9.5 Windstorms

- The Puget Sound region experiences strong windstorms, including ones with hurricane force winds known as mid-latitude cyclones. These storms are wider that tropical storms. The largest of these was the 1962 Columbus Day Storm. The moderating effects of the Pacific Ocean prevent hurricanes.
- Puget Sound is sheltered compared to the Washington Coast, but it can still receive sustained winds of 60-70 mph and gusts up to 90mph.[573] Local terrain has a strong effect on wind speeds. Winds speed up as they move over hills and ridges.
- Pineapple Express storms also pack strong winds, but these storms are known more for their rain than wind. They occur when the jet stream dips into the tropical regions and up into our area. Wind is just one component of these events that also can include flooding, landslides, and power outages.
- Tornadoes are very rare in the Puget Sound region. Washington ranks 43rd in tornado frequency. Between 1950 and 2005 there were 94 tornados in Washington and most were weak. Those in the Puget Lowland were mostly associated with the Puget Sound Convergence Zone.[574]
- Power outages are the most wide-spread problem caused by windstorms. The 2006 storm overwhelmed Seattle City Light when 49% of its customers lost power. 95% of customers were restored within two days, but full restoration took a week.
- Structural damage is the costliest consequence of windstorms. Much of the damage comes from falling trees.[575] Damage can occur at wind speeds as low as 32 mph and destroy wood frame structures at speeds around 100 mph. Seattle's building code requires new structures to withstand 85 mph for three seconds (with modifications to be made for location), but Seattle also has many older buildings. Almost 90,000 homes in Seattle were built before 1939.
- People have died from falling trees and branches. Because many windstorms happen in winter and many residents are dependent on electricity for heat, cold-related health problems are a hazard. Several people were killed in King County while heating their homes with charcoal fires during the power outages following the 2006 storm.
- Large windstorms are regional events. The more heavily forested suburban areas are often hit harder than Seattle is. The result is that resources to aid in recovery can be hard to find.
- Floating bridges are vulnerable to wind and wind-driven waves. The Hood Canal Bridge sunk in 1979 and the I-90 Bridge sunk in 1990.

9 5.1 Context

The Pacific Northwest experiences windstorms that can reach hurricane strength. Wind strength is measured in terms of sustained winds and gusts. Sustained winds are the speeds averaged over one minute near the surface of the earth. Gusts are the three to five second peaks that are often more than 25 – 50% stronger than the sustained winds. Gusts are often what cause the greatest damage.

The El Niño / La Niña cycle influences the development of major windstorms. El Niño periods bring warmer, drier winters to the Pacific Northwest, while La Niña brings wetter, cooler, and snowier winters. The cycle between these periods, called El Niño Southern Oscillation (ENSO), is typically three to seven years. It appears that the Pacific Northwest sees more frequent windstorms in the "neutral" years between the two extremes.[576] Because these transitions can be predicted three to six months ahead of time, meteorologists can give communities a general warning that the threat of windstorms is elevated.

Mid-Latitude Cyclones

Pacific Northwest wind storms that can reach hurricane strength are called mid-latitude cyclones. The mid-latitudes, from 30˚ to 60˚ north, experience a large difference in temperature between the tropics to the south and the arctic to the north. These temperature differences provide the energy source for the storms. The mixing of cold and warm air can create an area of low pressure as a cold front overtakes a warm front. Mid-latitude cyclones are larger than tropical cyclones and maintain their strength over land more effectively. This means they are typically larger and can reach further inland than tropical storms.

Tropical cyclones can become mid-latitude cyclones when they push into the mid-latitudes (30˚ - 40˚) through a process called *extratropical transition* (ET). The western North Pacific has the greatest number of these events in the world. Current metrological models often fail to anticipate these events. The largest recorded storm to strike the Pacific Northwest, the 1962 "Columbus Day Storm," was a mid-latitude cyclone.[577]

Atmospheric Rivers or "Pineapple Express"

Atmospheric Rivers or "Pineapple Express" storms in the Northwest have much weaker, although still considerable, winds and often much more precipitation. They occur when the jet stream funnels warm, moist air up from the tropics to Pacific Northwest. These more common storms cause more flooding and landslides than mid-latitude cyclones. When storms occur outside winter they hit the trees in full leaf. The leaves act as sails causing more stress on the tree.

Western Washington experiences several other kinds of wind that are more localized. They typically do not threaten Seattle but can be damaging to communities near Seattle. They are mentioned here to distinguish them from mid-latitude cyclones and Atmospheric Rivers.

Strait of Juan de Fuca Wind Surges

The Strait of Juan de Fuca can act as a wind funnel in the right conditions. In the winter, a strong surge can push sustained wind speeds to 50 – 70 mph and gusts to 70 – 80 mph. These events usually occur in north Puget Sound with damage occurring as far south as Mukilteo. Two significant events of this type occurred on December 17, 1990 and October 28, 2003.

Cascade Downslope Winds

These storms are caused by a build-up of high pressure east of the Cascades. When a low-pressure system moves into the Puget Lowlands, the dammed-up air east of the mountains comes surging through the lower passes. Stampede Pass is the lowest pass in the region and the area immediately below it, Enumclaw, routinely sees strong winds as a result. Occasionally, these winds push all the way to Puget Sound, south of Seattle. During one of these events, Fife and Federal Way can be experiencing winds of 50-60 mph while in Seattle the wind speed is close to zero.

Tornadoes

Tornadoes are unusual events in the Pacific Northwest. There have been several recorded in the Puget Lowlands. Tornadoes are ranked on the Fujita Scale from 0 to 5. They are an estimate of wind speed based on the damage pattern. The largest tornado to occur in the Puget Sound area was an F3.

9 5.2 *History*

The Pacific Northwest is periodically hit by mid-latitude cyclones and other more localized wind events. Most storms happen in late fall and winter. Of the ten major storms to hit Seattle since 1962, seven have occurred in winter. The other three occurred in March, August, and September.

1943. Official records at the Federal Building show one occurrence of 65-69 mph winds.[578] A weather station at the Federal Building in downtown Seattle showed that between 1935 and 1959, wind speed exceeded 50 miles per hour 37 times and 60 mph six times.[579]

9/28/1962. An F1 tornado damaged eight homes in the Sand Point/View Ridge area before travelling across Lake Washington and damaging homes in the Juanita area of Kirkland.

10/12/1962. The "Columbus Day Storm" had 85 mph sustained winds equal to hurricane speed. Higher wind speeds of 150 mph on the coast demonstrated the protection that the Olympic Mountains give the region. Nevertheless, the damage was widespread. Throughout the region, 46 people died, 53,000 houses were damaged, and the power went out in many areas of Washington. It is not clear how much of this damage was in Seattle. Parts of the power transmission system in Portland were destroyed.

12/12/1969. An F3 tornado struck the Kent valley. The storm caused 1 injury. It damaged a billboard and a farm.

3/26/1971. Sixty mph winds forced the closure of the Evergreen Point Bridge. The wind also ripped panels off the Seafirst building, forcing the Downtown Library to close. Two people died.

2/13/1979. The Hood Canal Bridge broke apart in a violent storm. The western part of the bridge sank into the canal.

2/19/1981. Wind and lightning damaged at least one home and left 100,000 without power in Seattle and King County. This storm began as a tropical cyclone.

11/13/1981. Two major storms caused power outages, closed bridges, and damaged buildings.

11/24/1983. The "Thanksgiving Day Storm." Downed trees were a leading cause of outages that left 75,000 without power in King County. The wind also damaged roofs and broke boats loose from their moorings. The storm was not predicted, increasing the damage.

11/25/1990. The Old Mercer Island Bridge sank in a storm. The sinking was caused in part by construction waste in the floats under the bridge (Also see Infrastructure Failure chapter).

11/16/1991. 400,000 were left without power in the Seattle area after the worst storm since the Thanksgiving Day Storm of 1983.

1/20/1993. "The Inauguration Day Storm" caused massive outages in Seattle, although the power was out the longest in the suburbs. Debris littered the road and traffic came to a stop as traffic lights failed. Winds gusts in the Puget Sound were 60-70 mph. Six people died in the state.[580]

12/14/2006. Unusually intense levels of rainfall in a very short period of time were immediately followed by very heavy winds up to 69 miles per hour that felled power poles and large, mature, healthy trees. Three-fourths of an inch of rain fell in less than 45 minutes in some areas of the city. As a result, more than 1.3 million customers were without power throughout western Washington, some for longer than a week. Making the situation worse, a late-afternoon Seahawk game in Seattle meant many more motorists attending the game were further delayed from getting home because of the storm.

8/29/2015. The strongest August windstorm on record hit Western Washington, with winds of 50-60 mph (46 mph at SeaTac). Almost half a million people lost power, two people died from falling trees, two people died from carbon monoxide poisoning, and four people were injured.[581] The damage was increased because the trees were in leaf. The North Puget Sound and coastal areas received the strongest winds.

9 5.3 Likelihood of Future Occurrences

Western Washington will continue to experience periodic windstorms. A storm with 40-50 mph wind gusts is expected at least once per year, with larger storms (60-80 mph wind gusts) expected every decade or so. Advancements in meteorological technology will increase the likelihood that these events will be forecasted before they occur. More research is needed on how climate change will affect the frequency and intensity of future windstorms in the Puget Sound region. One study, conducted by Seattle City Light (SCL) and the University of Washington, concluded that the modeled increases in the frequency of extreme wind events due to climate change was minor compared to the expected natural variability.[582]

9 5.4 Vulnerability

Tree density and wet soils are the biggest factors in the amount of damage produced from windstorms in the Pacific Northwest. Tall conifers are often shallow rooted and prone to being uprooted, especially when the ground is saturated with water. The ground is often saturated in the late fall and winter when the majority of these powerful storms occur. Seattle has fewer trees than suburban and rural areas, but it still has a substantial amount and has been actively working to regrow its tree canopy.

Falling trees and branches are the major hazard in windstorms. They snag power, cable television, and telephone lines, bringing them down and causing outages. When they fall across roads, they interrupt transportation. A downed tree can usually be cleared quickly; when accompanied by downed power lines, the job takes much longer. Finally, trees pose a direct hazard to homes and people.

Wind can cause direct damage to buildings. Seattle's Building Codes, which are built on the International Building Code, specify that structures must withstand a load caused by a three second wind gust of 85 miles per hour. Structural engineers apply this speed to structures using a formula to calculate wind load. Seattle's coast and hills affect this load. Winds are stronger over water and along hillsides. Areas on [Wind Speed Up Areas] that are shown in purple and red are prone to stronger winds. During a windstorm on December 12, 1995, a ship just outside of Elliott Bay reported a gust of 90 mph, exceeding the design threshold.

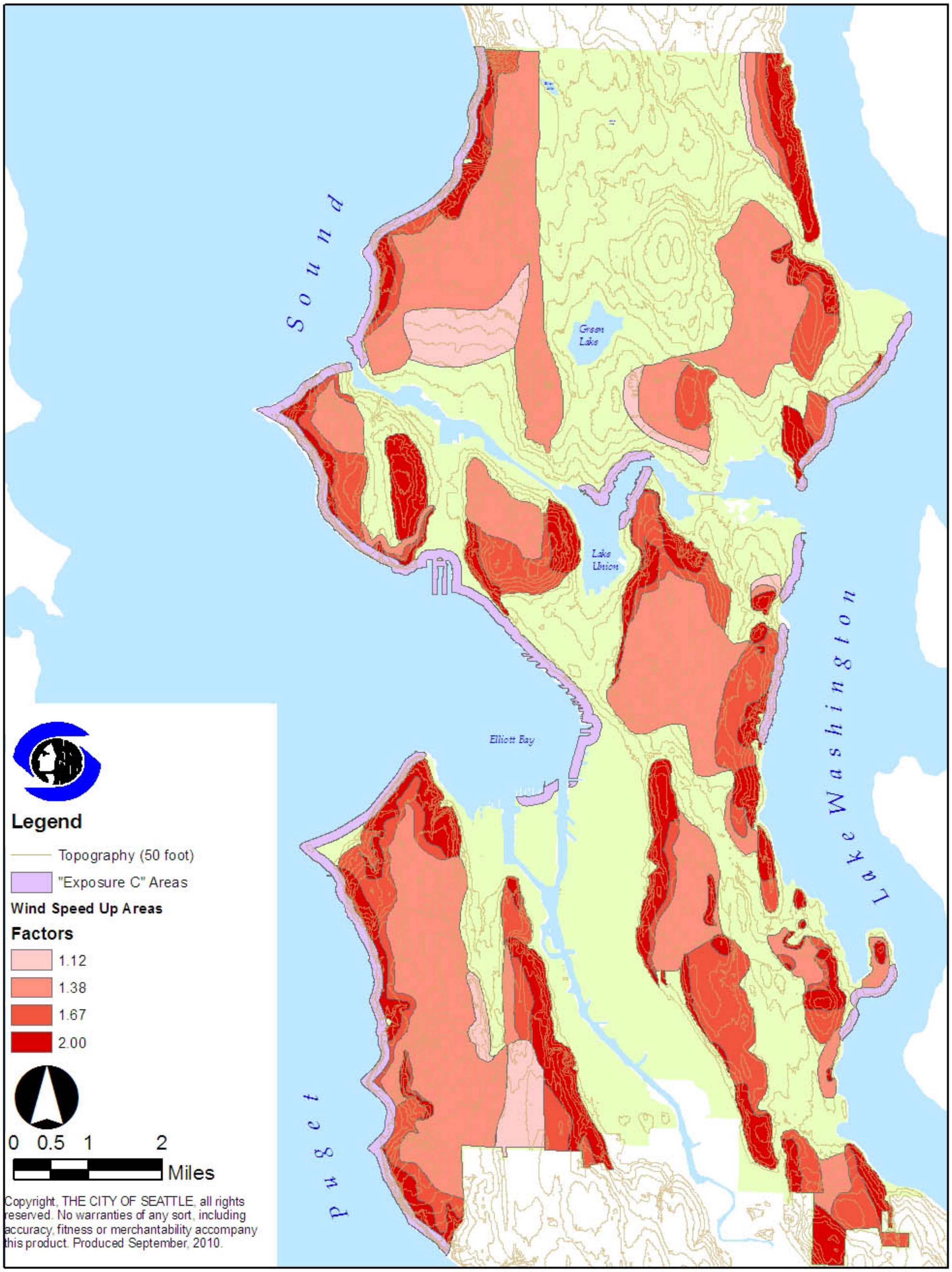
Areas with limited access, such as Magnolia, can become isolated if trees fall on the few roads that lead into them. North and West Seattle, which are the most heavily forested, may have a higher vulnerability of property damage than the rest of the city.

Wind-driven waves are another hazard for the city. Large waves can endanger the I-90 and SR 520 floating bridges. The SR 520 bridge, which was rebuilt in 2012, can withstand wind gusts up to 89 mph. On average, more than 200,000 vehicles move over these bridges daily. Sound Transit is currently building tracks for the Link light rail to travel over the I-90 bridge, adding another 50,000 daily passengers to its load.[583] This traffic gives them enormous socioeconomic importance. Their inherent exposure to wind and their value to the local economy make them vulnerabilities for Seattle.

During the 1993 Inauguration Day Storm, trees falling on buildings, power and telephone lines, and on roads caused most of the damage. In addition, falling trees and limbs damaged hundreds of homes, and fires, started by fallen power lines, damaged several buildings. Some major public structures suffered damage. For example, both floating bridges across Lake Washington, I-90 and SR 520, had damage to pontoons that keep the bridges afloat.[584] Extensive damage occurred from uprooted trees and brittle trees that broke, or whose branches broke off and fell onto power lines, buildings, and roadways.

If windstorms are accompanied by heavy rain or followed by extreme cold, the effects of the windstorm are multiplied. As detailed in other chapters, rain can lead to urban flooding and landslides while extreme cold will increase the hardship caused by power outages.

Figure 9-5. Wind Speed-Up Areas



9 5.5 Consequences

Windstorms are a regular part of Pacific Northwest weather as are rain-driven flooding and snow. They cause direct physical damage to structures, infrastructure for power and telecommunications, and coastal bluffs. Falling trees can also cause fatalities. Windstorms cause indirect damage to the economy through power outages and inhibiting the transportation system. Many people cannot or choose not to come to work because they fear long drives or must take care of damage at home. For local governments, debris removal can place a strain on budgets. Despite these costs, the biggest economic problem from windstorms is property damage. Families can incur major expenses even from light damage to roofing or siding. The 2006 record intensity storm of torrential rains and high-velocity winds took a toll on Seattle's residents and their property. Scores of city residents experienced thousands of dollars in damage to their homes and businesses from downed trees falling onto house roofs and cars, flooding inside homes and businesses, and severe roof and siding damage.

Even moderate wind speed can damage buildings. Wind speeds as low as 32 mph can drive objects through walls.[585] Other research shows that wood-frame and unreinforced masonry structures can be damaged or even destroyed at speeds less than 100 mph and that a home constructed according to any of the major codes in the U.S. will lose its roof in winds from 80 to 120 mph.[586] Winds have exceeded this threshold in Seattle, especially in areas where the topography increases wind speeds, demonstrating that widespread structural failures are possible.

Besides doing extensive property damage directly, wind can devastate vegetation and utility lifelines. The 2006 storm caused great damage to City property and infrastructure, with preliminary damage estimates at $16 million.[587]

Besides being an inconvenience to property owners and municipal governments who must clean up debris, falling trees are also a safety risk. In the 2006 windstorm, over 300 trees blocked roadways in King County,[588] including dozens of arterials in Seattle.[589]

Power outages are another widespread problem. Parts of the Eastside lost electricity for days after the 1993 Inauguration Day Storm. These outages also affect traffic lights, making driving a long and difficult process. Finally, falling trees and branches, downed power lines, and transformer explosions are health risks.

The bridges pose another safety risk. If a windstorm develops suddenly, as in 1983, it could hit them before the State Department of Transportation could close them preemptively.

Seattle has experienced severe windstorms regularly. The most likely situation is that this pattern will not change. Seattle can expect storms up to the magnitude of the Columbus Day storm. While the hazard intensity may not change, Seattle has grown, and our economy has become more time dependent. This increase in vulnerability means that the damage from windstorms is more likely to be higher than in past storms. While windstorms have caused fatalities, their main effect has been economic.

9 5.6 Conclusions

The Pacific Northwest experiences windstorms periodically and is prone to severe storms about once per decade. The population growth happening in Seattle means that future windstorms will likely cause more damage, mostly to private property.

10. APPENDIX A: EXPOSURE ANALYSIS

This section analyzes patterns of hazard exposure where hazardous areas can be clearly mapped. Not all hazards have a readily mappable component.

10.1 Earthquake Hazard Exposures

For earthquakes, one of the major hazards is liquefaction which occurs when certain soils liquify when shaken. These soils can be identified and mapped. Seattle's liquefaction prone areas have been mapped as shown in Figure x. The tables and charts below summary what is in these zones.

Table 10-1. Land Use in Liquefaction Prone Areas

Area	Acres	% of Seattle	% of Area
Seattle	53178.37	100%	
Liquefaction Prone Areas	8029.46	15%	100%
Property in Areas	**6172.02**	**12%**	77%
Commercial/Mixed-Use	718.78	1%	9%
Easement	2.07	0%	0%
Industrial	1510.42	3%	19%
Major Institution and Public Facilities/Utilities	2024.07	4%	25%
Multi-Family	217.96	0%	3%
Parks/Open Space/Cemeteries	463.74	1%	6%
Reservoirs/Water Bodies	2.92	0%	0%
Single Family	490.97	1%	6%
Unknown	17.31	0%	0%
Vacant	723.76	1%	9%
Right of Way in Areas	**1857.44**	**3%**	23%