State of Oregon
Oregon Department of Geology and Mineral Industries
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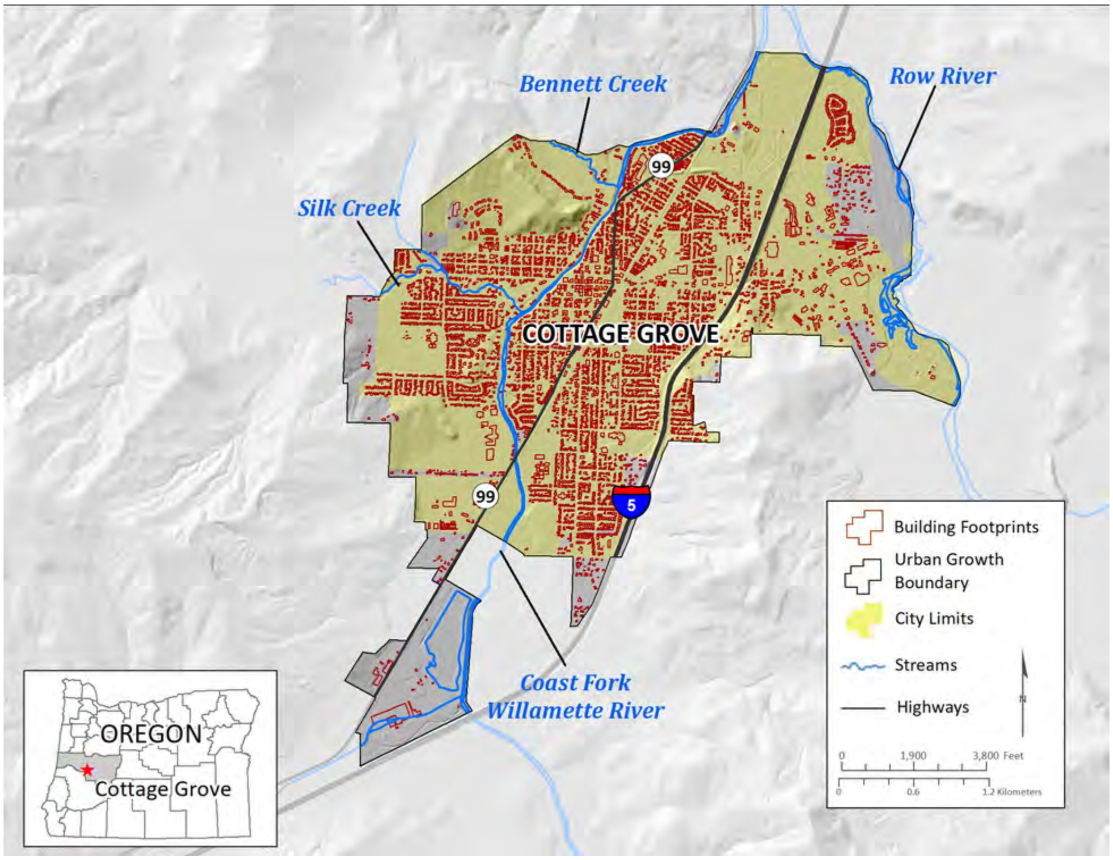
OPEN-FILE REPORT O-23-03

MULTI-HAZARD RISK REPORT FOR THE CITY OF COTTAGE GROVE, OREGON



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2023

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DISCLAIMER

Cover image: Study area of the Cottage Grove Risk Report. Map depicts Cottage Grove, Oregon and urban growth bourndary areas included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of multi-hazard risk assessment for the City of Cottage Grove, Oregon. The risk assessment can help a community better plan for disaster.

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GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.7 format. Metadata is embedded in the geodatabase and is also provided as separate .xml format files.

Cottage_Grove_Risk_Report_Data.gdb

Feature dataset: Asset_Data

feature classes:

- Building_footprints (polygons)
- Communities (polygons)
- UDF_points (points)

Metadata in .xml file format:

Each dataset listed above has an associated, standalone .xml file containing metadata in the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata format

EXECUTIVE SUMMARY

This report was prepared for the City of Cottage Grove, Oregon, with funding provided by the Oregon Department of Land Conservation and Development (DLCD). It describes the methods and results of the natural hazard risk assessment performed in 2022 by the Oregon Department of Geology and Mineral Industries (DOGAMI). The purpose of this project is to provide the City of Cottage Grove with a detailed risk assessment information to enable them to compare hazards and act to reduce their risk. The risk assessment results quantify the impact of natural hazards to this community and enhance the decision-making process in planning for disaster.

We arrived at our findings and conclusions by completing three main tasks: compiling an asset database, identifying and using the best available hazard data, and performing natural hazard risk assessment.

- In the first task, we created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, FEMA Hazus®-MH general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. With these data we were able to represent accurate spatial locations and vulnerabilities on a building-by-building basis.
- The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI and were produced using high-resolution lidar topographic data. Each hazard dataset was the best available at the time of writing.
- In the third task, we analyzed risk using Esri® ArcGIS Desktop® software. We took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using the Hazus-MH methodology, and (2) calculated the number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides and wildfire.

We performed this assessment using the best data available at the time of the study. However, it is important to note that some of the datasets used in this study will likely be updated and replaced within the next three years. The landslide hazard maps as well as the geohazard maps that inform the earthquake model are several decades old and not based on lidar topography. The flood dataset used was the draft FEMA flood depth maps produced in 2022. Changes to any of the datasets in the coming years will need to be incorporated into future, more accurate risk assessments.

The findings and conclusions of this report show the potential impacts of hazards in the City of Cottage Grove. An earthquake can cause widespread damage and losses throughout the community. Hazus-MH earthquake simulations illustrate the potential reduction in earthquake damage through seismic retrofits. Our findings also indicate that many of the critical facilities in the study area that were built before seismic building code standards are at high risk from earthquake hazard. Areas along much of the Coast Fork Willamette River are at risk from flooding. Our analysis shows that new landslide mapping based on improved methods and lidar information will increase the accuracy of mapping. Wildfire risk is low for the study area, but moderate and high wildfire hazard areas are present to the east and south. We also found that the 100-year flood poses the greatest potential of population displacement compared to other hazard scenarios analyzed in this study.

The information presented in this report is designed to increase awareness of natural hazard risk, to support public outreach efforts, and to aid local decision-makers in developing comprehensive plans and

natural hazard mitigation plans. This study can help emergency managers identify vulnerable critical facilities and develop contingencies in their response plans. The results of this study are designed to be used to help communities identify and prioritize mitigation actions that will improve community resilience.

Selected Cottage Grove Results
Total buildings: 5,776
Total estimated building value: $1.56 billion

Cascadia Subduction Zone (CSZ) Magnitude (Mw) 9.0 Earthquake Red-tagged buildings[a]: 28 Yellow-tagged buildings[b]: 290 Loss estimate: $112 million	**100-year Flood (2022 FEMA draft data)** Number of buildings damaged: 451 Loss estimate: $6.9 million
Landslide (High and Very High-Susceptibility) Number of buildings exposed: 44 Exposed building value: $12 million	**Wildfire (High Risk):** Number of buildings exposed: 0 Exposed building value: $0

[a]Red-tagged buildings are considered uninhabitable due to complete damage
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage

1.0 INTRODUCTION

A *natural hazard* is an environmental phenomenon that can negatively impact humans, and risk is the likelihood that a hazard will result in harm. A natural hazard risk assessment analyzes and quantifies how different types of hazards could affect the built environment, population, the cost of recovery, and identifies potential risk. Risk assessments provide the basis for developing mitigation plans, strategies, and actions, so that steps can be taken to prepare for a potential hazard event.

Key Terms:
- *Vulnerability:* Characteristics that make people or assets more susceptible to a natural hazard.
- *Risk:* Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard.

This report is a multi-hazard risk assessment analyzing individual buildings and resident population in the City of Cottage Grove, Oregon. Cottage Grove is situated at the southern extent of the Willamette Valley between the Oregon Coast Range and the Cascade Mountains. The city is subject to many natural hazards, including earthquake, riverine flooding, landslides, and wildfire. This report provides a detailed and comprehensive analysis of these natural hazards and provides a comparative perspective not previously available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to the community.

1.1 Purpose

The purpose of this project is to help the City of Cottage Grove better understand their risk and increase resilience to earthquakes (including liquefaction and site amplification), riverine flooding, landslides, and wildfire natural hazards that are present in their communities. This is accomplished by the best available, most accurate, and detailed information about these hazards to assess the number of people and buildings at risk.

The main objectives of this study are to:

- compile and/or create a database of critical facilities, tax assessor data, buildings, and population distribution data,
- incorporate and use existing data from previous geologic, hydrologic, and wildfire hazard studies,
- perform exposure and Hazus–based risk analysis, and
- share this report widely so that all interested parties have access to its information and data.

The body of this report describes our methods and results. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to analyze risk. Results for each hazard type are reported on a study area basis within each hazard section, and community-based results are reported in detail in **Appendix A**. **Appendix B** contains detailed risk assessment tables. **Appendix C** is a more detailed explanation of the Hazus-MH methodology. **Appendix D** lists acronyms and definitions of terms used in this report. **Appendix E** contains tabloid-size citywide hazard maps. These appendices can be helpful in clarifying the summarized results in each hazard section.

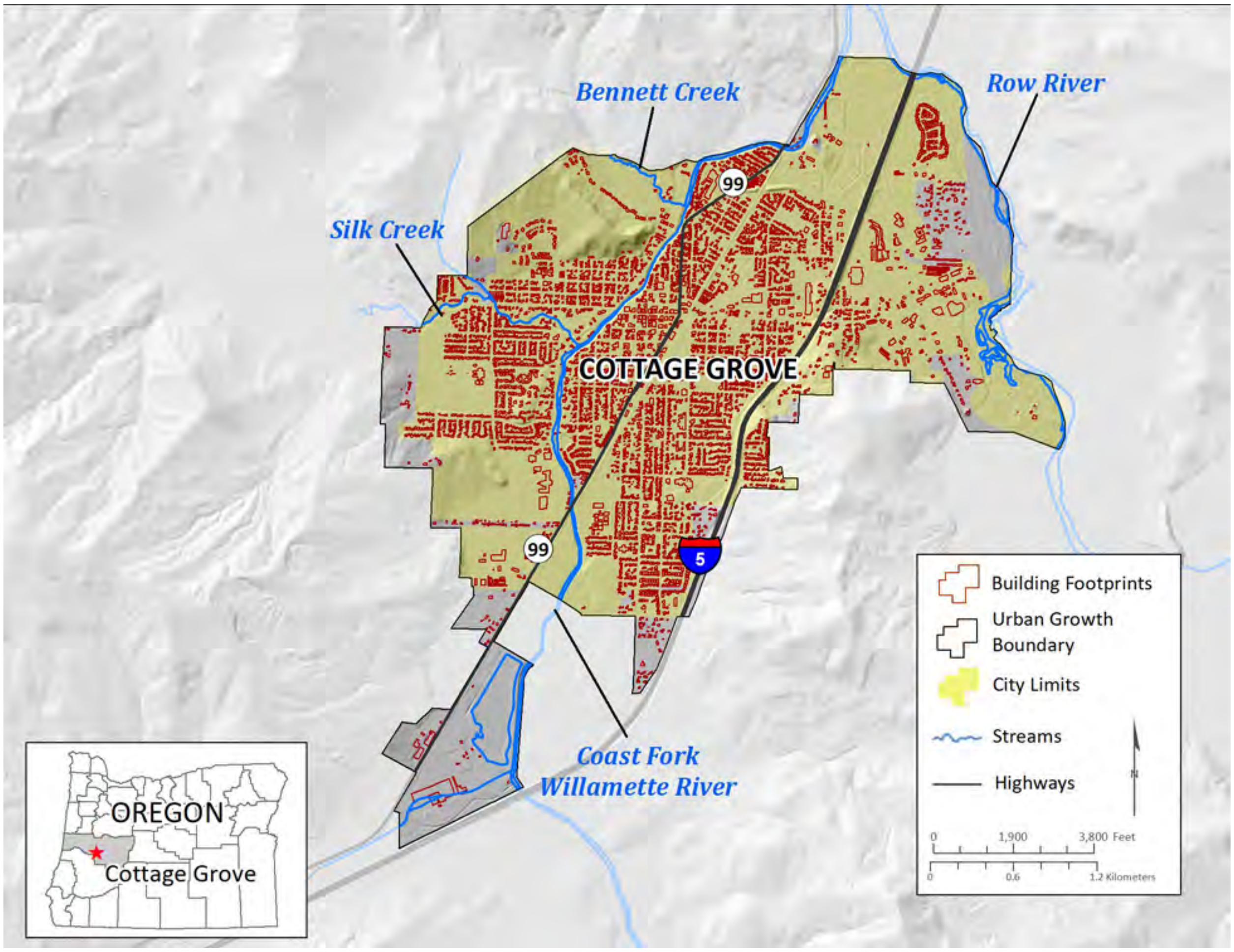
1.2 Study Area

The study area for this project includes the entire incorporated jurisdiction of Cottage Grove, Oregon and expanded to include the urban growth boundary (UGB) (**Figure 1-1**). Cottage Grove is located in Lane County in the central-western part of the state, south of Eugene, Oregon along Interstate 5. The study area covers approximately 5 square miles (13 square kilometers).

Cottage Grove is located at the confluence of the Coast Fork Willamette River and the Row River which is considered the southernmost extent of the Willamette Valley (**Figure 1-1**). At approximately 650 feet (198 meters) Cottage Grove is at a transition zone between the gentler terrain of the valley and the rugged terrain of the mountains. Additional streams within Cottage Grove are Silk Creek and Bennett Creek.

The population of the study area is approximately 10,000 based on an estimated population in 2020 from the Portland State University (PSU) Population Research Center https://www.pdx.edu/population-research/population-estimate-reports. Most of the residents in the study area reside within the city limits (9,500) and the remaining residents live within the urban growth boundary (500).

Figure 1-1. Study area: Cottage Grove, Oregon.



1.3 Project Scope

For this risk assessment, we limited the project scope to natural hazard impacts on buildings and population because of data availability, the strengths and limitations of the risk assessment methodology, and funding availability. We did not analyze impacts to the local economy, land values, or the environment. Depending on the natural hazard, we used one of two methodologies: loss estimation or exposure. Loss estimation was modeled using methodology from Hazus®-MH (FEMA, 2012a, 2012b, 2012c), a tool developed by FEMA for calculating damage to buildings from flood and earthquake. Exposure is a simpler methodology, in which buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), city and county population numbers from the 2010 U.S. Census data (U.S. Census Bureau, 2010a) was used to distribute people into residential structures on a census block basis. Permanent resident counts were then adjusted on a citywide basis to current estimates from the PSU Population Research Center (https://www.pdx.edu/population-research/sites/g/files/znldhr3261/files/2022-04/2021%20Annual%20Population%20Report%20Tables.pdf).

A critical component of this risk assessment is a citywide building inventory developed from building footprint data and the Lane County tax assessor database (acquired 2022). The other key component is a suite of datasets that represent the currently best available science for a variety of natural hazards. The geologic hazard scenarios were selected by DOGAMI staff based on their expert knowledge of the datasets; most datasets are DOGAMI publications. In addition to geologic hazards, we included wildfire hazard in this risk assessment. The Oregon Department of Forestry (ODF) provided recommendations on the use of wildfire datasets for risk analysis. The following is a list of the natural hazards and the risk assessment methodologies that were applied. See **Table 1-1** for data sources.

Earthquake Risk Assessment

- Hazus-MH loss estimation from a CSZ earthquake magnitude (Mw) 9.0 event. Includes earthquake induced or "coseismic" liquefaction, soil amplification class, and landslides

Flood Risk Assessment

- Hazus-MH loss estimation to four recurrence intervals (10%, 2%, 1%, and 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on Landslide Susceptibility Index (low to very high)

Wildfire Risk Assessment

- Exposure based on Fire Risk Index (low to high)

Table 1-1. Hazard data sources for Cottage Grove.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake	CSZ Mw 9.0	Statewide	DOGAMI OSHD 1.0 (Madin and others, 2021)
-Coseismic landslide	Susceptibility – wet (3-10 hazard classes)	″	″
-Coseismic liquefaction	Susceptibility (1-5 classes)	″	″
-Coseismic soil amplification class	National Earthquake Hazards Reduction Program (A-F classes)	″	″
Flood	Depth Grids: 10% (10-yr) 2% (50-yr) 1% (100-yr) 0.2% (500-yr)	Countywide	FEMA – draft data generated for 2022 Lane County National Flood Insurance Program mapping
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI O-16-02 (Burns and others, 2016)
Wildfire	Risk (Low, Moderate, High)	Regional (Pacific Northwest, US)	ODF (Gilbertson-Day and others, 2018)

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.3.1 or the report by Burns and others (2016) for more information.

1.4 Previous Studies

One previous risk assessment has been conducted that included the study area by DOGAMI. Wang (1998) used Hazus-MH to estimate the impact from a Mw 8.5 Cascade Subduction Zone (CSZ) earthquake scenario on the state of Oregon. The results of this study were arranged into individual counties. Lane County was estimated to experience 5.5% loss ratio in the Mw 8.5 CSZ scenario, due to its proximity to the earthquake source.

We did not compare the results of this project with the results of these previous studies, because the previous Wang (1998) study utilized a much lower level of detailed building information and site-specific earthquake hazard inputs. Additionally, this study analyzed a different earthquake scenario from the previous studies. Comparative analysis was not part of the scope of this project.

2.0 METHODS

We used a quantitative approach to assess the level of risk of buildings and people from natural hazards. The two modes of analysis were Hazus-MH loss estimation and exposure analysis.

2.1 Hazus-MH Loss Estimation

> ***Key Terms:***
> - *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology. This is measured as the cost to repair or replace the damaged building in US dollars.
> - *Loss ratio:* Percentage of estimated loss relative to the total value.

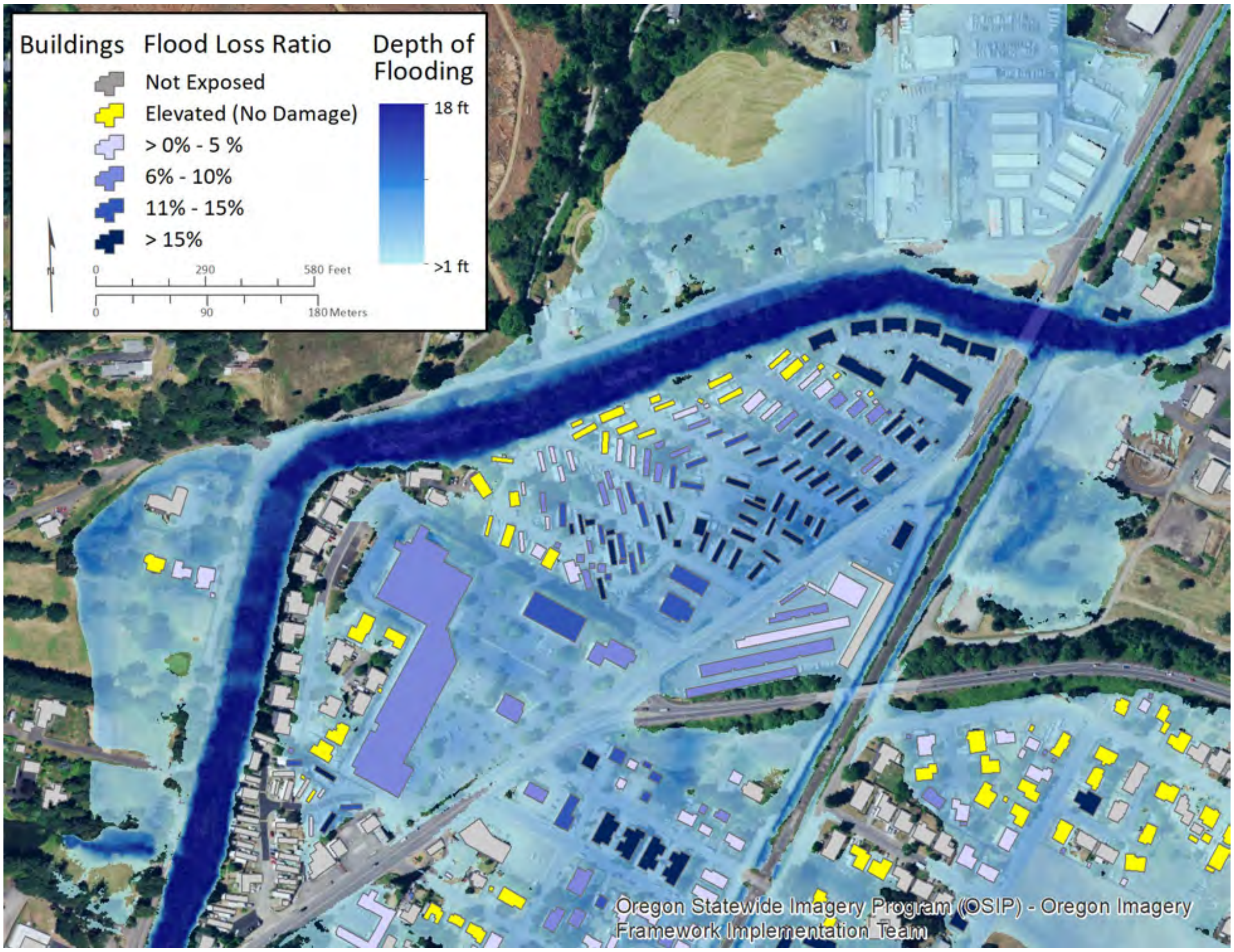
According to FEMA (FEMA, 2012a, p. 1), "Hazus provides nationally applicable, standardized methodologies for estimating potential wind, flood, and earthquake losses on a regional basis. Hazus can be used to conduct loss estimation for floods and earthquakes [...]. The multi-hazard Hazus is intended for use by local, state, and regional officials and consultants to assist mitigation planning and emergency response and recovery preparedness. For some hazards, Hazus can also be used to prepare real-time estimates of damages during or following a disaster."

Hazus-MH can be used in different modes depending on the level of detail required. Given the high spatial precision of the building inventory data and quality of the natural hazard data available for this study, we chose the user-defined facility (UDF) mode. This mode makes loss estimates for individual buildings relative to their "cost," which we then aggregate to the community level to report loss ratios. Cost used in this mode are associated with rebuilding using new materials, also known as replacement cost. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building area (in square feet) by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus-MH database.

Damage functions are at the core of Hazus-MH. The damage functions stored within the Hazus-MH data model were developed and calibrated from the observed results of past disasters. Estimates of loss are made by intersecting building locations with natural hazard layers and applying damage functions based on the hazard severity and building characteristics. **Figure 2-1** illustrates the range of building loss estimates from Hazus-MH flood analysis.

We used Hazus-MH version 5.0, which was the latest version available when we began this risk assessment.

Figure 2-1. 100-year flood zone and building loss estimates example in City of Cottage Grove, Oregon.



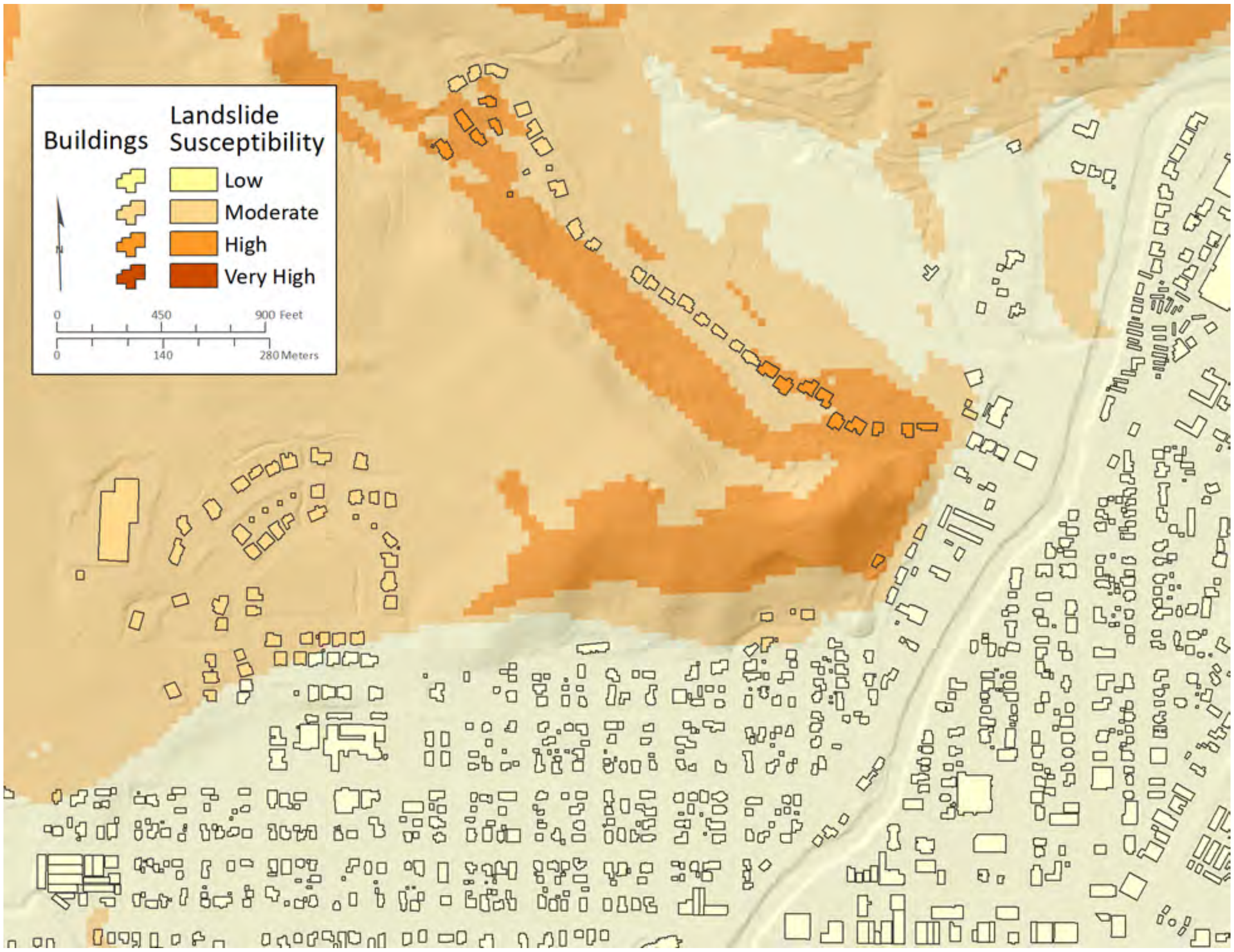
2.2 Exposure

> ***Key Terms:***
> - *Exposure:* Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.
> - *Building value:* Total monetary value of a building. This term is used in the context of exposure.

Since loss estimation using Hazus-MH is not available for all types of hazards, we used exposure analysis to assess the level risk for Cottage Grove for landslide and wildfire hazards. Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative to the more detailed loss estimation method for those natural hazards that do not have available damage models like in Hazus. It provides a way to easily quantify what is and what is not threatened. Exposure results are communicated in terms of total building value exposed, rather than a loss estimate. For example, **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility.

Exposure is used for landslides and wildfires. For comparison with loss estimates, exposure is also used for the 1% annual chance flood, that is a flood that has a 1% chance of occurrence in any given year.

Figure 2-2. Landslide susceptibility areas and building exposure example in Cottage Grove, Oregon.

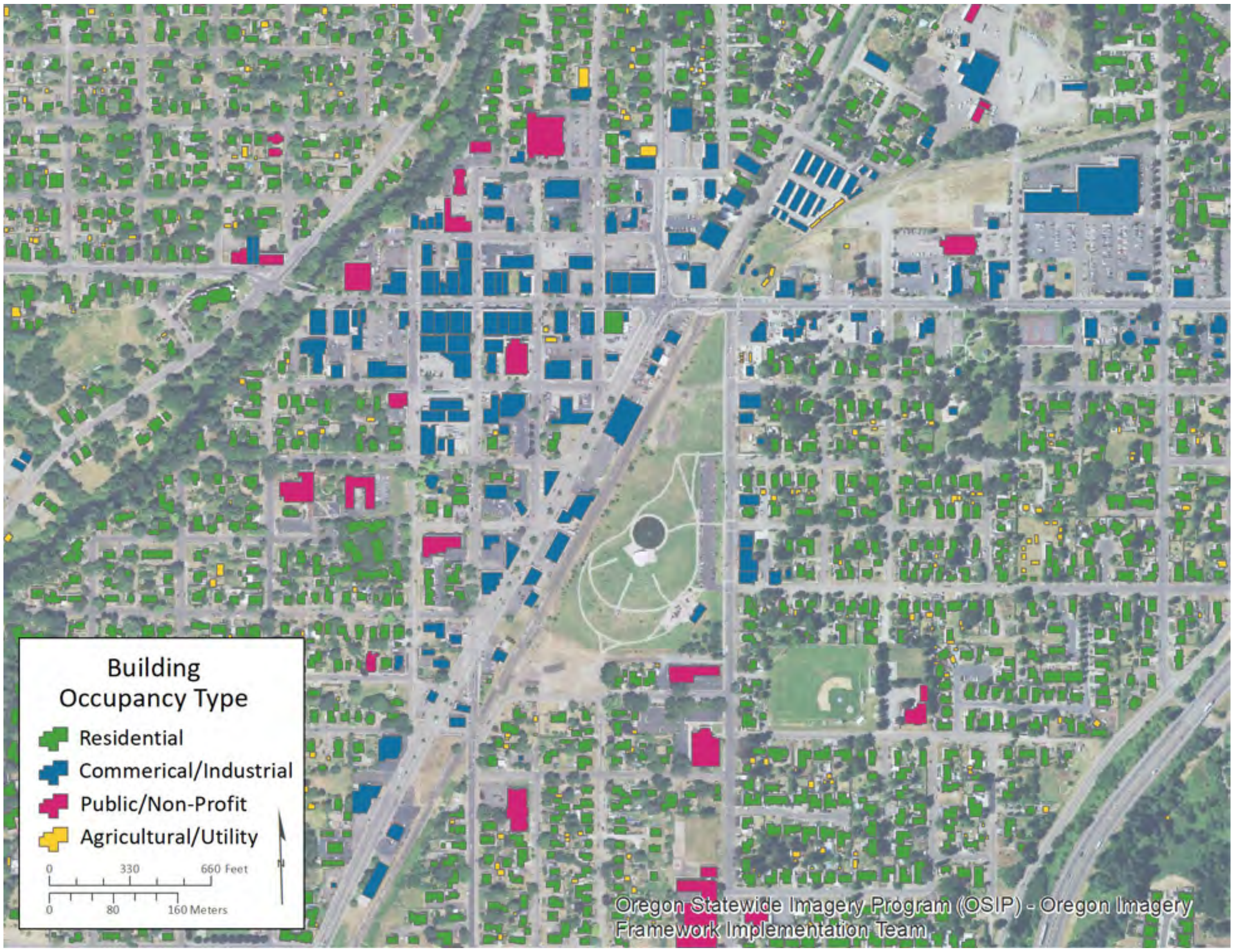


2.3 Building Inventory

A key piece of the risk assessment is the building inventory. This inventory consists of all buildings larger than 100 square feet (9.3 square meters), as determined from existing building footprints (Williams, 2021). A variety of building inventory occupancy types used in the Hazus-MH and exposure analyses are present in Cottage Grove (**Figure 2-3**). See also **Appendix B** Table B-1, and **Appendix E**, Plate 1 and Plate 2.

To use the building inventory within the Hazus-MH methodology, we converted the building footprints to points and migrated them into a UDF database with standardized field names and attribute domains. The UDF database formatting allows for the correct damage function to be applied to each building. Hazus-MH version 2.1 technical manuals (FEMA, 2012a, 2012b, 2012c) provide references for acceptable field names, field types, and attributes. The fields and attributes used in the UDF database (including building seismic codes) are discussed in more detail in Appendix **C.2.2**.

Figure 2-3. Building occupancy types, City of Cottage Grove, Oregon.



The building count and value of the City of Cottage Grove is 5,776 buildings and $1.56 billion of building value (**Table 2-1**). A table detailing the occupancy class distribution is included in **Appendix B: Detailed Risk Assessment Tables**.

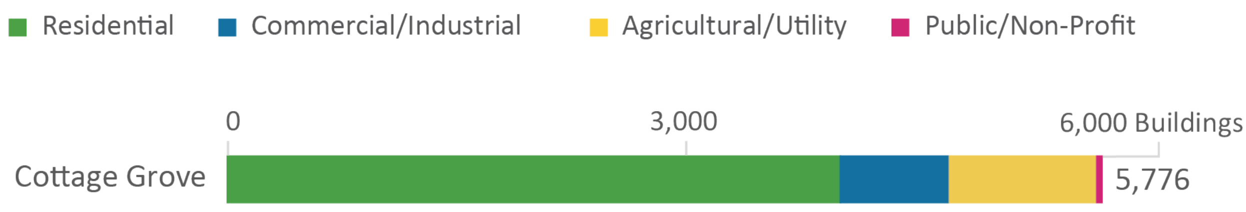
Table 2-1. Cottage Grove building inventory.

Community	Total Number of Buildings	Estimated Total Building Value ($)
Cottage Grove	5,776	1,561,735,000

The building inventory was developed from a building footprint dataset developed in 2021 called the Statewide Building Footprints for Oregon, release 1 (SBFO-1) (Williams, 2021), which covers all of Cottage Grove. The building footprints provide a location and 2D outline of a structure. The total number of buildings within the study area was 5,776.

Lane County supplied assessor data and we formatted it for use in the risk assessment. The assessor data contains an array of information about each building (i.e., improvement). Tax lot data, which contains property boundaries and other information about the property, was obtained from the county assessor and was used to link the buildings with assessor data. The linkage between the two datasets resulted in a database of UDF points that contain attributes for each building. These points are used in the risk assessment for both loss estimation and exposure analysis. The building occupancy composition is primarily residential and some commercial (**Figure 2-4**).

Figure 2-4. Building count in Cottage Grove by occupancy class.



Critical facilities are important to note because these facilities play a crucial role in emergency response efforts. We embedded identifying characteristics into the critical facilities in the UDF database so they could be highlighted in the results. Critical facilities data came from the DOGAMI Statewide Seismic Needs Assessment (SSNA; Lewis, 2007). We updated the SSNA data by reviewing Google Maps™ data. The critical facilities we identified include hospitals, schools, fire stations, police stations, and emergency operations. In addition, we included other buildings based on specific community input and structures that would be essential during a natural hazard event, such as public works and water treatment facilities. Communities that have critical facilities that can function during and immediately after a natural disaster are more resilient than those with critical facilities that are inoperable after a disaster. Various critical facilities are present within Cottage Grove **Table 2-2** Critical facilities are individually listed in **Appendix A**.

Table 2-2. Cottage Grove critical facilities inventory.

	Hospital & Clinic		School		Police/Fire		Emergency Services		Military		Other*		Total	
Community	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)														
Cottage Grove	1	11,838	5	89,288	2	6,336	0	0	0	0	2	3,281	10	110,743

Note: Facilities with multiple buildings were consolidated into one building.

* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

One purpose of the UDF database design was so that we could estimate the number of people at risk from natural hazards. Within the UDF database, the 2010 U.S. Census population of permanent residents per census block was distributed proportionally among residential buildings based on building area. This census block-based distribution was further adjusted with the PSU Population Research Center estimates for 2021. The difference in population between the 2010 U.S. Census and the PSU estimate were evenly distributed to all residential structures in the study area so that the total population was equal to the PSU population estimate. We did not examine the impacts of natural hazards on non-permanent populations (e.g., tourists), whose total numbers fluctuate seasonally. Due to lack of information within the assessor and census databases, the distribution includes vacation homes, which in many communities make up some of the total residential building stock (U.S. Census Bureau, 2010b).

From the Census and PSU Population Research Center data, we assessed the risk of the 10,373 residents of Cottage Grove that could be affected by a natural hazard. For each natural hazard, except for the earthquake scenario, a simple exposure analysis was used to find the number of potentially displaced residents within a hazard zone. For the earthquake scenario the number of potentially displaced residents was based on residents in buildings estimated to be significantly damaged by the earthquake.

3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers four natural hazards (earthquake, flood, landslide, and wildfire) that pose a risk to Cottage Grove. The assessment describes both localized vulnerabilities and the widespread challenges that impact the community. The loss estimation and exposure results, as well as the rich dataset included with this report, can lead to greater understanding of the potential impact of natural disasters. The community can use the results to update plans as part of the work toward becoming more resilient to future disasters.

In this section, hazard data sources are described, and results are presented for Cottage Grove. Detail results are in **Appendix A: Community Risk Profile**.

3.1 Earthquake

An earthquake results from a sudden movement of rock on each side of a fault in the earth's crust that abruptly releases strain accumulated over a long period of time. The movement along the fault produces waves of strong shaking that spread in all directions. If an earthquake occurs near populated areas, it may cause casualties, economic disruption, and extensive property damage (Madin and Burns, 2013).

Two earthquake-induced hazards are liquefaction and coseismic landslides. Liquefaction occurs when saturated soils suddenly lose bearing capacity due to ground shaking, causing the soil to behave like a liquid; this action can be a source of tremendous damage. Coseismic landslides are mass movement of rock, debris, or soil induced by ground shaking. All earthquake loss estimates in this report include damage derived from shaking itself, and from liquefaction and landsliding.

3.1.1 Data sources

Hazus-MH offers two scenario methods for estimating loss from earthquake, probabilistic and deterministic (FEMA Hazus-MH, 2012b). A probabilistic scenario uses U.S. Geological Survey (USGS) National Seismic Hazard Maps which are derived from seismic hazard curves calculated on a grid of sites across the United States that describe the annual frequency of exceeding a set of ground motions as a result of all possible earthquake sources (U.S. Geological Survey, 2017). A deterministic scenario is based on a specific seismic event, which in this case is the CSZ Mw 9.0 event. We used the deterministic method along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

The CSZ Mw 9.0 of Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Cottage Grove. This CSZ scenario by Madin and others (2021) includes information necessary for successful Hazus analysis. Other potentially damaging scenarios lacked detailed seismic data such that adequate results would be produced. A well understood earthquake scenario, like the CSZ, adds to the accuracy of the results.

To thoroughly characterize the risk of earthquake hazard in Cottage Grove, we also ran a Hazus scenario using a nearby crustal fault. We selected the Metolius Fault as a plausible source of a damaging earthquake for the Cottage Grove and surrounding areas. The Hazus results, using the same building inputs and site-specific data (coseismic landslide, liquefaction, and National Earthquake Hazard Reduction Program (NEHRP) soils) as the CSZ Mw 9.0 scenario, show that a Mw 7.4 earthquake from the Metolius Fault would produce damages between $300,000 to $400,000; this is less than 1% of the Cascadia impact. Because the damages were so slight in comparison to the CSZ Mw 9.0 scenario, we only used the CSZ result to characterize earthquake risk in Cottage Grove.

The following hazard layers used for the loss estimation analysis are derived from work conducted by Madin and others (2021): landslide susceptibility (wet), liquefaction susceptibility, and NEHRP soils. The liquefaction and landslide susceptibility layers together with peak ground acceleration (PGA) from Madin and others (2021) were used by the Hazus-MH tool to calculate probability and magnitude of permanent ground deformation. While the datasets used in the analysis to represent ground deformation (landslide susceptibility, liquefaction susceptibility, and NEHRP soils) were the best data available, substantial mischaracterizations of these hazards may be present that would reduce the impact of earthquake hazard within the community.

The statewide datasets developed by Madin and others (2021) are compilations of studies of varying accuracies and methodologies from across the state of Oregon. The liquefaction data used in the study area was derived from the work of O'Connor (2001). The mapping conducted in the O'Connor study was not done with geohazards in mind. Because liquefaction was specific looked at, there is uncertainty in how the sediments in the study area would react in a given seismic event.

3.1.2 Study area results

Because an earthquake can affect a wide area, every building in Cottage Grove will by shaken by a CSZ Mw 9.0 earthquake. Hazus-MH loss estimates (see **Appendix B** Table B-2) for each building are based on a formula where coefficients are multiplied by each of the five damage state percentages (none, low, moderate, extensive, and complete). These damage states are correlated to loss ratios that are then multiplied by the total building replacement value to obtain a loss estimate (FEMA, 2012b). We performed this assessment using the best data available at the time of the study. However, it is important to note that some of the datasets used in the study will likely be updated and replaced within the next three years. New data should be incorporated into future risk assessments.

In keeping with earthquake damage reporting conventions, we used the Applied Technology Council (ATC)-20 post-earthquake building safety evaluation color-tagging system to represent damage states (Applied Technology Council, 2015). 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. The number of red or yellow-tagged buildings we report for each community is based on an aggregation of the probabilities for individual buildings (FEMA, 2012b).

Critical facilities were considered non-functioning if the Hazus-MH earthquake analysis showed that a building or complex of buildings had a greater than 50-percent chance of being at least moderately damaged (FEMA, 2012b). Because building specific information is more readily available for critical facilities and due to their importance after a disaster, we chose to report the results of these buildings individually.

The number of potentially displaced residents from an earthquake scenario described in this report was based on the formula: ([Number of Occupants] * [Probability of Complete Damage]) + (0.9 * [Number of Occupants] * [Probability of Extensive Damage]) (FEMA, 2012b). The probability of damage state was determined in the Hazus-MH earthquake analysis results.

Cottage Grove CSZ Mw 9.0 earthquake results:

- Number of red-tagged buildings: 28
- Number of yellow-tagged buildings: 290
- Loss estimate: $111,599,000
- Loss ratio: 7.1%
- Non-functioning critical facilities: 8
- Potentially displaced population: 37

The results indicate that Cottage Grove could incur a moderate level of loss (7%) due to a CSZ Mw 9.0 earthquake. Much of the contributing factors to damage are soils that are susceptible to seismic shaking. The Coast Fork Willamette River floodplain is composed of seismically reactive soils where the majority of the buildings in Cottage Grove are located. Since these soils amplify ground shaking, the probability of earthquake damage is greater for structures built in these areas.

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a small amount of the estimated damage from the earthquake hazard in Cottage Grove. Landslide exposure results show that 0.8% of buildings in Cottage Grove are within a very high or high susceptibility zone. This indicates that a similar percentage of the earthquake loss estimated in this study may be due to coseismic landslide.

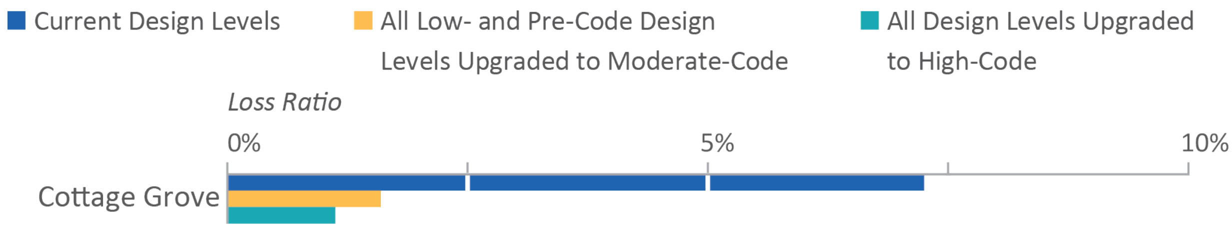
Building vulnerabilities such as the age of the building stock and occupancy type are also contributing factors in loss estimates. The first seismic building codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. Nearly 85% of Cottage Grove's buildings were built before the 1990's. 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.

If buildings could be seismically retrofitted to higher code standards, earthquake risk would be greatly reduced. In this study, a simulation in Hazus-MH earthquake analysis shows that loss ratios drop from 7.1% to 1.8%, when all buildings are upgraded to at least moderate code level. While retrofits can decrease earthquake vulnerability, areas of high landslide or liquefaction may need additional geotechnical mitigation to have an effect on losses. **Figure 3-1** illustrates the reduction in loss estimates from the probabilistic Mw 7.0 earthquake through two simulations where all buildings are upgraded to moderate code standards or to high code standards.

Key Terms:

- *Seismic retrofit:* Structural modification to a building that improves its resilience to earthquake.
- *Design level:* Hazus-MH terminology referring to the quality of a building's seismic building code (i. e. pre, low, moderate, and high). Refer to **Appendix C.2.3**for more information.

Figure 3-1. CSZ Mw 9.0 earthquake loss ratio in Cottage Grove, with simulated seismic building code upgrades.



3.1.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to earthquake hazard:

- A cluster of manufactured homes in the northeastern portion of Cottage Grove are more vulnerable to earthquake damage relative to other structures.
- Many high value buildings in commercial areas in Cottage Grove are built with more vulnerable building materials compared to wood-built structures.
- Critical facilities in the study area that were built before seismic building code standards are at risk to be non-functioning due to an earthquake like the one simulated in this study.

3.2 Flooding

In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Floods are a commonly occurring natural hazard in Cottage Grove and have the potential to create public health hazards and public safety concerns, close and damage major highways, destroy railways, damage structures, and cause major economic disruption. Flood issues like flash flooding, ice jams, post-wildfire floods, and dam safety were not examined in this report.

Floods vary greatly in size and duration, with smaller floods more likely than larger floods. A typical method for determining flood risk is to identify the size of a flood that has a particular probability of occurrence. This report uses floods that have an annual probability of occurrence of 10%, 2%, 1%, and 0.2%, henceforth referred to as 10-year, 50-year, 100-year, and 500-year scenarios, respectively. The size of floods estimated at these probabilities is based on a computer model that is based on recorded precipitation and stream levels.

The major streams within Cottage Grove are the Coast Fork Willamette River, Row River, Silk Creek, and Bennett Creek. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain.

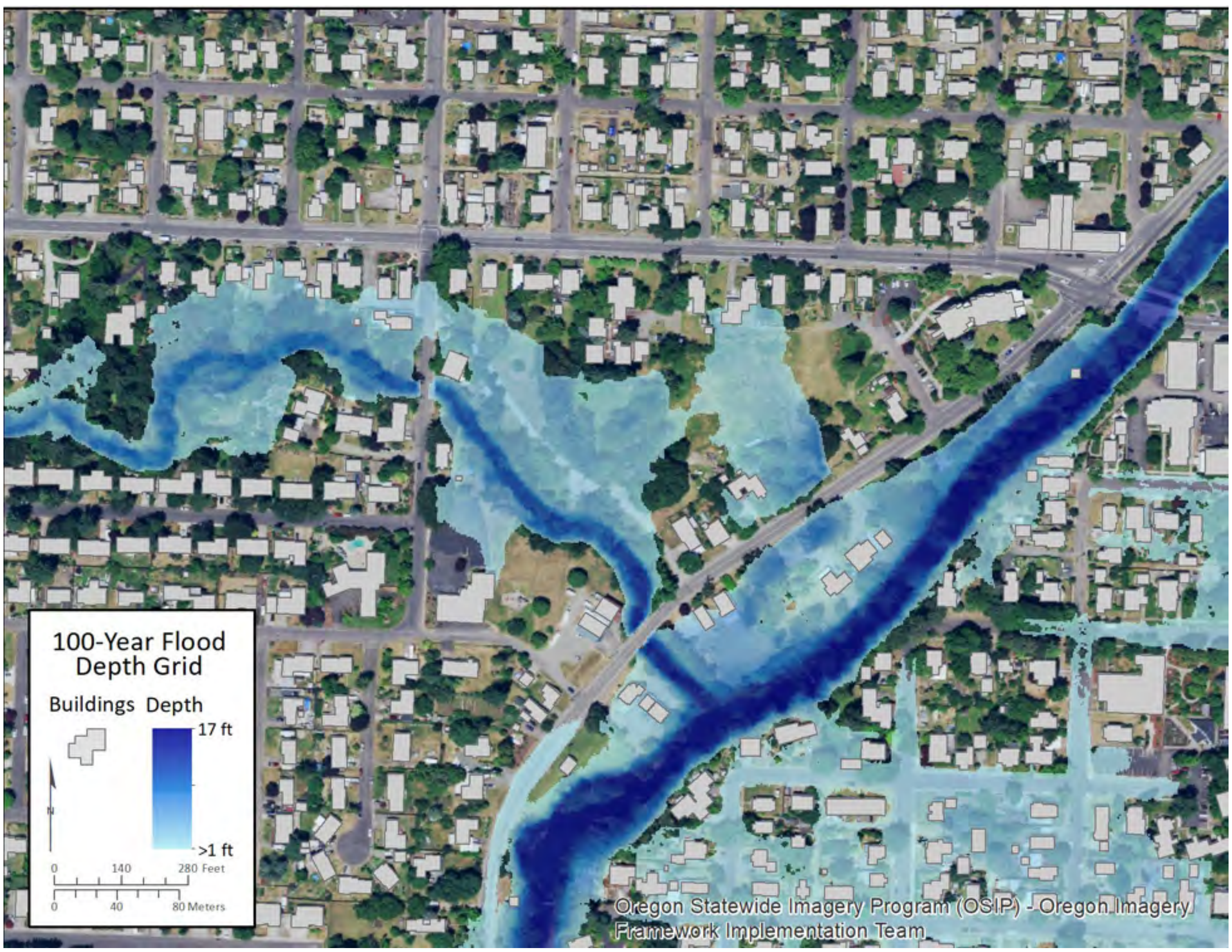
Floods commonly adversely impact human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of flooding or removing the structure through FEMA's property acquisition ("buyout") program.

3.2.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps for Cottage Grove were in the process of being updated by FEMA as of April 2022; this is the primary data source for the flood risk assessment in this report. In doing this update, FEMA provided DOGAMI depth grids for flood risk assessment. These depth grids are considered draft and are subject to possible change. FEMA approved of their usage in this report as they are considered the best available for the study area. Further information regarding the National Flood Insurance Program (NFIP) can be found on the FEMA website: https://www.fema.gov/flood-insurance. These were the only flood data sources that we used in the analysis.

The depth grids provided by FEMA were used in this risk assessment to determine the level to which buildings are impacted by flooding. Depth grids are raster GIS datasets in which each digital pixel value represents the depth of flooding at that location within the flood zone **(Figure 3-2)**. Though considered draft at the time of this analysis, the depth grid data are the best available flood hazard data. Depth grids for four flooding scenarios (10-, 50-. 100-, and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis. Each flood scenario is designated by a recurrence interval or the probability in any given year of a flood of that magnitude occurring. For example, the 100-year flood has a 1% annual chance of occurring.

Figure 3-2. Flood depth grid example of confluence of Silk Creek with Coast Fork Willamette River in Cottage Grove, Oregon using FEMA 2022 draft flood data.



Building loss estimates are determined in Hazus-MH by overlaying building data on a depth map. Hazus-MH uses individual building information, specifically the first-floor height above ground and the presence of a basement, to calculate the loss ratio from a particular depth of flood.

For Cottage Grove, occupancy type and basement presence attributes were available from the assessor database for most buildings. Where individual building information was not available from assessor data, we used oblique imagery and street level imagery to estimate these important building attributes. Only buildings in a flood zone or within 500 feet (152 meters) of a flood zone were examined closely to attribute buildings with more accurate information for first-floor height and basement presence. Because our analysis accounted for building first-floor height, buildings that have been elevated above the flood level were not given a loss estimate—but we did count residents in those structures as displaced. We did not look at the duration that residents would be displaced from their homes due to flooding. For information about structures exposed to flooding but not damaged, see the **Exposure analysis** section below.

3.2.2 Study area results

For this risk assessment, we imported the community UDF data and depth grids into Hazus-MH and ran a flood analysis for four flood scenarios (10-, 50-, 100-, and 500-year). We used the April 2022 draft 100-year flood scenario as the primary scenario for reporting flood results (also see **Appendix E** Plate 4). 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. See **Appendix B** Table B-4 for multi-scenario cumulative results. We performed this assessment using the best data available at the time of the study. However, it is important to note that the FEMA flood depth maps may still be amended before they are adopted. New data should be incorporated into future risk assessments.

Cottage Grove 100-year flood loss (FEMA 2022 draft data):

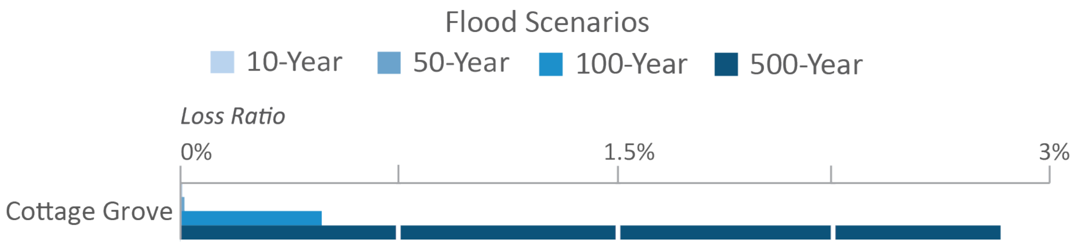
- Number of buildings damaged: 451
- Loss estimate: $6,851,000
- Loss ratio: 0.4%
- Non-functioning critical facilities: 0
- Potentially displaced population: 1,188

3.2.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is over $6.8 million. While the overall loss ratio for flood damage in Cottage Grove is 0.4%, 100-year flooding has a significant impact to areas where development exists near streams. Because most residents are not within flood designated zones, the loss ratio may not be as helpful as the actual replacement cost and number of residents displaced to assess the level of risk from flooding. The Hazus-MH analysis provides flood damage results at the building-level so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Cottage Grove are along the Coast Fork Willamette River floodplain. While the majority of the 100-year flooding is shallow, it is present in the entire area between the Coast Fork Willamette and Highway 99 throughout the community. Flooding is more severe in the northern portion of Cottage Grove at the Highway 99 bridge over the Coast Fork Willamette River. The 500-year is less probable but is likely to cause much more extensive damage (**Figure 3-3**).

Figure 3-3. Ratio of flood loss estimates for Cottage Grove (FEMA 2022 draft data).



3.2.4 Exposure analysis

Separate from the Hazus-MH flood analysis, we did an exposure analysis by overlaying building locations on the 100-year flood extent. We did this to estimate the number of buildings that are elevated above the level of flooding and the number of displaced residents, both of which are not considered in the Hazus analysis. This was done by comparing the number of non-damaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Some (12%) of Cottage Grove's buildings were found to be within designated flood zones. Of the 700 buildings that are exposed to flooding, we estimate that 249 are above the height of the 100-year flood. This evaluation also estimates that 1,188 residents might have mobility or access issues due to surrounding water. See **Appendix B** Table B-5 for community-based results of flood exposure.

3.2.5 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to flood hazard:

- Widespread shallow flooding throughout Cottage Grove between Coast Fork Willamette River and Highway 99.
- Flooding most severe in the area near the Highway 99 bridge over the Coast Fork Willamette River.

3.3 Landslide Susceptibility

Landslides are mass downhill movements of rock, debris, or soil. There are many different types of landslides in Oregon. In area around Cottage Grove the most common are debris flows and shallow- and deep-seated landslides. Landslides can occur in many sizes, at different depths, and with varying rates of movement. Generally, they are large, deep, and slow moving or small, shallow, and rapid. Some factors that influence landslide type are hillside slope, water content, and geology. Many triggers can cause a landslide: intense rainfall, earthquakes, or human-induced factors like excavation along a landslide toe or loading at the top. Landslides can cause severe damage to buildings and infrastructure. Fast-moving landslides may pose life safety risks and can occur throughout Oregon (Burns and others, 2016).

3.3.1 Data sources

We used the data from the statewide landslide susceptibility map (Burns and others, 2016) for the landslide analysis. This statewide susceptibility layer is an analysis of multiple landslide datasets. Burns and others (2016) used the Statewide Landslide Information Database for Oregon (SLIDO) inventory data along with maps of generalized geology and slope to create a landslide susceptibility overview map of Oregon that shows zones of relative susceptibility: Very High, High, Moderate, and Low. Mapped landslides from SLIDO data directly define the Very High landslide susceptibility zone, while SLIDO data coupled with statistical results from generalized geology and slope maps define the other relative susceptibility zones (Burns and others, 2016).

SLIDO, release 3.2 (Burns and Watzig, 2014) is an inventory of mapped landslides in the state of Oregon. SLIDO is a compilation of past studies; some studies were completed very recently using new technologies, like lidar-derived topography, and some studies were performed more than 50 years ago. Consequently, SLIDO data vary greatly in scale, scope, and focus and thus in accuracy and resolution across the state. Some landslide mapping for the area around Cottage Grove was done as recently as 2002 but before lidar was available for high-accuracy mapping.

Statewide landslide susceptibility map data have the inherent limitations of SLIDO and of the generalized geology and slope maps used to create the map. Therefore, the statewide landslide susceptibility map varies significantly in quality across the state, depending on the quality of the input datasets. Another limitation is that susceptibility mapping does not include some aspects of landslide hazard, such as runout, where the momentum of the landslide can carry debris beyond the zone deemed to be a high hazard area.

We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure (see **Appendix B** Table B-6). We combined high and very high susceptibility zones to provide a general sense of community risk for planning purposes (see **Appendix E**, Plate 5).

The total dollar value of exposed buildings was summed for the study area and is reported below. We also estimated the number of people threatened by landslides. Land value losses due to landslides and potentially hazardous unmapped areas that may pose a real risk to communities were not examined for this report.

3.3.2 Study area results

The landslide exposure results are tabulated below for the high and very high categories and shown for all categories in **Figure 3-4**. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results. We performed this assessment using the best data available at the time of the study. However, it is important to note that the landslide maps for this area are incomplete and an upcoming study will likely update and replace the source data within the next three years. New data should be incorporated into future risk assessments.

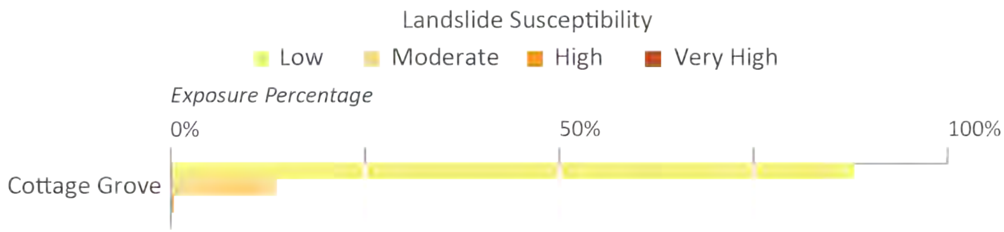
Cottage Grove landslide exposure (High and Very High susceptibility):

- Number of buildings: 44
- Value of exposed buildings: $12,103,000
- Percentage of total value exposed: 0.8%
- Critical facilities exposed: 0
- Potentially displaced population: 79

The amount of exposure to landslide hazard in Cottage Grove is low, with less than 1% of building value exposed to high or very high susceptibility. Much of Cottage Grove is built on stream sediments within the Coast Fork Willamette River floodplain, which tend to have low landslide hazard. Sloped areas surrounding the city are at higher risk for landslide. Existing landslides are present south of the city.

Landslide hazard is ubiquitous in a large percentage of undeveloped land and may present challenges for planning and mitigation efforts. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for Cottage Grove. A complete lidar-based landslide inventory for the Cottage Grove area would provide much more accurate and detailed results.

Figure 3-4. Landslide susceptibility exposure for Cottage Grove.



3.3.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to landslide hazard:

- Areas surrounding Cottage Grove are at greater risk to landslide hazard than within the city.
- Some areas in Cottage Grove may be at higher risk than what the data show, due to incomplete mapping of landslides.

3.4 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property in many communities. The most common severe wildfire conditions include: hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, its behavior is influenced by numerous conditions, including fuel, topography, weather, drought, and development (Gilbertson-Day and others, 2018). Post-wildfire geologic hazards can also present risk. These usually include flood, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

The Lane County Community Wildfire Protection Plan (CWPP), from 2020, recommends that the county develop policies that address fire restriction enforcement, fuel breaks, wildland urban interface standards, and building code enforcement related to emergency access. Forests cover large areas around Cottage Grove and many homes in the UGB are adjacent to wildfire risk areas. Contact the Lane County Planning Department for specific requirements related to the county's land use plan.

3.4.1 Data sources

The Pacific Northwest Quantitative Wildfire Risk Assessment (PNRA): Methods and Results (Gilbertson-Day and others, 2018) is a comprehensive report that includes a database developed by the United States Forest Service (USFS) for the states of Oregon and Washington. The steward of this database in Oregon is the Oregon Department of Forestry (ODF). The database was created to assess the level of risk residents and structures have to wildfire. For this project, the burn probability dataset, a dataset included in the PNRA database, was used to measure the risk to Cottage Grove.

Using guidance from ODF, we categorized the Burn Probability dataset into low, moderate, and high-hazard zones for the wildfire exposure analysis. Burn probability is derived from simulations using many elements, such as, weather, ignition frequency, ignition density, and fire modeling landscape (Gilbertson-Day and others, 2018).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. Within the study area, no wildfire data was available in urbanized areas. This indicates that there is minimal risk to wildfire hazard, because the omission implies low to no probability of wildfire risk (see **Appendix B**, Table B-8). We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.4.2 Study area results

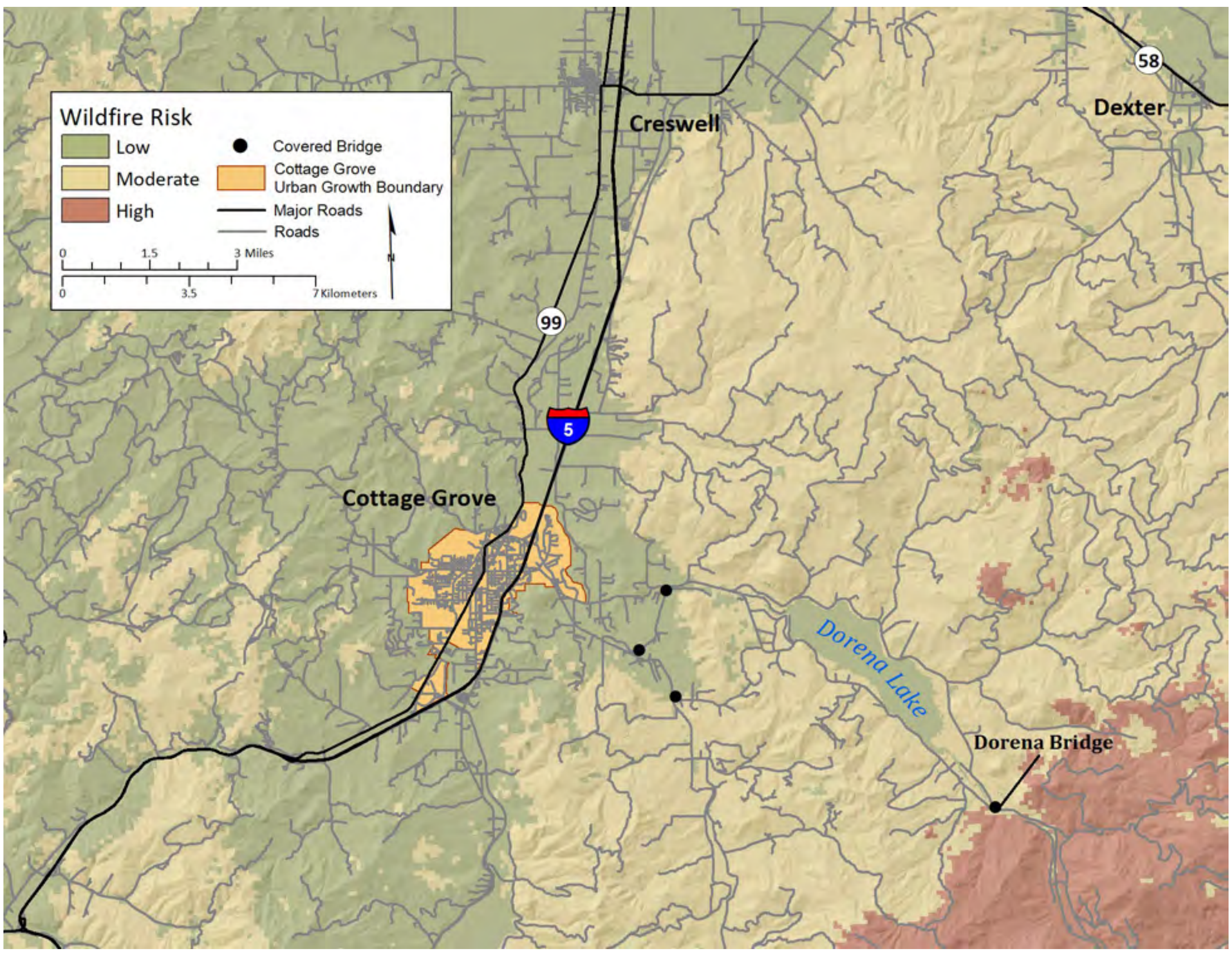
High to moderate wildfire hazard is present for large portions of the surrounding area but is low in Cottage Grove. The wildfire risk increases to moderate at 1 mile (1.6 kilometers) east and south of the incorporated boundary of Cottage Grove. The wildfire hazard continues to increase to high levels further into the Cascade Mountains to the east. Wildfire adjacent to Cottage Grove could still pose a risk related to evacuation routes and hazardous smoke.

Cottage Grove wildfire exposure (High hazard):

- Number of buildings: 0
- Value of exposed buildings: $0
- Percentage of total value exposed: 0%
- Critical facilities exposed: 0
- Potentially displaced population: 0

While wildfire risk is low for Cottage Grove, the risk of wildfire is still present. Low probability events do occur and often have a larger impact than high probability events. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results; we did not produce a wildfire specific map plate, due to the data indicating a uniformly low wildfire risk within the study area. High wildfire hazard exists in surrounding forested areas (**Figure 3-5.** Wildfire hazard areas near Cottage Grove).

Figure 3-5. **Wildfire hazard areas near Cottage Grove.**



3.4.3 Areas of significant risk

We identified locations within the study area that are comparatively at greater risk to wildfire hazard:

- Dorena Bridge is within an area of high wildfire risk. Other historical covered bridges in the area are at risk from wildfire due to their proximity to high-risk zones.

- While the probability of wildfire hazard is low, it is still a possibility in Cottage Grove. Nearby wildfire prone areas also pose a risk related to evacuation routes and hazardous smoke.

4.0 CONCLUSIONS

The purpose of this study is to provide a better understanding of potential impacts from multiple natural hazards at the community scale. We accomplished this by using the latest natural hazard mapping and loss estimation tools to quantify expected damage to buildings and potential displacement of permanent residents, or determine which buildings and residents are exposed to a hazard. This comprehensive and detailed approach to the analysis provides new context for the city's risk reduction efforts. However, new landslide and coseismic geohazard maps will be produced in the next three years, and the FEMA flood maps may change before they are adopted by Cottage Grove. This risk assessment should be updated based on the new maps. We note several important findings based on the results of this study:

- **Moderate overall damage and losses can occur from an earthquake—**Based on the results of a CSZ Mw 9.0 earthquake, every building and resident in Cottage Grove would experience moderate impact and disruption. Results show that an earthquake can cause building losses of 7% in the study area. The high vulnerability of the building inventory (building type) and the number of buildings constructed on seismically amplifying soils contribute to the estimated levels of losses expected in the study area. Lidar-based geohazard mapping would increase the accuracy of the earthquake hazard results.
- **Retrofitting buildings to modern seismic building codes can reduce damages and losses from earthquake shaking—**Seismic building codes have a major influence on earthquake shaking damage estimated in this study. We found that retrofitting to at least moderate code was the most efficient mitigation strategy because the additional benefit from retrofitting to high code was minimal. In our simulation of upgrading buildings to at least moderate code, the estimated loss for the entire study area was reduced from 7.1% to 1.8%. Communities with older buildings that were constructed below the moderate seismic code standards are both the most vulnerable and have the greatest potential for risk reduction. Although seismic retrofits are an effective strategy for reducing earthquake shaking damage, it should be noted that earthquake-induced landslide will also be present near the perimeter of Cottage Grove.
- **Cottage Grove is at significant risk from flooding—**Most of the buildings in Cottage Grove are built along the Coast Fork Willamette River in areas that are prone to flooding. Flood mapping was recently revised and represents the best available data to estimate risk. At first glance, Hazus-MH flood loss estimates may give a false impression of lower risk because they show lower damages for a community relative to other hazards we examined. This is due to the difference between loss estimation and exposure results, as well as the limited area impacted by flooding. Another consideration is that flood is one of the most frequently occurring natural hazards. The areas that are most vulnerable to flood hazard are along both banks of the Coast Fork Willamette River over to Highway 99 through commercial and residential portions of Cottage Grove.
- **Elevating structures in the flood zone reduces vulnerability—**Flood exposure analysis was used in addition to Hazus-MH loss estimation to identify buildings that were not damaged but that were within the area expected to experience a 100-year flood. By using both analyses in this way, the number of elevated structures within the flood zone could be quantified. This showed possible mitigation needs in flood loss prevention and the effectiveness of past activities. The flood depth

maps show that floods would occur over a wide area but would be relatively shallow, so that, many buildings exposed to flood hazard would be above the flood elevation. A large number (249) of buildings in the flood hazard area are higher than the base flood elevation (BFE). Based on the number of buildings exposed to flooding throughout the city, many would benefit from elevating above the level of flooding.

- **New landslide mapping would increase the accuracy of estimating landslide risk**—The landslide hazard data used in this risk assessment was created before the advent of modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results.
- **Wildfire risk is low for the overall study area**—Exposure analysis shows that buildings throughout the community are within low wildfire hazard areas. Nearby areas to the east and south of Cottage Grove are considered moderate wildfire risk zones.
- **Most of the study area's critical facilities are at significant risk to earthquake hazard**—Critical facilities were identified and were specifically examined for this report. We estimate that 80% (8 of 10) of Cottage Grove's critical facilities will be non-functioning after a CSZ 9.0 Mw earthquake. We found no exposure of critical facilities to flood, landslide, or wildfire.
- **The biggest cause of displacement to population is flood hazard**—Potential displacement of permanent residents from natural hazards was estimated in this report. We estimate that 11% of the population in the city could be displaced due to a flood. A small percentage of residents are vulnerable to displacement from earthquake, landslide, and wildfire hazards.
- **The results allow comparisons across hazards and prioritize their needs**—The study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard within areas in the community. It also allows for a comparison between different hazards, though care must be taken to distinguish loss estimates and exposure results. The loss estimates and exposure analyses can assist in developing plans that address the concerns of the community.

5.0 LIMITATIONS

There are several limitations to keep in mind when interpreting the results of this risk assessment.

- **Loss estimation for individual buildings** – Hazus-MH is a model of reality, which is an important factor when considering the loss ratio of an individual building. On-the-ground mitigation, such as elevation of buildings to avoid flood loss, has been only minimally captured. Also, due to a lack of building material information, assumptions were made about the distribution of wood, steel, and un-reinforced masonry buildings. Loss estimation is most insightful when individual building results are aggregated to the community level because it reduces the impact of uncertainty in building characteristics.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards and the inability to perform loss estimations due to the lack of Hazus-MH damage functions. Exposure is reported in terms of total building value, which could imply a total loss of the buildings in a particular hazard zone, but this is not the case. Exposure is simply a calculation of the number of buildings and their value and does not make estimates about the level to which an individual building could be damaged or how many buildings might be impacted in a single event.

- **Population variability** – Cottage Grove has some vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations (U. S. Census Bureau, 2010b) and unpublished data from the PSU Population Research Center. As a result, we are slightly underestimating the number of people that may be in harm's way on a summer weekend.
- **Data accuracy and completeness** – Some datasets in our risk assessment had incomplete coverage or lacked high-resolution data within the study area. We used lower-resolution data to fill gaps where there was incomplete coverage or where high-resolution data were not available. Assumptions to amend areas of incomplete data coverage were made based on reasonable methods described within this report. However, we are aware that some uncertainty has been introduced from these data amendments at an individual building scale. At community-wide scales the effects of the uncertainties are lower. Data layers in which assumptions were made to fill gaps are building footprints, population, some building specific attributes, and landslide susceptibility. Many of the datasets included known or suspected artifacts, omissions and errors, identifying or repairing these problems was beyond the scope of the project and are areas needing additional research.
- **Changing Conditions** – This assessment did not account for potential changes in climate, land use, or population. Human-induced climate change poses a significant and widespread risk to people around the world. In Oregon, climate change is expected impact future floods, wildfires, and landslides, but quantifying this impact was beyond the scope of this study.

6.0 RECOMMENDATIONS

The following actions are needed to better understand hazards and reduce risk to natural hazard through mitigation planning. These implementation areas, while not comprehensive, touch on all phases of risk management and focus on awareness and preparation, planning, emergency response, mitigation funding opportunities, and hazard-specific risk reduction activities.

6.1 Awareness and Preparation

Natural hazard awareness is crucial to lowering risk and lessening the impacts of natural hazards. When community members understand their risk and know the role that they play in preparedness, the community will become a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the time a community needs to recover from a disaster, commonly referred to as "resilience."

This report is intended to provide local officials with a comprehensive and authoritative profile of natural hazard risk to underpin their public outreach efforts.

Messaging can be tailored to stakeholder groups. For example, outreach to homeowners could focus on actions they can take to reduce risk to their property. The DOGAMI Homeowners Guide to Landslides (https://www.oregongeology.org/Landslide/ger_homeowners_guide_landslides.pdf) provides a variety of risk reduction options for homeowners who live in areas susceptible to landslides. This guide is one of many existing resources. Agencies partnering with local officials in the development of additional effective resources could help reach a broader community and user groups.

6.2 Planning

This report can help local decision-makers develop their local plans by identifying geohazards and associated risks to the community. The primary framework for accomplishing this is through the comprehensive planning process. The comprehensive plan sets the long-term trajectory of capital improvements, zoning, and urban growth boundary expansion, all of which are planning tools that can be used to reduce natural hazard risk.

Another framework is the natural hazard mitigation plan (NHMP) process. NHMP plans focus on characterizing natural hazard risk and identifying actions to reduce risk. Additionally, the information presented here can be a resource when updating the mitigation actions and inform the vulnerability assessment section of the NHMP plan.

While there are many similarities between this report and an NHMP, the primary difference is that the risk assessment is not a planning document. Additional difference can be the hazards or critical facilities that are examined in each report. Differences between the reports may be due to data availability or limited methodologies for specific hazards. The critical facilities considered in this report may not be identical to those listed in a typical NHMP due to the lack of damage functions in Hazus-MH for non-building structures and to different considerations about emergency response during and after a disaster.

6.3 Emergency Response

Critical facilities will play a major role during and immediately after a natural disaster. This study can help emergency managers identify vulnerable critical facilities and develop contingency plans. Additionally, detailed mapping of potentially displaced residents can be used to re-evaluate evacuation routes and identify vulnerable populations to target for early warning.

The building database that accompanies this report presents many opportunities for future pre-disaster mitigation, emergency response, and community resilience improvements. Vulnerable areas can be identified and targeted for awareness campaigns. These campaigns can be aimed at pre-disaster mitigation through, for example, improvements of the structural connection of a building’s frame to its foundation. Emergency response entities can benefit from the use of the building dataset through identification of potential hazards and populated buildings before and during a disaster. Both reduction of the magnitude of the disaster and a decrease in the response time contribute to a community’s overall resilience.

6.4 Mitigation Funding Opportunities

Several funding options are available to communities that are susceptible to natural hazards and have specific mitigation projects they wish to accomplish. State and federal funds are available for projects that demonstrate cost effective natural hazard risk reduction. The Oregon Office of Emergency Management (OEM) State Hazard Mitigation Officer (SHMO) can provide communities assistance in determining eligibility, finding mitigation grants, and navigating the mitigation grant application process. OEM has produced a document that can assist local officials in applying for mitigation funds (https://www.oregon.gov/OEM/Documents/Oregon_Hazard_Mitigation_Grant_Program_Handbook.pdf).

At the time of writing this report, FEMA has five programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP), HMGP Post-Fire Assistance, Pre-Disaster

Mitigation (PDM) Grant Program, and Building Resilient Infrastructure and Communities (BRIC) grant program, Flood Mitigation Assistance (FMA) (https://www.fema.gov/grants/mitigation). The SHMO can help with finding further opportunities for earthquake and tsunami assistance and funding.

6.5 Hazard-Specific Risk Reduction Actions

6.5.1 Earthquake

- Evaluate critical facilities for seismic preparedness by identifying structural deficiencies and vulnerabilities to dependent systems (e.g., water, fuel, power).
- Evaluate vulnerabilities of critical facilities. We estimate that 80% of critical facilities (**Appendix A: Community Risk Profile**) will be damaged by an earthquake scenario described in this report, which will have many direct and indirect negative effects on first-response and recovery efforts.
- Identify buildings that would benefit from seismic upgrades.
- Create modern liquefaction and ground motion amplification maps.

6.5.2 Flood

- Map areas of potential flood water storage.
- Identify structures that have repeatedly flooded in the past and would be eligible for FEMA's "buyout" program.
- Create channel migration zone maps.

6.5.3 Landslide

- Create modern landslide inventory and susceptibility maps.
- Monitor ground movement in high susceptibility areas.
- Consider land value losses due to landslide in future risk assessments.

6.5.4 Wildfire-related geologic hazards

- Evaluate post-wildfire geologic hazards including flood, debris flows, and landslides.

7.0 ACKNOWLEDGMENTS

This natural hazard risk assessment was conducted by the Oregon Department of Geology and Mineral Industries (DOGAMI) in 2022. It was funded by the Oregon Department of Land Conservation and Development (DLCD) (Interagency Agreement #21022). DOGAMI worked closely with DLCD to complete the risk assessment and produce this report. DLCD is coordinating with communities on the next Natural Hazard Mitigation Plan (NHMP) update, which will incorporate the findings from this risk assessment.

Many DOGAMI staff provided support throughout the project. We are grateful to everyone who contributed, with special thanks to Christina Appleby, Carlie Azzopardi, Jason McClaughry, and Alex Lopez.

Additionally, we would like to thank Rynn Lamb of FEMA and Pam Reber and Marian Lahav of DLCD for their assistance on this project.

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9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILE

A risk analysis summary for Cottage Grove is provided in this section to encourage ideas for natural hazard risk reduction. Increasing disaster preparedness, public hazards communication, and education, ensuring functionality of emergency services, and ensuring access to evacuation routes are actions that this community can take to reduce their risk. This appendix contains community specific data to provide an overview of the community and the level of risk from each natural hazard analyzed. In addition, a list of critical facilities and assumed impact from individual hazards is provided.

A.1 City of Cottage Grove

Table A-1. City of Cottage Grove.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Cottage Grove		10,373	5,776		10		1,561,735,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	1,188	11%	451	0	6,851,000	0.4%
Earthquake	CSZ Mw 9.0	37	0.4%	318	8	111,599,000	7.1%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Exposure Ratio
Landslide	High and Very High Susceptibility	79	0.8%	44	0	12,103,000	0.8%
Wildfire	High Hazard	0	0%	0	0	0	0%

[1]Facilities with multiple buildings were consolidated into one building complex.

[2]No damage is estimated for exposed structures with “First floor height” above the level of flooding (base flood elevation).

Table A-2. City of Cottage Grove.

	Flood 1% Annual Chance	Earthquake Moderate to Complete Damage	Landslide High and Very High Susceptibility	Wildfire High Hazard
Critical Facilities by Community	**Exposed**	**>50% Prob.**	**Exposed**	**Exposed**
Bohemia School	-	X	-	-
Cottage Grove City Hall	-	X	-	-
Cottage Grove High School	-	X	-	-
Cottage Grove Sewage Treatment	-	X	-	-
Cottage Grove State Airport	-	X	-	-
Harrison Elementary School	-	X	-	-
Lane Community College	-	-	-	-
Lincoln Middle School	-	X	-	-
Peach Health Cottage Grove Community Hospital	-	X	-	-
South Lane Fire and Rescue	-	-	-	-

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Cottage Grove building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Non-Profit			All Buildings			
Community	**Number of Buildings**	**Building Value ($)**	**Building Value per Community Total**	**Number of Buildings**	**Building Value ($)**	**Building Value per Community Total**	**Number of Buildings**	**Building Value ($)**	**Building Value per Community Total**	**Number of Buildings**	**Building Value ($)**	**Building Value per Community Total**	**Number of Buildings**	**Number of Buildings per Watershed Total**	**Building Value ($)**	**Value of Buildings per Watershed Total**
Cottage Grove	4,390	974,422	62%	459	355,404	23%	838	62,722	4%	89	169,186	11%	5,776	100.0%	1,561,735	100.0%

Table B-2. Earthquake loss estimates.

(all dollar amounts in thousands)

			Total Earthquake Damage							
			Buildings Damaged				All Buildings Changed to At Least Moderate Code			
	Total Number of Buildings	**Total Estimated Building Value ($)**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss ($)**	**Loss Ratio**	**Yellow-Tagged Buildings**	**Red-Tagged Buildings**	**Sum of Economic Loss ($)**	**Loss Ratio**
Cottage Grove	5,776	1,561,735	290	28	111,599	7.1%	28	1	27,536	1.8%

Table B-3. Flood loss estimates.

(all dollar amounts in thousands)

			10% (10-yr)			2% (50-yr)			1% (100-yr)			0.2% (500-yr)		
Community	**Total Number of Buildings**	**Total Estimated Building Value ($)**	**Number of Buildings**	**Loss Estimate ($)**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate ($)**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate ($)**	**Loss Ratio**	**Number of Buildings**	**Loss Estimate ($)**	**Loss Ratio**
Cottage Grove	5,776	1,561,735	3	3	0.0%	20	66	0.0%	700	6,851	0.4%	1,871	43,664	2.8%

Table B-4. Flood exposure.

			1% (100-yr)				
Community	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
Cottage Grove	5,776	10,373	1,188	11%	700	12%	249

Table B-5. Landslide exposure.

			(all dollar amounts in thousands)								
			Very High Susceptibility			High Susceptibility			Moderate Susceptibility		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed
Cottage Grove	5,776	1,561,735	0	0	0%	44	12,103	0.8%	760	191,918	12%

Table B-6. Wildfire exposure.

			(all dollar amounts in thousands)					
			High Hazard			Moderate Hazard		
Community	Total Number of Buildings	Total Estimated Building Value ($)	Number of Buildings	Building Value ($)	Percent of Building Value Exposed	Number of Buildings	Building Value ($)	Percent of Building Value Exposed
Cottage Grove	5,776	1,561,735	0	0	0%	0	0	0%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 5.0 and ArcGIS® Desktop® 10.7

C.2 User-Defined Facilities (UDF) Database

A UDF database was compiled for all buildings in Cottage Grove for use in both the flood and earthquake modules of Hazus-MH. The Lane County assessor database (acquired in 2022) was used to determine which tax lots had improvements (i.e., buildings) and how many building points should be included in the UDF database.

C.2.1 Locating buildings points

The Oregon Department of Geology and Mineral Industries (DOGAMI) used the SBFO-1 (Williams, 2021) dataset to help precisely locate the centroid of each building. Extra effort was spent to locate building points along the 1% and 0.2% annual chance inundation fringe. When buildings were partially within the inundation zone, the building point was moved to the centroid of the portion of the building within the inundation zone. An iterative approach was used to further refine locations of building points for the flood module by generating results, reviewing the highest value buildings, and moving the building point over a representative elevation on the lidar digital elevation model to ensure an accurate first floor height.

C.2.2 Attributing building points

Populating the required attributes for Hazus-MH was achieved through a variety of approaches. The Lane County assessor database was used whenever possible, but in many cases that database did not provide the necessary information. The following is list of attributes and their sources:

- **Longitude** and **Latitude** – Location information that provides Hazus-MH the x and y-position of the UDF point. This allows for an overlay to occur between the UDF point and the flood or earthquake input data layers. The hazard model uses this spatial overlay to determine the correct hazard risk level that will be applied to the UDF point. The format of the attribute must be in decimal degrees. A simple geometric calculation using GIS software is done on the point to derive this value.
- **Occupancy class** – An alphanumeric attribute that indicates the use of the UDF (e.g., 'RES1' is a single-family dwelling). The alphanumeric code is composed of seven broad occupancy types (RES = residential, COM = commercial, IND = industrial, AGR = agricultural, GOV = public, REL = non-profit/religious, EDU = education) and various suffixes that indicate more specific types. This code determines the damage function to be used for flood analysis. It is also used to attribute the Building Type field, discussed below, for the earthquake analysis. The code was interpreted from "Stat Class" or "Description" data found in the Lane County assessor database. When data was not available, the default value of RES1 was applied throughout.
- **Cost** – The replacement cost of an individual UDF. Loss ratio is derived from this value. Replacement cost is based on a method called RSMeans valuation (Charest, 2017) and is calculated by multiplying the building square footage by a standard cost per square foot. These standard rates per square foot are in tables within the default Hazus database.

- **Year built** – The year of construction that is used to attribute the Building Design Level field for the earthquake analysis (see "Building Design" below). The year a UDF was built is obtained from Lane County assessor database. When not available, the year of "1900" was applied.
- **Square feet** – The size of the UDF is used to pro-rate the total improvement value for tax lots with multiple UDFs. The value distribution method will ensure that UDFs with the highest square footage will be the most expensive on a given tax lot. This value is also used to pro-rate the **Number of People** field for Residential UDFs within a census block. The value was obtained from DOGAMI's building footprints; where (RES) footprints were not available, we used the Lane County assessor database.
- **Number of stories** – The number of stories for an individual UDF, along with Occupancy Class, determines the applied damage function for flood analysis. The value was obtained from the Lane County assessor database when available. For UDFs without assessor information for number of stories that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used for attribution.
- **Foundation type** – The UDF foundation type correlates with First Floor Height values in feet (see Table 3.11 in the Hazus-MH Technical Manual for the Flood Model [FEMA, 2012a]). It also functions within the flood model by indicating if a basement exists or not. UDFs with a basement have a different damage function from UDFs that do not have one. The value was obtained from the Lane County assessor database when available. For UDFs without assessor information for basements that are within the flood zone, closer inspection using Google Street View™ or available oblique imagery was used to ascertain if one exists or not.
- **First floor height** – The height in feet above grade for the lowest habitable floor. The height is factored during the depth of flooding analysis. The value is used directly by Hazus-MH, where Hazus-MH overlays a UDF location on a depth grid and using the **first floor height** determines the level of flooding occurring to a building. It is derived from the Foundation Type attribute or observation via oblique imagery or Google Street View™ mapping service.
- **Building type** – This attribute determines the construction material and structural integrity of an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information was unavailable from the Lane County assessor data, so instead it was derived from a statistical distribution based on **Occupancy class**.
- **Building design level** – This attribute determines the seismic building code for an individual UDF. It is used by Hazus-MH for estimating earthquake losses by determining which damage function will be applied. This information is derived from the **Year Built** attribute (Lane County Assessor) and state/regional Seismic Building Code benchmark years.
- **Number of people** – The estimated number of permanent residents living within an individual residential structure. It is used in the post-analysis phase to determine the amount of people affected by a given hazard. This attribute is derived from default Hazus database (United States Census Bureau, 2010a) of population per census block and distributed across residential UDFs and adjusted based on population growth estimates from PSU Population Research Center.
- **Community** – The community that a UDF is within. These areas are used in the post-analysis for reporting results.

C.2.3 Seismic building codes

Oregon initially adopted seismic building codes in the mid-1970s (Judson, 2012). The established benchmark years of code enforcement are used in determining a "design level" for individual buildings.

The design level attributes (pre code, low code, moderate code, and high code) are used in the Hazus-MH earthquake model to determine what damage functions are applied to a given building (FEMA, 2012b). The year built or the year of the most recent seismic retrofit are the main considerations for an individual design level attribute. Seismic retrofitting information for structures would be ideal for this analysis but was not available for Lane County. Table C-1 outlines the benchmark years that apply to buildings within the eastern part of Lane County (including Cottage Grove).

Table C-1. Cottage Grove seismic design level benchmark years.

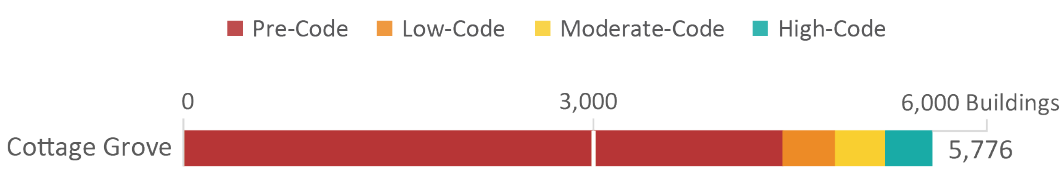
Building Type	Year Built	Design Level	Basis
Single-Family Dwelling (includes Duplexes)	prior to 1976	Pre Code	Interpretation of Judson (Judson, 2012)
	1976–1991	Low Code	
	1992–2003	Moderate Code	
	2004–2016	High Code	
Manufactured Housing	prior to 2003	Pre Code	Interpretation of OR BCD 2002 Manufactured Dwelling Special Codes (Oregon Building Codes Division, 2002)
	2003–2010	Low Code	
	2011–2016	Moderate Code	Interpretation of OR BCD 2010 Manufactured Dwelling Special Codes Update (Oregon Building Codes Division, 2010)
All other buildings	prior to 1976	Pre Code	Business Oregon 2014-0311 Oregon Benefit-Cost Analysis Tool, p. 24 (Business Oregon, 2015)
	1976–1990	Low Code	
	1991–2016	Moderate Code	

Table C-2 illustrates the current state of seismic building codes for the county.

Table C-2. Seismic design level in Cottage Grove.

		Pre Code		Low Code		Moderate Code		High Code	
Community	Total Number of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings	Number of Buildings	Percentage of Buildings
Cottage Grove	5,776	4,431	77%	476	8.2%	438	7.6%	431	7.5%

Figure C-1. Seismic design level in Cottage Grove, Oregon.



C.3 Flood Hazard Data

FEMA developed flood hazard data in 2022 for a revision of the Coast Fork Willamette River and its tributaries. The hazard data were based on new flood studies and new riverine hydrologic and hydraulic analyses. For riverine areas, the flood elevations for the 10-, 50-, 100- and 500-year events for each stream cross-section were used to develop depth of flooding raster datasets or "depth grids."

A 2-meter, lidar-based depth grid was developed for each of the 10-, 50-, 100-, and 500-year annual chance flood events. The depth grids were imported into Hazus-MH for determining the depth of flooding for areas within the FEMA flood zones.

Once the UDF database was developed into a Hazus-compliant format, the Hazus-MH methodology was applied using a Python (programming language) script developed by DOGAMI. The analysis was then run for a given flood event, and the script cross-referenced a UDF location with the depth grid to find the depth of flooding. The script then applied a specific damage function, based on a UDF's Occupancy Class [OccCls], which was used to determine the loss ratio for a given amount of flood depth, relative to the UDF's first-floor height.

C.4 Earthquake Hazard Data

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03). We also used landslide and liquefaction susceptibility data and National Earthquake Hazard Reduction Program (NEHRP) soil classification derived from Madin and others (2021). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate permanent ground deformation and associated probability.

During the Hazus-MH earthquake analysis, each UDF was analyzed given its site-specific parameters (ground motion and ground deformation) and evaluated for loss, expressed as a probability of a damage state. Specific damage functions based on Building type and Building design level were used to calculate the damage states given the site-specific parameters for each UDF. The output provided probabilities of the five damage states (None, Slight, Moderate, Extensive, Complete) from which losses in dollar amounts were derived.

C.5 Post-Analysis Quality Control

Ensuring the quality of the results from Hazus-MH flood and earthquake modules is an essential part of the process. A primary characteristic of the process is that it is iterative. A UDF database without errors is highly unlikely, so this part of the process is intended to limit and reduce the influence these errors have on the final outcome. Before applying the Hazus-MH methodology, closely examining the top 10 largest area UDFs and the top 10 most expensive UDFs is advisable. Special consideration can also be given to critical facilities due to their importance to communities.

Identifying, verifying, and correcting (if needed) the outliers in the results is the most efficient way to improve the UDF database. This can be done by sorting the results based on the loss estimates and closely scrutinizing the top 10 to 15 records. If corrections are made, then subsequent iterations are necessary. We continued checking the "loss leaders" until no more corrections were needed.

Finding anomalies and investigating possible sources of error are crucial in making corrections to the data. A wide range of corrections might be required to produce a better outcome. For example, floating homes may need to have a first-floor height adjustment or a UDF point position might need to be moved due to issues with the depth grid. Incorrect basement or occupancy type attribution could be the cause of a problem. Commonly, inconsistencies between assessor data and tax lot geometry can be the source of an error. These are just a few of the many types of problems addressed in the quality control process.

APPENDIX D. ACRONYMS AND DEFINITIONS

D.1 Acronyms

CRS	Community Rating System
CSZ	Cascadia subduction zone
DLCD	Oregon Department of Land Conservation and Development
DOGAMI	Department of Geology and Mineral Industries (State of Oregon)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRI	Fire Risk Index
GIS	Geographic Information System
NFIP	National Flood Insurance Program
NHMP	Natural hazard mitigation plan
NOAA	National Oceanic and Atmospheric Administration
ODF	Oregon Department of Forestry
OEM	Oregon Emergency Management
OFR	Open-File Report
OPDR	Oregon Partnership for Disaster Resilience
PGA	Peak ground acceleration
PGD	Permanent ground deformation
PGV	Peak ground velocity
Risk MAP	Risk Mapping, Assessment, and Planning
SHMO	State Hazard Mitigation Officer
SLIDO	State Landslide Information Layer for Oregon
UDF	User-defined facilities
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WUI	Wildland-urban interface
WWA	West Wide Wildfire Risk Assessment

D.2 Definitions

1% annual chance flood – The flood elevation that has a 1-percent chance of being equaled or exceeded each year. Sometimes referred to as the 100-year flood.

0.2% annual chance flood – The flood elevation that has a 0.2-percent chance of being equaled or exceeded each year. Sometimes referred to as the 500-year flood.

Base flood elevation (BFE) – Elevation of the 1-percent-annual-chance flood. This elevation is the basis of the insurance and floodplain management requirements of the NFIP.

Critical facilities – Facilities that, if damaged, would present an immediate threat to life, public health, and safety. As categorized in HAZUS-MH, critical facilities include hospitals, emergency operations centers, police stations, fire stations and schools.

Exposure – Determination of whether a building is within or outside of a hazard zone. No loss estimation is modeled.

Flood Insurance Rate Map (FIRM) – An official map of a community, on which FEMA has delineated both the SFHAs and the risk premium zones applicable to the community.

Flood Insurance Study (FIS) – Contains an examination, evaluation, and determination of the flood hazards of a community and, if appropriate, the corresponding water-surface elevations.

Hazus-MH – A GIS-based risk assessment methodology and software application created by FEMA and the National Institute of Building Sciences for analyzing potential losses from floods, hurricane winds, and earthquakes.

Lidar – A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Lidar is popularly used as a technology to make high-resolution maps.

Liquefaction – Describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually an earthquake, causing it to behave like liquid.

Loss Ratio – The expression of loss as a fraction of the value of the local inventory (total value/loss).

Magnitude – A scale used by seismologists to measure the size of earthquakes in terms of energy released.

Risk – Probability multiplied by consequence; the degree of probability that a loss or injury may occur as a result of a natural hazard. Sometimes referred to as vulnerability.

Risk MAP – The vision of this FEMA strategy is to work collaboratively with State, local, and tribal entities to deliver quality flood data that increases public awareness and leads to action that reduces risk to life and property.

Riverine – Of or produced by a river. Riverine floodplains have readily identifiable channels.

Susceptibility – Degree of proneness to natural hazards that is determined based on physical characteristics that are present.

Vulnerability – Characteristics that make people or assets more susceptible to a natural hazard.

APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

STATE OF OREGON
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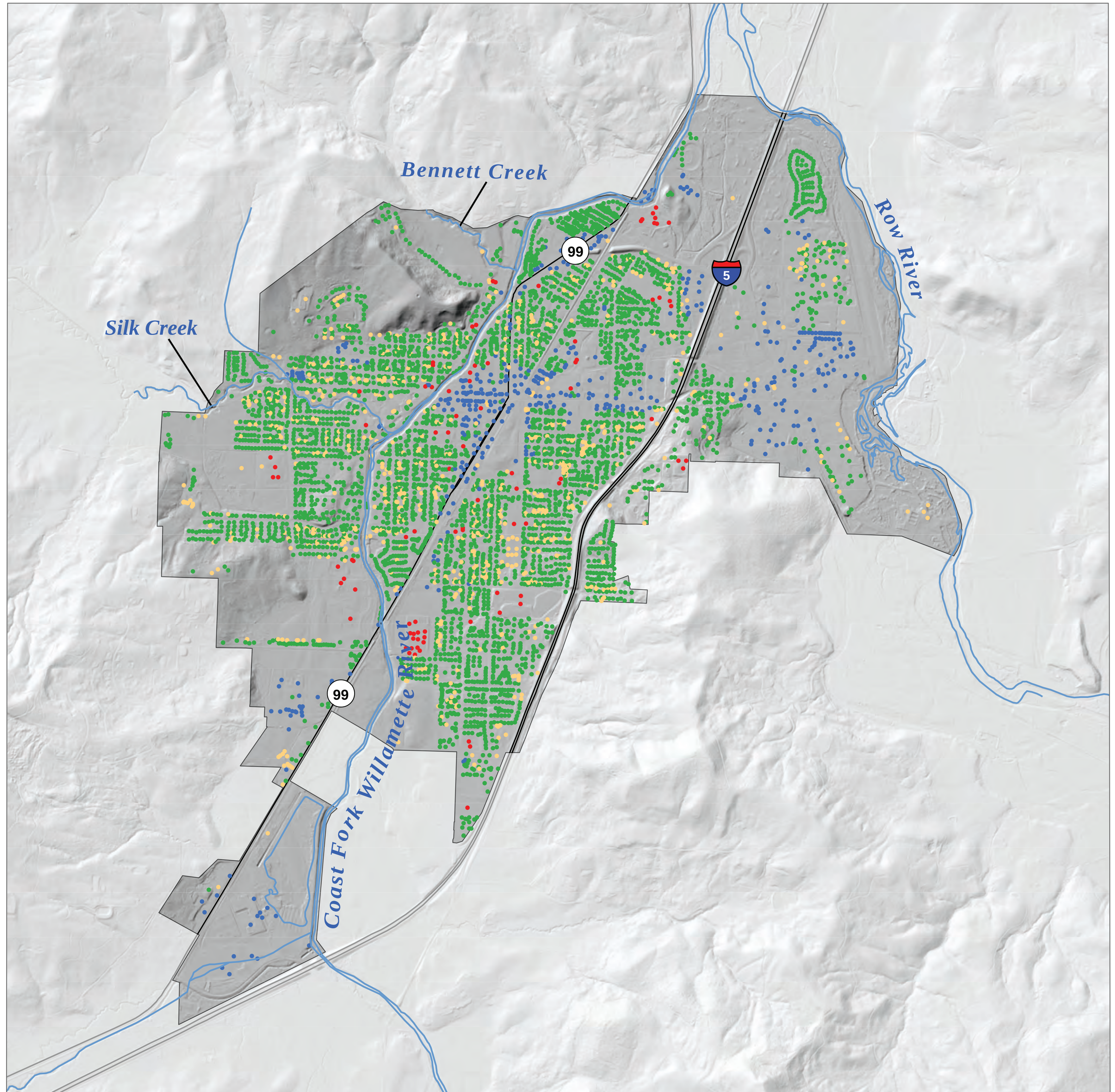
Building Distribution Map of Cottage Grove, Oregon

PLATE 1



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Building Occupancy

- Agricultural / Utility
- Commercial / Industrial
- Public / Nonprofit
- Residential

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

	Number of Buildings at Risk				
Community	Total Number of Buildings	CSZ Earthquake red or yellow-tagged	Flood Exposure	Landslide Exposure	Wildfire Exposure
Cottage Grove	5,776	318	700	44	0

Data Sources:
Building footprints: Statewide Building Footprints of Oregon (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitutefor site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication. See the accompanying text report for more details on the limitations of the methods and data used to prepare this publication.

This map is an overview map and not intended to provide details at the community scale. The GIS data that is published with the Cottage Grove Natural Hazard Risk Assessment can be used to inform regarding queries at the community scale.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES
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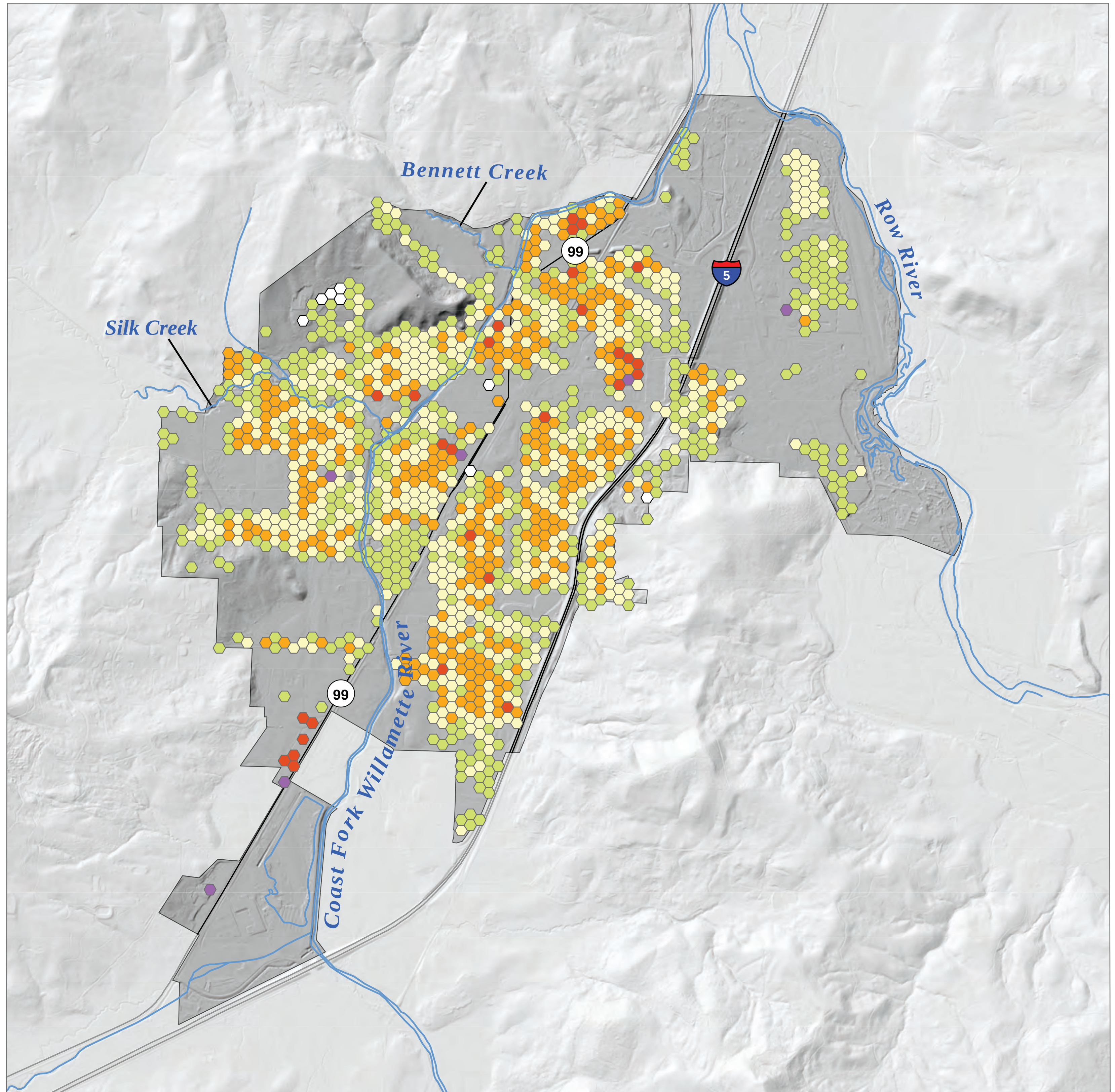
Population Density Map of Cottage Grove, Oregon

PLATE 2



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

People per 100 acres

- Building(s) present no permanent residents
- 1 - 5
- 6 - 10
- 11 - 20
- 21 - 30
- 31 +

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

Community	Number of Residents at Risk				
	Total Number of Residents	CSZ Earthquake displaced population	Flood Exposure	Landslide Exposure	Wildfire Exposure
Cottage Grove	10,373	37	1,188	79	0

Data Sources:
Population data: U.S. Census (2010) & Portland State University (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Cascadia Subduction Earthquake Shaking Map of Cottage Grove, Oregon

PLATE 3

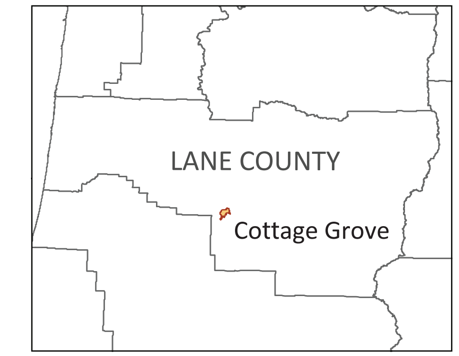
Modified Mercalli	Perceived Shaking	Potential Damage	Peak Ground Acceleration (g)
I	Not felt	None	< 0.000464
II	Weak	None	0.000464 - 0.00297
III	Weak	None	0.000464 - 0.00297
IV	Light	None	0.00297 - 0.0276
V	Moderate	Very Light	0.0276 - 0.115
VI	Strong	Light	0.115 - 0.215
VII	Very Strong	Moderate	0.215 - 0.401
VIII	Severe	Mod./Heavy	0.401 - 0.747
IX	Violent	Heavy	0.747 - 1.39
X	Extreme	Very Heavy	> 1.39

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

	Earthquake Risk					
Community	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%

Peak Ground Acceleration (PGA) is the maximum acceleration in a given location or rather how hard the ground is shaking during an earthquake. It is one measurement of ground motion, which is closely associated with the level of damage that occurs from an earthquake.



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

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Data Sources:
Earthquake peak ground acceleration: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Coseismic Landslide Map of Cottage Grove, Oregon

PLATE 4

Coseismic Landslide Susceptibility (Wet)

0 (None) — 9 (High)

Coseismic landslide is a type of ground deformation that occurs during an earthquake where slope failure creates a mass movement of rock and debris. Saturated ground increases the susceptibility of a landslide occuring from seismic shaking. Coseismic landslides are a significant factor in the risk from earthquake hazard.

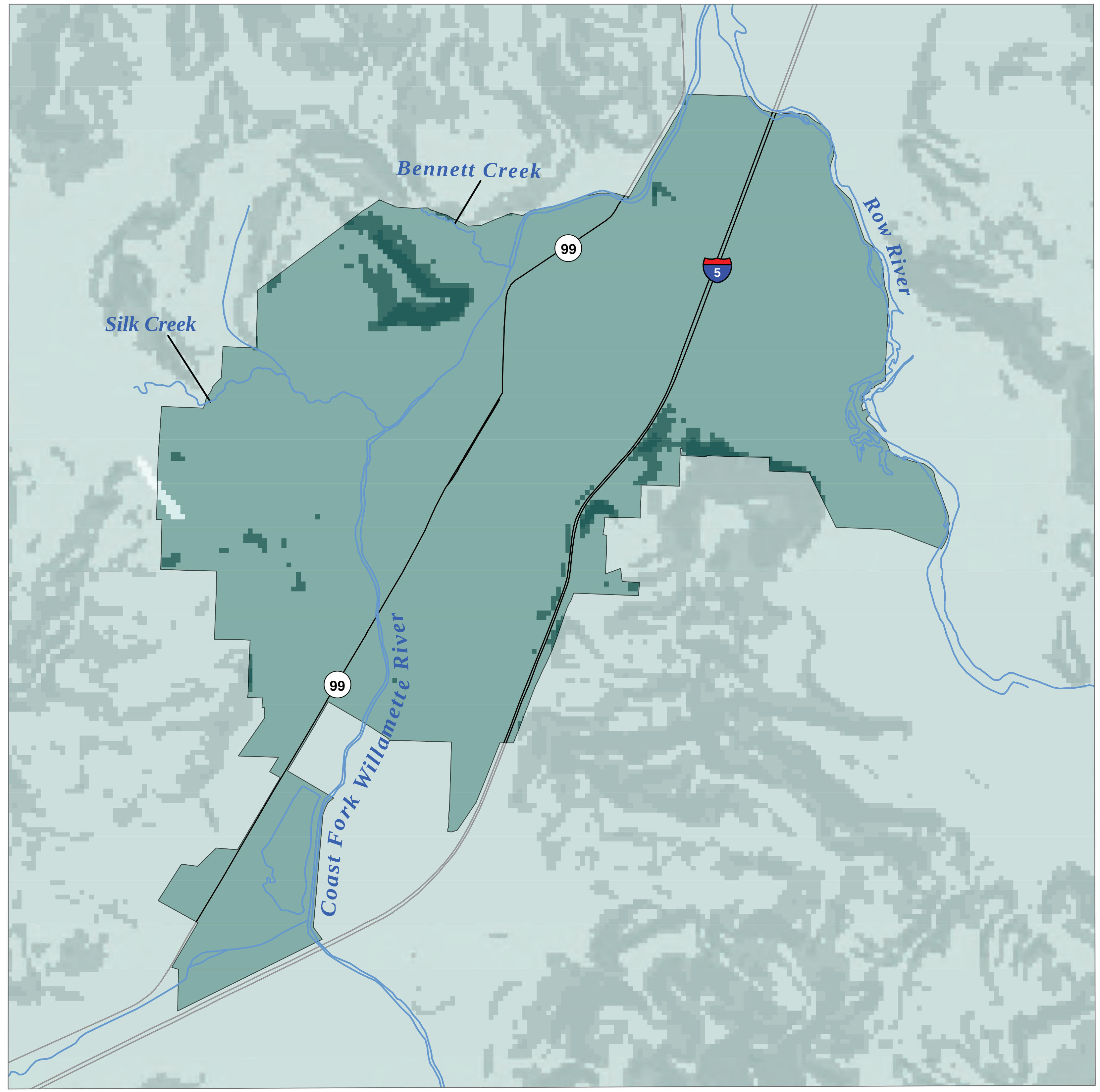
Map Elements

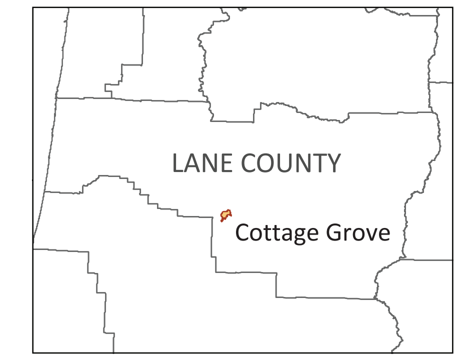
Cottage Grove Urban Growth

Boundary Streams

Major Roads

Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
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Data Sources:
Coseismic landslide: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Liquefaction Map of Cottage Grove, Oregon

PLATE 5

Liquefaction Susceptibility

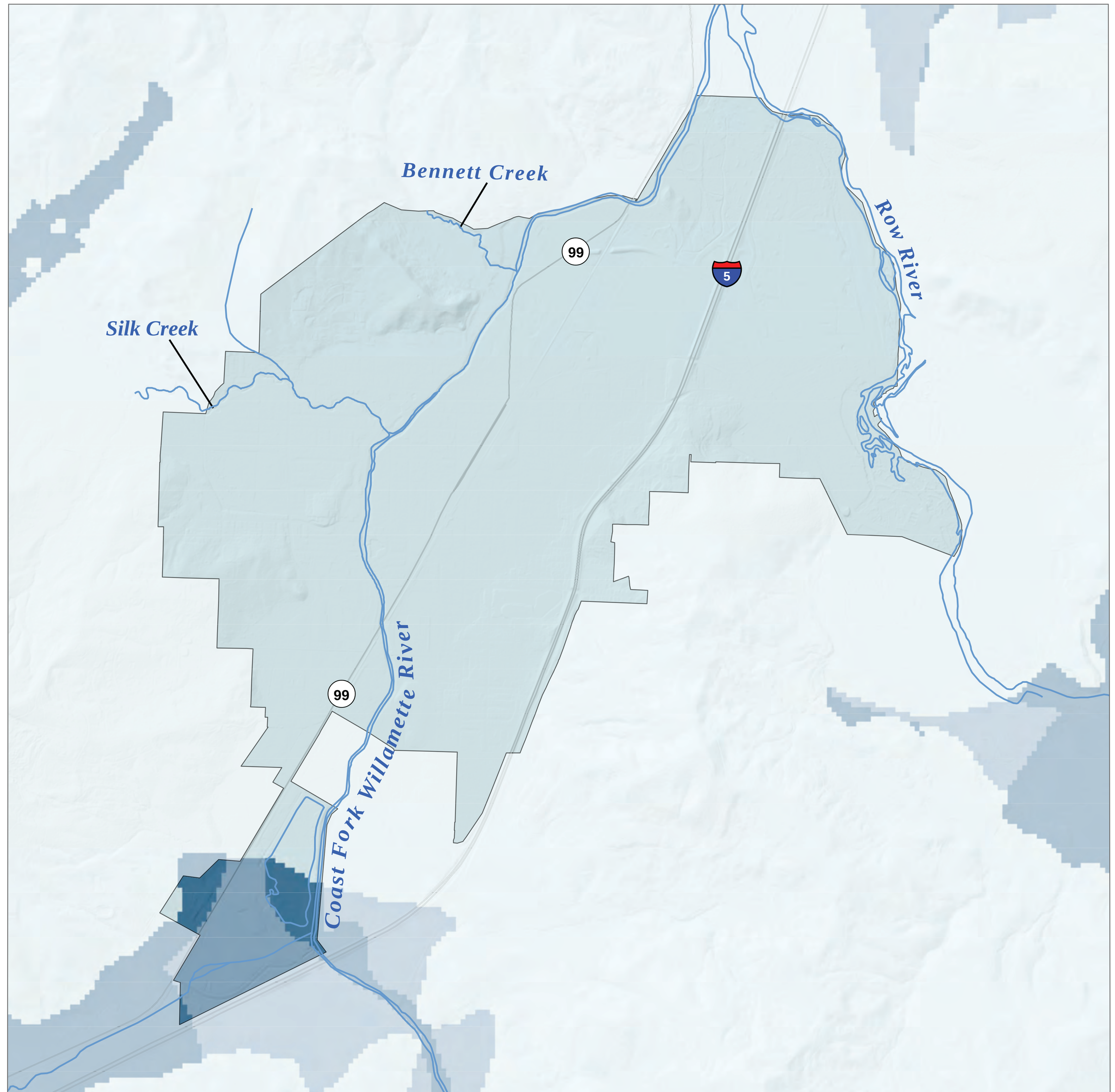
- Low or None
- Moderate
- High
- Very High

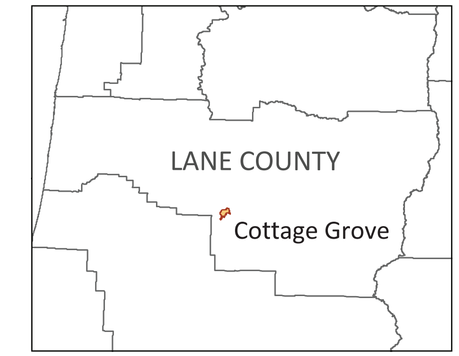
Liquefaction is a type of ground deformation that occurs during an earthquake where saturated, non-cohesive soil contracts and liquefies. The ground that becomes liquefied can no longer support heavy structures that are built on top of it. Liquefaction is a significant factor in the risk from earthquake hazard.

Map Elements

- Cottage Grove Urban Growth Boundary
- Streams
- Major Roads

Community	Earthquake Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%





0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
N

Data Sources:
Liquefaction: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Site Amplification Class Map of Cottage Grove, Oregon

PLATE 6

NEHRP Class

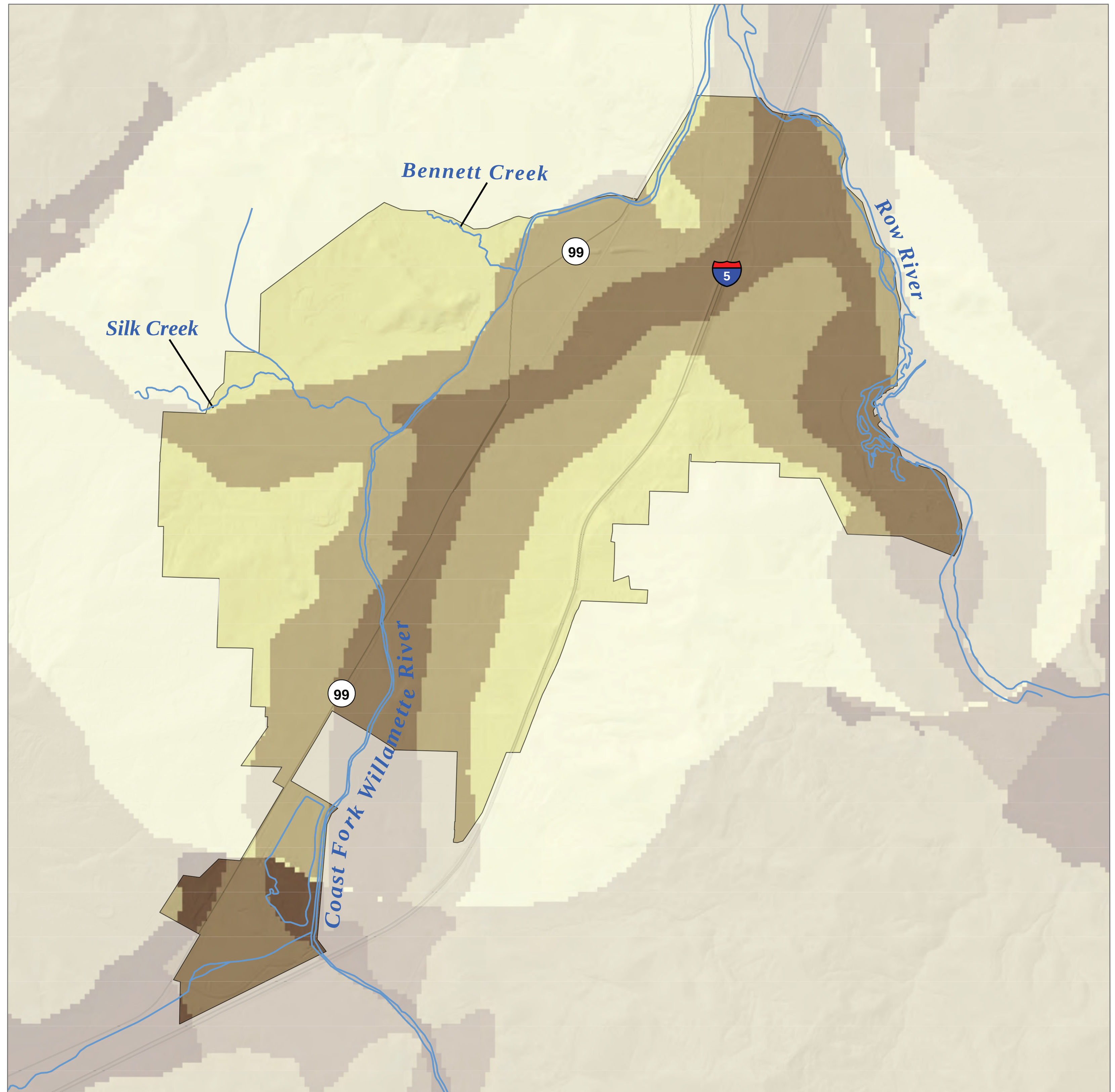
- B
- C
- D
- E, F

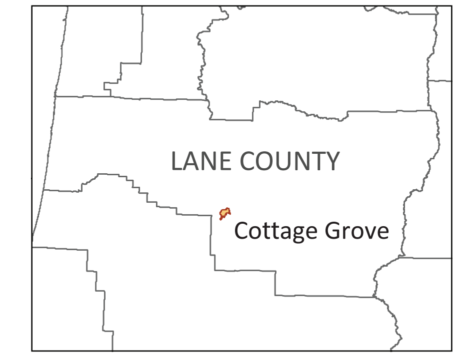
Site Amplification is the degree to which soil types attenuate (weaken) or amplify (strengthen) seismic waves produced from an earthquake. The National Earthquake Hazards Reduc-tion Program (NEHRP) classifies these geologic units into soft rock (B), dense soil or soft rock (C), stiff soil (D), and soft clay or soil (E, F). NEHRP soils can significantly affect the level of shaking and amount of damage that occurs at a specifically location during an earthquake

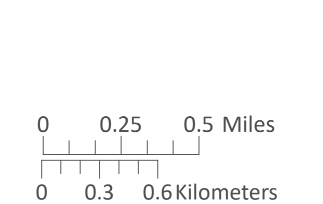
Map Elements

- Cottage Grove Urban Growth
- Boundary Streams
- Major Roads

	Earthquake Risk					
Community	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	37	0.4%	318	8	111,599,000	7.1%







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Data Sources:
Soil amplification: Oregon Seismic Hazard Database (2021)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

Projection: NAD 1983 HARN Oregon Statewide Lambert
Software: Esri ArcMap 10, Adobe Illustrator CC

Cartography by: Matt C. Williams, 2022

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Flood Hazard Map of Cottage Grove, Oregon

PLATE 7

Flood Hazard Zone

100-Year Flood (1% annual chance)

The flood hazard data show areas expected to be inundated during a 100-year flood event. Flooding sources include riverine. Areas are consistent with the regulatory flood zones depicted in Lane County's Digital Flood Insurance Rate Maps.

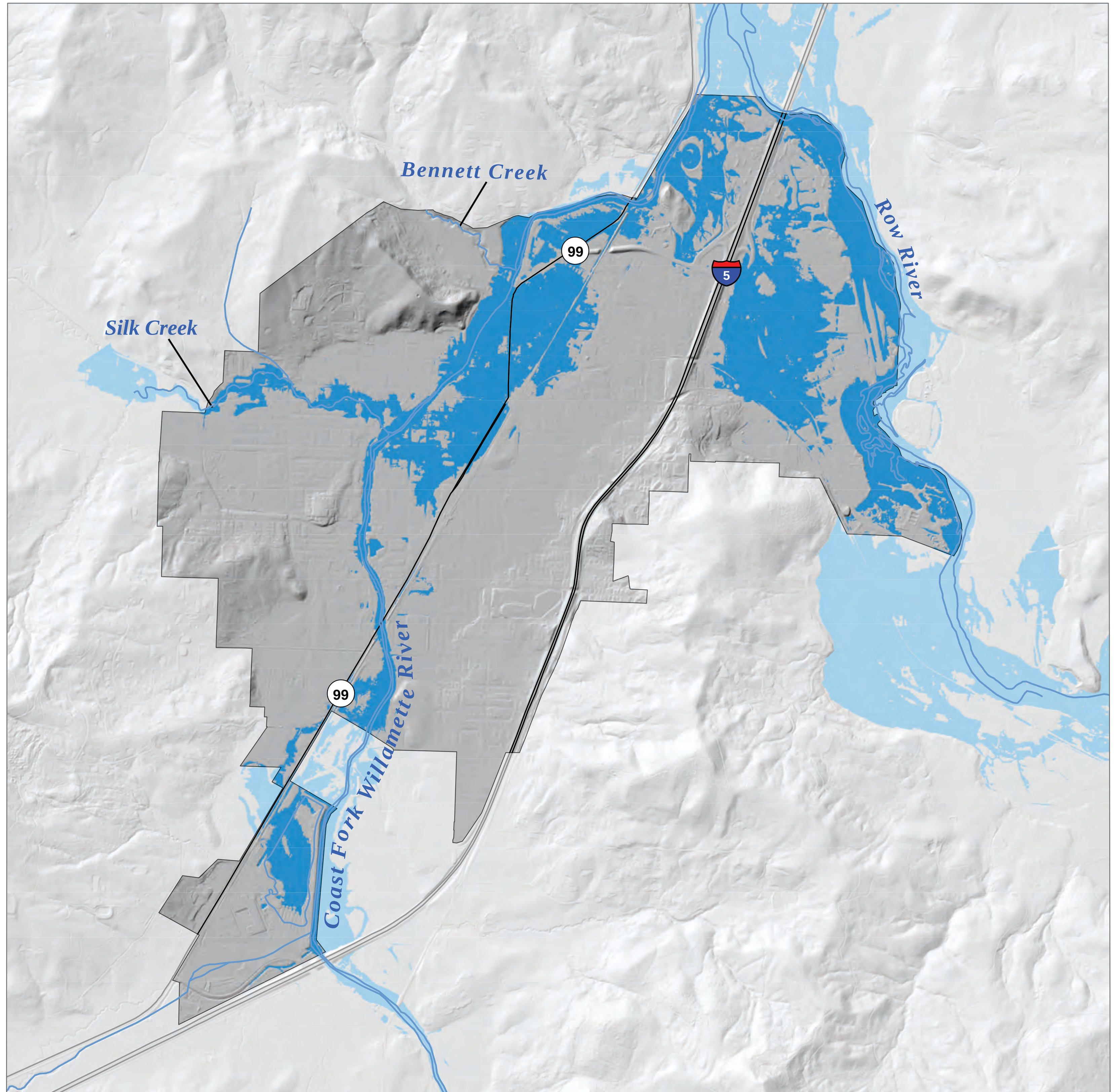
Map Elements

Cottage Grove Urban Growth Boundary

Streams

Major Roads

Community	Flood Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilites	Loss Estimate ($)	Loss Ratio
Cottage Grove	1,188	11%	451	0	6,851,000	0.4%



0 0.25 0.5 Miles
0 0.3 0.6 Kilometers
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Data Sources:
Flood hazard zone (100-year): Lane County Flood Insurance Rate Map - Draft (2022)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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Landslide Susceptibility Map of Cottage Grove, Oregon

PLATE 8

Landslide Susceptibility

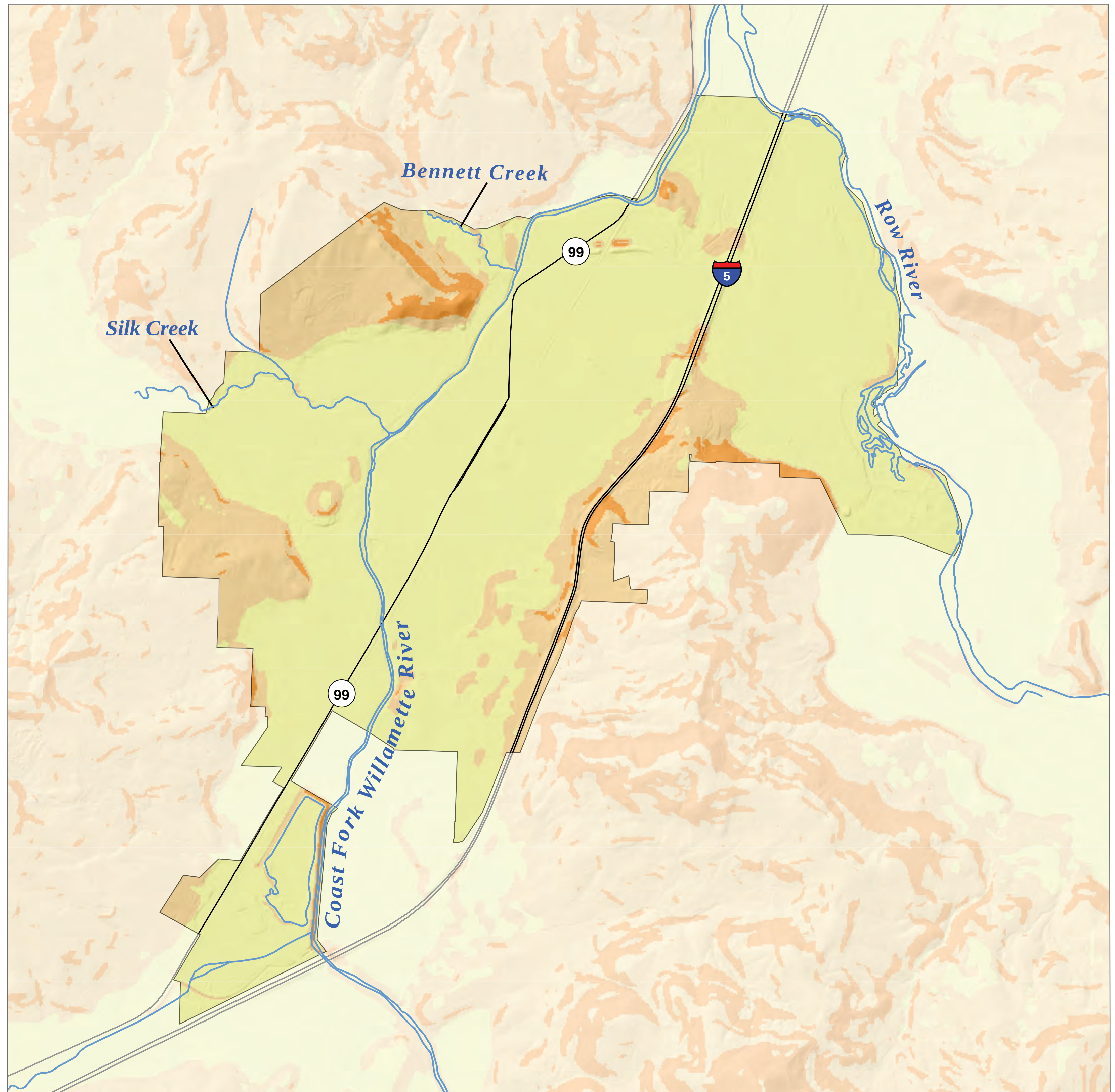
- Low
- Moderate
- High
- Very High

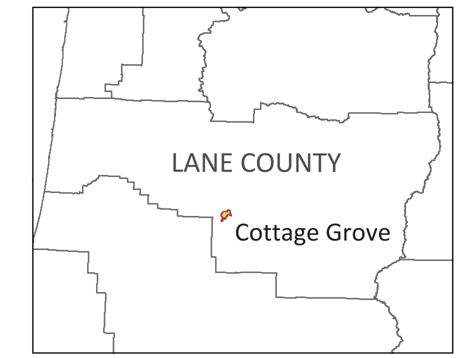
Landslide susceptibility is categorized as Low, Moderate, High, and Very High which describes the general level of susceptibility to landslide hazard. The dataset is an aggregation of three primary sources: landslide inventory (SLIDO), generalized geology, and slope.

Map Elements

- Cottage Grove Urban Growth
- Boundary Streams
- Major Roads

Community	Landslide Risk					
	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilites	Building Value Exposed ($)	Exposure Ratio
Cottage Grove	79	0.8%	44	0	12,103,000	0.8%





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Data Sources:
Landslide susceptibility: Oregon Department of Geology, Burns and others (2016)
Roads: Oregon Department of Transportation Signed Routes (2013)
Place names: U.S. Geological Survey Geographic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: Oregon Lidar Consortium (2017)
Hydrography: U.S. Geological Survey National Hydrography Dataset (2017)

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