Chapter 4 - Critical Buildings

Preliminary Report to OSSPAC

4.1 Introduction

Building safety and function will be critical during, and after, a potential magnitude 9.0 Cascadia Subduction Zone (CSZ) seismic event. Oregon's buildings must be able to withstand this intense ground shaking without devastating loss of life, damage to infrastructure, and significant disruption to our communities and economy. Because of this, the Critical Buildings Task Group was assigned to review the critical building sectors necessary for the State to remain resilient when considering the effects of a CSZ event. These sectors include those buildings necessary for immediate response to the event—the emergency operations centers, hospitals, police and fire stations, and emergency shelters, and the building sectors that become necessary for providing basic services to communities as they begin to restore function and return to normal life—schools, housing, certain retail stores, and banks. At the same time, however, this task group acknowledges that there are many other buildings and sectors that could also be considered vital for resilience, but chose to limit the study to those the Task Group believes are most critical to seismic resilience.

One additional building category was reviewed —vulnerable buildings. These are unreinforced masonry and non-ductile concrete structures that have shown time and again in past earthquakes that they pose a very significant and direct threat to life safety.

There are other critical buildings and structures that are needed for communications, utilities, ports, water supply, waste water, fuel storage, etc. These structures are also very important, but in most cases are accessory to the functions they serve. For this reason their evaluation and recommendations are addressed by other task groups as part of the Seismic Commission study.

To assess the overall seismic resiliency of the State of Oregon, the Task Group considered the gap between the building performance goal needed for seismic resilience (target state) and the expected seismic performance of the buildings as they are today (current state). Most of the building sectors critical for responding to a seismic event are recognized by the current building code. Oregon's current seismic design standard for new buildings, the Oregon Structural Specialty Code (OSSC), classifies buildings into four distinct occupancy categories based on their relative importance to life safety in the event of a natural disaster. See Figure 1. Occupancy Categories III and IV are structures that have large assembly areas such as schools, or that are deemed essential to emergency response such as hospitals, police and fire stations, and emergency operations centers. Buildings that fall under these Category III or IV classifications were obvious components of the Critical Buildings data set used in our evaluation. Under current code, occupancy category type III buildings are designed for a 25% higher seismic load than Category I and II buildings. Category IV buildings are designed for a 50% higher load.

Our task group also looked beyond the building code to buildings that have functions that we believe are vital to the seismic resiliency of the State as a whole. Supermarkets, pharmacies, some "big box" retail stores, and banks comprise a subset of buildings that will be relied upon heavily following a disaster. The importance of having an ample supply of basic needs such as food, water, medical supplies and money in affected areas after a natural disaster has been underscored by many previous events, including Hurricane Katrina and the

2011Tohoku earthquake and tsunami in Japan. If buildings that house these resources are not seismically resilient, the ability of the community to recover after the event occurs will be adversely affected. For these reasons, large community retail buildings and bank buildings have been classified as Critical Buildings in this study.

TABLE 1604.5
OCCUPANCY CATEGORY OF BUILDINGS AND OTHER STRUCTURES

OCCUPANCY CATEGORY	NATURE OF OCCUPANCY
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Occupancy Categories I, III and IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing elementary school, secondary school or day care facilities with an occupant load greater than 250. • Buildings and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500. • Group I-2 occupancies with an occupant load of 50 or more resident patients but not having surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5,000[a]. • Power-generating stations, water treatment facilities for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV. • Buildings and other structures not included in Occupancy Category IV containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2 occupancies having surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV structures. • Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the maximum allowable quantities of Table 307.1(2). • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

a. For purposes of occupant load calculation, occupancies required by Table 1004.1.1 to use gross floor area calculations shall be permitted to use net floor areas to determine the total occupant load.

Figure 1: Oregon Structural Specialty Code, Table 1604.5

Past earthquakes have brought to light the dangerous nature of unreinforced masonry (URM) and non-ductile concrete structures. Because of their tendency to sustain excessive damage or even collapse in moderate earthquakes, these buildings pose the greatest threat to life safety of any other building type in the State of Oregon. This, along with the fact that URM and non-ductile concrete buildings can be found in all occupancy categories, was the main reason that our task group included these vulnerable buildings in our Critical Buildings study.

Building Data and Analysis

Once we identified the building sectors, data sources for the existing building stock were identified that could be used for assessment of the buildings' seismic resiliency. Two sources were used: the *2007 Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings* (Open File Report 07-020) prepared by DOGAMI (the Oregon Department of Geology and Mineral Industries), hereafter referred to as the 2007 SSNA, and the Hazus Earthquake Model developed by the Department of Homeland Security and FEMA, hereafter referred to a FEMA Hazus.

The 2007 SSNA was an assessment made of existing hospitals, police and fire stations, emergency operations centers, and K-12 schools throughout Oregon and utilized a rapid screening method developed by FEMA to identify potential seismic hazards. In the report, evaluations were made of each facility, which were visited by screeners to establish a Rapid Visual Screening (RVS) score based on the FEMA 154 methodology. The data compiled by DOGAMI and the resulting scores were then reviewed by Structural Engineers on our Task Group, who, in the case of emergency operation centers, police stations, fire stations, and acute care hospitals, reviewed the screening for every building and converted the RVS scores to Expected Recovery scores that were then placed into the overall Critical Building Target States of Recovery Matrix shown in Table 1. A similar procedure was also used for schools, but because of the number of buildings, only about 10% of the total school building stock was reviewed directly. Additionally, considerations were made for the tsunami inundation, liquefaction and landslides which were not a part of the DOGAMI study.

To assess residential, community retail centers, banks, critical government facilities, and vulnerable buildings, data for expected damage estimates based on a CSZ event was extracted from the FEMA Hazus model and an analysis performed to develop Expected Recovery Scores that were input into the overall matrix shown in Table 2. Unlike the 2007 SSNA data, which looked at each actual individual building, the FEMA Hazus model utilizes a complex series of statistical analyses to predict damage estimates. This analysis makes predictions about the quantity, size, and construction of buildings in various sectors based on census data. It then calculates an expected performance for these buildings using additional statistical models. While a useful tool for looking at large populations of buildings, the outcomes do not correlate directly to any specific buildings. Since more detailed reports were not available, this data was used to establish Expected Recovery scores, and is subject to a larger variation in expected results and should not be viewed with same level of reliability as those in Table 1. Recovery scores developed from the 2007 SSNA report have been separated from the scores developed through the use of FEMA Hazus due the differences between the two sources.

Target States of Recovery

With Recovery scores established, the next step was to determine the recovery state that should be targeted in planning the path to statewide seismic resiliency. The recovery state is the average time that should be needed to repair a building in a given sector and restore most of its function. For the Phase 1 target states, which are measured in hours, there is not much differentiation in the building performance, though it should be realized that just evaluating buildings, particularly in the areas most severely affected, may take several days. Buildings with Phase 2 response times are anticipated to require some repairs, but generally should not sustain major damage to the primary structures. Phase 3 buildings are anticipated to undergo significant damage, likely requiring many months to a year or more to repair. The worst building performance—those in the 18 month and 36+ month categories—will likely be at, or near, a complete loss. Many buildings can be reconstructed in 18 months with sufficient resources, with remaining collapsed buildings likely requiring 36+ months.

The determination of target states was based mostly on assessing the relative importance of each of the occupancy types to the recovery effort after the seismic event. Buildings that house “first responders” or provide emergency functions are the most vital to the recovery effort, and will need to be functional immediately after the seismic event occurs. Schools in the affected areas need to provide a level of life safety protection for the children and adults in them during the earthquake but could be out of service for up to 60 days without significant impacts on resilience. The exceptions are those schools designated as emergency shelters for displaced citizens after the event occurs. The availability of food, water, medical supplies, and money will also be critical to the speed of recovery of the communities affected by the seismic event. Consequently, retail centers, pharmacies and banks will have to be able to return to normal operation in a reasonable amount of time. All of these considerations were made in the development of the Target Recovery scores for each building class that are reflected in Tables 1 and 2. Note that a specific target state was not determined for vulnerable buildings. This is because the use and function of these structures varies widely. Instead, the recovery state should either match the building occupancy category, if the building is used for a critical function, or an upgrade criteria should be established based on the needs of the facility, but not less than life safety.

With both expected and target recovery states identified and tabulated for each building class by seismic region, the gaps between expected and target building performance can be easily seen.

Table 1. Target States of Recovery For Oregon’s Buildings
Based on 2007 DOGAMI SSNA and Independent Structural Engineering Review

Infrastructure Cluster Facilities	Event Occurs	**Phase 1** (hours)			**Phase 2** (Days)		**Phase 3** (Months)		
		4	24	72	30	60	4	18	36+
Emergency Operations Centers (Coastal)								X	
Emergency Operations Centers (Valley)							X		
Emergency Operations Centers (Eastern)					X				
Police Stations (Coastal)									X
Police Stations (Valley)							X		
Police Stations (Eastern)					X				
Fire Stations (Coastal)									X
Fire Stations (Valley)						X			
Fire Stations (Eastern)				X					
Healthcare Facilities (Coastal)								X	
Healthcare Facilities (Valley)							X		
Healthcare Facilities (Eastern)				X					
Healthcare Facilities[1] (Coastal)									X
Healthcare Facilities[1] (Valley)								X	
Healthcare Facilities[1] (Eastern)					X				
Primary/ K-8 (Coastal)						[2]		X	
Primary/ K-8 Centers (Valley)						[2]		X	
Primary/ K-8 (Eastern)					X	[2]			
Secondary/High School (Coastal)								X	

Secondary/High School (Valley)								X	
Secondary/High School (Eastern)									
Emergency Sheltering (Coastal)								X	
Emergency Sheltering (Valley)								X	
Emergency Sheltering (Eastern)					X				

[1] Analysis includes consideration of non-structural components
[2] Range recognizes preference for shorter time frame, but acknowledges a longer period can be tolerable.

Target State **X Estimated Current State**

Table 2. Target States of Recovery For Oregon's Buildings Based on FEMA HAZUS Loss Estimations									
Infrastructure Cluster Facilities	**Event Occurs**	**Phase 1** (hours)			**Phase 2** (Days)		**Phase 3** (Months)		
		4	**24**	**72**	**30**	**60**	**4**	**18**	**36+**
Critical Government Facilities (Coastal)[1]							X		
Critical Government Facilities (Valley)[1]					X				
Critical Government Facilities (Eastern)[1]	X								
Residential Housing (Coastal)					X				
Residential Housing (Valley)				X[2]					
Residential Housing (Eastern)	X								
Community Retail Centers (Coastal)							X		
Community Retail Centers (Valley)					X				
Community Retail Centers (Eastern)	X								
Financial/Banking (Coastal)						X			
Financial/Banking (Valley)					X				
Financial/Banking (Eastern)	X								
Vulnerable Buildings (Coastal)									X
Vulnerable Buildings (Valley)								X	
Vulnerable Buildings (Eastern)					X				

[1] See section 4.3.5 for a definition of this building type.
[2]Average underestimates expected performance of older houses, which are vulnerable to several structural deficiencies.

Target State **X Estimated Current State**

While the gaps between the target state and the estimated current state may appear large, it was our task to look beyond them and formulate a 50 year plan for closing these gaps. The Critical Buildings Task Group has developed an extensive list of recommended actions that, if followed, provide a framework for achieving this objective. These recommendations, along with a proposed implementation timeline, can be found in Section 4.4 of this report. As the building stock continues to age and the likelihood of the CSZ event continues to grow, the gaps that we have identified will only continue to get larger. We cannot underscore enough the importance of taking immediate action so that the movement to an acceptable level of seismic resiliency in the most essential and vital buildings in our State can begin.

4.3 Assessment of Current Building Performance: A Sector by Sector Review

4.3.1 Emergency Operations Centers, Police and Fire Stations

Introduction

In 2005, the Oregon Department of Geology and Mineral Industries published a report titled, "Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings, Report to the Seventy-Fourth Oregon Legislative Assembly". This report catalogued the vast majority of, if not all, the emergency operations centers, police stations, and fire stations within Oregon. Of the data collected, 82 emergency operations centers, 109 police stations (which includes city, state police, and county sheriff), and 595 fire stations (which includes city and rural fire protection districts) provided enough information for the Critical Buildings Task Group to reasonably assess the state of seismic resilience of each of these buildings.

The majority of these buildings are typically one or two stories tall and are constructed from reinforced masonry or wood. The median building age is approaching 40 years. Despite the good performance record of wood structures during earthquakes, the age of these buildings and the low level of seismic design used prior to 1995 places the older structures at risk. Additionally, a number of buildings located in the coastal region are at risk of earthquake-caused tsunami inundation or large ground displacements due to either liquefaction or landslides. A number of buildings in the Valley region are also at risk of significant movement due to liquefaction or landslides resulting from an earthquake. All of these factors increase the risk of many buildings to all of the effects produced by the CSZ event.

Estimated State of Recovery

The expected state of recovery of these buildings ranges from a few buildings remaining fully functional during and immediately following a CSZ event to many others requiring three or more years for repair until the building is deemed fully functional or the building is demolished. Of particular concern are the buildings along the Oregon Coast, where 82% of the emergency operations centers, 86% of the police stations, and 67% of the fire stations will most likely take 18 months or more to resume normal operations. The buildings within the Valley zone are also problematic, with 27% of the emergency operations centers, 38% of the police stations, and 31% of the fire stations likely to sustain damage to the extent that 18 months or more will most likely be required to resume normal operations. Therefore, instead of being able to withstand and operate during and after a CSZ seismic event, which is what is expected of buildings performing these vital life-safety functions, it is anticipated that a significant percentage of these buildings that house these types of essential services will not be functional for some time after the event. Of significant concern is the anticipated longer time to recover for many of those buildings that are located along the Coast and in portions of the Valley.

Target State of Recovery

The importance of Emergency Operations Centers, police stations, and fire stations to the post-earthquake response and recovery is widely recognized. Building codes have required for some time that these facilities be designed to a higher standard with the intent that they will remain operational after a major earthquake. The public also recognizes that these facilities are the centers for first response, and as such, there is a general expectation that they remain functional after the disaster. For these reasons, the Target State of Recovery for these facilities must be "Event Occurs" as indicated in the Recovery Matrix, Table 1.

Sector Specific Recommendations/Conclusions

To our knowledge, a mandatory program with a formal mechanism to identify deficient structures and require their upgrade with a firm timeline does not currently exist. ORS 455.400 requires seismic rehabilitation of publicly-operated emergency operations centers, police stations and fire stations by 2022, but with the caveat of being, "subject to available funding." As a result, it appears to have had only limited effect in this and other essential and critical building sectors. Typically, the impetus to evaluate these types of buildings to determine their seismic-resisting capability is motivated at the local level, often by the public agency itself. Once the evaluation has been completed, a determination can be made about whether a particular building or group of buildings requires seismic rehabilitation. The agency will then submit a request to the voters within that community to support a general obligation bond to accomplish the needed work. This was recently done within the City of Portland where a general obligation bond was passed in 1998 to rehabilitate their fire stations. The last fire station rehabilitation was completed in 2012. Financing methods for the rehabilitation of public buildings is much more limited than the opportunities that exist for privately-owned buildings. As a result, general obligation bonds, or some variation thereof, are likely to be the primary method to finance the costs of seismically upgrading these critical facilities. Oregon Senate Bills 3 and 5 (2005) provided for the establishment and funding of a grant program for emergency services buildings to assist with upgrades of these facilities, but funding to date for this program has been limited. Public buildings ultimately must be financed, either substantially or completely, with public funds. This can only happen by implementing a broad program of education to inform the voters of the risks associated with these seismic hazards, and the impact that those risks, if unabated, will have on their communities when the CSZ event occurs.

In addition to the types of public buildings discussed above, other types of critical government facilities exist, including, but not limited to city halls, Public Safety Answering Points (PSAP, usually termed 911 Centers) and jails. The 2007 SSNA report did not collect data on these types of facilities, and to our knowledge, no publicly-available data exists about them within Oregon, except for broad statistical data which can be inferred from the FEMA Hazus data discussed in section 4.3.5 of this report. Consequently, no specific, data-driven recommendations regarding the seismic resilience of these other critical government facilities have been provided as part of this report.

4.3.2 Education Facilities

Introduction

Public school facilities make up a special category of Oregon's public infrastructure. Oregon has 1,355 K-12 public schools organized in 197 school districts that are overseen by independent elected local school boards. These schools combine for a total of over 2,000 buildings of various structural types, sizes, and vintages, including numerous buildings that are more than a century old.

Schools are among the most heavily used public buildings in Oregon and one of a few classes of buildings whose occupants' presence is compulsory. In 2010, the Western States Seismic Policy Council (WSSPC) adopted a policy recommendation that states "Children have the right to be safe in school buildings during earthquakes."[1] Based on the findings of the Critical Buildings Task Group, the State of Oregon is far from meeting this student safety ideal today.

The 2007 Statewide Seismic Needs Assessment (SSNA) employed the FEMA 154 Rapid Visual Screening methodology to characterize building structural performance into four broad categories of collapse potential. Of the full sample of 2,018 K-12 educational facilities assessed using the FEMA 154 methodology, 12 percent rated Very High, 35 percent rated High, 23 percent rated Moderate, and 30 percent rated Low collapse potential.[2] The assessment focused on school facilities constructed before 1994, although some more recent buildings were included. Of the buildings assessed, roughly 80 percent were built before Oregon first adopted a statewide building code in 1971, and 60 percent are more than 50 years old. The assessment revealed that inadequate or non-existent seismic design is pervasive in every region of Oregon, and that seismic retrofit investment at the school district level has been limited.

Schools are typically large, complex buildings with plan irregularities that will be sources of poor seismic performance. Many schools are campuses that are comprised of multiple buildings of varying sizes and construction dates, and often varied construction materials. Primary, K-8, and high schools generally consist of one or two-story wood-frame or CMU and concrete buildings with flexible roof diaphragms. One to three-story lightly-reinforced concrete buildings braced by concrete shear walls, concrete tilt-up buildings, and unreinforced masonry (URM) buildings are also common.

The building stock of Oregon's K-12 schools possesses seismic vulnerabilities that are common to the specific building types that comprise them. Unreinforced masonry (URM) buildings historically perform poorly in seismic events and are the most dangerous existing building type in the school building stock. Many 1930s-era multistory schools rely on lightly-reinforced concrete shear walls that are historically poor performers as well. Wood-framed schools should perform well provided they are well constructed even though many of them pre-date building codes. These wood buildings may possess deficiencies including weak or missing roof-to-wall connections, and weak or missing anchorage of walls to foundations—all of which could contribute to poor seismic performance. Concrete tilt-up buildings have also proven to perform poorly in earthquakes. Newer tilt-up buildings have been improved by code changes adopted following the 1994 Northridge earthquake in California, but older tilt-up buildings, and even CMU buildings, may remain vulnerable due to poor connections between heavy rigid walls and flexible roofs. Modular classrooms may also be vulnerable because they may have insufficient connections to the foundations. Many schools contain unsecured and inadequately braced nonstructural components that may present falling hazards during a seismic event.

Estimated State of Recovery

The 2,377 educational facility records in the 2007 SSNA were too numerous to be analyzed individually by members of the educational facilities subgroup. Our analysis and results are based on a random sample of approximately 300 records (224 primary school buildings and 79 secondary school buildings) that were selected as representative of the broader data set. We classified the building records into the appropriate geographic seismic zone (Coast, Valley, and Eastern) and verified that we had assembled an adequate sample size for each zone.

Our analysis revealed that in a CSZ earthquake scenario, pervasive structural vulnerabilities would likely result in recovery durations of 18 months or longer for primary and secondary schools in the Coast and Valley seismic zones. Primary and secondary schools in the Eastern seismic zone are expected to have recovery times of 60 days or less, mainly due to minimal level of ground motion expected in that geographical area.

Target States of Recovery

Giving consideration to the prioritized needs of the entire community for resilience and recovery, returning children to school within 30 days is preferred. However, it was also the opinion of the task group that a disruption of the public education system for up to 60 days could be tolerated without having a major impact on most communities and students. This determination was based on several considerations:

- School buildings will not initially be as critical to the recovery as most other critical buildings included in our study. The exception to this would be those schools which are needed as Emergency Shelters, and as such, should have a target state of recovery of 72 hours.
- Teacher/Employee contracts can be adjusted to accommodate a 2 month stoppage of work more readily than employee contracts in many private businesses.
- Temporary facilities, including portable buildings and large buildings that are undamaged after the event, can be employed to serve some of the more immediate education needs until full recovery is achieved.

Discussion/Sector Specific Recommendations

Oregon's K-12 educational facilities have been the focus of seismic rehabilitation policy efforts for more than a decade. In 2001, legislation (ORS 455.400) directed that, subject to available funding, K-12 educational facilities with seismic deficiencies should be rehabilitated to a life-safety performance level by 2032. In 2002, Oregon voters adopted ballot measures amending Oregon's constitution with Articles XI-M and XI-N, provisions that allow the state to issue General Obligation bonds for the purpose of seismic retrofits to existing schools and emergency response facilities. In 2005, a series of bills (Senate Bills 2, 3, 4, and 5) directed DOGAMI to organize and conduct the Statewide Seismic Needs Assessment, directed Oregon Emergency Management to establish a seismic rehabilitation grants program, and allowed the Department of Administrative Services and the State Treasurer to issue bonds to finance seismic rehabilitation.

In 2007, Senate Bill 1 provided funding to establish and staff the seismic rehabilitation grants program. The first opportunity to authorize a bond sale for an inaugural round of seismic retrofit grants came in the 2009-2011 biennium. The Legislative Assembly authorized $30 million for seismic grants, divided equally between the program for K-12 schools and the companion program for emergency response facilities. The first round of K-12 grants directed $5.6 million to projects at twelve schools in eight school districts in the spring of 2010. As the recession deepened, the Governor chose to rescind $7.5 million of the original authorization for the program, limiting additional granting during 2009-2011.

Three additional seismic grants were awarded to K-12 schools (including two URM buildings) in early 2011. These grants marked the end of the first funded cycle of the program.

On the final day of the 2011 legislative session, the Legislature authorized $7.5 million in new seismic grants for K-12 schools during the 2011-2013 biennium. These grants, announced in Fall 2011 and funded by a bond sale in July 2012, directed $7.2 million to seven K-12 schools. To date, the Seismic Rehabilitation Grants Program has funded retrofit projects at 22 schools, about 2 percent of the need documented by the Statewide Seismic Needs Assessment.

During the short 2012 session of the Legislative Assembly, legislators passed Senate Bill 1566. The bill directs the state's Department of Education (which communicates with parents about student achievement and school performance via an annual "report card") to include information on that annual report letting the public know that a database of seismic ratings exists and sharing a web link to the ratings. Further, the bill asks school districts to advise DOGAMI when they rebuild or renovate schools, so that the state can share information about the upgrades.[3] The first reports submitted by individual school districts are now posted on the DOGAMI website, although the agency has no funding to integrate information from the reports in an update of the statewide database itself.

Given the limited impact that existing policies have had on restoring resiliency in Oregon's schools, and the uneven success that Oregon school districts have had passing local capital bond measures for school rehabilitation and construction in recent years, an evaluation of Oregon's approach to characterizing and addressing the seismic vulnerability of school facilities is in order. Past outreach using the results of the Statewide Seismic Needs Assessment has emphasized the threat to life safety and the possibility of mass casualties in collapsed school buildings. By contrast, the gap analysis we have performed as part of this resiliency study focuses on quantifying the State's ability to resume public education after a region-wide CSZ earthquake, given what is known about the condition of the state's school facilities. The likelihood of disruption extending considerably beyond a full school year in the current condition, particularly in the Coast and Valley regions, due to anticipated damage to school facilities, will be a factor that could impede Oregon's economic and social recovery for years after the CSZ earthquake.

4.3.3 Healthcare Facilities

Introduction

There are 60, mostly privately-owned, healthcare facilities within the State of Oregon, with the majority of the buildings being over 40 years old. Each healthcare facility is comprised of either a single building or multiple buildings that form a campus. There are roughly 180 building structures within all of the 60 healthcare facilities that serve critical healthcare functions within each facility. There are additional buildings within each healthcare facility campus that have not been included in this study because they do not serve acute care needs and are not considered "essential".

In essential healthcare buildings, the most prevalent construction material is concrete with approximately 70% of concrete structures relying on concrete shear walls to resist lateral loads and the remaining relying on concrete moment frames. The second most prevalent construction material is steel with approximately an equal distribution using steel braced frames, steel moment frames, or concrete shear walls to resist lateral loads. Reinforced masonry and wood were seen more often in the smaller structures located in the Coast or Eastern zones.

The most notable structural lateral system vulnerabilities found within healthcare facilities are the non-ductile concrete and non-ductile steel frame buildings. These building structures were typically constructed before the increased seismic risk of in Oregon was well understood in the early 1990s, and before substantial code changes were made to require more robust connections that are better able to resist seismic forces.

Independent of the type of lateral system, there were two very notable structural irregularities found in many of the healthcare buildings that typically create problems. The first is a horizontal irregularity in the footprint of the building. Seismically, the most reliable shape for a floor plan of a building is a square or a rectangle. The least reliable shapes are "T", "E", "L" and "X" configurations or variations of these. Associated with these irregular shapes, many problems are seen at locations called "reentrant" or "interior" corners, which do not occur in a rectangular floor plan. The second notable structural irregularity is a vertical irregularity, which occurs when the building steps back in plan as the floor levels increase.

Historically, performance of healthcare facilities around the world has been extensively affected by nonstructural damage. The ability of a healthcare facility to function is greatly dependent on the nonstructural items within that facility. The building structure itself may perform very well during the "expected" earthquake, but the hospital might not be functional after the event due to nonstructural damage alone. Nonstructural vulnerabilities typically includes lack of proper anchorage of mechanical, electrical, and medical equipment and lack of proper bracing of ceilings, pipes, ductwork, electrical, medical gas such as oxygen, and other critical service lines. Healthcare facilities are often campuses made up of multiple buildings providing healthcare and often a "Central Utility Plant" (CUP) or a central building that contains a large number of pieces of essential equipment (boilers, air handling units, etc) that support the rest of the campus. Although this building may not provide healthcare directly, it is considered a vulnerability because damage to this building structure and its contents can have a great impact to the entire campus' utilities and ability to function.

Estimated State of Recovery

Currently, essential healthcare facilities in Oregon will not perform well during a CSZ seismic event. The facilities on the Coast and in the Valley will likely take over three years to recover to an operational state. Some facilities in Eastern Oregon will take approximately 30 days to recover to an operational state.

Target State of Recovery

Essential healthcare facilities are critical for the life safety of the population at large and must be capable of surviving the CSZ expected seismic event. This survival requires that the buildings must remain completely functional during the event and be available to respond to emergency needs immediately following the earthquake and any aftershocks that may occur. For these reasons, the Target State of Recovery for these facilities must be "Event Occurs" as shown in the Recovery Matrix.

Sector Specific Recommendations

Per the 2011 Oregon Revised Statutes (ORS 672.107), "significant structures" must be designed under direct supervision of a licensed Structural Engineer. Hospitals and other major medical facilities having surgery and emergency treatment areas are considered "significant structures" or "essential facilities" according to ORS 455.447. Standby power generating equipment for essential facilities is also considered "essential" and is covered under ORS 672.107. However, buildings containing the balance of equipment required to keep these vital facilities functional are not considered "essential", and therefore are typically designed to a lesser seismic standard. In order for critical healthcare facilities to be truly resilient, all buildings that provide mechanical, electrical, and plumbing service to the buildings must be designed to the same standard. This shift will require revisions to the building code and an expanded definition of "essential facility".

In 2001, legislation (ORS 455.400) directed that, subject to available funding, acute inpatient care facilities that are determined to pose an "undue risk to life" should be rehabilitated to a life-safety performance level by 2022. Currently, to our knowledge, most of the deficient acute care facilities in the State have not been upgraded in accordance with this legislation. By having the "subject to available funding clause" in the statute language, the legislation does not provide a mandate and therefore is not proving to be effective in addressing the problem. A more effective mandate should include specific measures that would incentivize private healthcare systems to make seismic improvements through tax credits or some other vehicle.

Facility buildings and internal infrastructure are not the only considerations for un-interrupted operation after the CSZ expected seismic event. Healthcare facilities are dependent on city water supply, distribution center buildings for supply availability, and roadways for supply delivery to name a few things. Healthcare facilities do not have control of any of these items. A minimum thirty day supply is recommended for all externally-dependent items, which would include water, fuel and medical supplies.

4.3.4 Emergency Sheltering

The need for shelter as an essential part of disaster recovery and resilience is great. There are many facilities throughout the State that are listed as designated emergency shelters by local jurisdictions and/or the Office of Emergency Management. The most common buildings on these lists are schools and churches, followed by other miscellaneous buildings with large occupant capacities, including community centers. The expected and target states of recovery for school buildings can be found in Section 4.3.2. As with all building sectors, the performance of churches and other facilities in a CSZ event will be a function of the building's vintage, construction type, and geographical location. In general, the expected and target states for churches should, at a minimum, match that of school facilities with similar construction.

Discussion of recommendations for buildings designated as emergency shelters can be found in Section 4.4.

4.3.5 Critical Government Facilities

Introduction

Critical government facilities would be those buildings necessary to provide continuing essential services following a significant event. The most obvious services—police stations, fire stations and emergency operations centers (EOC)—are addressed separately in this report. However, other services, which may include some limited administrative functions, essential health services, correctional facilities, and even maintenance buildings necessary for repairing roads and utilities following the earthquake are also necessary. Defining a specific listing of these services and their associated facilities was beyond the scope of this report—but in many ways obtaining a specific listing was not necessary to get a general overview of how these facilities may perform.

Estimated State of Recovery

Data for "General Government" facilities was available from the FEMA Hazus damage estimates, and was reviewed to determine the resilience scores included in the Resiliency Matrix. The statistical analysis from Hazus was based on an estimated total of 2,357 government buildings throughout the State, though not all are critical for resilience. We assumed that the non-critical buildings and remaining critical buildings (those not included in police, fire and EOC) will generally behave in a similar manner, so we were able to reasonably determine the level of performance that can be expected.

Construction types anticipated by Hazus statics are primarily steel and concrete prior to 1950, with about 20% of the inventory being shared between wood and unreinforced masonry (URM). These construction types change for construction periods between 1950 and 1970. The post-1970 distribution still anticipates concrete and steel, and some wood, but much more prevalent reinforced concrete masonry (CMU), which is now estimated to comprise about 25% of the building stock.

Target State of Recovery

The target state of recovery for these facilities will vary depending on the facility. An average target state was estimated to be 30 days, realizing that some buildings may need to be immediately serviceable (correctional institutions, for instance), while other critical functions may not be immediately needed and could wait several weeks before coming back into service. It will be necessary for the State and local governments to determine those functions critical for resilience, and then inventory and evaluate the associated facilities; eventually prioritizing and upgrading the deficient structures.

4.3.6 Residential Housing

Introduction

One of the basic elements needed for resilience is shelter. Following an earthquake, it is critical that people have shelter. In some cases, this may need to be provided by emergency shelters, either for people whose residences have been damaged and are not safe to occupy, or even for people who may be unable to reach their home. However, emergency shelters cannot provide for everyone. For a large segment of the population, their primary residence will serve as this shelter, though in many cases they will be without power and running water. Without residential shelters, the humanitarian needs following a large earthquake grow tremendously. Post-earthquake response can also be impeded if emergency responders have to first devote time to finding shelter and safety for their own families before they are available to help others.

In the State of Oregon, single-family residential homes make up the largest portion of residences, and therefore potential shelters. 2010 US Census data place the number of residential dwelling units in Oregon at approximately 1.6 million units. FEMA's Hazus program, which was used for this review, estimates that there are approximately 960,000 single-family homes, and is generally consistent with similar Census estimates.

Construction of single-family homes is almost entirely light wood framing. Historically, these buildings have generally performed relatively well in seismic events. One and two-story wood frame buildings are generally relatively light-weight compared to other structures, and will usually see larger forces from a design level wind storm than from a significant earthquake, since seismic forces are (in part) a function of the structure's weight.

However, the details of how wood frame structures are constructed have a lot to do with their ability to withstand earthquakes, and there are some common vulnerabilities in these structures that make them susceptible, particularly those built before 1976. One of the most common deficiencies is a lack of adequate anchorage between the upper wood frame structure and the concrete foundation or basement walls. Other common deficiencies include failure of cripple walls, which are short wood framed wall segments that typically extend from a foundation to the floor above, but frequently lack proper connections and can easily rotate similar to a hinge, allowing the building to shift laterally off of its foundation. In older structures, unreinforced masonry chimneys can fall and cause additional structural damage.

Estimated State of Recovery

Utilizing statistical data from FEMA's Hazus program, estimated damage data for single-family residences were reviewed. The average estimated recovery duration for residences on the Coast was less than 30 days, which may be low considering the intensity and duration of ground shaking that will likely result from a CSZ event in this area. In the Valley, the estimated recovery duration is 72 hours, which again may underestimate the damage. The Eastern zone had negligible damage based on the Hazus estimates. These results are compared with a target state of recovery of 72 hours based on the need for shelter as an essential part of disaster recovery and resilience.

Sector Specific Recommendations

Improving existing structures will require significant education for homeowners, who need to understand the risks, and potential costs, and steps necessary to evaluate and correct them. Additionally, common structural deficiencies should also be noted in home inspections at the time of purchase. It is likely that homeowners will bear the majority of the expenses for upgrading deficient structures. However, financial incentives such as tax credits and low interest loans might be considered to encourage improvements if future evaluations based on more complete data show unacceptable damage estimates.

Outreach should seek to provide education and resources for homeowners. A number of such tools are already available, though now widely known. FEMA provides a number of publication on their website for homeowners, such as FEMA-530 Earthquake Safety Guide for Homeowners. The City of Portland has also created a guide, Brochure #12-Residential Seismic Strengthening - Methods to Reduce Potential Earthquake Damage and provided additional information on the Bureau of Developments Services website at www.portlandoregon.gov/bds.

4.3.7 Community Retail Centers and Banks

Introduction

There are thousands of community retail centers and banks within the State of Oregon. These types of facilities have been deemed critical buildings because of their importance to the post-disaster recovery of communities throughout the state. The most important of the many community retail buildings in the State are the large supermarket and pharmacy chain stores that have large inventories of supplies that will be in high demand following a disaster. Many of these large chains have remote storage and distribution centers that will be of equal importance to supplying goods to damaged communities. Banks also have an important role in Oregon's seismic resiliency, as they will be critical to processing vital financial transactions for businesses and consumers as they recover from the disaster. Although many banks have emergency response plans in place, if the buildings they are housed in perform poorly during an earthquake, overall resiliency will be compromised.

FEMA's Hazus analysis includes a wide variety of commercial buildings, including some overlap with other structures evaluated separately in this report using different analysis methods. However, part of this large group of commercial buildings includes wholesale and retail buildings, and banks, which were reviewed to estimate the resilience of these structures. A specific estimate of building quantities for this subset was not available, but the statistical analysis considered their construction types, general age, and historical performance. The number of retail and bank buildings in each county was assumed to be proportional to the overall distribution of commercial buildings.

Structural Vulnerabilities

The construction types anticipated statistically by Hazus for retail buildings vary with the building age. Prior to 1950, wood, steel, concrete, concrete masonry (CMU), and even unreinforced masonry (URM) were common. As construction practices changed, buildings shifted toward larger stores and the post 1970 Hazus statistics reflect this with greater use of CMU and concrete, including precast (or tilt-up) construction which began seeing much wider use after 1970. Statistics for banking buildings also reflect some similar shifts in construction, moving away from steel and unreinforced masonry after 1950 and toward more wood frame, CMU, and concrete construction.

Today, most “big box” stores, supermarkets, distribution warehouses, and pharmacies are housed in concrete masonry (CMU) or tilt-up concrete structures with light-framed wood or steel roofs. Buildings of this type that were constructed prior to 1995 have historically not performed well in earthquakes. The seismic vulnerabilities of these buildings were highlighted in the aftermath of the 1994 Northridge earthquake. The most prominent structural failure in this building type has been the connection between the light framed roof and the relatively heavy exterior walls, which led to partial or full roof collapse. Building code provisions for the design and construction of the roof/wall connections were enhanced following the Northridge earthquake, with requirements for a higher degree of resistance being incorporated in the 1997 UBC and subsequent building codes. As a result, buildings of this type built after approximately1995 should have a higher degree of resiliency than those built prior.

Banks are different than “big box” stores in that they are housed in a multitude of structures including standalone one-story wood framed buildings, unreinforced masonry or non-ductile concrete buildings, and steel and concrete high rise buildings. The seismic performance of these buildings will vary based on their location, vintage, and construction type, however, structural vulnerabilities are present to some degree in a large percentage of the existing building stock.

Many existing community retail and bank structures can also be subject to extensive damage to non-structural elements and components within the buildings. Non-structural elements include, but are not limited to, mechanical, electrical, and plumbing systems and associated equipment, lighting fixtures, suspended ceiling and soffit systems, and unsecured storage racks and display shelving. These elements can be a falling hazard during a seismic event, impeding occupants from safely exiting the building, disrupting the operation of the facility, and extending the time it will take to restore the building to normal operation.

One unique aspect of retail and banking buildings is that they are almost exclusively privately owned. This makes establishing and enforcing building seismic upgrade requirements and/or mandates for these occupancies particularly difficult.

Estimated State of Recovery

The expected average time of recovery to normal operation for community retail “big box”, supermarket, and pharmacy buildings after a Cascadian Subduction Zone seismic event is 4 months and 30 days for Oregon Coastal and Oregon Valley regions, respectively. The recovery duration for this type of facility located in Eastern Oregon is expected to be nominal, mainly due to their distance from the earthquake source.

The recovery time for bank buildings after the CSZ seismic event is estimated at 60 days and 30 days for Oregon Coastal and Oregon Valley regions, respectively. Similar to that for community retail centers, the recovery duration for Eastern Oregon banks is expected to be nominal.

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A critical aspect to the resiliency of this building class is the degree to which their ancillary facilities that are not located within the high seismic hazard zone can provide support to and replacement of the functions of the damaged facilities. While this aspect was not considered in our analysis, it is possible that the actual impact of the CSZ event on the functionality of these buildings could be lessened if there are protocols in place to replace their functions remotely. Additionally, it should be noted that the ability to efficiently distribute goods, services and medical prescriptions to the general public has increased with the advent of "one-stop-shop" big box retailers that typically occupy newer tilt-up concrete or masonry (CMU) structures that have been designed and built to more stringent seismic code requirements. However, it is also likely that after the CSZ seismic event the inventory in these facilities will be quickly depleted, so overall seismic resiliency will depend upon the condition of ancillary facilities, including distribution warehouses, data centers, roads, bridges, and highways.

Target State of Recovery

The suggested statewide target state of recovery for community retail centers and banks is 30 days. This time frame is primarily due to the importance of having goods, services, and medical prescriptions available to the general public after a significant seismic event. The assumption behind this target is that facilities in areas unaffected by the earthquake will be able to fill the needs of the public remotely until the damaged buildings can be repaired. The target state is also consistent with the performance expectations behind code provisions for new buildings of this occupancy category as well as with the recommendations of the Business Continuity Task Group that is part of this resiliency study.

Sector Specific Recommendations

As community retail centers and banks are normally privately owned, the ability to mandate building upgrades with public funding is minimal. Therefore, it is most likely that seismic upgrades of deficient existing buildings will need to be incentivized through tax credits or similar means. Mandates, tax credits, and/or other means should also be developed to require and/or incentivize the building owners and tenants to properly brace and anchor deficient non-structural elements within their buildings, as it is anticipated that non-structural damage resulting from the CSZ seismic event will have a significant impact on the seismic resiliency of these building types.

For the existing building stock in this sector, the redundancy of critical business continuity elements such as distribution of goods and data, remote accessibility and support, and personnel availability should be assessed by each company. This redundancy is vital to achieving the 30 day target state of recovery over the entire state of Oregon.

Finally, improving the awareness of businesses and the general public of the seismic vulnerabilities of the existing community retail centers and banks is critical to moving toward a more resilient Oregon. Developing a Seismic Resiliency Rating for existing retail and bank building stock could serve as an effective tool for these businesses as they select buildings to lease or prioritize buildings for upgrades. As part of this rating program, common seismic vulnerabilities could be explained in layman's terms, in an effort to improve public awareness and understanding of Oregon's current seismic resiliency status.

4.3.8 Vulnerable Buildings

Introduction

For the purpose of this evaluation, vulnerable buildings are defined as unreinforced masonry (URM) and non-ductile concrete structures. These building types are classified as Critical Buildings in this study because they represent the most significant threat to life-safety and historically exhibit extremely poor performance in seismic events. URM buildings are constructed with clay brick, hollow clay tiles, or concrete block, with little or no reinforcement. Most of these buildings in Oregon were originally built prior to 1940, and the majority have not had seismic improvements made to them. Non-ductile concrete buildings have been historically susceptible to extreme damage in moderate to severe seismic events and have very little steel reinforcement. These buildings range in age from 40 to 100 years and are generally one to five stories in height. These "vulnerable buildings" represent a building "type" rather than an occupancy "use" and, as such, they can be found in many occupancy uses including essential facilities such as fire and police stations, but they can also be found in retail centers, restaurants, residential buildings and commercial office buildings.

Estimated State of Recovery

Based on the limited information available for these types of buildings throughout the State (that are not already addressed in the other occupancy use categories discussed above), recovery timelines were estimated based on FEMA Hazus data provided by the Oregon Department of Geology and Mineral Industries (DOGAMI). Categories included URM buildings only; specific data was not available for non-ductile concrete structures. Hazus software operates through a geographic information system (GIS) to display earthquake hazard information, inventory data, and estimated losses which approximate building damage from a particular seismic event. The Hazus data used for this study was based on a CSZ earthquake as well as the age and construction type of the buildings. In addition, the Hazus data assumes that all structures were designed prior to the incorporation of seismic provisions in the building code.

As expected, the data in Table 2 indicates that most of these buildings will experience significant structural damage, and partial or total collapse. Accordingly, most of the Vulnerable Building stock in the Coastal and Valley regions will require major repairs or wholesale replacement. Buildings in Eastern Oregon will experience ground shaking levels similar to or greater than those that URM buildings experienced during two previous Oregon earthquakes; Scott's Mills and Klamath Falls. However, the CSZ event will likely be of much longer duration and therefore has the potential for causing even more damage than these two previous events caused. For this reason, the expected recovery duration for Vulnerable buildings in Eastern Oregon was determined to be 30 days.

It should be noted that these recovery times are based on a CSZ earthquake event, which may not result in the highest ground shaking intensities in some Valley and Eastern regions, but would likely have a longer duration. Other hazards, such as soil liquefaction, landslides, and tsunamis, were considered in the projected states of recovery. DOGAMI's recent studies indicate that these soil hazards exist in all three State regions, and many Coastal regions are located in a tsunami inundation zone, thereby exacerbating the vulnerability of these buildings.

Because hard data related to non-structural components in Vulnerable Buildings was not readily available, the performance of these components was not a consideration in determining the recovery scores. However, it is likely that the damage to the primary structure of these buildings will override that of non-structural components in terms of effect on resiliency.

Target State of Recovery

As mentioned above, vulnerable buildings can be found in many different building occupancy uses. As such, the reader should reference the Target State of Recovery discussions in the occupancy-based sections of this Critical Buildings report to develop an understanding of the gap between projected and recommended performance of these buildings.

Codes, Past Legislation, and Funding Sources

A few jurisdictions have adopted code language mandating seismic upgrades for these types of buildings (primarily URM) to varying degrees. For legislation, or funding sources, refer to each sector-specific section of this report, and the recommendations in section 4.4.

4.4 Conclusions and Recommendations

Recommendations are provided below for Oregon's critical and vulnerable structures with the goal of achieving a resilient State.

In making these recommendations, it is recognized that not all buildings are critical and necessary to achieve resilience. Many buildings are anticipated to perform reasonably close to their target states in the Eastern portion of the State where the seismic design category is low. Residential buildings are anticipated to perform reasonably well and mandatory requirements for homeowners would be particularly onerous. Additionally, Oregon does not have jurisdiction over all structures within its borders.
Therefore, these recommendations should not apply to the following buildings, which should be exempt[4]:

- One and two-family dwellings, and their accessory structures.
- Agricultural buildings as defined in the building code.
- Buildings located on property that is exempt from regulation by the State building code, such as Federal land.
- Buildings in a low seismic hazard area, defined as Seismic Design Category A and B

Additionally, a timeline[5] should be developed for adopting standards and policies, evaluating and inventorying buildings, and rehabilitating structures. The development of the timeline for building towards seismic resiliency should be a priority- based effort considering the gaps between existing and target states of recovery and critical building functions.

As a word of caution, however, implementation and funding for seismic resilience should not wait for a full inventory, definition, and budgeting of the problem. More than enough is already known to begin making strides toward resilience. Whether the journey is a thousand miles or ten thousand miles shouldn't keep us from starting now. Rather, additional inventories and studies should be made as we progress along the way.

Immediate Actions

1. **Establish a State Office of the Structural Engineer**

   Finding: Currently the State has few structural resources (outside of ODOT) for addressing the many and varied structural needs and leadership necessary to achieve seismic resilience. DOGAMI and others have done an excellent job of defining the seismic problem. However, there is not a lead agency to tackle the solution.

   Recommended: It is recommended that a lead office, whose primary mission is seismic/structural resilience, be established. Ideally, this office would stand alone.

   Duties of this agency would include:
   a. Serve as the lead agency for implementing and coordinating statewide seismic/structural resilience policy.
   b. Advocacy and education for structural safety (buildings, towers, tanks, non-structural components, etc.)
   c. Assist other State agencies in evaluation and decision making for structural needs and upgrade requirements for State-owned structures (i.e., Owner's representative).
   d. Assist State and local communities in developing structural policies for new and existing structures.
   e. Provide plan review for jurisdictions that do not have structural engineering staff.
   f. Act as a liaison and advocate bringing together various regulatory agencies to streamline permitting and approval for seismic rehabilitation projects.
   g. Administer structural research grants and programs to Universities and Colleges in Oregon, particularly emphasizing seismic research.
   h. Develop and implement administrative rules for notification and enforcement of structural rehabilitation mandates and triggers (SRTF pg 26).
   i. Develop evaluation standards (SRTF pg 21, 22 and Appendix F)
   j. Serve as a structural engineering resource for emergency managers and planners.
   k. Maintain a database of ATC-20 trained structural engineering emergency responders.

2. **Education:**

   Finding: A broad education and understanding of the risks associated with seismic related hazards by all members of our society is needed to achieve a truly resilient Oregon. Each person can participate in achieving this goal if they have the knowledge and tools.

   Recommended: Public education regarding earthquake risk, preparedness, and response should be widespread and at the forefront of the resilience effort.

   a. Public Awareness and Public Relations
      i. Oregon seismicity
      ii. Earthquake preparedness
      iii. Earthquake response
      iv. Resources available
      v. Updates on efforts and progress

b. Education in Schools

c. Contractor Education
Institute broad contractor education for seismic construction. Experience has shown that while many contractors understand gravity loads and the basic framing requirements necessary to support them, they often do not have the same understanding of lateral seismic loads. This basic lack of understanding leads to many errors in the lateral system construction that would likely be minimized with a greater understanding of the systems being constructed.
   i. Concept-based seismic courses should be offered at community colleges, and be incorporated into continuing education requirements for contractors.

d. Education for Business, Facility and Property Managers
   i. Mitigating non-structural risks
   ii. Preparedness and response
   iii. Operational resilience plans

3. Building Inventory:

Finding: A complete statewide inventory of critical buildings serving the public does not exist. This inventory is necessary to fully understand the scope of the problem, to establish a baseline against which progress can be measured, and to indentify buildings requiring mandatory corrective actions.

Recommended: A statewide inventory of all nonexempt buildings not previously inventoried and covered by these recommendations should be conducted and completed within five years. An inventory has already been completed of hospitals, public schools, community colleges, police and fire stations and emergency operations centers.

   i. Initial screening based on the FEMA 154 methodology should be completed by registered Structural Engineers.
      a. Facilities designated as Emergency Shelters.
      b. Critical government facilities
      c. Community retail centers providing for essential needs
         - Grocery stores over 5,000 square feet
         - Pharmacies providing prescription medications
      d. Banks
      e. Vulnerable buildings
      f. Residential housing with more than 4 attached units. An inventory and assessment of single-family housing should not be required.

   ii. Buildings previously screened in the 2007 DOGAMI SSNA should be updated based on engineering reviews, and new buildings for the types screened should be added for completeness.

   iii. For buildings with a FEMA 154 RVS score of 2.0 or less in existing or future inventories, a Tier I ASCE-31 evaluation should be completed.

4. **Emergency Response:**

Finding: A critical component of seismic resiliency is the ability of first responders and building assessment volunteers to go to work immediately after the seismic event occurs. While police and fire officials have established procedures for responding to emergencies, we believe that the plan for contacting, dispatching, and otherwise managing the building assessment volunteers post-event may require some improvement.

Recommended:

a. An up-to-date, comprehensive database of ATC 20 certified inspectors needs to be assembled through efforts of BCD and other building jurisdictions. Enhancement of this roster could be done through SEAO offering ATC 20 training sessions yearly.

b. Protocol and procedures need to be established and disseminated to all volunteers in the database so that they know what do, where to report, etc. post event.

c. Good Samaritan laws should be strengthened to protect volunteers from liability.

<u>Sustained Actions</u>

5. Essential Facilities:

A. **Hospitals:**[6]

Finding: Hospitals as defined by the State Building Code as Occupancy Group I, Division 1, containing surgery or emergency treatment facilities are essential for responding to a natural disaster. They must be able to receive and care for patients immediately after a disaster occurs. However, the average estimated current state of recovery for these facilities is woefully short of this goal. In 2001, the Legislative Assembly directed (ORS 455.400) that acute inpatient care facilities, and fire department, fire district and law enforcement agency buildings “found to pose an undue risk to life safety during a seismic event” should be mitigated, subject to availability of funding, with “seismic rehabilitations or other actions to reduce seismic risk” before January 1, 2022. To date, little progress has been made toward this goal.

Recommended:

a. An inventory and seismic evaluation of these buildings should be completed within three years of adoption of inventory requirements. Seismic evaluations should also include a thorough evaluation of all nonstructural components of the buildings, and include critical support facilities such as power plants and data centers necessary for the continued operation of the hospital. The inventory and evaluation should be filed with the State Structural Engineer (see below).

b. The necessary seismic rehabilitation should then be completed within 15 years of the date the inventory and evaluations are filed. ORS 455.400 should be strengthened to incentivize building owners and to ensure that timelines for strengthening are met.

B. **Emergency Operations Centers, Fire and Police Stations:**[7]

Finding: Emergency Operations Centers and Fire and Police Stations are also essential for responding to a natural disaster and must be able to respond immediately. The average estimated current state of recovery for these structures is far short of this goal. URM and non-ductile concrete structures are typically the most severely deficient and usually have the highest upgrade priority.

Recommended:

a. Essential facilities constructed of URM or non-ductile concrete, including fire and police stations and emergency operations centers should be evaluated and rehabilitated within 20 years. Roof-to-wall connections, diaphragms and parapets should be upgraded within 10 years.

b. For facilities that are not constructed of URM or non-ductile concrete, a seismic evaluation should be performed within three years of adoption of these recommendations. Seismic rehabilitation should be completed within 30 years.

c. Update ORS 455.400 to be consistent with the recommendations in this report.

C. **Nonstructural Elements of Essential and Hazardous Facilities:** [8]

Finding: Historically many critical buildings have been rendered unserviceable following a seismic event because of non-structural elements that failed. Things such as ceilings that have fallen, generators that are damaged, broken gas lines that precipitate fire, etc. can make a building that otherwise may have survived the earthquake unusable.

Recommended: These items should be properly braced and anchored for seismic loads. Such nonstructural items include, but are not limited to, electrical transformers, switchgear, motor control centers, generators, and life-safety electrical, plumbing, and mechanical systems, fire suppression systems, and suspended ceilings and soffits. For hospitals, medical gas lines are also part of critical services. In hazardous facilities, nonstructural items such as pipes, tanks, and storage cabinets that contain hazardous or toxic chemicals should be properly braced and anchored for seismic loads. Rules to implement the requirements to properly brace and anchor elements should be developed.

6. **K-12 Schools:**

Finding: Public schools in Oregon, owned by 197 independent school districts and overseen by elected local school boards, comprise a special category of public infrastructure. In the Coastal and Valley regions the current average estimated state of recovery for these structures falls significantly short of the recommended target state. In 2001, the Legislative Assembly directed (ORS 455.400) that school buildings “found by a board to pose an undue risk to life safety during a seismic event” should be mitigated, subject to availability of funding, with “seismic rehabilitations or other actions to reduce seismic risk” before January 1, 2032. To date, little progress has been made toward this goal.

Recommended: The following recommendations relate to K-12 public schools; the same recommendations may be adapted for Oregon's community college and higher education buildings.

a. Expand Oregon's Seismic Rehabilitation Grant Program, which currently provides limited grant funding for retrofits to K-12 public schools and community colleges. Also, recognize and allow grants for replacement of schools located in the tsunami inundation zone, where moving the school is the most economical way to achieve seismic safety and resilience.

b. Prioritize the replacement of all unreinforced masonry (URM) school facilities in Coast and Valley school districts.

c. Require large school districts (with more than 2,500 students) to complete and publish ASCE 31 (or equivalent) assessment of school facilities when they update school facility plans in compliance with ORS 195.110. The ASCE 31 (or equivalent) assessments shall include non-structural components; in cases where previous ASCE 31 assessments have not included non-structural components, those ASCE 31 assessments shall be amended to include them.

d. Compile and publish full updates of the statewide seismic assessment of public school facilities each biennium. Assign this task to a new State Office of the Structural Engineer or to an appropriate office in the Oregon Department of Education, in consultation with DOGAMI. Prepare a statewide plan to organize and resume public education after a region-wide disaster.

7. **More Comprehensive Passive Trigger Seismic Strengthening Program:**[9]

Finding: Achieving a resilient Oregon requires that not only critical buildings be upgraded, but that businesses and other functions necessary to the economy and society also be resilient. However, mandates can too often place undue burdens and should be limited whenever possible. Yet, many existing structures are often significantly renovated, adding many years of life to buildings already beyond their intended service, without making improvements to the safety of the structure.

Recommended: All commercial nonexempt buildings should be subject to additional "passive triggers" as a means of balancing seismic upgrades with other needs and improvements. Passive triggers are actions within the control of the owner that "trigger" a need to do a seismic rehabilitation.

a. Code currently requires that a structure, or affected portion of a structure, be upgraded to meet current code provisions in the following circumstances:
   i. A change in the building occupancy; or
   ii. Alterations to the building that significantly increase gravity or lateral loads on the structure.

b. Additional triggers are recommended that include the following considerations. Specific rules will need to be developed, possibly by a taskforce, and may consider incorporating some portions of the City of Portland's Chapter 24.85, October 21, 2004, where appropriate.

i. Changes in use that increase the occupant load beyond a reasonable threshold, rather than just an occupancy change, should require an upgrade.

ii. Major renovations that are substantial relative to the market value of the building as reflected in the most recent property tax statement should require seismic upgrade for buildings built before 1995. A threshold (cost per square foot) should be provided for small projects without requiring upgrade, but a full upgrade should be required if the project is substantial. A percentage of the project budget should be required for seismic upgrade between these two extremes. Dollar thresholds should be adjusted annually based on inflation.

iii. Upgrade of the roof diaphragm and/or anchorage of the structural walls to the roof should be required if more than 50% of a building's roof is replaced for the following structure types:
   - URM and non-ductile concrete buildings: Upgrade roof diaphragm and wall anchorage.
   - Concrete tilt-up and reinforced masonry buildings built before 1998: Upgrade wall anchorage.
   - Concrete tilt-up and reinforced masonry buildings with straight sheathed diaphragms: Upgrade roof diaphragm and wall anchorage.

c. Seismic upgrades should receive the highest priority for non-conforming upgrades, except where federal law may control.

d. Seismic upgrades should not trigger requirements for other non-conforming upgrades.

e. The cost and implementation of triggered seismic upgrades should be allowed to be completed in a 10 year window, with any such agreements and requirements being recorded with the property.

8. Vulnerable Buildings:

A. **Unreinforced Masonry Buildings (URM) & Non-ductile Concrete Buildings**:

Finding: As a building class, unreinforced masonry buildings represent the most significant threat to life-safety in a seismic event. Non-ductile concrete buildings also possess a similar level of hazard to life safety. URM buildings typically have no, or very little, steel reinforcing and are typically constructed from clay brick, hollow clay tiles, unfired clay adobe, stone, or concrete block. Non-ductile concrete buildings also possess very little reinforcing, typically not enough to safely resist the loads created by moderate to severe seismic ground motions.

Recommended: Within 30 years, all URM and non-ductile concrete buildings should be upgraded to a minimum standard commensurate with the building occupancy (life-safety minimum), through either mandated or passive triggers, or removed from service and demolished. URM buildings pose a significant threat to life safety and should not be allowed to remain in service indefinitely. They also pose a falling hazard to people outside the building during an earthquake and should not be allowed to remain, even if unoccupied. Requirements for URM Essential

Facilities are addressed in a separate recommendation.

B. **URM and Unreinforced Concrete Parapets, Roof Diaphragms, Signage and Appendages**: [10]

Finding: Parapets, signage, and other building appendages (except for building cornices) pose a threat to the public near buildings and to occupants exiting a building during an earthquake.

Recommended: These elements should be evaluated and rehabilitated by building owners within 15 years of notification after the inventory or, in the case of parapets, when the buildings are being re-roofed, whichever comes sooner. Roof diaphragms and roof-to-wall connections should also be strengthened within this time frame.

C. Disclosure of URM and Non-ductile Concrete Building's Seismic Resistance:

Finding: URM and non-ductile concrete buildings pose a significant hazard to life and safety in a seismic event. However, these risks are rarely disclosed and few people fully understand them. This is in contrast to myriad of potential risks in other industries that either requires a full discloser of the risks, or outright mitigation.

Recommended: Consumers should be made aware of the risks associated with Vulnerable Buildings.

a. An earthquake safety disclosure statement should be provided to new buyers, lessees, and renters for all URM and non-ductile concrete buildings in moderate and high seismic regions (Seismic Design Category 'C' and higher). It should include <u>one</u> of the following:

   i. Default statement prepared by the State indicating the building is a URM building and describing the risks and anticipated seismic performance of these building types historically.

   ii. Results of a seismic investigation of the building and anticipated building performance prepared by a licensed Professional Engineer.

   iii. Earthquake Performance Rating in accordance with a generally accepted rating system as prepared by a licensed Professional Engineer. A statement of the rating's meaning should accompany the statement. (This rating system does not currently exist, but should be implemented. See below.)

b. The disclosure statement should also list all mandates and triggers for the building in effect at the time of closing.

D. **Historic buildings**:

Finding: Buildings placed on the Historic Register are subject to preservation requirements that limit what can be done to the building. Often this can make seismic rehabilitation very difficult and costly. Further, many of these buildings are unreinforced masonry (URM). Owners should be aware of the seismic requirements and deficiencies in these structures before placing them on the register.

Recommended: Require owners provide a preliminary seismic rehabilitation plan prepared by a licensed Professional Engineer as part of their application for inclusion in the historic registry.

E. Limitation of Liability:[11]

Finding: Today's understanding of Oregon's seismicity and the risks it poses were not understood decades ago when much of our current infrastructure was built. However, this growing knowledge has potential for tremendous liability that will take decades to mitigate.

Recommended: To provide incentive for compliance with adopted mitigation measures and temper the potential for a growing liability, building owners, municipalities and state agencies, and structural engineers adhering to the adopted seismic rehabilitation program and timelines should be protected from liability.

9. **Improved Plan Review and Construction Oversight**

A. ***Plan Review:***
Finding: Currently, in many jurisdictions structural plan reviews are not being performed by licensed Design Professionals, including significant and essential structures which are required to be stamped by a licensed Structural Engineer under ORS 672.107.

Recommended: A licensed Design Professional or Structural Engineer should be required to review buildings as a part of the plans review process, reciprocal with the licensing required to provide the design.

B. **Special Inspections and Structural Observations:**

a. Expand code requirements for structural observation to include most Occupancy Category II structures.

b. Increase code requirements for special inspection of non-structural components.

c. Expand special inspections to include critical connections in the roof-to-wall and floor-to-wall anchorage of tilt-up and CMU buildings with light-framed floors and roofs.

10. **Earthquake Performance Rating System:**[12]

Finding: Achieving resilience requires a broad and varied approach. Mandates are appropriate in some circumstances, but ideally resilience should grow from a knowledgeable and educated marketplace. Examples of similar systems already in use include LEED ratings for green buildings and BOMA building class definitions.

Recommended: Encourage and promote through educational efforts and professional organizations the use of a standardized rating system for the expected earthquake performance of buildings. A voluntary system with wide recognition and implementation should communicate seismic risk objectively to non-engineers. The ultimate goal of the system should be to increase awareness of seismic risk and encourage action that will reduce the overall risk of the building inventory. Anyone who makes decisions about buildings, regardless of their earthquake or engineering expertise, could be a potential audience, including occupants, buyers, sellers, and tenants, as wells as insurers and lenders.

A. An Earthquake Performance Rating System has been proposed by the Structural Engineers Association of Northern California, and bears consideration. This system uses a star rating system, giving buildings 1 to 5 possible stars considering three dimensions: Safety, Repair Cost and Time to Regain Function.

B. The system should estimate performance on an absolute scale, as opposed to rating buildings relative to a standard such as the current building code.

C. The earthquake performance rating should apply to all building types and occupancies, including residential structures. It should also be applicable to new and existing buildings alike.

11. **Performance Based Design:**

Finding: One of the best ways to achieve a resilient Oregon is through improved standards for new construction and better conformance to existing standards. Over the next 50 years, many of the existing buildings will need to be replaced, and many new structures will be added.

Recommended: A balanced approach should be adopted which encourages construction of more resilient structures without increasing construction costs beyond what is economically viable. Incentives to design new buildings to a higher performance standard should be promoted to encourage building owners to consider a higher seismic design standard than the minimum level of life safety required by the building code. SPUR[13] has suggested several possible incentives:

i. Density bonuses from planning/zoning
ii. Tax abatement for high performance buildings
iii. Reduction in insurance costs
iv. Deferred payment of permitting and system development fees.

B. *Finding:* Current methods for performance based design are often difficult to use and implement. These methods can be sensitive to input variables, and at times are very subjective. Further, many design professionals are often not aware of the impacts that building forms and configurations have on performance, and are therefore reluctant to incorporate principles of resilient design. Recommended: Research and education should be funded to provide better design information and tools for performance based design.

Recommended:

i. Through research and consensus, tools should be further developed for engineering performance based design.
ii. Education regarding the principles of performance based design should be made widely available to the larger design and construction community.

12. **New and Existing Building Sites:**

Finding: Geologic hazards, including landslides, liquefaction, lateral spreading and tsunami inundation are a significant cause of building damage in earthquakes, but are often unknown or not properly mitigated.

Recommended: Current laws restricting certain essential and critical facilities on these sites should be expanded to include evaluation and mitigation for all new construction on building sites with geologic hazards. Hazards on existing sites should be disclosed at the time of sale, and the hazard information made readily accessible through a centralized website.

A. New Building Sites
In addition to those requirements currently mandated in ORS 455.446 and 447 and ORS 195.260, criteria should be developed to require a geotechnical investigation for all nonexempt structures contemplated to be built in a tsunami inundation zone or in a liquefaction or landslide-prone area.
    i. Where it has been determined that a geotechnical hazard exists, foundation mitigation measures should be developed.

B. Existing Building Sites
Known geologic hazards should be disclosed at the time of building or property sale. To facilitate this, a statewide website should be established to provide a simple, single source of information for landslide, liquefaction, lateral spreading and tsunami inundation zones.

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[1] Western States Seismic Policy Council (WSSPC). 2010. "Identification and Potential Mitigation of Seismically Vulnerable School Buildings," Policy Recommendation 10-8. Broomfield, Colo.: WSSPC Annual Business Meeting.

[2] Lewis, Don. 2007. *Statewide Seismic Needs Assessment: Implementation of Oregon 2005 Senate Bill 2 Relating to Public Safety, Earthquakes, and Seismic Rehabilitation of Public Buildings* (Open File Report 07-020). Portland, Ore.: Department of Geology and Mineral Industries (DOGAMI). Online: http://www.oregongeology.org/sub/projects/rvs/default.htmhttp://www.oregongeology.org/sub/projects/rvs/default.htm

[3] Oregon Legislative Assembly. 2012. Senate Bill 1566. Relating to Seismic Information about Schools. Sponsored by Sen. Peter Courtney. Online: http://www.leg.state.or.us/12reg/measures/sb1500.dir/sb1566.en.htmlhttp://www.leg.state.or.us/12reg/measures/sb1500.dir/sb1566.en.html

[4] Seismic Rehabilitation Task Force created by Senate Bill 1057, "Seismic Rehabilitation of Existing Buildings in Oregon", Report to the Sixty-Ninth Oregon Legislative Assembly, September 30, 1996, p.13 item B
[5] ibid. p.38 item C, and Appendix E
[6] ibid. p.17 item D.3
[7] ibid. p.15 item D.2
[8] ibid. p.22
[9] ibid. p.19 item E
[10] ibid. p.15 item D.1
[11] ibid. p.25 item I

[12] SEAONC, "Rating System for the Expected Earthquake Performance of Buildings", 2011 SEAOC Convention Proceedings