Chapter 4.2

Earthquake Hazard Risk Assessment

Introduction

The Washington Department of Natural Resources (WADNR) Geological Survey reports that Washington has the second highest risk for large damaging earthquakes in the United States. This is due to the state's geological conditions and the proximity of large intensely developed population centers to known active faults. Large earthquakes have rattled Thurston County in 1949, 1965, and 2001 resulting in major damage and two federal disaster declarations. A University of Washington study following the 2001 Nisqually 6.8 magnitude earthquake found the event caused an estimated $1.5 billion in damage to approximately 300,000 residences. The study also revealed that the vast majority of the region's residents made little effort to adjust their earthquake preparedness following the incident.

Definition

An earthquake is the rapid movement and shaking of the ground caused by a sudden fracture, slipping, or movement in the Earth's crust. A fault is a fracture in the Earth where the two sides have been displaced relative to each other (see Figure 4.2.1 for the active faults in Washington State). A fault ruptures when the accumulation of stress overcomes friction. This rupture disperses energy in the form of seismic waves that move through the earth in all directions. With sufficient energy, it causes the ground to shake or tremor vigorously. This shaking motion and the subsequent behavior of the earth's surface – liquefaction, landslides, ruptures, or ground failure – damages and destroys roads, bridges, buildings, utilities, and other infrastructure. Earthquakes can also produce secondary destructive effects including fires, flooding, and tsunamis.

Effects of Earthquakes

Ground Motion

The intensity of ground shaking depends on a community's proximity to the fault or source that produced the earthquake: the closer to the rupture, the greater the ground shaking. The effects of ground shaking produce ground failures. The composition and structure of the underlying earth also affects intensity. Shaking is strongest in areas of soft soils, such as in river valleys or along the shorelines of bays and lakes. Softer soils amplify ground shaking. The greater the wave velocity difference, the greater the amplification of ground surface shaking. Consequently, ground shaking in areas of soft soils underlain by stiffer soils or rock is generally stronger than in areas where there is little or no variation between the surface and lower layer.[1] Observations of past earthquakes verify this phenomenon as evidenced by damage to buildings and infrastructure in downtown Olympia and Seattle in areas built on fill. Strong ground shaking can damage a variety of structures and utilities.

Ground Failures

Earthquakes can cause surface faulting, landslides, subsidence, and uplifting. Surface faulting occurs when the ground breaks apart. The length, width, and displacement of the ground characterize surface faults. During the 2001 Nisqually earthquake, surface faulting occurred along Deschutes Parkway and around Capitol Lake recreational trails near Interstate 5. Subsidence is the sinking of earth and uplifting is the elevation of earth. Unstable and unconsolidated soils are most vulnerable to ground failures and surface faulting.

Liquefaction

Liquefaction is a phenomenon that occurs when ground shaking causes loose soils to lose strength and act like viscous fluid. Liquefaction causes two types of ground failure: lateral spread and loss of bearing strength. Lateral spreads develop on gentle slopes and involve the sidelong movement of large masses of soil as an underlying layer liquefies. Loss of bearing strength results when the soil supporting a structure liquefies. This can cause structures to tip and topple. Liquefaction typically occurs in artificial fills and in areas of loose sandy soils that are saturated with water, such as low-lying coastal areas, lakeshores, and river valleys.

Area of Impact

The entire Pacific Northwest is seismically active, and all communities are at risk for earthquake hazards. Map 4.2.1 shows susceptibility level for liquefaction in Thurston County. For the risk assessment, three earthquake scenarios were modeled using the natural hazards GIS modeling tool Hazus to assess vulnerabilities, estimate losses, and characterize earthquake hazard risks for Thurston County:

- A Cascadia Subduction Zone Magnitude 9.3 (megathrust earthquake)
- A Nisqually 7.2 (deep intraplate earthquake)
- A Seattle Fault 7.2 (shallow or crustal faulting earthquake)

Earthquake ShakeMaps prepared by the United States Geological Survey were used in the modeling analysis. Data from the WADNR on National Earthquake Hazard Reduction Program (NEHRP) soil types and liquefaction susceptibility were also integrated into the Hazus model.

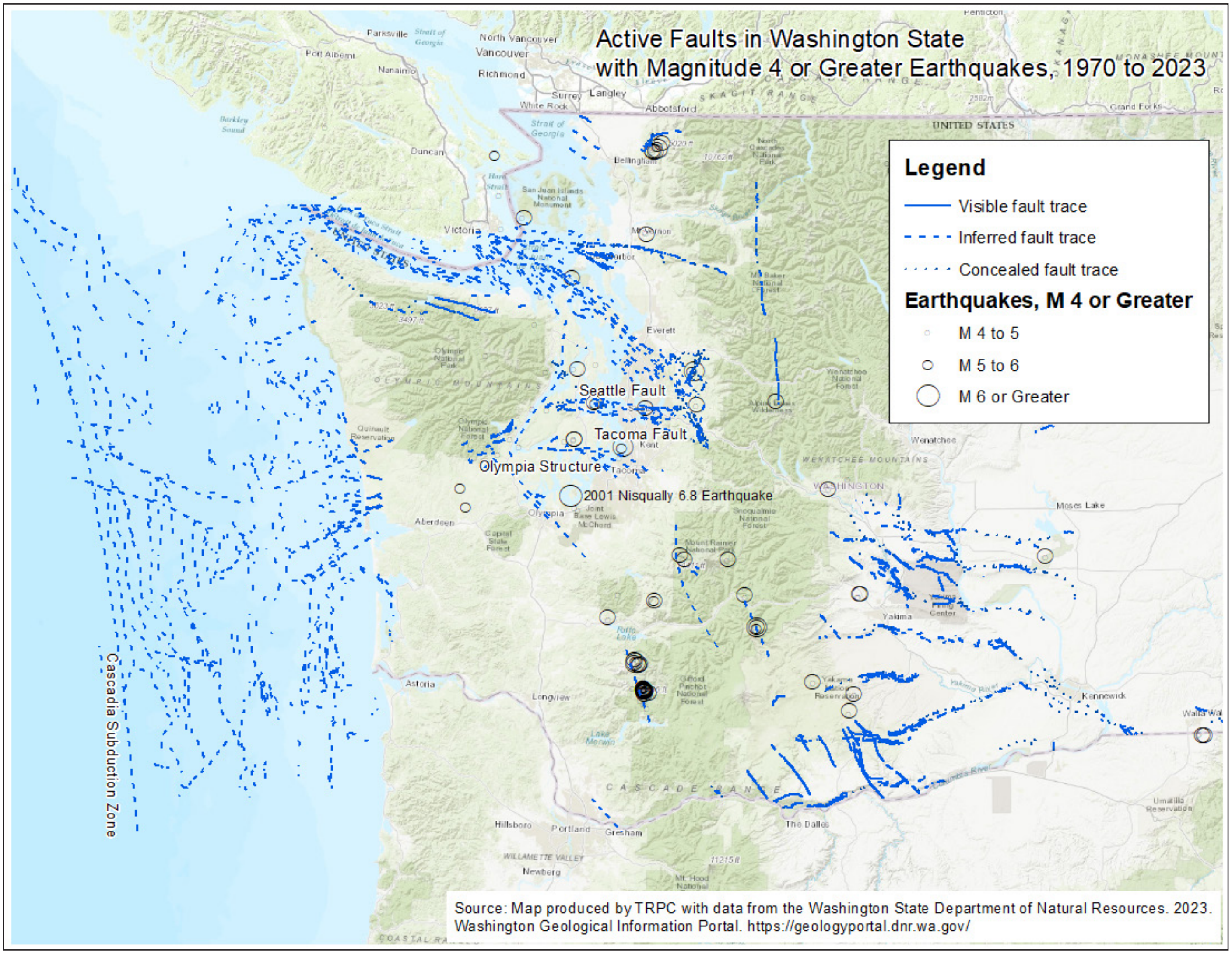
Communities Most Vulnerable to Earthquake Hazards

Maps 4.2.2, 4.2.3, and 4.2.4 are portions of ShakeMaps for Thurston County that show the level of ground shaking by the Mercalli Intensity (see Figure 4.2.4 for definitions) for the Cascadia Subduction Zone, Nisqually, and Seattle earthquake scenarios respectively. The Cascadia Subduction Zone scenario produces very strong to severe shaking across most of Thurston County with more severe shaking expected for the western half of the county. For the Nisqually scenario, moderate to very strong shaking will be felt across the entire county. For the Seattle scenario, strong shaking is expected for the northern third of the county and very light to moderate shaking will be felt further south.

Liquefaction hazards vary from very low to high throughout Thurston County. The following areas have moderate to high liquefaction susceptibility:

- **Town of Bucoda** – Most of Bucoda (63%) is categorized with a moderate to high risk for liquefaction due to the prevalence of sedimentary deposits left by historic surface waters.
- **City of Olympia** – The entire Port Peninsula approximately north of State Avenue, the entire margin of the north basin of Capitol Lake from Marathon Park to Budd Inlet, including Deschutes Parkway. The isthmus between Capitol Lake and West Bay, and the 4th and 5th Avenue corridors, and the filled portions of the western shore of West Bay including West Bay Park and the former Hardel Plywood property. The Henderson Boulevard/Moxlie Creek corridor from north of Watershed Park to East Bay.
- **City of Tumwater** – The entire Deschutes River Valley from Henderson Boulevard SE to the former Olympia Brewery. Percival Creek vicinity from Trosper Road SW to Sapp Road SW.
- **Thurston County** – The north and west ends of Young Cove on the Steamboat Island Peninsula near the Gravelly Beach Road NW and Gravelly Beach Loop NW intersections. Mud Bay at the southern end of Eld Inlet along Delphi Rd to 40th Avenue SW (U.S. Highway 101 runs through this vicinity). The Deschutes River Valley from Henderson Boulevard SE to north of Offut Lake. The entire Nisqually River Delta, including the portion of Interstate 5 that runs through it. The neighborhoods immediately straddling Mullen Road north of Pattison Lake.

Figure 4.2.1 Active Faults in Washington State and Source Locations of Magnitude 4 or Greater Earthquakes, 1970-2023

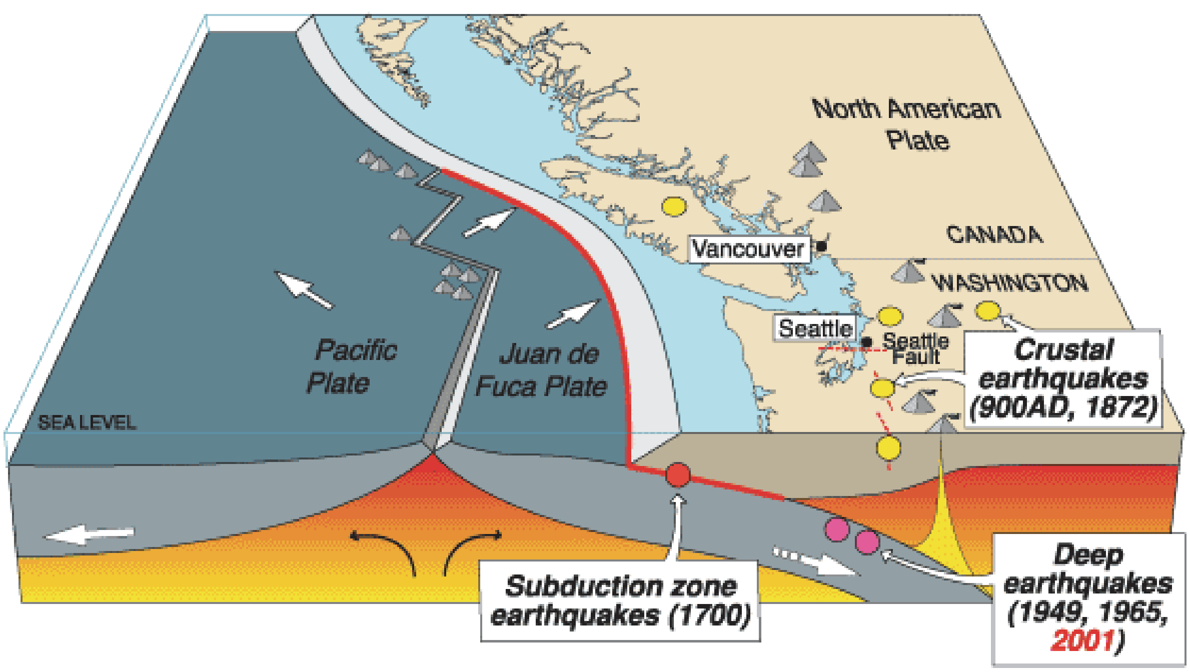


Extent

Sources of Earthquakes Affecting Pacific Northwest

Earthquakes predominantly occur due to the processes of plate tectonics. The Pacific Northwest is one of the most geologically active regions in North America. Seismologists categorize northwest earthquakes into three different source zones (Figure 4.2.2). The three source zones capable of causing major destruction are the Cascadia Megathrust (interplate), Deep Intraplate, and Crustal Faulting zones. The Thurston County region is vulnerable to earthquakes from all three zones. A fourth type, volcanic earthquakes, are generally smaller events and are in remote areas and therefore have less potential to cause damage directly to Thurston County communities.

Figure 4.2.2 Cascadia Earthquake Sources with Maximum Magnitudes and Recurrence Intervals[5]



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

Cascadia Megathrust or Subduction Zone

Most of the world's most damaging earthquakes take place near the ocean boundary between two or more plates, known as interplate earthquakes. Washington State is located on a convergent continental margin, the boundary between three tectonic plates known as the Cascadia Subduction Zone. Located offshore, it stretches nearly 1,000 kilometers from northern California to Vancouver Island, British Columbia. The younger Juan de Fuca Plate is spreading away from the Pacific Plate and plunging beneath the continental North American Plate. The strain between these plates has slowly built-up energy over the last several hundred years, but the plates are locked by friction. When the fault's frictional strength is exceeded and the rocks slip past each other, a megathrust earthquake will occur. When this pressure eventually releases, it will result in "the big one," an estimated magnitude 8.0 to 9.2 earthquake. The edge of the North American Plate will lurch suddenly upward and southwest and the oceanic plates will slip under and northeast. The western edge of the North American Plate is expected to flex, causing the coastline to subside or drop as much as 2 meters in elevation. An earthquake of this strength will result in violent ground shaking that can travel hundreds of miles and last for four to six minutes. Such earthquakes generate massive tsunamis (see Chapter 4.7 Tsunami Hazard Risk Assessment).

Subduction zone earthquakes are the largest, most destructive earthquakes on Earth as recently experienced in 2011 in Tohoku, Japan, the 2004 Sumatra-Andaman earthquakes, the 2001 southern Peru earthquake, the 1965 Alaska earthquake, and the 1960 Great Chilean earthquake. The last subduction zone earthquake in the Pacific Northwest is believed to have occurred in January 1700. Seismologists estimate that such earthquakes have occurred at least seven times in the last 3,500 years with a recurrence interval of 300 to 600 years. The next megathrust earthquake could strike the Pacific Northwest at any time or still be hundreds of years away. In the next 50 years, scientists believe there is a 40 to 80 percent chance of a magnitude 8 to 9 earthquake striking somewhere along the Cascadia Subduction Zone.

Megathrust earthquakes are followed by strong, persistent, and frequent aftershocks in the following weeks, months, and years. Aftershocks gradually diminish, but they pose major hazards to life safety and infrastructure. Earthquakes of such magnitude can drastically alter tens of thousands of points of stress along the plates of a subduction zone, completely modifying the frictional stability of the faults and making them susceptible to ruptures. A megathrust quake can also disrupt both deep intraplate and shallow crustal faults inland. The Olympia Structure, a theoretical fault that transverses Thurston County (see Figure 4.2.1), is one such shallow crustal fault that could be triggered by a megathrust quake.

Two years after the Tohuku earthquake, Japan experienced more than 9,500 aftershocks. While most originated offshore, many registered in the upper and lower range of magnitude 6, strong enough to shake buildings and trigger landslides. The persistent aftershocks forced more than 250,000 people from their homes. In April 2016 a magnitude 7.3 aftershock killed over 40 people and injured more than 1,000 in the city of Kumamoto.[2] In the event of a megathrust earthquake, aftershocks are likely strike the Pacific Northwest with similar frequency and strength.

Deep Intraplate Earthquakes

The Pacific Northwest Seismic Network states that deep intraplate earthquakes are the most common source of damaging earthquakes in Washington and Oregon. They occur along faults in the subducting portions of the Juan de Fuca plate, originating beneath the North American plate. Earthquakes from this zone are common in the greater Puget Sound Basin. They emanate from depths of 30 to 50 miles and can reach a strength as high as magnitude 7.5. Because they rupture at such great depths, their seismic energy is distributed over a large area and the intensity is less than a shallow quake of the same strength. Ground shaking generally lasts less than a minute. Aftershocks from these events are not typical. While tsunamis are not expected, earthquake-induced landslides into the Puget Sound may produce a local tsunami. Due to their proximity to larger urban communities in western Washington, deep earthquakes can cause significant damage.

Historically, earthquakes have originated from this zone about every 30 years. The 1949 Olympia (M6.8), 1965 Seattle (M6.5), and 2001 Nisqually (6.8) earthquakes were all deep intraplate events (see Figure 4.1.1). The 2001 Nisqually earthquake's focus was located about 32 miles deep below its epicenter in the Nisqually River Delta. The United States Geological Survey (USGS) estimates there is an 84 percent chance of another deep earthquake of Magnitude 6.5 or greater occurring within the Puget Sound region in the next 50 years.

Crustal Faulting or Shallow Earthquakes

Crustal (shallow) earthquakes occur along faults close to the surface of the North American plate. They are produced in the upper 18 miles of the Earth's crust, though most occur much closer to the surface. The Seattle fault is perhaps the most infamous, as it lies under the most densely populated area of the state. Most earthquakes in the Pacific Northwest originate from the Crustal Faulting Zone. They could potentially reach magnitudes as high as 7.5, though most are less than 3.0. Ground shaking from earthquakes on shallow faults typically last from 20 to 60 seconds and is localized to the source.

Evidence suggests that an Olympia fault structure may exist across the north end of Thurston County.[3] A strong earthquake is estimated to have occurred nearly 1,100 years ago, which resulted in rapid one to three-meter subsidence in lowland forests near present day McAllister Creek, the Nisqually River, and at Little Skookum Inlet. A magnitude 6.0 or greater earthquake originating from a surface fault could render incredible destruction. More research is necessary to verify the existence of the Olympia fault structure and its probability of rupturing.[4]

Measures of Earthquake Strength

Magnitude

Several common measures are used to articulate earthquake strength. Magnitude (M) is a measurement of the total quantified energy released by an earthquake. "Moment magnitude" is calculated from the amount of movement on the fault causing the earthquake and the area of the fault surface that ruptures during the earthquake. It is a base-10 logarithmic scale, where each whole number increase in magnitude represents a ten-fold increase in measured amplitude, and about 32 times more 'elastic' energy released in the form of seismic waves than the magnitude that precedes it. For example, a M7.0 earthquake releases about 32 times more energy than a M6.0, while a M8.0 releases about 30 times more energy than an M7.0. A M9.0 earthquake thereby releases nearly 1,000 times more energy than a large M7.0 earthquake and nearly 33,000 times more energy than a M6.0 event. Figure 4.2.3 illustrates the scale of the magnitude of historic earthquakes.

Modified Mercalli Intensity

The Modified Mercalli Intensity (MMI) Scale measures the earthquake intensity by the damage it causes. Peak ground acceleration (PGA) is a measure of the strength of ground movements. It expresses an earthquake's severity by comparing its acceleration to the normal acceleration due to gravity. The MMI value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at that place. The lower numbers of the intensity scale generally deal with how people feel the earthquake. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above.

The intensity of an earthquake is also dependent upon the magnitude, the epicenter, the depth, and the soil or rock conditions at the site. The intensity of ground shaking increases with the amount of energy released and decreases with distance from the causative fault or epicenter.

Figure 4.2.3 Comparison of Recent and Historic Earthquakes by Energy Release (Magnitude)[6]

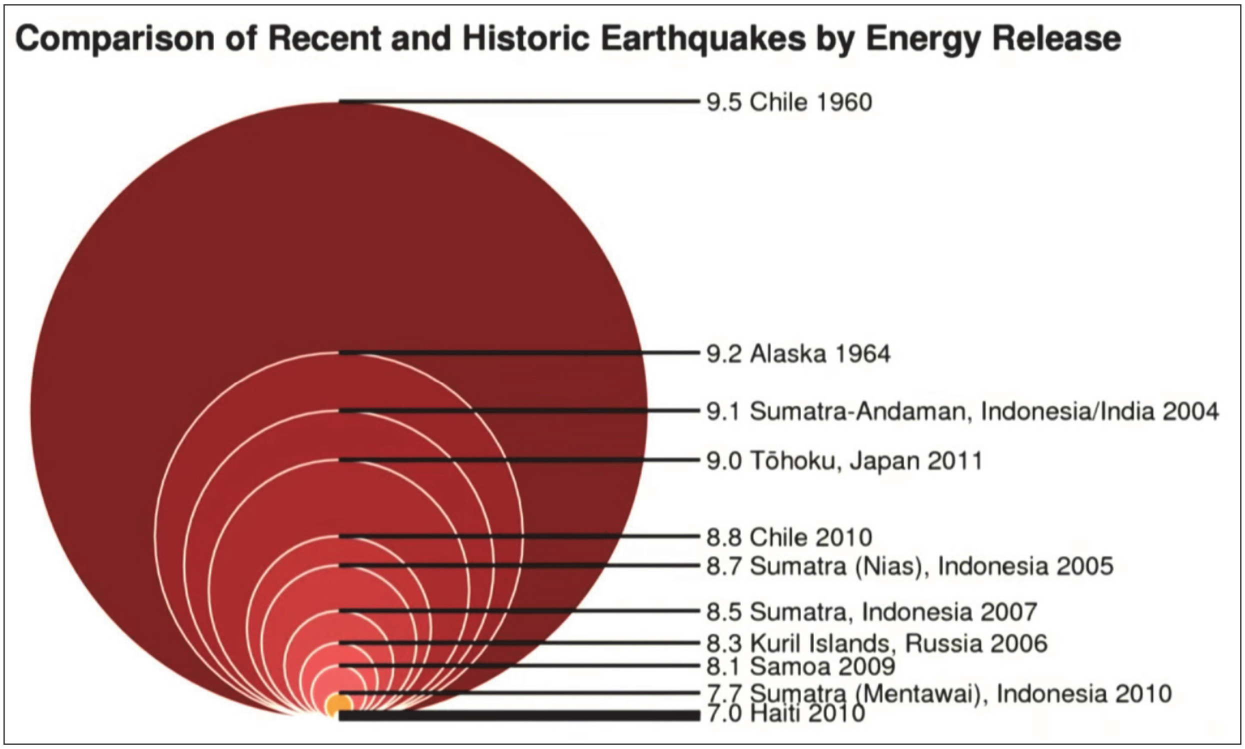


Figure 4.2.4 Modified Mercalli Intensity and Descriptions

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Previous Incidents

Earthquakes have impacted Washington State and the Thurston County region over the last several decades. Previous incidents offer insights into the types of losses that Thurston County communities could experience in future earthquakes.

February 28, 2001, Nisqually Earthquake. Federal Disaster 1361.

At 10:54 a.m. a magnitude 6.8 earthquake produced strong ground shaking across Washington State. The epicenter was located near Anderson Island, approximately 10 miles north of Olympia near the Nisqually River Delta. The observations of geotechnical engineers indicate that liquefaction was widespread in parts of Olympia and South Seattle. Several significant lateral spreads, embankment slides, and landslides also occurred.

Thurston County was among the hardest hit counties in Washington. Statewide, the Nisqually earthquake resulted in several hundred injuries (nearly a dozen considered serious) and one confirmed death (a trauma-induced heart attack). FEMA reported that 41,414 people registered for federal disaster aid, more than three times the number of any previous disaster in Washington.

Unreinforced brick masonry buildings lacking braced parapets and wall anchors were particularly vulnerable, resulting in numerous collapses. In many cases, fallen brick caused damage to objects, such as cars and canopies, outside the building. In the City of Olympia, chimney damage in the South Capitol neighborhood was the most concentrated of anywhere in Puget Sound. The 40-80-foot depth of loosely consolidated soils and gravel found in that neighborhood serves as a conduit for earthquake energy that is particularly hard on single-family homes. This type of damage mirrored that of the 1949 Olympia earthquake (described below).

In unincorporated Thurston County, 120 buildings were inspected, two buildings red-tagged, and six buildings yellow-tagged. In Olympia, 27 buildings were closed immediately following the earthquake. Most buildings performed well from a life-safety standpoint, in that the limited structural damage caused no loss of life or collapse. However, the economic cost of nonstructural damage, i.e., damage to nonessential building elements, such as architectural features, ceiling failures, shifting of equipment, fallen furniture/shelving, desktop computer damage, fallen light fixtures, and losses due to lost productivity, was high. In general, new buildings and buildings that had recently been seismically upgraded typically displayed good structural performance, but many still sustained non-structural damage.

The 74-year-old capitol dome sustained a deep crack in its exterior and damage to supporting columns, and non-structural damage occurred throughout the Legislative Building. Previously scheduled renovation of the building was started early to accommodate $20 - $22 million in earthquake repairs and seismic upgrades. Other state agency buildings were closed for inspection and repair.

A gas line rupture during the earthquake resulted in the evacuation of residents of 50 mobile homes in Tumwater. Part of a private street located within the mobile home park, a block of Pine Street, collapsed into a neighboring pond, taking two unoccupied cars into the water.

The 4th Avenue Bridge in Olympia was one of four bridges in the state to suffer substantial damage from the quake. Constructed in 1920 and retrofitted after the 1949 earthquake, the bridge had been scheduled for replacement even before the 2001 earthquake. The closure of the bridge severely restricted access to downtown Olympia and the City's west side. Replacing the bridge and connecting infrastructure cost $39 million; the largest public works endeavor in the city's history.

Deschutes Parkway in Olympia suffered the most damage of any road in the state. Waterlogged soil under the road liquefied during the shaking, creating huge voids beneath portions of the concrete road surface. Sections of road and sidewalk also buckled from the force of the quake. This road, a vital link between downtown Olympia, the City's west side, and Tumwater, was closed to traffic for 20 months.

A number of landslides occurred. Most of these slides occurred in natural materials, including a 400-foot slide on the northeast side of Capitol Lake. Other slides occurred in engineered fills, particularly at locations where they spanned low-lying areas of natural soils. A flow slide removed part of Highway 101 just west of Olympia, closing both northbound lanes of traffic, as well as Madrona Beach Road.

Except for transportation, lifeline systems generally performed well during the earthquake. Lifeline systems include water, wastewater, electrical power, communications, natural gas and liquid fuels, and transportation systems. In most cases, the impact of lifeline damage was minimal. Puget Sound Energy reported 200,000 customer power outages, and Seattle City Light reported 17,000 outages, but power was restored to most customers within a day. Landline and wireless communication systems were extremely overloaded immediately following the earthquake. Only five of the state's 290 dams were found to have earthquake-related damage. One of these was the McAllister Springs Reservoir Dam in Thurston County.

April 29, 1965, Seattle Tacoma Earthquake. DR 196.

A magnitude 6.5 earthquake struck the Puget Sound Region at 7:28 a.m. The epicenter was located about 12 miles north of Tacoma at a depth of about 40 miles. This quake killed seven people and damage was estimated to be $12.5 million (1965 dollars); with much of the loss in King County. The Union Pacific Railroad reported a hillside fill slid away from beneath a 400-foot section of a branch line just outside of Olympia. Damage to the Capitol Building – including a crack about 3 feet long on the inside of the inner dome of the rotunda – forced adjournment of the legislative session. A road around Capitol Lake, at the base of the Capitol complex, was damaged, allowing water to flow beneath the road. St. Peter Hospital reported treating four people for minor injuries.

April 13, 1949, Olympia Earthquake.

A magnitude 6.8 earthquake rattled the region at 11:55 a.m. The epicenter was located about eight miles north-northeast of Olympia. Property damage for the Puget Sound Region likely exceeded $25 million (1949 dollars). Eight state government buildings in Olympia were damaged at a loss of two million dollars. Two people died. The quake damaged nearly all large buildings in Olympia – with cracked or fallen walls and plaster. Two large smokestacks and many chimneys fell. Streets were damaged extensively. Water and gas mains broke. A large portion of a sandy spit jutting into Puget Sound north of the city disappeared completely during the earthquake.

Probability of Occurrence

There is a 40 to 80 percent chance of a large earthquake occurring in Washington State in the next 50 years. As such this plan assigns all three earthquake scenarios a medium probability of occurrence – all are likely to occur within 100 years.

Vulnerabilities and Impacts

Impacts to People

The immediate life safety impacts from collapsing buildings and other structures or from secondary hazards such as fires can cause serious injuries and fatalities. The 2010 and 2011 Christchurch, New Zealand earthquakes claimed 185 lives. Other near-term earthquake life safety risks include:

- Potential infections from untreated wounds.
- Disruption to water and wastewater utilities.
- Contamination of drinking water systems.
- Increased morbidity and risks of complications for people with chronic diseases due to interruption of medical treatment.
- Increased risk of complications related to pregnancy and childbirth due to interruption of neonatal and obstetric services.
- Increased mental health incidents due to post traumatic stress.
- Increased sheltering demand from individuals who are displaced due to damaged or uninhabitable residences.

Earthquake damage to transportation and utilities will disrupt manufacturing and supply chains and create critical shortages in goods and services that will impact individuals, households, and communities. Most homeowners do not have earthquake hazard insurance policies. Earthquake damage to homes, local economic impacts, and job losses will make it difficult for socially vulnerable individuals and households to recover from earthquake damage.

The entire Thurston County population is at risk to earthquakes. The risk assessment factors that 100 percent of each jurisdiction's population is exposed to earthquake hazards for all three earthquake scenarios (Table 4.2.1). Table 4.2.2 shows estimates of the number of households that will be displaced due to residential earthquake damage and the number of people who will require short-term sheltering.

Table 4.2.1 Thurston County Population Exposed to Earthquake Risks

		% Population Exposed		
Jurisdiction	**Total Population**	**Cascadia M9.3**	**Nisqually M7.2**	**Seattle M7.2**
Bucoda	610	100%	100%	100%
Lacey	58,180	100%	100%	100%
Olympia	56,370	100%	100%	100%
Rainier	2,510	100%	100%	100%
Tenino	2,030	100%	100%	100%
Tumwater	26,360	100%	100%	100%
Yelm	10,680	100%	100%	100%
Unincorporated Thurston County	143,760	100%	100%	100%
Total Planning Area	**300,500**	**100%**	**100%**	**100%**

Table 4.2.2 Thurston County Earthquake Household Displacement and Individual Sheltering Needs

Jurisdiction	Cascadia M9.3		Nisqually M7.2		Seattle M7.2	
	Households Displaced	Individuals Needing Shelter	Households Displaced	Individuals Needing Shelter	Households Displaced	Individuals Needing Shelter
Bucoda	40	24	2	1	0	0
Lacey	1,572	877	152	85	38	21
Olympia	2,010	1,096	185	97	47	26
Rainier	14	8	1	0	0	0
Tenino	13	7	0	0	0	0
Tumwater	811	406	68	35	15	8
Yelm	68	43	4	3	1	1
Unincorporated Thurston County	655	369	30	17	9	5
Total Planning Area	**5,182**	**2,830**	**443**	**237**	**111**	**61**

Impacts to Structures and Systems

A Cascadia Subduction Zone Earthquake will cause damage to homes, buildings, structures, and their contents. Aside from damage from shaking and ground failures, buildings may suffer damage from fires or water damage from severed water lines. In the Puget Sound Region, older unreinforced masonry structures such as buildings, walls, chimneys, and facades are vulnerable to crumbling from ground shaking. Areas with soft soils, such as downtown Olympia and adjacent neighborhoods have experienced this type of destruction during the 1949, 1965, and 2001 earthquakes and many homes and buildings remain vulnerable.

Transportation infrastructure including roads, bridges, transit facilities, rail lines, marine terminals, and airport runways will suffer damage and cause full or partial closure of facilities. All modes of transportation are vulnerable and major traffic disruptions will occur.

Energy distribution for electricity, natural gas, and fuel are vulnerable and will experience damage and disruptions. Drinking water and wastewater systems are also vulnerable as evidenced in previous earthquakes. Communications networks including internet, landline phone, and wireless services will experience disruptions from damage or power disruption and may be unreliable for prolonged periods. Major utility interruptions will force people and communities to adapt to life without the accustomed modern conveniences of indoor plumbing, electricity, and natural gas.

Hospitals and healthcare facilities could suffer damage resulting in a reduction in services or operational capacity. Even in the absence of damage, healthcare facilities that lack backup power or emergency water supply will be inoperable until utilities are restored.

Equipment in office buildings such as computers, monitors, and other equipment is subject to damage if not secured. Libraries, grocery stores, and other merchandisers are likely to suffer losses from damaged goods or experience closures due to unsafe business conditions.

The Pacific Northwest is heavily dependent on truck freight distribution. Any major disruption to transportation, energy, and communications will impact production and distribution of food and other general merchandise resulting in critical shortages for communities.

Estimates of Structural and Content Damage

Hazus modeling results for the Cascadia Subduction Zone M9.3 earthquake estimates there will be over $3.5 billion in structural losses and $1.5 billion in content losses countywide (Table 4.2.3).

Table 4.2.3 Thurston County Estimated Value of Earthquake Structural and Content Damage

	Cascadia M9.3		Nisqually M7.2		Seattle M7.2	
Jurisdiction	Structure Damage Value	Contents Damage Value	Structure Damage Value	Contents Damage Value	Structure Damage Value	Contents Damage Value
Bucoda	$6,483,618	$2,086,159	$1,135,105	$1,396,488	$38,530	$23,758
Lacey	$652,953,041	$294,139,558	$146,583,916	$165,638,440	$20,699,242	$13,927,947
Olympia	$1,120,596,938	$456,206,118	$198,776,101	$234,573,117	$48,840,580	$27,970,420
Rainier	$8,703,252	$3,693,126	$1,829,173	$2,062,368	$106,093	$67,599
Tenino	$12,441,838	$6,159,193	$2,200,024	$2,631,481	$85,319	$66,855
Tumwater	$682,594,027	$314,297,626	$109,742,430	$133,975,231	$16,949,031	$10,225,500
Yelm	$32,826,674	$17,612,336	$10,756,046	$11,772,790	$769,636	$558,440
Unincorporated Thurston County	$984,579,057	$357,753,068	$161,594,486	$177,886,479	$29,791,008	$15,264,168
Total Planning Area	$3,501,178,444	$1,451,947,183	$632,617,281	$729,936,394	$117,279,439	$68,104,686

Estimates of Structural Debris

A Cascadia Subduction Zone earthquake is estimated to generate nearly 1.4 million tons of structural debris countywide. Table 4.2.4 shows estimated debris generation for each earthquake scenario.

Table 4.2.4 Thurston County Estimated Earthquake Structure Debris

	Structure Debris (x 1000 tons)		
Jurisdiction	Cascadia M9.3	Nisqually M7.2	Seattle M7.2
Bucoda	16.79	1.67	0.22
Lacey	272.95	36.22	12.18
Olympia	474.69	61.57	20.12
Rainier	11.36	1.25	0.24
Tenino	22.72	2.05	0.40
Tumwater	198.35	24.70	6.59
Yelm	44.59	5.70	1.31
Unincorporated Thurston County	315.83	29.64	9.07
Total Planning Area	1,357.28	162.80	50.13

Estimates of Lifeline Damage Levels

Over 1,200 community lifeline assets were evaluated. The Hazus models provide estimates of the level of damage that facilities would experience in each earthquake scenario. Tables 4.2.5 - 4.2.7 show the number of buildings that have a 50 percent or greater probability of damage.

Table 4.2.5 Thurston County Community Lifelines Cascadia M9.3 Earthquake Estimated Damage Levels

		Number of Buildings with a 50% or Greater Probability for Damage			
Lifeline	Total Critical Facilities Evaluated	Slight	Moderate	Extensive	Complete
Communications	139	0	43	75	21
Energy	56	0	1	42	13
Food, Water, and Sheltering	298	25	78	133	59
Hazardous Material	54	1	3	41	9
Health & Medical	286	212	63	11	0
Safety & Security	301	63	116	105	9
Transportation	143	26	21	24	7
Total	1,277	327	325	431	118

Table 4.2.6 Thurston County Community Lifelines Nisqually M7.2 Earthquake Estimated Damage Levels

Lifeline	Total Critical Facilities Evaluated	Number of Buildings with a 50% or Greater Probability for Damage			
		Slight	Moderate	Extensive	Complete
Communications	139	60	55	0	0
Energy	56	25	29	2	0
Food, Water, and Sheltering	298	135	70	24	0
Hazardous Material	54	28	20	1	0
Health & Medical	286	108	2	0	0
Safety & Security	301	86	39	0	0
Transportation	143	26	15	0	0
Total	1,277	468	230	27	0

Table 4.2.7 Thurston County Community Lifelines Seattle M7.2 Earthquake Estimated Damage Levels

Lifeline	Total Critical Facilities Evaluated	Number of Buildings with a 50% or Greater Probability for Damage			
		Slight	Moderate	Extensive	Complete
Communications	139	5	0	0	0
Energy	56	0	0	0	0
Food, Water, and Sheltering	298	1	2	0	0
Hazardous Material	54	0	0	0	0
Health & Medical	286	0	0	0	0
Safety & Security	301	1	0	0	0
Transportation	143	4	0	0	0
Total	1,277	11	2	0	0

Impacts to Natural, Cultural, and Historic Resources

A major earthquake can compromise the containment of hazardous materials resulting in a release of pollutants that could pose health risks to areas of communities including impacting air quality, spills in populated areas, or infiltration of pollutants into water resources. Major disruptions to solid waste disposal services, water services, and wastewater treatment will require public education and interventions to protect public health and the environment from improper disposal of refuse and human waste.

Earthquakes can cause landslides that could impact river flows and subsequently cause flooding to surrounding areas. Major ground elevation changes such as subsidence could alter marine and freshwater habitats (see Tsunami Risk Assessment for related environmental impacts).

Without adequate proactive measures, historic homes, buildings, monuments, and other structures could be damaged or become total losses.

Impacts to Activities

A major earthquake is expected to change daily life for people and communities in Thurston County. All sectors of society will be affected. Recovery could take years and community members will need effective adaption measures and guidance from governments, private utilities, volunteer organizations involved in recovery, and media to overcome the challenges posed by earthquake damage and disruptions. Earthquake damage can disrupt work, school, access to healthcare, and access to goods and services.

Transportation

Disruptions to surface transportation networks and energy distribution will have a major impact on the movement of people, freight, goods, and services. All trip purposes will be affected. Commutes to workplaces and schools may be interrupted for prolonged periods. The lack of power and communications networks will also impact remote work/school options for large areas. In the near-term there will likely be a shortage of skilled workers in healthcare, construction, utilities, and other industries as people will be unable to commute long distances to their workplace.

Personal discretionary travel, especially by automobile, will be limited as transportation authorities will prioritize fuel and routes for emergency services and essential personnel for the restoration and reconstruction of transportation, utilities, and other critical facilities. Bicycling, walking, and adapted transit services could become effective modes to satisfy some basic travel needs.

Safety and Security

In the near term, fire and emergency medical services, police services, and public works will be in high demand. Communications and transportation disruptions will impact emergency response times in the days and weeks following a major earthquake. Community members will need to rely on neighborhood social networks to help address non-life-threatening emergencies.

Substandard living conditions and prolonged shortages of food, medicine, and other essential goods will be stressful to the unprepared population. Communities could experience increased rates of crime and civil unrest.

Commerce

Damage to buildings, power and water disruptions, and the inability of employees to commute to work will impact local businesses. Owners are likely to lose their businesses, and employees their jobs. The loss of revenue will impact local governments and public services.

Portions of Downtown Olympia are highly susceptible to liquefaction and there are many older buildings with unreinforced masonry that are vulnerable to earthquake damage. A major earthquake could render several buildings uninhabitable and cripple business activity. Some buildings may be so badly damaged, they will need to be demolished. Buildings not directly impacted by earthquake damages could be impacted by surrounding debris and street closures for response and recovery activities.

Risk Ratings

Social Vulnerability Rating and National Risk Index

Social vulnerability is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. As a consequence enhancing risk component of the National Risk Index, a Social Vulnerability score and rating represent the relative level of a community's social vulnerability compared to all other communities at the same level. A community's Social Vulnerability score measures its national rank or percentile. A higher Social Vulnerability score results in a higher Risk Index score. Map 4.2.5 shows all of Thurston County's building stock that is exposed to a major earthquake.

The Federal Emergency Management Agency National Risk Index (NRI) for earthquake in Thurston County is 98.9 (relatively high). The rating represents a community's relative risk for earthquake when compared to the rest of the United States. For comparison, Pierce County's NRI for earthquake is 99.5 (also relatively high). The NRI reports an estimated earthquake hazard annual loss of $96 million for Thurston County.

Community Hazard Risk Ratings for Earthquake Scenarios

The countywide Cascadia M9.3, Nisqually M7.2, and Seattle M7.2 risk ratings are high, medium, and medium, respectively. All special purpose districts' risk ratings for each earthquake scenario are 32, a medium rating. Tables 4.2.8 and 4.2.9 show community and special purpose earthquake hazard risk ratings. The details of the earthquake hazard risk assessment calculations are shown in Appendix C.

Table 4.2.8 Community Earthquake Hazard Risk Ratings

	Cascadia M9.3		Nisqually M7.2		Seattle M7.2	
Municipal Plan Participants	Risk Ranking Score	Risk Rating	Risk Ranking Score	Risk Rating	Risk Ranking Score	Risk Rating
Bucoda	36	High	32	Medium	32	Medium
Lacey	34	High	32	Medium	32	Medium
Olympia	34	High	32	Medium	32	Medium
Rainier	32	Medium	32	Medium	32	Medium
Tenino	32	Medium	32	Medium	32	Medium
Tumwater	36	High	32	Medium	32	Medium
Yelm	32	Medium	32	Medium	32	Medium
Unincorporated Thurston County	34	High	32	Medium	32	Medium
Total Planning Area	34	High	32	Medium	32	Medium

Table 4.2.9 Special Purpose District Dam Failure Hazard Risk Ratings

	Cascadia M9.3		Nisqually M7.2		Seattle M7.2	
Special Purpose District Plan Participants	Risk Ranking Score	Risk Ranking Score	Risk Ranking Score	Risk Rating	Risk Ranking Score	Risk Rating
East Olympia Fire District	32	Medium	32	Medium	32	Medium
Intercity Transit	32	Medium	32	Medium	32	Medium
Lacey Fire District	32	Medium	32	Medium	32	Medium
McLane Black Lake Fire District	32	Medium	32	Medium	32	Medium
Olympia School District	32	Medium	32	Medium	32	Medium
SE Thurston Fire Authority	32	Medium	32	Medium	32	Medium
South Bay Fire District	32	Medium	32	Medium	32	Medium
The Evergreen State College	32	Medium	32	Medium	32	Medium
Thurston PUD	32	Medium	32	Medium	32	Medium
West Thurston Regional Fire Authority	32	Medium	32	Medium	32	Medium

Changes in Earthquake Hazard Risks Since Last Plan Update

The 2017 Natural Hazards Mitigation Plan for the Thurston Region rated a M9.0 earthquake scenario risk as high for the overall planning area. The 2023 plan rates a Cascadia M9.3 earthquake as high, although a different risk rating methodology was used. Population exposure estimates are derived from residential units. Thurston County's total population has increased by approximately 30,000 since the plan was last updated. Overall, there are more people exposed to earthquake hazards. In the past year alone, over 11,000 people (3.9 percent of the County's population) located to Thurston County from outside of Washington State. It is likely that our region's newcomers are unfamiliar and unprepared for earthquake hazards.

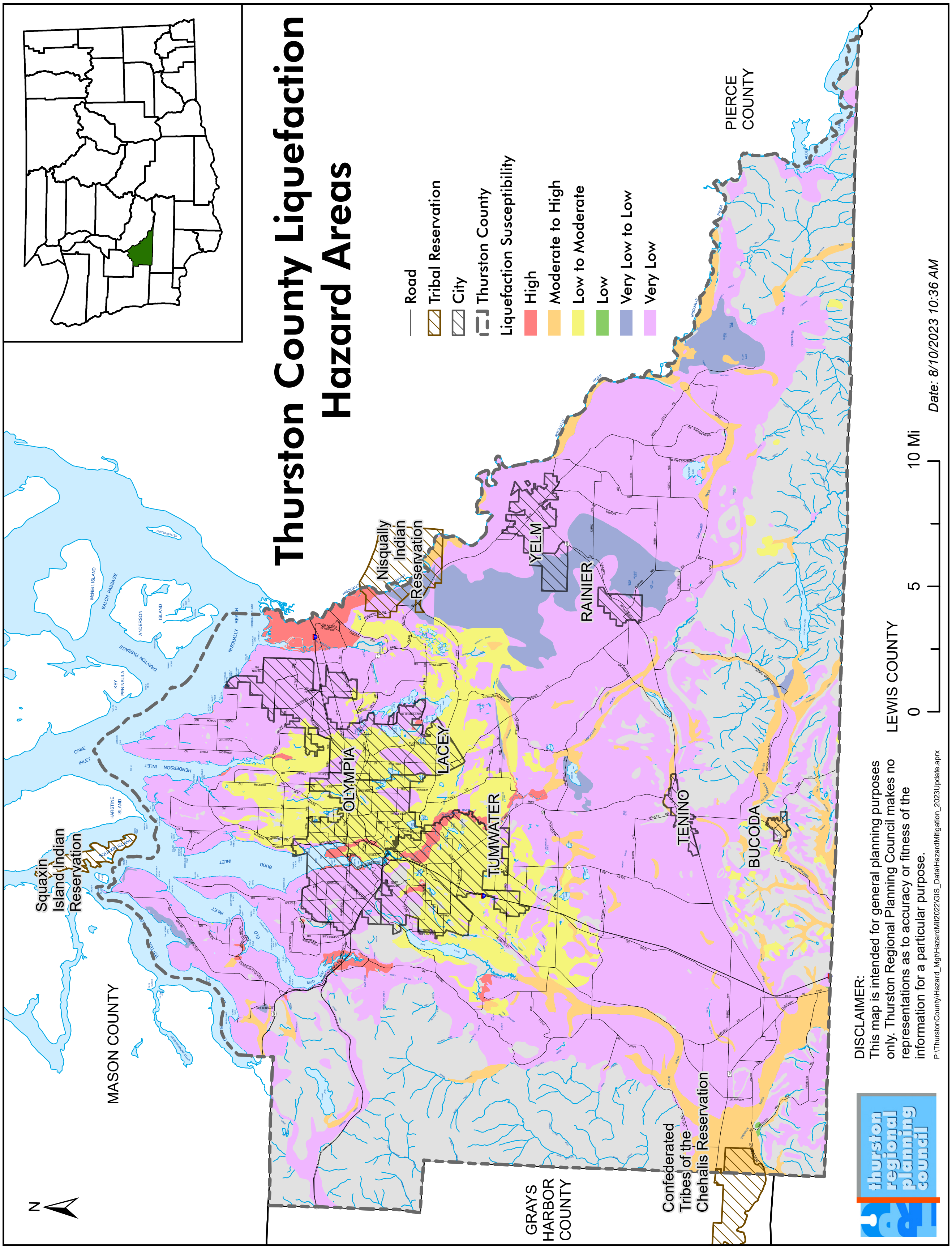
The COVID-19 pandemic dramatically changed how people work. A large share of the region's daytime working population shifted from traditional in-person office environments in central business districts to teleworking in residential areas. With the region being home to the state's capitol, a significant share of state and local government employees may face fewer risks than they did prior to 2020. An estimated 30 percent of the state's workforce teleworks 100 percent of the time while nearly 50 percent telework at least three days a week. This shift is expected to remain for the foreseeable future. As a consequence, fewer workers may be exposed to earthquake hazards. A reduction in peak hour commute trips to and from central business districts means a smaller share of the region's workforce will suffer transportation disruptions immediately following an event. Secondly, fewer workers will be in urban environments, which are likely to experience more damage than residential environments. As a consequence, remote workers may have a reduced risk for personal injuries that could occur in or around a more urbanized environment.

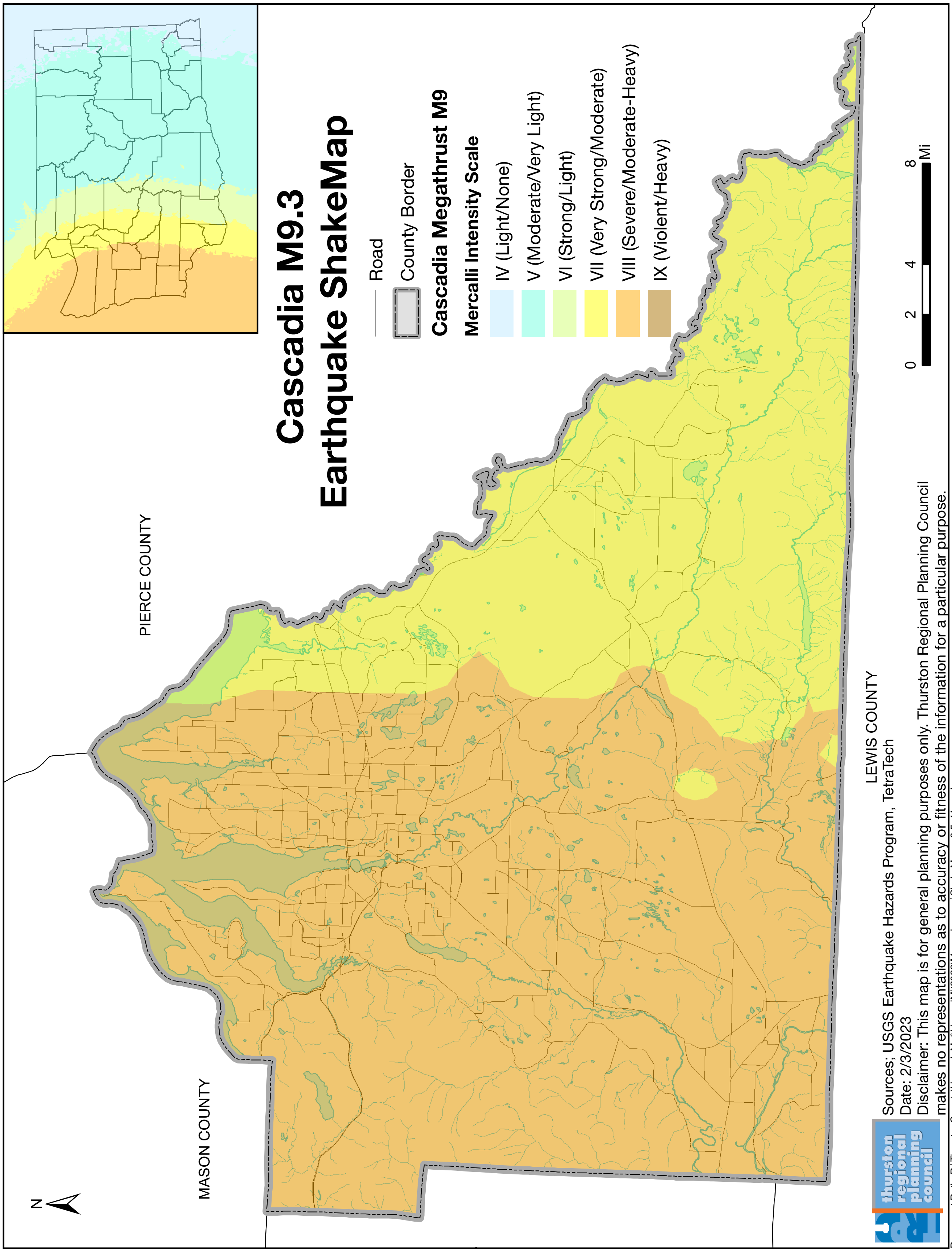
Connection to the Regional Mitigation Strategy

The 2022 "Thurston County Communities Natural Hazards and Resiliency Survey" results show that countywide, respondents ranked earthquake as the highest-rated hazard of concern. This is expected considering the region is prone to seismic hazards and residents recall the 2001 Nisqually earthquake. Only 43 percent of survey respondents indicated they have taken some steps to prepare for hazards. However, most households are likely very unprepared for the impacts from a megathrust earthquake. Earthquake hazard education and preparedness for community residents is critical. Earthquake hazard information will be included through Regional Hazard Mitigation Public Outreach Strategy initiative.

The region's planning partners recognize that more work is necessary to broaden the inventory and documentation of the location, characteristics, and vulnerabilities of the region's lifelines and critical infrastructure. To this end, the Critical Infrastructure Inventory will help inform and prioritize investments in strengthening communities' vital assets. The Hazard Modeling and Loss Estimation Capacity Building initiative will build local knowledge and technical skills to develop, operate, and maintain community-specific GIS-based hazard modeling tools that include local data. Local modeling tools can inform planning and decision making for hazard mitigation, emergency management, and disaster recovery, and training. The Lifeline Transportation Resiliency Plan will identify priority transportation projects to strengthen bridges, roads, and other multimodal transportation assets so they withstand the effects of earthquakes.

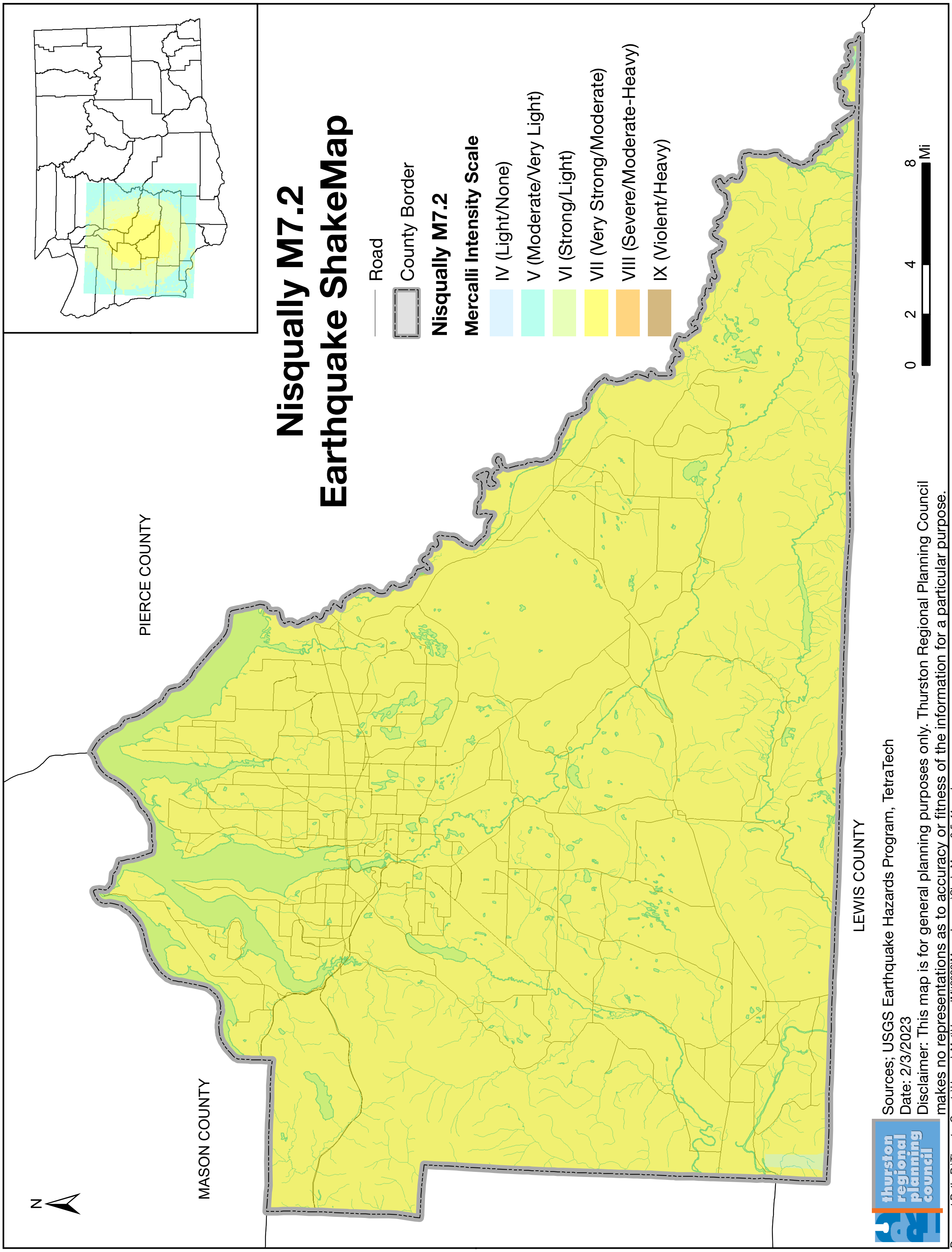
Map 4.2.1 Thurston County Liquefaction Susceptibility



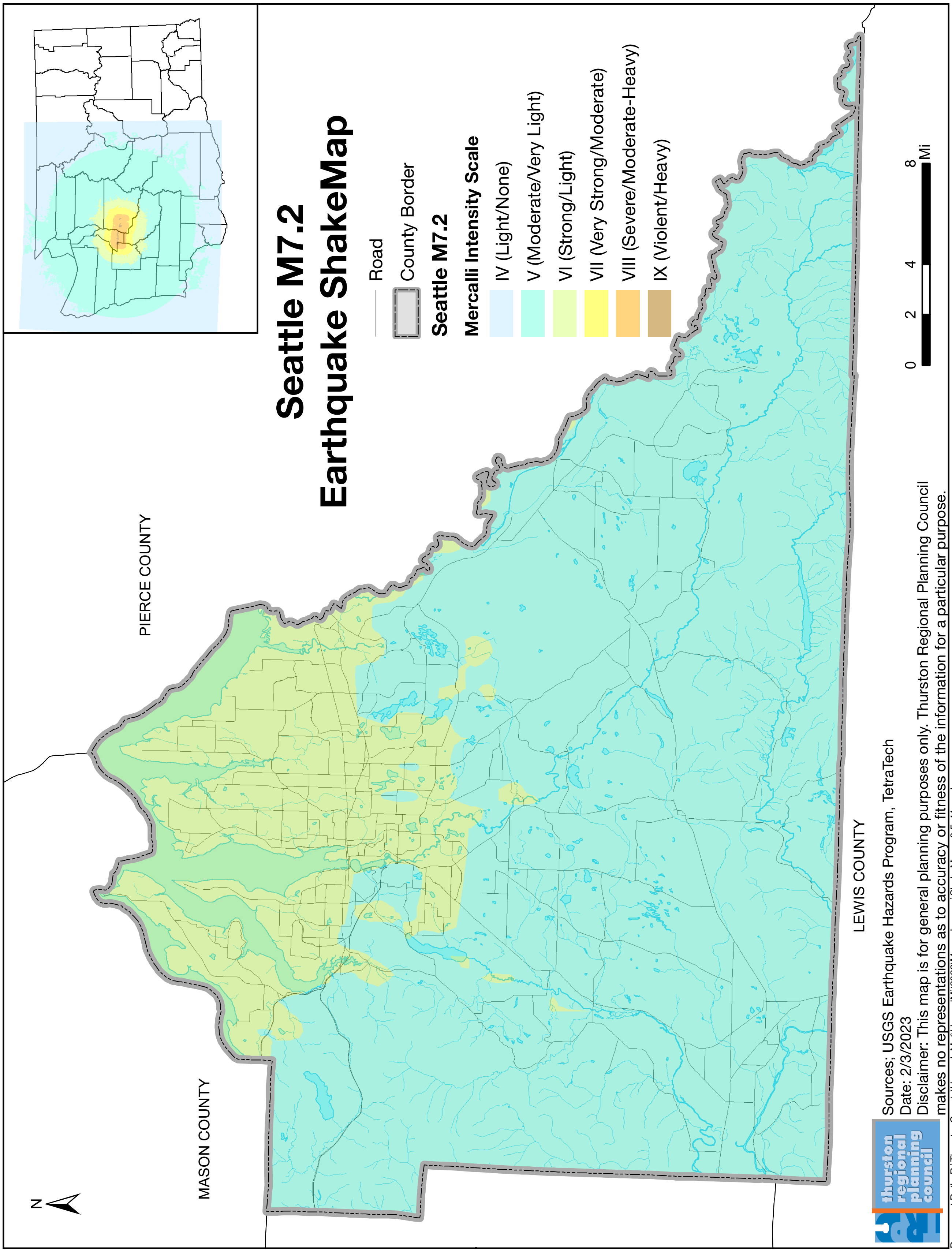


Map 4.2.2 Cascadia Subduction Zone M9.3 Earthquake Scenario ShakeMap

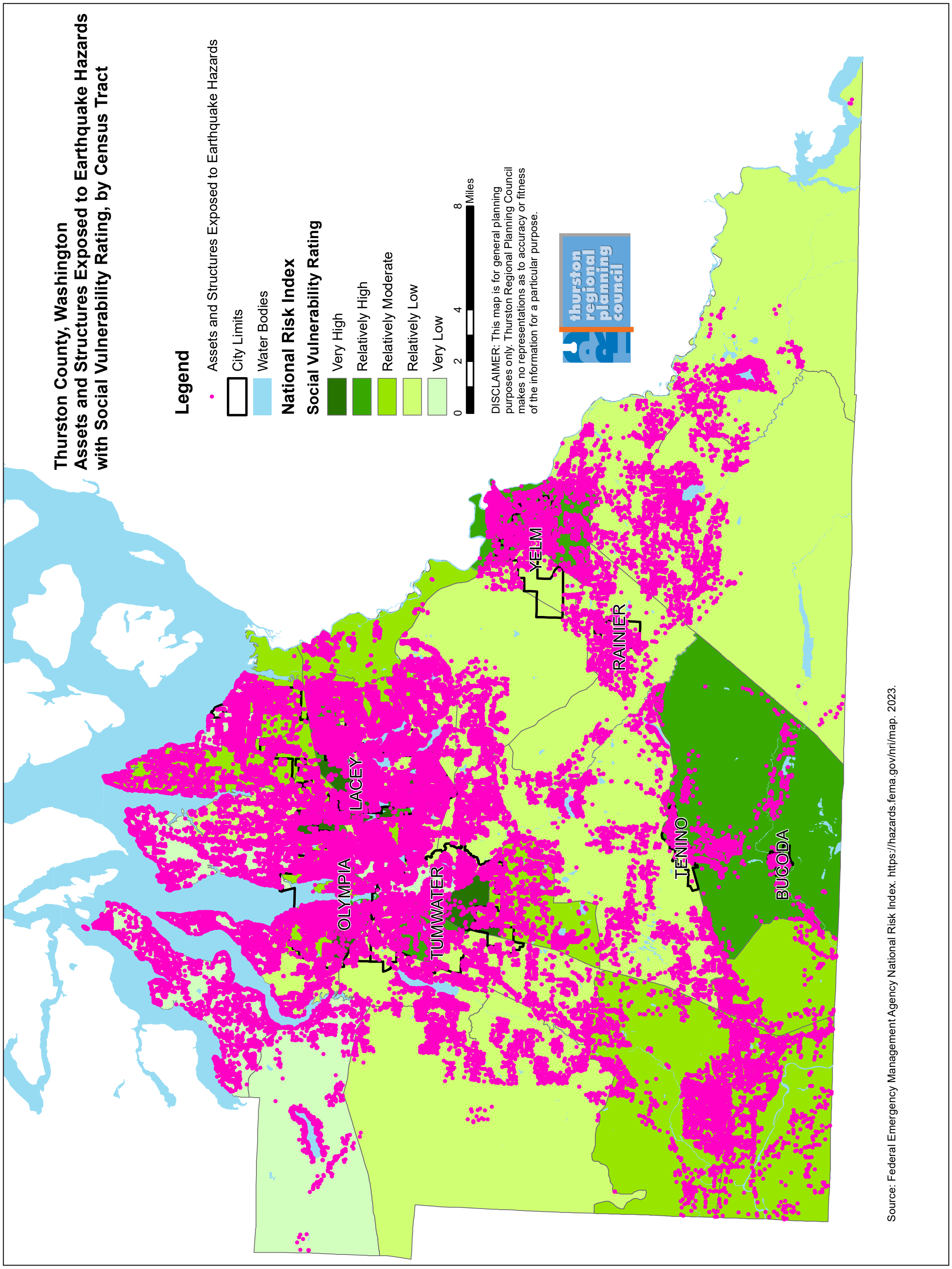
Map 4.2.3 Nisqually M7.2 Earthquake Scenario ShakeMap



Map 4.2.4 Seattle M7.2 Fault Earthquake Scenario ShakeMap



Map 4.2.5 Assets and Structures Exposed to Earthquake Hazards with Thurston County Social Vulnerability Index Rating by Census Tract



Endnotes

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[3]Brian L. Sherrod. 2001. Evidence for earthquake-induced subsidence about 1100 yr ago in coastal marshes of southern Puget Sound, Washington. GSA Bulletin; October 2001; v. 113; no. 10; p. 1299–1311.

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[5]USGS. 2008. Cascadia Earthquake Sources. http://geomaps.wr.usgs.gov/pacnw/pacnweq/#sources

[6]Pacific Northwest Seismic Network. "Earthquake: What does 'Magnitude' Mean?" Video Screen Capture. http://www.pnsn.org/outreach/about-earthquakes/magnitude-intensity