5. Transportation

Introduction

Emergency response, access to critical buildings, the restoration of utilities, and the reopening of businesses all depend on the transportation network. The resilience of the transportation network is considered a key factor for re-establishing other lifelines after a major Cascadia subduction zone earthquake.

To assess the status of the various modes of transportation and determine appropriate levels of resilience, a task group consisting of representatives of each mode of transportation, including highways, rail, airports, water ports, and transit, along with representatives of local agencies, met in person monthly and worked extensively outside these meetings to develop and collect data and formulate a plan that will help increase the survivability of citizens and critical features of the built environment.

GOALS

The overall resilience goal for the transportation network is first to facilitate immediate emergency response, including permitting personnel to access critical areas and allowing the delivery of supplies, and second to restore general mobility within specified time periods for various areas of the state. In order to establish specific resilience goals in support of this larger objective, the task group assessed the transportation network in four geographical areas:

- The tsunami inundation zone along the coast (based on DOGAMI maps).
- The coastal zone (the area outside of the tsunami zone, from the Oregon coastline to the summit of the Coast Range).
- The Willamette Valley zone (from the summit of the Coast Range to the summit of the Cascades).
- The central Oregon zone (east of the Cascades summit).

In addition, the task group established resilience targets for transportation facilities. These targets align with a phased, three-tiered approach to the restoration of the transportation network. The main factors in forming this approach were the need to optimize post-earthquake response for our state and the need to establish priorities for making future investments to achieve the targets. Similar to the Oregon Seismic Lifeline Routes identification project, the task group prioritized highways into three tiers: Tier 1 is a small backbone system that allows access to all vulnerable regions, major population centers, and areas considered vital for rescue and recovery operations. Tier 2 is a larger network that provides access to most urban areas and restores major commercial operations. Tier 3 is a more complete transportation network.

Resilience targets were further established at three levels:

- **Minimal.** A minimum level of service is restored, primarily for the use of emergency responders, repair crews, and vehicles transporting food and other critical supplies.
- **Functional.** Although service is not yet restored to full capacity, it is sufficient to get the economy moving again—for example, some truck/freight traffic can be accommodated. There may be fewer lanes in use, some weight restrictions, and lower speed limits.
- **Operational.** Restoration is up to 90 percent of capacity: A full level of service has been restored and is sufficient to allow people to commute to school and to work.

THE TASK GROUP'S OBJECTIVES

In developing a resilience plan for transportation, the task group's objectives were to:

- Summarize the state of our knowledge about the seismic ground shaking and tsunami inundation risks of various transportation modes.
- Estimate the ability of each mode to recover following a major earthquake.
- Develop recommendations for strategically focused retrofit solutions. For example, one of the recommended solutions proposed in the plan includes a program of prioritized investments over a 50-year period to achieve the desired level of operation after a major Cascadia subduction zone event. (The plan considers all modes of transportation to maximize both access to and the utility of the network, while minimizing the level of investment.)

THE TRANSPORTATION SYSTEM'S ROLE IN STATEWIDE RESILIENCE

A resilient transportation network is critical for re-establishing other lifelines, such as water, electricity, fuel, communication, and natural gas, after the earthquake. For example, a resilient transportation system allows repair crews to access and reconnect water pipes and power lines more quickly, and it provides access to much needed fuel and supplies.

Given the transportation system's current state of vulnerability to ground shaking and tsunami inundation, initial damage from a Cascadia subduction zone earthquake is expected to be devastating to the parts of the system located along the coast and in western Oregon. The resulting lack of mobility will have direct impacts that severely limit rescue operations, inspection of critical infrastructure, restoration activities, and the state's ability to restore services leading to recovery. The widespread damage and lack of access to many parts of western Oregon will be partially mitigated by disaster preparedness planning, but that effort will be hampered by the lack of access to disaster areas after the event, which could limit the ability of emergency responders to save lives, facilitate evacuation, and manage critical infrastructure.

To collect and develop the information used for this report, the members of the Transportation Task Group consulted transportation providers and collected data on potential infrastructure damage and the state of preparation and availability of trained, experienced personnel to manage transportation systems in the aftermath of a major earthquake. Keeping in mind that the core objective of the plan is to better support both immediate statewide post-earthquake/tsunami response and longer-term recovery and construction, the task group considered both emergency response actions and various ways to improve the resilience of the transportation network. This included strengthening or armoring existing systems, adding new facilities that will withstand seismic loads and motions, moving facilities out of tsunami inundation zones, and identifying alternate means to provide service. Resilient transportation systems planning must address all facets of the problem in order to provide for effective and efficient movement of goods and people after a large seismic event—an event that is expected to cause widespread damage to the built environment as well as significant reconfiguration of the natural environment.

THE TASK GROUP'S APPROACH

The task group's general approach in developing the transportation section of the Oregon's resilience plan was to use existing emergency operations or response plans and any existing programs for strengthening facilities and other assets within the various modes. The task group used existing plans for strengthening and armoring transportation systems. This chapter includes a section on each mode, covering response for life safety and recovery, and a section on strengthening and armoring options. The task group also considered the interdependencies among the various modes and the relevance of these interdependencies for response, recovery, and strengthening. Finally, a summary of known gaps in available data and a list of recommendations are provided to identify next steps in the transportation sector. These recommendations reflect the need to determine the most cost effective solutions to reduce interruptions in service and increase mobility immediately after an event and during long term recovery. An example of a fully developed assessment of a mode, including retrofitting recommendations and cost estimates, is provided in the 2012 Oregon Seismic Lifeline Routes identification project and ODOT Seismic Options Report.

Assessment of Transportation Performance

When a large earthquake is triggered within the Cascadia subduction zone, the result will be widespread disruption of the transportation system. This disruption will make rescue operations in many areas difficult, if not impossible, and will have an immediate, disruptive impact on the economy. The majority of bridges and other transportation infrastructure in western Oregon are susceptible to serious damage in a major seismic event, because they were built before modern seismic codes were in place. Dozens of unstable slopes and pre-existing deep slides are expected to fail under the extended three minutes or more of shaking that will accompany a large Cascadia event, further impacting our mobility by closing roads.

Modern seismic codes were developed in the late 1980s and early 1990s. The extended period of strong shaking from a Cascadia subduction zone event will damage many masonry and other structures built prior to modern seismic codes. Homes, hospitals, businesses, schools, and other critical structures that have not been seismically retrofitted may collapse or be severely damaged, killing or injuring many people. The injured will need immediate attention, but may be stranded due to the lack of mobility.

Our knowledge of the locations of faults and the geological history of major events in Oregon is very recent. Although Oregon has low seismicity in comparison to California and Washington, there is potential for less frequent—but much larger and more damaging—earthquakes than the crustal earthquakes that have occurred regularly in those states. Oregon has not yet seen the effect of a large damaging earthquake, and ODOT has so far expended minimal resources on seismic retrofitting. As a result, much of Oregon's highway system will not be usable immediately after a major seismic event.

Because the impacts will be widespread, a Cascadia earthquake and tsunami have the potential to cause unparalleled economic and human catastrophe for the state of Oregon. The issue is *when* not *if* the state will have a major damaging seismic event. The question is whether we will be effectively prepared to rescue our citizens and recover economically without the use of a continuous connected transportation system. Aftershocks and movement of historic slides will complicate rescue and extend recovery times.

The task group recognized that failure of a major dam would lead to additional impacts to transportation that were not explicitly considered in our study. Like much of our other infrastructure, it is assumed that most of the power generation and flood control dams in Oregon were constructed prior to consideration of modern seismic provisions. Well-constructed dams have fared well in other subduction zone events, however, so failure may not be likely in Oregon. Damage to spillway gates, on the other hand, may lead to unexpected water release, and the resultant flooding would compound damage from a Cascadia subduction zone event.

Highway Transportation

Because most of Oregon's highways were constructed before design codes considered the potential Cascadia subduction zone effects, many bridges and unstable slopes are vulnerable to severe damage. The chart below shows the age-related vulnerability of Oregon's bridges.

Resilience targets for mobility on highways vary from zone to zone and from tier to tier within the same zone. For example, a Tier 1 route in central Oregon is expected to be resilient within three days, whereas a Tier 3 route may take up to four weeks. Similarly, a Tier 1 route within the coastal zone is expected to become resilient within seven days, whereas a Tier 3 may take up to three months or more. The detailed range of targets is shown in the tables titled *Oregon Transportation Resilience Status* in Figure 5.22.

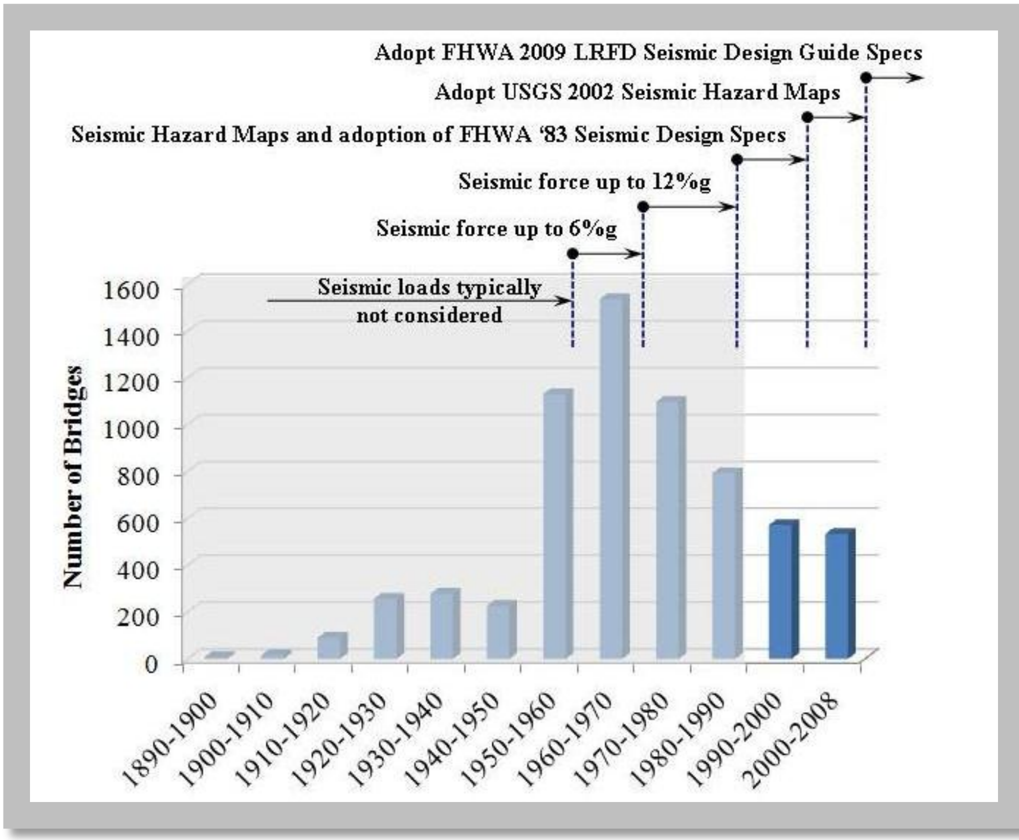
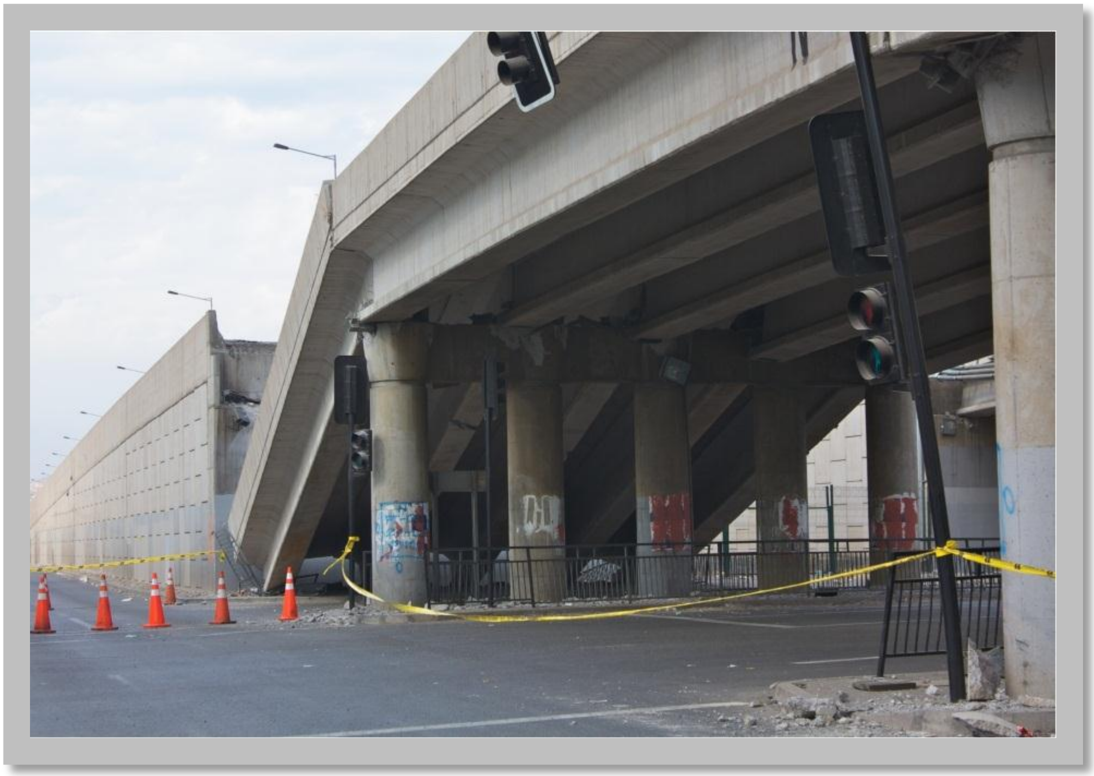


Figure 5.1: Oregon Bridge Seismic Design History (Source: Peter Dusicka, PSU)

The vulnerabilities of Oregon's bridges are complex and differ from bridge to bridge and from site to site. Some bridges are prone to more than one type of seismic deficiency, and a few may need to be replaced. ODOT has already conducted research and investigation to develop the best approach for mitigating the problem. Worldwide experience has shown that, while we are not knowledgeable enough to predict the exact time that an earthquake will strike, we can be proactive to save lives and speed up the recovery process.

The following photos and diagrams describe some of the most common vulnerabilities of highway bridges and one of the possible retrofits to mitigate that type of failure.



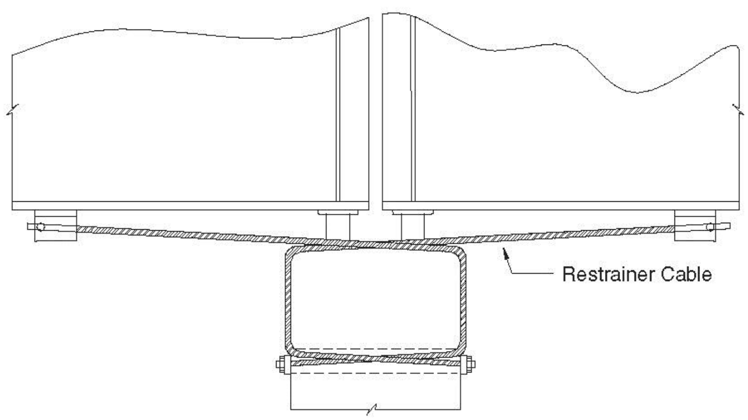


Figure 5.2: Restrainer cables will prevent bridge superstructure fall-off. (Photo Source: Flickr.com)

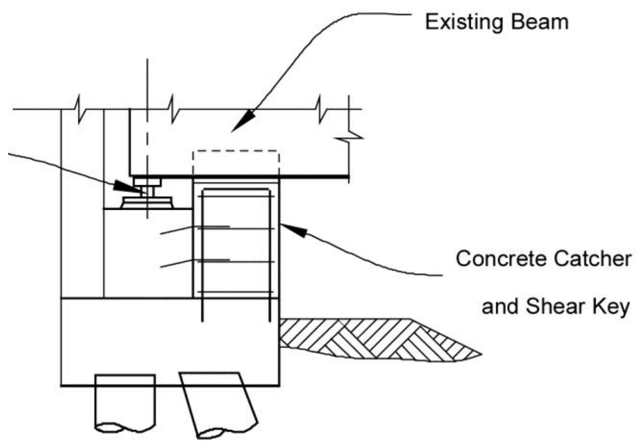
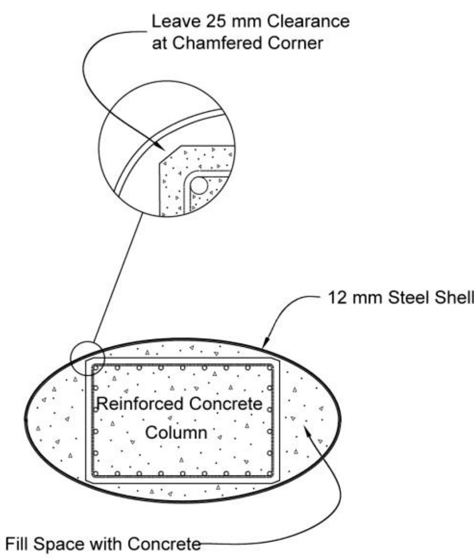
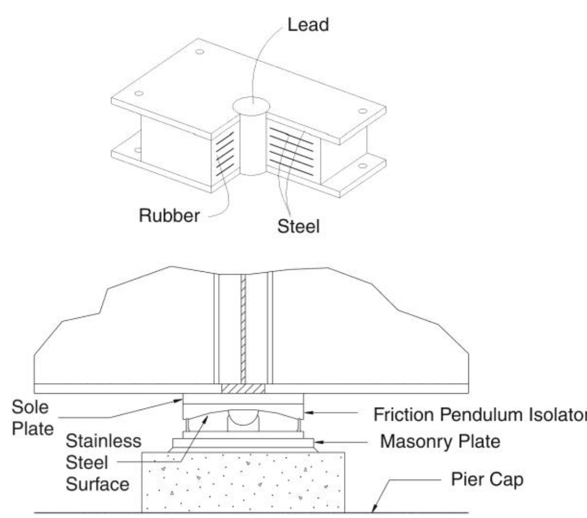


Figure 5.3: Shear Keys will restrain the superstructure transversally during an earthquake.
(Photo Source: www.fhwa.dot.gov)



a) Steel Shell Casing



b) Isolation Bearings

Figure 5.4: Preventing the Column Damage by: a) Steel Shell Casing and b) Isolation Bearing (Photo Source: ace-mrl.engin.umich.edu)

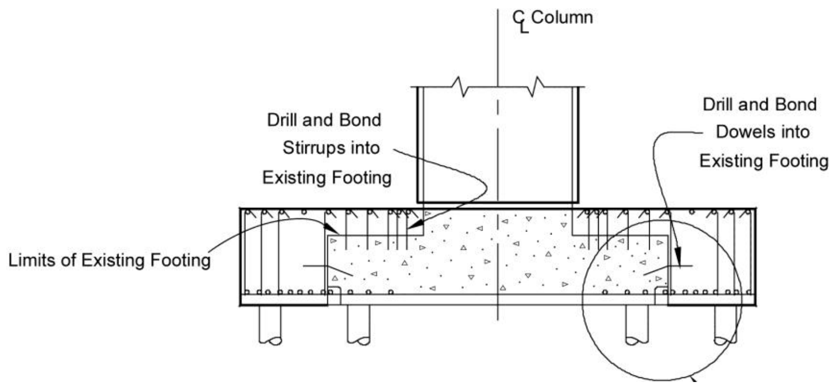


Figure 5.5: Strengthening the foundation or soil mitigation will prevent the damage to the bridge substructure due to liquefaction and lateral spreading (Photo Source: www.fhwa.dot.gov)

LOSS OF MOBILITY AFTER A MAJOR SEISMIC EVENT: BRIDGES

The combination of very strong and prolonged ground shaking, followed closely by a powerful and damaging tsunami—and by multiple strong aftershocks in the succeeding days and months—makes the Cascadia subduction zone earthquake the most dangerous natural hazard for Oregon, especially for Oregon's coastal communities. The ground shaking will cause destruction of buildings and roads, downed power lines, blocked streets, ruptured gas lines (resulting in explosions and fires), and broken water and sewer lines, creating a largely uninhabitable environment in many areas.

Oregon, or even the entire nation, has never witnessed a disaster of this magnitude in modern history; therefore, we can only speculate about how this event will impact Oregonians. Unlike other crises, such as a highway crash or a house fire, in which fire trucks and ambulances will arrive within a few minutes to rescue people in need, the situation after a Cascadia subduction zone earthquake will involve disruptions of emergency services along with everything else. There will not be enough firefighters to assist every household or business, nor enough medical staff to help every injured person, nor enough police officers to go door to door reminding people to be calm and quickly move to higher ground to avoid the oncoming tsunami. In order to gain some insight into what would happen after a major

Cascadia subduction zone earthquake, we can look at a very similar situation elsewhere: the earthquake and tsunami in Japan on March 11, 2011 (see Figure 5. 6).

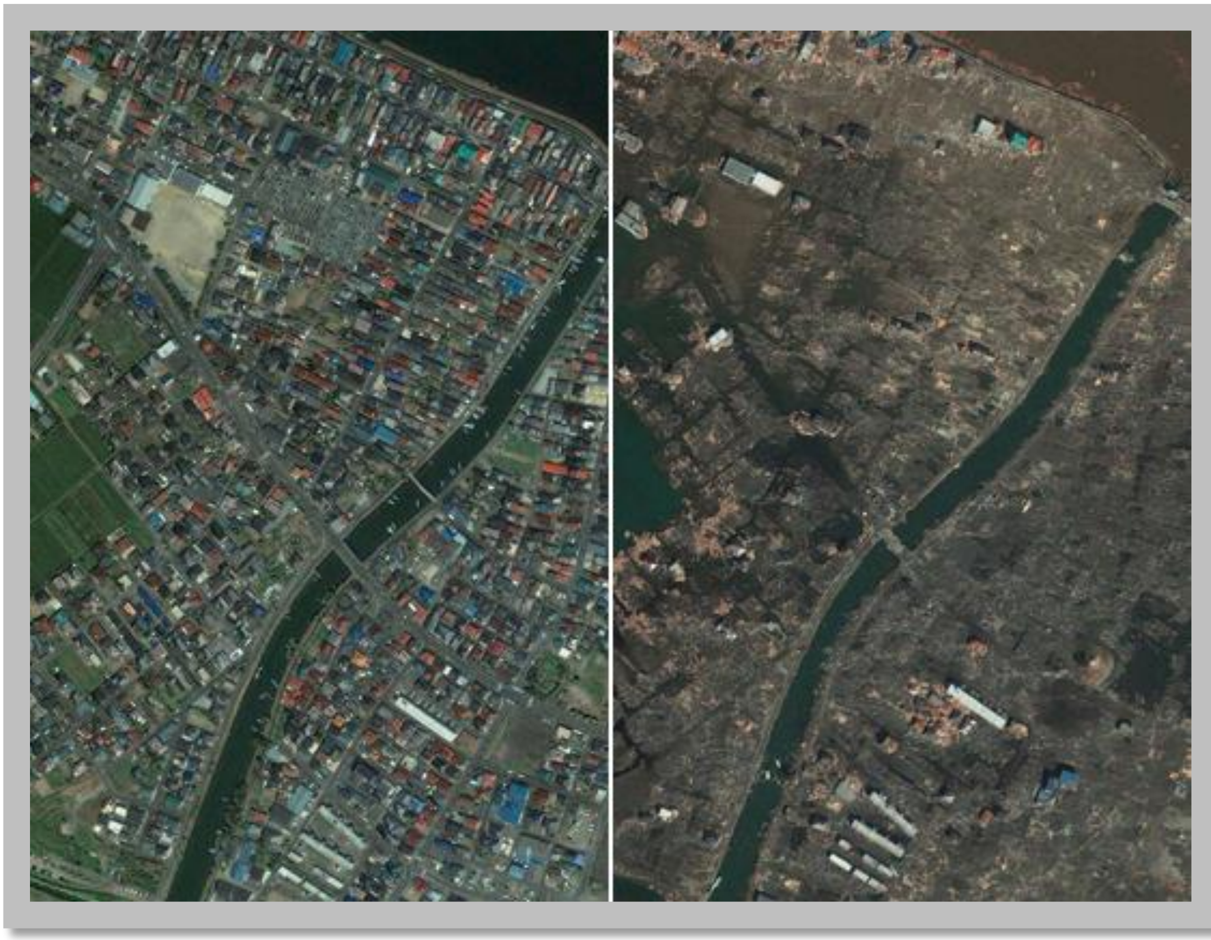


Figure 5.6: Before and after the March 11, 2011 earthquake and tsunami in Japan (Source: cbsnews.com)

Coastal Area Impacts

Assuming most of our citizens have a basic understanding about the effects of a subduction earthquake, a massive movement of people away from the coast is expected. Acknowledging that no immediate help will be available, many people will try to drive away from shore and out of reach of the tsunami—but, our transportation network will not be able to handle this huge, confused and panicked traffic. Coastal residents have been advised to get away from the shore on foot, but tourists and commercial travelers are not likely to know that.

For most of Oregon's coastal cities, U.S. 101 serves as the main route to other destinations. Unfortunately, after a Cascadia subduction zone earthquake, most of this route will be impassable. Most bridges carrying U.S. 101 were not designed for seismic loading and will suffer major damage under the expected ground shaking. Many other bridges, if they survive the shaking itself, will be washed away by the tsunami. In addition to the bridge damage, many highway segments are expected to become heavily damaged and impassible due to landslides. The latest assessment of state-owned bridges in Oregon shows that of 135 total bridges carrying U.S. 101, 56 bridges are expected to collapse, and 42 bridges will be heavily damaged. Some of these bridges are signature bridges and registered as historic.

East-West Corridor Impacts

East-west corridors between the coast and the Willamette Valley are the next tier of alternatives for people escaping from the disaster zone and for emergency crews responding to impacted areas. Unfortunately, the bridges on these corridors are also vulnerable to ground shaking, landslides, and liquefaction of supporting soils, so it is likely that these segments will not all be passable. The overall condition of bridges on these routes is moderately better than those carrying U.S. 101; however, there are many weak links along these routes that will make them impassable as well.

Route	Total No. of	Bridges	Heavily
U.S. 30 (Hwy 92)	27	6	3
U.S. 26 (Hwy 47)	52	3	10
OR 99W & OR 18 (Hwy 91 & Hwy 39)	35	5	4
OR 34 & U.S. 20 (Hwy 210 & Hwy 33)	42	7	3
OR 569 & OR 126 (Hwy 62 & Hwy 69)	50	9	9
OR 38 (Hwy 45)	19	1	3
OR 42 (Hwy 35)	47	23	5

Figure 5. 7: Vulnerability of Bridges on East-West Corridors (Source: ODOT – Bridge Section)

Because of the terrain these highways were built on, many of them lack options for detouring traffic around a bridge that collapses. The situation can become even more critical if the earthquake strikes during winter, when many of the state's secondary routes experience seasonal closure. Figure 5.7 shows the results of an inventory and damage assessment of state bridges located along the major routes connecting U.S. 101 to Interstate 5, when subjected to a Cascadia subduction zone event.

Interstate 5 and Mid-Willamette Valley Impacts

Interstate 5 (I-5) will also have some major problems after a Cascadia subduction zone earthquake. With the majority of bridges on I-5 built just before the modern seismic design specifications were developed, the most important segment of Oregon's transportation network may be fragmented, with some areas not operational after such an earthquake, depending upon the intensity and epicenter of the quake and its aftershocks. During the recent Oregon Transportation Investment Act (OTIA) program, ODOT was able to replace many deficient structures along this route; however, the main criterion for the selection of these bridges was the need to support current truck load requirements, and not necessarily to meet current seismic standards. Thus, several bridges that already have been identified as vulnerable to earthquake shaking are still in active service. From a total of 348 bridges carrying both northbound and southbound traffic, five bridges are expected to collapse and 19 bridges to be heavily damaged during the Cascadia subduction zone event.

Interstate 5 is expected to be the main corridor of traffic flow after the Cascadia subduction zone event. Because of its location and capacity, and because U.S. 101 is expected to be impassable, I-5 will become the critical backbone route for emergency response after the earthquake. To the extent I-5 is operable, emergency support can be staged along the corridor, and responders will be able to reach the coastal cities either through the east-west corridors (once these corridors become accessible) or by other means.

Interstate 5 becomes an even more important route during the statewide recovery effort. Many scientists believe that the Cascadia subduction zone event will be a mirror image of the 2011 Tohoku earthquake that hit Japan. This means that most of our coastal cities will be heavily damaged, and restoring their previous living environment will not be an easy task. Along with extensive building damage, many ports and airports in these cities will also be heavily damaged and most likely will not be operational immediately after the event. This puts more emphasis on the need for a resilient transportation network. Because we expect that the initial help for impacted coastal areas will come first from cities along I-5 and later from the rest of the state and entire Northwest region, we have identified I-5 as the most vital route for post-earthquake recovery.

Central Oregon U.S. 97 and Highways through the Cascades

In the event that Interstate 5 is not operational, particularly in areas without viable detours, U.S. 97 will be a critical facility for ongoing interstate commerce and for staging response and recovery efforts. Redmond Municipal Airport is a staging site for federal emergency response in Oregon. East-west corridors through the Cascades provide access to the more vulnerable parts of the state and are therefore a necessary part of the response and recovery system. Because there is far less likelihood of damage to facilities in these areas, they will be relied upon extensively after a Cascadia subduction zone event.

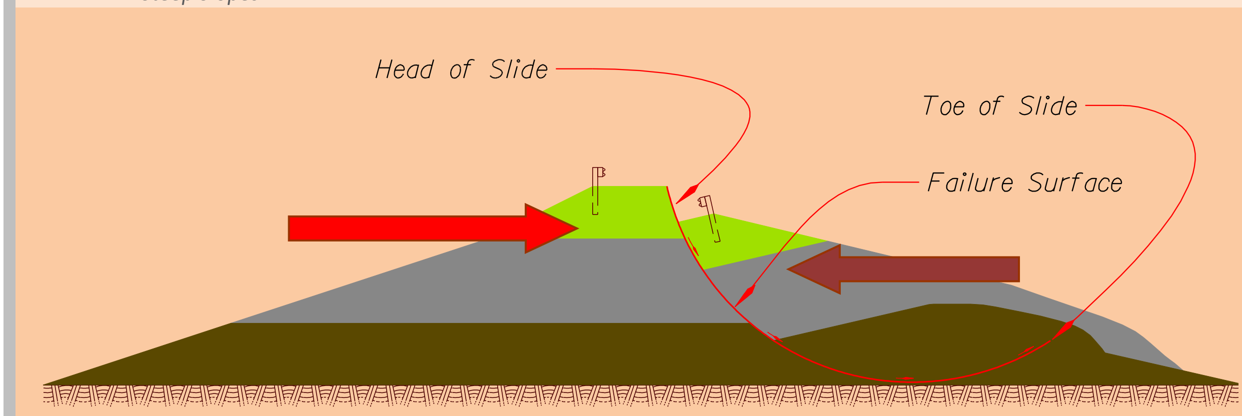
LOSS OF MOBILITY AFTER A MAJOR SEISMIC EVENT: LANDSLIDES & ROCKFALLS

Slope failures are as common to earthquakes as structural collapse, liquefaction, and ground deformation. Strong ground shaking from a Cascadia subduction zone event will trigger countless new slope failures and activate existing landslides. Reactivation of the known landslides alone will be catastrophic during the ensuing seismic emergency. Additional failure of weak slopes and embankments or reactivation of previously unknown landslides will further compound the catastrophe. Not only will the landslides occur during and soon after the main earthquake, strong aftershocks will also affect other landslides and slopes that will become more prone to failure in the ensuing months. Landslides will continue to impede rescue and relief efforts long after the shaking has stopped. Figure 5.8 shows one of the common vulnerabilities of unstable slopes.

Driving Force:

(Forces that Cause Sliding)

- *Mass of Soil/Rock at the Head of the Slide*
- *Water in the Slide*
- *Seismic Forces (Ground Shaking)*
- *Structures and Traffic Load*
- *Steep Slopes*



Resisting Force:

(Forces that prevent or Resist Sliding)

- *Mass of Soil/Rock at the Toe of the Slide*
- *Soil/Rock Strength*
- *Retaining Structures*
- *Flatter Slopes*

Factors that DECREASE Resistance to sliding:

- *Water*
- *Seismic Forces (Ground Shaking, Liquefaction Dilation)*

Figure 5. 8: Design Approach for Slide Mitigation (Source: ODOT – Geo-Environmental Section)

Landslides are one of the most significant secondary effects of earthquakes and, apart from the primary earthquake itself, one of the leading immediate causes of earthquake-related deaths worldwide. Currently, there are about 1,700 known landslides that directly affect the highway system between the Willamette Valley and the Oregon coast. Undoubtedly, western Oregon will be overwhelmed by the landslides that will accompany a Cascadia subduction zone earthquake. Landslides will affect all phases of the disaster, triggering a variety of consequences, including:

- Immediate injury or loss of life during the seismic event, as in the case of:
    - Motorists struck by rockfall or landslides/slide debris originating from slopes above the road.
    - Motorists striking materials in the roadway.
    - Motorists driving into collapsed roadways.
    - Motorists pushed off the roadway by landslides.
    - Vehicles or persons buried under slide debris.
- Immediate damage to the transportation infrastructure (resulting from numerous small to average-sized landslides and very large landslides), which becomes:
    - An impediment to tsunami evacuation.
    - An obstruction to rescue and evacuation efforts.
    - A hindrance both to recovery in the immediate aftermath and to long-term economic recovery.
- Long-term highway closures due to landslides.
- Ongoing landslides from weakened slopes.
- Disruption of utilities that share highway right-of-way.
- Long-term mitigation of very large landslides that will impede repairs to bridges and other facilities.
- Massive consumption and shortages of fuel and other material resources used in landslide repair work.

Steep slopes, weak soil and rock, heavy rainfall, and high groundwater are all conditions that can lead to slope failure and are widespread throughout the state, particularly in the western half. Almost every highway in western Oregon is affected in some way by landslides. Where the listed conditions exist, slopes are at a much higher risk of failure during an earthquake. The greatest hazards, however, are the existing known landslides and the existing slides that are yet to be discovered. Recent research by the U.S. Geological Survey (USGS) has shown that seismogenic landslides (that is, new slides initiated by earthquakes) tend to move a few inches to a few feet, while existing slides reactivated by earthquakes are more likely to move several yards. Highways traversing mountainous terrain will be the most disrupted; however, routes in low-lying areas, such as the Willamette Valley, will also be affected by liquefaction and lateral spreading, which can result in the failure of otherwise stable embankments and fills.

The following photos and diagrams describe some of the most common slope failure modes and one of the possible mitigation strategies for that type of failure.

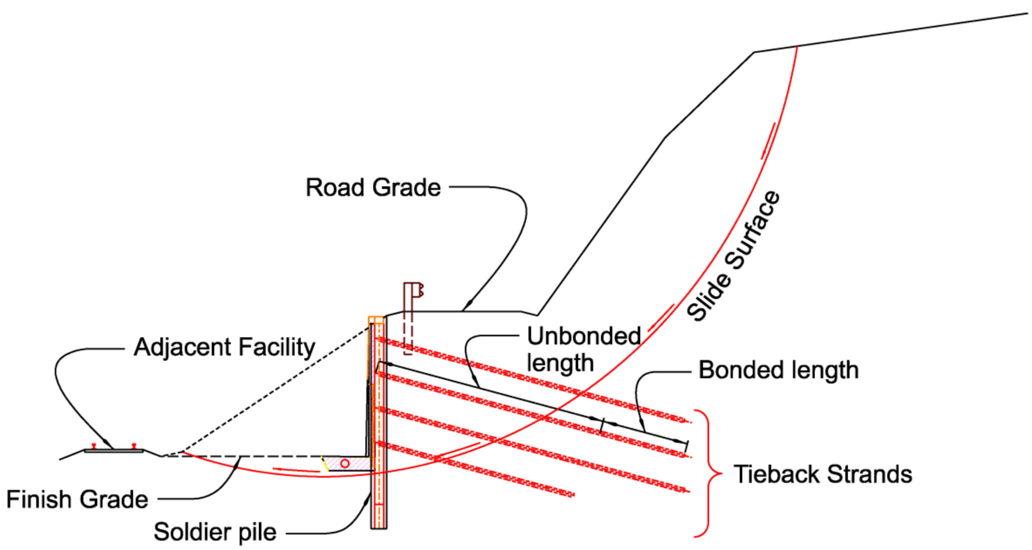


Figure 5.9: Structural mitigation of a landslide – Constructing a retaining wall (Source: ODOT – Geo-Environmental Section)

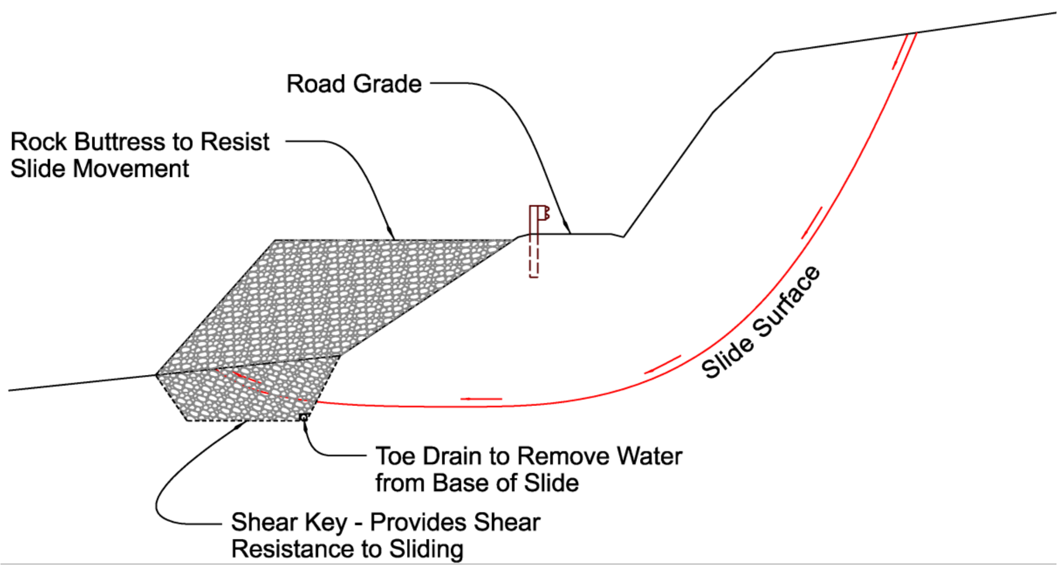


Figure 5.10: Stabilizing a landslide by constructing a shear key and buttress (Source: ODOT – Geo-Environmental Section)

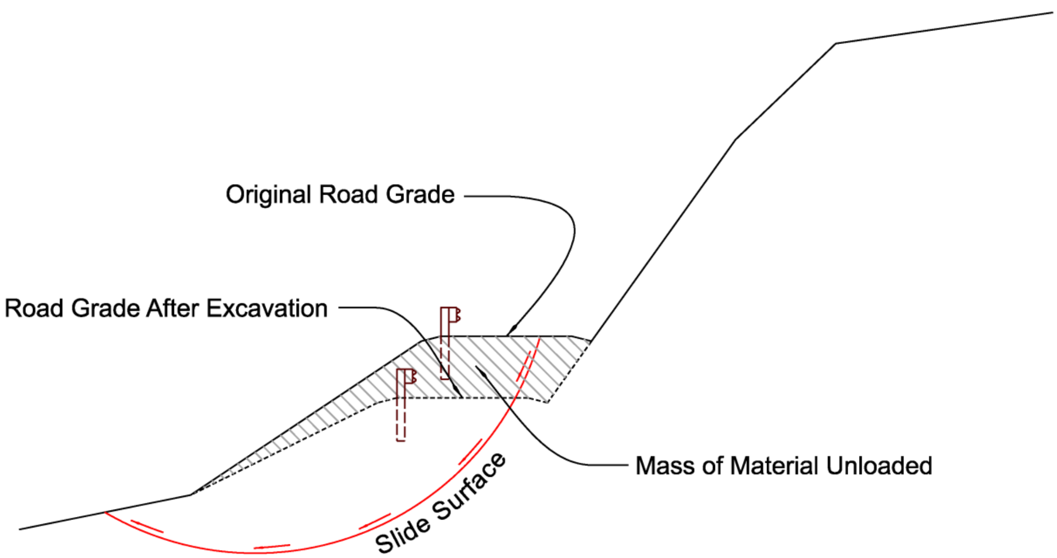


Figure 5.11: Stabilizing a landslide by the "unloading" method. (Source: ODOT – Geo-Environmental Section)

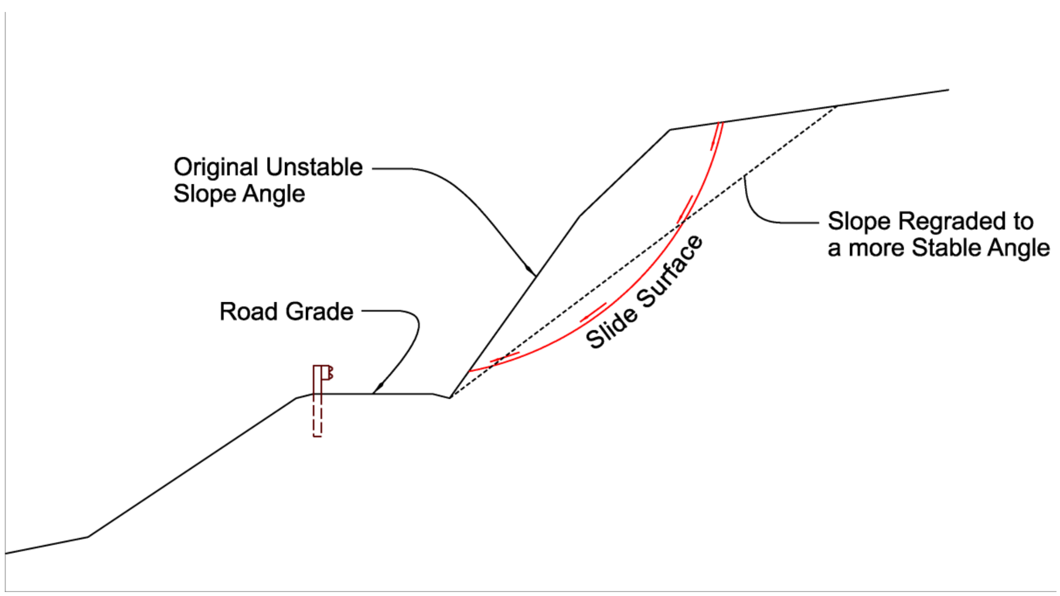


Figure 5.12: Flattening the slope decreases the "driving force" of an active slide (Source: ODOT – Geo-Environmental Section)

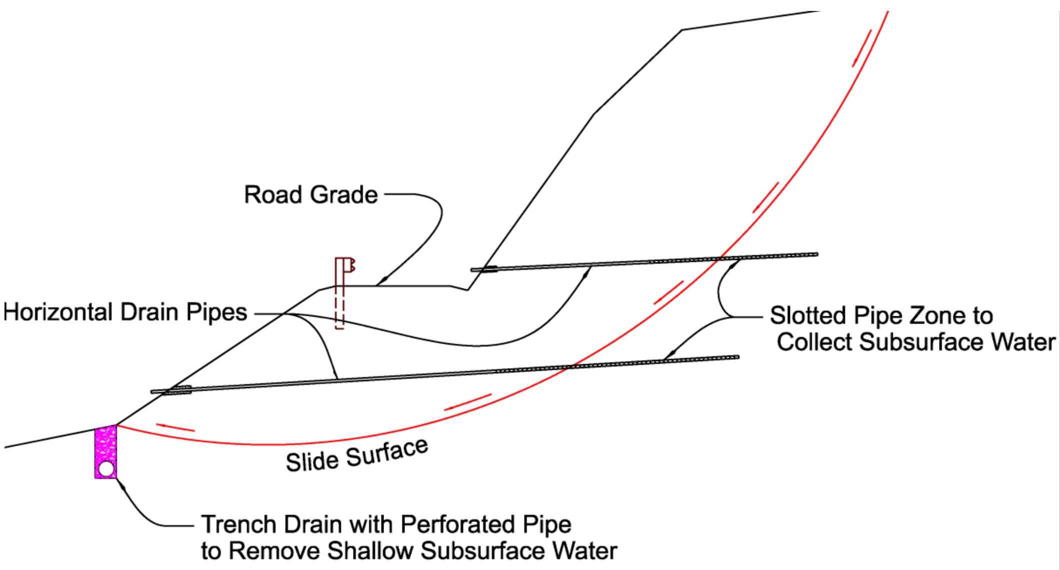


Figure 5.13: Drainage is one of the most cost-effective methods for landslide mitigation (Source: ODOT – Geo-Environmental Section)

Coastal Area: Impacts from Landslides and Rockfalls

As most residents of coastal Oregon know, there are numerous service disruptions on U.S. 101 every year from active landslides and rockfalls. It is a challenge for the agency just to keep this route functioning during normal winter weather. The results that strong ground shaking and the accompanying tsunami from a Cascadia subduction zone earthquake will have on this route are almost unimaginable, considering the large number of unstable slopes that will be affected by these forces.

Currently, 526 known unstable slopes directly affect U.S. 101. Many of these slides will fail catastrophically during the primary earthquake, while many others will fail during or soon after the tsunami. Slopes that do not immediately fail during the primary seismic event will be destabilized to varying degrees and may fail soon after, either during strong aftershocks or else at some time during the rescue and recovery efforts. Not only will coastal residents have to contend with the primary effects of the Cascadia subduction zone earthquake, but their evacuation, rescue, and recovery will be further hindered by landslides and rockfalls. Their escape from the tsunami may be blocked by failed slopes, and many could also become landslide victims.

East-West Corridor Impacts from Landslides and Rockfalls

If we take the hazard posed by landslides and rockfalls into account, the east-west routes connecting U.S. 101 to Interstate 5 are only marginally better than U.S. 101 itself. These routes traverse very steep terrain that is underlain by generally weak materials. In addition, the Oregon Coast Range experiences very high rainfall each year, which further serves to weaken slopes and embankments. A high number of landslides occur in this area on an annual basis, and a very high number should be expected during a Cascadia subduction zone event, solely on the basis of the geologic conditions.

What makes these routes particularly vulnerable is the existence of very large landslides along them. These existing slides are expected to have the highest amounts of displacement during an earthquake. Whole mountainsides can move tens of yards vertically and horizontally, taking the entire roadway with them. These landslides have the capacity to close roads for several weeks while efforts are made to reconstruct roadways or build detours around the slides. Recent LiDAR technology, where available, has led to the discovery of many of these large, sometimes ancient, landslides. In some cases, the slides were previously known, as they have had some effect on the highway in the past. In other cases, highways traverse enormous landslide features that were not known to exist and have been inactive since their initial failure. It has been theorized that many of the known large, ancient landslides in the Oregon Coast Range and the Columbia River Gorge are the result of past Cascadia subduction zone events.

Interstate 5 and Mid-Willamette Valley: Impacts from Landslides and Rockfalls

Interstate 5 and other highways in the Willamette Valley are not without their own landslide and rockfall vulnerabilities. Many fills and embankments were either constructed of or on liquefiable soils in areas with high groundwater, making them particularly susceptible to earthquakes. Interstate 5 also traverses mountainous terrain in the southern part of the state, and unfavorable geology contributes to ongoing slope instability along I-5 in the Portland area.

In all, there are 49 known landslide and rockfall areas along I-5. Other unstable areas are suspected. In the event of a Cascadia subduction zone earthquake, therefore, the most important route in the state will not be without problems. Many of the slides through the Willamette Valley are minor and can be readily mitigated. Most of the slides in the Portland area have been treated, but some could result in lengthy repairs and service disruption. For the Portland area, adequate detours exist in areas that are not as vulnerable to landslides, but delays will occur. The greatest concern for this route is the mountainous areas of southern Oregon. Unfavorable geology—in terms of geologic structure, materials, and groundwater—has formed some very large, complex landslides in this area. These slides have the capacity to cut this route off on the southern end for many weeks while repairs take place or detours are constructed.

Rail Transportation

Rail lines are generally privately owned businesses, not public entities. Detailed vulnerability assessments of this part of Oregon's infrastructure have not been conducted, although generalizations can be drawn about its possible performance based on experience in other regions where major earthquakes and tsunamis have occurred. Funding for such detailed studies may be problematic due to the private ownership status of railroads.

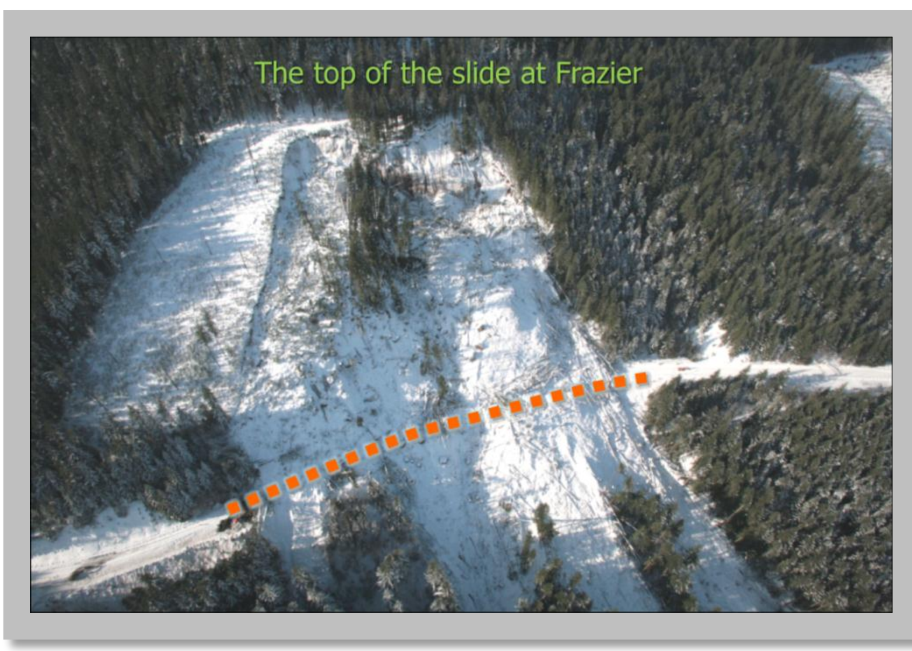


Figure 5.14: Landslide damage on the UPRR between Chemult and Eugene (Source: ODOT – Rail Division)

Trunk Lines

- California State Line to Klamath Falls
  - UPRR: Several miles of dredged fill, one highway overpass, two tunnels in California
  - BNSF: Two major bridges, one highway overpass
- Klamath Falls to Chemult
  - UPRR/BNSF: One major bridge, five highway overpasses
- Chemult to Redmond
  - BNSF: Two major bridges, five highway overpasses
- Redmond to OT Junction (BNSF); OT Junction to Troutdale (UPRR)
  - Seven major bridges, three tunnels, twenty-three highway overpasses
- Chemult to Eugene
  - UPRR: Fourteen major bridges, twenty-one tunnels, seven highway overpasses, six snow and rock sheds
  - Major historical landslide
- Eugene to Portland
  - UPRR: Fifteen major bridges, thirty-two highway overpasses
- Portland Terminal Area (Troutdale to Portland (UPRR); Vancouver, WA, to Portland (BNSF))
  - Four major bridges, forty-two highway overpasses

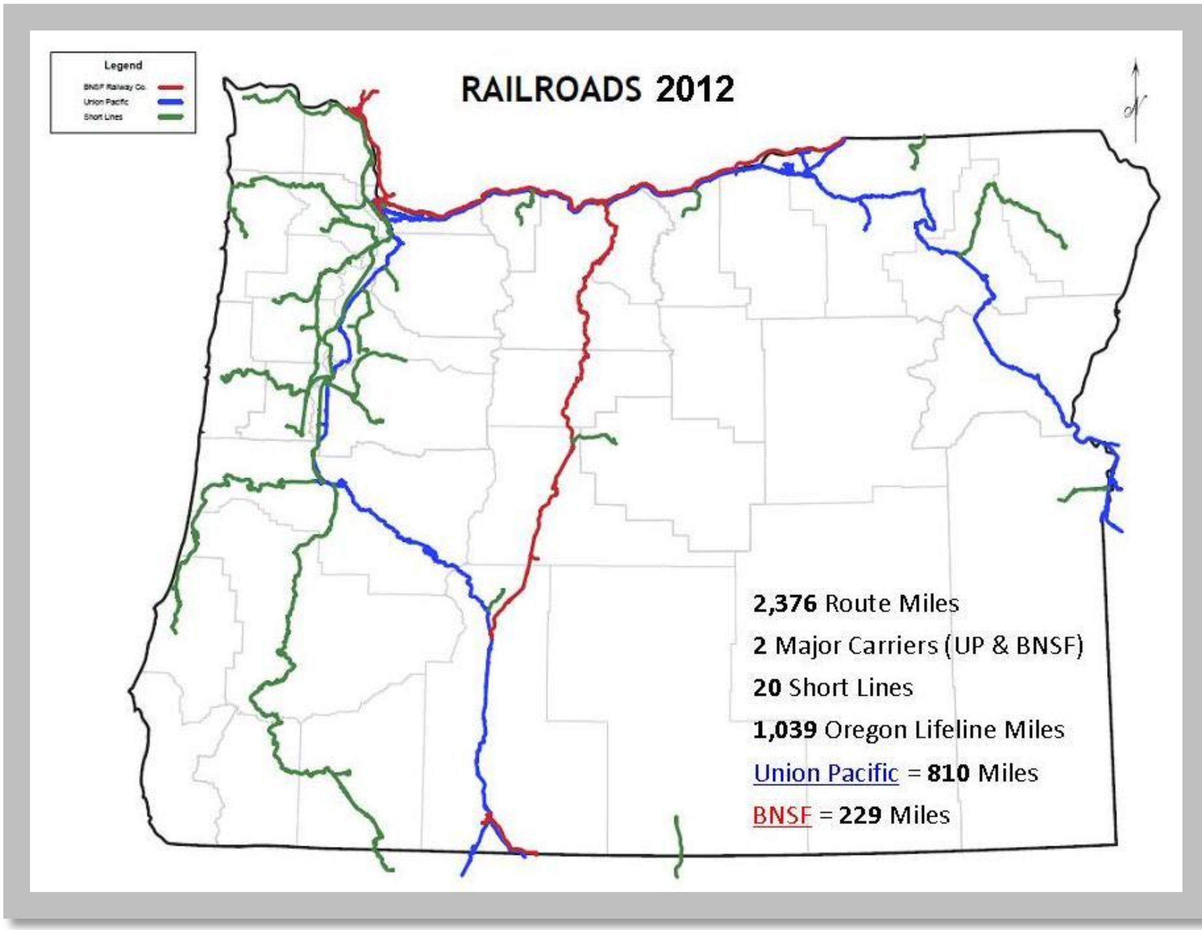


Figure 5.15: Railroad Corridors (Source: ODOT – Rail Division)

Detours for Trunk Lines

- Siskiyou Line (California to Eugene): Steep grades, twenty-four major bridges, eleven tunnels, twenty highway overpasses
- Oregon Electric Line (Eugene to Tigard): Fifteen major bridges, seven highway overpasses
- West Side District (Albany to Tigard): Fifteen major bridges, two highway overpasses
- Tigard to Willsburg Junction and connection with UPRR Trunkline: Three major bridges, three highway overpasses

Coastal Branch Lines

- Coos Bay Rail Link: Forty-nine major bridges, eight highway overpasses, nine tunnels
- Astoria District: One tunnel, six highway overpasses
- Albany to Toledo: Forty major bridges, one tunnel, three highway overpasses

Air Transportation

The state of Oregon has an extensive aviation system that provides valuable transportation options for the public, ranging from small airports in remote regions of the state to large commercial service airports. Ninety-seven public-use airports provide support to the economic health and vitality of Oregon and contribute to the quality of life for its citizens and visitors.

- Fifty-seven public-use airports are partially supported by FAA and included in the National Plan of Integrated Airport System (NPIAS).
- Sixteen public-use airports are either owned by other municipalities or are privately owned.
- Over 400 private airports and landing strips are located within Oregon.

The 2007 Oregon Aviation Plan established five categories of airports, based on the definitions outlined within the National Plan of Integrated Airports System (NPIAS), the design criteria outlined by the Airport Reference Code (ARC), and the facilities inventory.

CATEGORY I: COMMERCIAL SERVICE AIRPORTS
These airports support some level of scheduled commercial airline service in addition to a full range of general aviation aircraft. This includes both domestic and international destinations.

CATEGORY II: URBAN GENERAL AVIATION AIRPORTS
These airports support all general aviation aircraft and accommodate corporate aviation activity including business jets, helicopters, and other general aviation activity. The primary users are business related and service a large geographic region, or they experience high levels of general aviation activity.

CATEGORY III: REGIONAL GENERAL AVIATION AIRPORTS
These airports support most twin and single engine aircraft, may accommodate occasional business jets, and support regional transportation needs.

CATEGORY IV: LOCAL GENERAL AVIATION AIRPORTS
These airports primarily support single engine, general aviation aircraft, but are capable of accommodating smaller twin-engine general aviation aircraft. They also support local air transportation needs and special use aviation activities.

CATEGORY V: REMOTE ACCESS AND EMERGENCY SERVICE AIRPORTS
These airports primarily support single-engine, general aviation aircraft, special use aviation activities, and access to remote areas; or they provide emergency service access.

The following list identifies airports within each category that have the potential to maintain or quickly restore operational functions after a major earthquake. The Transportation Task Group arranged these 29 airports into a tier system to indicate the priorities for making future investments. Tier 1 (T1) is comprised of the essential airports that will allow access to major population centers and areas considered vital for both rescue operations and economic restoration. Tier 2 (T2) is a larger network of airports that provide access to most rural areas and will be needed to restore major commercial operations. Tier 3 (T3) airports will provide economic and commercial restoration to the entire region after a Cascadia subduction zone event.

Category I	Category II	Category III	Category IV	Category V
*Redmond (T1)	Scappoose (T2)	Tillamook (T2)	Mulino State (T3)	Independence State (T3)
PDX (T1)	Troutdale (T3)	Roseburg (T1)	Albany (T3)	Siletz Bay State (T2)
Salem (T1)	Hillsboro (T2)	Bandon State (T2)	Lebanon (T3)	Cape Blanco State (T2)
Eugene (T1)	Portland Heliport (T3)	Grants Pass (T3)	Florence (T3)	
Rogue Valley Medford (T1)	Aurora State (T3)		Creswell (T3)	
Klamath Falls (T1)	McMinnville (T3)		Cottage Grove State (T3)	
	Newport (T2)		Myrtle Creek (T3)	
	Corvallis (T3)		Brookings (T2)	

*Primary emergency response airport for FEMA Region X: Redmond municipal airport, centrally located in central Oregon, is ideally situated to be the primary FEMA emergency response airport.

Figure 5.16: Oregon Airports (Source: Oregon Department of Aviation)

The Portland International Airport (PDX) is one of Oregon's vital transportation network links. As the state's major airport, PDX will play a key role in re-establishing our economy by facilitating the movement of people, goods, and services after a major statewide emergency event. Other airports in Oregon will also play a vital role during the post-disaster emergency response and initial recovery phase. During the emergency response, for example, displaced residents, injured people, and the elderly may need to be evacuated by means of airports; and airports will also provide a staging area for needed supplies (such as water, food, medical supplies, and materials for temporary housing). Until highway and rail transportation can be fully restored, air transportation, along with ships off the coast, will be the lifelines for Oregon's citizens.

Figure 5.17: An aerial view of Port of Portland (Source: Port of Portland)

As described previously in this chapter, after a Cascadia subduction zone event, 29 airports have the potential for minimal damage, and operational service could be restored within a short timeframe. However, without a complete vulnerability assessment of these 29 airports, we cannot be certain which airports would be operational after an earthquake of magnitude 9.0. Based on Oregon Department of Geology and Mineral Industries (DOGAMI) tsunami inundation maps, we can predict with reasonable accuracy which airports would survive a tsunami. After studying these maps, we concluded that 8 out of 15 coastal airports will not survive due to the inundation of ocean water and debris. In the absence of a complete vulnerability assessment, our assumption is that seven of the coastal airports may survive a tsunami, but we do not know if they will survive an earthquake. Those seven airports are Tillamook, Siletz Bay State, Newport, Florence, Bandon State, Cape Blanco State, and Brookings.

Note: We did not consider the eastern airports in this particular scenario, as those airports are expected to sustain little to no damage during a subduction zone earthquake.

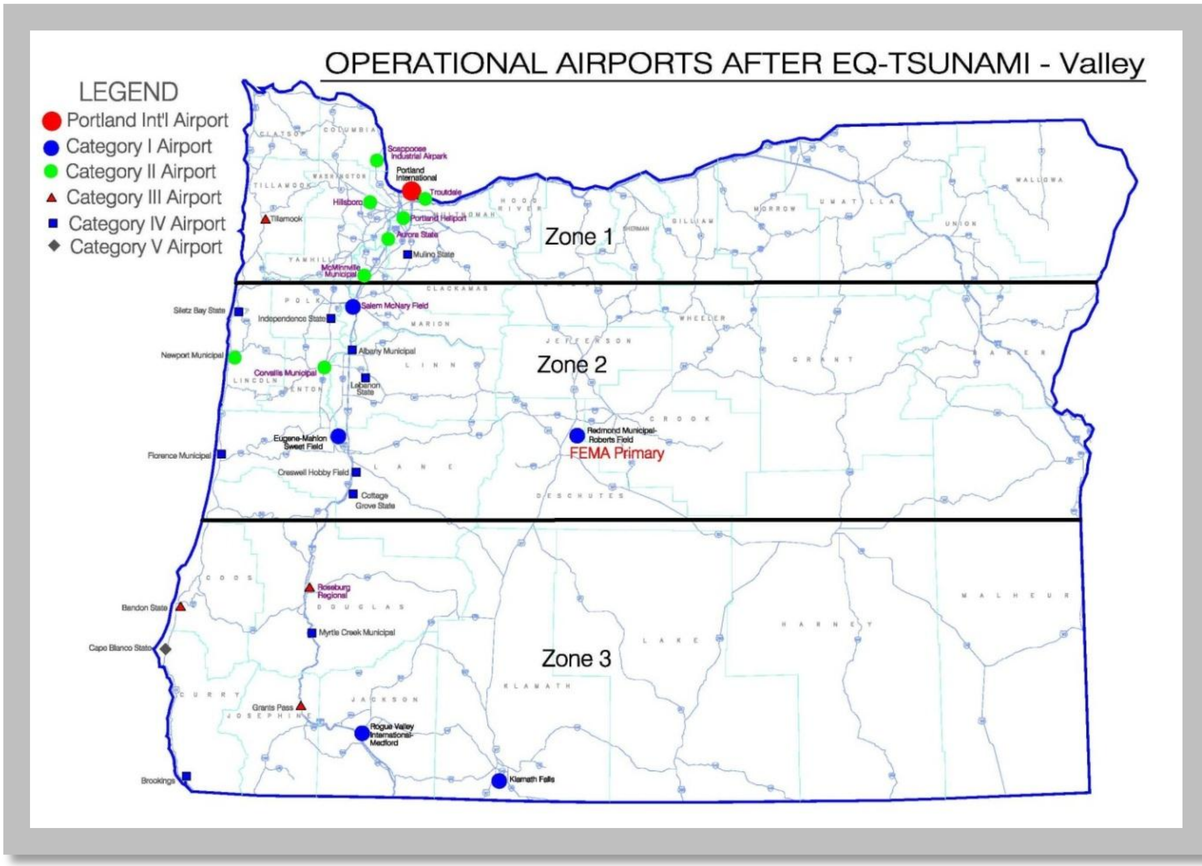


Figure 5.18: Emergency service zones served by air transportation (Source: Oregon Department of Aviation)

Columbia and Willamette Navigation Channels

The Columbia and Willamette Rivers are important transportation corridors for the states of Oregon and Washington. The lower Columbia (Pacific Ocean to Portland) and lower Willamette Rivers are deep draft channels and are critical for connecting transpacific trade to the region and the state. The mid-Columbia and Snake Rivers (Portland to Lewiston, Idaho) are shallow draft, inland waterways along which significant cargo can be moved from the east to the Portland region. Multiple dams and locks are necessary for the operation of this river route. Redundancy does not exist for these dams and locks—a cause for concern because the river channels may be obstructed when bridges collapse during a significant earthquake. A Cascadian event could significantly impact the river system and shipping channels. The jetty at the month of the Columbia is susceptible to severe damage from significant seismic event and tsunami. Failure of the jetties would significantly impact the channel. The channel depth at the mouth would likely be severely constrained due to sands migrating in from the beaches adjacent to the jetties. Additionally, the navigability of the Columbia River Bar would be difficult and unsafe for many vessels.

Critical factors affecting marine terminal viability include the condition of navigation channels immediately following a seismic event and how quickly and successfully resources can be deployed to assess and clear navigation channels of silt and structural obstructions. Shipping channels would be constrained as a result of lateral spreading of the channel banks, which will shift sediment into the channel. In addition, the pile dike systems along the river, which are intended to prevent sediments from migrating into the channel, are susceptible to failure during a major seismic event. Significant failures could dramatically impact the hydrology of the Columbia River. Depending on the seismic impact, deep-draft ships that are in transit in the waterway could become stuck due to a sudden shifting of material. This shift would cause the navigation channel to become shallower, cutting off navigation by other vessels and endangering the ships themselves. Additionally, structures that collapse into the navigation channel would need to be removed to allow ships to pass safely. Initially, shallow-draft barges may be the only viable option to move material and goods to and from marine terminals; or ship calls will be diverted to other, unaffected ports and regions. Marine terminals near the coast will also be exposed to the effects of tsunami waves, which could severely impact dock structures and support facilities. Timely restoration of the channel to resume current shipping operations is dependent upon the availability of dredges and federal funding authorizations.

In preparation for a Cascadia subduction zone event, dredging capabilities and resources should be identified and plans developed to assess and acquire services to ensure that the Columbia River navigation channel is cleared of sediment and returned to a minimal, and ultimately full, level of service. Pre-event analysis should be considered to identify which areas are likely to be most vulnerable to large-volume sediment movement during a Cascadia subduction zone event. Such analysis will help facilitate planning and ensure that resources will be dispatched to the areas of highest vulnerability. Following a Cascadia subduction zone event, hydrographic resources will need to be deployed to assess the condition of the navigation channel along its entire length and identify segments that need urgent dredging to re-establish river navigation of deep-draft ships. Disposal sites should be identified at strategic locations to align with dredging capabilities.

An assessment of contracting resources capable of accomplishing dredging in the region should be developed and agreements should be considered to establish who will have first rights to those construction resources. Such an assessment should also include the creation of an inventory of dredging resources and capabilities. It is expected that USACE will manage dredging activities and direct resources to areas of highest priority and need. Advance coordination with environmental permitting and regulatory agencies should be considered to ensure that dredging and placement do not violate statutory requirements.

RIVER PORTS

The vulnerability of marine terminals and navigable waterways to the effects of a major seismic event is highly variable and depends on many factors. There are several major elements associated with a marine terminal that have different—but interdependent—risks.

Some of the major elements of marine terminals that are critical to maintaining functional operation include dock structures; berths; dock-side equipment associated with material loading and unloading;

intermodal systems serving the marine terminals, including rail, roads, and bridges; the land on which the terminals were developed and its associated geotechnical characteristics; levee structures that protect marine commercial districts and, in some cases, aviation facilities; and river channels that provide passage for deep-draft vessels. These elements should be analyzed both individually and as parts of an overall system that serves marine cargo operations.

Dock structures are comprised of a wide array of systems of differing ages and with varying abilities to withstand seismic impacts. Their capacity to survive a great earthquake is dependent not only on the materials and methods used to construct them, but on their age, their condition, and the stability of the land beneath and surrounding them. For example, many marine facilities were constructed on fill material placed over historic wetlands. Such material is generally fine and granular in nature and susceptible to liquefaction if provisions are not made to resist such forces or relieve the pore pressure resulting from a high water table and seismic shaking. A structurally sound dock structure must also be supported by stable adjoining land. As has been noted in seismic events worldwide, lateral spreading (caused by seismically induced liquefaction) of the land adjacent to dock structures has contributed significantly to their damage profile. Stabilizing the adjoining land to resist lateral spreading minimizes the damage to the dock, reduces the sloughing of soil into the berth prism, and allows for a faster return to service of the dock and loading equipment.

The integrity of intermodal connections to other transportation systems, including rail, roads, and bridges, is critical to the functionality and viability of marine ports. The integrity and operability of the regional power grid and on-site generation capabilities are also critical to marine terminal operations. These elements are addressed in other sections of this report, but are noted here to emphasize the overall integration of the system that serves marine terminals.

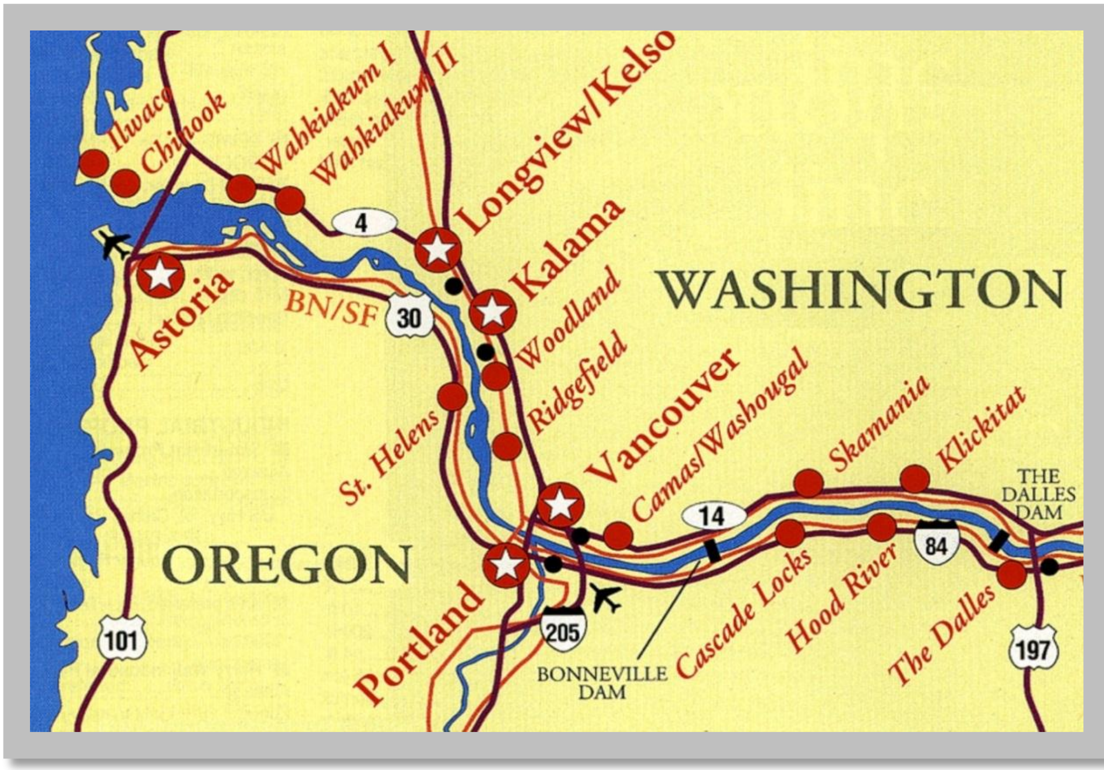


Figure 5.19: Columbia River Channel and port (Source: Port of Portland)

COASTAL INLET JETTIES

The tsunami generated by a Cascadia earthquake measuring magnitude 8–9 could range in height from 5 to 30 feet along the present shore face. In addition, co-seismic subsidence (caused by the release of built-up strain in the tectonic plates) may induce immediate lowering of the coastal margin by 2 to 8 feet (Atwater and Hemphill-Haley, 1997). In other words, the elevation of the shoreline is expected to drop during the earthquake and just before the first tsunami waves arrive.

The effect of a tsunami of this size on the coastal inlet jetties of the Pacific Northwest would be significant and transient: the overland flow of the tsunami is likely to destabilize the roots of all the jetties by eroding the morphology along the jetty roots, which may be flanked by the overland flow. Immediate repairs would be needed to re-secure the jetty roots. The seaward ends of the jetties could be affected by significant, severe scour due to the volume of water transported into and out of the inlet in response to the tsunami's passage and residual circulation. A significant volume of sediment may be mobilized and deposited within the inlet.

Violent shaking during the earthquake is also likely to destabilize many jetty areas having a side slope steeper than 1V:2H. Liquefaction of the jetty foundation may occur and initiate jetty settlement and toe failure. If vertical co-subsidence occurs with the Cascadia subduction zone earthquake, the long-term effects on the jetties of the lowering of the existing land margin by two to eight feet may be more profound than the earthquake and tsunami. Jetty freeboard could be significantly reduced and depthlimited wave height would be significantly increased. This effect would significantly increase the rate of jetty degradation and expose the landward areas of each jetty to increased wave loading and overtopping. Jetties that were in a good state of repair (or recently rehabbed) would be more resistant to earthquake related damages as opposed to jetties that were in a condition of deferred repair.

Following such an event, a triage approach would be implemented at USACE coastal navigation projects to assess the condition of jetties, inlets, and navigation channels. High tonnage, deep-draft projects would be given higher priority than shallow-draft, low tonnage projects. Estimates for channel shoaling (required dredging) and jetty damage (required repairs) would be developed, and, if available, resources would be mobilized to re-establish a minimum level of functionality for the navigation infrastructure.

Immediate response for high priority coastal navigation projects (within our ability to respond) would be to secure the jetty roots, if these areas were breached. A breached jetty root can lead to reformation of the inlet's channel and loss of navigation. Rapid placement of stone/rip-rap along the breached jetty (at the root) would be executed, sufficient to stop tidal flow through the breached area. If required, the navigation channel may be dredged in affected areas to make it navigable again. In the long term, the affected jetties may require expedited maintenance to address damage.

COASTAL PORTS

Coastal ports in Oregon are essential for the economies of the coastal communities and will be critical for disaster response and subsequent economic recovery. Unfortunately, they are also at risk for catastrophic damage in the event of a Cascadia subduction zone earthquake and subsequent tsunami. Elements of port infrastructure that should be considered priorities include jetty/breakwater structures protecting entrances, navigation channels, docks and piers, slips, pier-side equipment, structures, and transportation linkage with rail, air, and highway.

The vulnerability of jetties and breakwaters to the potential actions of an earthquake and tsunami should be analyzed further, along with the potential effects that vertical shifting, silting, debris, and obstruction could have on channel depths. Necessary reinforcement of jetties and breakwaters is essential to maintain port entrances, as is continuing maintenance-dredging of channels.

Dock and pier structures will be exposed to severe damage due to surging currents, debris impacts, possible tsunami inundation, and liquefaction (where piers are built on fill material). Reinforcement of pier and shore-side bulkheads, which could limit damage and allow for faster recovery of port operations, should be considered a priority.

Due to their locations, the intermodal connections of most coastal ports are critical for port functions. It is necessary that Oregon prepare for and mitigate against damage to rail links, bridges, highways, adjacent airports, power supplies, and communications. Critical equipment and structures will also need to be identified and reinforced for use as maritime disaster response command centers and subsequent recovery and rebuilding efforts.

Waterborne rescue and recovery operations may have to be provided through coastal ports; this may be the only viable option for many of Oregon's coastal communities if highway corridors fail. So even though the infrastructure of many coastal ports may be devastated, their very locations will have to serve as landing sites for waterborne support (from barge, amphibious, and shipping operations). Temporary facilities provided by barges and cranes may be used to restore makeshift docks quickly for rescue and recovery operations, as was experienced in Haiti. Functionality for commerce would take longer.

Transportation resilience planning and preparation for coastal ports is critical to minimize post-event casualties, speed rescue, and allow for the economic recovery of the Oregon coast. In addition to supporting rescue and recovery operations after the earthquake and tsunami, coastal ports should serve as recovery hubs from which transportation reconstruction can reach out along the coast while transportation corridors between coastal and inland areas are being restored.

Public Transit Services

Five public transit regions correspond to ODOT highway regions. Within these regions are approximately 113 significant public transit agencies and several dozen more subcontractors who provide various forms of publicly-funded transportation service, including demand response, intercity service, and alternative transportation options. The role played by public transit service has proven to be critical during the initial response to and recovery from other major natural disasters, earthquakes included. It should therefore be considered a major component of our disaster preparedness plan.

Oregon has a full spectrum of transit providers, ranging in size from very large to very small, and extending geographically from large urban centers, such as Portland, to small coastal communities and remote rural eastern Oregon towns. Transit services in some form are provided in all 35 Oregon counties and to nine federally-recognized Indian tribal communities. About 128.5 million one-way rides are provided for Oregon residents and visitors each year. Public transit buses and smaller vehicles log 52.1 million miles of travel each year, providing over three million total annual hours of public transit operating service statewide.

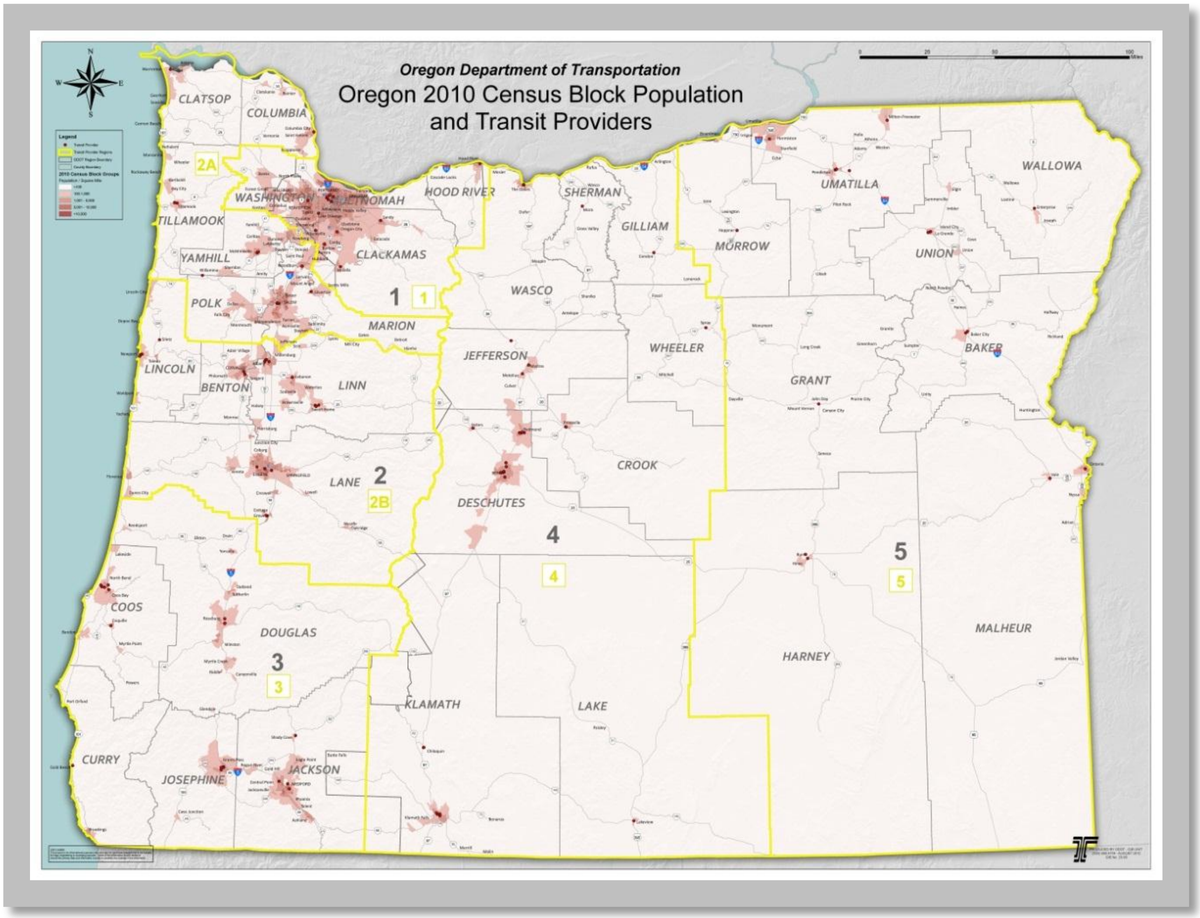


Figure 5.20: Oregon 2010 Census Block Population and Transit Providers (Source: ODOT Public Transit & GIS Technical Services)

Tri-Met, Lane Transit District (LTD), and Salem-Keizer Transit are the three largest transit agencies in the state. These are large, sophisticated agencies with their own extensive emergency management planning, incident command and response systems, and business recovery/resilience plans and procedures in place, all of which have been developed cooperatively with other public agencies and first responders in their respective areas. Additional systems, designated as small urban systems by the Federal Transit Administration and including the Rogue Valley area, Bend-Redmond, Corvallis, Albany, Grants Pass, and the Tri-Cities area, also have varying levels of detailed local emergency planning and recovery plans in place.

The remaining public transit agencies are rural or small town systems with often minimal resources in place to conduct significant planning and very few financial resources to invest in resilience following a catastrophic natural disaster. Excluding Tri-Met, LTD, and Salem-Keizer, the remaining 110 transit agencies share over $107 million in federal and state grants awarded through ODOT, with approximately two-thirds of available funding going towards simply maintaining daily or weekly operations and one-third toward capital expenditures (primarily replacement buses).

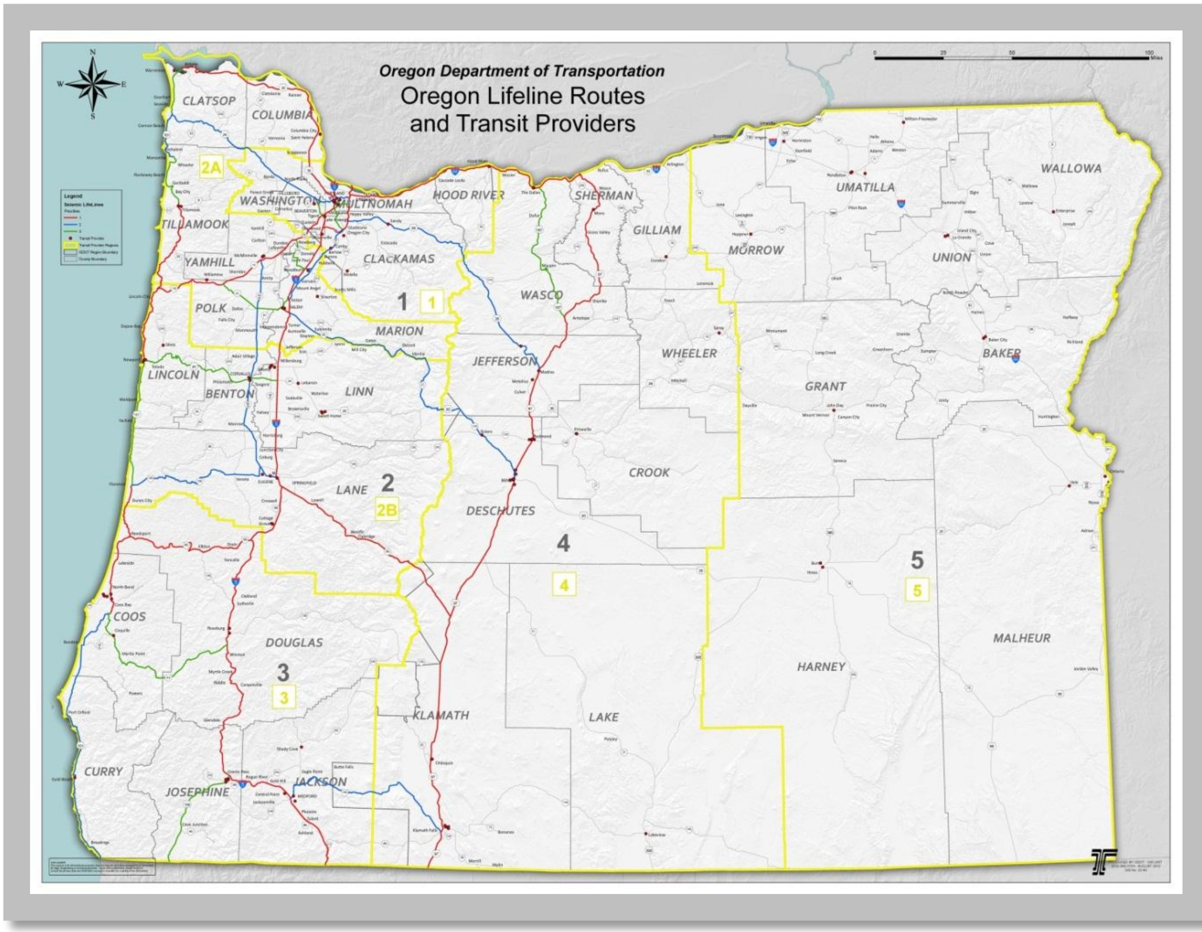


Figure 5.21: Oregon Transit Providers (Source: ODOT Public Transit & GIS Technical Services)

Transit agencies could play an important role in helping Oregon recover from a major natural disaster. Oregon transit agencies are positioned to serve the major state population centers. Public transit buses, in conjunction with school district buses, may be able to assist with emergency evacuation—either before the event, in the case of predictable natural disasters, or after the event, in situations such as a great earthquake, in which people must be transported out of an impacted area. Public transit buses could also be used to transport emergency workers or supplies to and from affected areas; to transport workers to recovery-related jobs when private automobile traffic is constrained due to road conditions and fuel supplies; and to transport seniors, persons with disabilities, and injured citizens to and from medical treatment appointments or to places where they can shop for food and other necessities.

Combining buses purchased through ODOT with those buses purchased directly by the larger urban agencies, over 1,500 buses and transit vehicles are currently deployed across the state; adding district school bus fleets would increase that number by several thousand. Most transit buses are equipped with wheelchair lifts, which, during emergency relief efforts, could also be useful in transporting and deploying both emergency personnel and their accompanying supplies and gear.

Transit providers are generally located on Oregon's lifeline routes. While this means that transit agencies are well placed to be able to assist with response and recovery activities, it also means that the transit system is dependent on local roads and highways and cannot respond if roads are impassable. Once roadways are cleared for minimum critical vehicle travel, public transit vehicles may be deployed by emergency command for the purposes of evacuating residents and transporting relief personnel.

Depending on the scale and location of the Cascadia subduction zone event and the resulting direction of tsunami wave generation, some coastal transit facilities, such as Columbia County CC-Rider, Sunset Empire Transit District, Tillamook County Transportation District, Lincoln County Transportation District, and Coos Bay Area Transit, may be inundated by the tsunami and consequently unable to respond. The ability of non-coastal transit agencies to assist coastal transit agencies is dependent on whether highways connecting the Willamette Valley to the coast remain passable. In particular, landslide risks may impair transit's ability to respond. Region 2 has the highest landslide risk (that is, this region has more historical landslide sites).

The importance of the human factor in recovery activities following a major emergency is often under-rated. Public transit is dependent on drivers, mechanics, dispatchers, and supervisors all working together to maintain and support daily operations. Some transit drivers are volunteers. Personnel must first be able to get to central agency locations, where both vehicle and communication assets must be operable, in order to provide public services. This also means there must be a way for these men and women to know that their families and loved ones are safe while they return to work. Although some emergency response personnel, such as firefighters and National Guard troops, do have commercial driver's licenses, they are generally not accustomed to driving buses, nor are they necessarily familiar with local streets and routes. Most importantly, drivers for demand-response transit services know where the vulnerable populations in their communities reside, which can be critical to saving lives in the hours and days immediately following a catastrophic event.

In summary, for public transit service restoration, short-term resilience is largely dependent on at least three primary factors:

- The condition and accessibility of the repaired roadway and (in coastal and valley areas) the bridge system.
- The ability of transit agency drivers, mechanics, dispatchers, and other key staff to respond following a catastrophic event.
- The status and availability of fuel supplies.

Longer-term resilience will also depend largely on the availability and prioritization of expenditure of public relief funds in the impacted areas. Certainly, without federal and state financial assistance, few of our local transit agencies would have the internal financial resources to finance major infrastructure rebuilds. These factors are difficult to forecast accurately given both the predicated severity of the natural event upon which the resilience assessment is based and the competing demands for public funds which would follow.

Local Roads and Streets

For many communities, the local road and street system provides the only access to many critical facilities following a disaster event. These facilities include hospitals, fire stations, and locations where temporary food and housing are to be provided. Local roads and streets can also provide detours around failed state highway system facilities. One of the observations made after the recent subduction zone earthquake in Chile was that the local road and bridge system tended to survive better than the state system. This was because the local roads tended to be straighter and wider, which resulted in larger roadway cuts and fills. As a result, many of the local roads and streets were used as detours for damaged state highway roadways and bridges. On the other hand, because many local roads and streets are narrow, with very sharp curves, they cannot safely accommodate a high volume of traffic.

In addition to local roads and streets, Oregon has thousands of miles of forest roads, and it may be possible to use these for low-volume, temporary local detours in the event of a major disaster. Many of these forest roads are privately owned and will also be subject to significant damage in a Cascadia subduction zone earthquake. Nonetheless, such local-road detours will likely serve emergency responders, repair crews, and vehicles transporting food and other critical supplies, and will therefore play an important role as recovery efforts progress and a minimum level of service is restored.

Resilience Gap Analysis Summary

Where possible, the gap analysis is based on an engineering evaluation of vulnerability and seismic resistance. Where engineering or other technical studies have not been completed, the analysis is subjective, based on generalizations of leading indicators, such as year of construction, seismic code at the time of design and construction, assessment of current conditions, and comparison with performance of similar facilities in subduction zone earthquakes in other areas of the world. Where detailed studies have not been completed, recommendations are included for further studies to fill the gap.

The current state of Oregon's transportation systems and the anticipated time to restore service after a Cascadia subduction zone event is represented in the figure shown below. The table also provides targets for the relative time needed to restore service if the system were strengthened or retrofitted.

Oregon Transportation Resiliency Status

***Key to the Table**

TARGETS TO ACHIEVE DIFFERENT LEVELS OF RECOVERY:	
Minimal: (A minimum level of service is restored, primarily for the use of emergency responders, repair crews, and vehicles transporting food and other critical supplies.)	R
Functional: (Although service is not yet restored to full capacity, it is sufficient to get the economy moving again—e.g. some truck/freight traffic can be accommodated. There may be fewer lanes in use, some weight restrictions, and lower speed limits.)	Y
Operational: (Restoration is up to 90% of capacity: A full level of service has been restored and is sufficient to allow people to commute to school and to work.)	G
ESTIMATED TIME FOR RECOVERY TO 60% OPERATIONAL GIVEN CURRENT CONDITIONS:	S
ESTIMATED TIME FOR RECOVERY TO 90% OPERATIONAL GIVEN CURRENT CONDITIONS:	X

Comparison of Target States and Estimated Time for Recovery

Infrastructure Facilities	*Event Occurs*	*0 – 24 hours*	*1 – 3 days*	*3 – 7 days*	*1 – 4 weeks*	*1 – 3 months*	*3 – 6 months*	*6 – 12 months*	*1 – 3 years*	*3+ years*
Central Oregon Zone										
▶ **OREGON STATE HIGHWAY SYSTEM**										
State Highway System - Tier 1 SLR [1)]			R	Y	G			S	X	
Roadways			R	Y	G/S		X			
Bridges			R	Y	G		S	X		
Landslides			R	Y	G			S	X	
State Highway System - Tier 2 SLR			R		Y	G			S	X
Roadways			R		Y	G/S		X		
Bridges			R		Y	G		S	X	
Landslides			R		Y	G			S	X
State Highway System - Tier 3 SLR				R		Y	G		S	X
Roadways				R		Y	G/S		X	
Bridges				R		Y	G		S	X
Landslides				R		Y	G		S	X
State Highway System - Other Routes					R		Y	G	S	X
Roadways					R		Y	G	X	
Bridges					R		Y	G	S	X
Landslides					R		Y	G	S	X
▶ **AIRPORTS & AIR TRANSPORTATION**										
Tier I - Oregon Airports System										
Redmond Municipal Roberts Field Airport - FEMA		R	S		Y	G	X			
Klamath Falls Airport		R	S		Y	G	X			
FAA Facility			R	Y	G					
▶ **OREGON RAIL TRANSPORTATION**										
UPRR										
CA/OR State Line to Bieber Line Jct. (Klamath Falls)			Y	G	S	X				

Infrastructure Facilities	*Event Occurs*	*0 – 24 hours*	*1 – 3 days*	*3 – 7 days*	*1 – 4 weeks*	*1 – 3 months*	*3 – 6 months*	*6 – 12 months*	*1 – 3 years*	*3+ years*
Bieber Ln Jct. (Klamath Falls) to Chemult (Shared			Y	G	S	X				
Chemult to Eugene					Y	G	S	X		
BNSF										
CA/OR State Line to Bieber Line Jct. (Klamath Falls)		G	S	X						
Chemult to Redmond		G	S	X						
Redmond to O.T. Jct. (connection with UP at Columbia			Y	G	S	X				
▶ OREGON PUBLIC TRANSIT										
Admin & Maintenance Facilities [2)]						R	Y	G	S	X
Local Area Paratransit On-Demand Service (critical				R	Y	S	G	X		
Local Area Paratransit On-Demand Service (full						R	Y	G	S	X
Local Roadway Fixed Route Service (emergency				R	Y	S	G	X		
Local Roadway Fixed Route Service (regular						R	Y	G	S	X
Intercity & Commuter Bus [4)]						R	Y	G	S	X
Willamette Valley Zone										
▶ OREGON STATE HIGHWAY SYSTEM										
State Highway System - Tier 1 SLR [1)]			R	Y	G			S	X	
Roadways			R	Y	G		S	X		
Bridges			R	Y	G			S	X	
Landslides			R	Y	G			S	X	
State Highway System - Tier 2 SLR			R		Y	G			S	X
Roadways			R		Y	G	S	X		
Bridges			R		Y	G			S	X
Landslides			R		Y	G			S	X
State Highway System - Tier 3 SLR				R		Y	G		S	X
Roadways				R		Y	G	S	X	
Bridges				R		Y	G		S	X
Landslides				R		Y	G		S	X
State Highway System - Other Routes					R		Y	G	S	X
Roadways					R		Y	G	S	X
Bridges					R		Y	G	S	X
Landslides					R		Y	G	S	X
▶ AIRPORTS & AIR TRANSPORTATION[5)]										
Tier I - Oregon Airports System										
Portland International Airport (PDX) (Tier 1)		R			Y	S		G	X	
Salem McNary Field		R			Y	S		G	X	
Eugene Mahlon Sweet Filed		R			Y	S		G	X	
Rogue Valley International Medford		R			Y	S		G	X	
Roseburg Regional Airport		R			Y	S		G	X	
Tier III Oregon General Aviation Airport System										
Troutdale			R		S	Y		G		X
Portland Heliport			R		S	Y		G		X
Aurora State			R		S	Y		G		X
McMinnville Municipal			R		S	Y		G		X
Corvallis			R		S	Y		G		X

Infrastructure Facilities	*Event Occurs*	*0 – 24 hours*	*1 – 3 days*	*3 – 7 days*	*1 – 4 weeks*	*1 – 3 months*	*3 – 6 months*	*6 – 12 months*	*1 – 3 years*	*3+ years*
Grants Pass			R		S	Y		G		X
Mulino State			R		S	Y		G		X
Albany Municipal			R		S	Y		G		X
Lebanon State			R		S	Y		G		X
Creswell Municipal			R		S	Y		G		X
Cottage Grove State			R		S	Y		G		X
Myrtle Creek			R		S	Y		G		X
Independence State Airport			R		S	Y		G		X
FAA Facility				R	Y	G	X			
► PORTS & WATER TRANSPORTATION										
Port of Portland Terminals			R			Y		G/S		X
► OREGON RAIL TRANSPORTATION										
UPRR										
O.T. Jct. to Troutdale			G	S	X					
Troutdale to Portland via Graham Line			Y	G	S	X				
Troutdale to Portland via Kenton Line			Y	G	S	X				
Eugene to Portland				Y	G	S	X			
BNSF										
Vancouver, WA to Portland					Y	G	S	X		
Portland & Western										
WES Commuter Rail, Wilsonville-Beaverton					Y	G	S	X		
► OREGON PUBLIC TRANSIT										
Admin & Maintenance Facilities [2]						R	Y	G	S	X
Local Area Paratransit On-Demand Service (critical					R	Y	S	G	X	
Local Area Paratransit On-Demand Service (full						R	Y	G	S	X
Local Roadway Fixed Route Service (emergency				R	Y	S	G	X		
Local Roadway Fixed Route Service (regular						R	Y	G	S	X
Intercity & Commuter Bus [4]						R	Y	G	S	X
Coastal Zone (Outside Tsunami Area)										
► OREGON STATE HIGHWAY SYSTEM										
State Highway System - Tier 1 SLR [1]			R		Y			G	S	X
Roadways			R		Y			G/S	X	
Bridges			R		Y			G	S	X
Landslides			R		Y			G	S	X
State Highway System - Tier 2 SLR				R		Y		G	S	X
Roadways				R		Y		G	S	X
Bridges				R		Y		G	S	X
Landslides				R		Y		G	S	X
State Highway System - Tier 3 SLR					R		Y		G	S/X
Roadways					R		Y		G/S	X
Bridges					R		Y		G	S/X
Landslides					R		Y		G	S/X
State Highway System - Other Routes							R		Y	S/X
Roadways							R		Y/S	X

Infrastructure Facilities	*Event Occurs*	*0 – 24 hours*	*1 – 3 days*	*3 – 7 days*	*1 – 4 weeks*	*1 – 3 months*	*3 – 6 months*	*6 – 12 months*	*1 – 3 years*	*3+ years*
Bridges							R		Y	S/X
Landslides							R		Y	S/X
▶ **AIRPORTS & AIR TRANSPORTATION** [5)]										
Tier II Oregon General Aviation Airport System										
Hillsboro Airport			R			Y	S		G	X
Newport Municipal Airport		R			Y		S	G		X
Scappoose Industrial Airpark Airport			R			Y	S		G	X
Tillamook Airport		R			Y		S	G		X
Bandon State Airport			R			Y	S		G	X
Brookings Airport			R			Y	S		G	X
Siletz Bay State Airport			R			Y	S		G	X
Cape Blanco State Airport		R			Y		S	G		X
Tier III Oregon General Aviation Airport System										
Florence Municipal Airport						R		Y	S	G/X
FAA Facility			R			Y	S		G	X
▶ **OREGON RAIL TRANSPORTATION** [6)]										
Coos Bay Rail Link										
Eugene to Cushman (Siuslaw River near Florence)					Y	G	S	X		
Portland & Western										
Albany to Toledo					Y	G	S	X		
Willbridge (N.W. Portland) to Wauna				Y	G		S	X		
▶ **OREGON PUBLIC TRANSIT**										
Admin & Maintenance Facilities [2)]						R	Y	G	S	X
Local Area Paratransit On-Demand Service (critical					R	Y	S	G	X	
Local Area Paratransit On-Demand Service (full						R	Y	G	S	X
Local Roadway Fixed Route Service (emergency					R	Y	S	G	X	
Local Roadway Fixed Route Service (regular						R	Y	G	S	X
Intercity & Commuter Bus [4)]						R	Y	G	S	X
Tsunami Inundation Zone										
▶ **OREGON STATE HIGHWAY SYSTEM**										
State Highway System - Tier 1 SLR [1)]				R		Y			G	S/X
Roadways				R		Y			G	S/X
Bridges				R		Y			G	S/X
Landslides				R		Y			G	S/X
State Highway System - Tier 2 SLR					R		Y		G	S/X
Roadways					R		Y		G	S/X
Bridges					R		Y		G	S/X
Landslides					R		Y		G	S/X
State Highway System - Tier 3 SLR						R		Y		S/X
Roadways						R		Y		S/X
Bridges						R		Y		S/X
Landslides						R		Y		S/X
State Highway System - Other Routes							R		Y	S/X
Roadways							R		Y	S/X

Infrastructure Facilities	*Event Occurs*	*0 – 24 hours*	*1 – 3 days*	*3 – 7 days*	*1 – 4 weeks*	*1 – 3 months*	*3 – 6 months*	*6 – 12 months*	*1 – 3 years*	*3+ years*
Bridges							R		Y	S/X
Landslides							R		Y	S/X
►AIRPORTS & AIR TRANSPORTATION [7)]										
Category I - Commercial Service Airports										
Southwest Oregon Regional Airport						R				X
Category II - Urban General Aviation Airports										
Astoria Regional Airport						R				X
Category IV - Local General Aviation Airports										
Seaside Municipal Airport									R	X
Gold Beach Municipal Airport									R	X
Category V - Remote Access/Emergency Service										
Nehalem Bay State Airport									R	X
Pacific City State Airport									R	X
Wakonda Beach State Airport									R	X
FAA Facility										
►PORTS & WATER TRANSPORTATION										
Port of Astoria					R	Y	S	G	X	
Gateway Piers					R	Y	S		G/X	
Tongue Point					R	Y	S	G/X		
Mooring Basins				R	Y		S	G	X	
Boatyard				R	Y		S	G	X	
Channels				R	Y	S		G	X	
►OREGON RAIL TRANSPORTATION [6)]										
Coos Bay Rail Link										
Cushman (Siuslaw R. near Florence) to Coos Bay &							Y	G	S	X
Portland & Western										
Wauna to Tongue Point/Astoria						Y	G	S	X	
►OREGON PUBLIC TRANSIT										
Admin & Maintenance Facilities [2)]							R	Y	G	S/X
Local Area Paratransit On-Demand Service (critical						R	Y	S	G	X
Local Area Paratransit On-Demand Service (full							R	Y	G	S/X
Local Roadway Fixed Route Service (emergency						R	Y	S	G	X
Local Roadway Fixed Route Service (regular							R	Y	G	S/X
Intercity & Commuter Bus [4)]							R	Y	G	S/X

TABLE NOTES:

1) SLR = Seismic Lifeline Routes (See Maps on Figure 5. 23 and 5. 24)

2) While temporary facilities can be used as an interim measure, it is anticipated that the prioritization of public relief funds would tend to push reconstruction of permanent transit facilities out into longer timeframes.

3) Critical needs evacuation and emergency usage of transit rolling stock would be at the direction of emergency operations center personnel.

4) Restoration of regular on-demand, fixed route, and intercity bus service is contingent on the extent of earthquake and tsunami damage, and on our ability to repair roads and bridges in all tiers of the state highway system and local roads.
5) Minimal level of service may indicate a heliport option only.
6) On these line segments, normal traffic is one train each way daily; consequently, restoration of minimal service means the same as functional.
7) Minimal level of service indicates the heliport option only. Due to the airport's proximity to the Pacific Ocean and elevation, the airport may be subject to relocation after the tsunami event.

Figure 5.22 – The current state of Oregon's transportation systems and the anticipated time to restore service after a Cascadia subduction zone event

HIGHWAY TRANSPORTATION

Sizable investments are needed to allow the highway system to be usable shortly after a major event. The total estimated cost to repair all seismically deficient bridges and unstable slopes is in the hundreds of millions of dollars; however, options exist for phased retrofitting that will provide the maximum degree of mobility with reasonable investments. The manner and timing of funding will influence how and where Oregon is prepared for rescue and recovery.

Analysis suggests that the longer the state delays increasing its investment in bridge and slope strengthening, the greater the cost and potential adverse effects an earthquake will have on the state's economy. If risks related to bridges and slopes are left unaddressed, the odds grow every day that we will be unprepared for an increasingly likely major earthquake. Oregon should therefore develop an investment package to begin a strategic retrofitting and replacement program for the state's bridges and unstable slopes. Securing both the interstate system in vulnerable areas and other key lifeline routes is the first priority, followed by critical city and county connector routes.

The strategic investment plan should be implemented in three tiers that build on each other. The Tier 1 routes listed in Figure 5. 23 (Phase 1 and then Phase 2) are considered top priorities for ensuring the greatest return on investment to support rescue and recovery operations. Strengthening Tiers 2 and 3 (Figure 5. 24) would follow as funding becomes available. This strategy anticipates that ODOT will continue bridge retrofits and slope strengthening in combination with other projects, even as it shifts to a more strategic, corridor-based approach to maximize potential future investments in seismic retrofitting.

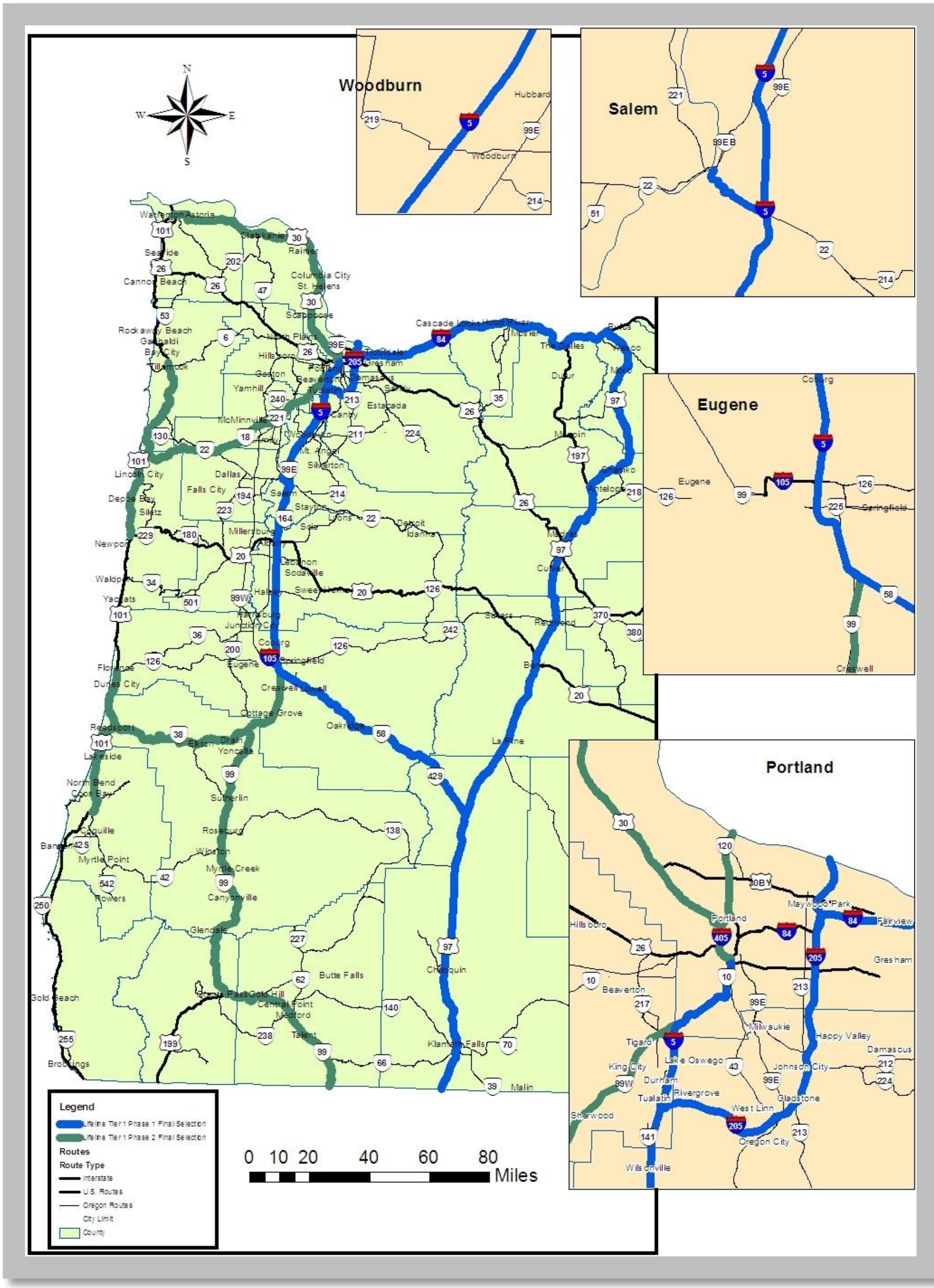


Figure 5.23 –Map of Seismic Options Program: Tier 1 Routes (Source: ODOT – Bridge Section)

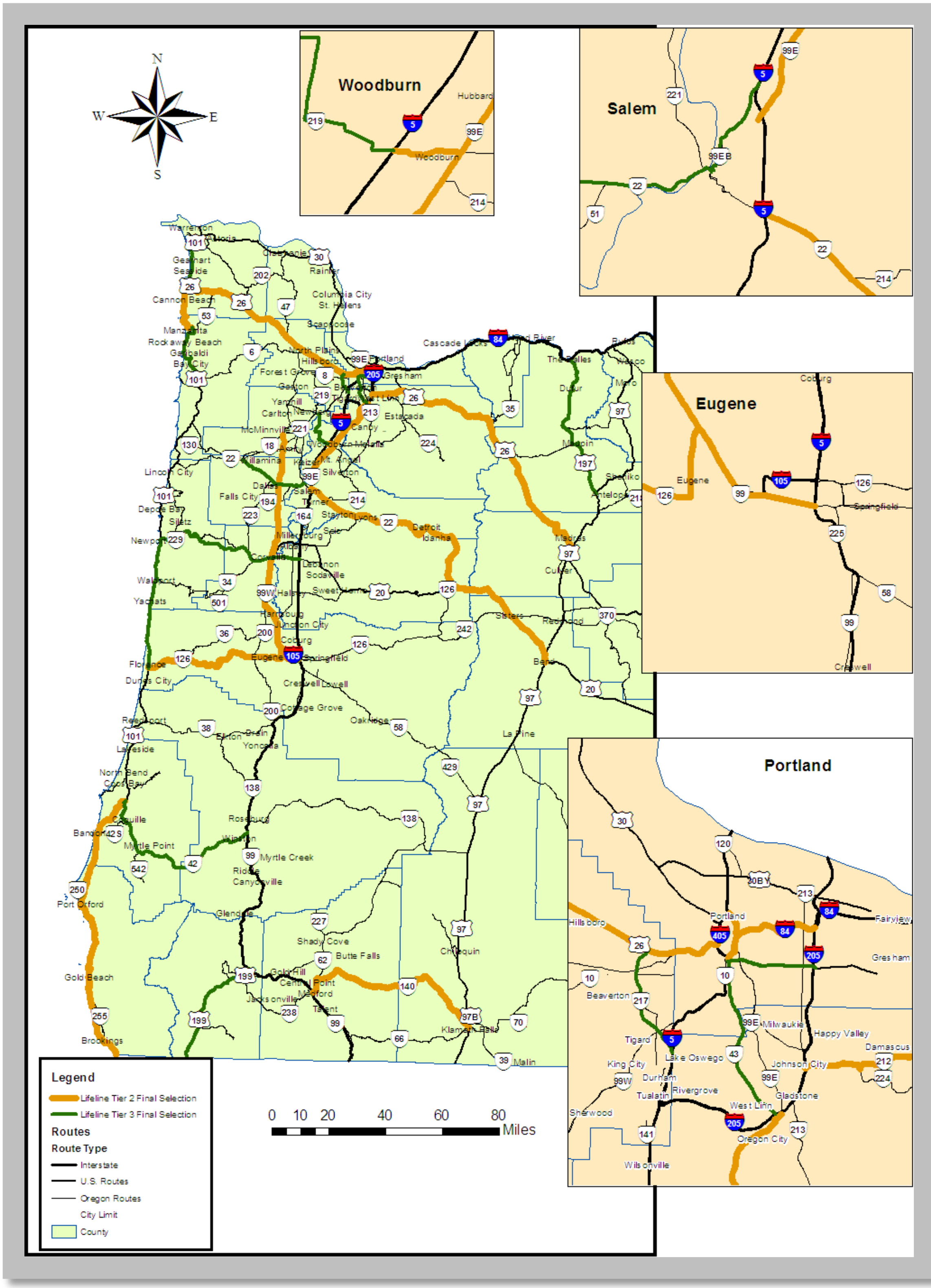


Figure 5.24 –Map of Seismic Options Program: Tier 2 & 3 Routes (Source: ODOT – Bridge Section)

RAIL TRANSPORTATION

A detailed vulnerability study and gap analysis should be done to identify strengthening and retrofit needs.

AIR TRANSPORTATION

A detailed vulnerability study and gap analysis should be done to identify strengthening and retrofit needs.

RIVER PORTS

A detailed vulnerability study and gap analysis should be done to identify strengthening and retrofit needs.

COASTAL PORTS

A detailed vulnerability study and gap analysis should be done to identify strengthening and retrofit needs.

PUBLIC TRANSIT SERVICES

A strategic investment strategy for public transit needs to start with the allocation of funds for gathering information, planning, and building collaboration with local and regional emergency planners. Specific projects for tactical hardening or relocation of certain transit structures and facilities may prove to be a valuable off-shoot of this effort, but in order to prioritize those and other potential expenditures, we first need to inventory and gather basic information about all transit resources in the four impact zones:

- An updated inventory of transit assets (buses, vans, fuel supplies, communications equipment, and repair facilities)—both those inside and those outside of the areas expected to be affected by the disaster—will be helpful. This should also include private carriers and school districts that may be of use in emergency response and recovery.
- An inventory of the assets of each facility, including general description, footprint, construction type, year built, and generator facilities, can provide a first-cut at seismic vulnerability estimation for those facilities that have not yet completed seismic assessments for a Cascadia-level event.
- Public transit needs to be included in emergency response preparations. As was recently revealed by Japan's Tohoku earthquake and the resulting tsunami impacts in Curry County and Del Norte County, transit agencies had not been at the table in emergency preparedness planning. A county-by-county assessment of transit's inclusion, role, and assigned activities for emergency preparedness should be conducted, and, where lack of involvement is indicated, inclusion and involvement should be formally encouraged.
- Assessment of the locations and needs of vulnerable and at-risk clients in all impact areas should be a priority. The lack of such information was a major factor in a number of deaths associated with Hurricane Katrina, many of which were potentially preventable. This is something each

local provider can do, with perhaps some general guidance and consistency of format provided at a statewide level.

- Transit agencies need to assess and prepare an inventory of routes, making note of the risk and vulnerability of both current transit routes and alternate routes; the inventory should identify alternate routes ahead of the actual event.
- Local transit providers should develop an emergency human resources plan that identifies:
    - Who their critical personnel are.
    - Where they live.
    - Full contact information.
    - Who is and who is not likely to be able to respond following an emergency.
    - Contingency plans for resuming at least minimal service using available and alternate personnel.
- Two aspects of preparedness should be considered for public transit: resilience planning and emergency response functions. These may include different roles for transit agencies, and they may entail different performance expectations. These differing roles and responsibilities need to be defined. The existence of mutual aid agreements with other local agencies and with nearby transit agencies should be identified; and, if do not exist, they should be encouraged as a means of building and sustaining collaboration and resilience.

LOCAL ROADS AND STREETS

As the strategic investment plan is implemented on the state highway system, certain elements of the local road and street system must also be retrofitted:

- In a few locations, critical emergency service facilities are separated from the state lifeline system by a substandard bridge. These bridges need to be retrofitted at the same time as the nearby state highway.
- Local road and street detours should be retrofitted wherever either of the following conditions exist:
    - The local road detour can be retrofitted for much less money than a retrofit on the section of state highway or bridge.
    - The local road detour can provide a substantially reduced time to restore the lifeline corridor to the minimal level of service for the use of emergency responders, repair crews, and vehicles transporting food and other critical supplies.

URBAN AREAS TRANSPORTATION

This chapter focuses mainly on statewide mobility between major hubs, cities, and towns. It is recognized, however, that travel within urban areas is also very important for rescue and recovery.

Large urban areas have critical needs for transportation resilience due to the relatively high volume of needs of a large population and the relatively high impact urban areas have on the state's economy.

Urban areas, such as Portland Metro, Eugene, Salem, Bend, Grants Pass, and Medford, face a large geographic barrier in the Columbia, Willamette, Deschutes, and Rogue Rivers and Bear Creek. These weak links in the urban transportation network create a potential for longer-term impacts because of the amount of time it is likely to take to restore traffic over large river bridges and to address problems caused by liquefiable soils along the river banks.

Most cities have established emergency response plans that identify critical facilities such as hospitals, fire stations, law enforcement facilities, schools, and emergency supply depots. Critical utility facilities, energy sources, and fuel depots are also needed for economic recovery. Access to these areas will be necessary to facilitate recovery, but specific modes and routes to provide this have not been identified in this study. This work is needed before a comprehensive plan for resilience can be finalized.

Transportation Interdependency Assessment

The Transportation Task Group determined that significant vulnerabilities exist for all transportation modes in western and central Oregon. While the desired approach is to raise the level of resilience of each mode by means of improvements programmed over a fifty-year timeframe, this may not be feasible due to the extremely high cost. The purpose of the interdependency effort was to select a multimodal transportation system that would provide the highest level of mobility to the largest area or to the highest population centers for the least cost.

The Transportation Task Group considered recommendations that would lead to a plan of measured improvements in ten-year increments that would include the most effective system of interconnected modes. The focus of this effort is to establish the resilience of portions of a transportation system—comprised of various modes—that would provide the greatest benefit for short-term rescue and longer-term economic recovery. To this end, the task group selected a minimum network of highway routes, termed a *backbone system*, and then supplemented it with other modes to provide statewide connectivity at what was perceived to be the lowest retrofit cost. The backbone system was identified as:

- I-5, from I-84 (Portland) to OR 58
- I-84, from I-5 (Portland) to U.S. 97
- U.S. 97, from I-84 to the California border
- OR 58, from I-5 to U.S. 97

Two alternate, interim transportation systems were assumed. The overall philosophy driving the selection process of the first system was that the movement of goods and people is likeliest, or most easily assured, along U.S. 97 (from both the north and the south and along the BNSF railroad line from

Klamath Falls), which also provides access to the Redmond airport in central Oregon. This assumption is supported by the low vulnerability of the highway, railroad line, and airport in comparison to routes and sites in western Oregon. The Redmond Municipal Airport was considered a key to short term mobility, because it would likely be available immediately following a Cascadia subduction zone earthquake. The Redmond airport should not need much investment to remain fully operational, although no specific study has been conducted to confirm this assumption. From the Redmond airport, goods and people would be easily distributed, by means of fixed-wing aircrafts, to Class 1 and commercial airports along the I-5 corridor. The task group considered this approach to be a high priority due to the high efficiency of fixed-wing aircrafts for moving people and freight. Goods and people would then access coastal areas by helicopter (a flight lasting approximately one half-hour each way). Airports in remote and coastal areas that can handle helicopters were identified as the second highest or moderate priority, with the resilience of the local roads and streets that provide access to those airports rated as equally important.

An alternate or redundant interim transportation system would serve Oregon from the west from ships, some anchored off shore for as long as needed. Goods and people would have access to the ships either through selected coastal ports hardened for use shortly after an event or by helicopter. Mobility from the ports to major population centers along the coast and inland would be achieved via hardened portions of U.S. 101 and selected local roads and streets.

The backbone highway system and seven airports are considered high priorities and should be made resilient within 10 years. The high-priority airports include:

- Redmond
- Portland International
- Salem
- Eugene
- Roseburg
- Medford
- Klamath Falls

Tier-1, Phase-2 Highway Lifeline Routes include segments of the coast highway (U.S. 101) and three highway segments connecting U.S. 101 to I-5. These segments should be considered moderate priorities as part of the multimodal transportation system. Airports designated as moderate priorities (to be hardened within 20 years) include:

- Scappoose/Hillsboro (one of these)
- Tillamook
- Siletz Bay (Lincoln City)

- Newport
- Florence
- Cape Blanco
- Brookings

North Bend and Astoria airports are very vulnerable, because they are both likely to be under water following a Cascadia subduction zone earthquake and tsunami. Both airports, however, may be potential recovery hubs due to the presence of the Coast Guard there. Unless the North Bend and Astoria/Warrenton facilities are completely destroyed, the Coast Guard intends to establish field facilities (tents/trailers) and begin operating those facilities as soon as possible after the event. (Airfields, which are unusable by fixed wing airplanes, may still be completely functional for helicopters as soon as the water recedes).

RAIL LINES

The task group considered the utility of rail lines in order to provide some redundancy to the basic backbone system, although nearly all the rail infrastructure predates modern seismic engineering standards. Rail lines into Redmond are considered a high priority, because Redmond is the hub for air transportation. The high priority mainline from Klamath Falls to Chemult is shared by BNSF Railway (formerly the Burlington Northern and Santa Fe Railroad) and UP (Union Pacific Railroad). The high priority BNSF mainline continues from Chemult to the Columbia River just west of Biggs. The UP mainline along the south side of the Columbia River from Portland to Idaho is also considered to be a high priority. The UP mainline from Chemult to Eugene and paralleling I-5 all the way to Portland is considered a moderate priority, because it is assumed that the cost of making the section through the Cascade Range resilient is very high.

All rail routes from the Willamette Valley to the coast are moderate to low priorities due to their vulnerabilities. The Coos Bay line could be functional to Reedsport after a Cascadia subduction zone event; but it is unlikely to be functional all the way to Coos Bay. The Tillamook line has been out of service since December 2007, with no plan for repairs. In general, short-line routes do not look very resilient, as they have not been built to current standards. There is very little rail redundancy outside of the Willamette Valley.

COASTAL AND RIVER PORTS

River and coastal ports are considered to be both part of a redundant system (in relation to the basic backbone system) and, in some cases, the primary access for specific areas. The task group considered it important to take into account the capabilities of the maritime industries, the Navy/Marine Corps, and the Coast Guard to bring in supplies by sea and distribute them to the state via air. The task group noted that this was done very effectively in Haiti.

River Ports

The Port of Portland has a very large capacity for handling supplies and is considered to be a major focus for restoring the economy after a seismic event. This port will be doing selective strengthening in the near future. The following upriver ports could provide significant supply links, although their levels of vulnerability and the vulnerability of the intervening locks still need to be confirmed:

- Arlington
- Morrow
- The Dalles
- Cascade Locks
- Umatilla

In addition, it was noted that the Port of St. Helens has a significant commodities capacity.

Locks are not designed to current seismic standards. In addition, seismic standards for locks are lower than for other structures. Seismic resistance is not an element of current evaluations conducted on river locks.

The overall plan needs to include a resilience evaluation of the Columbia River channel:

- An event could modify the channel's shape such that some larger vessels may not be able to navigate the river following an event.
- Dredging will likely be needed to restore the shipping channel following an event.
- Bridge failures could block the river for a period of time.
- The failure of dams or locks could block river navigation for an extended period of time.
- Elevation changes, subsidence, and other morphological changes could result in permanent changes to channels.

Coastal Ports

Coastal ports may be a significant lifeline for selected communities along U.S. 101. Immediately after a Cascadia subduction zone event, the coastal ports are not expected to be usable without some level of reconstruction. A detailed study is needed to determine whether there are practical ways to harden coastal ports so that they can be quickly restored and rendered operational. There is a study underway concerning identification of potential beach landing sites for naval vessels that would not require port facilities. The most practical solution may be to stockpile key resources at coastal locations. Such resources would include:

- Bailey bridges.
- Floating docks.

- Dredging equipment.

The task group recognized that storage of resources can be expensive, and consideration of deterioration and maintenance may lower the desirability of this option. Maintaining contingency contracts with local contractors who have the ability to repair structures or install temporary structures is considered a best practice.

Key roads are also needed to support port activity. Most of these connections are local agency routes that are considered to be the same level of priority as the coastal ports.

OTHER CONSIDERATIONS

- One of the issues that arose as the task group considered interdependencies is the lack of direct correlation between the modes. For example, air and water transport generally have definite take-off and landing points, although helicopters and beach landing craft can significantly extend the range of those modes to nonconventional landing areas. The highway system, on the other hand, has innumerable connections and no prescribed end points.
- Focusing simply on hardening the Phase 1 routes of OSLR Tier 1 will not ensure highway access to many coastal communities. If coastal communities are served primarily by air after an event, we would still need to consider local route resilience to make the most of the air corridors.
- The overall plan needs to take into consideration the potential for partial or complete failure of dams. Potential impacts and consequences of a failure could be extremely serious for rescue and recovery.

Alternate Routes

Selected local agencies were asked to assess the condition of their roads and streets in order to propose local bypasses (alternate routes) for the designated lifeline routes of the state highway system. The objective was to identify the places where the use of the local highway may be a more cost effective or practical means of making the transportation network resilient. Some examples are listed below.

- Klamath County proposed an 11-mile bypass of U.S. 97. This segment avoids the rockfall area north of Klamath Falls. Although this rockfall risk would be critical during an earthquake, the fallen rocks could be moved quickly out of the way shortly after the event. Moreover, the proposed bypass has liquefaction risk. The main north-south railroad is also next to the slide area. Because this railroad segment will be a Tier 1 facility, protection measures need to be planned. Such a protection scheme will likely protect both the highway and the railroad.
- Astoria suggested a route that runs parallel to U.S. 101 and bypasses Young's Bay Bridge. This parallel route has a few smaller bridges, would cost less to retrofit, and is at a higher elevation (no tsunami threat).

- Tillamook County noted an alternate route that parallels U.S. 101. This county route has small bridges and one major bridge, which is scheduled to be replaced in 2015. Connections to the airport and hospital would also need to be added.
- Albany suggested alternate north-south and east-west routes. The east-west route also connects to the hospital.
- Portland proposed priority local routes to hospitals, their lifeline routes on arterials connecting to the state highway lifeline routes, and connections to fuel depots.

Several other proposed local alternative routes are included in the ***Local Agency Alternatives to State Highway Lifeline Routes (http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/laashlr.pdf)***, a supplement to this Report. These routes will be studied at a later time as possible alternatives to state highway lifeline routes.

Public Transit

As noted earlier in this chapter, public transit agencies could play an important role in helping Oregon recover from a major natural disaster. The overall plan should therefore include funds to inventory public transit facilities and rolling stock (both inside and outside the projected impact areas) and to coordinate the integration of public transit into local and regional emergency relief and business recovery planning, including the development of mutual aid agreements where appropriate.

TRANSPORTATION INTERDEPENDENCY SUMMARY

The task group determined that no single transportation mode can be feasibly retrofitted to provide adequate mobility after a major Cascadia event for all areas of the state. A plan for strengthening particular components of each mode—to provide a combination of highway, air, rail, water ports, and local access roads—was developed that offers a cost effective strategy to increase mobility in incremental steps.

Recommendations

Recommendations for improving the resilience of transportation are based on the assumption that incremental improvements will be made over a 50-year timeframe. Phased investments to improve mobility are envisioned in order of priority and were chosen to best leverage cross modal improvements that will facilitate movement of goods and people on a multimodal transportation system. The recommended approach is to establish redundancy by routing people, supplies, and services from the east by air from Redmond Municipal Airport to hardened airports in the Willamette Valley, and by highway along I-84 and OR 58 to I-5 in the Willamette Valley to areas accessible by highways, and then by helicopter to isolated areas. Concurrently, people, supplies, and services would be able to travel from the sea through selected ports and then along portions of U.S. 101 or by helicopter to isolated areas.

Recommendations are presented for short-term goals and long-term goals.

SHORT-TERM RECOMMENDATIONS

► **Complete an updated inventory of local agency transit, port, and rail assets (such as service buildings, buses, vans, fuel supplies, communications equipment, repair facilities, and human resources, including identifying the needs of vulnerable and at-risk clients), assuring access to school buildings and hospitals, which could be used during emergencies.**

► **Complete a statewide evaluation, assessment, and gap analysis of:**

- Local agency roads and streets, including public transit. (Define the roles of local agencies, transit, port, and railroads in resilience planning and assessment of alternate routes.)
- Coastal and river port facilities, including jetties and breakwaters, the Columbia River channel (103.5 miles long, 43 feet deep, 600 feet wide), the levee system, dams and locks, port entrance channels, pile dikes, and specifically, Port of Portland facilities (including access to and the vulnerability of the four terminals that are interdependent with two rail lines, the river barge system, and two interstate highways) and the liquefaction vulnerability at Portland International Airport (PDX).
- Railroads—specifically, the UPRR (Willamette Valley) and BNSF (Central Oregon) trunk north-south rail lines and three railroad short lines (Astoria District, Albany-Toledo, and CBRL) with access to coastal communities.
- Ninety-seven public-use airports.

► **Encourage Federal agencies, such as USCG and the Corps of Engineers, to complete an assessment and gap analysis of Federal facilities that support transportation resilient planning.**

► **Develop a mitigation policy and retrofit plan for the assets and service facilities of vulnerable bridges, including all co-located utilities (such as power, communication, gas, water, and wastewater lines); rockfalls and unstable slopes; the 29 airports listed in the airport section of Chapter 5; river and coastal ports; the Columbia River channel, including emergency re-dredging options; local roads, streets, and transit; rail (on a corridor basis along the critical trunk and regional segments); and intermodal connections. Identify Redmond Municipal Airport (Roberts Field) as a key distribution point for other airports, and harden it as necessary so it will be operational after a major event; identify coastal and river ports or heliports as redundant access from ships stationed off shore for medical facilities and delivery of supplies from out of state, and the Columbia River as a priority with continued dredging. Encourage the development of formal cooperative assistance agreements with local agencies, nearby transit providers, rail providers, ports, and highway agencies.**

► **Continue to refine and gain consensus for the strategy contained in the interdependency section of Chapter 5 to optimize the recommendations for an incremental program for achieving resilience in western Oregon and to provide service to coastal areas and other potentially isolated areas with a combination of air, ports, regional rail, and highway segments, including**

consideration of the following airports and water transportation as the redundant first line of operational sites supporting lifeline highways:

- Redmond Municipal Airport
- Portland International Airport
- Salem Airport
- Eugene Airport
- Roseburg Airport
- Medford Airport
- Klamath Falls Airport
- Scappoose/Hillsboro Airport (one of these)
- Tillamook Airport
- Siletz Bay Airport (Lincoln City)
- Newport Airport
- Florence Airport
- Cape Blanco Airport
- Brookings Airport
- Selected Coastal and River Ports
- Columbia River Channel

► **Enhance the proposed Highway Lifeline Maps by considering the use of highway segments owned by cities and counties to provide access to critical facilities. Prioritize local routes to provide access to population centers and critical facilities from the identified Tier-1 routes. When developing projects for seismic retrofit of highway facilities, consider whether a local agency roadway may offer a more cost effective alternative for all or part of a lifeline route.**

LONG-TERM RECOMMENDATIONS

► **Enhance design and maintenance standards and requirements for bridges and unstable slopes, transit, rail, ports, and airfields based on the priority of a lifeline route.**

► **Develop a temporary bridge installation policy and standards, including an assessment of the number of temporary bridges or amount of temporary bridge materials to stockpile for emergency use. Coordinate with the DOTs of neighboring states to create an inventory of (portable, temporary) Bailey bridges that includes notes on their locations and transportation methods. Consider procurement of additional temporary bridge materials.**

► **Support research on retrofit methods and strategies for Cascadia subduction zone earthquake loads. Support research on tsunami effects, and develop a design policy for tsunami loads.**

References

1. Atwater, B.*F. and* Hemphill-Haley, E. (1997). *Recurrence intervals for great earthquakes of the past 3,500 years at northeastern Willapa Bay, Washington. USGS Professional Paper: 1576.*
2. ODOT Bridge Seismic Committee and Peter Dusicka (2009). *Seismic Vulnerability of Oregon State Highway Bridges – Mitigation Strategies to Reduce Major Mobility Risks.* For detailed information, see http://www.oregon.gov/ODOT/HWY/BRIDGE/Pages/index.aspx
3. ODOT Technical Services Branch and Planning Division (2013). *Oregon Highways Seismic Options Report.* For detailed information, see http://www.oregon.gov/ODOT/HWY/BRIDGE/Pages/index.aspx
4. ODOT (2012). *Local Agency Alternatives to State Highway Lifeline Routes*, Supplement to Oregon Resilience Plan, Chapter 5 Transportation. For detailed information, see http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/laashlr.pdf