EARTHQUAKE RISK-REDUCTION PROSPECTS FOR THE PUGET SOUND AND PORTLAND, OREGON, AREAS

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ABSTRACT

This chapter addresses current efforts and future prospects for earthquake risk reduction among major cities and counties within the the Puget Sound and Portland, Oregon, areas. There is a clear distinction among leading and lagging jurisdictions within the region with respect to existing and future efforts for earthquake risk reduction. The differences result not only from different risk profiles, but also from differing political and economic circumstances. The understanding of differing situations leads to four State- or regional-level risk-reduction strategies that might be undertaken as new information about seismic risk is produced. These strategies range from relatively passive hazards-information dissemination to more active efforts to seek policy reforms or to influence design practices.

INTRODUCTION

One of the important lessons of the U.S. Geological Survey's hazard-assessment program in Utah and California is that simply providing technical information about earthquake risks will not stimulate changes in local practices or policies. The design of State- or regional-level risk-reduction strategies requires identification of key features of the political and economic environment that are likely to shape future opportunities for and obstacles to local risk reduction. This chapter develops such an understanding for major cities and counties in the Puget Sound and Portland, Oreg., areas. It is important to remember that the scientific study of seismic risk in the Puget Sound–Portland region is still underway. This chapter also suggests how risk-reduction efforts might be altered as more is learned about the extent of seismic hazards and the risks they pose.

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JURISDICTIONS STUDIED

Thirteen counties within the Puget Sound area (Clark, Cowlitz, Grays Harbor, Island, King, Kitsap, Jefferson, Mason, Pierce, Skagit, Snohomish, Thurston, and Whatcom) and 6 counties within the Willamette Valley area (Clackamas, Marion, Multnomah, Polk, Washington, and Yamhill) were selected for this study. There are 43 cities of more than 10,000 population within these 19 counties (table 43), which are referred to as a single region in the following discussion.

Table 43. Oregon and Washington cities studied for this report.

Oregon	Washington	
Beaverton	Aberdeen	Mercer Island
Forest Grove	Anacortes	Mount Vernon
Gresham	Auburn	Mountlake Terrace
Hillsboro	Bellevue	Oak Harbor
Keizer	Bellingham	Olympia
Lake Oswego	Bothell	Puyallup
McMinnville	Bremerton	Redmond
Milwaukie	Des Moines	Renton
Newberg	Edmonds	Seattle
Oregon City	Everett	Tacoma
Portland	Kelso	Vancouver
Salem	Kent	
Tigard	Kirkland	
Tualatin	Lacey	
West Linn	Longview	
Woodburn	Lynnwood	

Within the 19-county region are 97 incorporated cities, more than 200 school districts, more than 200 special districts, and 22 port districts. The special districts consist of separately governed entities such as water and sewer districts, public utility districts, drainage districts, road districts, soil-conservation districts, and metropolitan councils of government. Within many of these cities and other local jurisdictions are multiple agencies with responsibility and overlapping authority for addressing public safety. Earthquake-risk-reduction efforts in this region include more than 500 jurisdictions and 4.7 million people as of 1987.

The potential vulnerability of this region to earthquake damage is indicated by statistics about the region. In 1988, the total value of all property in the region was estimated to be $180 billion. The value of new construction of apartment, office, commercial, and industrial buildings in 1987 was reported by the U.S. Census Bureau to be nearly $1.5 billion. This amount is an almost-50-percent increase since 1980. Because many newcomers, some who have left earthquake-prone areas of California, are moving to the region, the population and assessed property values will certainly grow over the coming decade.

The region's counties, utilities, port districts, and 43 largest cities were chosen for inclusion in the study because they have the greatest populations and property values. Within the 13 Washington counties studied are 27 cities of more than 10,000 population, including Bellingham, Bellevue, Everett, Olympia, Seattle, Tacoma, and Vancouver. Some 3.3 million people lived in these 13 counties as of 1987. Within the six Oregon counties studied are 16 major cities, including Beaverton, Gresham, Portland, and Salem, having a 1987 combined population of 1.4 million.

The study is based on interviews with 177 persons, conducted over a period of 6 months, beginning in September 1988. The following were interviewed:

- Those directly responsible for land-use and building regulation in the 43 cities and 19 counties
- Public-works or other utility personnel responsible for water and sewer functions for municipal systems in 41 of the cities
- Engineering directors of six of the larger port districts (Bellingham, Everett, Olympia, Portland, Salem, and Tacoma)

The interviews of personnel in cities and counties entailed talking with the planning director and the chief building official (or an individual they designated). The study's focus on risk reduction rather than response to seismic events led to the decision to exclude emergency-services personnel except in a few jurisdictions where such personnel had broader responsibilities. In many jurisdictions, personnel with public safety responsibilities in the office of the mayor, city manager, or county administrator were also interviewed. Additional interviews were conducted with State officials in State-level building-regulation and land-use agencies. In-person interviews lasting 30 minutes to 1 hour were conducted with officials at the State level and within the larger jurisdictions. The remaining interviews were by telephone.

The interviews were used to develop profiles of the earthquake-related policies and practices of the cities and counties and to develop the information that follows. Draft profiles were shared with key officials in each jurisdiction and were revised to correct factual errors.

DIFFERING RISK PERCEPTIONS

One aspect of the study characterized different risk perceptions within the jurisdictions. One set of questions addressed elected officials' perception of the likelihood of significant property damage, deaths, or injuries from an earthquake in the next 20–30 years.[2] Another set of questions was addressed to building officials and engineering directors to obtain their perceptions of the vulnerability to a major earthquake of the building stock or facilities within their jurisdictions.

RISK PERCEPTIONS OF ELECTED OFFICIALS

Information about risk perceptions of elected officials helps to depict the broad political context of earthquake risk reduction. The study results show a general awareness of seismic risks in the region, with a somewhat greater awareness by local officials in Washington. Some respondents reported reading in local newspapers about the U.S. Geological Survey research on seismic risk, commented about media reports of earthquake swarms, or recalled the 1965 or 1949 earthquakes. On the other hand, some respondents seemed to discount the risk. Whatever the risk perception, earthquake hazards appeared to be of relatively little concern to elected officials, because of other, more pressing concerns.

These results are consistent with similar investigations in other areas of moderate to high seismic risk, including California (for example, Berke and Wilhite, 1988; Drabek and others, 1983; Mushkatel and Nigg, 1987). Earthquake risk falls at the less dreaded and more accepted ends of the spectrum of attention to various risks by politicians and the general public.

The profile of responses by elected officials (fig. 234) suggests a general awareness of the potential for a moderate

[2]The responses for elected officials were based on asking an appropriate administrative-level employee in each jurisdiction: "On a scale of 0 to 100, how likely do you think most officials in this jurisdiction think the chances are in the next 20 to 30 years of significant property damage, injuries, or loss of life are from each of the following***"

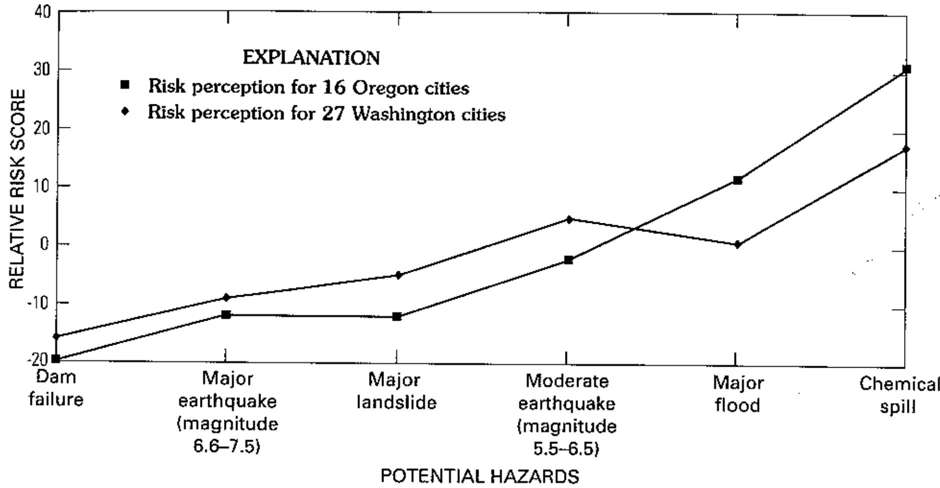

Figure 234. Hazard-risk perceptions of elected officials of Oregon and Washington cities in the study area. Relative risk scores are deviations from mean rating of risks posed by the combined hazards.

earthquake and a lesser sense of the potential for a major earthquake.[3] Because the absolute risks posed by these hazards are unknown, it is more appropriate to refer to relative comparisons of risks as represented by deviation scores.[4] In addition, the tendency for some respondents to rate all risks very highly and other respondents to rate all risks less high is accommodated by using relative scores.

Chemical spills are considered by elected officials to be the greatest risk (fig. 234). Moderate earthquakes were rated the second greatest risk by Washington city officials and the third greatest risk by Oregon city officials. Major earthquakes are considered less significant risks than major landslides but more significant than dam failures. Although major earthquakes are presumed to be more damaging than moderate earthquakes, elected officials appeared to discount the likelihood that major earthquakes will occur and thus rated them a lesser risk.

The results for county elected officials (not shown) are somewhat different than those for city officials. For both Oregon and Washington counties, flooding is considered to be the greatest risk, followed in decreasing order by chemical spills, landslides, moderate earthquakes, major earthquakes, and dam failures.

These results for elected officials suggest an awareness level that corresponds to some degree with the way in which seismic risks have been characterized in this region in the past. Earthquake risks are perceived to be lower in Oregon than in Washington. Yet, officials in both Oregon and Washington discount the potential for significant damage or loss of life, whereas earthquake engineers have said that even moderate events in this region can be very damaging.

In both States, moderate earthquakes were perceived to be more probable than major earthquakes. On the absolute rating scale (0 to 100), the mean rating by Oregon city officials for the likelihood of significant effects of a moderate earthquake is 28 and of a major earthquake is 18. The corresponding figures for Washington city officials are 48 and 34. Earthquake risks were generally perceived by county officials to be lower. On the same rating scale, the mean likelihood rating by Oregon county officials for significant effects of a moderate earthquake is 29 and of a major earthquake is 14. The corresponding figures for Washington county officials are 31 and 15.

DAMAGE PERCEPTIONS OF BUILDING OFFICIALS

Perhaps more important barometers for future risk-reduction efforts are the perceptions of building officials. This study attempted to learn these views in two ways. First, building officials were asked about potential earthquake-vulnerable classes of buildings in each jurisdiction. Because none of the jurisdictions maintain building inventories, the responses only reflect officials' impressions of vulnerability. Second, building officials and engineering directors were asked to assess the impacts of various earthquakes upon the building stock (or facilities) within their jurisdiction.

Three classes of buildings were considered to be potentially vulnerable: (1) unreinforced masonry buildings; (2)

[3]A "moderate" earthquake was defined as Richter magnitude 5.5–6.5 and a "major" earthquake as Richter magnitude 6.6–7.5. Duration, depth, and location were not specified. Most respondents seemed to understand the labels "moderate" and "major" better than information about potential magnitude of an event. "Great" earthquakes (greater than magnitude 7.5) were not addressed.

[4]Deviation scores were calculated for each respondent by subtracting the average rating of all hazards for that respondent from the respondent's ratings for each hazard.

tilt-up concrete buildings built before 1975, typically used as warehouses, as light-industrial facilities, or for other similar purposes; and (3) reinforced-concrete frame buildings built before the early 1960's, typically 3–10 stories, used as office buildings, schools, or apartments. Unreinforced masonry buildings (table 44) appear to pose the most widespread existing risk in the region's cities. Tilt-up concrete buildings built before the mid-1970's are about equally prevalent among cities in the two States. Reinforced-concrete frame buildings are more common in Washington cities than in Oregon cities. Unincorporated areas of counties are somewhat less at risk. Most unincorporated county areas are rural or suburban and have mainly single-family homes and newer commercial buildings. The most common hazardous-building type, reported to be "somewhat common" or "very common" in one-third of the counties, is tilt-up concrete buildings built before 1975.

To understand the risks that potentially hazardous buildings pose, building officials were asked to think about the damage that might follow from various earthquakes.[5] Because respondents were asked to assess damage as a result of a particular earthquake, their responses do not entail judgments about likelihood of an earthquake. Both lack of specific information about the location and duration of the seismic events and the difficulty that they had in envisioning the degree of damage that might follow constrained their responses.

City building officials perceived that the greatest potential for damage would be from major earthquakes, followed, in order, by moderate earthquakes, major flooding, and major landslides (fig. 235). On the absolute rating scale (0 to 100), the mean of responses by city building officials in Washington of the likelihood of significant damage from a major earthquake in the region was 46 (range from 10 to 90). The mean of responses for a moderate earthquake was 27 (range from 0 to 75). The corresponding mean for Oregon cities for a major earthquake was 44 (range from 15 to 85), and for a moderate earthquake event the mean was 21 (range from 5 to 60). County building officials in Washington and Oregon had similar damage perceptions.

The building officials' perception of prospective damage is consistent with their perception of the prevalence of the different types of hazardous buildings. For cities, the Pearson correlation (r) between prevalence of unreinforced masonry buildings and likelihood of significant damage from a major earthquake is a moderately strong +0.41. The corresponding Pearson correlations between the prevalence of tilt-up concrete buildings and prospective damage is +0.46 and between the prevalence of reinforced concrete frame buildings and prospective damage is +0.14.

[5]Specifically, they were asked: "Please think about what damage would follow if the following events actually occurred. On a scale of 0 to 100, how would you characterize the potential for damage to a significant number of structures from ***"

Table 44. Potentially hazardous buildings in Oregon and Washington cities studied for this report.

[Percentage of cities reporting that each building type is either somewhat or very common]

Building type	Oregon	Washington
Unreinforced masonry	31	52
Tilt-up concrete built before the mid-1970's.	25	22
Reinforced concrete frame built before the 1960's.	13	25

DAMAGE PERCEPTIONS OF UTILITIES AND PORT OFFICIALS

Utility and port officials viewed earthquake hazards as a potentially broader risk than flooding or landslides. Landslides are likely to affect only part of the utility system, whereas earthquake-related ground shaking would affect the whole system. As part of risk management, utilities and ports seek to protect the more valuable aspects of their facilities—reservoirs, storage facilities, and treatment plants for water or sewer utilities, and piers and cranes for ports. About one-third of the respondents from water utilities identified reservoirs as potentially vulnerable to a major earthquake. An equal number were concerned about disruption of major water-transmission lines within their system.

Utility personnel had perceptions of damage potential comparable to those of building officials. Both Oregon and Washington utility respondents rated major earthquakes as having the highest damage potential, followed, in order, by moderate earthquakes, major flooding, and major landslides. Oregon utility personnel as a group reported slightly higher likelihood of damage from moderate earthquakes (mean 22) and major earthquakes (mean 47) than the corresponding likelihood reported by Washington utility personnel. Washington respondents had much broader ranges of likelihood of damages.

Utility personnel reported considerably more experience with occasional flooding and landslide damage, such as transmission breaks in parts of their systems, broken connections to households, and so forth, than with earthquake damage. Only Seattle and Kent municipal water system officials reported more than minor damage from the 1965 earthquake. The response to flooding and landslides, particularly by the larger utilities, has been to build greater redundancy into their systems. Because of this redundancy and the localized nature of flood and landslide impacts, it is not surprising that personnel of larger utility systems tended to perceive less likelihood of significant damage from major flooding (Pearson $r = -0.41$) or from landslides

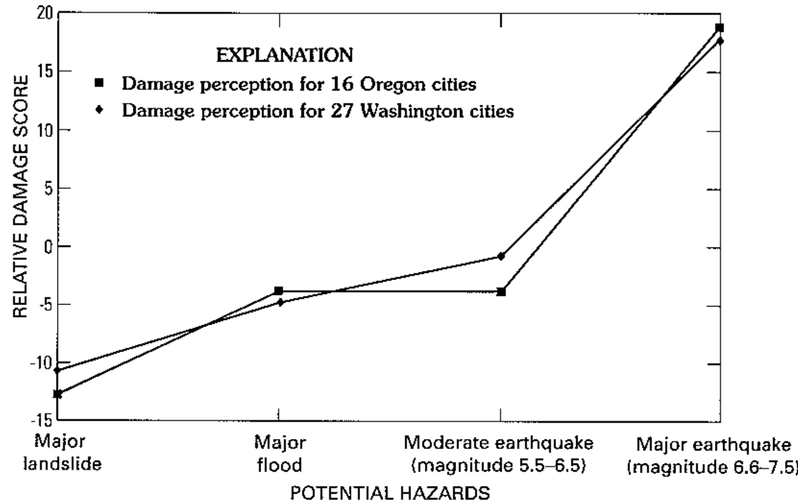

Figure 235. Expected-damage perceptions of building officials of Oregon and Washington cities in the study area. Relative damage scores are deviations from mean rating of expected damage from the combined hazards.

(Pearson $r = -0.31$) than officials of smaller utilities.[6] In contrast, the perceived likelihood of significant damage tended to increase with utility size for moderate earthquakes (Pearson $r = +0.27$) and for major earthquakes (Pearson $r = +0.16$).

Engineering personnel at the six major ports that were part of this study reported a likelihood of damage that generally corresponded to the perceptions of municipal utility and building personnel. However, the likelihood data and the qualitative responses to the interviews indicated a lower perception of the probability of prospective earthquake damage to port facilities. The likelihood of prospective damage from major earthquakes averaged 40 (on the 0 to 100 absolute scale) with a range of 20–50. Port personnel tended to be more confident than the utility officials that seismic forces had been adequately considered as part of facility design.

CURRENT RISK-REDUCTION POLICIES AND PRACTICES

Policies (as the term is used here) are officially adopted laws or regulations at the State level and local ordinances at the local level (May and Williams, 1986). Policies may be general in establishing broad goals, or they may be specific in specifying standards or in referencing other sources of standards as part of legislation. They may be strongly directive in mandating particular actions by other levels of government. Policies commonly have associated administrative regulations that provide specific guidelines about how to comply with the policies. At the State level, such regulations are part of administrative codes subject to State-level rule-making procedures.

An important category of policies considered here is State mandates that either require local governments to adopt policies consistent with certain State goals or require local governments to comply with State policies. The State mandate may allow discretion in the way local governments formulate policy, or the local policy may be highly prescribed. For example, Oregon's statewide land-use planning mandate requires local adoption of comprehensive plans consistent with 19 State planning goals. The State planning mandate establishes broad planning goals, and associated regulations specify the steps for local compliance with the mandate. The local comprehensive plans officially adopted by local governments establish local land-use policies.

Practices (as the term is used here) are the actions of local building officials, land-use administrators, and other government officials in carrying out their functions. Practices are governed by policies and their implementing regulations. The policy or associated regulations may be vague enough to allow discretion in carrying out the policy. As a result, there can be differences between written policies and actual practice. For some situations, no applicable policy may exist. Therefore, the realities of practice are often difficult to study.

BUILDING REGULATION

Building regulation is a shared governmental function for which Oregon and Washington specify State building

[6]The correlations reported in this paragraph were calculated by using deviation scores for risk perceptions and omitting relevant outliers. Previous flood experience and future damage potential were very weakly related (Pearsons $r=+0.04$) and previous landslide experience and future landslide damage potential were weakly related (Pearsons $r=+0.28$). Insufficient variation in earthquake-damage experience prevented analysis of the relationship between past earthquake experience and future damage perception.

codes, and local governments implement and enforce the codes through local ordinances and building regulatory practices. The State codes are based on the UBC (Uniform Building Code) (International Conference of Building Officials, 1988) as amended in each State. Discretion in building regulation comes both through local amendments to the State code (prohibited in Oregon) and through building officials' exercise of discretion as permitted by amended UBC provisions and relevant local ordinances.

Perhaps the greatest limit to the increase in earthquake-hazard risks in this region has been the adoption by Oregon in 1974 and by Washington in 1975 of State laws and associated administrative provisions establishing State building codes.[7] These may not seem like big steps forward, because some 80 percent of Washington cities and 60 percent of Oregon cities in this study had building codes with seismic provisions prior to these mandates, which were typically adopted in the 1950's or 1960's. Fewer counties had building codes prior to the State mandates. Yet, the establishment of State codes was important for jurisdictions where no building codes of any kind existed and for establishing a way to update the codes to reflect changes in UBC provisions. Neither State has enacted or even considered State policy mandates governing retrofit of existing hazardous buildings beyond the relevant UBC provisions concerning change in use or occupancy.

The two States' building-code mandates (table 45) are similar in approach but are different in some important specifics. Both mandates establish State building codes, require local compliance with those codes, and create means for updating the codes and monitoring local code compliance. The States adopt relevant structural code provisions by referencing and amending provisions of the Uniform Building Code.[8] As newer versions of the UBC have been produced, both States have adopted them with amendments. The 1988 edition has been recently adopted with amendments as the basis for each State's structural building code.

Because of differing seismic-zone delineations for Oregon (now designated zone "2B") and Washington (now designated zones "2B" and "3") and differing State-level amendments, there are important differences in seismic provisions between the two States. Oregon also has adopted the Council of American Building Officials One and Two Family Dwelling Code (Council of American Building Officials, 1986) as a basis for State code governing residential construction.

The main differences between the two mandates are in the degree of local discretion permitted in amending State provisions. Oregon does not permit any amendment by local jurisdictions. The Oregon code is a genuine State code for which the implementing responsibility is delegated by the State to local governments.[9] Washington permits amendments to the State building code as long as they do not weaken code provisions. Since 1986, State-level review and approval of amendments affecting one- to four-unit residential buildings has been required. The local discretion in amending the code combined with municipal building codes that existed prior to the State mandate has resulted in a greater variety of local codes in Washington than in Oregon.

Although local updating of ordinances to correspond with new versions of State building codes may lag, localities seem to have policies that comply with State mandates. The critical question about the effectiveness of the State building codes is the extent to which seismic provisions are enforced. Enforcement relates to the capabilities of the relevant local building departments (the quality of plans review and inspection) and the use of discretion by local building officials where permitted by the codes. Oregon has attempted to strengthen enforcement capabilities for all aspects of the code by requiring certification of building officials, plans examiners, and inspectors.

Data concerning local building regulation enforcement are very sketchy. A recently completed Washington study of code enforcement noted "a perception, and even public acknowledgment, that the level of building code enforcement varies throughout the state" (Washington State Building Code Council, 1989).[10] Some building officials who were interviewed as part of this study hinted at political pressures on them to be less stringent in interpreting codes. Others, including some building officials in relatively small jurisdictions, were very aggressive in code enforcement. The overall impression from the interviews was that current levels of enforcement for new commercial construction are high. Considerably more variation in code enforcement was suggested for code provisions regarding renovation of commercial structures. This variation reflects differences both in building officials' attitudes and in their use of discretion.

Data about building-department staffing provide a limited basis for assessing enforcement capabilities with respect to seismic-hazard provisions. Only 15 percent of the Washington cities and 20 percent of the Oregon cities in this study reported having structural engineers as part of the

[7]Each State has laws that specify seismic design for public facilities and "public places of assembly" dating from 1963 in Oregon (Oregon Revised Statutes 456.965 "Public Structures") and 1955 in Washington (Revised Code of Washington, Chapter 70.86, "Earthquake Resistant Standards"). Each of these laws has been superseded by State building-code provisions. The extent to which these provisions were enforced in the 1950's and 1960's is unknown but likely to have been limited because of the lack of State-level enforcement mechanisms at that time.

[8]Other codes govern electrical, mechanical, fire, and other aspects of construction.

[9]The delegation of responsibility for codes follows a hierarchy in Oregon (Oregon Building Codes Agency, 1988). If a municipality elects not to enforce the State code, the responsibility falls to the county. If the county elects not to enforce the State code, the responsibility falls to the State. Enforcement of the structural code has been delegated to the cities and counties in this study.

[10]The limited nature of the data is underscored by the fact that only 17 people gave public testimony at the five regional hearings held by the Washington State Building Code Council on this topic.

Table 45. State building-code mandates, Oregon and Washington.
[UBC, Uniform Building Code; CABO, Council of American Building Officials]

State mandate	Provisions	Local discretion
OREGON—1974 State Building Code (as amended).	Establishes State building code and agency with rule-making authority to update code provisions.	Unable to amend provisions to meet local conditions.
	1988 edition of UBC with amendments administratively adopted in 1989 (regularly updated since 1973 edition); CABO One- and Two-Family Dwelling Code also adopted.	Local enforcement with county and State backup (structural provisions almost always locally enforced).
	Mandates certification of building officials, plans examiners, and inspectors.	Discretion as provided within UBC as amended.
WASHINGTON—1975 State Building Code (as amended).	Establishes State Building Code Council with rule-making authority to update code provisions.	Able to amend provisions to meet local conditions, as long as minimum State standards are met.
	1988 edition of UBC administratively adopted in 1989 (regularly updated since 1976 edition with some technical modifications).	Solely local enforcement of building-code provisions.
	State Building Code Council authority to review local amendments for residential structures with 1–4 units (since 1986).	Discretion as provided within UBC provisions and in adding local amendments.

building-department staff. (The corresponding figures for the counties in this study are 12 percent in Washington and 33 percent in Oregon.) Seattle's building department has the greatest staff capability, consisting of a construction review staff of 19, of which 6 are licensed structural engineers, 4 have other engineering certification, and 9 have building-construction or architectural degrees. Some 60 percent of cities in the region reported sending complex drawings for plan review to the regional office of the International Conference of Building Officials or hiring consultants for the review. Not surprisingly, the smaller jurisdictions reported more limited ability to interpret seismic-hazard code provisions. This difficulty was summarized by one building official who stated, "I often have questions about what the seismic provisions are based on; it is hard for a non-engineer to tell."

The code-enforcement gaps in some of the smaller jurisdictions and more rural counties prior to the establishment of the State codes are illustrated by the following quotes from interviews with building officials:

- "We were derelict prior to 1975 or so in keeping up with UBC changes, but we are now tightly tied to State law."
- "There were blatant problems in the 1970's with bad engineering practice that we were unable to address."
- "Shifting the building function back and forth between the city and county made consistent code compliance difficult."

The existence of State building codes in Oregon and Washington may seem to make local building regulatory policies and practices less important aspects to consider for future earthquake-risk-reduction strategies in the region. For newly constructed, engineered buildings this is probably a reasonable conclusion. Given the apparent relatively good enforcement of seismic provisions as applied to such buildings, the degree of risk for engineered buildings built since the early 1970's (or even the early 1960's in larger cities) is essentially determined by UBC seismic provisions in place at the time the buildings were constructed. The judgment that seismic risk is low for these buildings presumes that good engineering practices were followed in building design and that the seismic zones were properly designated in the codes in place at the time of construction.[11]

Local policies and practices are especially important concerning (1) existing, potentially hazardous buildings, such as unreinforced masonry buildings (URM), tilt-up concrete buildings, and reinforced concrete frame buildings described earlier in this chapter; and (2) building and excavation provisions for steep slopes and unstable soils. The variation in local policies and practices concerning these hazards stems from multiple sources of code provisions and latitude within those codes.

[11]Oregon's zone classification has been changed somewhat, particularly in the 1988 edition of the UBC. This in itself provides a basis for wondering about risk posed even by the "newer" engineered buildings.

Two relevant UBC discretionary provisions define the trigger for applying seismic-code provisions to buildings undergoing renovation. Section 104 states that "additions, alterations, or repairs" may be made without requiring the existing building to comply with all of the code requirements. In addition, section 502 provides an exemption for proposed uses that are less hazardous than existing use for buildings undergoing a change in "character of occupancy or use." These provisions allow for interpretation for buildings that are remodeled in stages or for where the change of use can be debated. This is less of a problem for tilt-up concrete buildings, for which changes in use are less frequent than for other categories of potentially hazardous buildings.

The main UBC discretionary exemption that applies to older, potentially earthquake prone buildings consists of "historic building" provisions of the UBC Section 104(f). This section allows discretion in meeting current code requirements for buildings certified as having special architectural or historical significance. The key provision is that the restored building or structure be no more hazardous than the original.

Local ordinances referencing suggested model codes for other aspects of building regulation are an additional source of differing code-enforcement policies and practices in Washington and to a lesser extent in Oregon. Some jurisdictions incorporated provisions of the Uniform Code for Abatement of Dangerous Buildings in ordinances about dangerous buildings. That code allows building officials discretion concerning dangerous buildings. A few building officials reported using such ordinances to require demolition of earthquake-vulnerable buildings, but such actions were rare. In addition, the ordinances of some jurisdictions specifically refer to the Uniform Code for Building Conservation in establishing guidelines for renovation of buildings.

Another source of differences in local regulation of existing buildings is jurisdiction-specific building codes. Seattle has done the most in this regard (Perbix and Burke, 1989; Skolnik and Wood, 1975), beginning in 1973 with the enactment of amendments to the Seattle Building Code, which states:

> In cases where total compliance with all the requirements of this building code is physically impossible and/or impracticable, the applicant may arrange a pre-design conference with the design team and the building official to identify design solutions which will provide equivalent protection. The building official may waive specific requirements in this building code which he/she has determined to be impracticable. (Sec. 104 of the 1985 edition of the Seattle Building Code)

The only other examples of locally adopted seismic policies for existing buildings among the jurisdictions in this study were parapet provisions enacted in Tacoma and Seattle. (UBC seismic provisions concerning parapets and chimneys are in section 3704(c) of the 1988 edition.) Tacoma's ordinance was adopted after the 1965 earthquake (ordinance 17842, May 18, 1965). The ordinance made it possible to declare buildings with unanchored parapets dangerous and therefore a hazard requiring abatement. Seattle's provisions, in a section of the Seattle Building Code, are similar in making it possible to declare buildings with unanchored parapets unsafe. There have been various spurts of enforcement of these parapet provisions. Seattle, for example, reportedly looked actively for problem parapets in 1975 after a large chunk of a parapet fell from a now-demolished hotel. Some 200 building owners were cited for unsafe parapets at the time.

Important differences in practices concerning existing buildings involve negotiations for seismic-safety upgrading of buildings undergoing renovation. Seattle's building code appears to codify the existing practice in many jurisdictions. Seattle, Tacoma, and Portland appear to have done the most to establish administrative procedures for negotiating seismic-safety requirements in building renovation. Portland was particularly innovative in establishing a Structural Advisory Committee, composed of external structural engineers, for advising the city's building official about appropriate requirements for design changes as part of major renovations. The volume of renovations of unreinforced masonry buildings alone has been enough in these jurisdictions, about 20–30 per year in Seattle, 2 or 3 per year in Tacoma, and 20 per year in Portland, to justify having such procedures. Within jurisdictions having less experience with major renovations of potentially earthquake hazardous buildings, the practices are less formalized but are sometimes guided by the Uniform Code for Building Conservation.

LAND-USE AND SECONDARY HAZARDS

The contrast between State-level land-use planning mandates in Oregon and Washington is between a single, relatively strong Oregon land-use mandate and a set of relatively weak, more general environmental mandates in Washington. Despite differences in the written mandates, the differences in local practices between Oregon and Washington jurisdictions are not that great concerning seismic hazards other than landslides.

The primary State-level land-use planning mandate in Oregon relevant to earthquake hazards comes from provisions contained in legislation first enacted in 1973 as the Oregon Land Use Act. This legislation established 19 statewide planning goals and required local governments to develop comprehensive plans to be reviewed for consistency with the statewide planning goals (Oregon Land Conservation and Development Commission, 1986). Goal Seven is a statewide goal "to protect life and property from natural disasters and hazards." The guidelines for Goal Seven call for identification of areas subject to natural hazards and the development of "appropriate safeguards" as part of the planning process.

The Oregon mandate and associated administrative guidelines provide discretion in implementing Goal Seven. The Oregon jurisdictions in this study fully complied with the State mandate provisions requiring a State-approved local comprehensive plan. Goal Seven compliance appears to be very strong with respect to flood hazards (in complying with Federal Emergency Management Agency flood-insurance mandates), moderately strong for landslide hazards (in identifying areas of potential landslides and considering compatible land uses), and weak for other earthquake hazards. Planners cited lack of awareness of earthquake hazards and difficulties in identifying areas other than steep slopes as possibly subject to earthquake hazards as a primary limitation of their ability to apply land-use measures to earthquake risk reduction. State personnel who review local comprehensive land-use plans reported very few plans in which seismic hazards other than landslides were even mentioned.

The most relevant Washington State mandate for consideration of earthquake hazards is the State Environmental Policy Act of 1971 (SEPA).[12] This legislation and associated administrative regulations require cities and counties to adopt procedures for environmental review and designation of mitigating actions for certain categories of development (for example, planned developments, annexations, shoreline development) likely to have "significant" environmental impacts. Because many categories of development are exempted and the nature of mitigating actions is not specified, the SEPA process is not a very comprehensive approach for regulating development in areas subject to seismic hazards.

Administrative amendments, enacted in 1984, to the SEPA regulations allowed cities and counties to designate "environmentally sensitive areas," a procedure which would allow for review of land-use and development proposals that might normally be exempt from SEPA review. This more recent SEPA provision has been the basis for several of the "sensitive-areas ordinances" discussed in the following section.

The Federal flood-insurance program, authorized by Congress in 1968 and substantially strengthened in 1973 by providing penalties for communities failing to participate, provides a different set of mandates for local adoption of ordinances for management of land use and development within flood-prone areas. In this discussion, the flood-insurance provisions are relevant to localities potentially vulnerable to earthquake-induced water waves (tsunami). These provisions are potentially relevant to some coastal communities in Oregon and Washington, but relatively few of the relevant jurisdictions were included in this study (Urban Regional Research, 1988).

One of the central points in evaluating policies addressing secondary earthquake hazards is that, with relatively few exceptions, the relevant local ordinances do not prohibit development in potentially hazardous areas; they only control it to some degree. The typical approach is to require appropriate engineering in the form of special pilings or strengthened foundations for structures along steep slopes or in areas with expansive soils. This requirement is more or less routine as many building officials reported acting daily on geotechnical or soils reports they require under UBC provisions. More extensive approaches to mitigation of secondary hazards entail special review processes for development in areas with steep slopes or that are vulnerable to other seismic hazards.

The most specific local policies concern landslide hazards. Nearly 60 percent of the cities reported having some form of steep-slope or landslide-hazard ordinance. (All the Oregon counties and more than half the Washington counties reported having landslide regulations.) Those jurisdictions without specific steep-slope ordinances cited UBC provisions regarding excavation and foundations (UBC sections 2905 and 2910) as one basis for allowing building officials to request soils or geotechnical reports for proposed buildings. Excavation and grading ordinances based on appendix Chapter 70 of the UBC serve as the basis for some local ordinances requiring mitigating actions in areas subject to landslide hazards. Other jurisdictions have specific steep-slope ordinances that specify limits on construction and (or) requirements for geotechnical reports and mitigating actions. And yet other jurisdictions had more generic "sensitive-areas ordinances" that included special review and permit processes for development in designated areas subject to landslide hazards.

Liquefaction and subsidence hazards appear to be dealt with less directly. The UBC excavation and foundation provisions (section 2905) make general reference to "expansive soils," thereby providing building officials with a basis for requiring mitigating actions for areas subject to liquefaction and subsidence. However, building officials reported considerably more difficulty in deciding when to require the reports that trigger engineering solutions. Some officials appear to be very aggressive (for example, in requesting reports when in doubt), whereas others seem to be more restrained.

Sensitive-areas ordinances are more comprehensive approaches used by jurisdictions in establishing overlays on land-use maps that designate areas subject to such hazards as expansive soils, steep slopes, or subsidence. When development is proposed within the designated sensitive areas, special review processes that include consultant reports or

[12] Subsequent to completion of this study, Washington enacted in 1990 and further amended in 1991 the State Growth Management Act. This act requires every county and city in the State to designate critical areas within its planning jurisdiction, including areas with geologic hazards. Other provisions of the act require the faster growing counties, including those in this study, to protect the designated critical areas from incompatible land uses. In practice, the critical-areas provisions of the State Growth Management Act supersede the sensitive-areas provisions of the State Environmental Policy Act. The State Shoreline Management Act of 1971 is less directly relevant to earthquake-risk reduction. It establishes a cooperative program between the State and local governments under which specified local governments with coastal or riverine shorelines must establish plans for managing the shorelines.

other actions are required. The specific requirements for development in sensitive areas vary among the ordinances. Two different examples are the King County sensitive-areas ordinance and Bellevue's "natural determinants code." King County's ordinance requires geotechnical reports and negotiated mitigating actions. Bellevue's code is more prescriptive in specifying such things as the type of footings required for foundations of buildings in sensitive areas and in establishing a transfer of development credits to other sites for developers who agree to limit development in sensitive areas. Personnel involved with both programs report noteworthy success in modifying development in areas having steep slopes, moderate success in areas subject to subsidence, and limited attention to other seismic hazards.

Seismic hazards are only indirectly considered as part of longer range zoning or land-use decisions. Many Washington jurisdictions reported having comprehensive plans that generally refer to seismic hazards. Oregon jurisdictions are required by the State land-use planning mandate to evaluate natural hazards as part of their planning processes. In practice, most Oregon jurisdictions' land-use plans appear to be fairly general evaluations of earthquake potential.

The only way that jurisdictions in this study appeared to use land-use planning as a longer term response to seismic risks was public land acquisition so that the acquired property could remain as open space. For example, Bellingham planners cited their extensive open-space acquisition program as a long-term means for addressing seismic risks. In jurisdictions where such open-space acquisition was done, seismic concerns were a relatively minor impetus. These programs tend to be undertaken to protect wetlands, limit vulnerability to landslides, protect marine bluffs, or to reduce flood risk.

UTILITIES AND PORTS

The utilities and ports engineers who participated in this study reported considering seismic hazards as normal practice in constructing new facilities or upgrading existing ones. Good engineering practices were presumed to provide adequate seismic-risk resistance. Interviewees reported only rare instances when seismic-risk considerations entered into siting or land-use decisions. Only a few of the utilities included in this study have initiated formal reviews of the earthquake vulnerability of their systems.

The design of facilities for a water system or a port is obviously very different than the design of a major building. Utility personnel design a range of facilities including reservoirs, storage tanks, pumping stations, control centers, and transmission lines. Port personnel design piers, cranes, loading and storage facilities, drydocks, and other ship repair facilities. Because of the variety of facilities involved, ports and utilities depend greatly upon experienced and knowledgeable engineering consultants for all aspects of facility design. The larger ports and utilities have very sophisticated engineering units and spend large amounts (several reported hundreds of thousands to millions of dollars per year) on geotechnical and other engineering consultants for facility design.

Engineering practices relating to seismic-risk considerations for such facility design might be considered more an art than a science. Engineers who design such facilities do not have a single reference source like the UBC to guide sesismic-risk design. Instead, nearly a dozen professional associations provide guidance or standards concerning design elements for these facilities.[13] "Good" engineering results from knowing what guidelines might be helpful, what seismic forces to design for, and how to extrapolate from existing codes or standards to the particular design situation. Experience and professional knowledge are at the heart of this process.

This study provides little information about the adequacy of engineering practices for seismic safety in this region. Utility and port engineering personnel who were interviewed for this study reported confidence in the consultants they had worked with over the years. Earthquake hazards appeared to be only one of many engineering design concerns, of less concern than high winds to many of the respondents (particularly among ports). Although they acknowledged potential vulnerability of parts of water systems or port facilities to seismic hazards, most interviewees thought that seismic hazards were adequately addressed, particularly in newer facilities.

Only three utilities in this study, the Everett, Portland, and Seattle water departments, have initiated formal reviews of the seismic vulnerability of their systems. For two of these utilities, an engineering director who had previous experience with seismic design considerations in California provided an impetus for the review. Some of the other utilities had addressed seismic risk in isolated aspects of their systems, such as slope stability around some reservoirs, foundations in older pumping stations, and spillways for dams. These seismic-risk-reduction efforts typically emerged from facility reviews undertaken for other purposes.

Many water utilities reported ongoing renovation programs for their major pipelines and other water mains. In some jurisdictions, the water system contains major elements that are quite old. Tacoma has a water pipeline dating from 1915; Everett has one dating from 1929. Even newer pipelines constructed in the 1930's or 1940's were reported by utilities for which cast iron and brittle cement piping is common. Replacement of older pipes with ductile iron pipes

[13] For example, guidelines prepared by the Technical Council on Lifeline Engineering of the American Society of Civil Engineering address oil and gas piping systems, buried pipelines, and numerous other aspects of lifeline engineering. The American Water Works Association has created standards for welded-steel water-storage tanks. The American Concrete Association provides standards for concrete sanitary storage facilities used in treatment plants. Other compilations of existing practices have been published by the Structural Engineers Association of California and by the Building Seismic Safety Council.

and use of flexible piping for joints are common practices as part of renovations. Although such renovations are primarily to reduce future maintenance costs, they also increase seismic resistance.

Ports appear to be in a somewhat different situation regarding older structures. Modernizing facilities has been an important part of the business because of competitive pressures. All the ports in this study had substantially upgraded or replaced piers over the past few decades, except for one older wooden pier used by one of the ports. Most of the remaining older structures are warehouses that are planned to be replaced or whose use is limited to lower valued purposes.

Perhaps the greatest potential seismic vulnerability for ports is liquefaction. Port facilities in this region are mostly built on alluvial plains and extensive filled areas. The primary response to the liquefaction hazard has been incorporation of the potential in engineering designs. The liquefaction hazard was seldom cited by interviewees as an important land-use consideration. The examples respondents cited were of a proposed warehouse and other buildings for which more suitable sites were selected. The engineering directors commenting on these siting decisions were confident that engineering designs could have been developed to address the hazard, but it made more economic sense to put the buildings elsewhere. Such choices are more limited when it comes to the design of piers or other water-dependent elements of port operations.

THE POLITICAL AND ECONOMIC ENVIRONMENT FOR RISK REDUCTION

Risk reduction policies and practices are shaped by a host of local political and economic factors that are influenced by State and other mandates. Earthquake risks and the political-economic situation of the jurisdictions studied vary considerably. In the following discussion, cities and counties are categorized according to existing and potential risk-reduction efforts.

RELATIVELY VULNERABLE CITIES

Thirteen cities in the study can be classified as relatively vulnerable to earthquake hazards (table 46). The vulnerability of these cities is a function of the scale of existing development and of population size. Consideration of existing earthquake-risk-reduction practices and the political-economic environment for future risk-reduction efforts leads to further delineation of three categories of future risk-reduction prospects among the 13 more vulnerable cities (table 46).

The three largest cities in the region are in this grouping. The population of this group of cities has been fairly stable (median in 1987 of 44,000) with a median population growth from 1980 to 1987 of less than 2 percent. Valuable buildings are being constructed in these cities (median 1987 commercial building-permit values of about $20 million with a range of $1 million to $500 million). However, the value of new construction is a relatively small percentage of the total value of the building stock.

The extent of existing development and lack of substantial population growth of these cities have four main implications:

- Unreinforced masonry buildings, reinforced concrete frame buildings built before the 1960's, and concrete tilt-up buildings built before the mid-1970's constitute considerable potential risk
- The potential for property loss is substantial because of the amount of development in these cities

Table 46. Risk-reduction prospects for cities that are relatively vulnerable to seismic hazards, Oregon and Washington.

Category of cities	Cities	Risk-reduction prospects
"Pacesetter": Large cities with advanced building departments; weaker land use provisions.	Seattle and Tacoma, Wash.; Portland, Oreg.	Good: Potential for continued innovation for upgrades of existing buildings; retrofit provisions more difficult.
"Resourceful": Moderate-sized cities with risk-reduction initiatives spurred by individual efforts.	Aberdeen, Bremerton, Olympia, and Renton, Wash,; Salem, Oreg.	Mixed: Receptive to risk reduction, but limited resource base and political support; practices easier to influence than local policies.
"Restrained": Moderate to larger size cities constrained by economic conditions or lower risk perception.	Bellingham, Everett, Kelso, Longview, and Vancouver, Wash.	Constrained: Uphill effort to establish seismic-risk reduction because of economic and political factors.

- Land-use policies and practices with respect to seismic hazards are relatively weak at present and are likely to be relatively ineffective in the future. There is very little undeveloped land for which to apply traditional land-use risk-reduction measures
- The degree of earthquake-risk reduction in these areas is and will be largely determined by policies and practices concerning existing buildings and their renovation

PACESETTER CITIES

This category comprises the three largest cities in the region, Portland, Seattle, and Tacoma (average 1987 population of 360,000). These cities have the most knowledgeable building departments in the region and the most experience in negotiating renovation of existing potentially hazardous buildings. Seismic provisions in the building codes of these cities date to the late 1940's or early 1950's, although these early provisions were very minimal compared to today's standards. These cities are also leaders in developing advisory groups for negotiating the particulars of seismic-resistant building renovations, in establishing parapet ordinances, and in Tacoma, instituting a strong-motion instrument program for measuring earthquake forces in buildings.

The capabilities and experience of the building departments in these cities provide confidence that these cities are doing as good a job as any major city in the country in assuring adherence to current seismic standards for new construction.[14] Because these cities have their own building codes, local strengthening of code provisions is possible, except in Portland whose code is constrained by State law.

Modification of codes would not necessarily be done readily. One policy official, incorrectly referencing current practice, commented about the U.S. Geological Survey hazard assessment program:

> We've got conservative codes. They provide considerable protection. Right now, we're designing to what California has been designing for the past 20 years. But we're not going to start changing the codes just because of some new reports. There'd have to be considerable evidence before we make any changes. And if seismology has become an exact science, that's news to us.[15]

Building officials interviewed from these cities as a group gave the highest ratings for the likelihood of potential significant damage to buildings in their cities from moderate earthquakes (mean of 50 for the 0 to 100 scale used in the building officials' risk assessment) or major earthquakes (mean of 80 for the 0 to 100 scale). In contrast, elected officials from these cities appeared to have the same degree of concern (or indifference) to earthquake hazards as officials from other cities. The political-economic environment is such that building officials for these jurisdictions doubted that retrofit programs requiring seismic upgrading could be instituted. As one official stated: "We have kicked the idea [of a retrofit program] around at administrative levels, but it won't fly politically, and there are technical difficulties in establishing appropriate standards."

These cities tend to be much less innovative with traditional land-use practices such as the use of overlay zones to land-use plans, open-space zoning, or other measures to limit seismic risk. The comment of one planning director summarized the approach of this category of cities: "Besides landslide controls, we have done very little [in the way of land-use measures]. The building department is in the driver's seat since they handle geotechnical reviews and building regulation."

RESOURCEFUL CITIES

This category (table 46) comprises five cities of moderate population (average 1987 population 42,000) that are distinguished more by having initiated earthquake-risk-reduction practices than by having innovative seismic-hazard-reduction policies or sophisticated building departments. For example, Aberdeen personnel have participated in tsunami-warning studies, and at the time of our interviews were funding a study of risks posed by unreinforced masonry buildings. Bremerton officials have condemned potentially earthquake vulnerable buildings as unsafe and have upgraded school buildings for seismic safety (both undertakings were apparently controversial for the personnel involved). The building departments of Olympia, Renton, and Salem reportedly have been relatively aggressive in enforcing seismic-risk-abatement requirements, particularly regarding homes.

The label "resourceful" is applied to this category of cities because the impetus for risk reduction appears to have come through individual efforts to affect building practices rather than from external mandates or policy decisions. In most instances, a building official willing to endure criticism for being too stringent was a key factor in initiating risk-reduction efforts. For this category of cities, a strong base of support for pursuing risk reduction seems to exist in relevant administrative levels of government. However, the political climate, broadly defined in terms of elected officials and the building community, and the economic climate do not necessarily support further risk-reduction efforts. As one official said, "This jurisdiction struggled to institute its only retroactive ordinance—requiring smoke detectors in certain situations." Because of the tenuousness of these risk-reduction efforts, there is a potential that they could decline, moving these cities into the "restrained" category (see following) of

[14]The Building Seismic Safety Council trial-designs review of implications of designing different classes of new buildings according to the council's recommended provisions showed that following these new provisions in Seattle would result in lower construction costs than those incurred by following current Seattle building codes (Webber, 1985). Tacoma and Portland were not included in the trial-design program.

[15]Statement of the Director of Seattle's Department of Construction and Land Use, quoted from "Seattle Could Face 'Great' Quake But Building Officials Skeptical," Seattle Business Journal, September 10, 1984, p. 20.

relatively vulnerable cities. Practices change quickly as new directions are established by elected officials, as key employees leave, or as budgets are further constrained.

RESTRAINED CITIES

This category comprises five moderately populated (1987 average population 38,000), low-growth cities for which State-mandated actions appear to be well integrated with building regulatory and planning practices, but sustained earthquake-specific risk-reduction policies or practices have not been initiated. Yet, these communities have potentially noteworthy earthquake risk because of the nature of the building stock.

Many respondents from cities in this category indicated that earthquake-risk-reduction initiatives are constrained by political-economic circumstances that vary among jurisdictions, for example, resistant policy officials, unreinforced masonry buildings with concentrated ownership, vacant buildings that are not being renovated because of depressed economic conditions, and so forth. A component of the restrained response to seismic risk is the relatively depressed economies of these cities, as reflected by an average population growth from 1987 to 1988 of less than 1 percent and a 1987 median value of building permits issued for apartments, office buildings, and industrial buildings of only about $3 million.

The challenge for future risk-reduction efforts for this group of cities is building both a supportive political and economic climate and the capacity to undertake needed measures. As a group, elected officials of these five cities gave the lowest average ratings of the likelihood of significant deaths, injuries, or damage in the next 20–30 years from a moderate earthquake (average score 19) as well as the lowest average ratings of the likelihood of significant losses from a major earthquake (average score 13). These ratings are about one-half the corresponding averages reported in the other two categories of relatively vulnerable cities.

LESS VULNERABLE CITIES

The category of less vulnerable cities includes 30 cities for which earthquake risks are lower when compared with the more highly populated, more developed cities discussed previously. This lower risk is relative, as these cities still have considerable earthquake risks. As for the relatively vulnerable cities, this less vulnerable group can be further differentiated into three categories (table 47) in terms of existing risk-reduction practices and the general political and economic evironment.

The median population as of 1987 for these cities was 19,100. Newer development is indicated by the rapid growth rates of these cities, which had a median population growth rate of 13 percent and a median growth rate in commercial building permits of 19 percent from 1980 to 1987. The recent development of these cities and the lower population sizes have several implications in comparing these less vulnerable cities to the relatively vulnerable cities:

- Although there is an existing hazard posed by tilt-up concrete buildings and unreinforced masonry buildings in at least some of the cities, the rate of development forces attention to seismic considerations for new construction

Table 47. Risk-reduction prospects for cities that are less vulnerable to seismic hazards, Oregon and Washington.

Category of cities	Cities	Risk-reduction prospects
"New sophisticate": Rapidly growing cities for which building-code enforcement and planning efforts have been spurred by extensive commercial development.	Auburn, Bellevue, Kent, Kirkland, Mercer Island, and Redmond, Wash., Beaverton, Gresham, Lake Oswego, and Tigard, Oreg.	Good: Land-use considerations a key aspect of growth controls; capable and interested building departments.
"Measured": Smaller cities where varying hazards are addressed by existing building and land-use provisions.	Anacortes, Bothell, Edmonds, Lacy, Puyallup, and Mount Vernon, Wash.; Milwaukie and McMinnville, Oreg.	Mixed: Potential for hazard reduction limited by economic or other city-specific factors; local practices easier to influence than policies.
"Nonplayer": Smaller cities where earthquake hazards are not considered to pose much risk.	Des Moines, Lynnwood, Mountlake Terrace, and Oak Harbor, Wash.; Newberg, Forest Grove, Hillsboro, Keizer, Oregon City, Tualatin, West Linn, and Woodburn, Oreg.	Poor: Need to be convinced that there is noteworthy earthquake-hazard risk.

- Because most of these cities still have vacant land for further development, land-use measures can be used to reduce risk

As many of these cities cope with growth-control issues, land-use regulation is especially volatile. Thus both opportunities and problems exist: opportunities for linking earthquake risk reduction to growth controls and problems in adding risk-reduction measures to a highly charged political environment.

NEW-SOPHISTICATE CITIES

This category comprises 10 of the fastest growing moderate-sized cities in the region. The average 1987 population was 37,000, and the average population growth from 1980 to 1987 was 32 percent. The average growth in value of building permits issued for apartment, commercial, and industrial buildings during this period was 105 percent. The rapid growth, accompanied by development of commercial and manufacturing facilities in many of these cities, has stimulated an increase in the capacity of building and planning departments. Building and planning departments in these cities are relatively advanced compared to those of similar-sized cities of no or little growth.

Private engineering and design consultants have been important in increasing the sophistication of new construction within these cities. For example, Gresham city building department employees described how Japanese electronic firms and their California structural consultants brought them greater understanding of the need for seismic design. Auburn, Bellevue, Beaverton, Kent, Kirkland, Redmond, and Tigard have all had substantial growth in commercial development. Mercer Island and Lake Oswego are more residential in character and have lower growth rates. Their increased attention to seismic risk comes from a combination of building-department awareness and more custom designed homes than most communities have.

Because of the high growth rate of the cities in this category, land-use issues are more controversial for this category. All of the cities have some form of steep-slope regulation, typically involving some form of map-overlay zone designating areas where geotechnical reports are required prior to development. This category in general has the greatest potential for linking future land-use risk-reduction measures to growth controls.

MEASURED CITIES

This category (table 47) consists of eight smaller moderate-growth cities for which State-mandated earthquake-risk-reduction efforts appear to be integrated into normal practice. However, other risk-reduction policies or practices are limited. The primary reasons for designating these cities as less vulnerable are the smaller populations and lesser value of new commercial development. The average 1987 population for these eight cities was 16,500. Most of them have at least a few unreinforced masonry buildings in historic downtown areas. Building officials of cities in this category gave a somewhat higher average rating of the likelihood of significant damage from a major earthquake (57 on the 0 to 100 scale) than the corresponding rating of building officials in the new-sophisticate category (average rating of 39). The reported seismic-risk perception of elected officials was about the same for the two categories.

Cities in this category have potential for joining the new-sophisticate category, but that potential appears to be limited by economic circumstances. These cities do not have the new commercial development or redevelopment that the new-sophisticate category has. The median value of building permits issued in 1987 for apartment, commercial, and industrial buildings was $1.3 million, compared with a value for the "new sophisticates" of $17.3 million. These cities are not as sophisticated in their approach to land use and its relationship to risk reduction as are the "new sophisticates." Because growth is not as great in cities of this category, there has been less pressure to develop land-use controls that concurrently reduce earthquake risk.

Relevant city personnel seem to have a reasonably strong recognition of earthquake risks. However, their ability to act is severely constrained by economic circumstances. A change in economic circumstances, which might move some of these cities into the "new sophisticates" category, is difficult to forecast.

NONPLAYER CITIES

This category (table 47) comprises somewhat smaller cities (average 1987 population 16,000) for which seismic hazards appear to be of lesser concern to both elected and building officials. The "nonplayer" name indicates the perception of officials in these cities that seismic risks are not particularly relevant to them. The label does not imply that these cities are not enforcing seismic components of building codes or following reasonable planning practices.

Building officials for nonplayer cities had the lowest average ratings for the likelihood of significant losses from a moderate earthquake (14 on the 0 to 100 scale) and from a major earthquake (average rating of 30): These ratings are about one-half the corresponding ratings of building officials in each of the other categories of cities. Whether relative indifference is justified is difficult to judge—thus the need and purpose of the overall U.S. Geological Survey hazard-assessment process. Building officials from these cities consider their areas at lower risk because they are primarily residential, comprise wood-frame buildings, and have only newer commercial development.

The challenge for future risk-reduction efforts for this category of cities is to document the extent of earthquake hazards and then, if the documented hazard is serious, to convince relevant personnel that the hazard should be addressed.

COUNTIES

Relevant county risk-reduction policies and practices apply, with a few minor exceptions, only to unincorporated areas within the counties. Compared to their municipal counterparts, the unincorporated areas have lower population, less developed building stocks, and much lower densities of both population and structures. Although these factors no doubt have produced a lower sense of earthquake vulnerability, the recurring flooding and landslides in unincorporated areas of many counties are reminders that these areas are not insulated from natural hazards.

The unincorporated areas of the counties in the study area are undergoing the most change. Unincorporated fringes of urban areas are rapidly becoming urbanized, and rural areas are rapidly becoming suburbanized. The extent of development of the counties and how they have responded to increased pressure for both building and land-use regulation define the three categories of risk-reduction prospects for counties discussed in this section (table 48).

LEADING COUNTIES

This category (table 48) comprises the three most populated counties that surround the largest urban areas in the region. Nearly 1 million people (1987 estimate) live in unincorporated areas of these counties. The growth in these unincorporated areas can be characterized as increased urbanization accompanied by development of commercial, professional, and light manufacturing facilities. The counties are called "leaders" because they have relatively older building codes (since the 1950's and into the 1960's), relatively larger building departments than other counties, and some land-use provisions concerning seismic hazards.[16]

Compared to the other two categories of counties, this category has a greater stock of existing, potentially earthquake vulnerable buildings. These buildings are primarily tilt-up concrete buildings constructed before the mid-1970's. Building officials for these counties rated the likelihood of significant damage from a moderate earthquake (average rating of 48 on the 0 to 100 scale) as twice as likely as the corresponding rating for the other categories of counties. They rated the likelihood of significant damage from a major earthquake (average rating 65) as 1.5 times greater than the other two categories of counties. These counties have large building departments with experience in reviewing complex structures, but the in-house structural-review capacity (that is, the number of structural engineers on staff) is more limited than for the counterpart "pacesetter" cities.

The leading counties have paid more attention to land-use considerations than have "pacesetter" cities. Each county in the "leader" category has some form of landslide land-use controls in effect. King County has an ordinance that is commonly cited as an innovation in regulating land-use practices for risk reduction and preservation of environmentally sensitive areas. Land-use issues have been important considerations in debates about development, and seismic risk was considered in some decisions. For example, seismic factors relating to landslides reportedly were considered in Multnomah County's decision to deny a permit for a metropolitan-area landfill. King County officials have been embroiled in debates over delineation of environmentally sensitive areas. As one means of controlling growth, these counties are moving toward strengthening land-use policies that may also have beneficial side effects for earthquake risk reduction. These improved policies provide the best prospects for addressing earthquake risks in these counties.

TRANSITIONAL COUNTIES

This category (table 48) of 10 counties comprises those unincorporated areas for which growth has entailed the greatest transitions. Large unincorporated areas in these counties are rapidly changing from rural to suburban. The median growth rate in population of unincorporated areas of these counties from 1980 to 1987 was 17 percent. Building and planning departments are trying to catch up with the growth rate by increasing their capacity to address future growth pressures.

For some of these counties, catching up has consisted of establishing building departments and instituting land-use practices. As noted by interviewees:

- "In 1974 over one-half of the county was unzoned and there was no building code."
- "There was no building code until 1971. Since then, enforcement has been progressive. You can't just institute such regulation overnight."
- "Our first major commercial building was built in 1980. There was no county-wide zoning until 1980."

Other counties in this category are much further along in developing building departments and in land-use planning. For these, the main issues have been strengthening building-code enforcement and land-use practices.

Mixed reaction to growth pressures is shown by the variation in the status of current building regulatory and land-use practices. For example, a proposed comprehensive land-use plan for Pierce County that contained zoning and steep-slope provisions was defeated in a county-wide

[16]Because of the urbanized nature of Multnomah County, building regulation is somewhat different from that of the other two counties in this category. The incorporated areas that make up the county regulate building practices.

Table 48. Risk-reduction prospects for counties studied, Oregon and Washington.

Category of counties	Counties	Risk-reduction prospects
"Leading": More heavily populated counties near largest urban areas; established risk-reduction efforts.	King County, Wash.; Multnomah and Washington Counties, Oreg.	Good: Land-use considerations are a key aspect of growth controls; capable and interested building departments.
"Transitional": Counties whose unincorporated areas are changing from rural to suburban, forcing attention to building and planning concerns.	Clackamas, Clark, Island, Kitsap, Pierce, Snohomish, Thurston, and Whatcom Counties, Wash.; Marion County, Oreg.	Mixed: Prospects limited by county-specific factors; some counties are resistant to change.
"Rural": Counties whose unincorporated areas have remained rural; limited population exposure and fewer commercial buildings.	Cowlitz, Grays Harbor, Jefferson, Mason, and Skagit Counties, Wash.; Polk and Yamhill Counties, Oreg.	Poor: Recognize risk and have undertaken some risk reduction for flooding and landslides; further efforts not economically feasible.

referendum in 1986. Many voters apparently thought the plan went too far in regulating land use. Planning officials in three transitional counties specifically mentioned political pressures to go slow in regulating growth.

The future prospects for risk reduction appear to be somewhat mixed for this category of counties. Growth issues will inevitably continue to be an important factor pressing future land-use and building regulatory decisions. However, the political climate, broadly defined, does not necessarily support strong land-use regulation.

RURAL COUNTIES

This category (table 48) consists of seven counties in which growth is occurring but whose unincorporated areas have remained predominantly rural. Officials in these counties have thus not had to confront the growth issues that have affected policies and practices of the other two categories of counties. One building official noted that "we have not had a subdivision of any kind," and another pointed out that "this is a one-man building department." The median population growth rate of unincorporated areas of these counties was 5 percent from 1980 to 1987. The median population of unincorporated areas of these counties was 11,600 in 1987.

Despite the rural nature of these counties, they have had some noteworthy experiences with natural hazards. Grays Harbor County officials evacuated 14,000 people in 1986 in response to a tsunami warning (flooding but no tsunami occurred). Jefferson and Skagit County officials have been involved in lawsuits stemming from deaths caused by landslides in logged areas. Cowlitz County officials have been at the center of a series of negotiations concerning flood and debris control relating to Mount St. Helens. Jefferson County contains Port Townsend, an incorporated area with many unreinforced masonry buildings.

The constraints for future risk-reduction efforts for this category of counties appear to have less to do with recognition of risks than with the costs involved. The exception to this observation are the Oregon counties in this group for which there is little perceived seismic risk. The rural counties simply do not have resources to undertake more extensive risk-reduction efforts.

FUTURE EARTHQUAKE-RISK REDUCTION STRATEGIES

The preceding discussion provides a basis for considering risk-reduction strategies that might be undertaken as new information about earthquake risks is developed for this region. Ongoing research may provide a better understanding of the earthquake hazard in this region. Assumptions about presumed degree of risk will change dramatically if research indicates a high probability of a great (M>8.0) earthquake. Such information is potentially relevant to all jurisdictions studied, especially the "nonplayer" category of cities.

Prospective risk-reduction strategies range from a relatively passive one of hazards-information dissemination to more active efforts to seek policy reforms or to influence practices (table 49). These strategies are not mutually exclusive: pursuing one does not preclude pursuing another. However, because of limited resources, choices must be made as to the strategies to emphasize. Evaluating the strengths and limitations of the strategies entails envisioning the likely responses to the implementation of each strategy. The following assessments are based on the understanding of the political and economic environment described previously.

Table 49. Future earthquake risk-reduction strategies for the Oregon and Washington region studied.

Strategy and examples	Target groups	Strengths	Limitations
Disseminate hazards information: Workshops; publication of hazard maps, loss estimates.	Widely disseminated (targeting possible).	Easily implemented (status quo); information essential for risk reduction.	Only the more capable jurisdictions will act on information; does little for less capable jurisdictions.
Seek mandate revisions: State building-code and land-use mandates.	State agencies, code-writing authorities.	Uniform local policies; few entities to address.	Limited to new buildings or development; practices will still vary among jurisdictions.
Influence local government practices: Workshops, staff funding, demonstration programs, technical assistance.	Local building officials and planners.	Can target jurisdictions with greatest needs; does not require policy changes.	Building officials are restricted by codes (especially Oregon); cities in most need may not want assistance.
Influence private professional practices: Workshops, publication of guidebooks, technical assistance.	Architects, engineers (design and engineering community).	Can target specific groups; does not require State or local endorsement.	Competitive pressures may limit ability to exceed minimum code requirements.

DISSEMINATE HAZARDS INFORMATION

This strategy consists of dissemination of new scientific information about earthquake hazards in the region through professional publications, newsletters, and meetings. The information might be presented as hazards maps prepared at a scale that would show information relevant to at least the major jurisdictions in the region. Demonstration uses of Geographical Information Systems that translate hazards into the risks posed for people or structures might also be undertaken.

One strength of hazards-information dissemination is that it is fairly easy to implement. Several activities are already being jointly undertaken by the Federal Emergency Management Agency and the U.S. Geological Survey. This approach assumes that credible scientific information is essential for making the case for revising building regulatory or land-use policies.

The key uncertainty for this strategy concerns who is likely to act upon the new information. Although the details depend on both the substance and the form of the information, this study suggests that only a few categories of cities and counties are either capable of acting or willing to act upon such information without further external efforts to influence risk-reduction practices. Only the "pacesetter" and "new-sophisticate" cities, and "leading" counties appear to have both the technical in-house capacity and at least some willingness to respond to such information. The "non-player" cities may respond to new information about earthquake risks, but to get them to respond with risk-reduction measures would probably take more than simply providing the information. For the other categories of cities and counties, too many other factors constrain response.

Other potentially responsive audiences are attentive professional groups such as the structural engineers associations of Washington and Oregon. These groups effectively translate the information into new engineering or design practices. Depending on the extent of change in risk assumptions and the credibility of the information, the professional groups might use the information to lobby State building agencies and private code-writing authorities for changes in building standards.

Clearly, better hazards and risk information is necessary. However, this study of risk-reduction prospects suggests that mere dissemination of such information, without other efforts to influence policies or practices, will produce limited reduction of earthquake-hazard risk. The more capable cities and counties may make use of the information, whereas little will likely happen in the remaining jurisdictions. Some structural engineers, geotechnical consultants, and others who design structures may use the new information as part of their practice.

SEEK MANDATE REVISIONS

This strategy consists of directly seeking revisions in State-level building-code or land-use mandates. The specific changes sought will depend upon the nature of the information developed from the scientific research. These revisions might include new seismic-zone delineation, new design standards, special code provisions for particular categories of buildings, or better delineation of seismic hazards within land-use mandates. Building codes could be changed either by State amendments or through the code-revision process of the International Conference of Building Officials. Neither procedure would be easy, and both would require considerable technical justification.

Because State building-code and land-use mandates establish the foundation for local risk-reduction policies, the mandate-revision strategy could lead to desired changes in local policies. Moreover, the changes would be more or less uniform within each of the States. However, this strategy for influencing risk reduction has three main limitations. The first is the difficulty of achieving changes, particularly signficant ones, in State building codes, private codes, or State land-use mandates. The second limitation is that changed policies will only address future development and construction. Even with substantiation of sizeable risks, retroactive State-level policies concerning seismic-risk review or retrofit of existing, potentially hazardous buildings are very unlikely to be enacted in Oregon or Washington. The third limitation is that although local policies closely mirror State mandates, local practices still vary considerably. Implementation of the policies and the discretion used by building and land-use officials depends on the broader political and economic environment.

In sum, appropriate changes will likely be made for new construction (or renovation) throughout the region. To the extent that the new provisions allow discretion in interpretation or implementation, there will be a varied response that reflects differing political and economic factors among the categories of cities and counties. Overall risk reduction in the region can be expected to advance, but the categorization of cities and counties is unlikely to change.

INFLUENCE LOCAL GOVERNMENT PRACTICES

This strategy consists of efforts to influence the practices of building and planning departments in carrying out State mandates and local policies. This influence might entail providing jurisdiction-specific seminars on seismic risk, preparing guidelines for using discretionary building-code and land-use judgments, providing technical assistance in land-use planning or construction-plan review, or funding geologists or structural engineers as part of local staffs. These actions could be targeted to specific jurisdictions or classes of jurisdictions.

This strategy has several strengths. The targeting of assistance would respond to the varied situations of jurisdictions in this region. The emphasis on practice, as opposed to policy, would influence important discretionary judgments concerning such things as renovation of buildings. Also, several model risk-reduction efforts could be developed that could potentially be transferred to other jurisdictions.

The limitations of this strategy result from the constraints imposed by State mandates on local exceptions to those mandates. The Washington State building code allows local jurisdictions to enact stronger provisions than State mandates with appropriate State-level review. The Oregon State building code does not permit exceptions. Therefore, the effectiveness of this strategy is a function of the amount of discretion that exists within existing codes. This strategy would improve risk-reduction efforts the most among those jurisdictions in which current risk-reduction efforts are the weakest. It will do little in the "pacesetter" or "new sophisticate" cities, or in the "leading" counties.

INFLUENCE PRIVATE PROFESSIONAL PRACTICES

This strategy consists of efforts to influence the practices of the private-sector engineering and building-design community. This influence might entail providing special seminars on seismic risk and earthquake engineering, funding creation of special guidelines by professional associations, or providing some other form of professional development opportunities. These actions could be targeted to different types of engineers and building-design professionals.

The strength of this strategy is in the prospective direct influence on the design and engineering recommendations of this community in reducing earthquake risks. The results are likely to be greatest in those sectors that rely extensively on the judgments of design and engineering professionals, such as the utilities and ports in this study. Indirect benefits of changes in practices or knowledge might lead to interest in lobbying for code changes.

Obvious implementation difficulties for this strategy are identifying and reaching appropriate professionals and then convincing them of the need for changes in practice. If these difficulties were overcome, the main limits to the effectiveness of this strategy are the constraints under which the design and engineering community practices its professions. Without code changes, competitive pressures and client desire to reduce costs may restrict the extent to which practices exceed minimum code requirements. The main beneficiaries of this strategy may be the professionals and supportive clients who already are doing the most to address earthquake risks. Insurance companies and financial institutions could potentially be important in endorsing or requiring new seismic-design practices. However, competition and other factors have limited the influence of insurance companies and financial institutions in stimulating stronger risk-reduction efforts.

CONCLUSIONS

The results of this study of earthquake-risk perceptions, existing policies and practices, and the political and economic environment allow substantially different interpretations of the current state of earthquake risk reduction in the region. A positive assessment includes the general awareness of damage potential by building officials, the relatively advanced building and land-use policies in some of the more populous jurisdictions, and the growth in earthquake-engineering experience among private design professionals in this region. A negative assessment might include the seeming indifference of elected officials to earthquake risks, the limited attention to seismic hazards of several categories of cities and counties identified in this study, and the inevitability of a major earthquake that building officials acknowledge will likely lead to significant losses.

Also, any summary evaluation is likely to mask the variation in situations that was discussed in this report. The discussion not only shows the extent to which jurisdictions have different relative risks, but also demonstrates the importance of considering political and economic factors when designing future risk-reduction strategies. The current situation and future prospects for risk reduction are very different between "pacesetter" cities and "restrained" cities, and between "leading" counties and "rural" counties.

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