Introduction

Earthquakes are described as the sudden release of energy occurring from the collision of crustal plates on the earth's surface or from the fracture of stressed rock formations in that crust. Though it can be said that there are many technical differences in the rocking, rolling, jarring and jolting felt during an earthquake, they can be devastatingly damaging and seriously unnerving.

King County is geographically located in an area known as the Pacific Ring of Fire. The same geological events that result in volcanic activity also generate notable earthquakes. Washington State is framed by the Pacific, North American, and Juan de Fuca plates, segments of the earth's crust. A significant number of active fault lines or cracks in that crust have been identified in the central Puget Sound area including Seattle and King County. On an annual basis, thousands of minor earthquake events occur in the greater Puget Sound Region.[1]

King County has a long history of documented earthquake activity. The most recent significant activity was the Nisqually Earthquake of February 28, 2001. This earthquake, 10 miles northeast of Olympia in Thurston County (over 40 miles from Seattle), resulted in statewide losses exceeding $1 billion and injured 700 people, many in King County.[2]

High Probability Low Impact	**High Probability Moderate Impact**	**High Probability High Impact**
Moderate Probability Low Impact	**Moderate Probability Moderate Impact**	**Moderate Probability High Impact**
Low Probability Low Impact	**Low Probability Moderate Impact**	**Low Probability High Impact**

Earthquake Probability vs. Earthquake Impacts

Hazard Identification

Most earthquakes go unnoticed by the residents of King County; significant numbers of 'dish rattlers' occur on a regular basis to remind people of their vulnerability. Some people and animals are more sensitive to these minor events than others. Usually, it requires a magnitude of 2.5-3.0 for a local shaker to be noticed. These happen on a fairly frequent basis (see "History of Events"). Direct impacts from earthquakes may include damages to structures like buildings, pipelines, roadways, and bridges. Secondary impacts from earthquakes are common. These can include tsunamis, seiches, and

landslides. A slide in King County generated from the Nisqually Earthquake partially blocked the Cedar River – flooding several homes. Evidence of tsunami/seiche activity and major landslides has been identified from a 7.0 earthquake in Puget Sound around 900 A.D.

There are at least five active fault lines (crustal cracks) in the Puget Sound lowlands, any of which may impact King County. These are the Tacoma fault, Seattle fault, Darrington-Devil's Mountain fault, Utsalady Point fault, and southern Whidbey Island fault.[3] Many of these faults run east-west and extend for over 20 miles in length.

There are three technically distinct types of earthquakes: interplate or benioff zone earthquakes, subduction or interplate zone, and shallow crustal earthquakes. Each can generate powerful damaging motion in the greater Puget Sound area.[4]

Interplate or Benioff Zone Events[2]

These earthquakes occur at depths of 15 to 60 miles from the subducting Juan de Fuca plate. Examples of this type of damaging event include the Olympia earthquake in 1949, 1965 Seattle/Tacoma earthquake, 1999 Satsop earthquake and 2001 Nisqually earthquake. Depending on your location shaking could be felt for 15-40 seconds.

Subduction Zone Events[2]

Subduction zone events occur along the interface between tectonic plates. The energy generated from the collision of the Juan de Fuca, Pacific, and North American plates is considerable. These great magnitude events can reach 8.0 to 9.0 on the Richter scale.

Shallow Crustal Earthquakes[2]

Shallow earthquake events occur within 20 miles of the earth's surface. These are fairly common events with typical magnitudes of up to 5.5, though there is some evidence that a number of shallow events have exceeded this figure.

History of Events

The State of Washington has experienced 20 damaging earthquake events in the last 125 years. Most of these have been in western Washington[5]. The Seattle-Tacoma earthquake and the recent Nisqually earthquake type of events seem to reoccur about every 30 to 35 years, while a 1949 Olympia type event occurs about once every 110 years.

Subduction earthquakes do not recur based on anticipated time frames; events can be spaced anywhere from 100 to 1,100 years apart. The latest recorded subduction earthquake event in Washington State occurred in 1700.[6]

Table 5-8: Earthquake Events Felt or Impacting King County[7]

Date	Magnitude	Location
April 1945	5.7	12.5 km SSE of North Bend
February 1949	7.1	12.3 km ENE of Olympia
April 1965	6.5	18.3 km N of Tacoma
January 1995	5.0	17.5 km NNE Tacoma
July 1996	5.4	8.5 km ENE of Duvall
November 1996	2.9	Puget Sound
February 1997	3.0	SE of Seattle
April 1997	4.9	Puget Sound off Vashon Island
June 1997	2.7	Puget Sound
July 1997	3.1	Duvall
February 1998	2.9	NE of Seattle
March 1998	3.1	Pierce County
March 1998	2.9	Skykomish
July 1999	3.9	Tacoma
February 2001	7.2	Nisqually – Olympia
May 2002	4.2	Friday Harbor, San Juan Islands
May 2003	3.7	Bremerton, Kitsap County

Olympia Earthquake – April 1949[8]

The 7.1 magnitude earthquake was centered along the southern edge of Puget Sound. Eight people were killed and property damage in Olympia-Tacoma-Seattle amounted to about $25 Million in 1949 dollars. In Seattle, a sixty-inch water main ruptured, a radio tower collapsed, power lines and gas lines were broken in over 100 places. Three damaged schools needed to be demolished and one rebuilt.

Seattle-Tacoma Earthquake – April 1965[2]

At magnitude 6.5, the earthquake killed seven people and caused $12.5 Million in damage (1965 dollars). Severe shaking was felt in Seattle and as far east as Issaquah. Most damage was in the Pioneer Square area and waterfront. Older masonry buildings were most impacted. Damage patterns experienced in 1949 were repeated. Eight schools were closed for inspections and repairs; two were severely damaged. Areas along the Duwamish River experienced severe settling. Three water mains failed in Seattle.

Nisqually Earthquake – February 2001[9,10]

The 6.8 magnitude earthquake was centered under Anderson Island in south Puget Sound. Soil geology resulted in the most extensive damage occurring along the I-5 corridor, not around the epicenter. This pattern was the result of soft river bottom sediments (heavier damage) and improvements in building standards (lesser damage). Some damage was experienced in 300,000 households, many from settling foundations. Buildings built prior to 1950 located in the south downtown area and Pioneer Square in Seattle were the most impacted; structural damage to chimneys, walls, foundations and non-structural elements accounted for two-thirds of all damage reported.

Damages to airport runways and towers were significant and there were temporary closures of the SeaTac International and King County Airports as a result. The Alaskan Way viaduct and Magnolia bridges were both closed until repairs were done. Of the 290 dams inspected by state engineers, only five had earthquake-related damage. A hillside collapse blocked the flow of the Cedar River; this resulted in flooding that impacted several homes along the river that were otherwise untouched by the earthquake shaking.

Hazard Impacts

The impacts to a community from earthquake events include injuries to citizens and public safety officials, damage to property, lost revenue and economic damages, increased demand on public safety and infrastructure related services. Damage projections for a 6.7 magnitude earthquake centered in King County might damage more than 58,000 structures, displace 55,000 households, and result in up to 2,400 deaths and 800 injuries. These damages and impacts to the economy could reach $36 Billion.[11] Washington State ranks second only to California among states susceptible to earthquake damages.[12] Nationally, Seattle might incur the seventh largest potential dollar damages/losses.[2]

Populations and Economy at Risk

According to the 2000 US Census, King, Snohomish, Pierce, and Kitsap Counties are home to more than 60 percent of the state's population and much of its economic base.[13] Most vulnerable of these are non-English speaking individuals, people with disabilities, senior citizens, and people living in poverty, and school-age children. Older homes are also at greater risk of incurring damage from an earthquake.

Table 5-9: Vulnerable Population Groups						
Jurisdiction	**Non-English Speaking**	**Disabled**	**Over Age 65**	**Poverty**	**K-12 Students**	**Homes Over 40 Years Old**
King County	18.4%	15.1%	10.5%	6.4%	16.6%	33.5%
Washington State	14.0%	17.7%	11.2%	10.6%	19.1%	29.4%
Source: U.S. Census Bureau, Profile of Selected Social Characteristics: 2000, and Profile of Housing Characteristics: 2000.						

The King County Emergency Operations Center (EOC) becomes activated for earthquake events to coordinate damage assessment, information, response activities, and to insure continuity of government operations. Response activities include unanticipated overtime for EOC activations, evacuations, sheltering of displaced people, rerouting traffic destined for impassible roads, bridge and road damage repairs, and rescue or medical missions.

Not all earthquake events are eligible for federal assistance to public agencies. For this reason alone, mitigation efforts to minimize the impacts of earthquakes in King County can save a considerable amount of public moneys needed to repair damage from modest-sized events. The following list of presidential disaster declarations were associated with listed King County earthquake events above.

Table 5-10: FEMA Earthquake Disasters in King County		
No.	**Dates**	**King County Public Damage (FEMA or Congress Approved)**
*	April 1949	$25 Million (1949 dollars)
*	April 1965	$12.5 Million (1965 dollars)
1361	February 2001	$155.9 Million FEMA $84.3 Million SBA $93.8 Million US DOT
**FEMA was established in 1978*		

Often, Small Business Administration (SBA) loans are available to individuals and businesses that qualify without a presidential declaration of disaster.

Past Mitigation Efforts

The United States has been a world front-runner in mitigation efforts related to natural disasters. The advent of United States building codes, zoning codes, research on liquefaction areas and ground shaking, building retrofitting, non-structural mitigation/tie-downs, public education, drop-cover-and-hold exercises,

and public television specials have dramatically reduced the impact to property, injuries and economic damage. When the United States is compared to countries that do not have these codes and standards (e.g., Turkey, Iran, and Pakistan) the earthquake disaster results are dramatically different.

Earthquake Endnotes:

[1] *Washington State 2001 Hazard Identification and Vulnerability Assessment*, Washington State Military Department, Emergency Management Division, April 2001.
[2] Ibid.
[3] *Late Holocene displacement on the Southern Whidbey Island fault zone, northern Puget lowland, Washington*. 2001. U.S. Department of the Interior, U.S. Geological Survey. 2 Oct. 2003 http://erp-web.er.usgs.gov/reports/abstract/2000/pn/00HQGR0067.pdf.
[4] *Earthquake Hazards in Washington and Oregon – Three Source Zones*. U.S. Department of the Interior, U.S. Geological Survey. 2 Oct. 2003 http://www.ess.washington.edu/SEIS/PNSN/CascadiaEQs.pdf. http://www.psrc.org/datapubs/census2000/pl94-171/pl_report.pdf.
[5] *Earthquakes in Washington*. 13 Jul. 2001. Washington State Department of Natural Resources Division of Geology and Earth Resources. 5 Oct. 2003 http://www.dnr.wa.gov/geology/hazards/equakes.htm.
[6] *Earthquake Hazards in Washington and Oregon – Three Source Zones.* U.S. Department of the Interior, U.S. Geological Survey. 2 Oct. 2003 http://www.ess.washington.edu/SEIS/PNSN/CascadiaEQs.pdf.
[7] *Map and List of selected significant quakes in WA and OR*. 27 Mar. 2003. The Pacific Northwest Seismograph Network, University of Washington Department of Earth and Space Sciences. 5 Oct. 2003 http://www.ess.washington.edu/SEIS/PNSN/INFO_GENERAL/hist.html.
[8] *Earthquake History of Washington*. 5 Aug. 2003. U.S. Department of the Interior, U.S. Geological Survey. 5 Oct. 2003 http://neic.usgs.gov/neis/states/washington/washington_history.html.
[9] *Hazard Mitigation Survey Team Report, Nisqually Earthquake, February 28, 2001, DR-1361-WA*, Federal Emergency Management Agency and Washington Military Department, Emergency Management Division
[10] *The Nisqually Earthquake of 28 February 2001, Preliminary Reconnaissance Report*, Nisqually Earthquake Clearinghouse Group, University of Washington, March 2001.
[11] Preliminary Estimates of Damages and Loss from a run of HAZUS 99-SR2 by Kircher Associates Consulting Engineers for the Seattle Fault Scenario project funded in part by the EERI Foundation, May 2003. The figures developed from a Level 1 analysis of HAZUS default data adjusted for the year 2005 for a five county region – King, Kitsap, Pierce, Snohomish, and Thurston Counties.
[12] *HAZUS 99 Estimated Annualized Earthquake Losses for the United States*. Feb. 2001. Federal Emergency Management Agency. 5 Oct. 2003 http://www.fema.gov/hazus/pdf/eq_ael.pdf.
[13] *2000 Census P.L. 94-171 Restricting Data*. Aug. 2001. Puget Sound Regional Council. 5 Oct. 2003