EXECUTIVE SUMMARY

The Port of Portland has conducted a seismic risk assessment of selected high-value Port assets. The seismic risk assessment was conducted to: 1) evaluate the seismic performance of the selected assets at multiple earthquake/ground-motion hazard levels, 2) identify potential improvements to selected assets that would mitigate hazards and enhance the seismic performance, and 3) estimate benefits of such improvements in comparison to cost of implementation. The study was intended to advance the understanding of the degree to which Port facilities are at risk of damage from a major earthquake and the potential economic benefit of undertaking projects to improve seismic resilience.

1. Port Assets Evaluated in the Seismic Risk Assessment Study

The seismic risk assessment considered 18 of the Port's approximately 230 assets. The 18 assets were selected on the basis of critical Port functions, high value, high revenue generation, and significance to the region in terms of economic impact. The assets represent both Aviation and Marine operations, and comprise approximately half the total value of all Port assets combined and 80% of the Port's revenue generation. The assets are listed below. The numbers indicate priority in terms of relative importance to the Port's operations; priorities were assigned at the outset of the study.

PDX Buildings

- 1. Central Utility Plant (CUP)
- 3. Concourse C – three sections
- 4. Terminal Core and South Lobby – four structurally-distinct components
- 5. ARFF Facility
- 6a. Port Headquarters Building and P2 Parking Structure North
- 6b. P2 Parking Structure South
- 13. Ground Maintenance Administration and Shops
- 14. Ground Maintenance Facility
- 15. Ground Maintenance Facility

PDX Airfield

- 2. Runway 10R-28L – South Runway
- 2. Runway 10L-28R – North Runway

Marine Facilities

- 7. Terminal 6 – Berths 604 and 605
- 8. Terminal 5 – Berth 503
- 9. Terminal 4 – Berths 410 and 411
- 10. Terminal 5 – Berth 501
- 11. Terminal 6 – Berth 601
- 16. Terminal 6 – Maintenance Warehouse
- 17. Terminal 6 – Electric Shop Building

Hillsboro Airport

12. Runway 13-31

In addition to representing a large majority of the Port's asset value and revenue production, these assets represent a significant regional economic impact. The assets account for an estimated $100 million in annual Port revenue. In 2011, these assets were estimated to account for an estimated $2 billion in regional economic impact. The regional economic impact was taken from the report The Local and Regional Economic Impacts of the Port of Portland, 2011, prepared by Martin Associates. It is expected that the contribution of the Port's assets to the regional economy has grown since that report was issued in early 2012.

2. Seismic Risk Assessments

For each of the facilities, the study conducted an assessment of vulnerability to earthquake damage. Assessments considered structural systems of the specific assets as well as site-specific soil conditions at each location. Together with the structural and soils evaluations, the study estimated the length of time each facility was likely to be out of service – or the "downtime" – following ground motions with a return period of 475 years. The facilities vary in age from 60 years to no more than a few years. The assessments considered both inertial lateral forces on structures and kinematic loading from liquefaction-induced settlement or lateral spreading. Given the varying ages of the structures and changes in building codes over the years, the capacity of the structures to resist lateral loads varies considerably both for PDX buildings and marine structures. Newer structures typically have the capacity to resist larger forces than older structures, as would be expected.

The entire PDX site has subsurface conditions susceptible to soil liquefaction and seismically-induced settlement. Many of the buildings at PDX have pile foundations. Typically, buildings with shorter pile foundations that do not penetrate to dense, non-liquefiable soil deposits are more vulnerable to settlement-caused earthquake damage than buildings with long pile foundations. Most of the older structures have shorter pile foundations. The majority of buildings at PDX, even those with long pile foundations, have slab-on-grade ground floors which will settle as the result of soil liquefaction and settlement. Consequently, earthquake-induced settlement of ground floor slabs can occur even in a building that is otherwise undamaged by forces of a particular earthquake.

All of the Port's marine structures are also located in areas where the soil is susceptible to liquefaction as well as to lateral spreading. The large estimated soil displacements caused by lateral spreading can impose significant, damaging forces on structural elements. In larger earthquake events, the majority of the marine facilities will likely be damaged beyond repair.

Findings of the preliminary assessments for each facility are summarized in the following:

PDX Building Assessments

Central Utility Plant: Originally constructed in 1970; expanded in 1992 and upgraded in late 1990s. Design capacity of the lateral force-resisting system for earthquake forces ranges from

65% to 87% of current code lateral design forces. The building is composed of a variety of different structural systems which could result in an undesirable distribution of lateral earthquake forces. The building lacks ductile detailing, and the thin, brittle exterior masonry walls are susceptible to damage. Pile foundations are relatively shallow, and the building may to settle several inches even in a moderate earthquake. Downtime to rebuild and repair the CUP following seismic forces from ground motions having a 475-year return period is estimated to be approximately 12 months. Additional time could be needed to procure, install, and commission specialized equipment.

An 80-foot length of corrugated steel pipe (CSP) utility tunnel exists between the CUP and the utility tunnel under the P2 parking structure (P2). The CSP utility tunnel is not pile-supported, and it will settle relative to the CUP and the pile-supported utility tunnel under P2. The differential settlement can be expected to damage utilities inside the tunnel.

<u>Concourse C</u>: Constructed in late 1990s. The lateral force-resisting system is steel moment-resisting frames. Design capacity is 103% of current design requirements; however, lateral drifts of the building in a relatively large earthquake will exceed current standards for Immediate Occupancy, and the movement of the building could damage glazing and other non-structural components necessary to meet Immediate Occupancy conditions. The building is supported on deep piles which will prevent significant settlement of the structure. However, the slab-on-grade ground floor will settle in the event of earthquake-induced liquefaction. The settlement will damage architectural and MEP elements that are supported by the slab. Additionally, the utility tunnel below Concourse C is not pile-supported, and is likely to settle. Downtime to restore Concourse C to an occupiable condition after the 475-year hazard level ground motions is estimated to be two months.

<u>Terminal Ticket Lobby</u>: Originally constructed in 1973; seismically upgraded in the mid-1990s. The lateral force-resisting system is composed of concrete shear walls with steel braced frames above the Mezzanine. Design capacity for the shear walls is 97% of current code, and for the braced frames is 63% of current code. The building lacks ductile detailing which will likely result in localized damage in a major earthquake. The original pile foundation is relatively shallow, and was supplemented with deeper micropiles in the upgrade. The shallow piles will settle when soil liquefaction occurs, causing stresses in the building structure and increased loads on the micropiles. The slab-on-grade ground floor and exit vestibules will settle, possibly by 12 inches or more in a large earthquake. Downtime to restore the building to an occupiable condition after the 475-year event is estimated to be 12 months.

<u>Terminal South Node</u>: Constructed in late 1990s. Design capacity is 103% of current code. However, detailing of the shear wall reinforcing may not meet current code. A lack of ductile detailing could lead to localized damage in a large earthquake. The pile foundations are deep and are not expected to settle significantly. As elsewhere in the terminal, however, the slab-on-grade ground floor will settle 12 inches or more in a large earthquake. Downtime to repair damage from the 475-year event is estimated to be two months.

Terminal Oregon Marketplace South: Originally constructed in 1956; expanded and upgraded in 1986 and 2002. The lateral force-resisting system is a combination of concrete shear walls and steel braced frames. Design capacity for the concrete shear walls is 107% of current code, and for the braced frames is 70% of current code. Similar to the Ticket Lobby, a lack of ductile detailing will result in localized damage. Piles from the original construction are shallow, and will likely settle several inches in a soil liquefaction event. The settlement will cause stresses in the building and increased loads on micropiles that were installed in the 2002 upgrade. Soil liquefaction will cause slab-on-grade settlements of 12 inches or more. Downtime to restore the building to an occupiable condition after the 475-year event is estimated to be 24 months.

Terminal Oregon Marketplace Central: Originally constructed in 1956; upgraded in 1986 and late 1990s. The ongoing phased voluntary seismic upgrade of the Terminal has not been completed in this area. If completed, the design capacities based on the existing concrete shear walls and braced frames would be 107% and 70% of current code respectively. Due to a lack of ductility in the structure, the building is expected to perform poorly in a large earthquake. The existing pile foundation is shallow, and will not prevent settlement of the building in a large earthquake. The settlement will cause extensive damage to the older concrete structure. Settlement of the slab-on-grade could be as much as 10 inches in a 500-year event. Downtime to restore the building to an occupiable condition after the 475-year event is estimated to be 24 months.

PDX Aircraft Rescue and Firefighting Facility: Constructed in the 1990s. The ARFF facility building was designed as an Essential Facility with concrete masonry shear walls. The design capacity for seismic forces is 107% of current code requirements. The structure likely does not meet current requirements for ductility, and localized damage can be expected. With a high potential for liquefaction at the site, the building can be expected to settle due to its mat foundation rather than deep piles. Settlements of approximately 6 inches could occur with ground motions having a 200-year return period, and more than a foot with larger ground motions. The building may not be significantly damaged by the settlement, but certain elements such as the doors of the truck bays may not be workable. Downtime to restore the ARFF facility following the 475-year event is estimated to be two months.

Port Headquarters (HQ) and P2 Parking Structure: Constructed in 2009. The lateral force-resisting system is a combination of concrete shear walls and concrete and steel moment-resisting frames. Design capacity is 100% of current code requirements. The building meets code design and detailing requirements and code performance expectations. Deep pile foundations will prevent settlement of the building. However, the slab-on-grade ground floor – part of the P2 Garage – may settle as much as a foot in a large earthquake. Downtime to restore HQ/P2 to an occupiable condition after the 475-year event is estimated to be one month. The estimated one-month downtime would not include repairing the ground floor.

PDX Ground Maintenance Facilities: Constructed in the 1980s. The three buildings are of generally similar construction consisting of precast, tilt-up concrete walls with plywood diaphragm roofs. Design capacity for lateral seismic forces ranges from 31% to 37% of current code design forces. Lateral systems lack ductility, and the roof structures do not meet current design standards. The site is highly susceptible to soil liquefaction. Ground settlements of as much as 18 inches could occur in an earthquake with ground motions having a return period of as little as 200 years. Spread footings could settle an additional foot. The extreme settlements together with the seismic deficiencies of the structures will likely result in the buildings being unusable after a 200-year event. Downtime to replace the buildings is estimated to be approximately 16 months.

PDX Runway Assessment

Runways 10R-28L (South)/10L-28R (North): The South Runway was reconstructed in 2011; the North Runway was extended and rehabilitated in 2009 and 2010. As noted in the PDX building assessments, the soils at PDX are highly susceptible to seismically-induced liquefaction. The resulting settlement will affect airfield pavements. Minimal damage is likely to occur when subjected to ground motions having an average return period of72 years, while differential settlements are likely to become operationally unacceptable at ground motion levels greater than approximately 225-year exposure intervals. Soil conditions are generally similar at the two runway sites, with the exception that a higher risk of lateral spreading exists at the north runway location. Repair times to return a runway to service will of course depend on the extent of damage, and could range from a few days for minor repairs to 10 -12 months for full reconstruction. Repairs to the asphalt concrete North Runway will likely require less time in general than repairs to the portland cement concrete South Runway.

Marine Facility Assessments

Marine structures, with the exception of Terminal 6 – Berths 604/605, were assessed in this study for performance at 72-year, 475-year, and 975-year return period ground motions in accordance with current industry approach. Berths 604/605 were evaluated in an earlier study conducted by the Port. In general, all of the facilities in their existing condition will experience some degree of damage from a 72-year hazard level ground motions, and none would be expected to survive a 475-year event.

Terminal 6 – Berths 604/605: Originally constructed in 1974; modified in 1994 and 2011/2012. Berths 604 and 605 are sand-filled cellular sheet pile structures. Ground improvements to increase seismic resilience of an 800-foot section of the wharf were undertaken by the Port in 2011 and 2012. Based on evaluations conducted previously by the Port, the improved section should survive ground motions at a 200-year return period. The unimproved section of the facility is expected to be vulnerable to damage beyond a 50-year event.

Terminal 5 – Berth 503: Constructed in 1992. Original design criteria for Berth 503 are unknown. It can be expected that the criteria were considerably below current code requirements. The structure is composed of concrete piles, concrete pile caps and beams, and a concrete deck with isolated steel batter pile elements. The structure is expected to survive 72-

year ground motions with relatively minor damage. Downtime for repairs following the 72-year event is estimated to be 5 to 8 months. A recent evaluation conducted for the facility indicates that ground motions at the 475-year return period, without consideration of the effects of liquefied soils, would cause forces in the structure at or slightly above capacity. At this return period, soil liquefaction will result in lateral spreading estimated to be on the order of seven feet. This extent of soil displacement may cause substantial damage, such that the berth may not be repairable. A 26- to 38-month downtime for replacement can be expected.

<u>Terminal 4 – Berths 410/411</u>: Berth 411 constructed in 1959; Berth 410 constructed in 1962. Design capacity for the lateral systems is approximately 30% of current code design forces. Structural systems vary, with Berth 410 constructed primarily of timber elements and Berth 411 constructed of concrete elements. However, the performance of the two berths is expected to be similar. The structures will likely survive a 72-year return period event with repairable damage. The 475-year event will induce significant soil liquefaction which will cause large lateral soil displacements. The soil displacements will result in excessive forces on structural elements. The facilities are not expected to survive the 475-year event. Downtime to reconstruct the berths is estimated at 26 to 38 months.

<u>Terminal 5 – Berth 501</u>: Constructed in 1974. Design criteria for this facility are unknown, but are likely to have been well below current code. The facility is a hybrid pier structure consisting of three large-diameter sheet pile cells supporting a concrete deck. Earthquake-caused liquefaction at the site will induce large lateral soil deformations resulting in significant forces on the sheet pile cells. The 72-year event will likely cause significant damage requiring extensive repairs. Downtime to repair damage from the 72-year event is estimated to be 12 to 16 months. The 475-year event will likely damage the pier beyond repair. Reconstruction time is estimated to be 22 to 34 months.

<u>Terminal 6 – Berth 601</u>: Constructed in 1989. Berth 601 is a floating dock with a trestle connection to the shore. The floating dock will not experience significant damage from an earthquake, as a result of being waterborne. Design capacity for the lateral system of the trestle is approximately 11% of self-weight, which is approximately equal to current code forces for the 72-year return period event. Soil lateral spreading displacements at the site will be extensive, estimated at several feet from ground motions at the 72-year event and in excess of 10 feet at the 475-year event. The trestle and other landward elements are expected to suffer significant damage from the soil displacements in the 72-year event, and may not survive. Downtime to construct a new trestle and replace other landward elements is estimated at 15 to 21 months.

<u>Terminal 6 Maintenance Warehouse</u>: Constructed in the 1970s. Design capacity, originally based on wind loading, ranges from 35% to 77% of the current code seismic design forces. The lateral system is composed of a combination of tension rod bracing and steel moment frames. The design lacks the ductile configuration and detailing required by current code. Additionally, soil liquefaction could lead to settlements exceeding a foot in ground motions at a return-period

of less than 300 years, resulting in significant damage. The building is not likely to survive beyond a 200-year event. Downtime to replace the building is estimated to be 12 months.

Terminal 6 Electrical Shop: Constructed in the late 1980s. The building was designed for wind loading, similar to the Maintenance Warehouse. Design capacity is 167% of the current code seismic design forces in one direction, but only 28% of the current code in the other direction. The lateral system consists of tension rod bracing and moment frames, which lack the ductility required by current code. As noted for the Maintenance Warehouse, large settlements at the site will likely occur in relatively small earthquakes. The building is likely to be damaged beyond repair in a 200-year event. A 12-month replacement downtime would be expected.

Hillsboro Airport Runway Assessment

Hillsboro Runway 13-31: Soils at the site of the Hillsboro Airport are less prone to seismically-induced liquefaction and settlement than the soils at PDX. Screening-level analyses indicate that there is a low risk of significant soil settlement at the Hillsboro site. A magnitude 9.0 earthquake is likely to cause some runway settlement but not take the runway out of service. Portions of the runway may need to be repaired to return the runway to original condition, but such repairs will not likely need to be undertaken immediately to maintain the runway in service.

3. Seismic Risk Mitigation Strategies for Selected Assets

The study identified potential strategies to mitigate the expected seismic risk for a selected group of the assets evaluated. The selected group of assets included the CUP, Concourse C, sections of the main passenger terminal, and the South Runway at PDX, and marine Terminal 4 – Berths 410/411, Terminal 5 – Berths 501 and 503, and Terminal 6 – Berth 601. For buildings, seismic risk mitigation was targeted at achieving a condition of Immediate Occupancy for ground motions having a 475-year return period. For marine facilities, the objective of mitigation was to achieve survivability for the 475-year return period event.

Seismic risk mitigation for the Port's assets will generally entail both improvements of structural systems and improvements of soils. At all PDX and marine facilities, mitigation must necessarily address the liquefaction potential of the soils. The soils are deep alluvial flood deposits of the Columbia River and Willamette River, and as noted in the foregoing narrative are highly susceptible to liquefaction. The ground settlements and lateral spreading that are triggered by liquefaction can be damaging to all types of structures.

The potential mitigation strategies identified in the study are summarized in the following:

Central Utility Plant: Improve the foundation to prevent settlement of the building by installing deep micropiles at each column and other load-bearing elements, and at locations of critical equipment. Strengthen the lateral capacity of the building by retrofitting with a concrete shear wall system. Replace the brittle exterior wall system composed of masonry blocks and brick veneer with a more flexible system such as metal studs and metal panels. Improve anchorages and support for essential MEP equipment and systems. A rough order of magnitude estimate of probable construction cost for these actions is $16 million. The estimate is based on 2014/2015 costs.

In addition to the CUP, risks to the unsupported utility tunnel that exists between the CUP and the parking structure should be addressed. A new pile-supported concrete tunnel could be constructed around the existing tunnel to eliminate settlement potential.

Concourse C: Install micropiles under the slab-on-grade ground floor to prevent significant settlement. Alternatively, reinforcing the slab with a reinforced topping slab bonded to the existing slab would be feasible in some areas. Install micropiles to support the utility tunnel. For the lateral system of the building, install a force damping system to improve seismic performance. Some additional bracing of critical MEP systems would be needed. Order of magnitude estimate of cost: $81 million total for all three sections of the concourse.

Terminal Ticket Lobby: Install micropiles at each column and other load-bearing element to prevent settlement of the building. Install micropiles under the slab-on-grade ground floor to prevent settlement, or replace the slab with a structural slab. Replace steel braced frames in the lateral system with more ductile braces for better ductility performance, and reinforce certain structural connections. Additional bracing of critical MEP systems would be needed. Order of magnitude estimate of cost: $47 million.

Terminal South Node: Install micropiles under the slab-on-grade to prevent settlement, or replace the slab with a structural slab. Install micropiles to support the utility tunnel. Improve structural diaphragm connections to improve the strength and ductility of the lateral structural system. Additional bracing of critical MEP systems would be needed. Order of magnitude estimate of cost: $36 million.

Terminal Oregon Marketplace South: As for the Terminal Ticket Lobby, install micropiles at each column and other load bearing elements to prevent settlement. Install micropiles under the slab-on-grade. For the lateral system, replace braced frames with more ductile bracing, with the exception of two braced frames that should be replaced with concrete shear walls. Additional bracing of critical MEP systems would be needed. Order of magnitude estimate of cost: $20 million.

PDX Runway: Install stone columns or jet grout the supporting soil. At either the North Runway or the South Runway, stone columns would extend to a depth of approximately 40 feet below the pavement surface. Jet grouting treatment would extend to a depth of approximately 30 feet. Stone columns would be installed as part of a scheduled reconstruction project; jet grouting could be undertaken as a retrofit. Order of magnitude estimates of cost: $137 million for jet grout treatment of the South Runway, $67 million for stone column improvements for the South Runway, and $68 million for stone column improvements for the North Runway.

Terminal 4 – Berths 410/411: Given the age of these facilities and the cost of improvements that would be needed to achieve survivability at the 475-year return period, the only mitigation action that would be economically viable is to replace the berths with a modern facility. It is expected that replacing the two berths with a single combined facility would be the preferred approach. Order of magnitude estimate of cost for a combined replacement facility: $42 million.

Terminal 5 – Berth 501: Conduct ground improvements to limit soil displacements. Ground improvements could consist of installing stone columns or other strengthening method in the river embankment, around the trestle abutment, and in the cellular structures. Install new piles to support the conveyor bridge tower, and strengthen structural members and connections throughout the facility. Order of magnitude estimate of cost: $20 million.

Terminal 5 – Berth 503: Conduct ground improvements along the shoreline using stone columns, and strengthen piles, pile connections, and concrete beams. Order of magnitude estimate of cost: $13 million.

Terminal 6 – Berth 601: Conduct ground improvements using stone columns around the approach trestle bents and abutments, and install piles at each bent. Retrofit the trestle structure by strengthening structural elements and connections. Order of magnitude estimate of cost to retrofit the trestle with new piles and stronger connections: $5 million.

It should be noted that mitigation strategies other than those mentioned here were considered and may be appropriate; discussion of other strategies was omitted in the interest of brevity. Future work and additional in-depth studies by the Port would determine the optimal mitigation strategy for any asset.

4. Risk and Benefit-Cost Analyses

The study conducted risk and cost-benefit analyses of the assets and the potential mitigation strategies. The analyses were conducted to evaluate the benefits of mitigation by comparing existing "as is" conditions with the mitigated conditions. Eight different cases were evaluated, considering Port-only revenue impacts and Port-plus-Region combined economic impacts:

a. Port Only Impacts – Buildings, Existing ("As-is")
b. Port Only Impacts – Buildings, Runways and Marine Facilities, Existing ("As-is")
c. Port Only Impacts – Buildings with Mitigation
d. Port Only Impacts – Buildings, Runways and Marine Facilities with Mitigation
e. Port and Regional Impacts – Buildings, Existing ("As-is")
f. Port and Regional Impacts – Buildings, Runways and Marine Facilities, Existing ("As-is")
g. Port and Regional Impacts – Buildings with Mitigation
h. Port and Regional Impacts – Buildings, Runways and Marine Facilities with Mitigation

Benefit-Cost for Mitigation of PDX Assets

The total order of magnitude estimated cost of the potential mitigation strategies identified in the study for the PDX assets is $267 million. The assets include the CUP, Concourse C, the three units of the passenger terminal, and the South Runway.

	Estimated Cost of Mitigation
CUP	$16,000,000
Concourse C	$81,000,000
Terminal Ticket Lobby	$47,000,000
Terminal South Node	$36,000,000
Terminal Oregon Marketplace South	$20,000,000
South Runway	$67,000,000
Total	$267,000,000

Considering Port plus regional economic impacts, benefit-cost analysis shows a benefit-cost ratio of 1.4 for the combined mitigations. A benefit-cost ratio of 1.4 represents a relatively good payback on investment, on the basis that a ratio greater than 1 indicates a positive economic benefit.

A comparison of the cost-effectiveness of the potential mitigation actions for each of the PDX building assets showed that the greatest benefits in loss reduction would be produced by mitigations for the CUP, the Terminal Ticket Lobby, and the Terminal Oregon Marketplace South. The order of magnitude cost estimate for mitigations of these three building assets is $83 million. With the South Runway mitigation at $67 million, the total cost of the mitigation strategies for this smaller group of assets would be $150 million. Considering Port and regional economic impacts, the benefit-cost analysis shows a benefit-cost ratio of 2.2 for risk mitigation for this smaller group.

Benefit-Cost for Mitigation of Marine Assets

Benefit-cost analysis for the potential retrofit mitigation actions at all of the marine facilities evaluated, with the exception of Terminal 4 – Berths 410/411, shows benefit-cost ratios greater than 1 considering Port and regional economic impacts. Specific benefit-cost ratios for mitigation actions are as follows:

	Estimated Cost of Mitigation	Benefit-Cost Ratio
Terminal 4 – Berths 410/411	$42,000,000	0.8
Terminal 5 – Berth 501	$20,000,000	3.5
Terminal 5 – Berth 503	$13,000,000	1.8
Terminal 6 – Berth 601	$5,000,000	2.9
Terminal 6 – Berths 604/605	$15,000,000	2.2

As noted, the only economically viable mitigation strategy for Terminal 4 – Berths 410/411 is complete replacement. The cost of facility replacement and the time out of service take the benefit-cost ratio for that action below 1.

5. Conclusions and Recommendations

The Seismic Risk Assessment Study identified risks of seismic damage in the majority of the Port assets evaluated. Given the importance of the Port's function to the region, it is recommended that the Port continue with actions to improve the seismic resilience of key Port assets. For PDX, the focus could be on improving the resilience of a group of assets that would together represent a functional airport – a portion of the passenger terminal, a concourse, the CUP, and a runway. The Terminal Ticket Lobby, Terminal South Node, Terminal Oregon Marketplace South, Concourse C, the CUP, and either the North Runway or the South Runway would fit this description. For marine facilities, the focus could be on protecting the assets that provide the greatest revenue and functionality. Accordingly, it is recommended that the Port give consideration to the following specific mitigation projects:

PDX Runway

Mitigation of risks to a PDX runway should be a top priority. Given the liquefaction potential of the ground at PDX, relatively low to moderately strong ground motions will cause ground settlement and distortion of pavement to some extent. This would result in a high probability of a repair project that would take the runways out of service for some length of time. Without a usable runway, the airport would not be functional. Further study would determine if the mitigation should be for the South Runway or the North Runway. Planning for a runway mitigation project should include discussions with the FAA about physical condition requirements for a runway to remain in service after an earthquake, and about the potential for improving the survivability of critical FAA-owned navigational aids.

PDX Terminal

A terminal mitigation project should be pursued as a second priority. The terminal is necessary for passenger check-in functions and baggage handling. The focus of a mitigation effort should be on terminal units T1 – Ticket Lobby and T3 – Oregon Marketplace South, for which mitigation actions show the greatest cost-effectiveness. The mitigation could be part of the Terminal Core Redevelopment project that the Port has initiated; that project would provide an avenue and mechanism to accomplish the seismic retrofits.

PDX Central Utility Plant or Concourse C

A mitigation project for either the CUP or Concourse C should be a third priority. A functioning CUP is critical for full operation of the terminal and airfield functions. Further study would confirm the vulnerability of the CUP and determine the optimal retrofits. If the further study finds that the CUP is not as vulnerable as believed, consideration should be given to mitigating the risks at Concourse C as the third priority.

Marine Terminal T6 – Berths 604/605

Mitigation at Terminal 6 – Berths 604/605 should be completed, as the top priority for the Port's marine assets. A portion of the wharf has been seismically upgraded. A project to mitigate risks for the remainder of the wharf would improve the resilience of the entire facility to withstand a large earthquake. Berths 604/605 would likely be the most important Port marine asset in supporting a regional rebuilding effort in the aftermath of a major disaster.

Marine Terminal T5 – Berth 503

Mitigation at Terminal 5 – Berth 503 should be the second priority for the marine assets. Berth 503 operates under the most stable, long-term lease of the Port's marine facilities. Seismic vulnerabilities should be mitigated to keep this facility in business for the long term.

For each of these potential projects, next steps will include detailed geotechnical site assessments, detailed structural engineering analyses, and further explorations of potential mitigation measures, costs, and benefits.

Beyond the specific, prioritized project recommendations outlined in the foregoing, this study offers the following additional recommendations:

- Evaluate the benefit of designing each new project for greater seismic resilience than the minimum required by Building Code. Considering that code requirements for seismic design forces are based on life-safety and collapse prevention, not on property preservation or operational continuity, structures designed to minimum code requirements cannot be expected to maintain uninterrupted functionality after a major earthquake.
- Identify and evaluate mitigations for other key Port assets. This study identified and evaluated potential mitigation actions for only a limited number of the Port's key assets. A similar effort should be undertaken for other assets considered to be critical for the Port's functions.
- Establish a plan for extricating aircraft rescue and firefighting vehicles from the ARFF facility if the doors of the truck bays become inoperable after an earthquake.
- Broaden future seismic risk assessment efforts to include non-Port critical assets and lifelines, in coordination with other agencies and with utility owners. Pertinent examples include:
    - Services provided by regional lifeline systems such as electrical power, telecommunications, water/wastewater, fuel, and surface transportation
    - The Columbia River levee system adjacent to PDX
    - Jetties at the mouth of the Columbia River, and navigation channels along the full lengths of the Columbia River and Willamette River shipping lanes
- Confirm the plan for Port emergency operations and recovery. Immediate occupancy after a significant ground motion should not be expected for any Port facility as it currently exists. The Port should assess the current emergency response plan to ensure there is an allowance for the probable temporary unavailability of existing Port facilities.

End of Executive Summary