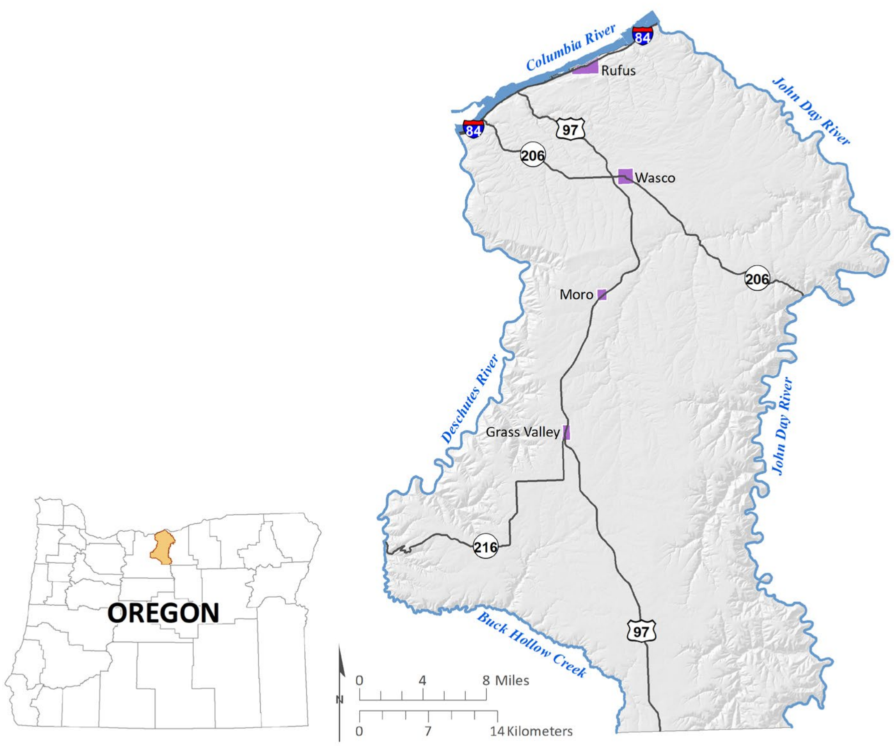
State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

OPEN-FILE REPORT O-21-06

NATURAL HAZARD RISK REPORT FOR SHERMAN COUNTY, OREGON

INCLUDING THE CITIES OF GRASS VALLEY, MORO, RUFUS, AND WASCO



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2021

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Cover image: Study area of the Sherman County Risk Report. Map depicts Sherman County, Oregon and incorporated communities included in this report.

WHAT'S IN THIS REPORT?

This report describes the methods and results of natural hazard risk assessments for Sherman County communities. The risk assessments can help communities better plan for disaster.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAP PLATES

Appendix E

GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

See the digital publication folder for files.
Geodatabase is Esri® version 10.2 format. Metadata are embedded in the geodatabase and are also provided as separate .xml format files.

Sherman_County_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 communities of Sherman County, Oregon, with funding provided by the Federal Emergency Management Agency (FEMA). It describes the methods and results of the natural hazard risk assessments performed in 2018 by the Oregon Department of Geology and Mineral Industries (DOGAMI) within the study area. We also performed an update to the earthquake and flood analysis in 2021. The purpose of this project is to provide communities within the study area a detailed risk assessment of the natural hazards that affect them to enable them to compare hazards and act to reduce their risk. The risk assessment contained in this project quantifies the impacts of natural hazards to these communities and enhances the decision-making process in planning for disaster.

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

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 location and vulnerability 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; some were produced using high-resolution lidar topographic data. While not all the data sources used in the report are countywide, each hazard dataset was the best available at the time of writing.

In the third task, we performed risk assessments 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 Hazus-MH methodology, and (2) calculated number of buildings, their value, and associated populations exposed to earthquake and flood, or susceptible to varying levels of hazard from landslides and wildfires.

The findings and conclusions of this report show the potential impacts of hazards in communities within Sherman County. An earthquake can cause minor to moderate damage and losses throughout the county. The communities of Grass Valley and Moro have moderate risk from flooding, and we quantify the number of elevated structures that are less vulnerable to flood hazard in the study area. Our analysis shows that new landslide mapping based on improved methods and lidar information will increase the accuracy of future risk assessments. During the time of writing, the best available data show that wildfire risk is high for the overall study area. Our findings indicate that most of the critical facilities in the study area are at high risk from an earthquake and wildfire. We also note that the biggest causes of population displacement are wildfire and flood hazards. Lastly, we demonstrate that this risk assessment can be a valuable tool to local decision-makers.

Results were broken out for the following geographic areas:

- Unincorporated Sherman County (rural)
- City of Moro
- City of Wasco
- City of Grass Valley
- City of Rufus

Selected Countywide Results
Total buildings: 2,405
Total estimated building value: $543 million

2500-year Probabilistic Magnitude 7.0 Earthquake
Red-tagged buildings[a]: 13
Yellow-tagged buildings[b]: 58
Loss estimate: $37 million

100-year Flood Scenario
Number of buildings damaged: 68
Loss estimate: $1.9 million

Landslide (High and Very High-Susceptibility)
Number of buildings exposed: 29
Exposed building value: $7.7 million

Wildfire Results (High Risk)
Number of buildings exposed: 273
Exposed building value: $53 million

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

1.0 INTRODUCTION

> ***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.

A natural hazard is a naturally occurring phenomenon that can negatively impact humans, which is typically characterized as risk. A natural hazard risk assessment analyzes how a hazard could affect the built environment, population, the cost of recovery, and identifies potential risk. In natural hazard mitigation planning, risk assessments are the basis for developing mitigation strategies and actions. A risk assessment enhances the decision-making process, so that steps can be taken to prepare for a potential hazard event.

This is the first natural hazard risk assessment analyzing individual buildings and resident population in Sherman County. It is therefore the most detailed and comprehensive analysis to date of natural hazard risk and provides a comparative perspective never before available. In this report, we describe our assessment results, which quantify the various levels of risk that each hazard presents to Sherman County communities.

The northcentral part of Oregon is typically characterized as the Columbia Plateau and is subject to natural hazards including earthquakes, riverine flooding, landslides, and wildfire. This region of the state is also sparsely populated with most of the development occurring in the county's four incorporated cities. The primary goal of the risk assessment is to inform communities of the risk posed by various natural hazards and to be a resource for risk reduction actions.

1.1 Purpose

The purpose of this project is to help communities in the study area better understand their risk and increase resilience to natural hazards that are present in their communities. This is accomplished by providing accurate, detailed, and best available information about these hazards and by measuring 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 the methods and results for these objectives. We describe the methods for creating the building and population information used in this project. Two primary methods (Hazus-MH or exposure), depending on the type of hazard, were used to assess risk. Results for each hazard type are reported on a countywide basis within each hazard section, and community based results are reported in detail in **Appendix A: Community Risk Profiles**. **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 maps showing county-wide hazard maps.

1.2 Study Area

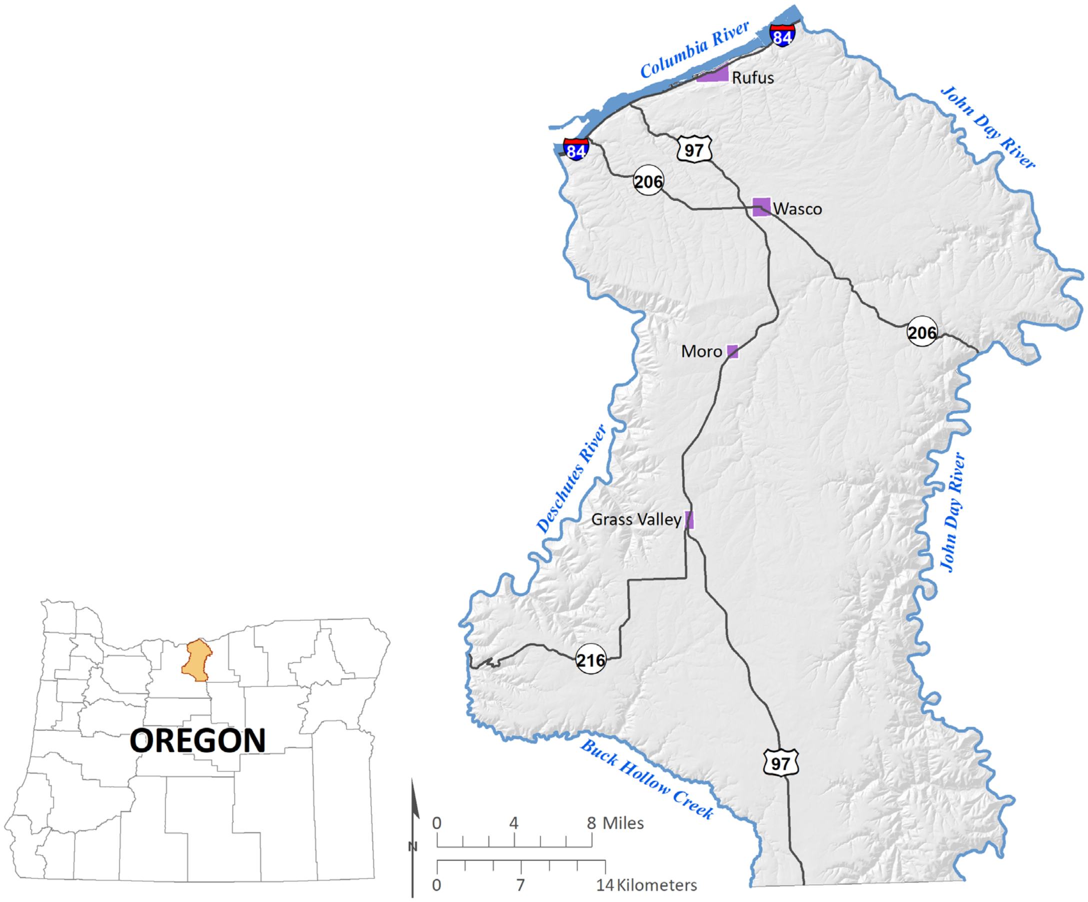
The study area for this project is the entirety of Sherman County, Oregon. Sherman County is located in the northcentral portion of the state and is bordered by Wasco County on the west and south, Gilliam County on the east, and by the Columbia River on the north. The total area of Sherman County is 827 square miles (2,142 square kilometers). A significant portion of the county is privately owned agricultural land. The federally owned sections within Sherman County are along the Deschutes and John Day rivers, which make the county's western and eastern borders, respectively.

The geography of Sherman County consists mostly of the rolling topography found within the Columbia Plateau within the central part of the county. Almost all the borders of Sherman County are defined by river valleys that often form canyons. There are very few trees in this part of Oregon and land cover is primarily grasslands or other types of agricultural vegetation, undeveloped areas tend to be rocky and barren scrublands.

The population of Sherman County is 1,765 according to the 2010 U.S. Census Bureau (2010a). The county seat and county's largest community is the City of Wasco. The residents of the county are fairly evenly distributed throughout the study area, with small clusters in each of the incorporated communities. The incorporated communities of the study area are Grass Valley, Moro, Rufus, and Wasco (**Figure 1-1**).

No unincorporated communities within Sherman County were selected as separate communities from the unincorporated county. DOGAMI considers a community's population size and density to determine if it should be distinct from the overall unincorporated county. We use census block and building count information to make these determinations.

Figure 1-1. Study area: Sherman County with communities in this study identified.



1.3 Project Scope

For this risk assessment, we applied a quantitative approach to buildings and population. We limited the project scope to 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, where buildings are categorized based on their location relative to various hazard zones. To account for impacts on population (permanent residents only), 2010 U.S. Census data (U.S. Census Bureau, 2010a) were associated with residential buildings.

A critical component of this risk assessment is a countywide building inventory developed from building footprint data and the Sherman County tax lot database. 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 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 2,500-year probabilistic magnitude (Mw) 7.0 scenario

Flood Risk Assessment

- Hazus-MH loss estimation to two riverine recurrence intervals (1% and 0.2% annual chance)
- Exposure to 1% annual chance recurrence interval

Landslide Risk Assessment

- Exposure based on landslide susceptibility (low to very high)

Wildfire Risk Assessment

- Exposure based on wildfire risk index (low to high)

Table 1-1. Hazard data sources for Sherman County.

Hazard	Scenario or Classes	Scale/Level of Detail	Data Source
Earthquake (includes liquefaction and coseismic landslides)	2,500-year probabilistic Mw 7.0	Statewide	DOGAMI (Madin and others, 2021)
Flood	Depth grids: 1% (100-yr) 0.2% (500-yr)	Countywide	FEMA – draft data generated for 2021 Countywide National Flood Insurance Program mapping.
Landslide*	Susceptibility (Low, Moderate, High, Very High)	Statewide	DOGAMI (Burns and others, 2016)
Wildfire	Risk (Low, Moderate, High)	Regional (Western United States)	Oregon Department of Forestry (Sanborn Map Company, Inc., 2013)

*Landslide data comprise a composite dataset where the level of detail varies greatly from place to place within the state. Refer to Section 3.4.1 or the report by Burns and others (2016) for more information.

1.4 Previous Studies

One previous earthquake risk assessment that included Sherman County was conducted by DOGAMI. Wang and Clark (1999: DOGAMI Special Paper 29) ran two general level Hazus-MH earthquake analyses, a magnitude 8.5 CSZ earthquake and a 500-year probabilistic earthquake scenario, for the entire state of Oregon. In those analyses Sherman County was ranked in the lower range for loss ratio relative to most counties in the state.

We did not compare the results of this project with the results of the previous study because of limited time and funding and differences in methodologies.

2.0 METHODS

2.1 Hazus-MH Loss Estimation

According to FEMA (FEMA, 2012a, p. 1-1), "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."

Key Terms:

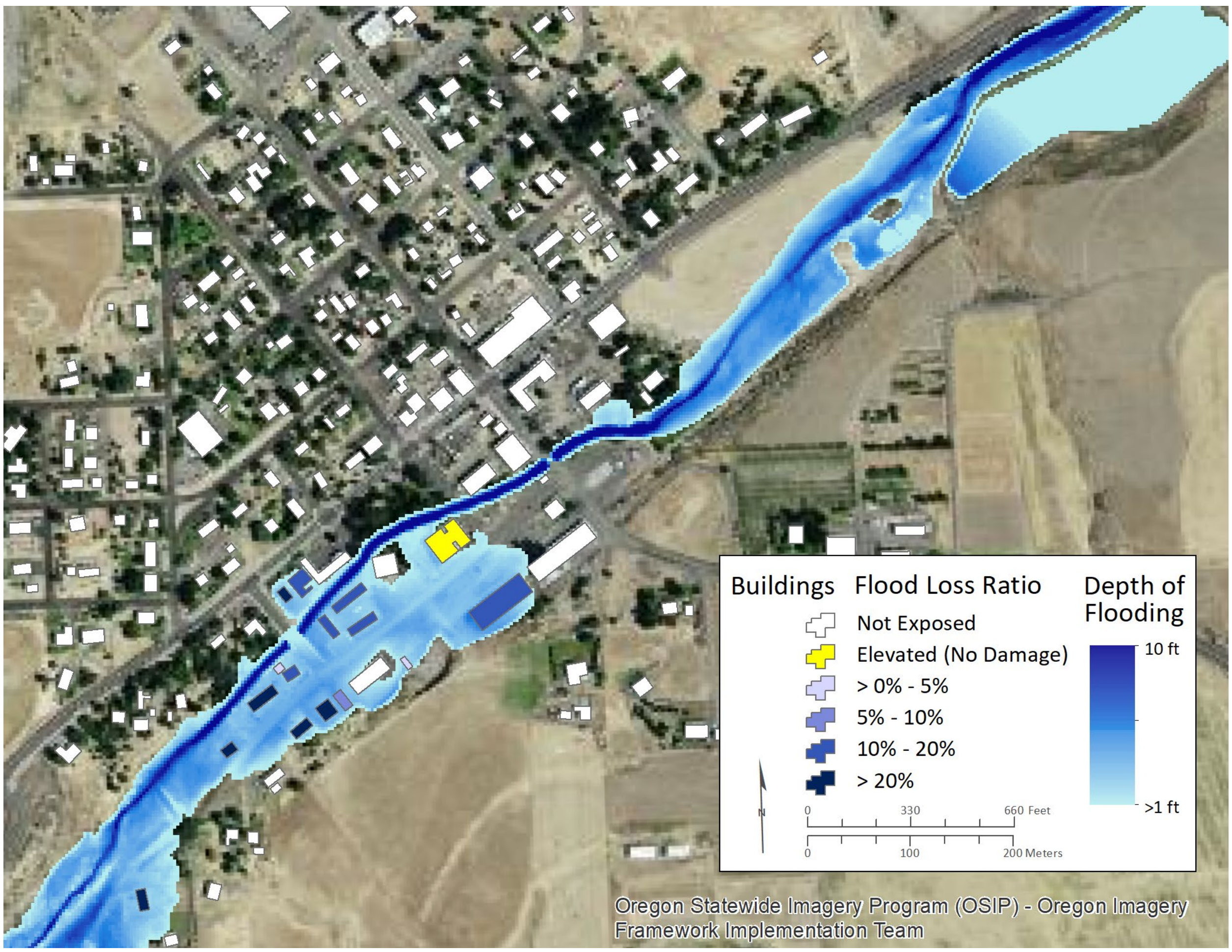
- *Loss estimation:* Damage that occurs to a building in an earthquake or flood scenario, as modeled with Hazus-MH methodology.
- *Loss ratio:* Percentage of estimated loss relative to the total value.

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 estimations 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 square footage 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 3.0 (FEMA, 2015), 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 the community of Grass Valley.



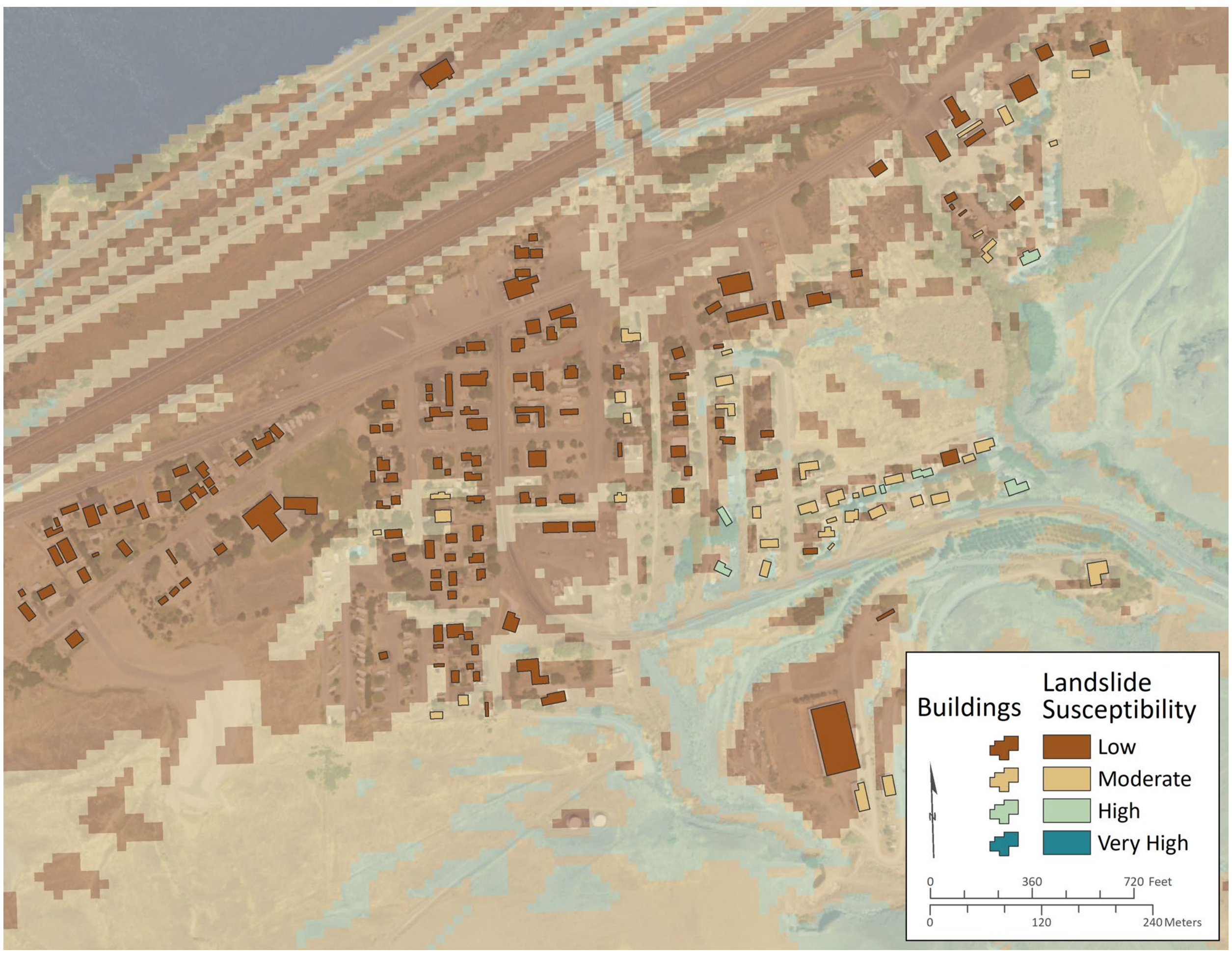
2.2 Exposure

> ***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.

Exposure methodology identifies the buildings and population that are within a particular natural hazard zone. This is an alternative for natural hazards that do not have readily available damage functions to relate damage to the intensity of the hazard. 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 because without a damage function a loss ratio cannot be calculated. For example. **Figure 2-2** shows buildings that are exposed to different areas of landslide susceptibility.

Exposure is used for landslide and wildfire to quantify buildings and residents at risk. For comparison with loss estimates, exposure is also used for the 1% annual chance flood.

Figure 2-2. Landslide susceptibility areas and building exposure example in the City of Rufus, Oregon.



2.3 Building Inventory

A key piece of the risk assessment is the countywide building inventory. This inventory consists of all buildings larger than 400 square feet (122 square meters), as determined from existing building footprints. **Figure 2-3** shows an example of building inventory occupancy types used in the Hazus-MH and exposure analyses in Sherman County. 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, 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 Rufus, Oregon.

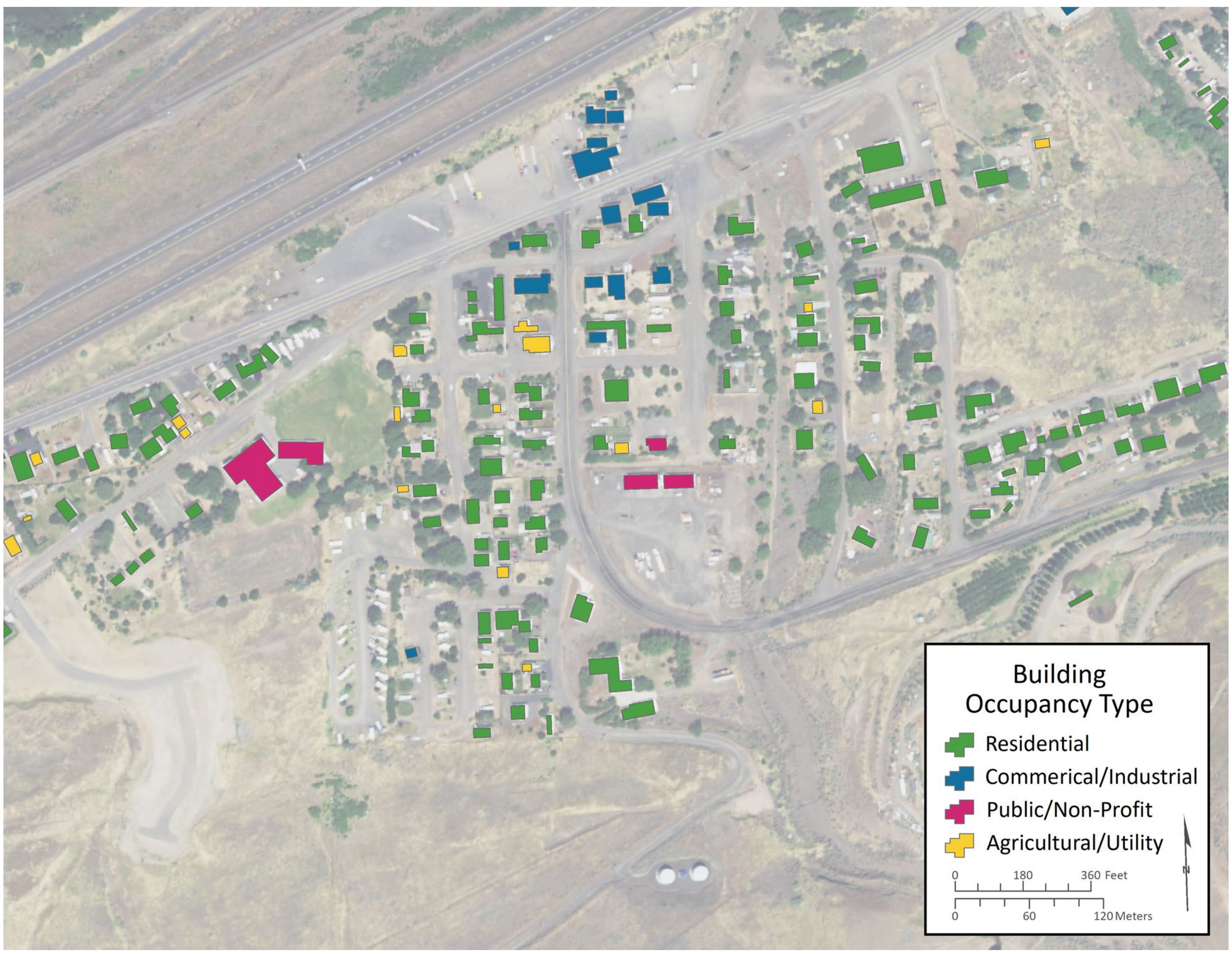


Table 2-1 shows the distribution of building count and value within the UDF database for Sherman County. A table detailing the occupancy class distribution by community is included in **Appendix B: Detailed Risk Assessment Tables**.

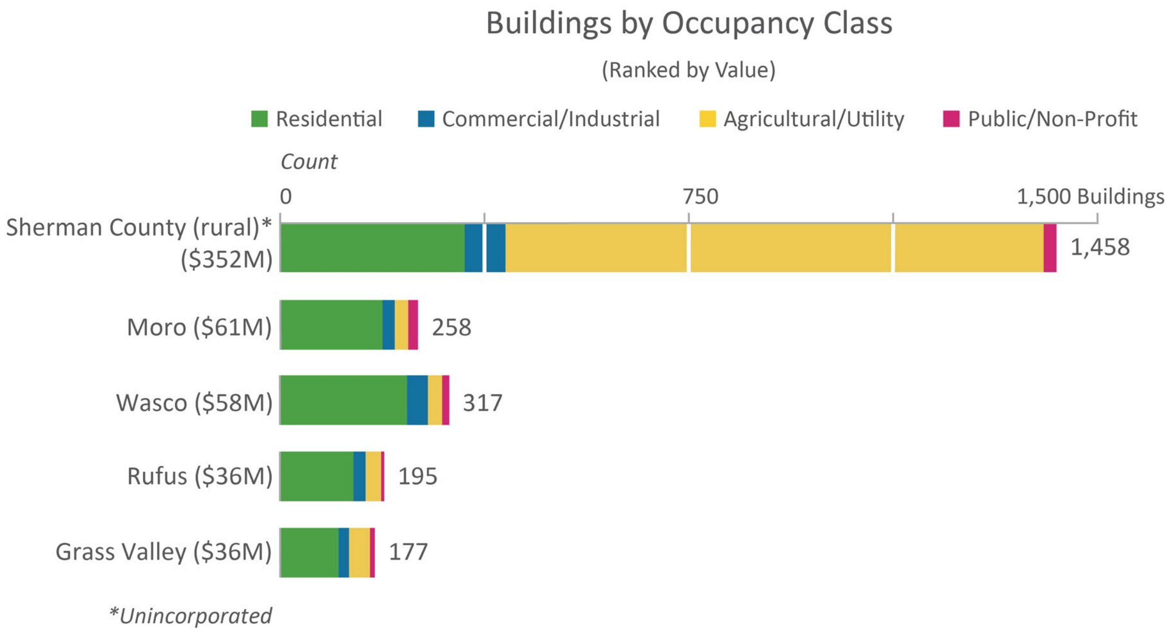
Table 2-1. Sherman County building inventory.

Community	Total Number of Buildings	Percentage of Buildings of Sherman County	Total Estimated Building Value ($)	Percentage of Building Value of Sherman County
Unincorporated County (rural)	1,458	61%	351,505,000	65%
Grass Valley	177	7.4%	35,781,000	6.6%
Moro	258	10.7%	61,210,000	11.3%
Rufus	195	8.1%	35,965,000	6.6%
Wasco	317	13.2%	58,194,000	10.7%
Total Sherman County	2,405	100%	542,655,000	100%

The building inventory was developed from several data sources and was refined for use in loss estimation and exposure analyses. Building footprints in the database were digitized from high-resolution lidar collected in 2010 through 2016 (Oregon Lidar Consortium [OLC], Wasco; USGS, Cottonwood Canyon; OLC, Grass Valley; see http://www.oregongeology.org/lidar/collectinglidar.htm). The building footprints provide a spatial location and 2D representation of a structure. The total number of buildings within the study area was 2,405.

Sherman County building footprints were attributed initially by referencing the Oregon Department of Land Conservation and Development's (DLCD) GIS dataset for zoning or land use (https://www.oregon.gov/lcd/About/Pages/Maps-Data-Tools.aspx, accessed in 2018). We made assumptions about the occupancy class of the buildings based on the various areas that were zoned for a specific purpose. Further refinement of the building attributes occurred through the use of Google Street View™ mapping service within the incorporated communities. Within the rural areas of the county, we assumed that clusters of buildings were farms and were attributed as agricultural with at least one building attributed as residential. The resulting data was a dataset of UDF points that contain attributes for each building. These points are used in the risk assessments for both loss estimation and exposure analysis. **Figure 2-4** illustrates the building value and occupancy class across the communities of Sherman County.

Figure 2-4. Community building value in Sherman County by occupancy class.



Note that "Sherman County (rural)" excludes incorporated communities.

We attributed 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 attributed include hospitals, schools, fire stations, police stations, and emergency operations. In addition to these occupancy types, we considered other types based on local input or special considerations that are specific to the study area that would be essential during a natural hazard event, such as public works and water treatment facilities. Critical facilities are important to note because they play a crucial role in emergency response efforts. Communities with critical facilities that can function during and immediately after a natural disaster are more resilient than those with critical facilities inoperable after a disaster. **Table 2-2** shows the critical facilities on a community basis. Critical facilities are listed for each community in **Appendix A**.

Table 2-2. Sherman County critical facilities inventory.

	Hospital & Clinic		School		Police/Fire		Emergency Services		Other*		Total	
Community	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)	Count	Value ($)
(all dollar amounts in thousands)												
Unincorp. County (rural)	0	0	1	12,168	0	0	0	0	3	851	4	13,019
Grass Valley	0	0	0	0	1	393	0	0	1	496	2	888
Moro	1	1,034	0	0	1	2,110	1	689	1	173	4	4,005
Rufus	0	0	0	0	1	761	0	0	3	2,926	4	3,687
Wasco	0	0	1	3,315	1	2,688	0	0	3	1,260	5	7,263
Total Sherman County	1	1,034	2	15,483	4	5,952	1	689	11	5,706	19	28,862

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

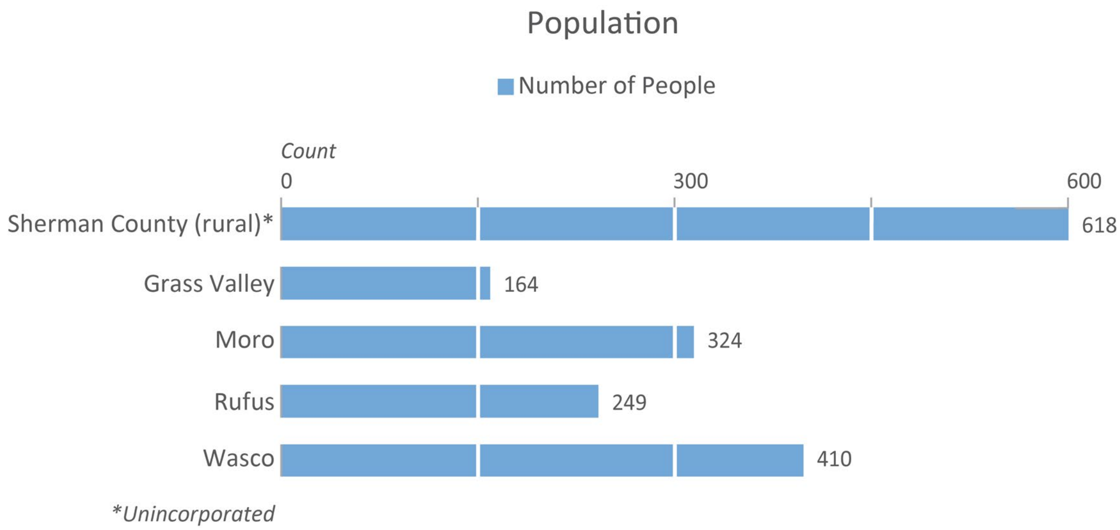
* Category includes buildings that are not traditional (emergency response) critical facilities but considered critical during an emergency based on input from local stakeholders (e.g., water treatment facilities or airports).

2.4 Population

Within the UDF database, the population of permanent residents reported per census block was distributed among residential buildings and pro-rated based on square footage (**Figure 2-5**). 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. From information reported in the 2010 U.S. Census, American FactFinder regarding vacation rentals within the county, it is estimated that approximately 6% of residential buildings are vacation rentals in Sherman County (U.S. Census Bureau, 2010b).

From the census data, we analyzed the 1,765 residents within the study area that could be affected by a natural hazard scenario. For each natural hazard, with the exception of 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.

Figure 2-5. Population by Sherman County community.



3.0 ASSESSMENT OVERVIEW AND RESULTS

This risk assessment considers four natural hazards (earthquake, flood, landslide, and wildfire) that pose a risk to Sherman County. The assessment describes both localized vulnerabilities and the widespread challenges that impact all communities. 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 disasters. Communities can use the results to update plans as part of the work toward becoming more resilient to future disasters.

3.1 Hazards and Countywide Results

In this section, results are presented for the entire study area. The study area includes all unincorporated areas, tribal lands, unincorporated communities, and cities within Sherman County. Individual community results are in **Appendix A: Community Risk Profiles**.

3.2 Earthquake

An earthquake is 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 causalities, economic disruption, and extensive property damage (Madin and Burns, 2013).

Two earthquake-induced hazards are liquefaction and landslides. Liquefaction occurs when saturated soils substantially 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 damages in this report include damages derived from shaking, liquefaction, and landslide factors.

3.2.1 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 (USGS, 2017). A deterministic scenario is based on a specific seismic event, such as a Cascadia Subduction Zone magnitude 9.0 event. We used the probabilistic scenario method for this study along with the UDF database so that loss estimates could be calculated on a building-by-building basis.

The 2% in 50 years or 2,500-year (actually 2,475-year) probabilistic shaking map by Madin and others (2021) was selected as the most appropriate for communicating earthquake risk for Sherman County. We based this decision on several factors such as previous Hazus-MH earthquake analyses in the region, available seismic data (historical events, fault locations, etc.), existing building code standards, and an analysis that simulates a worst-case scenario. It is important to note that the probabilistic shaking map is based on the highest level of shaking that could reasonably be expected to occur once every 2,475 years. For practical purposes it can be considered a worst-case event, although it does not represent shaking that occurs simultaneously in a single earthquake. The probabilistic earthquake results should be used carefully for risk assessment and emergency response planning purposes.

The following hazard layers used for our loss estimation are derived from work conducted by Madin and others (2021): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). The liquefaction and landslide susceptibility layers together with PGA were used by the Hazus-MH tool to calculate the probability and magnitude of permanent ground deformation caused by these factors. Although the probabilistic shaking map encompasses all possible earthquake sources, Hazus uses a characteristic magnitude value to calculate the impacts of liquefaction and landslides. For this study, we followed the example of Madin and others (2021) and used Mw 7 as the characteristic event.

3.2.2 Countywide results

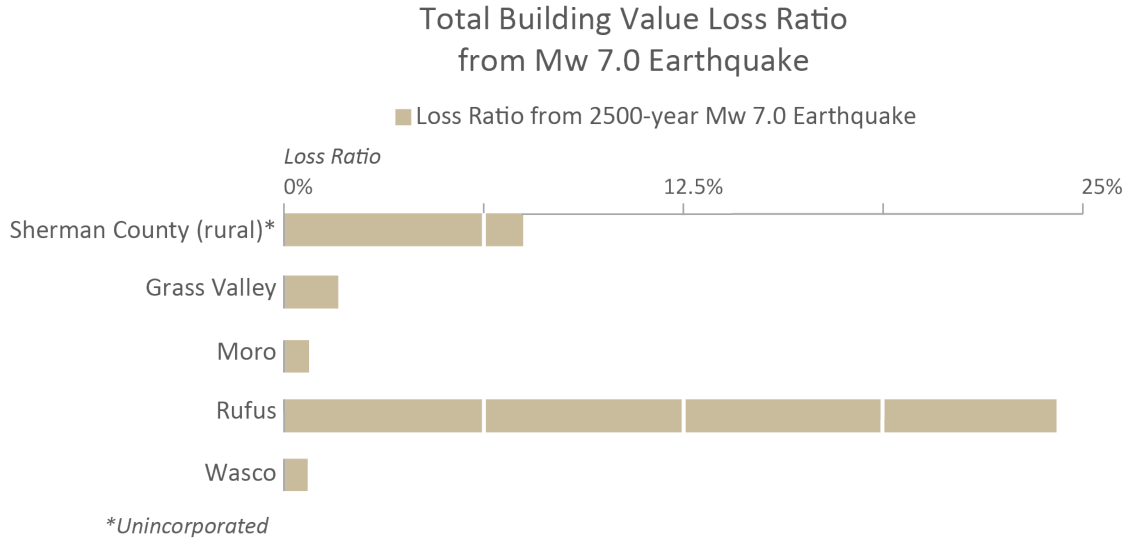
Because an earthquake can affect a wide area, it is unlike other hazards in this report—every building in Sherman County is exposed to significant probabilistic shaking hazard (though not necessarily simultaneously). Hazus-MH loss estimates (see **Appendix B, Table B-2**) for each building are based 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 building dollar value to obtain a loss estimate (FEMA, 2012b). **Figure 3-1** shows the loss estimates by community for Sherman County from an earthquake scenario described in this report.

In keeping with earthquake damage reporting conventions, we used the 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% 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.

Figure 3-1. Earthquake loss ratio by Sherman County community.



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.

Sherman County 2,500-year probabilistic Mw 7.0 earthquake results:

- Number of red-tagged buildings: 13
- Number of yellow-tagged buildings: 58
- Loss estimate: $36,922,000
- Loss ratio: 6.8%
- Non-functioning critical facilities: 5
- Potentially displaced population: 4

The results indicate that Sherman County would incur minor to moderate losses (6.8%) due to the earthquakes represented in the probabilistic shaking map. These results are strongly influenced by ground deformation from liquefaction. Most of the study area is mapped as low liquefaction susceptibility, with small areas of moderate susceptibility along Interstate 84. These areas of moderate liquefaction correspond to building clusters that we estimate to incur more damage from earthquake relative to other parts of the study area. Future mapping of liquefaction in the study area may show areas with higher levels of liquefiable soils than what is currently mapped.

Although damage caused by coseismic landslides was not specifically looked at in this report, it likely contributes a minor amount of the estimated damage from the earthquake hazard in Sherman County. Landslide exposure results show that 1.4% of buildings in Sherman County are within a very high or high susceptibility zone. This indicates that a similar percentage of the 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 damage estimates. The first seismic buildings codes were implemented in Oregon in the 1970's (Judson, 2012) and by the 1990's modern seismic building codes were being enforced. 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 moderate or high code standards, the risk of earthquake hazard would be greatly reduced. While we were unable to simulate the reduction of earthquake damage because assessor information was unavailable, this can be one mitigation method to lower risk from earthquakes.

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.

3.2.3 Areas of significant risk

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

- Many buildings along Interstate 84 exist on moderate liquefaction susceptibility zones and are estimated to be damaged more by an earthquake relative to other parts of the study area.

3.3 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 Sherman County 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.

A typical method for determining flood risk is to identify the probability of flooding and the impacts of flooding. The annual probabilities calculated for flood hazard used in this report are 1%, and 0.2%, henceforth referred to as 100-year and 500-year scenarios, respectively. The ability to assess the probability of a flood, and the level of accuracy of that assessment is influenced by modeling methodology advancements, better knowledge, and longer periods of record for the stream or water body in question.

The major streams within the county are the Deschutes, Columbia, and John Day rivers and Buck Hollow Creek. All the listed rivers are subject to flooding and can cause damage to buildings within the floodplain.

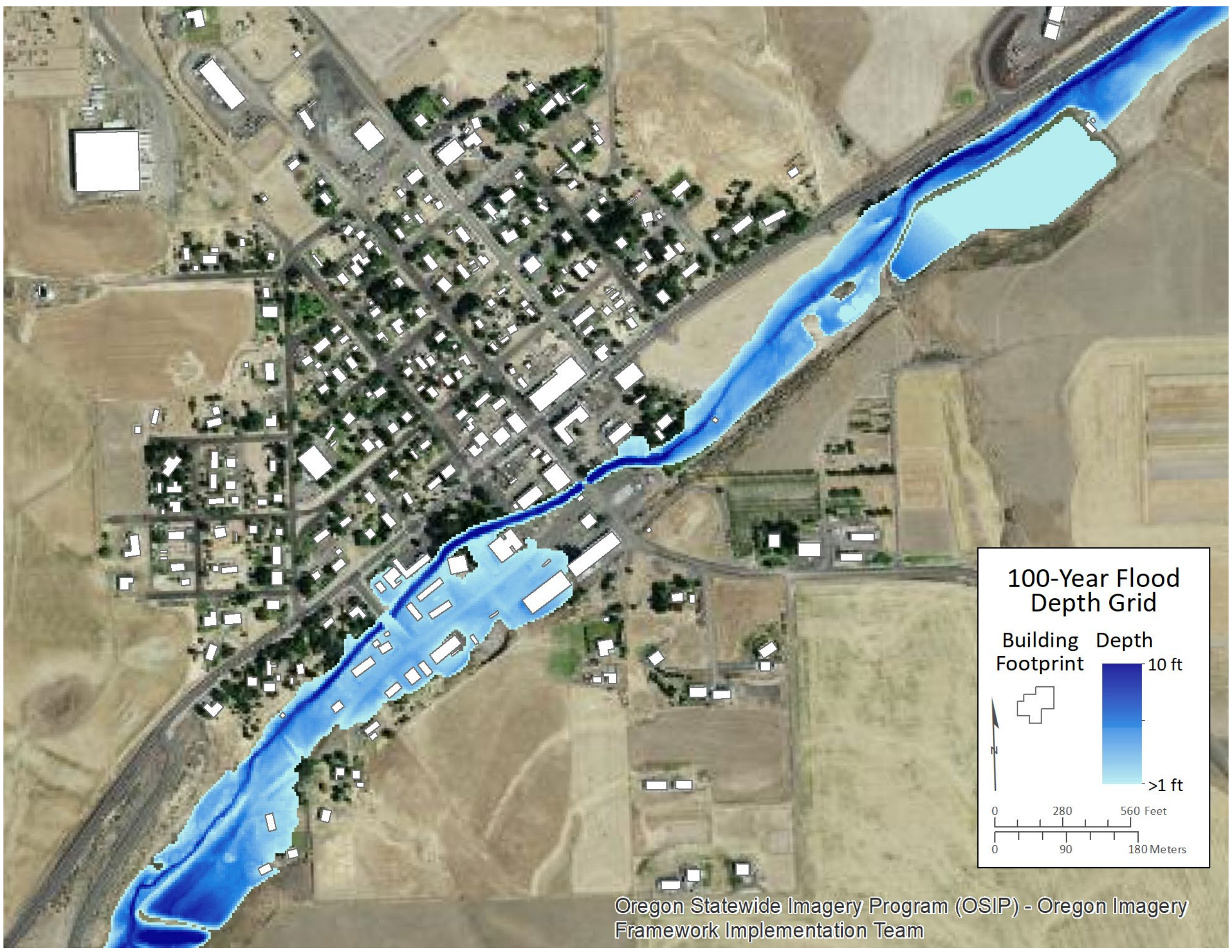
The impacts of flooding are determined by adverse effects to human activities within the natural and built environment. Through strategies such as flood hazard mitigation these adverse impacts can be reduced. Examples of common mitigating activities are elevating structures above the expected level of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

3.3.1 Data sources

The Flood Insurance Study (FIS) and Flood Insurance Rate Maps for Sherman County were in the process of being updated by FEMA as of 2021; 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, but flooding does occur in areas outside of the detailed mapped areas.

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 (100- and 500-year) were used for loss estimations and, for comparative purposes, exposure analysis.

Figure 3-2. Flood depth grid example in the community of Grass Valley.



Building loss estimates are determined in Hazus-MH by overlaying building data on a depth grid. 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 Sherman County, occupancy type was inferred from land use and zoning data. Basement presence attributes were derived from oblique imagery and street level imagery to estimate this important building attribute. 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.

3.3.2 Countywide results

For this risk assessment, we imported the countywide UDF data and depth grids into Hazus-MH and ran a flood analysis for two flood scenarios (100- and 500-year). We used the 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.

Sherman countywide 100-year flood loss:

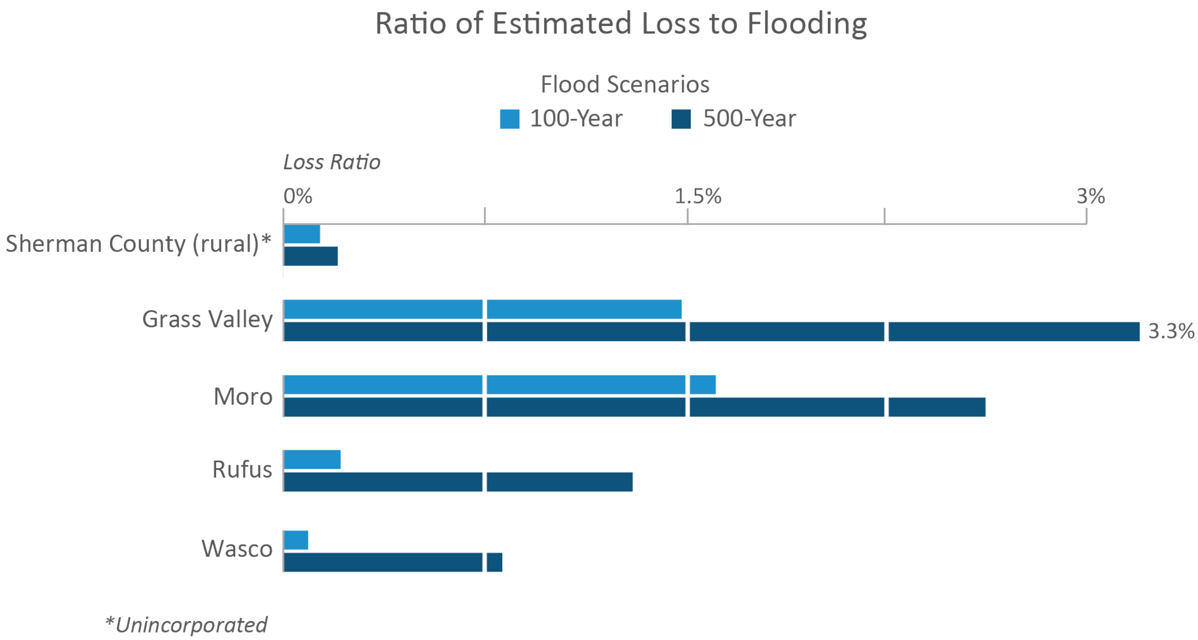
- Number of buildings damaged: 68
- Loss estimate: $1,918,000
- Loss ratio: 0.4%
- Damaged critical facilities: 3
- Potentially displaced population: 61

3.3.3 Hazus-MH analysis

The Hazus-MH loss estimate for the 100-year flood scenario for the entire county is more than $1.9 million. While the overall loss ratio for flood damage in Sherman County is only 0.4%, 100-year flooding has a significant impact to Sherman County where development exists near streams that are prone to flooding. (**Figure 3-3**). In situations with communities where 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 also provides useful flood data on individual communities so that planners can identify problems and consider which mitigating activities will provide the greatest resilience to flooding.

The main flooding problems within Sherman County are in Grass Valley and Moro. Flooding from creeks that flow through these communities can flood and cause damage to nearby buildings. The loss estimate of the 100-year flood scenario for the entire county is over $1.9 million (**Figure 3-3**). In the incorporated parts of the county there are no concentrations of buildings that are estimated to be damaged by flooding.

Figure 3-3. Ratio of flood loss estimates by Sherman County community.



3.3.4 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. This was done by comparing the number of undamaged buildings from Hazus-MH with the number of exposed buildings in the flood zone. Many of Sherman County's buildings were found to be within designated flood zones. Of the 72 buildings that are exposed to flooding, we estimate that 11 are above the height of the 100-year flood. This evaluation also estimates that 60 residents might have mobility or access issues due to surrounding water. See **Appendix B, Table B-5** for community-based results of flood exposure.

3.3.5 Areas of significant risk

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

- Developed areas along local creeks in Grass Valley and Moro are vulnerable to the 100-year flood.
- Approximately 10% of the residents in Grass Valley and Moro could potentially be displaced from a 100-year flood.

3.4 Landslide Susceptibility

Landslides are mass movements of rock, debris, or soil most commonly downhill. There are many different types of landslides in Oregon. In Sherman County, 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).

3.4.1 Data sources

The Statewide Landslide Information Layer for Oregon [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. Most of the landslide inventory mapping for Sherman County was done in the early 1970s.

Burns and others (2016) used 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. 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). 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 used the data from the statewide landslide susceptibility map (Burns and others, 2016) in this report to identify the general level of susceptibility of given area to landslide hazards, primarily shallow and deep landslides. We overlaid building and critical facilities data on landslide susceptibility zones to assess the exposure for each community (see **Appendix B, Table B-6**). 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 real risk to communities were not examined for this report.

3.4.2 Countywide results

Sherman County's communities have very little exposure to landslide risk. High landslide susceptibility is most prominent in the areas near the Deschutes and John Day river valleys. While these areas are highly prone to landslides, most of the populated areas are outside these zones. The percentage of building value exposed to very high and high landslide susceptibility is approximately 1% for the entire study area.

We combined high and very high susceptibility zones as the primary scenarios to provide a general sense of community risk for planning purposes (see **Appendix E, Plate 5**). It was useful to combine exposure for both susceptibility zones to best communicate the level of landslide risk to communities. These susceptibility zones represent areas most prone to landslides with the highest impact to the community.

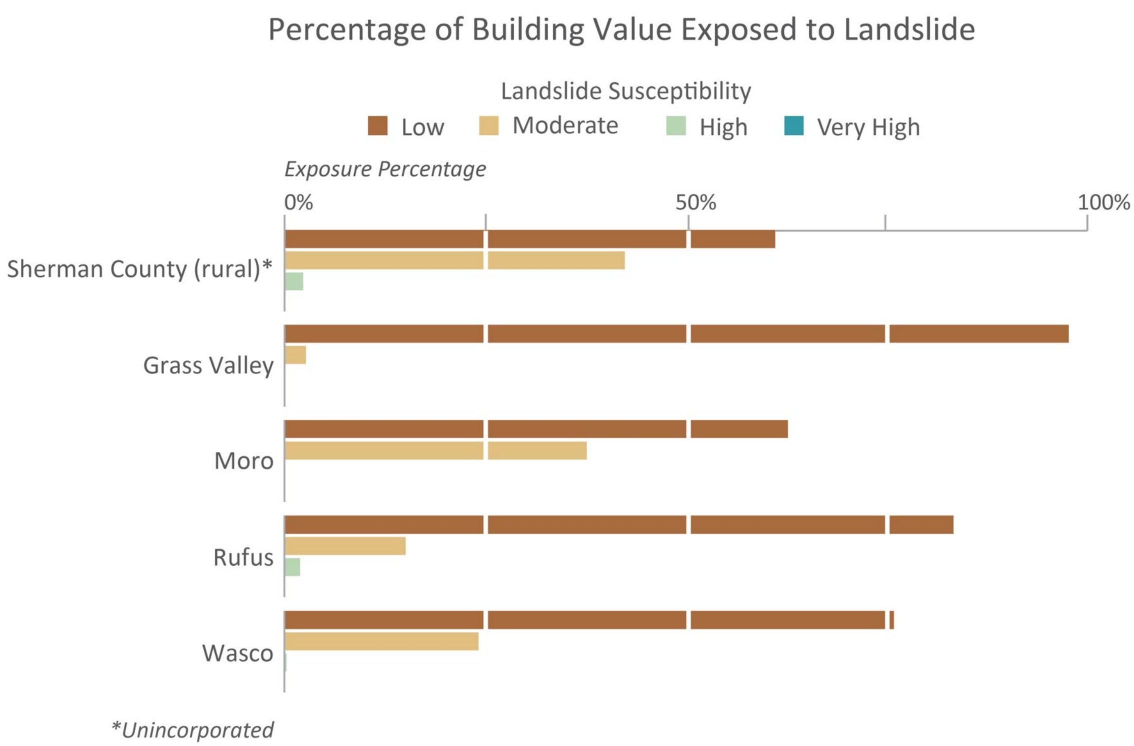
For this risk assessment we compared building locations to geographic extents of the landslide susceptibility zones (**Figure 3-4**). The exposure results shown below are for the high and very high susceptibility zones. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Sherman countywide landslide exposure (High and Very High susceptibility):

- Number of buildings: 29
- Value of exposed buildings: $7,713,000
- Percentage of total county value exposed: 1.4%
- Critical facilities exposed: 0
- Potentially displaced population: 26

The majority of developed land in Sherman County are located on the Columbia Plateau which has generally low landslide susceptibility. While there are some areas in the county where landslide hazard is high, current and future land development does not appear likely to occur in these areas at this time. Awareness of nearby areas of landslide hazard is beneficial to reducing risk for every community and rural area of the county.

Figure 3-4. Landslide susceptibility exposure by Sherman County community.



3.4.3 Areas of significant risk

We did not identify locations within the study area that are comparatively at greater risk to landslide hazard. However, given the lack of lidar-based landslide mapping, some communities in Sherman County may be at higher or lower risk than what the data show. Lidar-based landslide mapping would provide a better understanding of the risk.

3.5 Wildfire

Wildfires are a natural part of the ecosystem in Oregon. However, wildfires can present a substantial hazard to life and property, because communities often grow in the transition areas between developed areas and undeveloped areas, commonly called the wildland-urban interface (WUI) (Sanborn Map Company, Inc., 2013). The most common 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 (Sanborn Map Company, Inc., 2013). Post-wildfire geologic hazards can also present risk. These usually include flooding, debris flows, and landslides. Post-wildfire geologic hazards were not evaluated in this project.

There is potential for losses due to wildland-urban interface fires in Sherman County. Fire prone areas cover a large portion of the county and are present in developed areas in the county. In the Sherman County Community Wildfire Protection Plan, it recommends several steps that homeowners can take to reduce their risk to wildfire. Some risk reduction examples are maintaining defensible space around structures, reducing fuels, and using non-flammable materials in construction (Baker and Glenn, 2005). Contact the Sherman County Department of Planning for specific requirements related to the county's comprehensive plan.

3.5.1 Data sources

The West Wide Wildfire Risk Assessment (WWA; Sanborn Map Company, Inc., 2013) is a comprehensive report that includes a database developed over the course of several years for 17 Western states and some Pacific Islands. 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 Fire Risk Index (FRI) dataset, a dataset included in the WWA database, was used to measure the level of risk to communities in Sherman County.

Using guidance from ODF, we categorized the FRI into low, moderate, and high hazard zones for the wildfire exposure analysis. The FRI hazard zones are based on a combination of the impacts of wildfire (Fire Effects Index) and the probability of wildfire (Fire Threat Index). Both indices are the result of an integration of several input datasets. Broadly, the Fire Effects Index is based on potentially impacted assets and the difficulty of suppression. The components that make up the Fire Threat Index are fire occurrence, fire behavior, and fire suppression effectiveness (Sanborn Map Company, Inc., 2013).

We overlaid the buildings layer and critical facilities on each of the wildfire hazard zones to determine exposure. In certain areas no wildfire data are present which indicates areas that have minimal risk to wildfire hazard (see **Appendix B, Table B-8**). The total dollar value of exposed buildings in the study area is reported below. We also estimated the number of people threatened by wildfire. Land value losses due to wildfire were not examined for this project.

3.5.2 Countywide results

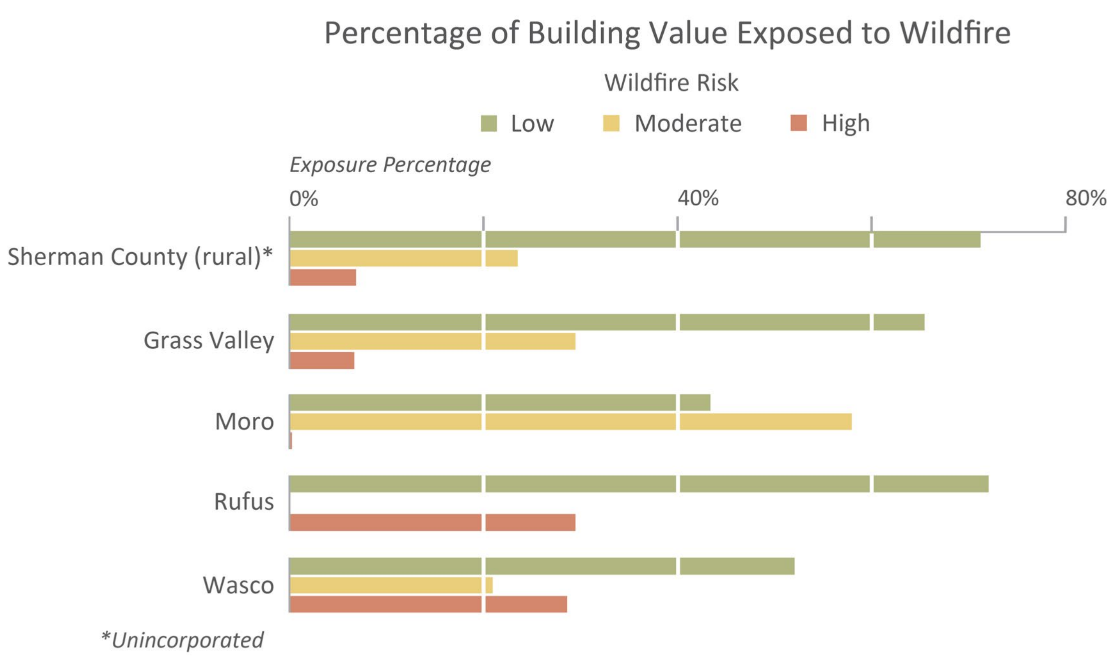
The high hazard category was chosen as the primary scenario for this report because that category represents areas that have the highest potential for losses. However, a large amount of loss would occur if the moderate hazard areas were to burn, as almost every community has ~30–50% of exposure to moderate wildfire hazard. Still, the focus of this section is on high hazard areas within Sherman County to emphasize the areas where lives and property are most at risk.

Sherman countywide wildfire exposure (High hazard):

- Number of buildings: 273
- Exposure value: $52,753,000
- Percentage of exposure value: 9.7%
- Critical facilities exposed: 4
- Potentially displaced population: 254

For this risk assessment, building locations were compared to the geographic extent of the wildfire hazard categories. Many of the communities in Sherman County have a significant amount of high-risk exposure to wildfire. The communities of Rufus and Wasco are at a higher risk to wildfire than other communities in the study area (see **Appendix E, Plate 6**). **Figure 3-5** illustrates level of risk from wildfire for the different communities of Sherman County. See **Appendix B: Detailed Risk Assessment Tables** for multi-scenario analysis results.

Figure 3-5. Wildfire hazard exposure by Sherman County community.



3.5.3 Areas of significant risk

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

- Wildfire risk is present throughout the county, but the greatest threats are along U.S. Highway 97 and within the Deschutes and John Day river valleys.
- Wildfire risk is high for many homes in the WUI around the communities of Grass Valley and Moro.
- The eastern half of the community of Wasco is within a high wildfire hazard area.
- The community of Rufus is within a high wildfire hazard area. This hazard presents a significant threat to the community.

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 county's risk reduction efforts. We note several important findings based on the results of this study:

- **Minor to moderate overall damage and losses are expected from an earthquake**—Based on the results of a 2,500-year probabilistic Mw 7.0 earthquake, most communities in Sherman County will experience minor to moderate impact and disruption. Results show that an earthquake can cause building losses of less than 10% to nearly all communities in the study area. The community of Rufus was estimated to have a higher percentage of losses (24%) than the other communities in the study area. The number of buildings in Rufus constructed on liquefiable soils contributed to the estimated levels of losses expected.
- **Some communities in the study area are at moderate risk from flooding** —Many buildings within the floodplain are vulnerable to significant damage from flooding. At first glance, Hazus-MH flood loss estimates may give a false impression of low 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 from flooding. Another consideration is that flood is one of the most frequently occurring natural hazard. An average of 9% loss was calculated when looking at just the buildings within the 100-year flood zone. The areas with the highest flood hazard risk are some residential buildings in Grass Valley and Moro along local creeks.
- **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. Based on the number of buildings exposed to flooding throughout the unincorporated county, many would benefit from elevating above the level of flooding.
- **New landslide mapping would increase the accuracy of future risk assessments**—The landslide hazard data used in this risk assessment was created before modern mapping technology; future risk assessments using lidar-derived landslide hazard data would provide more accurate results. Exposure analysis was used to assess the threat from landslide hazard. Based on current mapping, landslide is a widespread hazard for much of the undeveloped portions of the county near the Deschutes and John Day river canyons. With most of the development occurring in the highlands on the Columbia Plateau, which is also a low landslide susceptibility area, there is very little overall risk from landslide to buildings.
- **Wildfire risk is significant for the overall study area**—Exposure analysis shows that buildings at greatest risk to wildfire hazard are along U.S. Highway 97 and within the Deschutes and John Day river valleys. The communities within the county have roughly 30% to 50% exposure to high or moderate wildfire risk. The communities of Rufus and Wasco have nearly 30% of building value exposed to high wildfire risk.

- **Most of the study area's critical facilities are at high risk to an earthquake and wildfire**—Critical facilities were identified and were specifically examined within this report. We have estimated that 25% (5 of 19) of Sherman County's critical facilities will be non-functioning after a 2,500-year probabilistic earthquake. Additionally, 20% (4 of 19) of critical facilities are exposed to high wildfire risk and 16% (3 of 19) to flood hazard.
- **The biggest causes of displacement to population are wildfire and flood hazards**—Potential displacement of permanent residents from natural hazards was estimated within this report. We estimated that 14% of the population in the county to be displaced due wildfire hazard. Flood hazard is a potential threat to 3% of permanent residents. A small percentage of residents are at risk to displacement from earthquake and landslide hazards.
- **The results allow communities the ability to compare across hazards and prioritize their needs**—Each community within the study area was assessed for natural hazard exposure and loss. This allowed for comparison of risk for a specific hazard between communities. 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 for those individual communities.

5.0 LIMITATIONS

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

- **Spatial and temporal variability of natural hazard occurrence** – Flood, earthquake, landslide, and wildfire are extremely unlikely to occur across the fully mapped extent of the hazard zones. For example, areas mapped in the 1% annual chance flood zone will be prone to flooding on occasion in certain watersheds during specific events, but not all at once throughout the entire county or even the entire community. While we report the overall impacts of a given hazard scenario, the losses from a single hazard event probably will not be as severe and widespread.
- **Loss estimation for individual buildings** – Hazus-MH is a model, not 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 data outliers.
- **Loss estimation versus exposure** – We recommend careful interpretation of exposure results. This is due to the spatial and temporal variability of natural hazards (described above) 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.
- **Population variability** – Some of the communities in Sherman County have a number of vacation homes and rentals, which are typically occupied during the summer. Our estimates of potentially displaced people rely on permanent populations published in the 2010 U.S. Census (U. S. Census

Bureau, 2010b). 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 assessments 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 slight. 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.

6.0 RECOMMENDATIONS

The following areas of implementation 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

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 in general is a much safer place to live. Awareness and preparation not only reduce the initial impact from natural hazards, but they also reduce the amount of recovery time for a community to bounce back from a disaster—this ability is commonly referred to as "resilience."

This report is intended to provide local officials 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 high landslide susceptibility areas. 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

Information presented here are available for local decision-makers in developing their local plans and help identify 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 hazards or critical facilities in the two reports can vary. 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 contingencies in their response 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 the frame to the 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.

At the time of writing this report, FEMA has two programs that assist with mitigation funding for natural hazards: Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM) Grant Program. FEMA also has a grant program specifically for flooding called Flood Mitigation Assistance (FMA). 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, which will have many direct and indirect negative effects on first-response and recovery efforts.

- Identify communities and buildings that would benefit from seismic upgrades.

6.5.2 Flood

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

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 DOGAMI in 2018-2019. Revisions to the earthquake and flood analyses were conducted in 2021. It was funded by FEMA Region 10 through its Risk Mapping, Assessment, and Planning (Risk MAP) program (Cooperative Agreement EMW-2014-CA-00288 and EMS-2019-CA-00021). In addition to FEMA, DOGAMI worked closely with the Oregon Department of Land Conservation and Development (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 people contributed to this report at different points during the analysis phase and during the writing phase and at various levels. We are grateful to everyone who contributed, especially the following from DOGAMI: John Bauer, Jed Roberts, and Deb Schueller.

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9.0 APPENDICES

APPENDIX A. COMMUNITY RISK PROFILES

A hazard analysis summary for each community 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 every 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, for each community a list of critical facilities and assumed impact from individual hazards is provided.

A.1 Unincorporated Sherman County (rural)

Table A-1. Unincorporated Sherman County hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Unincorporated Sherman County	618	1,458	4	351,505,000

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	5	0.8%	17	1	352,000	0.1%
Earthquake	2500-year Probabilistic	3	0.4%	43	1	26,082,000	7.4%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	10	1.7%	21	0	6,863,000	2.0%
Wildfire	High Hazard	68	11%	124	2	23,498,000	6.7%

[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. Unincorporated Sherman County critical facilities.

Critical Facilities by Community	**Flood 1% Annual Chance Exposed**	**Earthquake Moderate to Complete Damage >50% Prob.**	**Landslide High and Very High Susceptibility Exposed**	**Wildfire High Hazard Exposed**
Biggs Junction Wastewater Treatment		X		X
Grass Valley Water Supply				
Sherman Elementary and High School	X			
Wasco State Airport				X

A.2 City of Grass Valley

Table A-3. City of Grass Valley hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Grass Valley		164	177		2		35,781,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	16	9.5%	29	1	530,000	1.5%
Earthquake	2500-year Probabilistic	0	0.0%	0	0	796,000	2.2%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	0	0.0%	0	0	0	0.0%
Wildfire	High Hazard	14	8.2%	24	0	2,331,000	6.5%

[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-4. City of Grass Valley critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Grass Valley City Hall	X			
South Sherman Fire and Rescue				

A.3 City of Moro

Table A-5. City of Moro hazard profile.

Community Overview				
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)
Moro	324	258	4	61,210,000

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	38	12%	18	1	941,000	1.5%
Earthquake	2500-year Probabilistic	0	0.0%	0	0	709,000	1.2%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	0	0.0%	0	0	0	0.0%
Wildfire	High Hazard	0	0.0%	1	0	110,000	0.2%

[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-6. City of Moro critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
City of Moro Fire Department	X			
Moro City Hall				
Sherman County Courthouse and Sheriff				
Sherman County Medical Clinic				

A.4 City of Rufus

Table A-7. City of Rufus hazard profile.

Community Overview					
Community Name	Population	Number of Buildings	Critical Facilities[1]	Total Building Value ($)	
Rufus	249	195	4	35,965,000	

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	0	0.0%	2	0	64,000	0.2%
Earthquake	2500-year Probabilistic	4	1.5%	28	4	8,713,000	24%

Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	12	4.8%	6	0	695,000	1.9%
Wildfire	High Hazard	97	39%	70	1	10,430,000	29%

[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-8. City of Rufus critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
North Sherman Fire – Rufus Station		X		
Public Works		X		
Rufus City Hall		X		
Rufus Wastewater Treatment		X		X

A.5 City of Wasco

Table A-9. City of Wasco hazard profile.

Community Overview							
Community Name		Population	Number of Buildings		Critical Facilities[1]		Total Building Value ($)
Wasco		410	317		5		58,194,000
Hazus-MH Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Damaged Buildings	Damaged Critical Facilities	Loss Estimate ($)	Loss Ratio
Flood[2]	1% Annual Chance	3	0.3%	2	0	32,000	0.1%
Earthquake	2500-year Probabilistic	0	0.0%	0	0	622,000	1.1%
Exposure Analysis Summary							
Hazard	Scenario	Potentially Displaced Residents	% Potentially Displaced Residents	Exposed Buildings	Exposed Critical Facilities	Building Value ($)	Percent of Exposure
Landslide	High and Very High Susceptibility	3	0.9%	2	0	155,000	0.3%
Wildfire	High Hazard	75	18%	54	1	16,384,000	28%

[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-10. City of Wasco critical facilities.

Critical Facilities by Community	Flood 1% Annual Chance Exposed	Earthquake Moderate to Complete Damage >50% Prob.	Landslide High and Very High Susceptibility Exposed	Wildfire High Hazard Exposed
Cellular repeater				
North Sherman Fire – Wasco Station				
Wasco City Hall				
Wasco School Events Center				X
Wasco Wastewater Treatment				

APPENDIX B. DETAILED RISK ASSESSMENT TABLES

Table B-1. Sherman County building inventory.

(all dollar amounts in thousands)

	Residential			Commercial and Industrial			Agricultural			Public and Nonprofit			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 County Total**	**Building Value ($)**	**Building Value per County Total**
Unincorp. County (rural)	346	67,748	19%	77	50,145	14%	1,011	214,960	61%	24	18,652	5.3%	1,458	61%	351,505	65%
Grass Valley	109	13,283	37%	20	6,788	19%	39	5,108	14%	9	10,602	30%	177	7.4%	35,781	6.6%
Moro	192	23,901	39%	23	21,227	35%	25	3,278	5.4%	18	12,804	21%	258	11%	61,210	11%
Rufus	137	21,660	60%	23	5,886	16%	29	4,511	13%	6	3,908	11%	195	8.1%	35,965	6.6%
Wasco	238	28,131	48%	39	18,488	32%	27	2,009	3.5%	13	9,566	16%	317	13%	58,194	11%
Total Sherman County	1,022	154,723	29%	182	102,534	19%	1,131	229,866	42%	70	55,532	10%	2,405	100%	542,655	100%

Table B-2. Earthquake loss estimates.

	(all dollar amounts in thousands)					
			Buildings Damaged			
Community	Total Number of Buildings	Total Estimated Building Value ($)	Yellow-Tagged Buildings	Red-Tagged Buildings	Sum of Economic Loss	Loss Ratio
Unincorp. County (rural)	1,458	351,505	34	9	26,082	7.4%
Grass Valley	177	35,781	0	0	796	2.2%
Moro	258	61,210	0	0	709	1.2%
Rufus	195	35,965	25	4	8,713	24.%
Wasco	317	58,194	0	0	622	1.1%
Total Sherman County	2,405	542,655	59	13	36,922	6.8%

Table B-3. Flood loss estimates.

			(all dollar amounts in thousands)					
			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**
Unincorp. County (rural)	1,458	351,505	17	352	0.1%	19	551	0.2%
Grass Valley	177	35,781	29	530	1.5%	49	1,206	3.3%
Moro	258	61,210	18	941	1.5%	28	1,516	2.6%
Rufus	195	35,965	2	64	0.2%	11	577	1.3%
Wasco	317	58,194	2	32	0.1%	6	258	0.6%
Total Sherman County	2,405	542,655	68	1,919	0.4%	113	4,108	0.8%

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**
Unincorp. County (rural)	1,458	618	5	0.8%	18	1.2%	1
Grass Valley	177	164	16	9.5%	31	18%	2
Moro	258	324	38	12%	19	7.4%	1
Rufus	195	249	0	0.0%	2	1.0%	0
Wasco	317	410	3	0.3%	2	1.3%	0
Total Sherman County	2,405	1,765	62	3.4%	72	3.1%	4

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**
Unincorp. County (rural)	1,458	351,505	0	0	0%	21	6,863	2.0%	469	97,434	28%
Grass Valley	177	35,781	0	0	0%	0	0	0.0%	7	955	3%
Moro	258	61,210	0	0	0%	0	0	0.0%	155	22,969	38%
Rufus	195	35,965	0	0	0%	6	695	1.9%	41	5,413	15%
Wasco	317	58,194	0	0	0%	2	155	0.3%	101	14,023	24%
Total Sherman County	2,405	542,655	0	0	0%	29	7,713	1.4%	773	140,794	26%

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**
Unincorp. County (rural)	1,458	351,505	124	23,498	7%	305	81,269	23%
Grass Valley	177	35,781	24	2,331	7%	67	10,372	29%
Moro	258	61,210	1	110	0%	123	34,950	57%
Rufus	195	35,965	70	10,430	29%	0	0	0%
Wasco	317	58,194	54	16,384	28%	97	11,975	21%
Total Sherman County	2,405	542,655	273	52,753	10%	592	138,566	26%

APPENDIX C. HAZUS-MH METHODOLOGY

C.1 Software

We performed all loss estimations using Hazus®-MH 3.0 and ArcGIS® Desktop® 10.2.2.

C.2 User-Defined Facilities (UDF) Database

We compiled a UDF database for all buildings in Sherman County for use in both flood and earthquake modules of Hazus-MH. We attributed the UDF data initially by referencing the DLCD GIS dataset for zoning or land use (DLCD, 2014).

C.2.1 Locating buildings points

DOGAMI used its existing dataset of building footprints (unpublished) to help precisely locate the centroid of each building. Where the building footprint dataset lacked coverage in the eastern portion of the county the centroid of the tax lot was taken, and for tax lots larger than 10 acres the building centroid was moved and approximated using orthoimagery. 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

We populated the required attributes for Hazus-MH through a variety of approaches. We used the DLCD zoning dataset or Google Street View™ whenever possible, but in many cases this data or application 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 positions 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 the DLCD zoning dataset. 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 (The Gordian Group, 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. The year of "1900" was applied as a default value.
- **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.
- **Number of stories** – The number of stories for an individual UDF, along with Occupancy Class, determines the applied damage function for flood analysis. Due to lack of information the default values of 1 story was used throughout. 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 Hazus-MH, 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. For UDFs without adequate 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 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 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 (U. S. Census Bureau, 2010a) of population per census block and distributed across residential UDFs.
- **Community** – The community that a UDF is within. These areas are used in the post-analysis for reporting results. The communities were based on incorporated area boundaries; unincorporated community areas were based on building density.

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 Sherman County. **Table C-1** outlines the benchmark years that apply to buildings within Sherman County.

Table C-1. Sherman County seismic design level benchmark years.

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

C.3 Flood Hazard Data

FEMA developed flood hazard data in 2020 for a revision of the Sherman County FEMA Flood Insurance Study. The hazard data were based on new flood studies and new riverine hydrologic and hydraulic analyses. For riverine areas, the flood elevations for the 100- and 500-year events for each stream cross-section were used to develop depth of flooding raster datasets or “depth grids.”

A countywide, 2-meter (~6.5 foot), 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): National Earthquake Hazard Reduction Program (NEHRP) soil classification, peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration at 1.0 second period and 0.3 second period (SA10 and SA03), and liquefaction susceptibility. We also used landslide susceptibility data derived from the work of Burns and others (2016). 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 taxlot 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 Special Flood Hazard Areas 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.

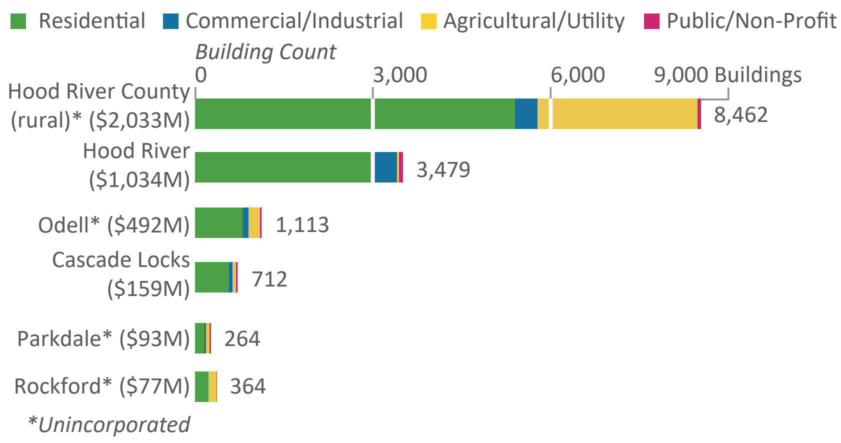
APPENDIX E. MAP PLATES

See appendix folder for individual map PDFs.

PLATE 1

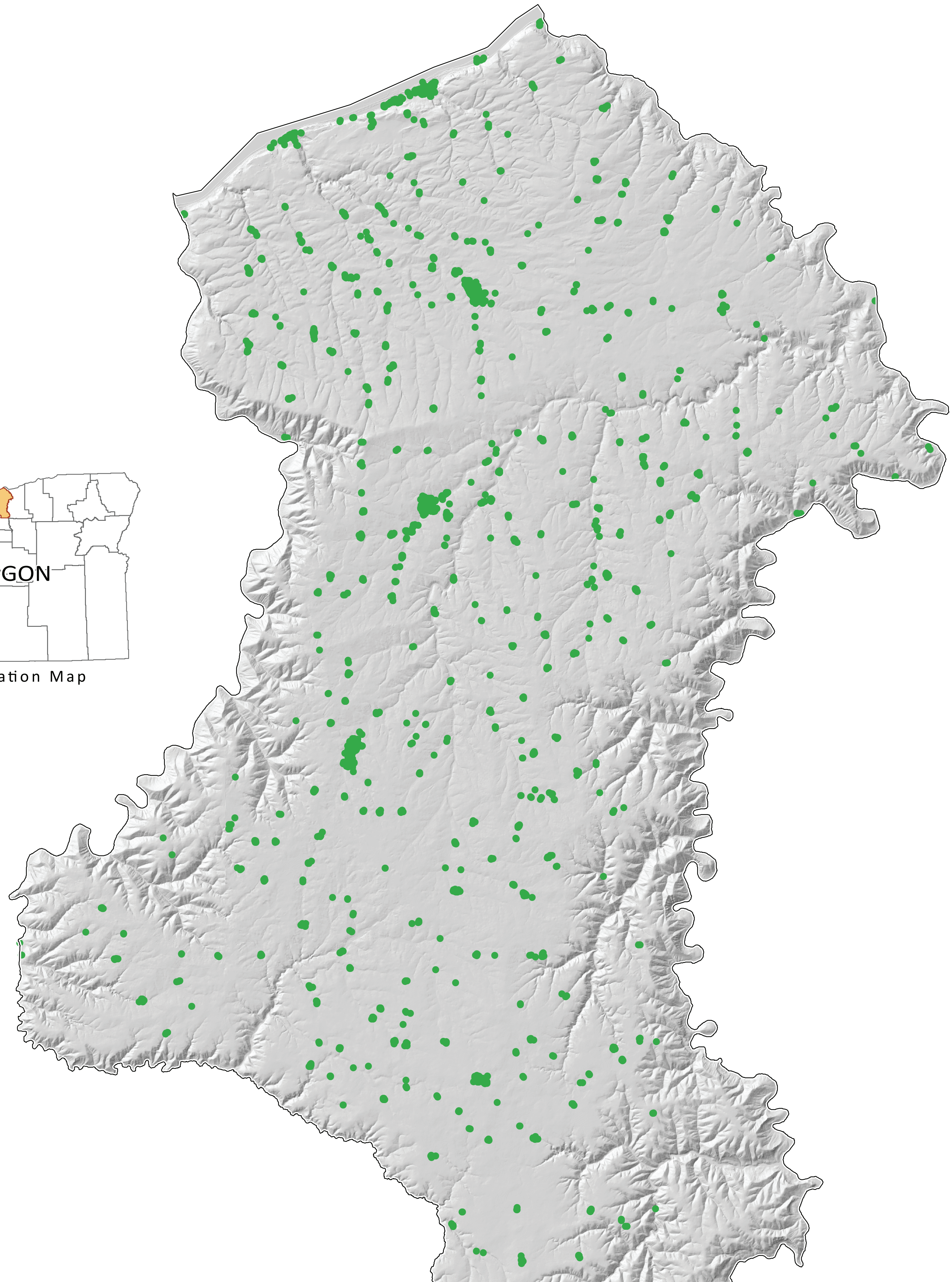
Building Distribution Map of Sherman County, Oregon

Buildings by Occupancy Class
(Ranked by Value)



Building Occupancy

- Agricultural / Utility
- Commercial & Industrial
- Public & Non Profit
- Residential



Study Location Map

Data Sources:
Building footprints: Oregon Department of Geology and Mineral Industries, (2016)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

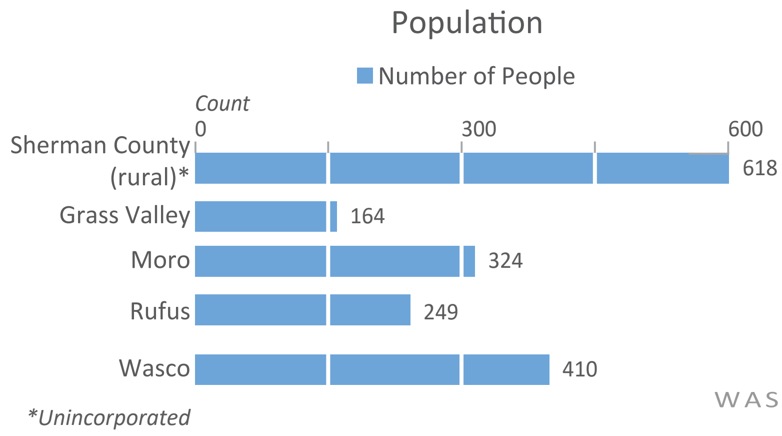
Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6
Cartography by: Lowell Anthony, 2018

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 substitute for 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.

N
0 1.5 3 Miles
0 2.5 5 Kilometers

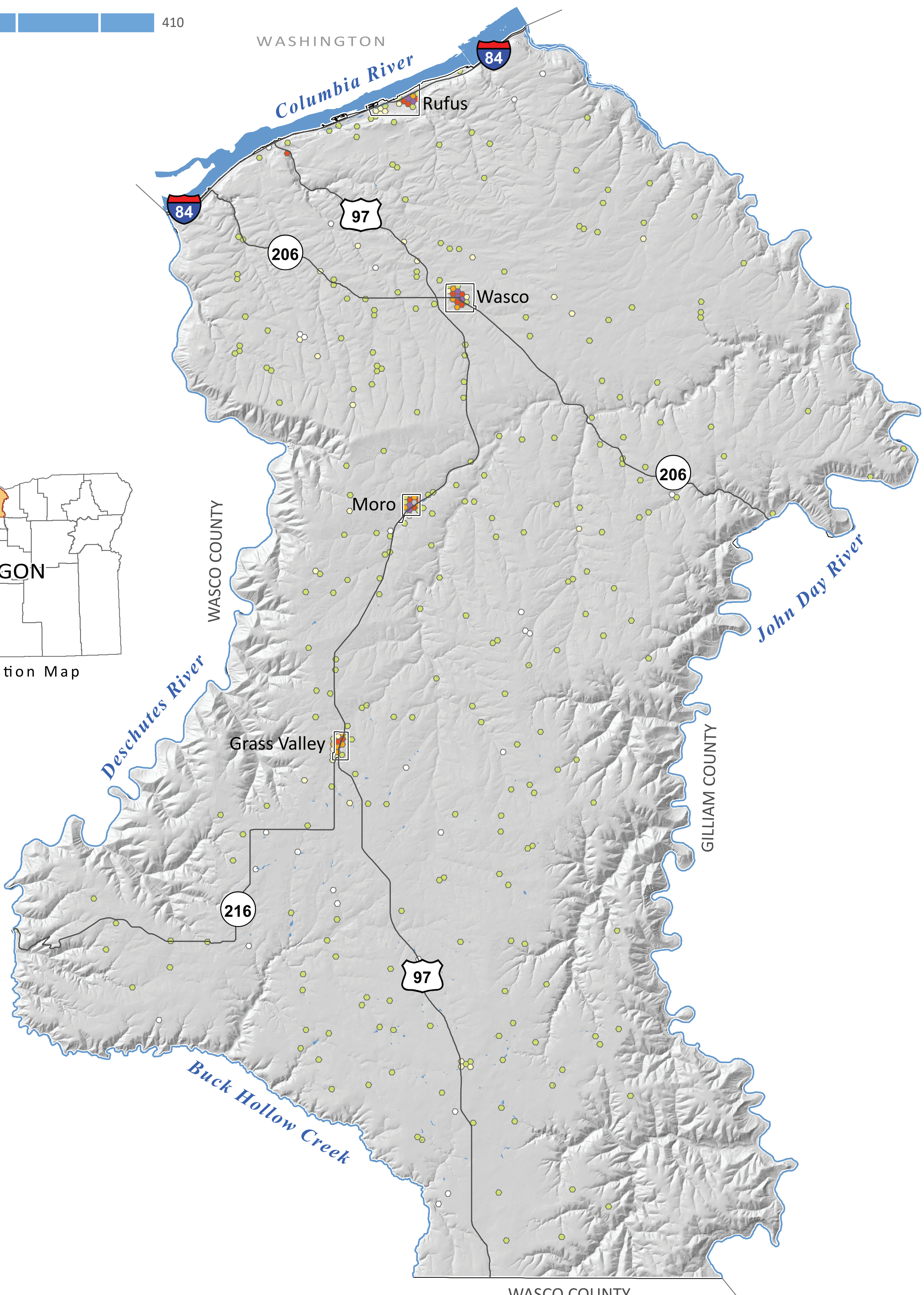
PLATE 2

Population Density Map of Sherman County, Oregon



People per 20 acres

- Building(s) present no permanent residents
- 0 - 10
- 11 - 20
- 21 - 40
- 41 - 80
- 81 +



Study Location Map

Data Sources:
Population data: U.S. Census (2010)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6
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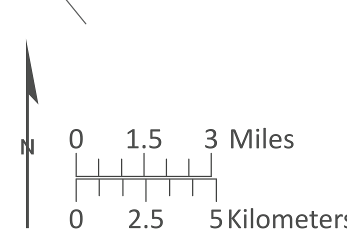
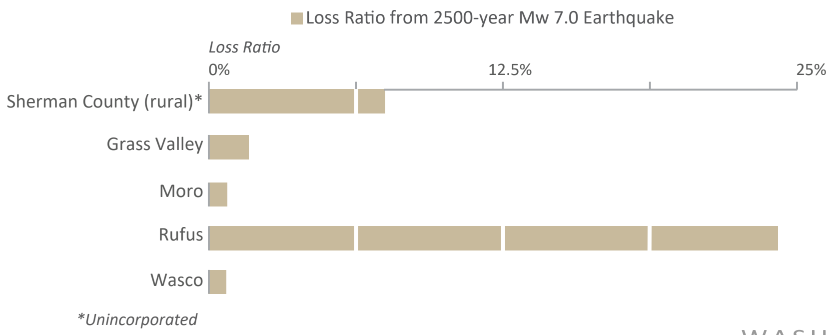


2,500-year Probabilistic Earthquake Shaking Map of Sherman County, Oregon

PLATE 3

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.

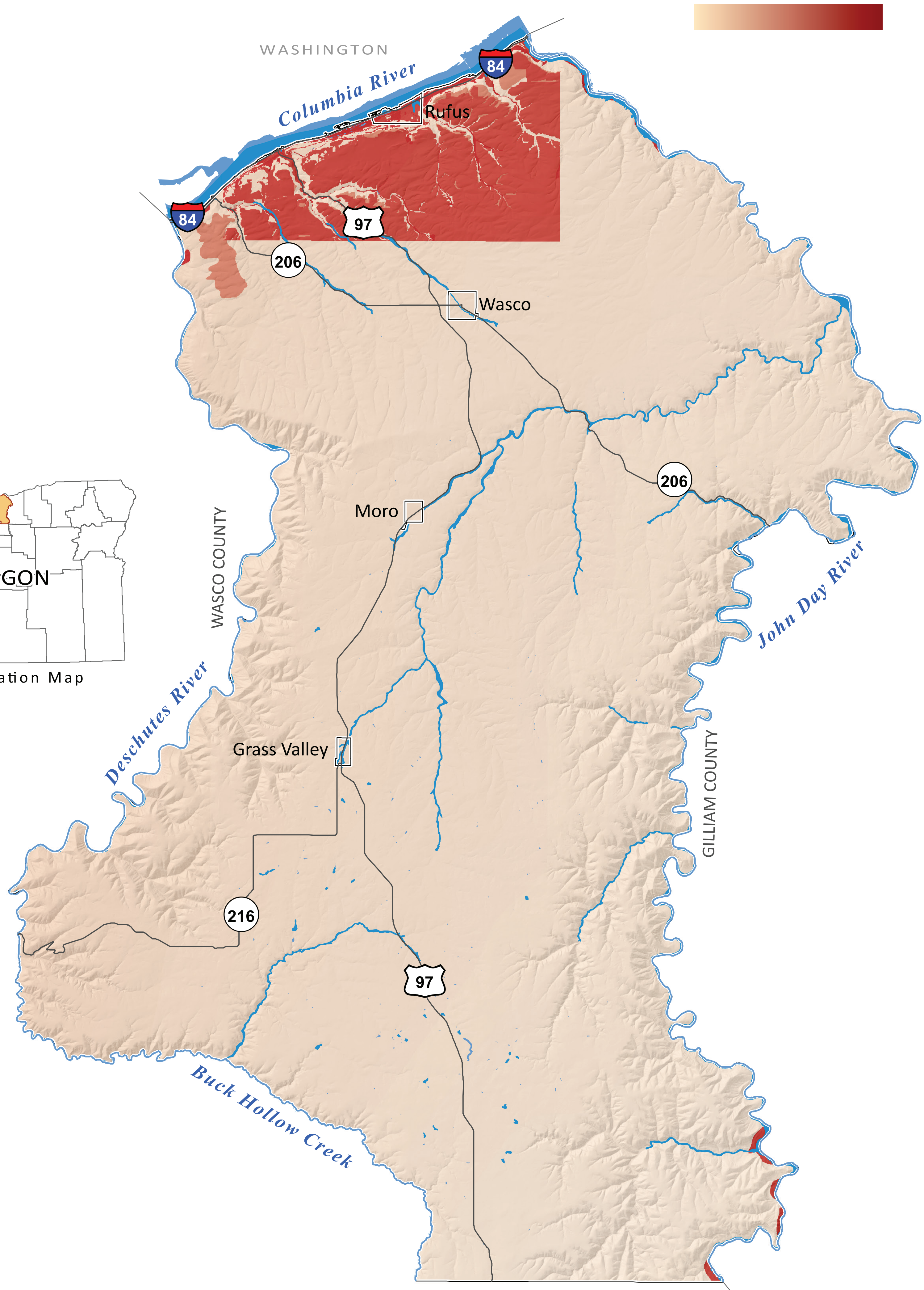
Total Building Value Loss Ratio from Mw 7.0 Earthquake



Earthquake Peak Ground Acceleration

(Correlated Modified Mercalli Scale)

Strong — Very Strong



Study Location Map

Data Sources:
2,475-year probabilistic PGA: Oregon Seismic Hazard Database, Madin and others (2021)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

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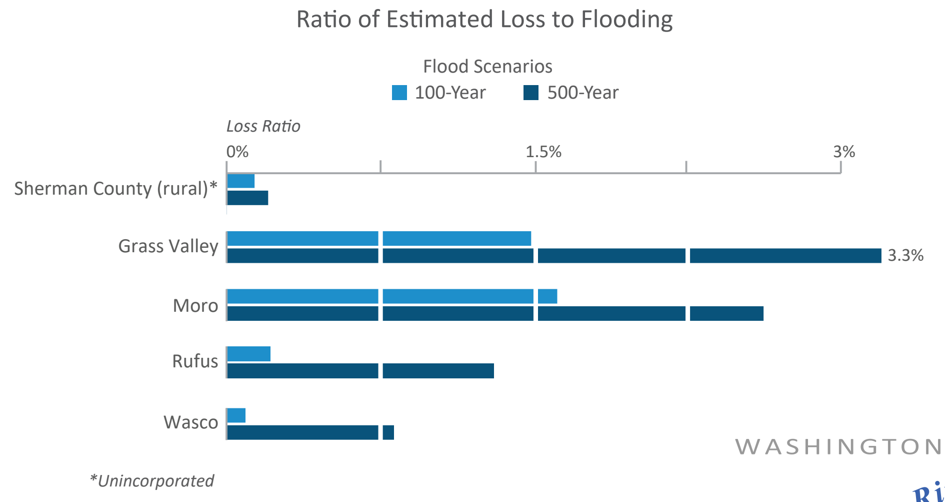
N

0 1.5 3 Miles
0 2.5 5 Kilometers

PLATE 4

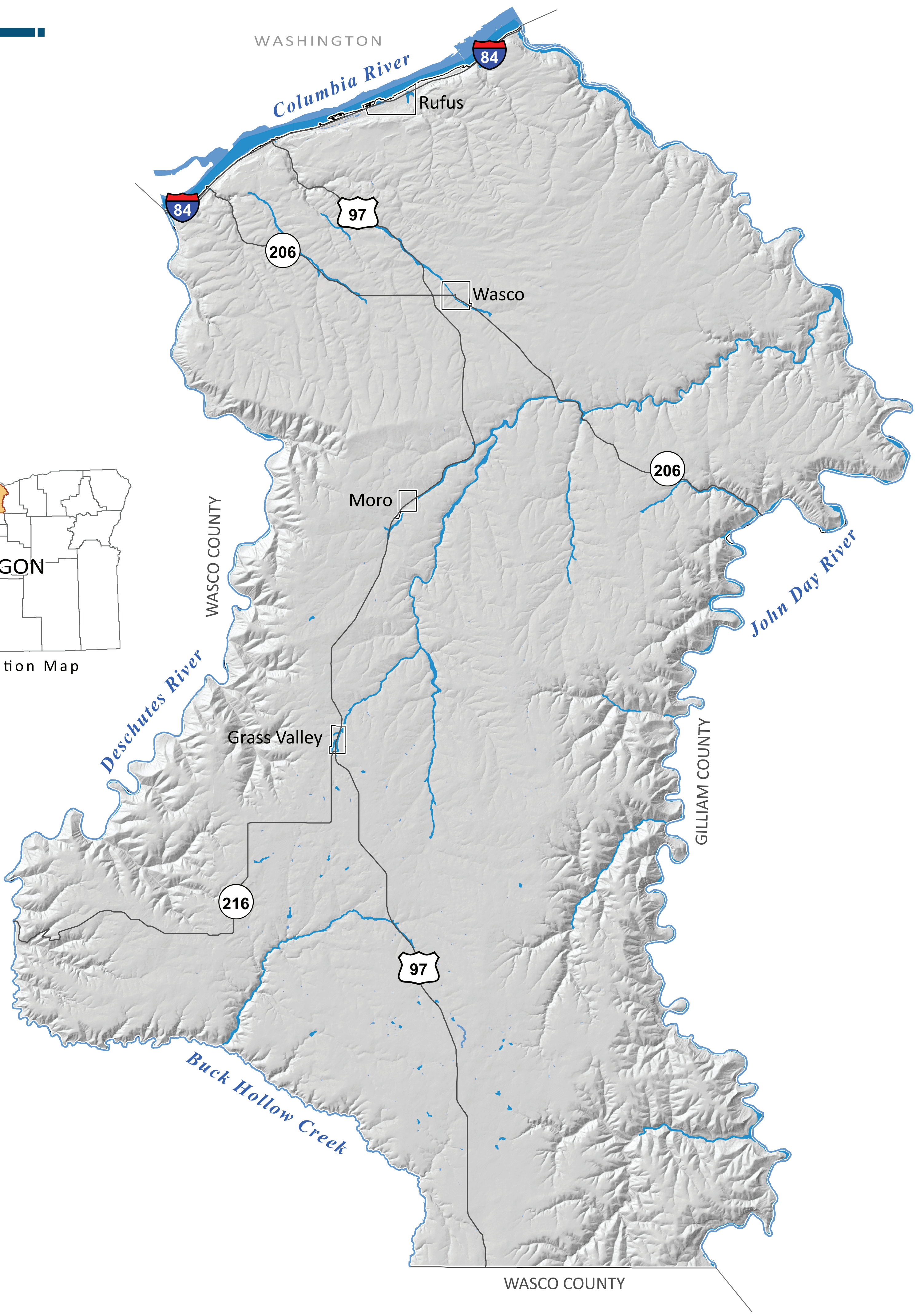
Flood Hazard Map of Sherman County, Oregon

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 Sherman County's Digital Flood Insurance Rate Maps.



Flood Hazard Zone

100-Year Flood (1% annual chance)



Study Location Map

Data Sources:
Flood hazard zone (100-year): FEMA (1984)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

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N

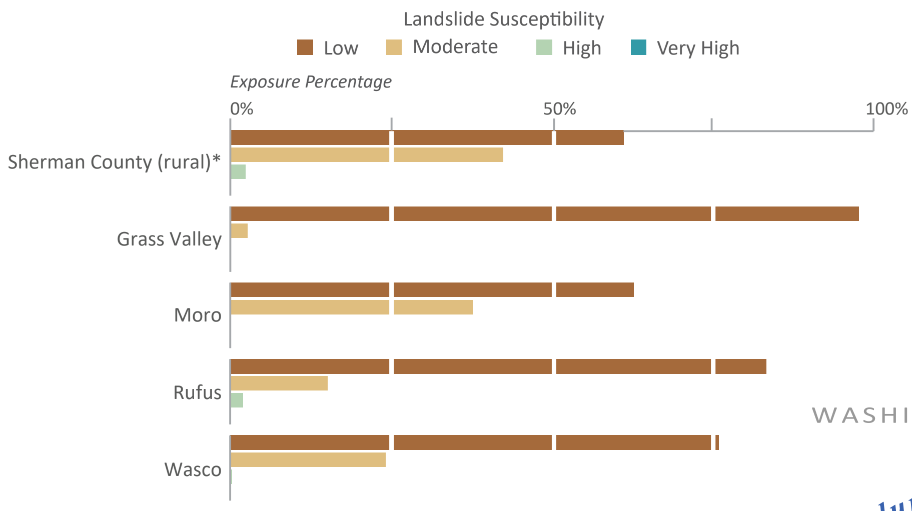
0 1.5 3 Miles
0 2.5 5 Kilometers

PLATE 5

Landslide Susceptibility Map of Sherman County, Oregon

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.

Percentage of Building Value Exposed to Landslide

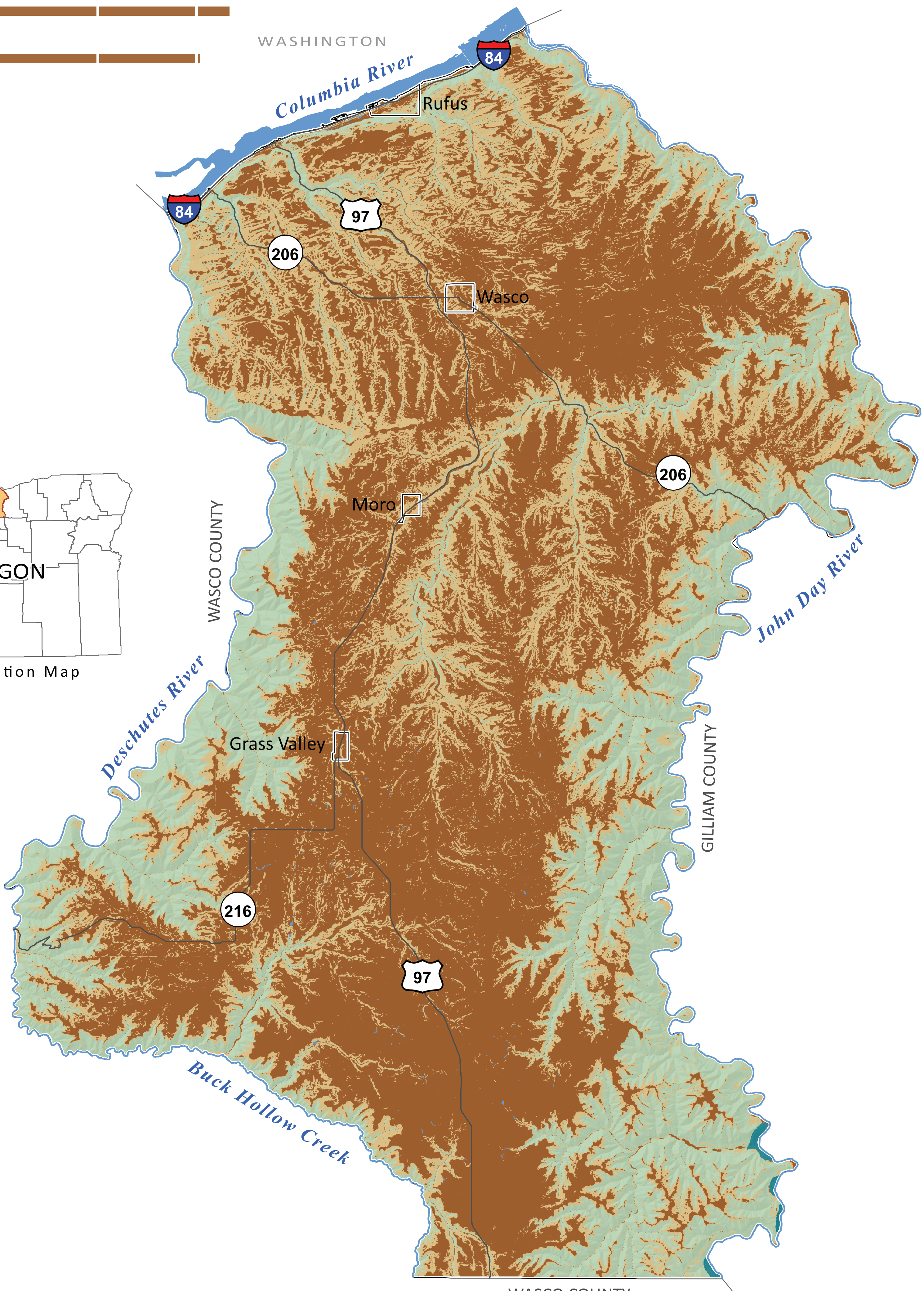


*Unincorporated

Landslide Susceptibility

- Low
- Moderate
- High
- Very High

Study Location Map



Data Sources:
Landslide susceptibility: Burns and others (2016)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

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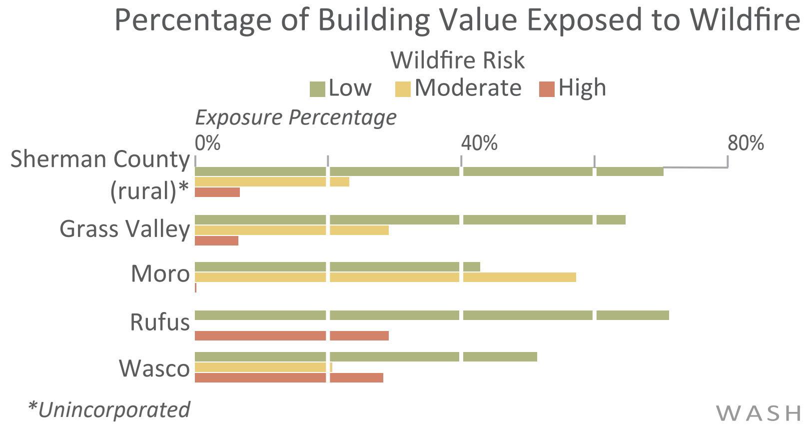
N
0 1.5 3 Miles
0 2.5 5 Kilometers

PLATE 6

Wildfire Risk Map of Sherman County, Oregon

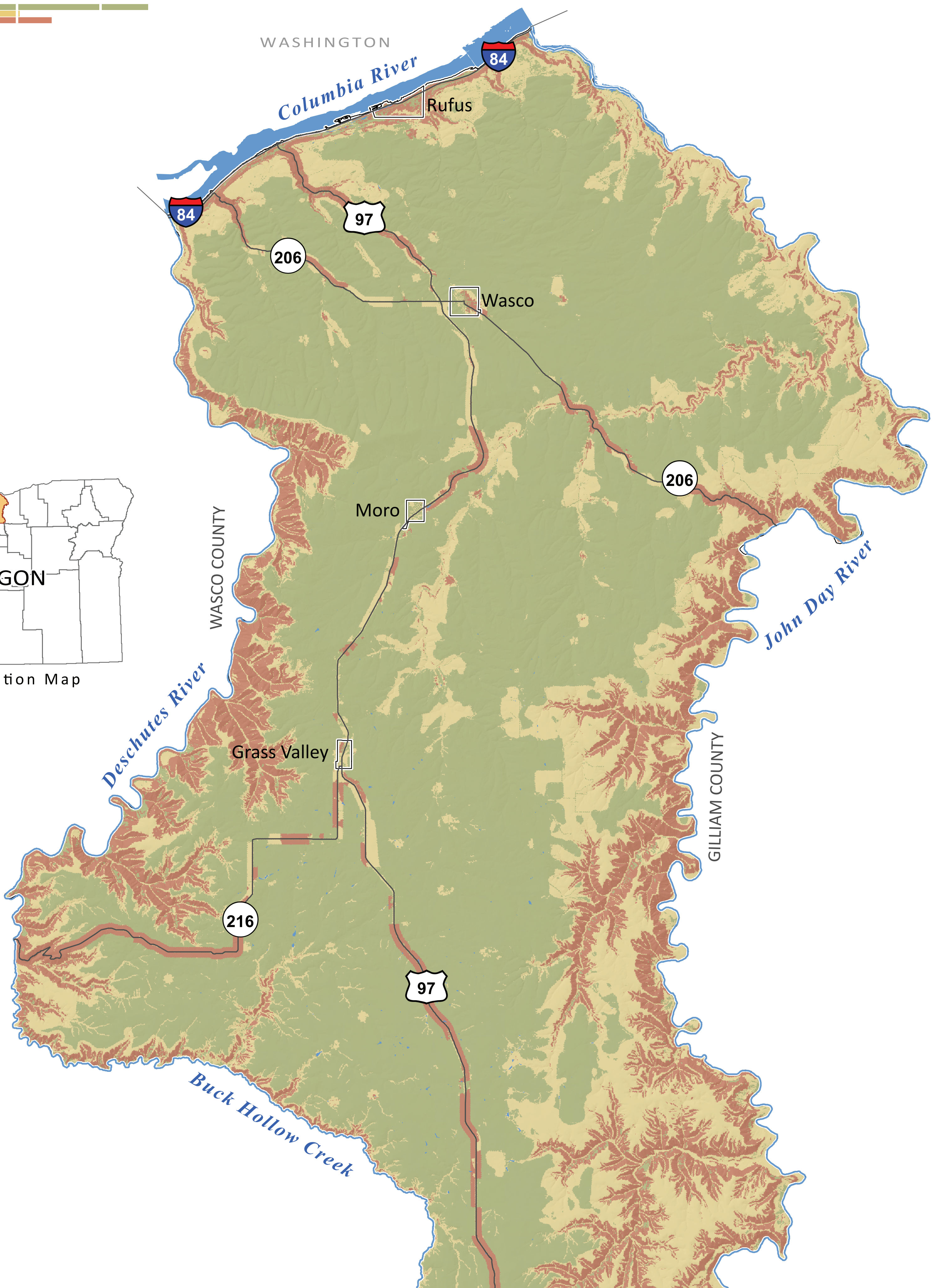
Wildfire Risk is categorized as Low, Moderate, and High and indicates the level of risk a location has to wildfire hazard. The Wildfire Risk data layer (Fire Risk Index) is derived from a combination of the Fire Threat Index (fire history and behavior) and the Fire Effects Index (infrastructure and assets).

Percentage of Building Value Exposed to Wildfire



Wildfire Risk

- Low
- Moderate
- High



Study Location Map

Data Sources:
Wildfire risk data: Oregon Department of Forestry (2013)
Roads: Oregon Department of Transportation (2014)
Place names: U.S. Geological Survey Geograpic Names Information System (2015)
City limits: Oregon Department of Transportation (2014)
Basemap: U.S. Geological Survey and Oregon Lidar Consortium (2012)

Projection: NAD 1983 UTM Zone 10N
Software: Esri® ArcMap 10, Adobe® Illustrator CS6

Cartography by: Lowell Anthony, 2018

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N
0 1.5 3 Miles
0 2.5 5 Kilometers