REGION 6
Central Oregon[1]
Hazards Assessment

[1] Crook, Deschutes, Jefferson, Klamath, Lake, and Wheeler counties

DROUGHT

Characteristics and Brief History

Droughts are not uncommon in the State of Oregon, nor are they just an "east of the mountains" phenomenon. They occur in all parts of the state, and in both summer and winter. They appear to be cyclic and they can have a profound effect on the state's economy, particularly the hydro-power and agricultural sectors. The environmental consequences also are far-reaching, including insect infestations in Oregon forests and the insufficient stream flows to support endangered fish species. Severe drought conditions preceded the four disastrous Tillamook fires (1933, 1939, 1945, 1951) and pitted farmers against fish propagation groups during the Klamath Basin drought of 2001. The minimum drought loss included about 1200 jobs and $150 million dollars in goods and services. Local farmers maintain that the cost was considerably more. Water allocation continues to be controversial. In recent years, the State has addressed drought emergencies through the Oregon Drought Council. This interagency (state / federal) council meets to discuss forecasts and advise the Governor as the need arises. Significant Oregon droughts are listed in Table 1.

Recurrence

Oregon's drought history reveals many short-term and a few long-term events. The average recurrence interval for severe droughts in Oregon is somewhere between 8 and 12 years. Table 1 provides an overview of some severe droughts in Oregon.

TABLE 1. SIGNIFICANT DROUGHTS

DATE	DESCRIPTION
1904-1905	A statewide drought period of about 18 months
1917-1931	A very dry period throughout Oregon, punctuated by brief wet spells in 1920-21 and 1927
1939-1941	A three-year intense drought in Oregon
1959-1964	Primarily affected eastern Oregon
1985-1997	Generally a dry period, capped by statewide droughts in 1992 and 1994
2000-2001	Klamath drought intensifies; Low snow pack in mountains worsens conditions Draw down at Detroit Lake, Oregon, all but curtails lake recreation

Source: Taylor, George H., and Ray Hatton, 1999, *The Oregon Weather Book*.

Vulnerability

The probability that Region 6 will experience drought and the region's vulnerability to their effects are depicted in Table 2 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 2. Vulnerability and Probability Assessment of Drought

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	H	H	H	H	M	H
Probability	H	H	H	H	H	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

EARTHQUAKES

Characteristics and Brief History

The geographical position of this region makes it susceptible to earthquakes from four sources, though expert opinions vary regarding the degree of susceptibility from each. These four sources are: (1) the off-shore Cascadia Fault Zone, (2) deep intra-plate events within the subducting Juan de Fuca plate, (3) shallow crustal events within the North America Plate, and (4) earthquakes associated with renewed volcanic activity. All have some tie to the subducting or diving of the dense, oceanic Juan de Fuca Plate under the lighter, continental North America Plate. In the "Basin and Range" area in the southern part of the region (Klamath and Lake counties) earthquakes are also associated with extension (pulling apart of the crust). Stresses occur because of these movements. There also appears to be a link between the subducting plate and the formation of volcanoes some distance inland from the off-shore fault zone

When crustal faults slip, they can produce earthquakes with magnitudes (M) up to 7.0 and can cause extensive damage, which tends to be localized in the vicinity of the area of slippage. Deep intraplate earthquakes occur at depths between 30 and 100 kilometers below the earth's surface. They occur in the subducting oceanic plate and can approach M7.5. Subduction zone earthquakes pose the greatest hazard. They occur at the boundary between the descending oceanic Juan de Fuca Plate and the overriding North American Plate. This area of contact, which starts off the Oregon coast, is known as the Cascadia Subduction Zone (CSZ). The CSZ could produce a local earthquake up to 9.0 or greater.

Central Oregon includes portions of five physiographic provinces (High Cascades, Blue Mountains, Basin and Range, High Lava Plains, and Deschutes-Columbia Plateau). Consequently, its geology and earthquake susceptibility varies considerably. There have been several significant earthquakes that have been centered in the region, all in Klamath and Lake counties: 1906 north of Lakeview, 1920 Crater Lake, 1923 Lakeview area, 1958 Adel (M4.5), 1968 Adel swarm (4.7-5.1) and the 1993 Klamath County earthquakes (M5.9 and 6). There are also numerous identified faults in the region (mostly Lake and Klamath counties) that have been active in the last 20,000 years. The region has also been shaken historically by crustal and intraplate earthquakes and prehistorically by subduction zone earthquakes centered outside the area (Table 3). All considered, there is good reason to believe that the most devastating future earthquakes would probably originate along shallow crustal faults in the region.

Earthquake associated hazards include severe ground shaking, liquefaction of fine-grained soils, and landslides. The severity of these effects depend on several factors, including the distance from the earthquake source, the ability of soil and rock to conduct seismic energy and the degree (angle) and composition of slope materials.

Earthquakes produced through volcanic activity could reach magnitudes of M5.2. However the Cascade volcanoes are some distance away from populated centers, which tends to lessen the concern.

Earthquake risk in Region 6 is reflected in the Uniform Building Code's (UBC) earthquake hazard maps (i.e., seismic zones 1-4). The higher the numerical designation, the more stringent the building standards become. Region 6 is within UBC Seismic Zone 2b, except for Klamath County, which is in Zone 3.

TABLE 3. SIGNIFICANT EARTHQUAKES

DATE	LOCATION	MAGNITUDE (M)	REMARKS
Approximate Years 1400 BCE* 1050 BCE 600 BCE 400 CE 750 CE 900 CE	Offshore, Cascadia Subduction Zone	Probably 8-9	Based on studies of earthquake and tsunamis at Willapa Bay, Washington. These are the mid-points of the age ranges for these six events. * BCE: Before the Common Era
January, 1700	Offshore, Cascadia Subduction Zone	Approximately 9.0	Generated a tsunami that struck Oregon, Washington, and Japan; destroyed Native American villages along the coast
April, 1906	N of Lakeview	V	Three felt aftershocks
April, 1920	Crater Lake	V	One of three shocks
January, 1923	Lakeview	VI	
March, 1958	SE of Adel	4.5	
May-June, 1968	Adel	4.7-5.1	Damage to homes. Twenty earthquakes of M4.0 or greater were recorded between 05/28/68 and 06/24/68. Shallow crustal
September, 1993	Klamath Falls	5.9 and 6.0	Series of earthquakes, the largest being M 6.0. Considerable damage in and around Klamath Falls. Two earthquake-related fatalities (rock fall on highway and heart attack).

Source: Wong, Ivan and Bolt, Jacqueline, November 1995, A Look Back at Oregon's Earthquake History, 1841-1994, *Oregon Geology,* p.125-139.

Probability

The Cascadia Subduction Zone generates an earthquake on average every 500-600 years. However, as with any natural process, the average time between events can be misleading. Some of the earthquakes may have been 150 years apart with some closer to 1,000 years apart.[2] Establishing a probability for crustal earthquakes is difficult given the small number of historic events in the region. Earthquakes generated by volcanic activity in Oregon's Cascade Range are possible, but likewise unpredictable.

[2] DOGAMI Special Paper 29: Earthquake Damage in Oregon, p.3.

Vulnerability

Region 5 is vulnerable to earthquake-induced landslides and strong ground shaking, specifically in Lake and Klamath counties.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has developed two earthquake loss models for Oregon based on the two most likely sources of seismic events: (1) the Cascadia Subduction Zone (CSZ), and (2) combined crustal events (500-year model). Both models are based on HAZUS, a computerized program, currently used by the Federal Emergency Management Agency (FEMA) as a means of determining potential losses from earthquakes. The CSZ event is based on a potential 8.5 earthquake generated off the Oregon coast. The model does not take into account a tsunami, which probably would develop from the event. The 500-year crustal model does not look at a single earthquake (as in the CSZ model); it encompasses many faults, each with a 10% chance of producing an earthquake in the next 50 years. The model assumes that each fault will produce a single "average" earthquake during this time. Neither model takes unreinforced masonry buildings into consideration.

DOGAMI investigators caution that the models contain a high degree of uncertainty and should be used only for general planning purposes. Despite their limitations, the models do provide some approximate estimates of damage. Results are found in table 4-6.

TABLE 4. PROJECTED DOLLAR LOSSES BASED ON A M8.5 SUBDUCTION EVENT AND A 500-YEAR MODEL

REGION 6 COUNTIES	ECONOMIC BASE IN THOUSANDS (1999)	GREATEST ABSOLUTE LOSS IN THOUSANDS (1999) FROM A M 8.5 CSZ EVENT	GREATEST ABSOLUTE LOSS IN THOUSANDS (1999) FROM A 500-YEAR EVENT
CROOK	$733,000	Less than $1,000	$6,000
DESCHUTES	$4,673,000	$5,000	$71,000
JEFFERSON	$707,000	Less than $1,000	$14,000
KLAMATH	$3,134,000	$41,000	$939,000
LAKE	$393,000	Less than $1,000	$40,000
WHEELER	$82,000	Less than $1,000	$1,000

Source: DOGAMI, 1999, Special Paper 29: Earthquake Damage in Oregon.

TABLE 5. ESTIMATED LOSSES ASSOCIATED WITH A M 8.5 SUBDUCTION EVENT

REGION 6 COUNTIES	CROOK	DESCHUTES	JEFFERSON	KLAMATH	LAKE	WHEELER
INJURIES	0	1	0	14	0	0
DEATHS	o	0	0	0	0	0
DISPLACED HOUSEHOLDS	0	0	0	37	0	0
ECONOMIC LOSSES FOR BUILDINGD	$156,000	$5 million	$764,000	$41 million	$231,000	$11,000
OPERATIONAL THE DAY AFTER THE EVENT						
Fire stations	96%	100%	100%	99%	100%	No data
Police stations	96%	99%	100%	99%	100%	No data
Schools	97%	99%	99%	97%	99%	100%
Bridges	100%	100%	100%	98%	100%	100%
ECONOMIC LOSSES TO INFRASTRUCTURE						
Highways	$6,000	$17,000	$9,000	$339,000	$32,000	$5 million
Airports	0	$40,000	0	$642,000	$96,000	$8 million
Communications	$8,000	$2,000	0	$141,000	$10,000	$946,000
DEBRIS GENERATED (thousands of tons)	0	3	1	28	0	247

Source: DOGAMI, 1999, Special Paper 29: Earthquake Damage in Oregon.

TABLE 6. ESTIMATED LOSSES ASSOCIATED WITH A 500-YEAR MODEL[1]

REGION 6 COUNTIES	CROOK	DESCHUTES	JEFFERSON	KLAMATH	LAKE	WHEELER
INJURIES	1	17	7	630	19	0
DEATHS	0	0	0	12	0	0
DISPLACED HOUSEHOLDS	0	5	12	1,409	18	0
ECONOMIC LOSSES FOR BUILDINGS[2]	5.5 million	$71 million	$14 million	$939 million	$40 million	$708,000
OPERATIONAL THE DAY AFTER THE EVENT Fire stations Police stations Schools Bridges	N/A[3] N/A N/A N/a	N/A N/A N/A N/A	N/A N/A N/A N/A	N/A N/A N/A N/A	N/A N/A N/A N/A	N/A N/A N/A N/A
ECONOMIC LOSSES TO INFRASTRUCTURE Highways Airports Communications	$879,000 $316,000 $18 million	$572,000 $2 million $1 million	$698,000 $395,000 $104,000	$28 million $15 million $14 million	$20 million $8 million $4 million	$338,000 $688,000 $123,000
DEBRIS GENERATED (thousands of tons)	0	47	10	610	30	0

Source: DOGAMI, 1999, Special Paper 29: Earthquake Damage in Oregon.

Table 6 Notes:

[1]Every part of Oregon is subject to earthquakes. The 500-year model is an attempt to quantify the risk across the state. The estimate does not represent a single earthquake. Instead, the 500-year model includes many faults, each with a 10% chance of producing an earthquake in the next 50 years. The model assumes that each fault will produce a single "average" earthquake during this time. More and higher magnitude earthquakes than used in this model may occur (DOGAMI, 1999).

[2] "…there are numerous un-reinforced masonry structures (URMs) in Oregon, the currently available default building data does not include any URMs. Thus, the reported damage and loss estimates may seriously under-represent the actual threat" (page 126 – 1998, DOGAMI)

[3]NA - Because the 500-year model includes several earthquakes, the number of facilities operational the "day after" cannot be calculated

The probability that Region 6 will experience earthquakes and the region's vulnerability to their effects are depicted in Table 7 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 7. Vulnerability and Probability Assessment of Earthquakes

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	H	H	H	H	H	M
Probability	M	L	L	M	M	L

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

FIRES IN THE WILDLAND/URBAN INTERFACE

Characteristics and Brief History

Oregon has a very lengthy history of fire in undeveloped wildland and in the developing urban/wildland interface. In recent years, the cost of fire suppression has risen dramatically, a large number of homes have been threatened or burned, more fire fighters have been placed at risk, and fire protection in wildland areas has been reduced. These things prompted the passage of Oregon Senate Bill (SB) 360 (Forestland / Urban Interface Protection Act, 1997). SB 360: (1) establishes legislative policy for fire protection, (2) defines urban/wildland interface areas for regulatory purposes, (3) establishes standards for locating homes in the urban/wildland interface, and (4) provides a means for establishing an integrated fire protection system. Table 8 describes some of the significant wildfires that have occurred in Region 6.

TABLE 8. Significant Wildfires

Year	Name of Fire	Location	Acres Burned	Remarks
1981	Redmond			State Conflagration Act Fire
1984	Crooked River Ranch			State Conflagration Act Fire
1985	Crooked River Ranch			State Conflagration Act Fire
1990	Delicious	Deschutes	1704	
1990	Awbrey Hall	Deschutes	3,400	This fire was an act of arson that affected the western fringe of Bend.
1992	Hanes Butte	Deschutes	348	
1992	Sage Flat	Deschutes	995	
1992	Round Lake	Klamath	490	
1992	Lone Pine	Klamath	30,320	
1994	LaClair	Jefferson		
1995	Day Road	Deschutes		
1996	Little Cabin	Jefferson	2,438	
1996	Smith Rock	Deschutes	500	1 structure was destroyed in this fire.
1996	Simnasho	Jefferson		
1996	Wheeler Point	Wheeler	21,980	
1996	Skeleton	Deschutes	17,700	19 structures were destroyed in this fire impacting the eastern fringe of Bend.
1996	Ashwood/Donnybrook	Central Oregon	118,000	This fire burned in areas of the state not protected from fire.
1999	McCoin Road	Deschutes	99	Prineville
2002	Eyerly	Jefferson	23,573	37 structures destroyed.
2002	Winter	Lake	35,779	
2002	Cache Mountain	Deschutes	4,200	2 structures destroyed.

Source: Oregon Emergency Management, State Natural Hazard Mitigation Plan, 2003, Wildland/Urban Interface chapter.

Note: This list is representative of a lengthy wildfire history. There have been many fires, named and unnamed. Statistics differ, depending on the source.

Probability

The natural ignition of forest fires is largely a function of weather and fuel; human-caused fires add another dimension to probability. Dry and diseased forests can be mapped accurately and some statement can be made about the probability of lightning strikes. Each forest is different and consequently has different probability/recurrence estimates.

This document defines wildfire as an uncontrolled burning of forest, brush, or grassland. Wildfire always has been a part of these ecosystems and sometimes with devastating effects. Wildfires result from natural causes (e.g., lightning strikes), a mechanical failure (Oxbow Fire), or human-caused (unattended campfire, debris burning, or arson). The severe fire season of 1987 resulted in a record setting mobilization of the state. Most wildfires can be linked to human carelessness.

Vulnerability

An understanding of risk begins with the knowledge that wildfire is a natural part of forest and grassland ecosystems. Past forest practices included the suppression of all forest and grassland fires. This practice, coupled with hundreds of acres of dry brush or trees weakened or killed through insect infestation, has fostered a dangerous situation. Present state and national forest practices include the reduction of understory vegetation through thinning and prescribed (controlled) burning.

Each year a significant number of people build homes within or on the edge of the forest (urban/wildland interface), thereby increasing wildfire hazards. In Many Oregon communities (incorporated and unincorporated) are within or abut areas subject to serious wildfire hazards. Oregon, there are about 240,000 homes worth around $6.5 billion within the urban/wildland interface. Such development has greatly complicated firefighting efforts and significantly increased the cost of fire suppression. These communities have been designated “Interface Communities” and include those in Table 9.

A detailed community inventory of factors that affect vulnerability is important in assessing risk and is beyond the scope of the statewide assessment.

When assessing the risks from natural hazards, established mitigation practices already provide benefits in reduced disaster losses. It is important for communities to understand the benefits of past mitigation practices when assessing their risks, being mindful of opportunities to further reduce losses.

Possible mitigation practices include:

- Identify and map current hazardous forest conditions such as fuel, topography, etc.;
- Identify forest / urban interface communities - List of interface communities, Federal Register, 08/17/01. V. 66, N. 160;

- Identify and map Forest Protection Districts;
- Identify and map water sources;
- Implement effective addressing system in rural forested areas;
- Clearly mark evacuation routes;
- Identify and locate seasonal forest users. Initiate information program through schools, summer camps, forest camping grounds, lodges, etc;
- Identify and map bridges that can (and can not) support the weight of emergency vehicles. This is a basic requirement for fire suppression;
- Form committees to implement Oregon Senate Bill 360. This is required in Oregon Senate Bill 360; and
- Create road standards in interface areas to reflect fire suppression needs. Roads must be wide enough for fire suppression vehicles to turn around. Road grades cannot be too steep for large, heavy vehicles.

TABLE 9. WILDLAND/URBAN INTERFACE COMMUNITIES

CROOK	DESCHUTES	JEFFERSON	KLAMATH	LAKE	WHEELER
Jasper Point Resort	Bend	Ashwood	Beaty	Adel	Fossil
Paulina	Black Butte	Camp Sherman	Beaver Marsh	Christmas Valley	Mitchell
Post	Brothers	Crooked River Ranch	Bly	Drew's Gap	Richmond
Prineville	Elk Lake	Culver	Bly Mountain	Lakeview Basin	Spray
	Hampton	Gateway	Bonanza	New Pine Creek	Twickenham
	LaPine	Madras	Chemult	Paisley	Winlock
	Redmond	Metolius	Chiloquin	Plush	
	Sisters-Cloverdale	Warm Springs	Crater Lake	Silver Lake	
	Sunriver		Crescent	South Drews	
	Terrebonne		Crescent Lake	Summer Lake	
	Tumalo		Dairy	Valley Falls / Chandler	
			Diamond Lake Junction		
			Gilchrist		
			Harriman		
			Keno		
			Klamath Falls		
			Little River		
			Malin		
			Merrill		
			Odell Lake		
			Rocky Point		
			Rosedale		
			Running Y		
			Sand Creek		
			Klamath		
			Sprague River Valley		
			Sycan Estates		

Source: Federal Register

The probability that Region 6 will experience interface fires and the region's vulnerability to their effects are depicted in Table 10 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 10. Vulnerability and Probability Assessment of Fires in Interface Areas

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	M	H	H	M	M	H
Probability	H	H	H	H	H	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

FLOOD

Characteristics and Brief History

Central Oregon is subject to a variety of flood conditions, including (1) spring run-off from melting snow, (2) intense warm rain during the winter months, (3) ice-jam flooding, (4) local flash flooding, (5) lake flooding associated with high winds (e.g., Klamath Lake), (6) closed basin playa flooding (e.g., N. Goose Lake Basin, Lake County) and (6) flooding associated with the breeching of natural debris dams. Although not as notable as flash floods, the most common flood condition in Central Oregon is associated with warm winter rain on snow.

Rain-on-snow floods, so common in western Oregon, also occur east of the Cascades. The weather pattern that produces these floods occurs during the winter months and has come to be associated with La Nina events, a three to seven year cycle of cool, wet weather. In brief, cool, moist weather conditions are followed by a system of warm, moist air from tropical latitudes. The intense warm rain associated with this system quickly melts foothill and mountain snow. Above-freezing temperatures may occur well above pass levels in the Cascade Mountains (4,000-5,000 feet). Some of Oregon's most devastating floods are associated with these events.[3]

Although flooding occurs throughout central Oregon, local geology and the relatively low population of the six-county area lessen its effects. Volcanic rocks, some of which have a large capacity for water storage, underlie much of the region. Consequently, the discharge rates for some streams (e.g., Deschutes River) are very low considering the size of their basins[4]. In addition, there are some large reservoirs in the upper watersheds that can contain considerable quantities of runoff. Potential flood losses also are mitigated through land-use standards; all Region 6 communities participate in the National Flood Insurance Program.

The Flood Insurance Studies (FIS) for each of the Region 6 counties provide some insights associated with ice jam flooding (Deschutes County), basin lakes that receive run-off from all directions (e.g., Goose Lake Basin, Lake County), lake level differentials produced by local wind conditions (Klamath County), and possible flooding caused by the failure of natural debris dams (Deschutes County). Although these phenomena have not and would not produce devastation like historical flash floods in Jefferson and Wheeler counties, they certainly warrant the consideration of local emergency managers.

Table 11 describes significant floods in the region; Table 12 describes principal flood sources.

[3] George Taylor, 1999.

[4] June 8, 1998, Deschutes County Flood Insurance Study.

TABLE 11. SIGNIFICANT FLOODS

DATE	LOCATION	DESCRIPTION	TYPE OF FLOOD
June, 1884	Wheeler County (Painted Hills)	Mother and 3 children perished	Flash flood
June, 1900	Wheeler County (Mitchell)	Large area of county devastated	Flash flood
July, 1956	Wheeler County (Mitchell)	Much of town destroyed (20 buildings)	Flash flood
December, 1964	Entire state	Severe flooding in central Oregon	Rain on snow
August, 1976	Jefferson County (Ashwood)	Severe flooding. Damaged buildings	Flash flood
February, 1986	Entire state	Severe flooding	Rain on snow
August, 1991	Crook County (Aspen Valley)	Severe flooding. 1 fatality	Flash flood
March, 1993	Wheeler County	Severe flooding. Damage	Rain on snow
May, 1998	Crook County (Prineville)	Federal disaster declaration (FEMA-DR-1221-OR); Ochoco Dam threatened	Rain on snow

Source: Taylor, George and Raymond Hatton, 1999, *The Oregon Weather Book.*

TABLE 12. PRINCIPAL RIVERENE FLOOD SOURCES

CROOK COUNTY	DESCHUTES COUNTY	JEFFERSON COUNTY	KLAMATH COUNTY	LAKE COUNTY	WHEELER COUNTY
Crooked River	Deschutes River	Willow Creek	Sprague River	Chewaucan River	Bridge Creek
Ochoco River	Little Deschutes River	Unnamed stream north of Culver	Williamson River	N. Goose Lake Basin	Keyes Creek
	Squaw Creek	Muddy Creek	Klamath River		
	Paulina Creek		Williamson River		
	Spring River		Link River		
			Four Mile Creek		
			Varney Creek		
			Upper Klamath Lake		

Sources: FEMA, Crook County Flood Insurance Study (FIS) 07/17/89; FEMA, Deschutes County FIS, 06/08/98; FEMA, Jefferson County FIS, 07/17/89; FEMA, Klamath County FIS, 06/18/84; FEMA, Lake County FIS, 12/05/89; FEMA, Wheeler County FIS, 07/17/89.

Probability

The Federal Emergency Management Agency (FEMA) has mapped the 10, 50, 100, and 500-year floodplains in the Region 6 counties. This corresponds to a 10%, 2%, 1% and 0.2% chance of a certain magnitude flood in any given year. In addition, FEMA has mapped the 100-year floodplain (i.e., 1% flood) in the incorporated cities. The 100-year flood is the benchmark upon which the National Flood Insurance Program (NFIP) is based.

Vulnerability

The probability that Region 6 will experience floods and the region's vulnerability to their effects are depicted in Table 13 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 13. Vulnerability and Probability Assessment of Floods

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	M	L	M	M	M	H
Probability	M	M	L	H	H	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

LANDSLIDES / DEBRIS FLOWS

Characteristics and Brief History

Landslides and debris flows always have and always will shape Oregon's landscape. Landslides become problematic, however, when people place buildings and infrastructure in harm's way. Additionally, development practices can cause or contribute to the severity of landslides.

There are several categories of landslides, based on configuration (slide mechanism), slide materials, and rate of movement. Some slides are ancient, deep-seated, and slow moving. Others move rapidly as a mass of rock, mud, and large woody debris. All can be problematic when in the vicinity of buildings and infrastructure. Fast-moving landslides, or debris flows, occur throughout Oregon, but are especially noteworthy in the Cascade and Coast Ranges.

Debris flows (mudslides, mudflows, debris avalanches) are a common type of rapidly moving landslide that generally occur during intense rainfall on previously saturated ground. They usually begin on steep hillsides as slumps or slides that liquefy, accelerate to speeds as great as 35 mph or more, and flow down slopes and channels onto gently sloping ground. Their consistency ranges from watery mud to thick, rocky, mud-like wet cement, dense enough to carry boulders, trees, and automobiles. Debris flows from different sources can combine in canyons and channels, where their destructive power is greatly increased. In general, slopes that are over 25% or have a history of landslides might signal a landslide problem.

In recent events, particularly noteworthy landslides accompanied storms in 1964, 1982, 1966, and 1996. Two major landslide producing winter storms occurred in Oregon during November 1996. Intense rainfall on recently and past logged land as well as previously un-logged areas triggered over 9,500 landslides and debris flows that resulted directly or indirectly in eight fatalities. Highways were closed and a number of homes were lost. The fatalities and losses resulting from the 1996 landslide events brought about the passage of Oregon Senate Bill 12, which set site development standards, authorized the mapping of areas subject to rapidly moving landslides and the development of model landslide (steep slope) ordinances.

Oregon's landslide / debris flow warning system primarily involves three state and one federal agency: the Oregon Department of Forestry (ODF), the Oregon Department of Geology and Mineral Industries (DOGAMI), the Oregon Department of Transportation (ODOT), and the National Oceanic and Atmospheric Administration (NOAA). The warning system is triggered by rainfall and monitored in areas that have been determined to be hazardous.

As the lead agency, ODF is responsible for forecasting and measuring rainfall from storms that may trigger debris flows. Advisories and warnings are issued as appropriate. Information is broadcast over NOAA weather radio and on the Law Enforcement Data System. DOGAMI provides additional information on debris flows to the media; ODOT provides information concerning the location of landslides / debris flows, alternate transportation routes, etc.

Most landslides in Region 6 occur within the US Highway 26 corridor (Prineville-Mitchell). U.S. Highway 97 just north of Klamath Falls has a history of rock falls. One person was killed by a rockslide in this area during the 1993 Klamath Falls earthquake.

Probability

The probability of rapidly moving landslide occurring depends on a number of factors; these include steepness of slope, slope materials, local geology, vegetative cover, human activity, and water. There is a strong correlation between intensive winter rainstorms and the occurrence of rapidly moving landslides (debris flows); consequently, the Oregon Department of Forestry tracks storms during the rainy season, monitors rain gages and snow melt, and issues warnings as conditions warrant. Given the correlation between precipitation or snowmelt and the onset of rapidly moving landslides, it would be feasible to construct a probability curve. The installation of slope indicators or the use of more advanced measuring techniques could provide information on slower moving slides.

Geo-engineers with the Oregon Department of Forestry estimate widespread landslide activity about every 20 years; In western Oregon, landslides at a local level can be expected every 2 or 3 years.[5] It is reasonable to expect a longer recurrence interval within Region 6.

Vulnerability

The probability that Region 6 will experience landslides and the region's vulnerability to their effects are depicted in Table 14 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

[5] Mills, 2002.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

In some cases, counties either did not rank the hazard or did not find it to be a significant concern. These cases are noted with a dash (-) in the table below.

TABLE 14. Vulnerability and Probability Assessment of Landslides

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	-	L	M	-	L	H
Probability	-	L	L	-	L	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

VOLCANO-RELATED HAZARDS

Characteristics and Brief History

The western boundaries of Jefferson, Deschutes and Klamath counties coincide with the Cascade Mountains. Volcanic activity in the Cascades will continue, but questions regarding how, to what extent, and when, remain. Most volcano-associated hazards are local (e.g., explosions, debris, lava, and pyroclastic flows). However, lahars can travel considerable distances down stream valleys and wind-borne tephra (ash) can blanket areas many miles from the source.

There is virtually no risk from lahars, debris or pyroclastic flows in Wheeler and Crook counties, although normal prevailing winds could carry ash into those areas. Jefferson, Deschutes, and Klamath counties are at risk, however, and should consider the impact of volcano-related activity on small mountain communities, natural debris dams (e.g., South Sister, Broken Top), dams creating reservoirs, tourist destinations (e.g., Crater Lake), highways and railroads. These counties also should consider probable impacts on the local economy (e.g., wood products and recreation) should a volcano-related hazard occur.

The history of volcanic activity in the Cascade Range is contained in its geologic record, and the age of the volcanoes vary considerably. Some lava flows on Washington's Mt. Rainier are thought to be older than 840,000 years; Mt. Saint Helens erupted in May 1980, and continues to be active. In short, all of the Cascade volcanoes are characterized by long periods of quiescence and intermittent activity. And these characteristics make predictions, recurrence intervals, or probability very difficult to attain.

Several Region 6 communities are within a few miles of prominent volcanoes. Mt. Jefferson, the Three Sisters, Broken Top, and Mt. Bachelor dominate the skyline between Redmond and Bend (Deschutes County). A less imposing, but none-the-less important volcano, Newberry Crater, is within 15 miles of La Pine (Deschutes County) and less than 25 miles from the City of Bend. The string of volcanoes continue south with Mt. Thielsen, Mt. Scott (Crater Lake), and Mt. McLaughlin dominating the horizon. The composition, eruptive behavior and history of these volcanoes are not the same, which probably has a bearing on any future activity.

A brief overview of the prominent Region 6 volcanoes is contained in Table 15.

TABLE 15. PROMINENT VOLCANOES

NAME	ELEVATION	TYPE	REMARKS
Mt. Jefferson	10,495 ft.	Composite	Capable of large explosive eruptions. Not extinct. Partly on Warm Springs Reservation. Lahar inundation zones on Shitike Creek; Warm Springs settlement endangered. Lahars could enter Lake Billy Chinook via the White River, overtop dam and create damage below. (USGS OFR 99-24)
Mt. Washington	7,796 ft.	Mafic volcano	Popular recreation area. Information on Mt. Washington is very limited. Best source: USGS Cascade Volcano Observatory (CVO) web sites. No report on potential hazards. Mafic volcanoes are less explosive than composite volcanoes.
North Sister	10,085 ft.	Mafic volcano	
Middle Sister	10,047 ft.	Composite volcano	May erupt explosively in the future (USGS OFR 99-437)
South Sister	10,358 ft.	Composite volcano	May erupt explosively in the future. Carver Lake on mountain is formed by a natural debris dam. Dam failure, for any reason, could send flood water down Squaw Creek toward City of Sisters (Ref. USGS OFR 87-41 and Deschutes Co. Flood Insurance Study) City of Sisters (pop. 900 plus many tourists) also subject to possible lahars (USGS OFR 99-437, Plate 1). Recent uplift detected near the South Sister (about 1 in./yr), but no indication of pending eruption.
Broken Top	9,152 ft.	Composite volcano	Popular hiking destination; Source of Bend water supply
Mt. Bachelor	9,065 ft.	Mafic volcano	All-season recreation area. Mt. Bachelor ski resort.
Newberry Crater	7,984 ft.	Composite volcano	Popular recreation area. Less than 25 miles from Bend. Violent eruptions in past. Will erupt in future. Lahars could reach residential areas in the vicinity of Sun River via Little Deschutes River (USGS OFR 99-437)
Mt. Thielsen	9,187 ft.	Basalt/andesite Shield volcano	Popular hiking / climbing destination
Crater Lake (Mt. Mazama)	8,926 ft. (Mt. Scott)	Overlapping shield and composite volcanoes	Popular destination.
Mt. McLaughlin	9,496 ft.	Mafic volcano	Less explosive than composite volcanoes

Source: USGS/Cascades Volcano Observatory, web site information

Probability

The probability of volcanic activity can be very difficult to predict, unless there are obvious precursors. The precursors might include increased seismic activity, temperature and chemical changes in groundwater, etc. Probability is especially difficult when the volcano has been inactive for many thousands of years and lacks a clear geologic record of past events. Also, the knowledge of volcanoes is too limited to know how long a dormant period at any volcano can last[6], and this probably is the case for most Cascade volcanoes. Eruption probabilities generated by the USGS for the Oregon Cascades are largely based on the position of volcanic rocks in the geologic record. There is a considerable opportunity for error. Table 16 describes the probability of volcano-related hazards in Region 6.

[6] USGS OFR 99-24, p. 6.

TABLE 16. PROBABILITY OF VOLCANO-RELATED HAZARDS

VOLCANO-RELATED HAZARDS	AFFECTED AREA						REMARKS
	Jefferson	**Deschutes**	**Klamath**	**Wheeler**	**Crook**	**Lake**	
Tephra (volcanic ash) (annual probability of 1cm or more accumulation from eruptions throughout the Cascade Range)	1 in 5,000	1 in 5,000	1 in 5,000	1 in 1,000 to 1 in 5,000	1 in 5,000	1 in 5,000	USGS Open File Report (OFR 97-513) p.9)
Lahar	Source: Mt. Jefferson	Source: Newberry Crater and Three Sisters	Source: Crater Lake	No Risk	No Risk	No Risk	If the Detroit Lake dam is breached, lahars could reach Mill City, Lyons, and Stayton in Marion County. OFR 99-24 (Maps) Lane County: OFR 99-437 (Map)
Lava flow	Source: Mt. Jefferson	Source: Newberry Crater and Three Sisters	Source: Crater Lake	No Risk	No Risk	No Risk	Mt. Jefferson: OFR 99-24 (Maps) Three Sisters: OFR 99-437 (Maps)
Debris flow / avalanche	Source: Mt. Jefferson	Source: Three Sisters	Source: Crater Lake	No Risk	No Risk	No Risk	Mt. Jefferson: OFR 99-24 (Maps) Three Sisters: OFR 99-437 (Maps)
Pyroclastic flow	Source: Mt. Jefferson	Source: Newberry Crater and Three Sisters	Source: Crater Lake and Newberry Crater	No Risk	No Risk	Source: Newberry Crater	Mt. Jefferson: OFR 99-24 (Maps) Three Sisters: OFR 99-437 (Maps)

Source: USGS Open File Reports 99-24, 99-437, 97-513

Vulnerability

The probability that Region 6 will experience volcano-related hazards and the region's vulnerability to their effects are depicted in Table 17 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

In some cases, counties either did not rank the hazard or did not find it to be a significant concern. These cases are noted with a dash (-) in the table below.

TABLE 17. Vulnerability and Probability Assessment of Volcano-Related Hazards

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	-	H	M	H	L	H
Probability	-	L	L	L	L	L

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

WINDSTORMS

Characteristics and Brief History

Extreme winds (other than tornadoes) are experienced in all of Oregon's eight regions. The most persistent high winds occur along the Oregon Coast and the Columbia River Gorge, so much so that these areas have special building code standards. This is not the case in Central Oregon, although high winds in inter-mountain valleys are not uncommon. For example, stiff winds from the Ochoco Mountains often occur in the City of Prineville (Crook County).

The majority of the destructive surface winds in Oregon are from the southwest. Under certain conditions, very strong east winds may occur, but these usually are limited to small areas in the vicinity of the Columbia River Gorge or other low mountain passes. The much more frequent and widespread strong winds from the southwest are associated with storms moving onto the coast from the Pacific Ocean. A historic overview of high winds affecting Region 6 may be found in Table 18.

TABLE 18. SIGNIFICANT WINDSTORMS

DATE	AFFECTED AREA	CHARACTERISTICS
Apr., 1931	N. Central Oregon	Unofficial wind speeds reported at 78 mph. Damage to fruit orchards and timber.
Nov. 10-11, 1951	Statewide	Widespread damage; transmission and utility lines; Wind speed 40-60 mph; Gusts 75-80 mph
Dec., 1951	Statewide	Wind speed 60 mph in Willamette Valley. 75 mph gusts. Damage to buildings and utility lines.
Dec., 1955	Statewide	Wind speeds 55-65 mph with 69 mph gusts. Considerable damage to buildings and utility lines
Nov., 1958	Statewide	Wind speeds at 51 mph with 71 mph gusts. Every major highway blocked by fallen trees
Oct., 1962	Statewide	Columbus Day Storm; Oregon's most destructive storm to date. 116 mph winds in Willamette Valley. Estimated 84 houses destroyed, with 5,000 severely damaged. Total damage estimated at $170 million
Mar., 1971	Most of Oregon	Greatest damage in Willamette Valley. Homes and power lines destroyed by falling trees. Destruction to timber in Lane Co.
Nov., 1981	Statewide	Severe wind storm
Dec., 1991	N. Central Oregon	Severe wind storm; Blowing dust. Damage reported in Bend (Deschutes County)
Dec., 1995	Statewide	Severe wind storm

Source: Taylor, George H., and Ray Hatton. (1999), The Oregon Weather Book. p.151-157; and FEMA-1405-DR-OR, February 7, 2002, Hazard Mitigation Team Survey Report, Severe Windstorm in Western Oregon.

Probability

Generally, windstorms occur yearly even east of the Cascades. More destructive storms occur once or twice per decade. High wind events on the order of the 1962 Columbus Day storm are thought to have a 100-year recurrence interval.

Vulnerability

Many buildings, utilities, and transportation systems within Region 6 are vulnerable to wind damage. This is especially true in open areas, such as natural grasslands or farmlands. It also is true in forested areas, along tree-lined roads and electrical transmission lines, and on residential parcels where trees have been planted or left for aesthetic purposes. Structures most vulnerable to high winds include insufficiently anchored manufactured homes and older buildings in need of roof repair. The Oregon Department of Administrative Service's inventory of state-owned and operated buildings includes an assessment of roof conditions as well as the overall condition of the structure. Oregon Emergency Management has arranged this information by county.

Fallen trees are especially troublesome. They can block roads and rails for long periods of time, impacting emergency operations. In addition, up-rooted or shattered trees can down power and/or utility lines and effectively bring local economic activity and other essential facilities to a standstill. Much of the problem may be attributed to a shallow or weakened root system in saturated ground. Many roofs have been destroyed by uprooted trees felled by high winds. In some situations, strategic pruning may be the answer. Prudent counties will work with utility companies in identifying problem areas and establishing a tree maintenance and removal program.

The probability that Region 6 will experience windstorms and the region's vulnerability to their effects are depicted in Table 19 below. These scores are based on the perceptions of area emergency managers.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 19. Vulnerability and Probability Assessment of Windstorms

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	M	M	M	M	M	M
Probability	H	H	H	H	H	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.

WINTERSTORMS

Characteristics and Brief History

Within the State of Oregon, Region 6 communities are known for cold, snowy winters. This is advantageous in at least one respect: in general, the region is prepared, and those visiting the region during the winter, usually come prepared. However, there are occasions when preparation cannot meet the challenge. Drifting, blowing snow has often brought highway traffic to a standstill. Also, windy, icy conditions have often closed mountain passes and canyons to certain classes of truck traffic. In these situations, travelers must seek accommodations, sometimes in communities where lodging is very limited. And local residents also experience problems. During the winter, heating, food, and the care of livestock and farm animals are everyday concerns. Access to farms and ranches can be extremely difficult and present a serious challenge to local emergency managers. Table 20 provides an historic overview of severe winter conditions within Region 6.

TABLE 20. SIGNIFICANT WINTERSTORMS

DATE	LOCATION	REMARKS
Dec., 1861	Entire state	Storm produced between 1 and 3 feet of snow
Dec., 1892	Northern counties	Between 15 and 30 inches of snow fell throughout the northern counties
Jan., 1916	Entire state	Two storms. Heavy snowfall, especially in mt. areas
Jan., Feb., 1937	Entire state	Deep snow drifts
Jan., 1950	Entire state	Record snow falls; Property damage throughout state.
Mar., 1960	Entire state	Many automobile accidents; Two fatalities
Jan., 1969	Entire state	Heavy snow throughout state
Jan., 1980	Entire state	Series of string storms across state. Many injuries and power outages.
Feb., 1985	Entire state	Two feet of snow in northeast mountains; Downed power lines. Fatalities
Feb., 1986	Central / Eastern Oregon	Heavy snow in Deschutes Basin. Traffic accidents; Broken power lines
Mar., 1988	Entire state	Strong winds; Heavy snow
Feb., 1990	Entire state	Heavy snow throughout state
Nov., 1993	Cascade Mountains	Heavy snow throughout region
Mar., 1994	Cascade Mountains	Heavy snow throughout region
Winter 1998-99	Entire state	One of the snowiest winters in Oregon history (Snowfall at Crater Lake: 586 inches)

Source: Taylor, George and Ray Hatton, 1999, *The Oregon Weather Book* p.118-122.

Probability

The recurrence interval for severe winter storms throughout Oregon is about every 13 years, however, there can be many localized storms between these periods.

Vulnerability

The probability that Region 6 will experience winterstorms and the region's vulnerability to their effects are depicted in Table 21 below. These scores are based on an analysis of risk conducted by county emergency program managers, usually with the assistance of a team of local public safety officials.

The probability scores below address the likelihood of a future major emergency or disaster within a specific period of time, as follows:

High = One incident likely within a 10 to 35 year period.

Moderate = One incident likely within a 35 to 75 year period.

Low = One incident likely within a 75 to 100 year period.

The vulnerability scores address the percentage of population or region assets likely to be affected by a major emergency or disaster, as follows:

High = More than 10% affected

Moderate = 1-10% affected

Low = Less than 1% affected

TABLE 21. Vulnerability and Probability Assessment of Winterstorms

	Crook	Deschutes	Jefferson	Klamath	Lake	Wheeler
Vulnerability	H	H	H	H	H	H
Probability	H	M	H	H	H	H

Source: Oregon Emergency Management, July 2003, County Hazard Analysis Scores.