. Many slower moving slides present in developed areas have been identified and mapped; however, the probability and timing of their movement is difficult to quantify. The installation of slope indicators or the use of more advanced measuring techniques could provide information on these slower moving slides.

Development and other human activities can also provoke landslides. Increased runoff, excavation in hillsides, shocks and vibrations from construction, placement of non-engineered fill, and changes in vegetation from fire, timber harvesting, and land clearing have all led to landslide events. Weathering and decomposition of geologic material, and alterations in flow of surface or groundwater, can further increase the potential for landslides. As population growth continues and development expands into landslide-susceptible terrain, greater losses are likely to result.

2.7.6.4.1. Climate Change

Changing climate, precipitation patterns, and more frequent wildfire events may increase the planning area's susceptibility to landslides.[160]

Landslides are often triggered by heavy rainfall events when the soil becomes saturated. It is likely that the County will experience an increase in the frequency of extreme precipitation events. Because landslide risk depends on a variety of site-specific factors, it is more likely than not that climate change, through increasing frequency of extreme precipitation events, will result in increased frequency of landslides.[161]

Because landslides often occur together with other natural hazards, the ways in which climate change alters the frequency and intensity of earthquakes, seismic tremors, volcanic activity, precipitation amounts, wildfires, and erosion will impact the probability and strength of future landslides.

2.7.6.5. Vulnerability Assessment

2.7.6.5.1. Populations

Although rapidly moving landslides, including debris flows and earth flows, can present a large risk to human life, the population of the planning area has not experienced impacts from previous events. Injury and loss of life from landslides is more likely to occur to people who live, travel, and pursue recreation opportunities in areas prone to landslides.

2.7.6.5.2. Economy

Disruption of infrastructure, roads, and critical facilities by landslides may also have a long-term effect on the local economy. Roads and bridges are subject to closure during landslide events. Because many Washington County residents are dependent on roads and bridges for travel to work, delays and detours are likely to have an economic impact on county residents and businesses. Affected communities may also be subject to the economic impacts of road closures, which may disrupt ingress to and egress from communities.

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[160] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[161] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

2.7.6.5.3. Structures, Improved Property, Critical Facilities, and Infrastructure

Landslides can affect utility services, transportation systems, and critical lifelines. Communities may suffer immediate damages and loss of service. Utilities, including potable water, wastewater, telecommunications, natural gas, and electric power, are essential to service community needs. Loss of electricity has the most widespread impact on other utilities and on the whole community. Natural gas pipes may also be at risk of breakage from landslide movements.

In Washington County, many areas with high susceptibility to landslides are in hilly, forested areas. Landslides in these areas may damage or destroy some access roads through rural, hilly areas. Many of the major highways in the County are at risk for landslides at one or more locations, with a high potential for road closures and damage to utility lines. The western portions of the County have limited road network redundancy, and road closures may isolate some communities.

Approximately 3% DOGAMI combined high and very high susceptibility zones as the primary scenarios to provide a general sense of community risk for planning purposes. It was useful to combine exposure for both susceptibility zones to best communicate the level of landslide risk to communities. These susceptibility zones represent areas most susceptible to landslides with the highest impact to the community.

Comparing building locations to geographic extents of identified landslide susceptibility zones provides the following high and very high exposure susceptibility information[162]:

- Number of buildings: 8,997
- Value of exposed buildings: $2,689,627,000
- Percentage of total county building value exposed: 3.6%
- Critical facilities exposed: 1
- Potentially displaced population: 20,383

Proper site evaluation and construction techniques and thorough building codes for buildings in steep and landslide-prone zones are imperative to decrease the potential for loss of life and property damage. Flowing water is the most common trigger of landslides, so managing water is key.[163] Sources of water on a site can include rainfall, broken or leaking sewer or water lines, water retention facilities that direct water onto slopes, lawn irrigation, and streams or creeks. It is important to recognize that water flow can affect the natural geology and/or exacerbate the altered conditions of the site that resulted from grading and construction. Water flow may need to be directed off the site or controlled through construction, drainage and erosion control, and/or grading requirements. As with all other codes and regulations, monitoring and enforcement are essential.

It is vital to consider how uphill buildings and properties can impact downhill developments and communities. Wet, dense soils on the uphill side of a building's foundation can exert a lot of force on the uphill foundation walls of the structure and becomes like a dam holding back a lake of mud. Retention walls are an important structural mitigation measure in these areas.[164]

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[162] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[163] Oregon Department of Land Conservation and Development and Oregon Department of Geology and Mineral Industries. (2019, October). Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities. https://www.oregongeology.org/Landslide/Landslide_Hazards_Land_Use_Guide_2019.pdf
[164] MacEvilly, C. (2016, December 13). Should I Buy a Home on a Steep Hillside? https://www.myseattlehomesearch.com/blog/should-i-buy-a-home-on-a-steep-hill-side/

2.7.6.5.4. Natural Environments

Crops, vegetation, parks, and other natural systems can be damaged by landslides if they are located in susceptible areas.

2.7.6.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of landslide. Additional information is in the participant annexes.

Table 37: Participant Overall Risk of Landslide[165]

Participant	Overall Risk of Landslide
City of Beaverton	86
City of Cornelius	118
City of Forest Grove	118
City of Hillsboro	34
City of North Plains	24
City of Sherwood	61
City of Tigard	73
Clean Water Services	96
Tualatin Hills Park & Recreation District	72
Tualatin Valley Water District	88
Washington County	102

[165] 2023 NHMP Participant Planning Documentation

2.7.7. Volcanic Ash

Significant Changes
- Previous volcano hazard profile streamlined to focus on volcanic ash.
- Added information on vulnerabilities and how climate change may impact the frequency and severity of volcanic ash.

2.7.7.1. Characteristics

A volcano is a vent or opening in the earth's crust from which molten lava (magma), pyroclastic materials, and volcanic gases are expelled onto the surface. Volcanoes and other volcanic phenomena can unleash cataclysmic destructive power and can pose serious hazards if they occur in populated and/or cultivated regions. These hazards may occur during eruptive episodes or in the periods between eruptions.[166]

The distal eruptive hazards of tephra and ashfall are of the greatest concern in Washington County. Tephra is any type and size of rock fragment that is forcibly ejected from the volcano and travels an airborne path during an eruption.[167] Large fragments generally fall back close to the erupting vent; however, billions of smaller and lighter particles of ash can be carried hundreds to thousands of miles away from the source by wind.[168] Westerly winds dominate in the Pacific Northwest, sending volcanic ash east and north-eastward about 80% of the time, though ash can blow in any direction.[169] Falling ash, even in low concentrations, can cause negative impacts hundreds of miles downwind by causing breathing problems, shorting out utility systems, and making transportation difficult.[170]

2.7.7.2. Location and Extent

Volcanic activity is possible from Mount Hood, Mount St. Helens, Three Sisters, Mount Bachelor, Mount Adams, Mount Rainier, and the Newberry Crater areas. All these volcanoes are known or suspected to be active, and most have geological records that indicate past histories of explosive eruptions with large ash releases. Washington County is not located near these volcanoes, but ashfall has the potential to impact the entire planning area equally, although the scale and types of impacts may differ. The extent of ashfall and the specific consequences from an event can vary depending on the height attained by the eruption column and the atmospheric conditions at the time of the eruption.

Scientists use wind direction to predict areas that might be affected by volcanic ash; during an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascade Range originates from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes, away from Washington County. The annual probability of 1 centimeter or more of ash accumulation from eruptions throughout the

[166] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[167] U.S. Geological Survey Cascades Volcano Observatory. (n.d.). Tephra Fall Is a Widespread Volcanic Hazard. https://www.usgs.gov/observatories/cascades-volcano-observatory/tephra-fall-widespread-volcanic-hazard
[168] U.S. Geological Survey Cascades Volcano Observatory. (n.d.). Tephra Fall Is a Widespread Volcanic Hazard. https://www.usgs.gov/observatories/cascades-volcano-observatory/tephra-fall-widespread-volcanic-hazard
[169] U.S. Geological Survey Cascades Volcano Observatory. (n.d.). Tephra Fall Is a Widespread Volcanic Hazard. https://www.usgs.gov/observatories/cascades-volcano-observatory/tephra-fall-widespread-volcanic-hazard
[170] U.S. Geological Survey. (n.d.). Ash3d: Volcanic Ash Dispersion Model. https://vsc-ash.wr.usgs.gov/ashgui/#!/#%2F

Cascade Range is 1 in 5,000 to 1 in 10,000 for Washington County.[171] The county is not at risk from other volcanic hazards, such as lahars, lava flows, debris flows or avalanches, and pyroclastic flows.[172]

The Volcanic Explosivity Index (VEI) is a relative measure of the explosiveness of volcanic eruption. The scale is open-ended, with the largest volcanic eruptions in history (supereruptions) given a magnitude 8.0. A value of 0 is given for non-explosive eruptions, defined as less than 10,000 m^3 (350,000 cubic feet) of tephra ejected, and 8 representing a mega-colossal explosive eruption that can eject 1.0 x 1012 m^3 (240 cubic miles) of tephra and have a cloud column height of over 12 miles.[173]

The eruption of Mount St. Helens on May 18, 1980 was a magnitude 5.0, with an erupted tephra volume of 1 km^3. Other eruptions of the mountain, on June 12, 1980, December 7, 1989, and October 1, 2004, ranged from magnitude 3.0 to 0, with erupted tephra volumes ranging from 0.01 km^3 to .0001 km^3.[174]

2.7.7.3. History

There have been no volcanic ash events since the adoption of the 2017 NHMP.

2.7.7.4. Probability of Future Events

The U.S. Geological Survey's Cascades Volcano Observatory (CVO) volcanic-hazard zonation reports include a description of potential hazards that may occur to immediate communities if any of the major Cascade volcanoes were to erupt. The CVO volcanic tephra fall map (see Figure 25) shows the one-year probability of accumulation of 1 cm (0.4 inch) or more of tephra from volcanic eruptions in the Cascade Range and can be used by participants as a guide for forecasting potential tephra hazard problems. Probability zones extend farther east of the range because winds blow from westerly directions most of the time. The patterns on the map show the dominating influence of Mount Saint Helens as a tephra producer. Because small eruptions are more numerous than large eruptions, the probability of a thick tephra fall at a given locality is lower than that of a thin tephra fall. The annual probability of a fall of one centimeter or more of tephra is up to 1 in 10,000 for Washington County.

[171] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[172] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[173] U.S. Geological Survey Volcano Hazards Program. (n.d.). Volcanic Explosivity Index (VEI) is a numeric scale that measures t. https://www.usgs.gov/media/images/volcanic-explosivity-index-vei-a-numeric-scale-measures-t
[174] U.S. Geological Survey Volcano Hazards Program. (n.d.). Volcanic Explosivity Index (VEI) is a numeric scale that measures t. https://www.usgs.gov/media/images/volcanic-explosivity-index-vei-a-numeric-scale-measures-t

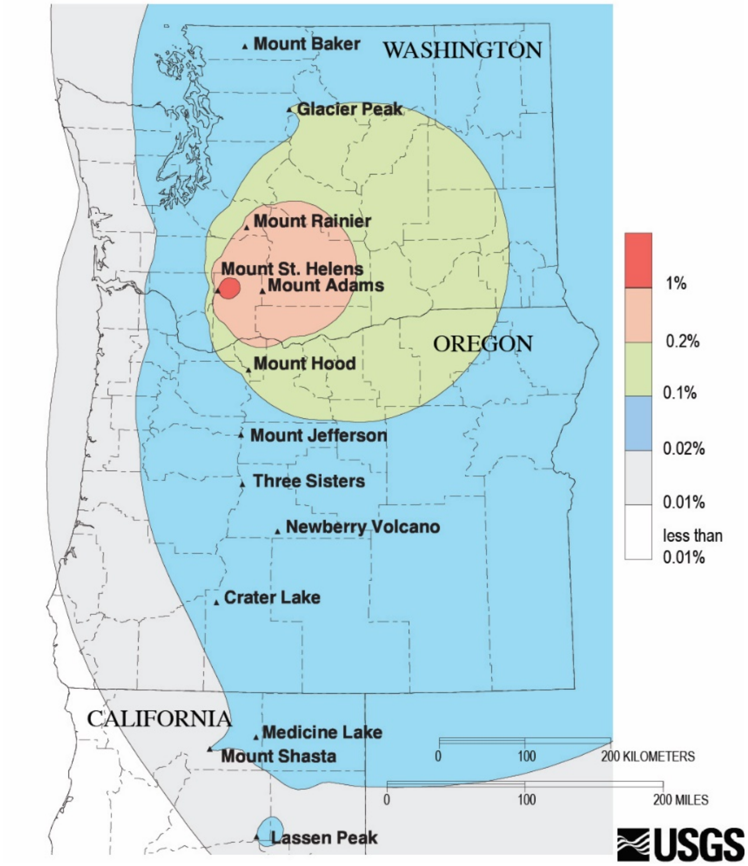

Figure 25: One-Year Probability of Accumulation of 0.4 Inches or More of Tephra from Eruptions of Volcanoes in the Cascade Range[175]

Per the 2020 Oregon NHMP, one method of evaluating the probability of volcanic-hazard events in Oregon is to consider the proximity of a county to the Cascade Range volcanoes along with the probability of tephra accumulation over a 30-year period and apply professional expertise and judgment. Based on the County's western proximity to the Cascade Range volcanoes, the 30-year probability of tephra accumulation of at least 1 cm and at least 10 cm is nonexistent (not applicable). DOGAMI calculated the probability of proximal, distal, and overall volcanic-hazard risks for each county in the state, assigning a number from 1 to 5 indicating very low to very high probability. Washington County has an overall probability of volcanic hazards of 1.5 or lower.[176]

Gases from major explosive eruptions can impact the climate, and several eruptions during the past century have caused a decline in the average temperature at the Earth's surface of up to half a degree (Fahrenheit scale) for periods of one to three years.[177] Sulfur dioxide can cause global cooling, and volcanic carbon dioxide, a greenhouse gas, has the potential to promote global warming; however, volcanoes release less than a percent of the carbon dioxide released currently by human activities.[178] There is limited research on how climate change may impact the frequency and severity of volcanic

[175] U.S. Geological Survey. (2013). Map Showing One-Year Probability of Accumulation of 1 Centimeter. https://www.usgs.gov/media/images/map-showing-one-year-probability-accumulation-1-centimeter
[176] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[177] U.S. Geological Survey Volcano Hazards Program. (n.d.). Volcanoes Can Affect Climate. https://www.usgs.gov/programs/VHP/volcanoes-can-affect-climate
[178] U.S. Geological Survey Volcano Hazards Program. (n.d.). Volcanoes Can Affect Climate. https://www.usgs.gov/programs/VHP/volcanoes-can-affect-climate

eruptions, but a recent study suggests that a warming planet could contribute to an increase in volcanic activity.[179, 180]

2.7.7.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County have the potential to be exposed to and impacted by volcanic ash. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Appendix A and participant annexes.

People with chronic lung problems and preexisting health conditions, children, pregnant women, older adults, and people without access to effective dust masks, eye protection, and drinking water and food uncontaminated by ash are at especially elevated risk of negative impacts.[181]

Though unlikely, the impact of a significant ashfall could be substantial. Any future eruption of a nearby volcano (e.g., Mount Hood, Mount Saint Helens, or Mount Adams) occurring during a period of easterly winds would likely have adverse consequences for the County.

Exposure to volcanic ashfall rarely endangers human life directly, except where very thick ashfalls cause structural damage to buildings (e.g., roof collapse) or indirect casualties, such as those sustained during ash cleanup operations or in traffic accidents.[182]

Short-term effects commonly include irritation of the eyes and upper airways and exacerbation of preexisting respiratory disease, such as asthma; serious health problems are rare. In addition, affected communities may experience increased levels of psychological distress. This is particularly the case when eruptions cause social and economic disruption.[183]

Additional impacts from ashfall include disruption of transportation, including air travel; effects on water supplies, hydroelectric power generation and transmission in northwestern Oregon and southwestern Washington, sanitation, and animal and crop health; and economic disruptions due to short-term business closures.[184]

There are many businesses in the County that could be impacted by volcanic ash, including several electronic manufacturing companies. These companies specialize in hardware, including computer chips, electronic displays, and printers, and volcanic ash can impact their machinery and products, in addition to their staff's health.

Volcanic ash is very abrasive, and vulnerability data from post-eruption impact assessments and laboratory experiments confirm that heating, ventilation, and air-conditioning (HVAC) systems and small electronics components are impacted by tephra fall, especially if the ash is moist. Common impacts are abrasion of fans and motors; blockage of filters and ventilation holes; decreased usability of computers;

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179 Cooper C.L., Swindles G.T., Savov, I.P., Schmidt, A., & Bacon, K.L. (2018). Evaluating the Relationship Between Climate Change and Volcanism. https://eprints.whiterose.ac.uk/124024/1/FinalManuscript.pdf

180 NPR. (2017, December 22). Climate Change Likely to Increase Volcanic Eruptions, Scientists Say. https://www.npr.org/sections/thetwo-way/2017/12/22/572795936/climate-change-likely-to-increase-volcanic-eruptions-scientists-say

181 International Volcanic Health Hazard Network . (n.d.). Health Impacts of Volcanic Ash. https://www.ivhhn.org/information/health-impacts-volcanic-ash

182 U.S. Geological Survey Volcanic Ashfall Impacts Working Group. (2018, May 16). Volcanic Ash Impacts & Mitigation. Health. https://volcanoes.usgs.gov/volcanic_ash/health.html

183 U.S. Geological Survey Volcanic Ashfall Impacts Working Group. (2018, May 16). Volcanic Ash Impacts & Mitigation. Health. https://volcanoes.usgs.gov/volcanic_ash/health.html

184 International Volcanic Health Hazard Network. (n.d.). Health Impacts of Volcanic Ash. https://www.ivhhn.org/information/health-impacts-volcanic-ash

and temporary shutdown of systems. The primary damaging mechanism is ingestion of tephra into the component, which is primarily driven by component design.[185]

Free-hanging and portable ambient air cleaners utilize high-efficiency particulate air (HEPA) filters, which significantly improve air quality. HEPA filters trap 99.97% of particles 0.3 microns or larger. In comparison, dangerous volcanic ash particles are less than 4 microns. HEPA filters employ negative air pressure to cleanse the air and recycle it back into the room. These systems are easy to install because they recycle the air instead of requiring ductwork that directs the air outside. Activated carbon filters can also provide additional protection by trapping the gas pollutant molecules and absorbing them.[186]

Emergency power generation equipment is also vulnerable to volcanic ash and should be protected.[187]

2.7.7.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of volcanic ash. Additional information is in the participant annexes.

Table 38: Participant Overall Risk of Exposure to Volcanic Ash[188]

Participant	Overall Risk of Exposure to Volcanic Ash
City of Beaverton	178
City of Cornelius	99
City of Forest Grove	99
City of Hillsboro	126
City of North Plains	124
City of Sherwood	119
City of Tigard	137
Clean Water Services	86
Tualatin Hills Park & Recreation District	152
Tualatin Valley Water District	119
Washington County	124

185 Wilson, G., Wilson, T.M., Deligne, N.I., Blake, D. M., & Cole, J.W. (2017). Framework for Developing Volcanic Fragility and Vulnerability Functions for Critical Infrastructure. *Journal of Applied Volcanology, 6*(14). https://doi.org/10.1186/s13617-017-0065-6
186 Sentry Air Systems, Inc. (2018, May 18). Dangers & Side Effects of Breathing Volcanic Ash. https://www.sentryair.com/blog/indoor-air-quality/dangers-and-side-effects-of-breathing-volcanic-ash/
187 Volcanic Ashfall Impacts Working Group. (2015, November 25). HVAC and Generators. https://www.volcano.gov/volcanic_ash/equipment_HVAC.html#:~:text=Air%20intakes%20on%20heating%2C%20ventilation%20and%20air-conditioning%20%28HVAC%29,air%20flow%20and%20and%20HVAC%20condenser%20system%20performance
188 2023 NHMP Participant Planning Documentation

2.7.8. Wildland Fire

Significant Changes
- Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency and severity of wildland fires added.
- Added information about wildfire smoke impacts.

2.7.8.1. Characteristics

A wildland fire is a type of wildfire that spreads through consumption of vegetation. Wildfires occur in areas with large amounts of flammable vegetation, and a suppression response may be required to limit impacts of uncontrolled burning. They often begin unnoticed, spread quickly, and are usually signaled by dense smoke that may be visible and cause health impacts for miles around. Wildland fires can be caused by human activities, such as arson or campfires, or by natural events like lightning.

Fire is an essential part of Oregon's ecosystem but can also pose a serious threat to life and property, particularly in areas experiencing population growth and expansion of the built environment in areas with the greatest amount of risk from wildfire.

Due to the large amount of forested land in Washington County and the County's growing population and built environment, wildfire is a significant hazard. Additionally, the County occasionally experiences influxes of smoke from wildfires in nearby areas, which can negatively impact the population and economy.

Wildfires are more likely to pose a risk to communities when conditions are favorable for fire ignition and spread, such as hot, dry and windy weather and large vegetation fuel loads are present, or when suppression is challenging, due to ground conditions or the occurrence of multiple fires that overwhelm committed resources. Once a fire has started, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development.

Wildfire severity is a quantitative measure of the effects of a fire on the environment, typically considering both the damage to vegetation and the impacts on the soil. This measure has three categories[189]:

- **Unburned/low severity:** Less than 25% tree mortality, with limited effects on soils.
- **Moderate severity:** 25%–75% tree mortality, with moderate effects on soils.
- **High severity:** Greater than 75% tree mortality, with extensive mineral soil exposure.

Fire severity is driven by multiple factors that affect how a fire behaves. These factors, also known as the fire behavior triangle, include the following [190]:

- The amount, arrangement, and type(s) of **fuels** present during the fire. These are important factors that determine how a given fire will respond to the landscape and to the degree of fire severity. For example, high-severity burned areas are generally associated with two types of forests: dense, multi-layered forests with "ladders" of flammable materials that allow a ground fire to ignite the canopy, and uniform, young, even-aged forests.
- The **topography** of the landscape, including slope and aspect. Fires tend to be more severe on mid- and upper-slope positions than on lower slopes because wind speeds and convection winds

[189] Oregon State University. (2020, August). Fire FAQs – Are Structures Fuel? The Wildland Urban Interface and the "Built" Environment. https://catalog.extension.oregonstate.edu/em9291/html
[190] Oregon State University. (2020, August). Fire FAQs – Are Structures Fuel? The Wildland Urban Interface and the "Built" Environment. https://catalog.extension.oregonstate.edu/em9291/html

are often greater on the upper slopes due to drainages, canyons, and saddles that channel upslope winds. In most cases, south- and west-facing slopes burn more severely than north-facing slopes because these aspects get more sun for longer periods. Natural barriers such as rock outcroppings and waterways can help to slow the spread of a fire and decrease the severity.

- The **weather** conditions during the fire, including wind, temperature, and humidity. When fires burn during extreme weather conditions, weather almost always overrides the other local factors when fuels are present. Weather that can lead to rapid fire growth and extreme conditions occur when wind speeds are greater than 20 mph at slightly above ground level, temperatures are at 80 ºF or greater, and relative humidity is less than 20 percent. Weather conditions during a fire can change daily or even within the day.
- Decreased soil moisture and increased temperatures associated with **drought** stress vegetation and increase plant mortality, providing fuel for fires. Reduced pond, stream, and reservoir levels can also limit withdrawal sources for fighting wildfires. The extreme conditions can also increase the likelihood of shrub and tree mortality by wildfire in previously fire-adapted ecosystems.
- Areas where **homes and other structures** meet or intermingle with wildland or vegetation fuels can be a part of the WUI. Oregon Senate Bill 762 (SB 762) determines WUI zones by looking at proximity to vegetation and density of development in the area. The WUI is where wildfire impacts are most pronounced and costly. Structures, wood piles, propane tanks, and automobiles in the WUI can act as wildfire fuel, rapidly increasing the size and intensity of the fire and contributing hazard materials to the flames and smoke.

Post-wildfire geologic hazards can also present risk. These secondary hazards typically include:

- **Flood:** Flash floods are particularly common after wildfires. Even areas that are not traditionally flood-prone are at risk, due to changes to the landscape caused by fire. Flood risk remains significantly higher until vegetation is restored—up to five years after a wildfire. Flooding and flood damage after fire is often more severe, as debris and ash left from the fire can form mudflows. As rainwater moves across charred and barren ground, it can also pick up soil and sediment and carry it in a stream of floodwaters. This can cause more significant damage.[191]
- **Landslide and erosion:** Post-fire landslide hazards include fast-moving, highly destructive debris flows that can occur in the aftermath of wildfires in response to high intensity rainfall events. These debris flows are particularly hazardous because they can occur with little warning and move quickly, destroying objects in their paths. The force of the flows can strip vegetation, block drainage, damage structures, and endanger human life. Wildfires could result in the destabilization of preexisting deep-seated landslides over long time periods.[192]
- **Air quality issues:** Exposure to air pollutants in wildfire smoke can irritate the lungs, cause inflammation, alter immune function, and increase susceptibility to respiratory infections. People with asthma, chronic obstructive pulmonary disease (COPD), or heart disease, and children, pregnant women, and responders, are especially at risk.[193]
- **Water quality issues:** During a fire, interruption of electrical power and limited to no access to water treatment plants, ambient water-quality monitoring equipment, and stream diversion and monitoring locations are common. Because existing water quality cannot be adequately determined, source-water suppliers are often forced to shift to stored water or other secondary water supplies. These sources tend to be of lower quality, which can necessitate increased

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[191] Federal Emergency Management Agency. (2020, November). FEMA Fact Sheet Flood after Fire: Flood Risks Increase after Fires. https://www.fema.gov/sites/default/files/documents/fema_flood-after-fire_factsheet_nov20.pdf
[192] U.S. Geological Survey. (n.d.). What should I know about wildfires and debris flows? https://www.usgs.gov/faqs/what-should-i-know-about-wildfires-and-debris-flows#:~:text=Post%2Dfire%20landslide%20hazards%20include,and%20loss%20of%20soil%20strength
[193] Centers for Disease Control and Prevention. (2022, July 11). Protect Yourself from Wildfire Smoke. https://www.cdc.gov/air/wildfire-smoke/default.htm#:~:text=Exposure%20to%20air%20pollutants%20in,during%2C%20and%20after%20a%20wildfire

pretreatment actions and processes at considerable additional cost. Runoff from burned areas contains ash, which may have significant effects on the chemistry of receiving waters, such as lakes, wetlands, reservoirs, rivers, and streams. Runoff from burned areas also produces higher nitrate, organic carbon, and sediment levels; warmer temperatures; and flashier streamflows.[194]

2.7.8.2. Location and Extent

In Washington County and throughout the state of Oregon, areas of high hazard are mapped separate from the WUI. The two areas are then overlaid to identify areas where the most population and/or property is at risk. Forest land in the County has the highest wildland fire risk, but these lands do not overlap with the County's WUI, as updated by SB 762. Under this bill, which updated statewide fire risk mapping, the County's WUI became smaller; however, future rural development and expansion in urban growth boundaries in the County may increase the amount of interface between wildlands and developed areas. Figure 26 illustrates landcover in the County that transitioned to urban uses. The dark gray on the map signifies areas that underwent landcover transition but did not change to urban. For example, forested land that became agricultural areas or bare ground.

Much of the forested portions of the rural unincorporated county have elevated levels of wildfire risk compared to densely developed urban locations. Recreation and scenic areas, wildlife habitats, and community watersheds may also be at risk. The City of Beaverton does not experience threat from wildfire due to its high-density urban landscape and will not have a wildfire hazard analysis or action items in their participant annex. An example of a rural-urban fringe not at risk in Beaverton is the Cooper Mountain expansion area. It is mapped as being in the WUI; however, it is not mapped as high risk. Wildfire risk experienced by Tualatin Hills Park & Recreation District, which includes urban forested parks located within Beaverton, is analyzed in the district's participant annex.

[194] U.S. Geological Survey. (2019, March 1). Water Quality After Wildfire. https://www.usgs.gov/mission-areas/water-resources/science/water-quality-after-wildfire

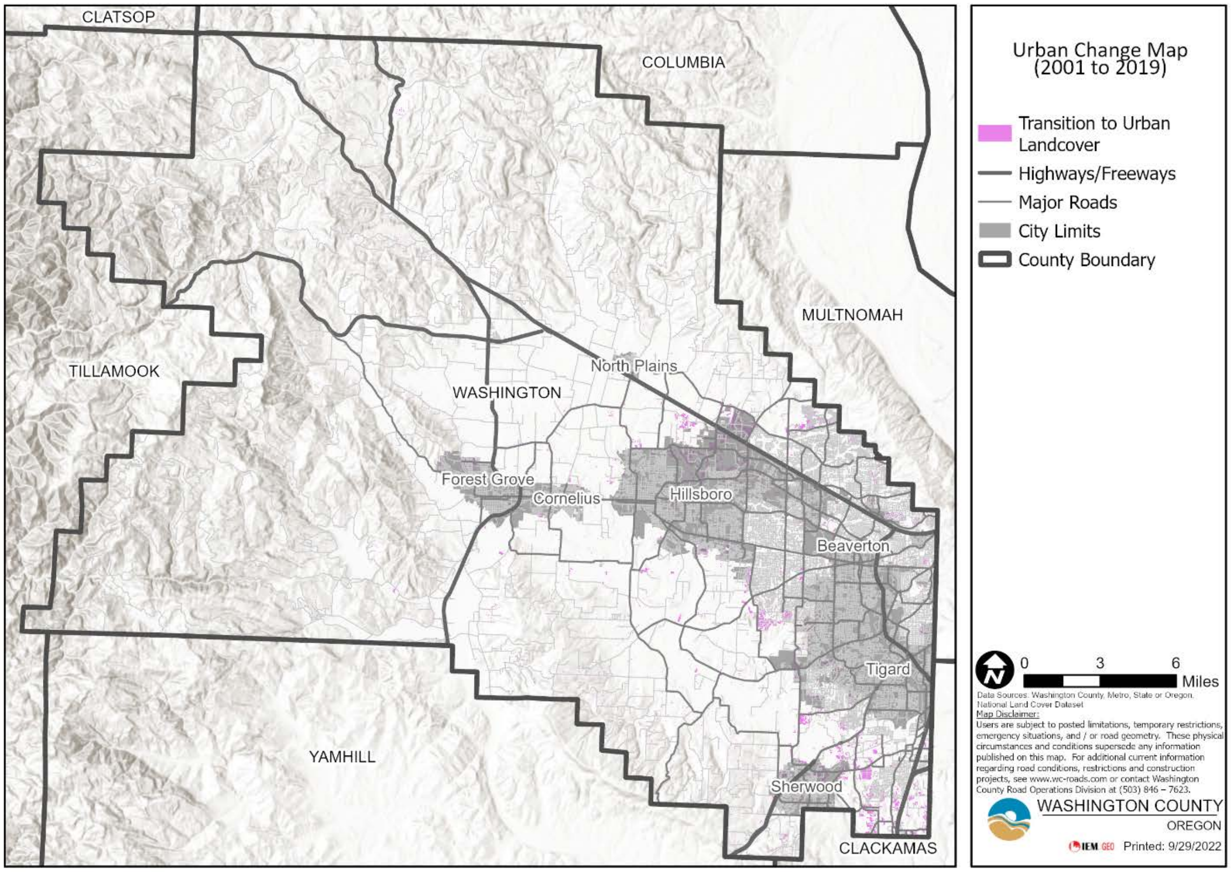

Figure 26: Land Transitioned into Urban Land Cover in Washington County, 2001–2019

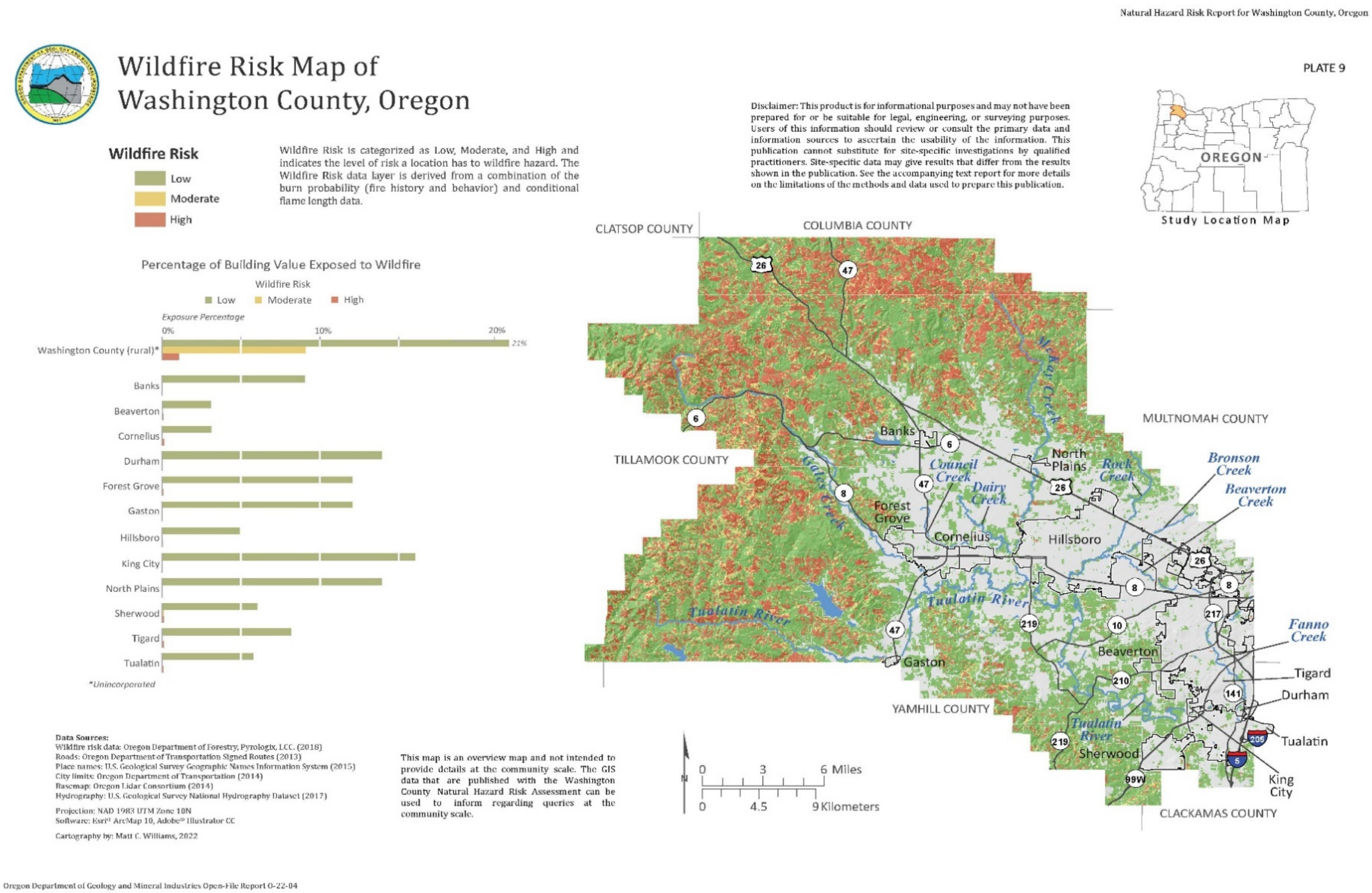

Figure 27: Wildfire Risk Map of Washington County, Oregon[195]

[195] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm

2.7.8.3. History

Per ODF records, there have been 210 wildfire events in Washington County since the adoption of the 2017 NHMP.[196] Most of these fires have burned less than one acre. Of the 59 fires that were investigated to determine ignition source, 17 were the result of debris burning, 17 were caused by equipment use, 9 were recreation related, 6 were ignited by lightning, 3 were caused by smoking, and 7 were from miscellaneous sources, including a burning building and spontaneous combustion.[197]

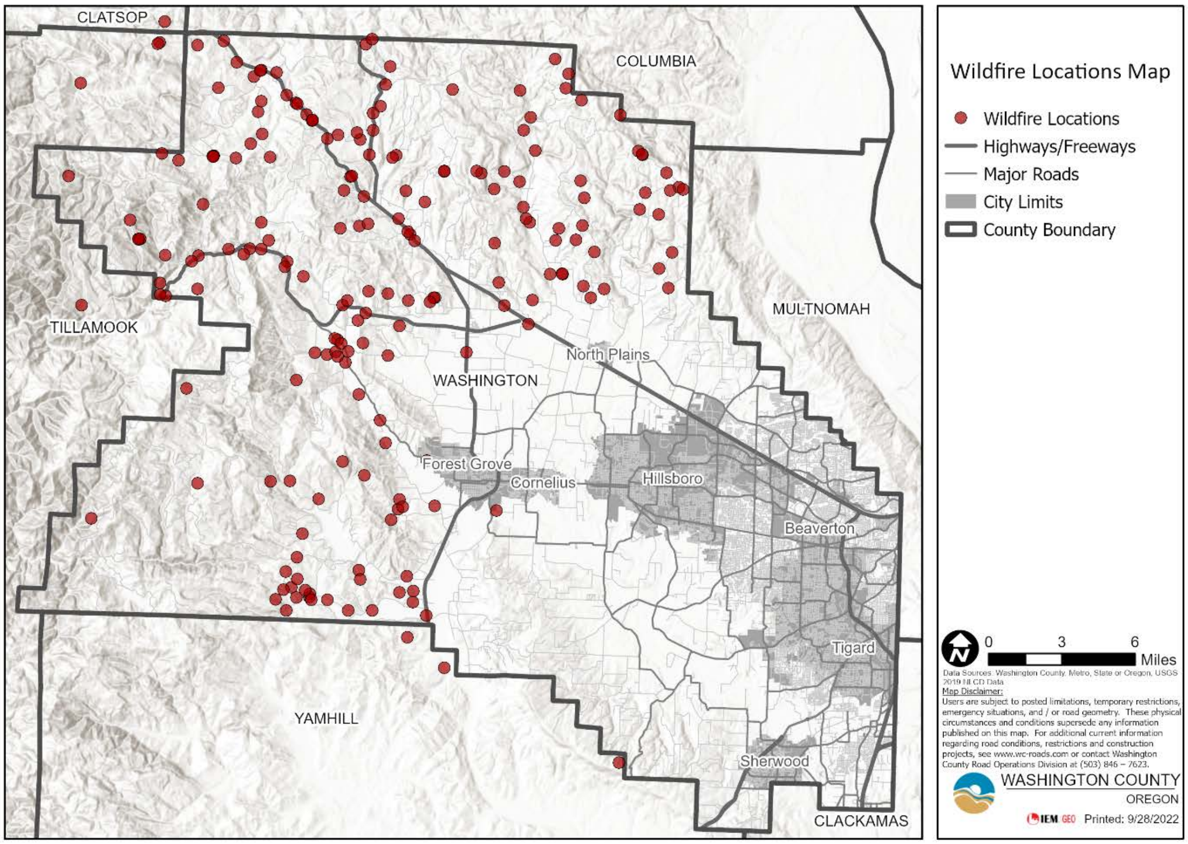

Figure 28: Locations of Wildland Fires in Washington County

Since the adoption of the 2017 NHMP update, Tualatin Valley Fire & Rescue (TVF&R) has responded to 5 fires caused by lightning and 232 wildland fires that required a task force or alarm to be dispatched in the County.[198] There is variation between the data from ODF and TVF&R due to the availability of information at the local level compared to the state level, the diversity of methods for collecting and verifying data between the organizations, and the different service areas of the agencies

There have been two significant wildfire events in Washington County since the adoption of the 2017 NHMP and two instances of smoke from nearby wildfires impacting the County. In September of 2020, two wildfires burned concurrently in the County: the Powerline–Henry Hagg Lake–Cherry Grove wildfire (Powerline wildfire) and the Chehalem Mountain–Bald Peak wildfire.

[196] Oregon Department of Forestry. (2022, July 1). Personal communication with Matt Mackey, Northwest Oregon Area Protection Policy Coordinator
[197] Oregon Department of Forestry. (2022, July 1). Personal communication with Matt Mackey, Northwest Oregon Area Protection Policy Coordinator
[198] Tualatin Valley Fire & Rescue. (2022, May 9). Personal communication with Brian Smith, Captain

The Powerline wildfire began on September 8 and was considered contained on September 13. The fire was started by sparks from powerlines and burned 126 to 175 acres.[199] Day- and night-shift wildland resources assigned to the fire included 3 hand crews, 11 engines, 1 dozer, 1 excavator, 3 water tenders, and overhead personnel. A total of 109 personnel worked on the event.[200] A Level 3 evacuation, the highest evacuation level, and an indication of current or imminent danger, was issued to approximately 150 homes, including those throughout the entire unincorporated community of Cherry Grove and on Dundee Road, SW Patton Valley Road, SW Lee Road, and SW Cascara Road.[201] It also forced the closure of Henry Hagg Lake and Scoggins Valley Park for several days and caused unhealthy air quality.

The five-alarm Chehalem Mountain-Bald Peak wildfire also began on September 8 and was declared 100% contained on September 14. The fire was started by an improperly extinguished campfire on private property in unincorporated Washington County and burned approximately 875 acres in Washington and Yamhill counties. TVF&R conducted fire protection, suppression, and patrols throughout 1,555 acres.[202] The fire spread quickly because of dry fuels, low humidity, high winds, and steep and rugged terrain. In some cases, fire jumped over areas, leaving unburned timber and dry fuels.203 A Level 3 evacuation was issued for approximately 150 people. Level 2 evacuations were issued in several areas. A Level 2 evacuation means there is significant danger to the area and residents should voluntarily relocate to either a shelter or a family or friend's home outside of the affected area. If residents choose to remain in the area, they should be ready to evacuate at a moment's notice. Three barns were destroyed in the fire and power was disrupted. No injuries or deaths were reported.

In response to the fire and evacuations, the following support services were established[204]:

- A staging site and shelter for evacuees was set up at Mountainside High School in the City of Beaverton.
- Three comfort centers were set up at a church in the City of Newberg in Yamhill County. These centers provided air-conditioning, food, water, and showers.
- Animal shelters were set up at the Washington and Yamhill County Fairgrounds. These shelters accepted pets and livestock.
- Campsites and spots for recreational vehicles were created at the Washington County Fairground.

Seven federal, state, and local disaster declarations and emergency executive orders were issued as a result of the fires.

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[199] Forest Grove Fire & Rescue. (2022, May 11). Personal communication with David Nemeyer, Division Chief, Fire & Life Safety
[200] Forest Grove. (2020, September 13). Powerline Fire Final Update. https://www.forestgrove-or.gov/fire/page/powerline-fire-final-update
[201] KATU. (2020, September 8). Evacuation Orders Upgraded for Powerline Fire Near Hagg Lake. Evacuation orders upgraded for Powerline Fire near Hagg Lake | KATU
[202] Tualatin Valley Fire & Rescue. (2013, January 30). Civic Alerts. https://www.tvfr.com/CivicAlerts.aspx?AID=608
[203] KGW8. (2020, September 15). Chehalem Mountain–Bald Peak Fire in Washington County Caused by Campfire on Private Property. https://www.kgw.com/article/news/local/wildfire/chehalem-mountain-bald-peak-fire-was-caused-by-a-campfire-on-private-property/283-2a8f44aa-0041-441c-9d92-935b8faca3af
[204] Tualatin Valley Fire & Rescue. (2020, September 9). Civic Alerts. https://www.tvfr.com/CivicAlerts.aspx?AID=608

Table 39: Major Federal Disaster Declarations Related to September 2020 Wildfires[205]

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories
		From	To			
DR-4562	9/15/2020	9/7/2020	11/3/2020	Wildfire and straight-line winds	No	B
Federal Fire Management Assistance Declarations (FM) Including Washington County Since November 1, 2016						
FM-5371	9/10/2020	9/8/2020	9/15/2020	Wildfire	None	B
FM-5358	9/8/2020	9/8/2020	9/14/2020	Wildfire	None	B
Federal Emergency Declarations (EM) Including Washington County Since November 1, 2016						
EM-3542	9/10/2020	9/8/2020	9/15/2020	Wildfire	None	B

Table 40: State of Oregon Emergency Executive Orders Related to September 2020 Wildfires[206]

Emergency Executive Order (EO) Number	Declaration Date	Incident Period		Executive Order Title
		From	To	
EO-20-43	9/14/2020	9/8/2020	9/14/2020	Invocation of Emergency Conflagration Act for the Powerline Fire
EO-20-41	9/9/2020	9/8/2020	11/1/2020	Invocation of Emergency Conflagration Act

Table 41: Washington County Emergency Declaration Related to September 2020 Wildfires[207]

Declaration Date	Incident Period		Incident
	From	To	
9/11/2020	9/8/2020	9/29/2020	Two concurrent wildfires: Powerline–Henry Hagg Lake–Cherry Grove wildfire (Powerline wildfire) and Chehalem Mountain–Bald Peak wildfire

2.7.8.3.1. Wildfire Smoke

The Eagle Creek fire in the Columbia River gorge, located approximately 45 miles east of Washington County, started on September 2, 2017, and was declared 100% contained on November 30, 2017. The fire was started by the illegal use of fireworks during a burn ban and burned 50,000 acres. The Air Quality Index (AQI) daily average in the County reached as high as 99 particulate matter 2.5 ($PM_{2.5}$) during the fire.[208]

[205] FEMA. (2022). Declared Disasters. https://www.fema.gov/disaster/declarations
[206] Office of the Governor. (n.d.) Executive Orders. https://www.oregon.gov/gov/Pages/executive-orders.aspx
[207] 2023 NHMP Participant Planning Documentation
[208] Air Quality Historical Data Platform. (n.d.). City of Beaverton data. https://aqicn.org/data-platform/register/

In September 2020, multiple wildfires throughout Oregon and Washington caused some evacuees to come into the County. The AQI daily average in the County reached as high as 328 $PM_{2.5}$ during the month.[209]

During these events, Washington County residents and evacuees were required to take protective actions, such as staying indoors with the doors and windows closed, using air-cleaning filters indoors, and wearing goggles and face masks when outside.

2.7.8.4. Probability of Future Events

Washington County has a low burn probability, meaning there is a less than approximately 1 in 5,000 chance of a wildfire burning more than 250 acres in a single year.[210] There are eight low-risk communities, one medium-risk community, and one high-risk community.[211] A community at risk is defined as a geographic area within and surrounding permanent dwellings with basic infrastructure and services, under a common fire protection jurisdiction, government, or tribal trust or allotment, for which there is a significant threat due to wildfire. Overall, the County has a very low wildfire exposure rating.[212]

Wildfire season normally begins in late June, peaks in August, and ends in October. However, a combination of above-normal temperatures and drought can increase the length of the traditional fire season, and wildfires can occur during any month of the year. Wildfire hazards throughout the County are highest during prolonged periods of drought, especially after periods of below-normal rainfall, which can result in a combination of high fuel loads and unusually dry conditions. Fire susceptibility throughout the County dramatically increases in late summer and early autumn as summer thunderstorms with lightning strikes increase and vegetation dries out, decreasing plant moisture content and increasing the ratio of dead fuel to living fuel.

The severity of a fire season can usually be determined in the spring by how much precipitation is received, which in turn determines how much fine fuel growth there is. These factors, combined with the annual easterly wind events typically in September and October, drastically increase the chance that a fire start will grow rapidly and resist suppression activities. Furthermore, grain harvest is also occurring at this time. Occasionally, harvesting equipment causes an ignition that can spread into populated areas and timberlands.[213]

Factors influencing the occurrence and severity of wildfires include poor forest health; invasive plant and tree species; great amounts of vegetation from long-term fire exclusion; changes in weather patterns, including warmer and drier summers; and the presence of humans and human development. Human activities such as debris burning, equipment use and malfunction, along with improper use and disposal of cigarettes and fireworks also increase fire risk in the WUI and in heavily vegetated rural areas with greater fire hazards. Not all property owners in high hazard areas or in the WUI are aware of the threats they face due to wildfire and some owners have done very little to manage fire hazards or offset risks on their own property.

2.7.8.4.1. Climate Change

Declining mountain snowpack, earlier spring snowmelt, and increasing frequency and intensity of drought and extreme heat due to climate change has resulted in a lengthening of the fire season over the last several decades. Dry spells during the winter months, especially when combined with winds and dead

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209 Air Quality Historical Data Platform. (n.d.). City of Beaverton data. https://aqicn.org/data-platform/register/
210 Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
211 Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
212 Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
213 Washington County, Oregon Community Wildfire Protection Plan. (2007, August 6). https://www.co.washington.or.us/EmergencyManagement/upload/WashCo_CWPP_Final.pdf

fuels, may result in fires that burn with a high intensity and rate. Historically, some of the state's largest wildfires have occurred in the climate region that contains the planning area. Though the average rainfall is high within this climate region, past heavy fuel loads created a low-frequency, high-intensity fire environment during the dry periods.[214]

2.7.8.5. Vulnerability Assessment

2.7.8.5.1. Populations

Stress caused by disruptions due to evacuations, staying in shelters, and the uncertainty of wildfire behavior, in addition to experiencing damaged or destroyed property and belongings, can severely negatively impact the mental and physical health of Washington County residents. Additionally, health impacts can occur due to the presence of smoke, even if the wildfire is not directly impacting the County, as seen in 2017 and 2020.

Wildfire smoke is a mixture of gases and fine particles from burning trees and other plant material. The gases and fine particles can be dangerous if inhaled. The particulate matter in wildfire smoke poses the biggest risk to the public's health. The potential health effects vary based on the type of plants burning, atmospheric conditions, and most importantly, the size of the particles. Particles larger than 10 micrometers (PM_{10}) usually irritate only the eyes, nose, and throat. Fine particles 2.5 micrometers or smaller ($PM_{2.5}$) can be inhaled into the deepest part of the lungs and may cause greater health concerns. Smoke can irritate the eyes and the respiratory system and worsen chronic heart and lung diseases. The amount and duration of smoke exposure, as well as a person's age and degree of susceptibility, play a role in determining if someone will experience smoke-related health problems. People with chronic heart disease or lung disease, such as asthma and COPD may be more likely to have serious health effects.[215]

2.7.8.5.2. Health Effects of Wildfire Smoke[216]

Smoke may worsen symptoms for people who have preexisting health conditions and those who are particularly sensitive to air pollution. Sensitive groups include:

- Persons with asthma or other chronic respiratory disease.
- Persons with cardiovascular disease.
- Persons older than 65 years of age.
- Infants and children.
- Pregnant women.
- Smokers, especially those who have smoked for several years.

Wildfire smoke can cause the following effects:

- Watery or dry eyes.
- Persistent cough, phlegm, wheeze, scratchy throat, or irritated sinuses.
- Headaches.
- Shortness of breath, asthma attack, or lung irritation.

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[214] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[215] Oregon Health Authority. (2017, October). Frequently Asked Questions About Wildfire Smoke and Public Health. https://sharedsystems.dhsoha.state.or.us/DHSForms/Served//le8626.pdf
[216] Oregon Health Authority. (n.d.). Wildfires and Smoke. https://www.oregon.gov/oha/ph/preparedness/prepare/pages/prepareforwildfire.aspx#health

- Irregular heartbeat, chest pain or fatigue.
- Non-fatal and fatal heart attacks.

For example, first responders and other personnel working directly on fire protection, suppression, and patrols or near a wildfire can experience burns; smoke exposure; heat-related impacts like heat stroke, heat exhaustion, and dehydration; physical fatigue; mental health challenges; injuries; and death.

Additionally, drinking water sources and water treatment infrastructure, food supplies and availability, and access to medical resources or care may be impacted by wildfire and can cause health impacts on a large scale.

2.7.8.5.3. Economy

Wildfires can have both positive and negative effects on local economies. Positive effects come from economic activity generated in the community during fire suppression and post-fire rebuilding. These may include forestry support work, such as building fire lines and performing other defenses, or providing firefighting teams with food, ice, and amenities, such as temporary shelters and washing machines. However, local economies only experience positive effects if fire suppression spending and contracting are done locally. In addition, future benefits are only possible if the fire stimulates, rather than stops, economic development efforts associated with recovery and forest restoration.[217]

Local governments have the obligation to ensure public safety and fire protection. The short-term budget impact of wildfire to governments includes costs for fire suppression, staff, equipment, supplies, and transportation and mobilization of those fighting the fire.[218] Governments may also be responsible for the costs of evacuations and sheltering operations. Long-term budget impacts include post-fire recovery and rebuilding costs associated with government-owned buildings, property, and infrastructure, and loss of local revenue due to business and property tax losses, agriculture production losses, and reduced recreation and tourism activity. Although some event-related costs may be recouped via state and federal assistance, it is not guaranteed.

In addition to physical impacts to facilities, businesses can experience shipping delays, low stock, interruptions in employee productivity or staffing shortages, and loss of revenue.[219] Wildfires can affect personal and household economics through loss of income, increased medical costs, and property damage that may not be covered by insurance. If a fire threatens an agriculture area, it may require emergency watering, feeding, evacuation, and shelter of livestock.

Post-fire management of the natural environment is a complex issue. Management requires extensive funding for watershed restoration and hazard mitigation efforts. Portions of these funds are used to restore habitat and control the potential impact of erosion and floods in the following seasons. While not easily measured, loss of ecosystem services can be included in the total economic loss.[220]

2.7.8.5.4. Structures, Improved Property, Critical Facilities, and Infrastructure

The 2022 multi-hazard report for Washington County created by the Oregon DOGAMI includes a wildfire risk analysis. This analysis was based on historical data collected prior to adoption and implementation of Senate Bill 762 in 2021, and as such the resulting risk categories are not consistent with current state wildfire program policy and implementation. Additionally, the data used for the report is not the same data as ODF and other state agencies that implement wildfire policy are currently using.

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[217] Diaz, J.M. (n.d.). SFE Fact Sheet 2012-7: Economic Impacts of Wildfire. Southern Fire Exchange. https://fireadaptednetwork.org/wp-content/uploads/2014/03/economic_costs_of_wildfires.pdf
[218] Diaz, J.M. (n.d.). SFE Fact Sheet 2012-7: Economic Impacts of Wildfire. Southern Fire Exchange. https://fireadaptednetwork.org/wp-content/uploads/2014/03/economic_costs_of_wildfires.pdf
[219] Diaz, J.M. (n.d.). SFE Fact Sheet 2012-7: Economic Impacts of Wildfire. Southern Fire Exchange. https://fireadaptednetwork.org/wp-content/uploads/2014/03/economic_costs_of_wildfires.pdf
[220] Diaz, J.M. (n.d.). SFE Fact Sheet 2012-7: Economic Impacts of Wildfire. Southern Fire Exchange. https://fireadaptednetwork.org/wp-content/uploads/2014/03/economic_costs_of_wildfires.pdf

The Oregon DOGAMI uses 2021 Oregon State University – Extension Service Fire Program and Wildland Fire Associates' Integrated Hazard database to categorize the extent of wildfire exposure. The dataset combined conditional flame length and burn probability data from the 2018 Pacific Northwest Quantitative Wildfire Risk Assessment. Conditional flame length is a measurement of fire intensity or the predicted level of severity of a simulated wildfire. Burn probability is derived from simulations using many elements, such as, weather, ignition frequency, ignition density, and fire modeling landscape. Under this analysis, the following three hazard categories were used based on mean annual burn probabilities[221]:

- **Low wildfire hazard:** 1 in 10,000 to 1 in 5,000 mean annual burn probability (0.0001–0.0002)
- **Moderate wildfire hazard:** 1 in 5,000 to 1 in 500 mean annual burn probability (0.0002–0.002)
- **High wildfire hazard:** 1 in 500 to 1 in 25 mean annual burn probability (0.002–0.04)

The DOGAMI wildfire analysis identified Washington County's countywide wildfire exposure as high or moderate risk, with the following projections:

- Number of buildings exposed to wildfire risk: 2,297
- Value of exposed buildings: $589,719,000
- Percentage of total county value exposed: 0.8%
- Critical facilities exposed to wildfire risk: 0
- Potentially displaced population due to wildfire: 3,309

The high and moderate hazard categories were the primary risk scenarios for the DOGAMI wildfire risk report. Moderate wildfire risk was included because under certain conditions moderate risk zones can be very susceptible to burn. By looking at these two risk categories together within Washington County, analysts can emphasize areas where lives and property are most at risk.

Per the DOGAMI analysis, there are no critical facilities exposed to direct wildfire risk; however, damage, destruction, and operational impacts may still occur to critical facilities and infrastructure due to secondary wildfire impacts. After a wildfire is extinguished, hazards and risks arise from potential flooding, erosion, debris flows, and infrastructure damage. Water supplies and infrastructure, if not damaged during the active fire period, can be at risk during subsequent post-fire flood events.

For this DOGAMI risk assessment, the building locations were compared to the geographic extent of the wildfire hazard categories. A total of 2,111 buildings in rural unincorporated Washington County are exposed to high or moderate wildfire hazard, but the incorporated communities have little exposure to high or moderate wildfire risk. The primary areas of exposure to this hazard are in the forested unincorporated areas in the northern and western portions of the County. The incorporated cities of Forest Grove, North Plains, and Sherwood have the highest percentage of exposure to moderate wildfire hazard within the County.[222]

Wildfires frequently damage community infrastructure, including water delivery systems. In Washington County, both public and private water systems, including wells, are especially vulnerable to the impacts of wildfire. Because of the heat of the fire, some plastic components in the water systems can melt and decompose before cooling, and contaminated water can compromise the broader water system.[223] Direct impacts to public water systems and private water systems may occur through contamination of ash and

[221] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[222] Oregon Department of Geology and Mineral Industries. (2022). Open-File Report O-22-04: Natural Hazard Risk Report for Washington County. https://www.oregongeology.org/pubs/ofr/O-22-04/p-O-22-04.htm
[223] National Academies of Sciences, Engineering, and Medicine. (2020). Implications of the California Wildfires for Health, Communities, and Preparedness: Proceedings of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/25622

debris during the fire; destruction of water delivery lines; equipment malfunction or failure; and soil erosion or debris deposits into waterways after the fire.

People moving from urban areas to more rural ones may be unaware of where structural fire protection services are provided or what level of service to expect. New residents do not always realize when they are living outside of a structural fire protection district. Even when located within a rural fire district service area, equipment and personnel can be substantially limited. Protection of lives and property from fire may rely more on the landowner’s personal initiative to take fire prevention and suppression measures than initiatives undertaken by the rural fire district. Therefore, public education and awareness plays a greater role in rural areas.

2.7.8.5.5. Natural Environments

If not promptly controlled, wildland fires may grow exponentially and cause serious damage to the natural environment and ecosystems. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, thereby enhancing flood potential, harming aquatic life, and degrading water quality. Lands stripped of vegetation are also subject to increased debris flow hazards.

2.7.8.6. Alignment and Integration with Existing Plans and Regulations

Washington County Community Wildfire Protection Plan

The County’s Community Wildfire Protection Plan (CWPP) was completed in 2007, consistent with the 1997 Forestland-Urban Interface Fire Protection Act (SB 360). The CWPP builds on and supplements the wildfire information presented in this NHMP. The goals of the CWPP planning process include integration with the federal-level initiatives of the National Fire Plan, the Healthy Forests Restoration Act of 2003, the DMA 2000, and FEMA Region 10 guidelines for local hazard mitigation plans.

The 2007 CWPP considered the following local planning documents:

- Washington County Comprehensive Plan: Framework Plan for the Urban Area, Rural/Natural Resource Plan, and Community Development Code
- Oregon Fire Code: Metro Code Committee
- Oregon Ballot Measure 37: Washington County Ordinance No. 636

The following Oregon Statewide Planning Goals and Guidelines are integrated into the current CWPP:

- Goal 4: Forest Lands (OAR 660-015-0000(4))
- Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces (OAR 660-015-0000(5))
- Goal 6: Air, Water, and Land Resources Quality (OAR 660-015-0000(6))
- Goal 7: Areas Subject to Natural Disasters and Hazards (OAR 660-015-0000(7))

State of Oregon Wildfire Legislation

Comprehensive wildfire legislation Senate Bill 762 was passed in 2021. To improve wildfire preparedness, the bill focuses on three key strategies: creating fire-adapted communities, developing safe and effective response, and increasing the resiliency of Oregon's landscapes. This omnibus bill provides more than $220 million to addresses a broad set of wildfire-related topics including utility infrastructure, clean-air shelters, availability of property insurance, as well as mapping wildfire risk statewide.

Unincorporated Washington County Development Review

Land use siting standards guide the location of new dwellings in the County's forested areas designated Exclusive Forest and Conservation (EFC). Some of the wildland fire mitigation standards in County building code and land use regulations include:

- Use of fire-rated construction materials
- Egress requirements
- Limitations to building wall openings and roof coverage
- Structural fire protection
- Identification of water supply for fire suppression
- Provision of adequate road access in urban and rural areas
- Use of fire breaks to buffer habitable structures from vegetative fuels and guide development away from steep slopes that increase rate of wildfire spread
- Using fire retardant roofs and spark arresters on chimneys

2.7.8.7. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of wildland fire. Additional information is in the participant annexes.

Table 42: Participant Overall Risk of Wildland Fire

Participant	Overall Risk of Wildland Fire
City of Beaverton	–
City of Cornelius	240
City of Forest Grove	240
City of Hillsboro	177
City of North Plains	201
City of Sherwood	142
City of Tigard	168
Clean Water Services	127
Tualatin Hills Park & Recreation District	143
Tualatin Valley Water District	161
Washington County	191

2.7.9. Windstorm, Including Tornado

Significant Changes

- Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency of windstorm, including tornado added.
- Enhanced Fujita scale added to illustrate extent of tornadoes.

2.7.9.1. Characteristics

A windstorm is generally a short duration event involving straight-line winds or gusts in excess of 50 mph. The most persistent high winds take place along the Oregon Coast and in the Columbia River gorge. The most impactful winds experienced in Washington County are the result of low-pressure weather systems that form over the Pacific Ocean and make landfall on the Oregon Coast. Most of the winds that come from the west are subdued by the time they reach the planning area because of the influence of the Coast Range. The most destructive winds are those that blow from the south, parallel to the major mountain ranges.

A tornado is a violently rotating column of air touching the ground, usually attached to the base of a thunderstorm. Though tornadoes are not common in Washington County, they do occasionally occur and sometimes produce significant property damage and even injury. Most of the tornadoes that occur in the County are caused by intense local thunderstorms common between April and October.

Windstorms can intensify the magnitude, extent, and impacts of extreme heat, landslides, volcanic ash spread, wildland fire, and winter storm events. Each of these natural hazards is individually discussed in detail in their respective hazard profiles.

2.7.9.2. Location and Extent

The entire county is susceptible to damaging windstorm events. In general, higher elevations experience stronger winds than areas in low-lying valley floors. Therefore, the following areas tend to experience the strongest winds: western portions of the County in the Coast Range, northern and eastern areas within the Tualatin Mountains, southern areas in the Chehalem Mountains, and Bull Mountain the southeastern portion of the County.

Several low-pressure centers make landfall in the Pacific Northwest each winter. The low-pressure centers bring sustained winds (40–60 mph) strong enough to topple power lines and trees. These prolonged windstorms are likely to last an average of three to six hours before moving on, and the damaging effects of windstorms may extend for distances of 100 to 300 miles from the center of storm activity.[224]

The Enhanced Fujita Scale (EF Scale) is used to rate how strong a tornado was, using a scale of EF0 to EF5. It is calculated by surveying the damage and comparing it with damage to similar objects at certain wind speeds. The EF Scale is not meant to be used as a measure of how strong a tornado currently on the ground is. It uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage based on 28 indicators.[225] These estimates vary with height and exposure.

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[224] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[225] National Weather Service. (n.d.). The Enhanced Fujita Scale (EF Scale). https://www.weather.gov/oun/efscale

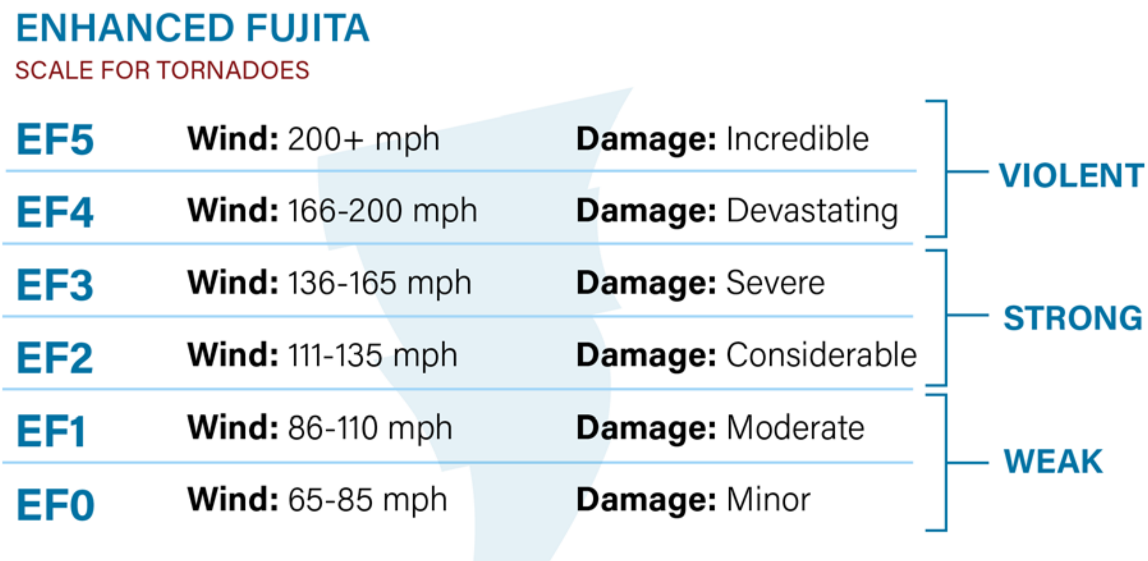

Figure 29: Enhanced Fujita Scale for Tornadoes

2.7.9.3. History

There have been 11 windstorm events of varying degrees and 1 tornado event in the planning area since the adoption of the 2017 NHMP.

Table 43: Historic Windstorm Events in Washington County[226]

Date	Event
December 8, 2016	A strong frontal system brought strong east winds to the north Willamette Valley, with wind gusts up to 47 mph. A mix of snow, sleet, and freezing rain were also part of the event. Approximately $13,000 in damages were reported.
February 1, 2017	A high-pressure system sliding down into the Columbia Basin and a low-pressure system offshore generated strong easterly winds through the Columbia River gorge and into the northern Willamette Valley, with wind gusts around 30–40 mph. There were $5,000 in damages reported.
April 7, 2017	Many weather stations across the planning area recorded wind gusts up to 60 to 75 mph. The Hillsboro Airport Automated Surface Observing System stations recorded wind gusts up to 61 mph. Several trees came down across the area. One fatality occurred due to a fallen tree branch, and another fatality was due to rough conditions on the Columbia River. Damages totaling $70,000 were reported.
April 7, 2018	A strong low-pressure system tracking northeast towards Vancouver Island generated strong winds along the coast and in the Willamette Valley. Approximately $3,000 in damages were reported.

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Date	Event
October 29, 2018	Multiple greenhouse structures were damaged at a farm on Thatcher Road in the city of Forest Grove. Witness accounts also confirmed a tornado. The tornado was likely on the ground for about 30 seconds to 1 minute. A cold front that moved through on October 27 brought a much cooler air mass in aloft, which destabilized the atmosphere enough for thunderstorm development across the area on October 28 and 29. There were $100,000 in damages reported.
December 14, 2018	A strong low-pressure system tracked northeast into British Columbia. The associated cold front brought with it strong southerly winds on the north and central Oregon coast. This system also brought windy conditions to the Willamette Valley, bringing down tree limbs and a few trees, which caused scattered power outages and $10,000 in damages.
December 18, 2018	Several power outages were reported by PG&E. Peak wind gusts of 35 to 43 mph were recorded across the north Willamette Valley. A strong low-pressure system over the Gulf of Alaska brought a strong cold front and generated strong winds across northwest Oregon.
January 5, 2019	A strong low-pressure system moving up the coast from the south brought strong southerly winds across all of northwest Oregon. Wind gusts of up to 54 mph were recorded in the Willamette Valley. At one point there were over 100,000 people without power. PGE reported that 150 power lines were brought down by strong wind. Damages totaling $750,000 were reported.
September 7, 2020	After a period of upper-level ridging brought a return to above-normal temperatures in early September, strong easterly downslope and offshore winds off the Cascades and Pacific Coast Ranges occurred. Winds increased rapidly during the afternoon and evening of September 7, with the passage of an unseasonably strong backdoor cold front and persisted through much of the following day. Widespread wind gusts from 50 to 70 mph were common on ridge tops and in numerous other exposed areas, including portions of the Willamette Valley. Strong winds caused widespread damage to trees and downed numerous power lines across the region, which started at least 13 wildfires. Seven federal, state, and local disaster declarations and emergency executive orders were issued as a result of the fires; evacuations were ordered; and approximately 1,730 acres were burned in the County.
January 13, 2021	A front brought a burst of 35–50 mph winds to the Willamette Valley and southwest Washington interior, resulting in over 100,000 customers without power across southwest Washington and northwest Oregon. Approximately $2,000 in damages were reported.
April 30, 2022	Significant infrastructure, tree, and personal property damage was sustained throughout the city of Tigard. A short-lived gustnado (a brief, shallow surface-based vortex that forms within the downburst emanating from a thunderstorm) at the lowest level elevation in the city tore off roofs of dugouts at a youth baseball field during the game.

2.7.9.4. Probability of Future Events

Windstorms in the County usually occur in the winter from October to March, and their extent is determined by their track, intensity (the air pressure gradient they generate), and local terrain. Summer thunderstorms may also bring high winds along with heavy rain and hail. The NWS uses weather forecast models to predict oncoming windstorms while monitoring storms with weather stations in protected valley locations throughout Oregon.

The 2020 Oregon NHMP shows the probability of severe wind events in Washington County, one-minute average, 30 feet above the ground. The table below shows the wind speed probability intervals that structures 30 feet above the ground would expect to be exposed to within a 25-, 50-, and 100-year period.

Table 44: Probability of Severe Wind Events in Washington County

Probability of Severe Wind Events in Washington County (One-Minute Average, 30 Feet above the Ground)	25-Year Event (4% annual probability)	50-Year Event (2% annual probability)	100-Year Event (1% annual probability)
	65 mph	72 mph	80 mph

Climate and weather conditions in Washington County make the occurrence of major tornadoes unlikely; however, minor tornadoes rated EF0–EF1 may occasionally occur.

2.7.9.4.1. Climate Change

There is insufficient research on changes in the likelihood of windstorms in the Pacific Northwest as a result of climate change. While climate change has the potential to alter surface winds through changes in the large-scale free atmospheric circulation and storm systems, there is as yet no consensus on whether or not extratropical storms and associated extreme winds will intensify or become more frequent along the Pacific Northwest coast under a warmer climate.[227]

2.7.9.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the planning area have the potential to be exposed to and impacted by windstorm and tornado events; however, higher elevations are likely to experience more exposure and impacts compared to lower elevations. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

2.7.9.5.1. Populations

Downed trees, power lines, and damaged property caused by windstorm events can be major hindrances to emergency response and disaster recovery, which can impact populations throughout the planning area. Debris carried by high winds or tornadoes can directly contribute to injuries or loss of life. Power outages and transportation disruptions can also negatively impact populations. Widespread and powerful windstorms can result in the need for public shelters and care for adversely impacted individuals.

2.7.9.5.2. Economy

The planning area is susceptible to indirect impacts and costs stemming from business closures and lost work time resulting from windstorm and tornado events. Industry and commerce can suffer losses from power interruptions and extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from windstorms and tornadoes related to both physical damages and interrupted services. Additionally, high winds can impact renewable energy facilities and agricultural operations.

Windstorms and tornadoes have the potential to create tons of storm-related debris that planning participants may be responsible for clearing and disposing of in accordance with federal, state, and local

[227] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

laws and regulations. This process can be very costly and time-consuming and may impact the economic well-being of planning participants.

2.7.9.5.3. Structures, Improved Property, Critical Facilities, and Infrastructure

Most vulnerabilities to windstorms and tornadoes occur in the built environment. Many buildings, utilities, and transportation systems in the planning areas are vulnerable to wind damage.

Old or poorly constructed structures and insufficiently anchored manufactured homes are vulnerable to strong winds and can be heavily damaged. Well-built and newly constructed structures are more resilient to strong wind events, although the entire built environment is vulnerable to high winds and may experience varying degrees of damage.

Wind pressure can create a direct frontal assault on a structure, pushing walls, doors, and windows inward. Conversely, passing currents can create lift and suction forces that act to pull building components and surfaces outward. The effects of winds are magnified in the upper levels of multistory structures. The forces applied by the wind to the building's protective envelope (doors, windows, and walls) can cause the failure of some of the building's components, resulting in considerable structural damage.

Major infrastructure and above-ground utility lines can also be damaged by wind events, especially trees downed during these events. Fallen trees can block roads and rails for long periods. Uprooted or shattered trees can down power and other utility lines, disrupting essential services and hindering the operation of essential facilities and infrastructure. Trees in forested areas, along tree-lined roads and electrical transmission lines, and on residential parcels where trees have been planted for aesthetic purposes may be especially prone to damage. During wet winters, saturated soils cause trees to become less stable and more vulnerable to uprooting from high winds.

2.7.9.5.4. Natural Environments

Windstorms and tornadoes can damage natural environments, mostly through the uprooting of trees, which can affect habitats and disturb ecosystems. Natural grasslands, farmlands, and forested areas are at highest risk.

2.7.9.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of windstorm, including tornado. Additional information is in the participant annexes.

Table 45: Participant Overall Risk of Windstorm, Including Tornado[228]

Participant	Overall Risk of Windstorm, Including Tornado
City of Beaverton	208
City of Cornelius	240
City of Forest Grove	240
City of Hillsboro	205
City of North Plains	132
City of Sherwood	178

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Participant	Overall Risk of Windstorm, Including Tornado
City of Tigard	205
Clean Water Services	147
Tualatin Hills Park & Recreation District	208
Tualatin Valley Water District	169
Washington County	132

2.7.10. Winter Storm

Significant Changes
• Additional information on hazard history, vulnerabilities, and how climate change may impact the frequency of winter storms added.

2.7.10.1. Characteristics

Winter storm events occur annually in Washington County, sometimes becoming severe. Severe winter weather in the County is characterized by extreme cold, snow, ice, and sleet.

A severe winter storm is generally a prolonged event involving snow or ice. The characteristics of severe winter storms are determined by a number of meteorological factors, including the amount and extent of snow or ice, air temperature, wind speed, and event duration.

Winter storms occurring in the County can result in other natural hazards, including floods, landslides/debris flows, and windstorms. Each of these natural hazards is individually discussed in detail in their respective hazard profiles.

The principal types of winter storms that can occur in the County include the following:

- **Snowstorms** require three ingredients: cold air, moisture, and air disturbance. The result is snow—small ice particles that fall from the sky. In Oregon, the further inland and north one moves, the more snowfall can be expected.
- Meteorologists define **heavy snow** as 6 inches or more falling in less than 12 hours, or snowfall of 8 inches or more in 24 hours.
- A **blizzard** is a severe winter weather condition characterized by low temperatures and strong winds blowing a great deal of snow. The NWS defines a blizzard as having wind speeds of 35 mph or more, with a visibility of less than a quarter mile. Sometimes a condition known as a **whiteout** can occur during a blizzard. This is when the visibility drops to zero because of the amount of blowing snow.
- **Ice storms** occur when a layer of warm air is sandwiched by two layers of cold air. Frozen precipitation melts when it hits the warm layer and refreezes when hitting the cold layer below the inversion. These storms can include sleet (when the rain refreezes as ice pellets before hitting the ground) or freezing rain (when the rain freezes once hitting the ground). Rain freezes to surfaces, such as on trees and utilities, and roads become glazed with ice. Even small accumulations of ice can cause a significant hazard to property, pedestrians, and motorists. Sleet can accumulate like snow and cause roads and walkways to become hazardous.
- The planning area can also experience **silver thaws**, which result from the formation of ice on cold surfaces during a period of rapid thaw after a severe frost. This clear ice can coat all solid surfaces and impact transportation, utilities, and communication infrastructure.[229]
- **Extreme cold** includes dangerously low temperatures accompany many winter storms. The wind chill factor is a measure of how cold the combination of temperature and wind actually feels. Wind chill of 50 °F or lower can be dangerous. Hypothermia can occur quickly, exposed skin can develop frostbite in less than a minute, and a person or animal could freeze to death after just 30 minutes of exposure.

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[229] Decker, F. (2010, July 8). Oregon's Silver Thaw https://www.tandfonline.com/doi/abs/10.1080/00431672.1979.9931868?journalCode=vwws20

Temperature (Fahrenheit)

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

Frostbite Times

30 minutes · 10 minutes · 5 minutes

Figure 30: Wind Chill Chart

2.7.10.2. Location and Extent

The entire county is susceptible to damaging winter storms. Elevations over 500 feet will experience more risk of snow and ice; however, the entire county can face damage from winter storms and, for example, the hail or dangerously cold temperatures that winter storms bring. Additionally, although the entire planning area can experience winter storms, the vulnerability faced by participants varies due to differences in populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments.

2.7.10.3. History

Severe winter storms affecting the planning area are typically most common from October through March. Severe freezes, where high temperatures remain below freezing for five or more days, occur every three to five years in Washington County. Severe or prolonged snow events occur less frequently.

Table 46: Historic Winter Storm Events in Washington County[230, 231]

Date	Event
December 8, 2016	A strong frontal system brought strong east winds to the north Willamette Valley and a mix of snow, sleet, and freezing rain down to the valley floor. Four to six inches of snow fell along Interstate 84 before turning to sleet and freezing rain. One to 1.5 inches of ice accumulation was also reported. The Portland Metro area generally had 1–2 inches of snow, with 0.2 to 0.3 inches of ice accumulation. Ice accumulations were higher in the West Hills and near the Columbia River gorge, with 0.8 inches of ice accumulation reported at Council Crest in southeast Portland. The NWS office in Parkrose had 0.4 inches of ice accumulation.
January 7–8, 2017	A broad shortwave trough brought multiple rounds of precipitation, including a wintry mix of snow and ice for many locations across northwest Oregon. Strong easterly pressure gradients generated high winds through the Columbia River gorge as well on January 8. General snowfall totals of 2–4 inches were reported, with the greatest total being 4.5 inches. Major ice accumulations occurred after the snow, with several locations reporting 0.50–1.00 inches. The combination of snow and ice resulted in significant power outages and closures across the area. DR-4328 was declared for Columbia, Hood River, Deschutes, and Josephine counties. Columbia County is directly north of Washington County.
February 2017	The area received light freezing rain, ice pellets, and light snow. No major impacts occurred.
February 2018	Less than a half inch of light snow fell in the area. No impacts occurred.
February 2019	The lowest temperature of the year, 23 °F, was recorded on the mornings of February 6 and 7. Light snow also occurred. No impacts were documented.
January 2020	Many areas in the County received an inch of snow, and areas of the region lost power for up to five days. In the city of Tigard, road and water infrastructure had significant impacts, and trees and powerlines were damaged.
December 2021	The area experienced 1–3 inches of snowfall during a minor event. Tualatin Hills Park & Recreation District buildings experienced delayed openings, partial openings, or were completely closed due to weather and road conditions December 27–30.
February 2021	Between February 11 and February 14, freezing rain and heavy snow came down, and gusty winds up to 50 mph occurred, resulting in a five-day ice storm. Primary impacts in the County were in the West Hills and southeast areas of the Cities of Beaverton, Tigard, and Tualatin. An initial damage assessment was completed by the County and noted that multiple trees were downed at Metzger Park in unincorporated Washington County near Washington Square. In Tigard, Emergency Transportation Routes were impacted, overhead powerlines connecting residents and commercial structures were damaged, and structure damage impacts were reported. The city of Hillsboro experienced snowy and icy roads, downed tree limbs, localized power outages, and travel impacts. Tualatin Valley Water District received 30 calls for service that required response, and over 18 staff worked throughout the event. Additionally, two water mains broke.

[230] National Centers for Environmental Information Storm Events Database, Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx
[231] Weather Spark. (n.d.). Winter Weather History. https://weatherspark.com/

2.7.10.4. Probability of Future Events

Winter storms occur annually in Washington County. Based on historical data, severe winter storms could occur about every four years in the area. It is expected that the planning area will have continued annual storm events.[232]

2.7.10.4.1. Climate Change

Climate models project future warmer winter temperatures in the planning area. It is anticipated that this will result in an increase in the proportion of precipitation falling as rain rather than snow and a decrease in mountain snowpack; however, exact impacts are not known. These changes could have multiple, concurrent impacts in the County.

- **Drought:** Watersheds in the northwest that receive both rain and snow, and in which snowmelt contributes substantially to streamflow during spring and summer, are the most sensitive to projected winter warming.[233] The frequency of hydrological drought is projected to increase in such watersheds. Snow drought is also projected to occur more frequently under a warmer climate as the proportion of precipitation falling as snow decreases. These conditions are projected to increase winter runoff and decrease runoff during spring and summer.[234]
- **Flooding:** The frequency and intensity of heavy precipitation events in winter is projected to grow. As temperatures warm, the proportion of precipitation falling as rain rather than snow is projected to increase, especially at lower to intermediate elevations. Projected increases in wet-season precipitation are likely to increase winter flood magnitude.[235]
- **Wildfire:** Decreased soil moisture and increased temperatures stress vegetation and increase plant mortality, providing fuel for fires. Reduced ponds, streams, and reservoir levels can also limit withdrawal sources for fighting wildfires.[236]

2.7.10.5. Vulnerability Assessment

All populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County have the potential to be exposed to and impacted by winter storm events; however, elevations over 500 feet are likely to experience more exposure and impacts compared to lower elevations. Additional information about populations, economies, structures, improved property, critical facilities and infrastructure, and natural environments in the County is provided in Volume III, Appendix A and participant annexes in Volume II.

2.7.10.5.1. Populations

People can experience frostbite and hypothermia during winter storms due to the extreme cold and wind chill. These health concerns are especially elevated for populations that are unhoused or do not have access to sufficient heating, insulated clothing, or dry living conditions. Older adults and infants, and people who take certain medications, have certain medical conditions, or have been drinking alcohol, also are at increased risk for hypothermia. Additionally, carbon monoxide poisoning can occur if proper

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[232] Oregon Natural Hazards Mitigation Plan. (2020, September 24). Oregon Department of Land Conservation and Development. https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

[233] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka

[234] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka

[235] Dalton, M. & Fleishman, E. (Eds.). (2021). Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://oregonstate.app.box.com/s/7mynjzhda9vunbzqib6mn1dcpd6q5jka

[236] American Planning Association. (2019). Falling Dominoes: A Planner's Guide to Drought and Cascading Impacts. A Planner's Guide to Drought and Cascading Impacts (planning-org-uploaded-media.s3.amazonaws.com

ventilation is not used or available when heating sources are utilized. The potential for power outages during winter storm events can increase the likelihood that frostbite, hypothermia, and carbon monoxide poisoning may occur.

Overall, most winter storm deaths result from vehicle or other transportation accidents caused by ice and snow. Black ice is likely to form under bridges and overpasses, in shady areas, and at intersections. This thin layer of ice is difficult to see, and tires and brakes do not work properly on it, which can lead to immediate loss of vehicular control.

Exhaustion and heart attacks brought on by overexertion are two other common causes of deaths related to winter storms. Such tasks as shoveling snow, pushing a vehicle, or even walking in heavy snow can cause a heart attack, particularly in people who are older or who are not used to high levels of physical activity. The number of injuries and deaths due to falls may also increase due to slick or icy conditions.

2.7.10.5.2. Economy

The planning area is susceptible to indirect impacts and costs stemming from business closures and lost work time resulting from winter storms. Industry and commerce can suffer losses from power interruptions and extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from winter storms related to both physical damages and interrupted services.

2.7.10.5.3. Structures, Improved Property, Critical Facilities, and Infrastructure

Direct impacts to infrastructure and property can occur during winter storm events. Snow and ice can disrupt essential infrastructure systems such as public utilities, telecommunications, and transportation routes. Historically, falling trees due to snow and ice accumulation and wind have been the major cause of power outages. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted.

Additionally, buildings and roofs can collapse or be damaged, roads and bridges can be damaged or blocked, and pipes can freeze and burst. Home fires also occur more frequently in the winter because people do not take the proper safety precautions when using alternative heat sources. Fires during winter storms present a great danger because water supplies may freeze, and it may be difficult for firefighting equipment to get to the fire.

2.7.10.5.4. Natural Environments

Crops, vegetation, parks, and other natural systems can be damaged by winter storm events. Livestock can also be negatively impacted by extreme cold, snow, and ice.

2.7.10.6. Hazard Risk Score Summary

Based on the hazard analysis methodology described in Section 2.2, plan participants assigned the scores below to their overall risk of winter storm. Additional information is in the participant annexes.

Table 47: Participant Overall Risk of Winter Storm[237]

Participant	Overall Risk of Winter Storm
City of Beaverton	203
City of Cornelius	240
City of Forest Grove	240
City of Hillsboro	205
City of North Plains	187
City of Sherwood	208
City of Tigard	205
Clean Water Services	142
Tualatin Hills Park & Recreation District	208
Tualatin Valley Water District	206
Washington County	211

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3. Mitigation Strategy

CFR 44 §201.6 Requirements

- **§201.6(c)(3):** [The hazard mitigation plan shall include a] mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs, and resources, and its ability to expand on and improve these existing tools.
  - **§201.6(c)(3)(i):** [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.
  - **§201.6(c)(3)(iii):** [The hazard mitigation strategy shall include an] action plan describing how the actions identified in paragraph (c)(3)(ii)…will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost-benefit review of the proposed projects and their associated costs.

3.1. Overview

The mitigation strategy serves as the long-term blueprint for reducing the potential losses identified in the risk assessment. The Stafford Act directs hazard mitigation plans to describe hazard mitigation actions and establish a strategy to implement those actions. Therefore, all other requirements for a hazard mitigation plan lead to and support the mitigation strategy.

This section provides a summary of the mitigation strategy for the NHMP. Additional details about each participant's mitigation strategy are in the participant annexes. Each annex provides an analysis of current mitigation capabilities, including an assessment of NFIP participation and compliance, as applicable.

3.2. Mitigation Plan Mission

The purpose of the Washington County NHMP is to foster coordinated partnerships and the development of multi-objective strategies for mitigation. The NHMP mission is intended to provide overall direction for the hazard mitigation programs of participants.

The mission of the Washington County NHMP is to promote a disaster-resilient Washington County by taking actions to reduce risk, minimize loss, and protect life, property, and the environment from natural hazard events.

The 2023 NHMP Steering Committee reviewed the previous plan's mission statement and agreed that it still applies as written.

3.3. Funding Priorities

As necessary, plan participants will seek outside funding sources to implement mitigation projects in both pre-disaster and post-disaster environments. When applicable, potential funding sources have been identified for each participant's proposed action items listed in participant annexes. Funding priority will go toward action items with a high positive impact on community mitigation and resilience as measured by the action's scope and cost-benefit analysis.

3.4. Mitigation Goals

Mitigation plan goals provide statements of directions to form a bridge between the broad mission statement and the mitigation strategy, including action items. These goals serve as checkpoints as plan participants begin implementing mitigation action items.

The Steering Committee reviewed and evaluated goals from the 2017 Washington County NHMP, 2020 city of Beaverton NHMP, 2011 cities of Cornelius and Forest Grove NHMPs, and 2020 Oregon NHMP. The goals from each plan were grouped by topic and then synthesized to create the seven goals below. These goals are the basis of this plan and summarize what the Steering Committee will accomplish by implementing this plan.

1. Develop and implement strategies to minimize loss of life, public and private property damage, and damage and disruption of essential infrastructure from the impact of natural hazards while protecting and restoring the environment.
2. Ensure effective implementation of mitigation strategies and increased success in funding opportunities. This includes:
    a. Develop and maintain partnerships and promote mitigation leadership within local and regional public agencies; the public; non-profit organizations; and businesses.
    b. Ensure consistency between city, county, regional, and state mitigation strategies.
    c. Consistently seek diverse funding and resource partnerships for future mitigation efforts.
3. Develop and implement natural hazard education and outreach programs to increase awareness, engagement, and partnership among the public; local, city, and regional agencies; nonprofit organizations; and businesses. Includes:
    a. Engage and motivate the public to invest in natural hazard risk reduction policies and projects.
    b. Motivate the “whole community” to build resilience and mitigate against the effects of natural hazards through engagement, listening, learning, information-sharing, and funding opportunities.
4. Support the adoption and application of development policies and standards that address the potential impacts of natural disasters and prevent development within mapped hazardous areas where risks to people and property cannot be practicably mitigated.
5. Enhance communication, collaboration, and coordination among agencies at all levels of government and the private sector to mitigate natural hazard risks.
6. Integrate and align hazard mitigation strategies with local comprehensive plans, climate adaptation efforts, and emergency operations plans and procedures, when possible.
7. Enhance the ability of the economies of Washington County and its jurisdiction to rebound quickly from natural hazard events, by strengthening emergency operations including increasing communication, collaboration, and coordination among public agencies, non-profit organizations, and businesses. Includes mitigating the inequitable impacts of natural hazards by prioritizing and directing resources and investments to build resilience in the most vulnerable populations and the communities least able to respond and recover.

3.5. Action Items

A mitigation action is a specific action, project, activity, or process taken to reduce or eliminate long-term risk to people and property from hazards and their impacts. Implementing mitigation actions helps achieve the plan’s mission and goals. The actions to reduce vulnerability to threats and hazards form the core of the plan and are a key outcome of the planning process.

A list of action items was identified by each plan participant and is located in their respective annexes. Previous action items are also recorded in these annexes, as applicable.

FEMA identifies four primary types of mitigation actions to reduce long-term vulnerabilities: (1) local plans and regulations, (2) structure and infrastructure projects, (3) natural systems protection, and (4) public education and awareness programs. Additional details about these types of actions are shown in Table 48. These actions are also traditionally eligible for hazard mitigation and other types of funding.

Table 48: Primary Types of Action Items

Local Plans and Regulations	
Definition	**Examples**
These actions include government authorities, policies, or codes that encourage risk reduction.	• Comprehensive plans • Land use ordinances • Subdivision regulations • Development review • Building codes and enforcement • Capital improvement programs • Open space preservation • Stormwater management regulations and master plans • Fuels management, and fire breaks
Structure and Infrastructure Projects	
Definition	**Examples**
These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. These actions also include constructing new structures to reduce the impact of hazards. This could apply to public or private structures as well as critical facilities and infrastructure.	• Acquisitions and elevations of structures in flood-prone areas • Utility undergrounding • Seismic structural retrofits • Floodwalls and retaining walls • Detention and retention structures • Culverts
Natural Systems Protection	
Definition	**Examples**
These are actions that minimize damage and losses while preserving or restoring the function of natural systems.	• Sediment and erosion control • Stream corridor restoration • Forest management • Conservation easements • Wetland restoration and preservation

Public Education and Awareness Programs	
Definition	**Examples**
These are long-term, sustained programs to inform and educate the public and stakeholders about hazards and mitigation options. This can also include training.	• Radio or television spots • Websites with maps and information • Social media • Real estate disclosure • Presentations to school groups or neighborhood organizations • Mailings to populations in hazard-prone areas • StormReady® certification through the NWS StormReady program • Participation in the National Fire Protection Association's FireWise USA® program

3.5.1. Previous Mitigation Actions

A thorough review of mitigation actions identified in previous NHMPs was conducted to determine the effectiveness of each action and the progress made to date. Each participant with previous actions was asked to review and update the status of each to determine whether: the action was completed, the project is in progress, the strategy is no longer applicable, or the action should be moved forward and included in the 2023 plan. The updated status of previous mitigation actions is provided in the individual participant annexes of Washington County and the Cities of Beaverton, Cornelius, Forest Grove, Hillsboro, and Tigard.

3.5.2. New Mitigation Actions

Each participant updated its list of mitigation actions based on the review of its risk assessment, its existing capabilities, and the status of its previous action items, as applicable. The lists of actions include participant-specific details from a comprehensive range of action item categories and are included in each participant annex. To facilitate implementation, each action item includes information on timeline, coordinating and partner organizations, ideas for implementation, and plan goals addressed. Additional information about implementation resources and funding opportunities is in Volume III, Appendix C.

3.5.2.1. Action Item Development Process

Members of the Steering Committee worked with their Technical Committees to review and analyze the results of their risk assessment and current planning, regulatory, administrative, technical, education, outreach, and NFIP capabilities to identify a comprehensive range of action items to reduce the impact of natural hazards. Committee members consulted subject matter experts, collected ideas from stakeholders and the public, researched existing guides and resources, and reviewed and considered activities eligible for FEMA Hazard Mitigation Assistance funding, as applicable.

3.5.2.2. Evaluating and Prioritizing Mitigation Actions

Through discussion and analysis, each participant used the STAPLEE evaluation method to evaluate and prioritize mitigation actions. The STAPLEE evaluation method uses seven criteria to assess a mitigation action: social, technical, administrative, political, legal, economic, and environmental. Actions that met the STAPLEE evaluation criteria to the satisfaction of the participant and had the potential to reduce vulnerability to hazards are included in the plan.

Within each of these criteria are additional considerations that may call upon the hazard risk assessment and other sources of information for evaluation. Table 49 describes each category and its considerations.

Table 49: STAPLEE Evaluation Criteria for Mitigation Actions

Social (S)	
Definition	**Considerations**
The public must support the overall mitigation implementation strategy and specific mitigation actions. Mitigation actions are evaluated in terms of community acceptance and impact on the population.	• **Community acceptance:** Will the action disrupt housing or cause the relocation of people? Is the action compatible with present and future community values? • **Impact on population:** Will the proposed action adversely affect one segment of the population?
Technical (T)	
Definition	**Considerations**
It is important to determine if the proposed action is technically feasible, will help to reduce losses in the long term, and has minimal secondary impacts. This category evaluates whether the action is a whole or partial solution, or not a solution at all.	• **Technical feasibility:** How effective is the action in avoiding or reducing future losses? • **Long-term solution:** Does the action solve the problem or only a symptom of the problem? • **Secondary impacts:** Will the action create more problems than it solves?
Administrative (A)	
Definition	**Considerations**
This category examines the anticipated staffing, funding, time, and maintenance requirements for the mitigation action to determine if the participant has the personnel and administrative capabilities to implement the action or whether outside help will be necessary.	• **Staffing:** Does the organization have the capability (staff, technical experts, and training) to implement the action? • **Funding allocated:** Does the organization have the funding to implement the action or can it readily be obtained? • **Time:** Can the action be accomplished in a timely manner? • **Maintenance/Operations:** Can the community provide the necessary maintenance? It is important to remember that most federal grants will not provide funding for maintenance.

Political (P)	
Definition	**Considerations**
This category considers the level of political support for the mitigation action.	• **Political support:** Is there political support to implement and maintain this action? Have political leaders participated in the planning process so far? • **Local champion or proponent:** Is there a respected community member willing to help see the action to completion? • **Public and stakeholder support:** Is there enough public support to ensure the success of the action? Have all stakeholders been offered an opportunity to participate in the planning process?
Legal (L)	
Definition	**Considerations**
Whether the participant has the legal authority to implement the action or whether the participant must pass new laws or regulations is important in determining how the mitigation action can be best carried out.	• **State authority:** Does the State of Oregon have authority to implement the action? • **Existing local authority:** Are proper laws, ordinances, and resolutions in place to implement the action? • **Potential legal challenge:** Is there a technical, scientific, or legal basis for the mitigation action (i.e., does the mitigation action "fit" the hazard setting)? Are there any potential legal consequences? Is the action likely to be challenged by stakeholders who may be negatively affected?
Economic (E)	
Definition	**Considerations**
Economic considerations must include evaluation of the present economic base and projected growth. Cost-effective mitigation actions that can be funded in current or upcoming budget cycles are more likely to be implemented than actions requiring general obligation bonds or other instruments that would incur long-term debt to a community.	• **Benefits of action:** What financial benefits will the action provide? • **Cost of action:** Does the cost seem reasonable for the size of the problem and the likely benefits? What burden will be placed on the tax base or local economy to implement this action? • **Contribution to economic goals:** Does the action contribute to community or organizational economic goals, such as capital improvements or economic development? • **Outside funding required:** Are there current sources of funding that can be used to implement the action? Should the action be considered "tabled" for implementation until outside sources of funding are available?

Environmental (E)	
Definition	**Considerations**
The impact on the environment is an important consideration due to public desire for sustainable and environmentally healthy communities. Statutory considerations, such as the National Environmental Policy Act (NEPA), also need to be kept in mind when using federal funds.	• **Impact on land/water bodies:** How will this action impact land/water? • **Impact on endangered species:** How will this action impact endangered species? • **Impact on hazardous materials and waste sites:** How will this action impact hazardous materials and waste sites? • **Consistency with community environmental goals:** Is this action consistent with community and organizational environmental goals? • **Consistency with federal laws:** Is the action consistent with federal laws, such as NEPA?

After considering the STAPLEE criteria, each participant assigned a prioritization category of low, medium, or high to each action item being created or retained. The categories were defined as:

- **Low:** The action has the potential to reduce vulnerability to hazards, is based on one to two STAPLEE criteria and is feasible and important for the jurisdiction. The action should be implemented as funding becomes available. The projected timeline for completion is five or more years.
- **Medium:** The action has the potential to reduce vulnerability to hazards, is based on three to four STAPLEE criteria and is feasible and important for the jurisdiction. Its implementation is not as urgent as a high-priority action item, and it can be implemented in the long term. The projected timeline for completion is three to five years.
- **High:** The action has the potential to reduce vulnerability to hazards, is based on five or more STAPLEE criteria, and is feasible and important for the jurisdiction. It is especially important for the jurisdiction to implement it in the short term and as quickly as possible. The projected timeline for completion is one to two years.

The evaluation and prioritization process helps the planning team weigh the pros and cons of different action alternatives. However, the decision-making process is not necessarily straightforward; it is highly specific to each jurisdiction. Prioritization may change over time in response to changes in community characteristics and risks and to take advantage of available resources.

It is not intended that this plan and its participants will attempt to act on all identified action items, but the list of actions will be maintained to provide documentation for future planning efforts.

4. Plan Execution, Maintenance, and Adoption

CFR 44 §201.6 Requirements

- **§201.6(c)(4)(i):** [The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.
- **§201.6(c)(4)(iii):** [The plan maintenance process shall include a discussion] on how the community will continue public participation in the plan maintenance process.

4.1. Overview

This mitigation plan is a living document that will guide mitigation actions over time. As conditions and circumstances change, new information may become available, and actions may progress over the life of the plan. The actions and plan contents may be adjusted as necessary to maintain the relevance and effectiveness of the plan.

Each jurisdiction or special district has identified an individual by position or title and department or division who is responsible for ensuring the participant's plan is achieving its purpose and goals during the planning cycle. The participant annexes provide the primary and alternate contacts for mitigation planning for each plan participant.

Additionally, clearly defined roles, responsibilities, procedures, and schedules for plan implementation, monitoring, evaluating, and updating outlined in this section will increase the possibility that the plan will remain current, useful, applicable, and that mitigation strategies are being utilized, implemented, and integrated into existing plans, policies, and procedures.

Plan maintenance activities take place at two levels. This section describes how the Steering Committee will carry out the plan maintenance functions related to Volume I of the plan and its supporting appendices in Volume III. Concurrently, each participant has the authority and responsibility to maintain its annex to the plan and may choose to establish an internal schedule to be consistent with the planning area's schedule.

Any necessary revisions to plan elements shall follow the plan amendment process outlined in state and FEMA guidance. Mitigation actions may be changed, updated, removed, or added by a participant at any time if the change or addition is considered, evaluated, and approved by the participant's Technical Committee and the public has had the opportunity to review and comment on the modification.

If a participant no longer wishes to actively partake in the development and maintenance of the plan, it must notify the Washington County NHMP Project Manager and OEM in writing.

4.2. Plan Implementation

Each participant in this plan is responsible for implementing specific mitigation actions as described in the mitigation strategies located in the annexes. In each mitigation strategy, every proposed action is assigned to a specific department or division in order to assign responsibility and accountability and increase the likelihood of subsequent implementation. This approach enables individual participants to update their unique mitigation strategy as needed, without altering the broader focus of the countywide plan. The separate adoption of participant-specific actions also ensures that each plan member is not held responsible for monitoring and implementing the actions of other jurisdictions or special districts involved in the planning process.

The Washington County NHMP Project Manager is the lead position for plan implementation and will work with the Steering Committee to ensure mitigation actions are implemented according to jurisdictional or special district capabilities and planning procedures. Each participant will implement the plan and their individual mitigation actions, as resources permit, through existing plans, programs, and policies and in the timeframe appropriate for their planning processes. As necessary, participants may consider seeking outside funding sources to implement mitigation projects in both the pre-disaster and post-disaster environments. When applicable, potential funding sources have been identified for proposed actions listed in the mitigation strategies.

4.3. Monitoring Plan Implementation

Following review of the plan maintenance process and meeting schedule outlined in the NHMP, the Steering Committee, which includes the Project Manager, have agreed to meet on at least a semiannual basis. Additional meetings will be called on an as-needed basis, such as following a natural hazard event or federal, state, or local disaster declaration. The committee will meet once in the fall prior to the governmental budget season and once in the spring following the winter storm season. These biannual meetings fulfill Emergency Management Performance Grant reporting requirements and exceed FEMA NHMP guidance.

Each Steering Committee member is responsible for monitoring and tracking the progress of action items identified by their jurisdiction or special district in this NHMP and submitting a status summary to the County's project manager biannually using the action item planning document. The committee, including the project manager, will also participate in and complete the functions below.

During the fall meeting, the Steering Committee will, at minimum:

- Discuss methods for continued public involvement and education; and
- Document successes and lessons learned during the year.

During the spring meeting, the Steering Committee will, at minimum:

- Update all hazard histories;
- Review new hazard data and update risk assessments as needed; and
- Review potential funding availability, including state and federal grant program Notices of Funding Opportunities.

Additionally, each committee member will work with their Technical Committee and other jurisdictional or special district representatives to:

- Review existing action items to determine appropriateness for local funding;
- Update decision makers on progress of the plan;
- Review existing action items to determine appropriateness for funding; and
- Prioritize potential mitigation projects.

Table 50: NHMP Monitoring Roles and Responsibilities

Responsible Party	Tasks
Washington County NHMP Project Manager	• Coordinate and facilitate the monitoring process. • Initiate and maintain a schedule of monitoring activities. • Collect data and disseminate reports. • Maintain records and documentation of all monitoring activities.
NHMP Steering Committee	• Participate in the monitoring process as requested by the Washington County NHMP Project Manager. • Assist in collecting and analyzing data. • Assist in disseminating reports to stakeholders and the public. • Maintain records and documentation of all jurisdictional and special district monitoring activities. • Promote the mitigation planning process with the public and solicit public input.

The format of the plan allows the County and participating jurisdictions to review and update sections and action items when new data and information becomes available. New data can be easily incorporated, resulting in an NHMP that remains current and relevant to the participating jurisdictions. To make the coordination and review of the Washington County NHMP as broad and as useful as possible, the Steering Committee will engage additional stakeholders and other relevant hazard mitigation organizations and agencies to implement the identified action items. Specific organizations have been identified as either internal or external partners on the individual action item forms participants completed as part of the NHMP planning documentation.

4.4. Evaluating Plan Effectiveness

This plan evaluation step assesses the effectiveness of the plan at achieving its stated purpose and goals. Plan evaluation may not occur as frequently as plan monitoring, but it is an important step to ensure that the plan continues to serve a purpose. This evaluation will include analysis of current mitigation projects, evaluation of success, reevaluation of future mitigation needs, and prioritization based upon changes in needs and/or capabilities. The mitigation plan shall be viewed as an evolving, dynamic document.

Table 51: NHMP Evaluation Roles and Responsibilities

Responsible Party	Tasks
Washington County NHMP Project Manager	• Coordinate and facilitate the evaluation process. • Initiate and maintain a schedule of evaluation activities. • Collect data and disseminate reports. • Maintain records and documentation of all evaluation activities.
NHMP Steering Committee	• Participate in the evaluation as requested by the Washington County NHMP Project Manager. • Assist in collecting and analyzing information. • Assist in disseminating reports to stakeholders and the public. • Maintain records and documentation of all jurisdictional and special district evaluation activities. • Promote the mitigation planning process with the public and solicit public input.

Table 52 describes the steps that the NHMP Project Manager will take annually and/or following a federally declared disaster or significant event to evaluate the effectiveness of the plan.

Table 52: NHMP Evaluation Procedure and Schedule

Action	Responsible Party	Tasks	Deliverable or Outcome
Initiate Annual Review	Washington County NHMP Project Manager	Notify lead agency/individual in each jurisdiction and special district to facilitate the annual review.	Work plan, schedule, and assigned resources to implement the plan review process.
Invite Steering Committee and Key Stakeholders	Washington County NHMP Project Manager	Invite Steering Committee members, key stakeholders, and others to participate in the plan evaluation process.	Invitation to participate, list of invited jurisdictions and special districts, existing and new stakeholders and other key planning partners, and public notice of annual evaluation.
Review Policies, Regulations, and Studies	Washington County NHMP Project Manager	Work with the Steering Committee to facilitate the research of new or updated laws, policies, regulations, initiatives, and studies that contribute to the hazard risk assessment or identified mitigation actions.	Status update for existing and new policies, regulations, initiatives, and/or studies.

Action	Responsible Party	Tasks	Deliverable or Outcome
Review Funding Programs and Planning Mechanisms	Washington County NHMP Project Manager	Coordinate with the Steering Committee to assess changes in local, state, and federal agencies and their funding procedures, new grant programs or areas of focus, and their potential integration into existing planning mechanisms.	Status update on existing and new funding procedures, grant programs, new areas of focus, and progress on integration into planning mechanisms.
Hazard Information	Washington County NHMP Project Manager	Work with the Steering Committee to facilitate the research of new or updated data and information that can contribute to risk assessments, loss estimates, or vulnerabilities in assets for plan participants.	Status update on recent hazard events, impacts, and losses, lessons learned, and status of facilities and infrastructure. Annual update of NHMP to reflect new risk assessment and capability data gathered from review of hazard events and impacts.
Mitigation Actions	Washington County NHMP Project Manager	Coordinate with the Steering Committee to assess progress in previously implemented actions that reduce vulnerability and losses and any new opportunities for mitigation actions.	Status update on completed actions, pending actions, and the implementation status of actions collected through monitoring procedures.
Outcomes	Washington County NHMP Project Manager	Coordinate with the Steering Committee to maintain and complete documentation of the NHMP review process, including any needed plan updates, and prepare a summary report.	Summary report, including the results of the annual monitoring and evaluation processes.

4.5. Five-Year Plan Update

This plan will be updated every five years in accordance with the update schedule outlined in the DMA 2000. The 2023 Washington County NHMP is due to be updated by April 11, 2028. The Washington County NHMP Project Manager will be responsible for organizing the Steering Committee to address plan update needs. The Steering Committee, which includes the project manager, will be responsible for updating any areas for improvement found in the plan and for ultimately meeting the DMA 2000 plan update requirements.

Table 53: NHMP Update Roles and Responsibilities

Responsible Party	Tasks
Washington County NHMP Project Manager	• Coordinate and facilitate the plan review, revision, and update process. • Initiate and maintain a schedule of all plan update activities. • Collect data and disseminate reports. • Maintain records and documentation of all monitoring, evaluation, and update activities. • Identify and implement opportunities for public participation and input in the planning process, including review of the revised draft plan.
NHMP Steering Committee	• Each committee member shall act as a representative of the jurisdiction or special district to which they belong and participate in the planning cycle, including the plan review, revision, and update process. • Collect and report data to the Washington County NHMP Project Manager. • Maintain records and documentation of all plan review and revision activities conducted in the jurisdiction or special district they represent. • Promote the mitigation planning process with stakeholders and the public and solicit public input.

The plan review and revision process is ongoing throughout the five-year life cycle of the plan. The monitoring and evaluation activities that are conducted, at a minimum, annually and following a major disaster will assist in maintaining currency of multiple components of the plan, such as the hazard identification and risk assessment and mitigation actions and priorities.

Table 54: NHMP Plan Five-Year Update Process and Schedule

Schedule	Plan Update Processes and Related Activities
Monitoring and Evaluation Activities Ongoing throughout the five-year planning cycle	• Monitoring and evaluation results, meeting documentation, and other pertinent documents will be collected throughout the five-year life cycle of the plan and used in the next NHMP update. • Multiple meetings with elected officials, the Steering Committee, local jurisdictions, state and federal agencies, and interested parties will be conducted. • Activities, meetings, and interactions will be tracked and documented throughout the planning cycle. • The initial review of the NHMP to kick off the plan update process will be conducted using the most recent version of the NHMP that has incorporated annual and periodic revisions as the basis. •
Updating the Risk Assessment Conducted in the first quarter of the fifth year of the planning cycle	• The NHMP Project Manager will work with the Steering Committee to identify key stakeholders to invite to participate and contribute to the updated risk assessment. • Monitoring and evaluation results will be incorporated. • Changes since the previous plan approval will be identified. • Each hazard will be assessed and updated to include new data since the date of plan approval and adoption and subsequent updates. • New hazard occurrences and potential changes in low-ranked hazards will be identified and assessed. • Any significant changes in jurisdictional risk assessments will be noted during plan review and integrated into the updated NHMP.
Reviewing and Updating the Goals and Objectives Conducted in the second quarter of the fifth year of the planning cycle	• The NHMP Project Manager will coordinate with the Steering Committee and key partners to assess the status of current mitigation goals and objectives for potential revision. • The status of integration of mitigation goals and objectives with existing planning mechanisms will be assessed. • Any significant changes in mitigation goals, especially those that are not consistent with the current plan goals, will be assessed and incorporated as appropriate in the updated NHMP. • Monitoring and evaluation results will be used to modify the goals and objectives and describe achievements.
Reviewing and Updating Mitigation Actions Conducted in the third quarter of the fifth year of the planning cycle	• The NHMP Project Manager and Steering Committee and key partners will obtain an update on the current status of actions. • Monitoring and evaluation results will be used to assess the status and effectiveness of mitigation actions in meeting the goals and reducing risks. Actions may be changed, updated, removed, or added as necessary if approved by the participant's Technical Committee. • Plan maintenance data from the implemented activities will be used to describe progress in the previous five years.

Schedule	Plan Update Processes and Related Activities
Compiling and Reviewing Information Conducted in the third quarter of the fifth year of the planning cycle	• The NHMP Project Coordinator and Steering Committee will compile data and develop the updated NHMP. • A draft will be made available for stakeholder review and input. • A draft will be made available for public review and comment. • All comments and suggestions will be incorporated, and the final draft completed.
FEMA Review Conducted in the fourth quarter of the fifth year of the planning cycle	• FEMA will review the draft NHMP update.
Plan Adoption Conducted in the fourth quarter of the fifth year of the planning cycle	• The updated NHMP will be adopted prior to the plan expiration date.

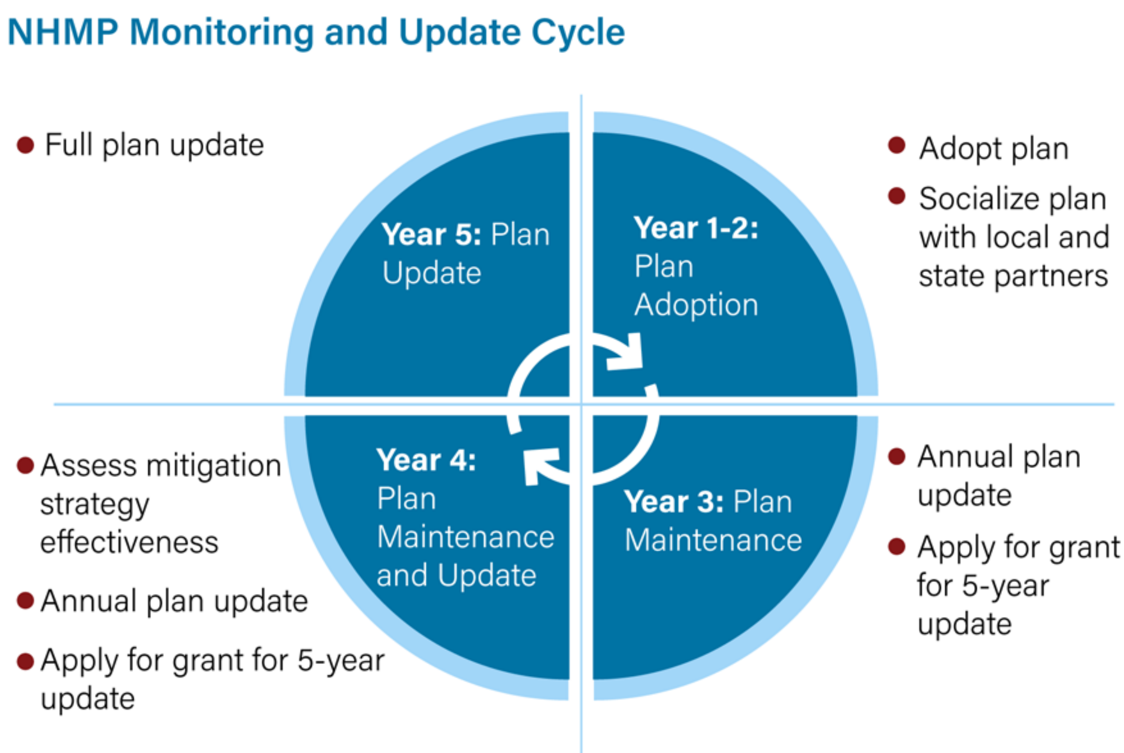

Figure 31: Plan Update and Monitoring Cycle

Adherence to the monitoring, evaluation, and update process schedule will ensure the plan is kept current throughout its five-year cycle. The plan update process and schedule are designed to focus on various components of the plan throughout the five-year cycle. Based on the schedule described, all parts of the plan will have been reviewed at the end of the five-year cycle, potentially reducing the time and resource burden in the final planning year.

4.6. Incorporation into Existing Planning Mechanisms

This NHMP includes a range of actions that, when implemented, will reduce loss from hazard events in the County. An ongoing responsibility of the Steering Committee is to identify additional stakeholders and existing planning mechanisms that can be used to integrate mitigation planning into short- and long-term community development and resiliency planning. This involves establishing hazard mitigation as a planning priority supported through the same capabilities defined in the participant capabilities assessment in each annex:

- Planning and regulatory
- Administrative and technical
- Safe growth
- Fiscal and resources
- Education and outreach

Each step in the planning cycle includes ongoing opportunities to identify existing planning processes that will provide a platform for the integration of hazard mitigation into existing planning mechanisms. The primary means for integrating mitigation strategies will be through the revision, update, and implementation of each participant’s individual plans and regulations such as comprehensive plans, capital improvement plans, and land development regulations, as applicable.

The members of the Steering Committee will remain charged with ensuring the goals and strategies of new and updated local planning documents for their jurisdictions and special districts are consistent with the goals and actions in the NHMP and will not contribute to increased hazard vulnerability in the County. Specific planning initiatives that provide the opportunity to integrate hazard mitigation are described in the participant annexes.

4.7. Continued Public Involvement

Participants are committed to involving the public directly in the maintenance and update of the NHMP. Although the Steering Committee members are responsible for annual review and update of the NHMP and represent the public to some extent, the public will still have an opportunity to provide direct feedback about the NHMP.

Public participation will be sought throughout the implementation, evaluation, and maintenance of the NHMP. This participation can be sought in a multitude of ways, including but not limited to periodic presentations on the plan’s progress to elected officials, schools, or other community groups; questionnaires or surveys; public meetings; and postings on social media and participant websites.

Each participant in this plan is responsible for creating and documenting continued public involvement opportunities throughout the life of the NHMP. The Washington County NHMP Project Manager may facilitate countywide public involvement strategies that include plan participants, such as partnering with the Washington County Emergency Management Cooperative to distribute and disseminate public surveys and information related to mitigation. Copies of the NHMP and annual revisions will be posted on the websites of plan participants, as appropriate.

4.8. Plan Approval and Adoption Process

Once the NHMP has received FEMA Approvable Pending Adoption (APA) status, each participating jurisdiction or special district will take the plan to their governing body for final public comment and adoption. A copy of each adoption resolution will be inserted into Appendix B and held on file at FEMA, OEM, and the Washington County Emergency Management Office.