California Seismic Safety Commission Findings
Notes and Observations from the Nisqually Earthquake, February 28, 2001
Puget Sound Region, State of Washington
CSSC Publication No. 2001-03

On the cover clockwise from the top left.

Figure i Damaged dome of the Washington State Capitol Building in Olympia. Masonry columns supporting the dome shifted up to several inches. Building was temporarily closed and scaffolding erected for repairs. It has since reopened.

Figure ii The Fenix underground building in downtown Seattle after partial demolition removed additional brickwork.

Figure iii Closed 4th Avenue bridge in Olympia spanning across the Deschutes Parkway.

Figure iv Settlement along a closed roadway in the Deschutes Parkway.

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Executive Summary

A magnitude 6.8 earthquake occurred near Olympia, Washington on February 28, 2001. This was the largest earthquake to occur in near a urban area in the United States since the Northridge earthquake of 1994. The earthquake motion, depth, and duration of strong ground shaking, all contributed to a short duration low ground acceleration earthquake. The California Seismic Safety Commission (CSSC) and the Governor's Office of Emergency Service (OES) sent a team to interview the State of Washington Department of Emergency Management and the Department of Natural Resources regarding the earthquake, the response to the earthquake damage and recovery from the earthquake. The joint CSSC and OES team also observed damage to buildings as well as lateral spreading, liquefaction and earthquake induced landslides. Damage observed by the team tended to follow areas of poor soil conditions, loose, young alluvium or fill, combined with buildings or structures that were not built to current seismic codes.

This was the first federally declared disaster under the Bush Administration. Twenty-two counties and twenty-four Indian tribal nations were included in the declaration. A HAZUS computer run was initially conducted indicating that damage estimates would be around one billion dollars with some casualties. The HAZUS run was determined to have geologic information that was not representative of the earthquake and local soil conditions. HAZUS was run again and the estimate was increased to two billion dollars with casualties. The HAZUS results did not reflect the filed observations and damage results received by the Department of Emergency Management. As of July 30, 2001, FEMA had paid out $129.7 million in recovery aid to residents and business in Washington. The total financial impact of the earthquake is not yet known but is considered to be substantially less that what the HAZUS models results indicated. The amount of damage is approximately two to four per cent of the amount of damage from the Northridge earthquake. One person died from a heart attack and 400 persons were injured during the earthquake.

The main lesson learned from the event was that although the earthquake was moderate in size, (slightly larger than the Northridge earthquake) it did not seriously test the performance of buildings or infrastructure. The earthquake did test the effectiveness of local state and federal officials in dealing with an earthquake in a seismically active area (Western Washington and the Cascadia Subduction Zone) where great earthquakes have been known to occur.

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Purpose of California's Investigation in Washington

The Seismic Safety Commission and the Governor's Office of Emergency Services sent a team to collect information about public policy and earthquake response, recovery and mitigation.

The Nisqually earthquake was the first significant disaster under President Bush and FEMA Director Allbaugh, as well as the first since the passage of the Federal Disaster Mitigation Act of 2000. This earthquake provides California an opportunity to examine the latest local, state, and federal policies and disaster management tools in action.

Emergency response materials gathered included information on the use of the HAZUS 99 loss estimation model, and the use of SHAKE maps (a map showing the intensity of strong ground shaking, or acceleration or velocity near the epicenter of the earthquake) for initial estimates of areas likely to be damaged or to have undergone strong ground shaking.

Recovery information gathered included information on the interaction between the State of Washington Emergency Management Department and FEMA, the number of public assistance claims, and a description of the protocols followed to process such claims, the disposition of not for profit entities and public assistance fund availability, the amount of public assistance claims verses dollars available and the amount of damage initially projected by the HAZUS 99 model.

Mitigation information collected included an overview of pre-earthquake activities undertaken by the State and the city of Seattle (Seattle is a Project Impact city).

The information was gathered by John Rowden and Grace Koch from the Governor's Office of Emergency Services Hazard Mitigation Program, D.A. Christian, from the Governor's Office of Emergency Services Public Assistance Division, and Fred Turner and Robert Anderson of the California Seismic Safety Commission.

The Commission developed this report for use by Commissioners, its staff, and the Governor's Office of Emergency Services.

Introduction

The Nisqually earthquake was centered 11 miles northeast of Olympia and 50 miles southwest of Seattle. It occurred over the Juan de Fuca tectonic plate, which is moving under the North American plate in a process called "subduction (a process of one tectonic plate descending beneath an adjacent tectonic plate)."

The Cascadia Subduction Zone extends from Victoria Island, British Columbia southward to California's Cape Mendocino. It can produce similar earthquakes affecting California's northernmost counties of Del Norte, Humboldt, Trinity and Siskiyou.

The Cascadia Subduction Zone is also capable of generating very large, rare, so-called great (magnitude 8+) earthquakes. The last such know earthquake was a magnitude 9 event in January 1700, which generated a tsunami that was recorded in Japan.

Notes and Observations

A series of SHAKE maps were produced based upon data retrieved from the various strong ground motion nets. The SHAKE maps varied by period and as the seismic data was clarified.

A HAZUS 99 model run was produced using default soils parameters for the Olympia, Tacoma, and Seattle areas. Within hours of the earthquake, FEMA's new computer hazard simulation tool called HAZUS generated loss estimates of $1 billion with numerous casualties. The results of the model did not match (over predicted damage and loss of life) field observations. HAZUS was re-run with more realistic (but not necessarily correct) soils input and still the model over predicted the extent of damage. Later, more refined estimates grew to $2 billion with many more casualties. Based upon information generated by HAZUS, FEMA mobilized its resources anticipating much larger amounts of damage and casualties than actually occurred. The reasons for the high HAZUS results are:

- Default parameters used in early HAZUS estimates did not reflect the seismologic setting.
- HAZUS tends to overestimate the losses from small to moderate earthquakes as experienced after the September 2000 Napa Earthquake.

One major need that became apparent after the running of the HAZUS program was accurate information regarding soil velocities, composition, and profiles. This will enable future HAZUS users to better describe the input parameters applicable to the Olympia, Tacoma, and Seattle areas. The default geologic input parameters used in the first several HAZUS runs demonstrated that the HAZUS model is rightfully sensitive to alteration in the geologic input and that the use of the wrong input for event a low ground shaking event can generate damage and loss estimates that are unrealistically high. This problem can be compounded by persons not verifying data input and reacting to the damage and loss estimates prematurely. The revised Nisqually earthquake HAZUS input data set will also allow users to have an example of a moderately deep (subduction zone associated) earthquake instead of just shallow crustal earthquakes such as Loma Prieta or the Northridge earthquakes.

Impacts on Infrastructure

Power supplied via the Pacific Intertie from the Pacific Northwest to California was not diminished enough to affect electric service within California.

Electric service was interrupted to 217,000 customers in the Puget Sound (EERI 2001) area but was restored within one day to most of the affected customers. It is noted that the Bonnie power Administration had conducted a seismic retrofit of the 500 KvA electric transmission system prior to the earthquake. It is also noted that the ground motion and deformation associated with the earthquake were well below design levels for the electric transmission system and the earthquake did not serve as a test for the performance of the high voltage electric transmission system.

Some of low voltage transformers were observed in Olympia to be set upon a wooden platform between two poles. The transformers were not bolted to either the platform or to the poles. This arrangement was also observed in various places (by the Commission) in Adapazari, Turkey, where ground accelerations were higher than those found in Olympia. Many of the transformers in Turkey had fallen off of their platforms, making local power recovery more difficult. It is the recommendation of the Commission staff that the platform-mounted transformers be anchored.

Figure 1. ***Platform Mounted Transformers, Olympia, WA***

No significant damaged occurred to the water supply system. Damage that was reported was primarily associated with small-scale deformation of soils due to liquefaction.

Schools

One hundred-and-one schools and buildings had been retrofitted for structural components and seven had been retrofitted for non-structural components in the Seattle Public Schools District when the Nisqually earthquake occurred. None of the districts schools suffered significant structural damage. Non-structural damage to colleges and universities included toppling of bookcases and the localized flooding due to a ruptured water line. Some primary and secondary schools in Olympia and Seattle suffered limited structural (damaged beams and columns) and non-structural damage from strong ground shaking.

Figure 2 ***Sand Boil at Rail Road Track, Deschutes Parkway, Olympia, WA***

Geoscience Observations

Observations of the Deschutes Parkway along the shore of Capitol Lake in Olympia indicated that lateral spreading was prevalent along the western side south of the 4th Avenue Bridge. The parkway is out of service and is under assessment by the Washington Department of Transportation. Ground motions recorded in the vicinity of the Deschutes Parkway indicated a geometric mean peak horizontal ground acceleration of 0.34g (34% the acceleration of gravity). The highest recorded geometric mean peak horizontal acceleration was 0.36g and was recorded at Seward Park, in Seattle. The soil type at the Deschutes Park way is a NEHRP classification S_E. The railway along the Deschutes Parkway and Marathon Park had several soil boils of approximately 4 to 6 inches in diameter. The railway was out of service at the Parkway.

Nisqually verses Northridge earthquakes

The following notes provide an overview comparing and contrasting the Nisqually and Northridge earthquakes:

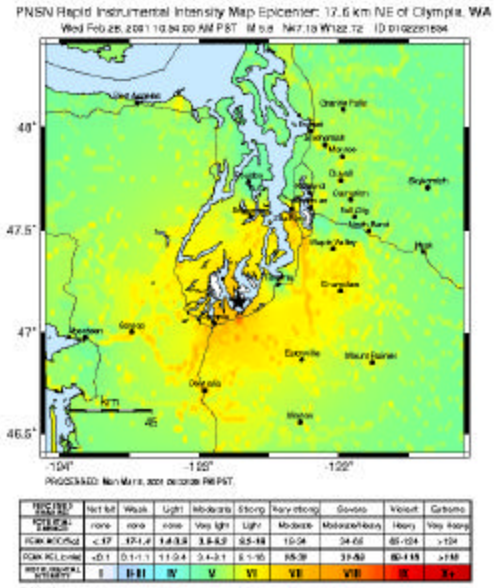
- The Nisqually earthquake released slightly more energy than the Northridge earthquake (M_w 6.8 and M_w 6.7).
- The different depths of the origin of the earthquakes lead to significantly higher ground motions recorded in the

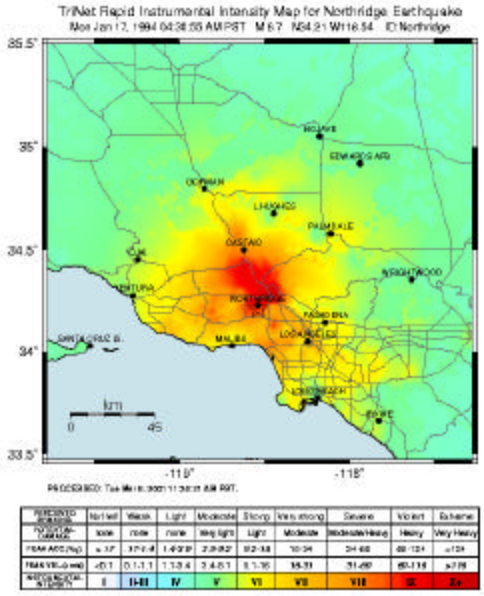
Northridge earthquake (19km [shallow] verses 52km [moderate] depth) for the Nisqually earthquake.

- The low ground accelerations associated with the Nisqually earthquake did not approach the design level of buildings designed to comply with the 1997 Uniform Building Code mainly because the ground accelerations and the degree of strong ground shaking was low (0.34g and a maximum Modified Mercalli Intensity value of VII). Buildings were subjected to high ground accelerations and severe ground shaking during the Northridge earthquake (0.91g) and a Modified Mercalli Intensity locally of VIII and IX).
- Shallower earthquakes like Northridge cause significantly higher intensities of shaking at the surface.
- The Nisqually earthquake occurred along a normal fault. The Northridge earthquake occurred on a thrust fault. Thrust fault earthquakes are generally more intense than normal fault earthquakes of the same size and depth.
- Soil conditions in the Puget Sound region are considerably different than in Southern California. The Puget Sound area is characterized by stiffer rock and shallower glaciated soils with considerably smaller percentages of land with soft soils compared to the San Fernando Valley.
- Both events were "blind," that is faulting did not rupture the surface.
- The Northridge earthquake area experienced aftershocks for many months after the mainshock. The largest Northridge earthquake aftershock was a M_W 5.9 event (an earthquake the size of the 1987 Whittier Narrows, California earthquake). There have been eight magnitude 5 or greater aftershocks from the Northridge earthquake.
- The Nisqually earthquake has generated few significant (magnitude 3+ aftershocks). The largest Nisqually earthquake aftershock occurred on June 10, 2001, and was a magnitude 5.0 event.
- Earthquake induced landslides were relatively few compared to the Northridge earthquake. This may be due to the low ground acceleration and the relatively dry soils.
- Scattered, life-threatening damage occurred to generally only the most vulnerable unreinforced brick buildings on soft soils. Modified Mercalli Intensities did not appear to exceed VII.
- The economic loss from the Northridge earthquake is approximately $40 Billion while the Nisqually earthquake is approximately $0.75 Billion.
- Only one person died during the Nisqually earthquake while 57 persons died as a result of the Northridge earthquake.
- 400 persons were injured in the Nisqually earthquake while 9,000 persons were injured during the Northridge earthquake.

- One of the most important observations for both the Northridge and Nisqually earthquakes is that neither earthquake was a major earthquake. Both the Puget Sound Area and portions of California are at risk from magnitude 7 to 9 earthquakes. One side observation is that for a major earthquake, such as the Chi Chi, Taiwan (M_W 7.6) earthquake of 1999 (with aftershocks from magnitude 6.2 to 6.8) or the Arequipa, Peru (M_W 8.4) earthquake of 2001 (with aftershocks of 6.6, 6.8 and 7.2), is that aftershocks from a major or great earthquake maybe as large or larger than either the Northridge or Nisqually earthquakes.

Figure 3 Comparisons of Nisqually and Northridge Earthquake SHAKE Maps





Legislative Actions

The total federal disaster recovery costs are estimated to be $322 million excluding damage to roads and highway under the jurisdiction of the Federal Highway Administration. The federal share of the non-highway recovery is estimated to be $246 million and the non-federal share is estimated to be $76.5 million.

The state legislature, the capitol, and the Governor's mansion were evacuated during/shortly after the earthquake. The State is prepared to pay one half of the non-federal share for cost of repairs for public assistance projects approved by FEMA.

Aside from the cost sharing for non-federal recovery expenses, there was little additional interest in earthquake recovery or mitigation at the State level and as of June 30, 2001, there had been no formal legislative briefings regarding the Nisqually earthquake. It is also important to note that the Nisqually earthquake occurred approximately one day before S 424 (Feinstein) was introduced to the United States Senate. The bill was not a direct result of the Nisqually earthquake, but was in the development stage for quit some time before the earthquake.

If S 424 is enacted into law, significant seismic retrofit financial incentives will be made available to both the public and to non-profit public organizations. At the request of the congressman from the Olympia area Dr. Steve Palmer from the Washington State Department of Natural Resources gave testimony to the United States Congress on the Nisqually earthquake. Dr. Palmer's testimony was given three weeks after the introduction of S 424 to the Congress. It is noted that no new major research and mitigation funding initiatives such as Washington's financial interests in PEER were manifested after the Nisqually earthquake.

Post-Earthquake Information Clearinghouse

The Clearinghouse established after the Nisqually earthquake created several new precedences that may influence how California organizes its Clearinghouses after future earthquakes: 1) The first major use of the Internet and e-mail for sharing information; 2) The first Clearinghouse to receive specific funding from both the Federal Emergency Management Agency ($50,000 approx.) and the Pacific Earthquake Engineering Research Center ($10,000 approx.); and 3) First to remain operational more than five months after the event while transitioning from collecting perishable data in the first few days to compiling other remotely-gathered systematic data in the later months.

This third precedence suggests a major shift in the future role of clearinghouses. The Northridge Earthquake Clearinghouse lasted only 14 days. Typically Clearinghouses after prior, smaller California earthquakes lasted one to seven days and focused only on gathering perishable data. With the development of HAZUS and other recent interest in systematically collecting earthquake data to provide a statistics for performance-based earthquake engineering, California should anticipate the need to fund and staff longer-term Clearinghouses.

Figure 4 ***Starbuck's Corporate Headquarters Under Repair, Seattle, WA***

Washington has received 300 project worksheets that are initial requests for public assistance and expects an additional 1000 worksheets in the coming months.

FEMA adopted somewhat different policies regarding eligibility for federal assistance compared to its policies in 1994. Some differences reflect the passage of time since the Northridge Earthquake. Other changes reflect climatic or regional differences.

For example, after recent California earthquakes, FEMA did not regard chimney repairs as eligible for Individual Assistance grants. However, after the Nisqually Earthquake, FEMA ruled that, if an owner can demonstrate that a fireplace is used as a primary source of heat, chimney repairs are eligible.

A recurring message relayed to Washington public assistance officials was that FEMA would no longer regard various

losses as eligible for federal funds "because of the Northridge Earthquake." Washington officials were taking these statements for granted. However, Washington officials within the Emergency Management Division were not that familiar with what transpired in California back in 1994. The lesson here is that both states can benefit from maintaining strong communication ties to take full advantage of the latest FEMA policies and to ensure consistency. It is noted that as of July 30, 2001, FEMA paid $129.7 million in recovery aid for damages from the Nisqually earthquake to residents and businesses.

Nisqually was the first major disaster to use the National Emergency Management Information System (NEMIS), a computer database for compiling the response and recovery process. Significant lessons are now being integrated into California OES as a result of Washington's experience with NEMIS.

Mitigation-Related Observations:

Initial estimates of the large dollar losses generated great statewide interest in the potential for FEMA-funded hazard mitigation grants after Nisqually. Washington's Hazard Mitigation Grant Program received 370 letters of interest proposing $427 million in projects. However, the Program now has only about $26 million in expected funds, so they plan to limit funding for multi-hazard mitigation to up to five projects and $2.6 million per community statewide. This disbursement policy will benefit smaller communities to a greater degree than larger communities like Seattle and Olympia. The Program is expected to last six years and require $2 million to manage.

The Disaster Mitigation Act of 2000 increased Hazard Mitigation Grant funds up to 20 percent – up from 15% under the previous Stafford Act. However, FEMA is arguing that, since it hasn't yet developed regulations for the new law, Washington is still only entitled to 15%. As a result, Washington is now disagreeing with this ruling. This issue and other appeals regarding FEMA policies will likely have relevance to future California dealings with FEMA.

Human Response

Nisqually was the first modern U.S. earthquake to occur during school hours. Reports were that drop, cover, and hold responses by school children were well executed. In contrast, occupants of the damaged State Capitol fled the building. Perhaps training of adults to drop, cover, and hold, could also help save lives in future events.

One of the State of Washington's strengths is their state reservists program. The Emergency Management Division relies on a cadre of retired state workers to augment their small, permanent staff.

The reservists are a pool of trained Emergency Management Division staff (such as engineering, building inspectors, and emergency responders) that are activated and deployed during an emergency such as a flood or earthquake. California has a less developed resource of reservists. OES representatives recognized the benefits of Washington's reservists program and plan to explore the feasibility of enhancing California's pool of reservists.

Recommendations

The following recommendations are based upon Commission and OES observations related to the Nisqually earthquake:

1. **Improve decisions based on multiple measures of earthquakes.** The magnitude of an earthquake should not be used as a sole decision parameter. Instead, emergency responders should make decisions for allocating resources after considering other information including SHAKE maps, ground shaking intensities, accelerations, velocities, and deformations, HAZUS

estimates, media reports, and initial damage and casualty reports.

2. **Use HAZUS with caution.** Most of California must still rely on default data within HAZUS that can produce unrealistic dollar loss and casualty estimates. California's state and local agencies should continue to enhance HAZUS databases with best available information as well as train personnel in its proper use. HAZUS output should be compared and recalibrated with systematically collected data after future earthquakes.
3. **Expand the use of trained reservists to supplement state and local government response and recovery personnel.** Engineer, building inspector, and emergency responder retirees and volunteers provide a resource that can help speed recovery. Agencies should spend time before disasters to identify and train such personnel.
4. **Establish and use formal mutual aid agreements between states.** These would facilitate sharing of intelligence, resources and personnel, as well as speed recovery and provide training opportunities after future events.
5. **Establish protocols for future Post-Earthquake Information Clearinghouses.** Funding commitments from multiple beneficiaries, scopes of work, and termination protocols would help ensure the effectiveness of future intelligence-gathering activities.
6. **Ensure timeliness of future Seismic Safety Commission investigations.** Visits to damaged regions should ideally occur within three to six months after earthquakes that are likely to be relevant to California's policies. This would allow for the Commission to assess information gathered by others during earlier reconnaissance efforts, as well as allow time for policy changes to materialize.

Acknowledgements

The Commission would like to thank Mr. Timothy Walsh and Dr. Steven Palmer from the Washington Department of Natural Resources, Mr. Marty Best, Mr. George Crawford, and Ms. Donna Voss from the Washington Emergency Management Department, and Dr. Bill Steele from the University of Washington for sharing their experiences with OES and Commission staff.

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