Hazard Inventory and Risk Assessment (HIRA)

CITY OF BELLEVUE

2018-2023

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1.0 Introduction

1.1 Purpose

The purpose of the City of Bellevue Hazard Inventory and Risk Assessment (HIRA) is to provide background information and guidance for hazard response, continuity, mitigation, and recovery in the City of Bellevue. This document is designed to supplement the Comprehensive Emergency Management Plan (CEMP). This hazard inventory meets the intent of Washington Administrative Code (WAC) WAC 118-30-060 (1), Emergency Plan, and 118-30-070, Program Papers (1g). The hazard inventory will be expanded during 2014 to encompass the requirements of Disaster Mitigation Act of 2000 (DMA2K) and the Emergency Management Accreditation Program (EMAP) Standard, which are much more prescriptive in nature.

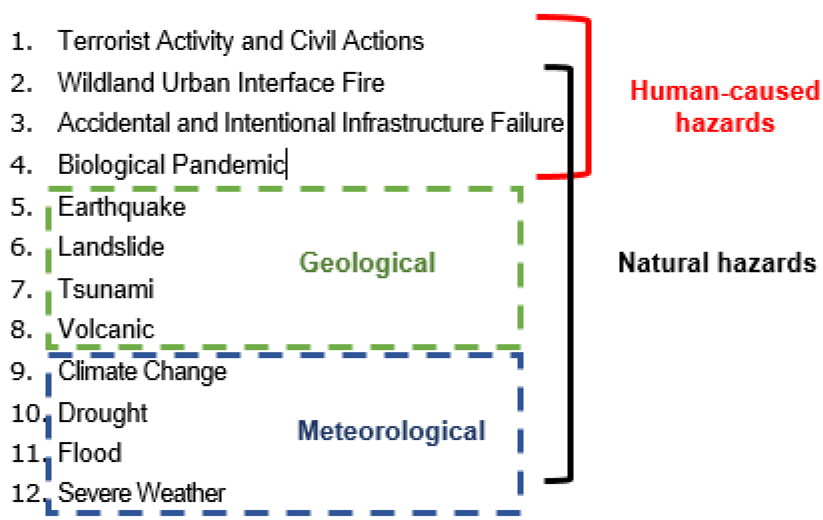
1.2 Scope

The scope of each hazard varies depending upon the unique subject matter. Some hazards are specific to Bellevue (such as earthquakes, flooding, and landslides), while others are more regionally based (such as terrorist activity and civil actions). Some of the data shown in the hazards originated from other partner jurisdictions and compliments the hazard inventories if the information lends itself to a broader application.

2.0 Content Organization

2.1 Hazard Profiles

The City of Bellevue Office of Emergency Management (OEM) uses a hybrid of federal, state, and local hazard categories. Hazard profiles are grouped by the following types: infrastructure, biological, geological, and meteorological:



Three of the hazard profiles—Wildland Urban Interface Fire, Accidental and Intentional Failure, and Biological Pandemic—can be both human-caused hazards as well as natural hazards. Both aspects of origination are covered in each inventory. With further analysis, many of the human-caused elements are similar in nature to the Terrorist Activity and Civil Actions as the primary hazard.

Relationships can exist between the hazard types*, further complicating impacts and vulnerabilities depending upon the unique emergency situation:

- Natural hazards may initiate other natural hazards
    - Earthquake may lead to landslides or tsunami
    - Hurricane may produce tornadoes
    - Excessive flooding may result in a rise of infectious disease
- Natural hazards may initiate infrastructure failures
    - A major flood may cause a dam to break
    - A lightning strike may result in power failure
- Human-caused hazards may initiate other natural hazards
    - A hazardous materials explosion may create a wildfire
    - A nuclear accident will adversely affect the environment
    - A bombing may lead to fire
    - A cyber attack may lead to a power failure
    - A terrorist attach may spread deadly disease
    - Deforestation may result in extreme flooding

The hazard inventories can be used to complement one another if an interface or relationship is created based on a specific incident type.

*Per Dr. McEntire, Hazard Taxonomies/Hazard Relationships

2.2 Risk Assessment

The hazards addressed in each inventory are intended to work with the data in the Community Profiles in the Comprehensive Emergency Management Plan (CEMP). The hazard inventories are intended to be analyzed within each of the 14 Neighborhood Analysis Areas. Specific neighborhoods in Bellevue are prone to certain hazards based on topography, land use, population, and proximity to items such as the pipelines. A risk matrix is not used at this time for risk analysis per neighborhood.

3.0 Profile Document Structure

Each hazard profile follows the same content structure and table of contents as identifies in Figure 1 below.

Contents

Figure 1. Hazard Inventory Table of Contents

Section 1 is an introduction, with sub headers including a definition of the hazard(s), potential types, and possible secondary hazards. The next section is a profile of the hazard. Location and extent, occurrences, and recurrence rate are included with each hazard to ensure consistence of the inventories. Section 3 includes the same header content throughout each unique hazard, which provides consistency when analyzing different impacts and vulnerabilities. Section 4 includes regional and national resources and the related website information. Sources are notated with endnotes throughout the inventories.

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1.0 Introduction

1.1 Definition

1.1.1 Terrorism

The United States (US) Code of Federal Regulations Chapter 28 [28 CFR, Section 0.85(l)] defines terrorism as: "Domestic terrorism is the unlawful use, or threatened use, of force or violence by a group or individual based and operating entirely within the United States or Puerto Rico without foreign direction committed against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof in furtherance of political or social objectives."[1]

1.1.2 Civil Action

Any incident that disrupts a community where intervention is required to maintain public safety is a civil disturbance. Examples are demonstrations, riots, strikes, public nuisances, and criminal activities. They may be caused by such political grievances and urban economic conflicts as racial tension, unemployment, unpopular political actions and a decrease in the supply of essential goods and services. In general, civil disturbance most often arises from highly emotional social and economic issues.

Police continue to use variations of riot tactics common for over a hundred years: horse-mounted police and officers on foot with riot shields and batons. Arrests are made of key violent individuals. The 1960s saw the advent of the use of tear gas, also known as CS. There has been an evolution of tactics used by demonstrators and agitators that has resulted in an increasingly complex confrontation/interface between local officials and civilians.

Sophisticated communications capabilities are now available for retail purchase. Radios and "police scanners" have made it possible for demonstrators to organize their efforts and counter law enforcement tactics. This was seen during the World Trade Organization (WTO) disturbances in Seattle, 1999. Members of one group intercepted police tactical communications and broadcast the information over the Internet. One group transmitted over an illegal radio station. The result has been an increase in the integration of efforts between federal agency officials from the Federal Communications Commission and the Federal Bureau of Investigation with local law enforcement.

1.2 Types

1.2.1 Types

Terrorist groups choose targets and actions to maximize the psychological effect on a society or government. Their goal is to create a situation in which a government will change its policies because of their actions. For these reasons, terrorist groups can choose methods of mass destruction, such as bombings, and choose targets, such as transportation or crowded places, to increase anxiety and fear. Individuals and groups planning terrorist acts typically work to get as much media exposure as possible. Media coverage magnifies the terrorist act by spreading fear among a mass audience and giving attention to the terrorist cause. The hostage-taking attacks and subsequent murders of Israeli athletes at the 1972 Olympics assured a worldwide television audience, as did crashing planes into the World Trade Center buildings in September 2001.

Terrorist groups have multiple types of attacks that have been used in operations. The major attack types seen worldwide are discussed below.

Explosive Attack (Bomb): Explosive attacks come in three main forms: suicide bombers (persons wearing the explosive device, who may/may not have the detonation device in their control, and who may/may not be willing to die); improvised explosive devices (a device placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and designed to destroy, incapacitate, harass, or distract. It may incorporate military stores but is normally devised from nonmilitary components.); and, vehicle-borne improvised explosive devices. Explosive attacks may be directed at facilities and their occupants or may even be directed at specific human targets. Explosive attacks usually result in death or injury; destruction of facilities and equipment; critical disruption of work activities; loss of key employees (survivors) due to workplace trauma; loss due to civil liability; and secondary consequences (e.g., Hazmat).

Vehicle Attacks: One trend that has emerged in the past couple years is the use of vehicles in terrorist attacks. In 2016, a large truck was used as a weapon to kill over 80 people in a terrorist attack in Nice, France. Since then, similar attacks have been seen in terrorist attacks around the world, including Berlin, Barcelona, and New York City. It is seen as a low-cost, low-tech terrorist attack that can result in high casualties.

Arson: Terrorists use arson with the deliberate intention of destroying property and possibly injuring/killing people. Arson is an inexpensive attack option for a terrorist and an easy one to execute. Results of arson terrorism are generally: loss of facilities and physical assets; death/injury of people; disruption of work activities; and loss due to civil liability.

Kidnapping: Terrorist-initiated kidnapping generally takes the form of armed abduction, usually for the purposes of extortion. The effects of terrorist-initiated kidnapping may be: loss of key employees; disruption of work activities; loss due to ransom; and loss due to civil liability.

Armed Attack: Armed attack is a physical assault by armed terrorists with the intention of killing people or seizing hostages. Armed attack is usually seen as armed occupation; hijacking; or a barricaded hostage situation. Armed attack may result in: death or injury of employees; disruption of work activities; damage of physical property; loss of key employees (survivors) due to workplace trauma; loss due to civil liability; loss due to reduced patronage (if the public perceives security is weak).

Chemical/Biological/Radiological: Chemical/biological/radiological (CBR) terrorism has a broad range of threat scenarios, but generally requires a high level of resources for a successful, mass casualty attack. Results of a CBR attack would be: death/injury of people (common 0-20; rare 20-2500; possible 2500-15000 (15000+ biological only); contamination of physical property; disruption of work activities; and loss of key employees (survivors) due to workplace trauma.

Nuclear: Nuclear terrorism is the employment of a weapon capable of producing nuclear fission or fusion. Nuclear weapons produce massive destructive effects: blast; thermal radiation; initial nuclear radiation (1000+ REM); and residual nuclear radiation. Terrorists require a high level of resources to execute a nuclear attack. The results of using a nuclear weapon would likely be: death/injury to people; catastrophic destruction of physical assets; critical disruption of work activities; and radioactive contamination of facilities and assets (outside blast and thermal effects range).

Radio Frequency Weapons: Radio frequency weapons produce electromagnetic energy for the purpose of disruption or damaging electronic systems (e.g., explosive flux compression generators; high-powered microwave devices; high altitude nuclear detonation – electromagnetic pulse; and, non-nuclear electromagnetic pulse). Radio frequency weapons have ranges from tens of meters to tens of kilometers. The advantage of radio frequency weapons is that they can be hidden in an attaché case, suitcase, van, or aircraft. The attack can result in computer upsets or burnouts, but generally the computer users would attribute the failures to internal problems. Basically, radio frequency weapons require a larger investment in hardware than cyber-attacks, and such attacks are limited to local area effects rather than worldwide, as in the case of cyber-attacks. Although the effects of attack vary considerably among scenarios, these weapons are designed to: disable or destroy electronic equipment used in critical facilities; disrupt critical work activities; and produce secondary consequences.

Cyber Attack: Cyber-attack is the online sabotage of computer information systems or deliberate compromise of sensitive data through a wide range of attack options (e.g., computer virus attacks; denial-of-service attacks; hack attacks). Terrorist cyber-attacks seek to achieve: disruption of work activities; loss/compromise of sensitive data; loss due to civil liability; loss of patronage (if the attack resulted in compromise of sensitive data); and possible severe secondary consequences (e.g., death/injury to people; destruction of physical assets; disruption of critical public support systems; severe economic loss/destabilization).

1.2.2 Civil Action

The modern civil disturbance has become increasingly associated with sports events and issues unrelated to political positions. Civil disorders have become a part of the urban environment in Washington State. “Riots” can now generally be classified as either being politically motivated or spontaneously erupting around another event. The most important characteristic of civil disorders is an association with property damage and clashes with law enforcement and authorities. In the 1960s, civil unrest was focused on civil rights. The Watts riots in Los Angeles left 34 people dead. Similar events occurred in Newark, New Jersey, with similar results. In recent years, civil disorder typically begins as nonviolent gatherings. Injuries are usually restricted to police and individuals observed to be breaking the law. Crowds throwing bottles, rocks, and other projectiles are usually responsible for the majority of law enforcement injuries. Injuries to protestors, demonstrators, or law breakers are often the result of efforts to resist arrest, exposure to tear gas or mace, attempts to strike a police officer or from other civilians and law breakers.

Political demonstrations that become civil disorders or riots have specific targets for their attention. Examples would be protests outside a national embassy, city hall, or federal building. These incidents are typically marked by efforts by organizers to obtain permits to demonstrate and are nonviolent in nature. Occasionally, these demonstrations become violent when triggered by some other event. Often, out-of-town agitators are the catalyst for these violent outbreaks. In the Pacific Northwest, groups with such notoriety are the Skinheads, White Supremacists, and Anarchists. There are two types of riots that can occur among divergent groups:

- Communal riots are types of disorders that are classified by direct battles between groups.
- Commodity riots are disorders that stress the economic and political distribution of power among groups.

Celebrations resulting from outcomes of sporting events and annual holiday celebrations occasionally evolve into violence. The central characteristic of these "riots" has been related to substance abuse and consumption of alcohol. Incidents of this type are common in other parts of the world following soccer matches. In the United States, civil disturbances have come to be anticipated following basketball championships (Chicago Bulls, 1991 and 1992; Detroit Pistons, 1990; and recently the LA Lakers, 2001).

1.3 Secondary Hazards

The secondary hazards vary depending upon the type and scope of a terrorist attack or a civil action. Violence from either activity could lead to a multitude of secondary hazards, such as health and safety of residents, structural instability, reduced first responder and law enforcement capabilities, fire, poor air quality and safety, etc.

2.0 Profile

2.1 Location and Extent

2.1.1 Terrorism

The entire region is vulnerable to a terrorist attack. The region is home to a large population base, several cities, military bases, and all the associated infrastructure of a major metropolitan area with a large international port. Bellevue is the second largest metropolitan area in the state of Washington, fifth largest city by residential population. Additionally, Bellevue is home to a number of businesses and Bellevue College, which means the population is significantly increased during the day. Community characteristics that make Bellevue particularly vulnerable to terrorist activities include: the location of the Olympic Pipeline, a major grocery distribution site, three interstate highways that transect the city, a high concentration of high-rise buildings and development downtown, several highly attended public events, a convention center and a major shopping mall. It is also host to the homes and offices of a number of elected officials and high-profile business executives.

2.1.2 Civil Action

The last decade has seen increased rioting and looting in the US following sporting events. Seattle, home of major sport teams, has the potential to have similar disturbances. Generally, the cities of Seattle, Spokane, Tacoma, Vancouver, and Bellevue with populations of more than 100,000 are vulnerable to civil disturbances. Smaller college towns like Bellingham, Olympia, and Pullman also are subject to civil disturbances. Olympia, the center of state government, faces an increased potential for civil disturbance. Communities with concentrations of ethnic groups and disparate economic status are susceptible to civil disorder. Cities with unions, capabilities of hosting world venues, and ethnic groups are likely areas for civil disturbance.

2.2 Occurrences

2.2.1 Terrorism

Explosive Attack (Bombs): Explosive attack (suicide bomber, improvised explosive device, vehicle-borne improvised explosive device) is the number one method of terrorist attack worldwide. Domestically, potential violent extremists linked to terrorism ideologies or groups pose a current threat. The most likely threat of terrorist explosive attacks to the US homeland is from a "lone wolf" scenario (e.g., Timothy McVeigh's 1995 bombing of the Murrah Federal Building in Oklahoma City; Eric Rudolph's 1996 and 1997 bombings of the Atlanta Olympics and abortion clinics in the South; the 1978-1995 letter-bombing spree by Ted Kaczynski, the Unabomber; and the 2013 Boston marathon bombing by Dzhokhar and Tamerlan Tsarnaev). In this scenario, a terrorist attack would be perpetrated by one or more individuals who may embrace an extreme ideology of a terrorist group, but act without assistance or approval of any established group. The admiration of violent high-profile offenders and their attacks by extremists (e.g., anti-government; anti-abortion) highlights continued concerns relating to potential or similar threat activity as noted by the following cases:

- January 1, 1976, the radical George Jackson Brigade bombed the Laurelhurst substation, causing $737,137 in damage.
- 1984 Seattle bombing by Skinhead Group, The Order.

- 1993 A pipe bomb is detonated at the Tacoma hall of the National Association for the Advancement of Colored People. A month later, skinhead Jeremiah Knesal, 19, of Auburn and Wayne Wooten Jr., 18, of Tacoma were arrested in Salinas, Calif. A couple days later, skinhead Mark Kowaalski, 23, was arrested in Auburn. All three eventually plead guilty to charges linked to the Tacoma bombing and a terrorist campaign against Jewish and African Americans.

Arson: While national attention is focused on the substantial threat posed by international terrorists to the homeland, local officials must also contend with an ongoing threat posed by domestic terrorists based and operating strictly within the United States. Domestic terrorists motivated by a number of political or social agendas, including white supremacists, black separatists, animal rights/environmental terrorists, anarchists, anti-abortion extremists, and self-styled militia, continue to employ violence and criminal activity in furtherance of these agendas. Arson is the fourth most widely used terrorist attack method in the world and is a favorite in the United States of domestic terrorists (e.g., Earth Liberation Front's arsons: 2003 in San Diego - $50 million in damages; 2001 at the University of Washington, Seattle - $2 million in damages; 1998 in Vail, Colorado - $12 million in damages).

Kidnapping: Kidnapping is the number two mostly widely used method of terrorist attack in the world, especially in Asia and South America. Although some kidnappings are "politically motivated," extortion is generally the aim of terrorist kidnapping attacks.

Armed Attack: Armed attack is third most used terrorist attack method worldwide. This form of attack came into prominence during the 1972 Olympic Games in Germany when it was employed by Palestinian fedayeen against the athletic team from Israel. Domestically, Patriot movement groups—consisting of militias, common law courts, tax protesters, and other anti-government extremists—remain a continuing threat in America today. Sporadic incidents resulting in direct clashes with law enforcement are possible and will most likely involve state and local law enforcement personnel, such as highway patrol officers and sheriff's deputies. Local armed attacks include:

- 2012 Seattle Café shooting spree
- 2006 Seattle Jewish Federation shooting

Chemical/Biological/Radiological: Historically, the use of chemical/biological/radiological (CBR) weapons has appealed to a limited range of terrorists worldwide. To date, less than one percent (1%) of terrorist attacks worldwide used CBR weapons. However, terrorist attack methodology adapts and evolves to address the changes to their operating environment (e.g., improved counter-terrorism activities; greater public awareness of the signs of terrorism). While a mass casualty attack using relatively low-tech methods will be their most likely approach, terrorists are seeking weapons of mass destruction including chemical weapons, some type of biological agent such as anthrax, or some type of radiological weapons – the so-called dirty bombs.

Nuclear: There have been no nuclear terrorist attacks worldwide to date. Proliferation of weapons of mass destruction (WMD), including nuclear weapons, and the acquisition of WMDs by a terrorist group, through theft or manufacture, remain a significant issue for the US. Homeland Security Presidential Directive – 4 (the unclassified version of National Security Presidential Directive – 17), which discusses the national strategy to combat WMDs. In addition, Homeland Security Presidential Directive – 14 establishes a Domestic Nuclear Detection Office.

Radio Frequency Weapons: There have been no radio frequency weapons attacks worldwide to date.

Cyber Attack: Although cyberterrorism has been limited to date, terrorists show a growing understanding of the critical role that information technology plays in the day-to-day operations of our economy and national security. Terrorists' recruitment efforts have expanded to include young people studying mathematics, computer science and engineering in an effort to move from the limited physical attacks to attacks against our technical systems. Hackers that plant malicious code or upload bots that are designed to steal information are the main threats in this group. These individuals have the ability to take down a critical computer system or steal trade secrets, either of which can be devastating to a company or agency. The growing number of hackers motivated by money is a cause for concern. If this pool of talent is utilized by terrorists, foreign governments, or criminal organizations, the potential for a successful cyber-attack on our critical infrastructures is greatly increased.

2.2.2 Civil Action

Washington State witnessed race riots in the 1960s, protests against the Vietnam War in 1960s and the 1970s, abortion clinic demonstrations in the 1980s, and civil disturbances and allegations of police brutality in the 1990s. In Seattle, a small-scale riot occurred after the 1992 Rodney King verdict. On the night the jury rendered its decision, small groups of people roamed Seattle's downtown streets smashing windows, lighting dumpster fires, and overturning cars. The following day some Seattle residents went to Capitol Hill where they set fires and attacked the West Precinct Police Headquarters.

On May 3, 1998, the Washington State Emergency Operations Center (EOC) activated in response to a civil disturbance at the Washington State University in Pullman. The disturbance developed when students' end-of-the-year celebrations got out of hand. The disturbances consisted of large crowds of students lining the streets, throwing rocks, debris, beer bottles, and starting fires. Local and state law enforcement officials were assembled to restore order. Several officials were injured. Washington National Guard (NG) units were placed on standby status.

On August 26, 1998, the Makah Indian Nation proposed whale hunting activities at Neah Bay. The state provided resources from the NG, Washington State Patrol (WSP), Department of Fish and Wildlife, Department of Natural Resources (DNR), and Emergency Management Division (EMD), at Clallam County Sheriff's request to control disturbances between protestors and residents.

On November 30, 1999, civil disturbance and violence occurred during the WTO Ministerial Conference (see Figure 2).[3] The city of Seattle declared an emergency and the Governor signed a proclamation of emergency allowing commitment of state resources to support affected local jurisdictions. WSP, Department of Transportation, NG, DNR, EMD, and an

Figure 1. WTO Protest

The Seattle downtown Westlake Park area was the focal point of days of protests in late September/early October of 2011 for the Occupy Seattle movement. There were dozens of arrests as the city grappled with the legality of demonstrators camping out in the public space. The local protest was part of a national movement aimed at making economic policies fairer for "the 99 percent." Big banks were a primary target.[4]

2.3 Recurrence Rate

The Office of Emergency Management determined the probability of recurrence for terrorism or civil disturbance in King County to be an estimated "25 years or less". This is based on information of past occurrences.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

The impacts to personnel in the area of a terrorist event or civil action will depend greatly on the type and size of the incident. Most terrorist events have the capability to cause large-scale or mass casualties and injuries, whereas civil actions may only cause a few injuries (depending on the scope of the action). Because of the unpredictable nature of terrorist events or civil actions, it is difficult to predict how and to what extent Bellevue would be impacted.

3.2 Health and Safety of Personnel Responding to the Incident

Depending upon the type of incident, responders may face a variety of hazards in the response phase of the emergency, including structural collapse issues, chemical/biological/radiological environments, and mass casualty situations. First responders frequently have adverse psychological reactions to trauma. Long term psychological impacts were noticed years ago, such as after the collapse of the Hyatt Regency Hotel walkway in Kansas City, Missouri in 1981. Post-Traumatic Stress Disorder may be common in responders to a terrorist incident, especially if the responders must remove and identify casualties from the incident location.

3.3 Continuity of Operations and Delivery of Services

For a large terrorist event or civil action impacting Bellevue, continuity of operations will be impacted for many of the agencies and jurisdictions located therein. The impacts affecting continuity of operations may include:

- Death or injury to staff limiting the number of staff able to fill normal operational duties,
- Inability of staff to respond to their work sites due to road closures from debris or damage to the roads and bridges or overpasses damaged closing arterials in particular,
- Staff absenteeism while checking on or taking care of family and handling damage to home or other personal property,
- Damage to communications systems will limit organizations' ability to coordinate their own resources, and it will also limit their ability to pull together a full picture of the damage suffered in their jurisdiction and to request assistance if needed,
- Damage to facilities and equipment, and
- Damage to the water, energy, and sewer systems connected to agency facilities will not allow operations to continue in their normal manner.

Because of the unpredictable nature of terrorist events or civil actions, it is difficult to predict how and to what extent Bellevue would be impacted.

3.4 Property, Facilities, and Infrastructure

Terrorist activities and civil actions have numerous impacts to property, facilities, and infrastructure based on data from past events. The scope and size of the terrorist activities and civil actions dictates the amount of damage to a city's property, facilities, and infrastructure. If a terrorist event or civil action occurred in Bellevue, the city could sustain considerable impacts and damage, especially in the downtown neighborhood given the close proximity of high-rise structures (both commercial and residential) and the high number of residents in the area during the day. Cyberterrorism impacts a different type of infrastructure, and the City of Bellevue currently has preventative measures in place. A cyber-attack could impact property and facilities should a utility service be targeted.

3.5 Environment

Air pollution: some chemicals released as gasses can cause immediate damage to plants, animals, and humans. Tanks filled with, for example, chlorine, ammonia, or any other hazardous gas can harm or kill animals, birds, and plants, not just in the area of the release but for some distance downwind depending on the chemical involved and the size of the release. The damage will usually be temporary and physical recovery to the environment will begin as soon as the gas dissipates. Because of the unpredictable nature of terrorist events or civil actions, it is difficult to predict how and to what extent Bellevue would be impacted.

3.6 Economic and Financial Condition

Terrorism and civil action both have an adverse effect on local economy and financial status. The economic impact of terrorism can be calculated from a variety of perspectives. There are direct costs to property and immediate effects on productivity, as well as longer term indirect costs of responding to terrorism. The damage to consumer confidence in an area of a terrorist event or civil action further impacts the region's economy, and travel advisories would limit the number of tourists in a given area.

3.7 Public Confidence in the Jurisdiction's Governance

Both terrorism and negative civil actions may cause potentially long-term psychological effects. Frequent warnings without actual attacks (highlighting the rare and unpredictable nature of a terrorist attack) pose more negative psychological effects and lack of confidence in governmental systems, and—ironically—an attack can bring about enhanced support and a sense of community.

Terrorist violence – and the threat of such violence – can work to bind communities together with a sense of common purpose and common outrage. Not only do terrorist attacks give a perception that there is a shared enemy out there, such attacks also bolster an individual's ties to their local community, deepening their sense of belonging and their identification with others living in the area. This is a powerful social effect which has been witnessed many times before. For example, during the London Blitz in World War II, many people noted the widespread camaraderie and closeness of what became known as the Blitz Spirit. Some aspects of this effect have already been seen in the US after 9/11. While many commentators talked about the sense of fear and panic sweeping the country, it was equally clear that there was a massive and widespread sense of shared community. Sales of American flags rocketed and millions of homes flew flags in a very public display of shared identity. Similar trends have been seen in Israel, where relentless terrorist attacks, rather than shattering society psychologically, have instead witnessed a remarkable resilience effect.[9]

4.0 Resource Directory

- King County Department of Emergency Management
  http://www.kingcounty.gov/safety/prepare.aspx
- Federal Bureau of Investigation
  http://www.fbi.gov
- Homeland Security Presidential Directives, Federation of American Scientists
  http://www.fas.org/main/home.jsp

[1] http://www.fbi.gov/stats-services/publications/terrorism-2002-2005

[2] Ibid.

[3] 1999 Seattle WTO Protests, http://en.wikipedia.org/wiki/1999SeattleWTOprotests

[4] Some of the more famous riots/protests in Seattle history, May 1, 2012, (accessed October 22, 2013), http://blogs.seattletimes.com/today/2012/05/some-of-the-more-famous-riotsprotests-in-seattle-history/

Science and Technology Institute, Proceedings from the Conference December 9-11, in New York City.

[5] Ibid.

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1.0 Introduction

As identified in the Climate Change Hazard Section, larger changes in the atmospheric conditions across the globe, due to climate change, will lead to the potential changes in how we define hazards, identify future recurrence rates, and identify vulnerabilities and related consequences. This is of important note as we document the wildland/urban interface hazards in the City.

1.1 Definition

A wildland/urban interface (WUI) area is that geographic area in which structures and other human development meets or intermingles with wildland or vegetative fuels. A WUI fire is a fire located in that geographic area. There are some locations within Bellevue city limits where structural developments meet and intermingle with the wildland areas. This condition gives rise to the possibility of WUI fires, especially when weather conditions are dry and fuels are abundant. Though compared to other areas of the region, the risk is low.[1]

1.2 Types

WUI fires occur naturally (lightning strikes) or are started by people. Secondary events such as erosion, landslides, and flash floods often occur in areas which have been affected by wildland fires. There are three types of WUI fires, delineated by cause.

1.2.1 Naturally Occurring Fires

Naturally occurring interface fires, especially those caused by lightning, are rare in western Washington[2]. However, wildland fires started by lightning in Washington state burn more state-protected acreage than any other cause, an average of 10,866 acres annually.[3]

1.2.2 Human-Caused Fires

Human-caused interface fires, stemming from people's carelessness and lack of fire knowledge, are common causes of interface fires. "West-side" people start 67% of the wildland fires that occur in Eastern Washington[4]. Major causes include arson, recreational fires that get out of control, smoker's carelessness, debris burning, and children playing with fire. From 1992 to 2001, on average, people caused more than 500 wildland fires each year on state-owned or protected lands; this compares to 135 fires caused by lightning strikes. Human-caused fires in Washington burn an average of 4,404 state-protected acres each year[5].

1.2.2 Controlled Burns

Controlled burns are fires conducted because the fire cycle is an important aspect of management for all ecosystems and controlled burns are not considered hazards unless they get out of control.[6]

2.0 Profile

2.1 Location and Extent

Eastern Washington faces the greatest risk of fire, though Western Washington does have areas of risk as well. The Washington State Department of Natural Resources and its federal and local partners determined the communities in the state that are at high risk after evaluating them for fire behavior potential, fire protection capability, and risk to social, cultural and community resources[7]. As Figure 1 indicates, Bellevue is not considered at high risk from Wildland fire by the Department of Natural Resources[8].

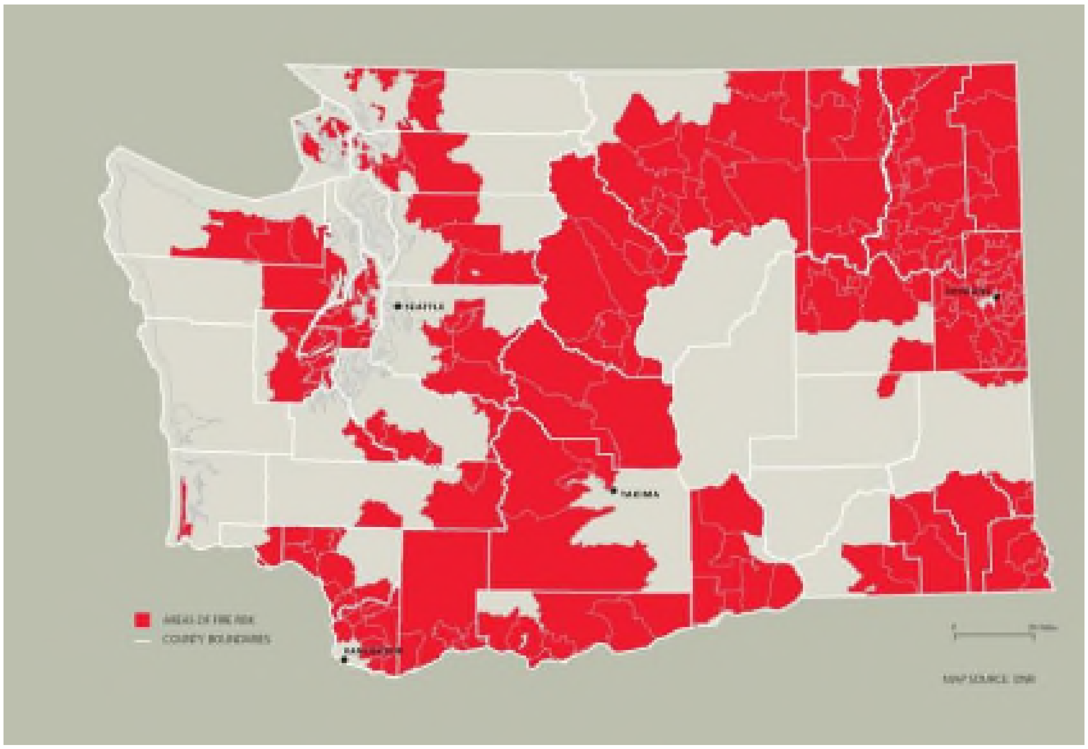


Figure 1. Washington State Fire Hazard Map

The City of Bellevue Fire Department has developed pre-fire plans for certain areas in the City that have increased potential due to terrain, fuels, exposed structures, access, or a combination of such factors. The areas include: Ardmore, Bell Way, Bellewood, Bridle Trails, China Creek, Coal Creek, Cougar Mountain, Factoria West (Glen Eden), Factoria East (Allen Road), Hunts Point (Wetherill), Kelsey Creek, Lakemont (Cougar), Larson Lake (Lake Hills), Lewis Creek, May Creek, Mercer Slough, Meydenbauer Hill, NewPort Hills, Overlake (520), Somerset, Vasa Park, Weowna, Woodridge, and Yarrow Bay. These do not represent all potential wildland fire areas in the City but outline a number of high risk areas. The City is in the process of developing a single map to show this extent.

In order to prevent wildland fires from logging activities, the Washington State Department of Natural Resources (DNR), along with the United States Forest Service, the Bureau of Land Management, and the Bureau of Indian Affairs follow the Industrial Fire Precaution Levels (IFPL). This classification is based on the National Fire Danger Rating System (NFDRS) and covers the types of equipment that can be used and their hours of operation.[9]

Industrial Fire Precaution Levels (IFPL)

Level 1. Closed Season – Fire precaution requirements are in effect. A fire watch/security is required at this and all higher levels unless otherwise waived.

Level 2. Partial Hootowl – The following may operate only between the hours of 8 p.m. and 1 p.m. local time: power saws except at loading sites; cable yarding; blasting; welding or cutting of metal.

Level 3. Partial Shutdown – The following are prohibited except as indicated: cable yarding – except that gravity operated logging systems employing non-motorized carriages or approved motorized carriages may operate between 8 p.m. and 1 p.m. when all block and moving lines, except for the line between the carriage and the chokers, are suspended ten feet above the ground; power saws – except power saws may be used at loading sites and on tractor/skidder operations between the hours of 8 p.m. and 1 p.m. local time.

In addition, the following are permitted to operate between the hours of 8 p.m. and 1 p.m. local time: tractor, skidder, feller-buncher, forwarder, or shovel logging operations where tractors, skidders, or other equipment with a blade capable of constructing fireline, are immediately available to quickly reach and effectively attack a fire start; mechanized loading and hauling of any product or material; blasting; and welding or cutting of metal.

Level 4. General Shutdown – All operations are prohibited.

National Fire Danger Rating System (NFDRS)

Color-coded levels to help the public understand fire potential within the current conditions and help mitigate their actions to prevent human-caused wildfires.

Fire Danger Level: Low

- When the fire danger is "low" it means that fuels do not ignite easily from small embers, but a more intense heat source, such as lightning, may start fires in duff or dry rotten wood. Fires in open, dry grasslands may burn easily a few hours after a rain, but most wood fires will spread slowly, creeping or smoldering. Control of fires is generally easy.

Fire Danger Level: Moderate

- When the fire danger is "moderate" it means that fires can start from most accidental causes, but the number of fire starts is usually pretty low. If a fire does start in an open, dry grassland, it will burn and spread quickly on windy days. Most wood fires will spread slowly to moderately. Average fire intensity will be moderate except in heavy concentrations of fuel, which may burn hot. Fires are still not likely to become serious and are often easy to control.

Fire Danger Level: High

- When the fire danger is "high", fires can start easily from most causes and small fuels (such as grasses and needles) will ignite readily. Unattended campfires and brush fires are likely to escape. Fires will spread easily, with some areas of high-intensity burning on slopes or concentrated fuels. Fires can become serious and difficult to control unless they are put out while they are still small.

Fire Danger Level: Very High

- When the fire danger is "very high", fires will start easily from most causes. The fires will spread rapidly and have a quick increase in intensity, right after ignition. Small fires can quickly become large fires and exhibit extreme fire intensity, such as long-distance spotting and fire whirls. These fires can be difficult to control and will often become much larger and longer-lasting fires.

Fire Danger Level: Extreme

- When the fire danger is "extreme", fires of all types start quickly and burn intensely. All fires are potentially serious and can spread very quickly with intense burning. Small fires become big fires much faster than at the "very high" level. Spot fires are probable, with long-distance spotting likely. These fires are very difficult to fight and may become very dangerous and often last for several days.

Recognizing the many benefits that urban tree canopy brings to urban environmental quality, the City of Bellevue engaged American Forests to update their 1998 Urban Ecosystem Analysis, initially conducted using Landsat satellite data. This analysis examines forest, tree canopy and other land cover changes over the last decade and quantifies the ecosystem benefits of the City’s green infrastructure (see Figure 2). The percentage of forest canopy in Bellevue shows the potential for the threat of fires and how the area may be impacted.

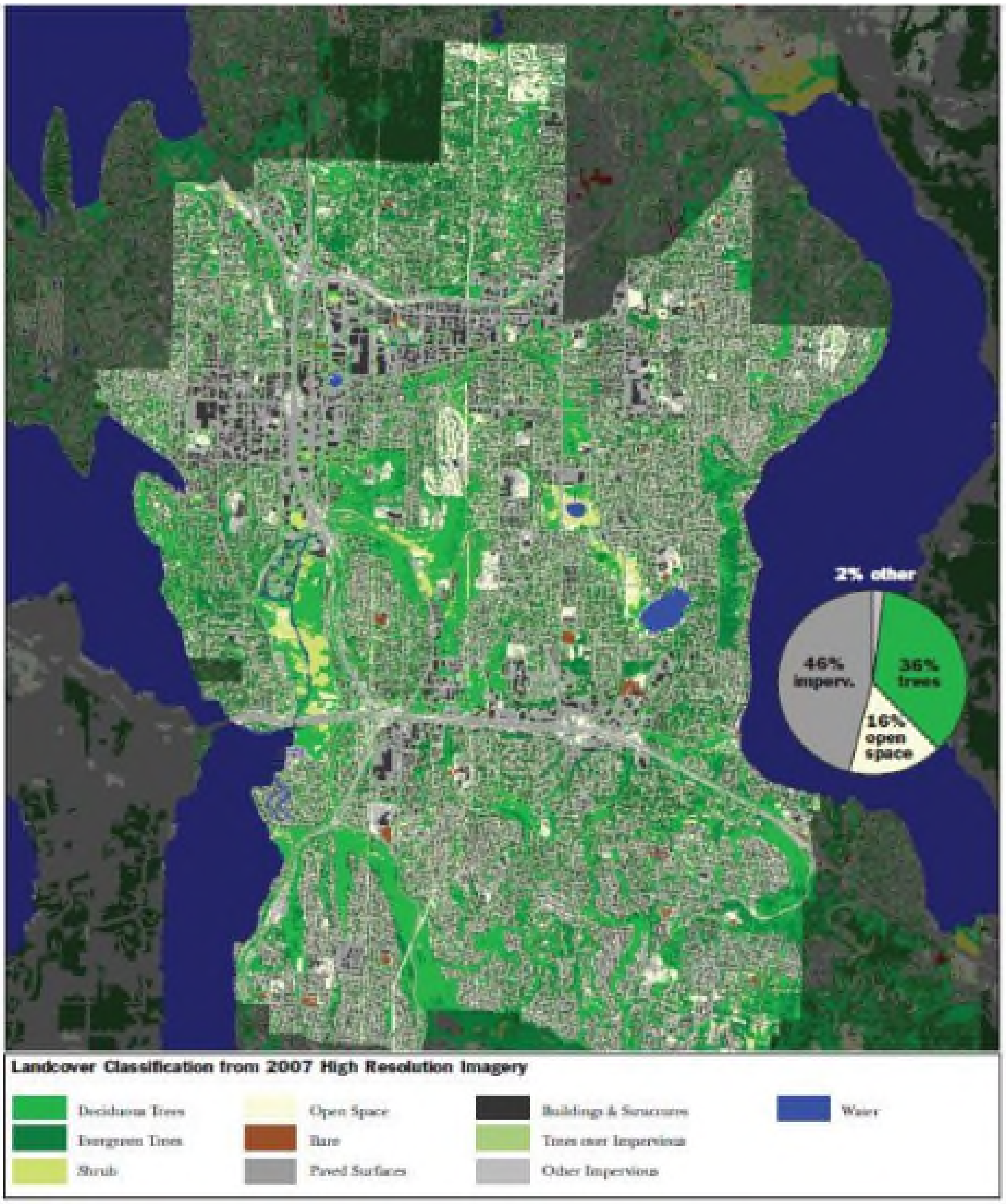


Figure 2. Bellevue Forest Canopy[10]

Due to variables affecting the fire threat caused by topography, weather, and the amount of fuel the DNR has created 38 different fire danger rating areas, or zones, based on recommended actions by the NFDRS. Of these, there are five different fire danger rating areas that cover different portions of King County. These include areas shown on Figure 3.

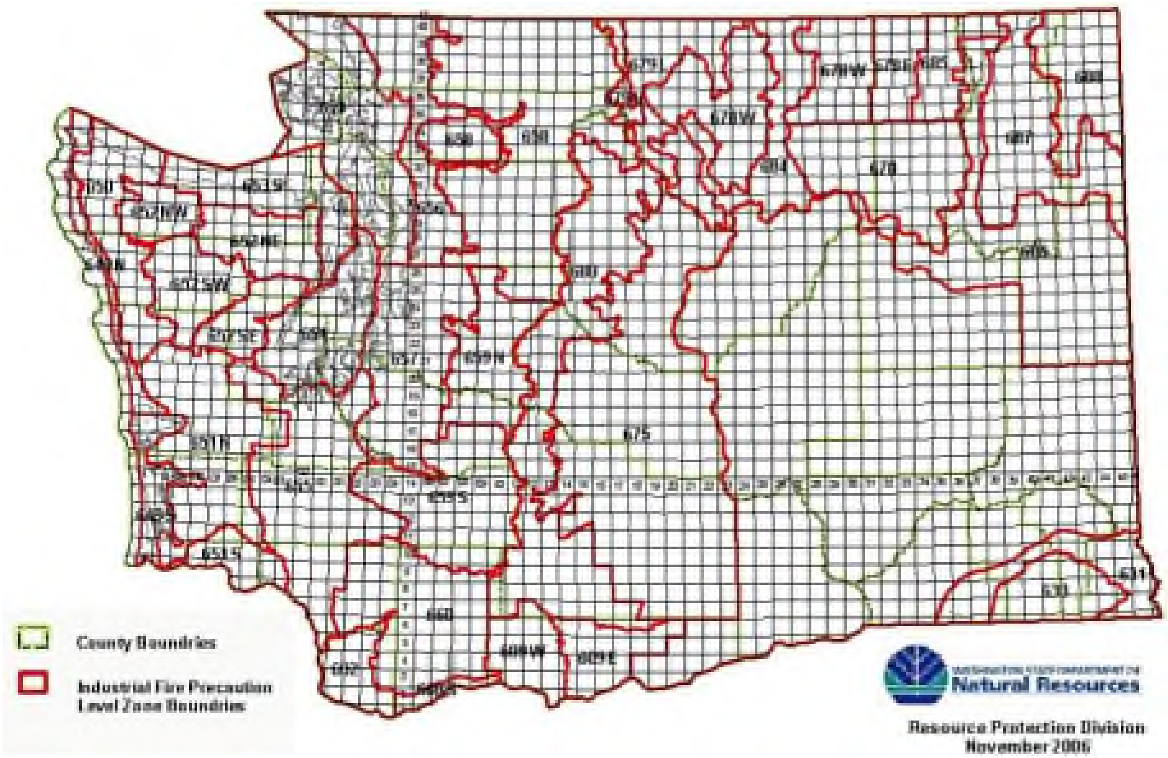


Figure 3. IFPL Shutdown Zones

Each Shutdown Zone has unique characteristics, as mentioned above, of topography, weather and the quantity of available fuel, that usually create situations of similar fire danger throughout the zone; but that could be different for adjacent zones. These different characteristics can lead to the IFPL also being different for adjacent zones.

In addition to the industrial controls, the DNR administers the Public Use Restrictions, limiting the public's use and access to forested lands during periods of high fire danger[11]. Summer fire rules may be in effect from April 15 to October 15 or longer if warranted. Like the industrial limitations, there are four levels of control that can be exercised. These are:

- **Burn Ban:** When initiated by DNR, a burn ban prohibits all open fires on DNR lands. It may be done in coordination with federal and local agencies to cover land under their control.
- **Closed Entry Areas** Usually designated as "regions of extra fire danger" in the spring and closed to recreation throughout the summer.
- **Forestland Closure**: In periods of extreme fire weather conditions, DNR may restrict all activities on some private and public lands, even to the point of not allowing home owners access to their homes.

2.2 Occurrences

Historically, wildland fires were not necessarily considered a hazard. Fire is a normal part of most forest and range ecosystems in temperate regions of the world. Fires traditionally burn on a fairly regular cycle, recycling carbon and nutrients stored in the ecosystem, and strongly affecting the species within the ecosystem.

While wildland fires are predominately recognized as an Eastern Washington phenomenon, they also happen on the west side of the Cascades. The burning cycle in western Washington is every 100 to 150 years[12]. This assumes a normal regrowth pattern after a forest has burned.

The Carbon Copy fire in Pierce County and the Bear Gulch fire in Mason County during the summer of 2006 (see Figure 4) and the Cascade Creek Fire in Skamania and Klickitat Counties in 2012 are some of the most recent large fires in Western Washington.

Figure 4. Carbon Copy Fair August 2006

Due to the proximity of homes and businesses throughout King County to areas with natural vegetation, given the right location and conditions, many fires could turn into a WUI fire.

Wildland fires in King County are largely confined to the drier periods of the year. In most years, this falls during the summer or the very earliest portion of fall. At that time, due to the lack of rain, the fuel moisture content is usually at its lowest[13]. Any time the weather turns dry and hot for a lengthy period of time in Bellevue there is the possibility of a wildland fire. This brings into focus, the various periods of concern for the City of Bellevue which would include “Flare” and “Drought” periods. A “Flare” period is an abbreviated time-frame (a couple weeks) of very hot, dry weather that quickly dries out flashy fuels such as annual grasses. Under such conditions, Bellevue fire crews will see an up-tick in incidents such as grass fires along the freeways, and small brush fires. Of greater concern is a “Drought” period, where extended dry weather, impacting through a spring, summer and into fall (or even extending for 2 or 3 years) with well below average precipitation. Under such conditions, heavier fuels such as our coniferous trees begin to experience drought related stress, and become susceptible to wildfire. It is under such a “Drought” condition, that some Bellevue neighborhoods could face a very significant wildfire danger.

The best available information at this time indicates that fires have occurred in or near the locations identified above in the location and extent description. Figure 5 illustrates fire occurrences in the records kept by DNR from 1973 through 2007.

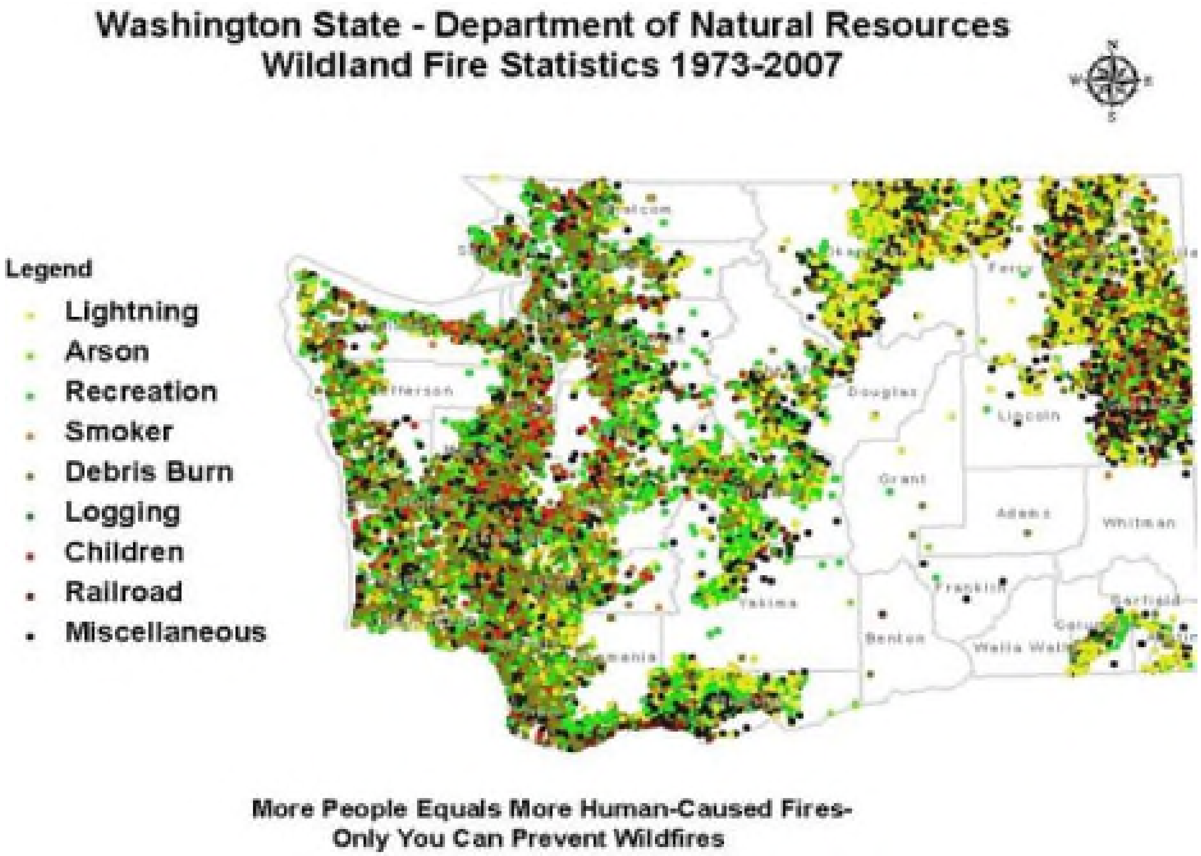


Figure 5. Washington State DNR Wildland Fire Statistics: 1973-2007

While not all of these are technically WUI fires, their relatively frequent occurrence indicates that there is some risk to the WUI fire hazard near populated areas of Bellevue. Table 1 shows the number of classified fires that DNR responded to from 2002 through 2007 in the South Puget Sound Region[14] and their cause.

Table 1. Wildland Response South Puget Sound Region: 2002-2007[15]

Cause	2002	2003	2004	2005	2006	2007	Total	%
Arson	10	18	7	2	15	1	53	12.4
Children	11	8	4	4	10	3	40	9.4
Debris Burn	19	10	13	4	18	9	73	17.1
Lightening	1	4	5	1	0	0	11	2.6
Logging	2	1	2	1	1	0	7	1.6
Misc.	13	29	14	13	29	23	121	28.3
Rail Road	1	1	0	0	0	1	3	.7
Recreation	19	20	14	13	21	10	97	22.7
Smoker	10	8	0	2	2	0	22	5.2
Totals	86	99	59	40	96	47	427	100

While the vast majority of the fires listed would not be defined as WUI fires, the Department of Natural Resources, South Puget Sound Region is involved fighting a WUI fire as least every couple of years[16]. Very few structures have been lost in these fires due to the quick response and the high priority put on preventing the fires from involving the threatened structures. When this is combined with the WUI involvement of individual jurisdictions (cities, towns, and rural fire districts) in fighting wildland fires that threaten homes and other improved property outside the DNR boundaries, the potential for a major fire is always there. Wildfires will exist every year within the boundaries of King County. Few will have the potential of developing into a WUI fire affecting Bellevue.

2.3 Recurrence Rate

Today, many factors affect the overall recurrence rate of fires. The main factor that was not part of the ecosystem in the past is the effect of the encroachment of humans into what has traditionally been forested area. The potential for fires to impact the human community has changed over the past century and a half. Based on information from past fire occurrences and information from the DNR, the probability of recurrence for the WUI fire hazard in King County and Bellevue is a five year or less occurrence rate.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

The health and safety of persons in the affected area at the time of the fire could be much compromised. Burns, smoke inhalation, psychological trauma, and death are all some of the impacts on the population living, working, recreating, or visiting within the impacted area. The Southern California wildfires of 2003 and 2007 and the Oakland Hills fire of 1991 are perfect examples of major WUI fires that can not only cause damage, but death as well. The Oakland Hills fire killed 25 people, the 2003 Southern California fire 22, and the 2007 fires a dozen. This does not count the dozens who were injured in each of these fires.

In some ways, the psychological damage can be as traumatic as some of the physical injury. Both adults and children can present long term psychological changes due to the incident. Children may manifest through regression or other actions. This can include:

- Fear of injury or death;
- Fear of separation;
- Inability to sleep;
- Afraid of the dark;
- Afraid of closed spaces;
- Afraid of outdoors;
- Regression of toilet training/bed wetting or other outgrown childish behavior;
- Withdrawal from normal activities;
- Fear of sudden noises;
- Refusing to eat, nightmares, hyperactivity and irritability; and
- Aggressive episodes with other children[17].

"Adult Stress Symptoms include: Anxiety, depression, insomnia, irritability, impairment in concentration, loss of productivity, feelings of sadness and gloom, and the tendency to link the fire to other traumatic events in their life."[18]

3.2 Health and Safety of Personnel Responding to the Incident

The impacts to personnel responding to a WUI Fire include burns, trauma, smoke inhalation, psychological trauma and death. Injury and death can occur from equipment failure or not wearing the proper equipment. The one more recent reported major injury to a wildland firefighter included the deaths of 19 firefighters in Arizona in 2013 due to erratic fire behavior[19]. They can occur from falling snags, burnover, or even a bulldozer rolling over on steep terrain.
During the 17-year period, from 1990 to 2006, 310 people nationwide were killed during wildland fire operations. This number includes contractors working the fire. Of those 310 firefighters killed, four major causes were responsible for 275 or 89% of those deaths. They include:

- Aircraft accidents, 72 people, 23% of total,
- Vehicle accidents, 71 people, 23% of total,
- Heart attacks, 68 people, 22% of total, and
- Burnovers, 64 people, 21% of total[20].

For example in 2005, of the 12 wildland fire deaths in the United States, three were from an airplane crash and three from auto accidents. Three were from heart attacks and the final three were one each from burns/smoke inhalation, snag, and electrocution. Half of those killed were from volunteer fire departments[21]. Long-term effects can include heart disease, emphysema, and other environment-caused disease.

3.3 Continuity of Operations and Delivery of Services

Depending on the area impacted by a WUI fire, the continuity of operations for multiple jurisdictions or agencies might all be affected at the same time. Another problem is the isolation of certain areas. Many areas exist with their only access is the narrow two lane roads that connect them to the more populated portions of the city.

3.4 Property, Facilities, and Infrastructure

Within the geographic area covered by a WUI fire there will be considerable damage to the facilities and infrastructure. The fires that burn throughout the western states present year-to-year images of the destruction possible. These fires can become hot enough to burn asphalt, which can render the roads impassable for some time. Utility poles and wires will be totally gone. Many buildings of individual jurisdictions can be destroyed just as individuals' homes can be burned. Cars, trucks, busses, and equipment caught in the path of a fire can be a total loss.

3.5 Environment

Environmental impacts from a major wilderness fire can be extreme, and may be exacerbated even further if the fire becomes a WUI fire. Normal environmental damage includes deforestation, death of animals, pollution of streams and rivers with burnt material, increased erosion and later landslides. This damage may take decades to reverse. If the fire happens in an area of old growth forest, which may have been in existence for hundreds of years, it could take centuries for the environment to regain its original form and biodiversity. However, even with the damage done, not everything about the damage is detrimental. The damage done to the environment and the destruction of the forest opens up areas for colonization by new plants and animals. These burned areas allow sunlight to reach the ground. In doing so, plants that have not been able to survive in the heavily shaded understory that normally exist in old growth forests will thrive. As they do so, they will attract animals that thrive on them. Over time, the remnants of the original forest will encroach on the open area and it will once again return to forest.
With a fire that affects the interface between the forest and the developed areas of the city, there is the problem of further pollution. The burning of materials used in construction, the rupturing of oil, gas, or other hazardous materials tanks, the melting and burning of tires, and the distribution of firefighting chemicals across the landscape.
Over the past few years, an increase in the knowledge of the effects from firefighting chemicals has shown that there can be long term detrimental impacts on the environment, especially on water features and areas where the groundwater may become contaminated[22][23]. This is particularly relevant when there are repeat uses of the chemicals to control fires.

3.6 Economic and Financial Condition

The economic and financial condition of any individual jurisdiction will depend on the size of the WUI fire and which parts of the community are directly affected. A fire that burns a couple of thousand acres of previously logged but not regrown terrain and destroys a dozen homes will have a relatively benign long-term economic impact for the larger community. In comparison, one that destroys an area the same size, but burns an entire small community, will have long term lasting effects, if the community is able to rebuild at all. The Southern California wildfires of 2003 and 2007 and the Oakland Hills fire of 1991 are perfect examples of major WUI fires that were able to destroy a large quantity of very expensive real estate. The long term- effects include: a loss of economic vitality because of the destroyed businesses and wilderness jobs associated with recreation and logging; a loss of tax revenue; and, possibly the permanent loss to the community of the people that lived in the homes either due to death from the fire or moving away in the aftermath of the disaster.

3.7 Public Confidence in the Jurisdiction's Governance

The reputation of the entity will be directly related to the perception of competence in handling the fire threat and how well it was handled. The more damage caused by the fire that is shown to have been preventable by some action of the agency or jurisdiction, the lower the resulting reputation will be and the greater the decrease in confidence in the entity's ability to handle future situations. A rapidly handled fire with little damage to homes or businesses will enhance the jurisdiction's reputation while a fire that burns many homes or businesses, even if it was well handled may allow a lack of confidence to develop. Visuals of teams working to protect the homes and property of individuals will help to shore up this image.

4.0 Resource Directory

- Bellevue Firefighters IAFF Local 1604
  http://www.iaff1604.org/index.cfm
- State of Washington Department of Natural Resources
  https://www.dnr.wa.gov/Wildfires
  https://www.dnr.wa.gov/programs-and-services/wildfire-resources
- The Washington State Industrial Fire Precaution Level System
  https://www.dnr.wa.gov/ifpl
- Firewise Communities
  http://www.firewise.org
- Forest Service, United States Department of Agriculture
  http://www.fs.fed.us
- Bureau of Land Management, United States Department of the Interior
  https://www.blm.gov/programs/fire-and-aviation
- National Park Service, U.S. Department of the Interior
  https://www.doi.gov/wildlandfire
- Fish and Wildlife Service, U. S. Department of the Interior
  http://www.fws.gov/fire/
- National Fire Plan
  https://www.fs.fed.us/database/budgetoffice/NFP_final32601.pdf

[1] Modified from PC HIVA, WUI Fire Section, September 5, 2002, p.33.
[2] Modified from PC HIVA, WUI Fire Section, September 5, 2002, p.33.
[3] Modified from Washington State Natural Hazard Mitigation Plan (DRAFT), WUI Fire Section. Washington State Emergency Management Division. September 5, 2002. Web.
[4] Modified from PC HIVA, WUI Fire Section, September 5, 2002 p.33.
[5] Modified from Washington State Natural Hazard Mitigation Plan (DRAFT), WUI Fire Section. Washington State Emergency Management Division. September 5, 2002. Web.
[6] Ibid.
[7] Risk factors included area fire history, type and density of vegetative fuels, extreme weather conditions, topography, number and density of structures and their distance from fuels, location of municipal watershed, and likely loss of housing or business. The evaluation used the criteria in the wildfire hazard severity analysis of the National Fire Protection Association's NFPA 299 Standard for Protection of Life and Property from Wildfire, 1997 Edition.
[8] Graphic from A Progress Report on the National Fire Plan in Washington State, Department of Natural Resources, September 2002. http://www.dnr.wa.gov/Publications/rp_fire_nationalfireplan.pdf
[9] The Washington State Industrial Fire Precaution Level System, Washington State Department of Natural Resources, http://www.dnr.wa.gov/Publications/rp_burn_ifpl_pocket_card.pdf
[10] Urban Ecosystems, 2008 City of Bellevue, Washington, American Forests http://www.ci.bellevue.wa.us/pdf/Manager/Urban_Ecosystem_Analysis.pdf Urban Ecosystem Analysis
[11] The Washington State Industrial Fire Precaution Level System, Public Use Restrictions, Washington State Department of Natural Resources, Web.
[12] In Western Washington the 100 to 150 year burning cycle is based on a normal forest regrowth after a major fire that burns a large section of a forest. These fires are called "Stand Replacement Fires." Once a stand replacement fire has happened it takes that long to develop enough vegetative material to support a repeat of the previous fire. Pierce County Emergency Management received this information from personal conversation with Chuck Frame, Fire Operations Manager, DNR South Puget Sound Region, 02/01/2008.
[13] Fuel Moisture Content is the quantity of moisture in the fuel expressed as a percent of the oven-dried weight. http://www.pfmt.org/fire/glossary.htm
[14] The DNR South Puget Sound Region consists of King, Pierce, Kitsap, and Mason Counties as well as small portions of Lewis and Snohomish Counties.
[15] Data from statistics compiled by the Department of Natural Resources and received in a meeting of Pierce County Emergency management with Chuck Frame, Fire Operations Manager, DNR South Puget Sound Region, 02/28/08.
[16] Personal phone conversation with Chuck Frame, Fire Operations Manager, DNR South Puget Sound Region, March 3, 2008.
[17] California Wildfires — Psychological Effects; Psychologist is Available to Discuss Trauma, From the Business Wire Oct. 26, 2003, Web.
[18] Ibid.
[19] Fox News, http://www.myfoxphoenix.com/story/22726613/2013/06/30/yarnell-hill-wildfire-grows-to-almost-1000-acres
[20] Wildland Fire Operations Risk Management Information Paper, Emphasis on risk management in wildland fire operations for 2007, FEMA, U.S. Fire Administration, U.S. Fire Administration, 16825 S. Seton Ave., Emmitsburg, MD 21727, Web.
[21] Madden, Gene, Safety Zone: Too Many Lost, Reflecting on 2005 wildland fatalities, Wildland Firefighter Magazine, May 2006, Vol 24, Issue 5 as reprinted
[22] Ecological Effects of Fire Fighting Foams and Retardants, Robyn Adams and Dianne Simmons, Conference Proceedings, Australian Bushfire Conference, Albury, July 1999. Web.

[23] Perfluorinated Surfactants and the Environmental Implication of Their Use in Fire-Fighting Foams, Cheryl A. Moody and Jennifer A Field, Environmental Science & Technology, Vol. 34, NO. 18, 2000, pps.3864 – 3870.

Table of Contents

1.0 Introduction

1.1 Definition

1.1.1 Accidental Infrastructure Failure

Infrastructure failure can occur due to two types of incidents: accidental or intentional. Accidental infrastructure failure is caused by natural events, such as inclement weather or infrastructure wear and tear. Accidental infrastructure failure is the primary hazard, and the secondary hazards are the residual impacts based on the type of failure (loss of energy, outage, hazardous materials (HAZMAT) leakage, etc.).

1.1.2 Intentional Infrastructure Failure

Intentional infrastructure failure is linked with terrorism, and the hazard inventory for Terrorist Activity and Civil Actions should be used in concert with this document. All infrastructure failures due to acts of terrorism represent secondary hazards and impacts from the terrorist act itself. The residual impacts of the infrastructure failure are tertiary in nature.

1.2 Types

1.2.1 Energy Shortage or Power/Utility Failure

An energy shortage is a significant shortage of any energy resource or the inability to pay for high priced energy resources, which results in a loss of fuel supplies for space heating and emergency and health care service, thereby endangering both life and property.

A power/utility failure is an interruption or loss of services for an extended period of time (gas, oil, electricity, fiber optics, telephone, microwave towers, water, and sewage sites) caused by an accident, sabotage, natural hazards, equipment failure, or fuel shortage. These interruptions can last anywhere from a few seconds to several days. Power failures are considered significant problems only if the local emergency management organization is required to coordinate the provision of food, water, heating, etc., as a result. Power failures are common with severe weather and winter storm activity.

1.2.2 HAZMAT Fixed Facility or Transportation

Hazardous materials are defined as such because of their chemical, radiological, or biological nature that can pose a potential risk to human health, property, or the environment when released. A release may occur by spilling, leaking, emitting toxic vapors or any other process that enables the material to escape its container, enter the environment, and create a potential hazard.[1] Hazardous materials incidents can occur during the manufacture, transportation, storage and use of hazardous materials, as well as being naturally occurring. These incidents can occur because of human error, natural hazards, deliberate deed, or a breakdown in equipment or monitoring systems. The impact depends upon the quantity and physical properties of the chemical, environmental and weather factors at the point of release, the type of release and its proximity to human and wildlife populations and valuable ecosystems.[2]

1.2.3 Pipeline[3]

Pipelines are conduits that are primarily used to transport liquids and gases. A pipeline system is defined as: "All parts of a pipeline facility through...which a hazardous liquid or gas moves...in transportation."[4]

1.2.4 Abandoned Coal Mine

Abandoned mine lands present serious threats to human health and the environment. Addressing abandoned mine lands impacts is becoming increasingly important due to increased exposure to people and risks of accidents, injuries, and tort claims. There are estimates of as many as 500,000 abandoned mines in the country[5].

Abandoned mine lands are those lands, waters, and surrounding watersheds contaminated or scarred by the extraction, beneficiation or processing of coal, ores and minerals. Abandoned mine lands include areas where mining or processing activity is determined to have ceased.[6] The following are definitions that apply to abandoned coal mines:

- Angle of Draw (also termed Limit Angle): The angle of inclination from the vertical of the line connecting the edge of the coal mine workings with the outer limit of the trough subsidence area. For inclined coal seams (such as those in the Coal Creek area of Bellevue), downdip and updip limit angles (which in general will not be identical) are defined at the downdip and updip limits of the coal mine workings, respectively.
- Coal Mine Subsidence (CMS) Zones: Areas where there is a potential for future trough subsidence or sinkhole development due to collapse of abandoned coal mines as delineated on Figure 1.
- Coal Mine Waste Dump: Also termed spoil piles, coal mine waste dumps are a loose-dumped mix of soil, rock, coal, and any other materials that are produced as a waste product during mining.
- Gas Emissions: Explosive, poisonous, or suffocating gases emitted from coal seams.
- Mine Hazard: Any hazard associated with abandoned coal mines or prospects including but not limited to trough subsidence, coal mine waste dumps, and public safety mine hazards such as sinkholes and shafts.
- Mine Subsidence: Lowering of the ground surface, with resulting tilts and strains, due to movement of the underlying soil and/or rock into a void resulting from an underground mine or mine entry.

Open shafts are vertical mine openings that can extend hundreds of feet to the lower level of a mine. Open shafts can be concealed by mine debris, dirt, rock, and even water. Horizontal and vertical openings can be miles of openings that randomly follow the original ore veins. Within a short distance of the entrance there is no light, and these openings can be the cause of becoming lost and disoriented inside a mine. Unstable rock and decayed support includes once solid beams and frameworks that have been decaying for more than a hundred years. In many cases, there may be no support beams at all and the fractured roof or walls of the mine tunnel eventually collapse in response to vibrations and/or the force of gravity. Highwalls and open pits are located where large areas of the surface have been disturbed to get at minerals near the surface. Open pits can be filled with water that can be highly acidic or laden with harmful chemicals. Highwalls can be unstable at the top and the bottom and are prone to collapse. When approached from the top, the vertical edge of a highwall may not be seen in time or may crumble, leading to a fatal fall.

Deadly gases and lack of oxygen can be present in abandoned mines that are not ventilated. Pockets of methane, carbon dioxide, and other deadly gases can form or simply displace oxygen with no visible sign. When these gases enter the body, muscles stop responding normally, thinking becomes clouded, and unconsciousness and death can occur. Explosives and toxic chemicals were often left behind when an active mining operation was abandoned. Explosives such as dynamite and blasting caps become very unstable over time, and can explode if disturbed. Storage containers, boxes, barrels, and drums deteriorate allowing toxic chemicals to leak or combine into highly dangerous mixtures.

1.3 Secondary Hazards

Many secondary hazards exist with each infrastructure failure. An energy failure and the resulting hazards represent a good example to walk through possible secondary hazards. Although there is not necessarily a connection between an energy incident and specific other emergency conditions (as, for example, in an earthquake causing a gas line breach or an ice storm causing an electrical outage), there may be more subtle connections, such as a prolonged period of energy shortage could result in increased crime and/or high heating fuel prices or shortages may result in increased reliance on firewood; shortages of dry firewood may result in increased burning of green wood, increasing the risk of chimney fires.

Electric outages may result in increased reliance on in-home generators; generators used without proper ventilation can pose safety risks. Energy disruptions may affect other utility sectors; the electricity and telecommunications sectors are increasingly inter-dependent. An energy event can be the result of a short-term crisis when unplanned and unexpected events dramatically impact the supply and availability of resources; or can develop over a longer time period where it is the culmination of an unfolding sequence; or can be a chronic condition or exacerbated by chronic conditions, such as overreliance on a particular type of energy resource, inadequate energy infrastructure, or inefficient use of available energy resources. Sharp price fluctuations can also be indicators of supply disruptions. An unexpected or dramatic increase in the price of energy resources, therefore, is capable of triggering an energy emergency. Factors that could result in energy events include weather, world events, and industry conditions, for example:

- Severe winter cold creates an increased demand for heating.
- A natural disaster can destroy energy delivery infrastructure or hinders its use.
- High summer gasoline demand results in continued refinery production of gasoline and delayed production of home heating oil; cold weather creates demand for home heating oil before inventories are built.
- Political events result in actions against the US, such as the oil embargo that was imposed in the 1970s.
- Terrorist acts or acts of war destroy energy infrastructure or supply, or slow deliveries to key ports due to safety concerns.
- Unexpected refinery outages delay just-in-time production and /or delivery of fuels at a time when storage levels are already low.
- Increased demand for winter fuels displaces refinery production of gasoline.

The potential seriousness of an energy supply or price disruption can vary greatly, and in some cases will depend on exogenous circumstances. Seriousness may depend on such factors as:

- Situation duration and magnitude
- Available storage levels, if applicable, and replenishment options

- Availability of energy alternatives
- Prevailing weather
- Economic conditions, and
- Financial impact.

Energy resources are interrelated, and disruptions in one type of energy may result in disruptions or issues in other energy markets. For example, disruptions in natural gas supply may cause electric generation plants or large industrial customers to fuel switch to #2 oil; #2 oil is also used for residential home heating. The percentage of the region's electric generation fueled by natural gas is increasing; a disruption in natural gas supply could result in electricity shortages. High natural gas prices may make it more profitable to delay production of the gasoline oxygenate methyl tert-butyl ether (MTBE), which is made from natural gas and on which much of the region still depends; shortages of MTBE could result in delayed gasoline deliveries to the region. High gasoline demand could result in delayed refinery production of home heating oil; delayed production could mean lower inventory levels, which would make the region more vulnerable to weather-related supply disruptions. Drought may result in reduced hydroelectric production, stressing fossil fuel supplies.

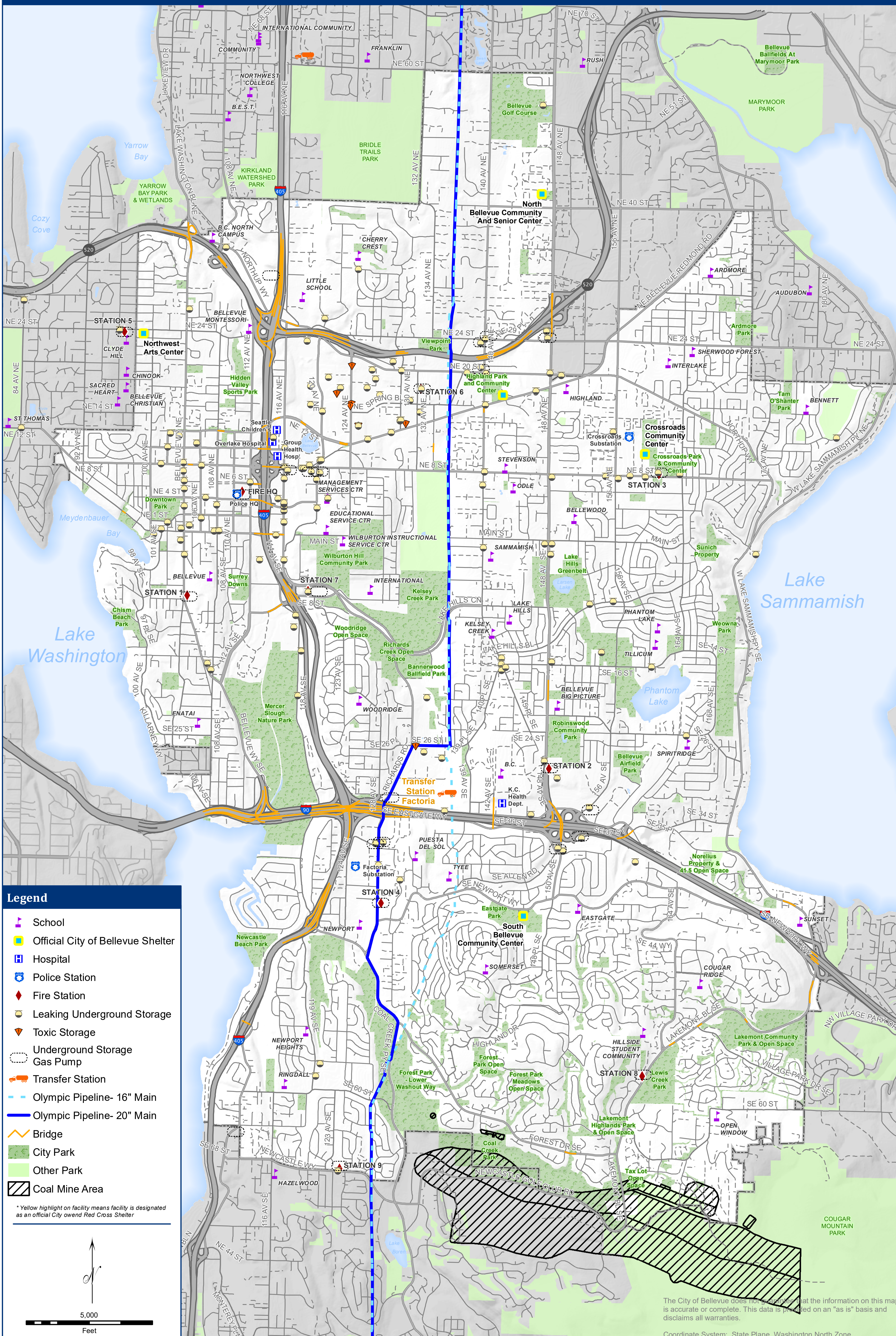
2.0 Profile

2.1 Location and Extent

Figure 1 displays the some of the potential human-caused hazards in Bellevue. The blue demarcations show the locations of the 16 and 20-inch pipelines, whereas the red lines note the bridge areas. The coal mine areas are shown in the shaded locations, predominately in the south region of Bellevue. Toxic storage sites, leaking underground storages, and underground storage gas pumps are identified as potential locations of hazard fixed HAZMAT Facilities. Bridge infrastructure is identified as potential locations of infrastructure failure either as potential primary or secondary hazards, such as related to the seismic hazard.

Human Created Hazards

City of Bellevue
GIS Services



The City of Bellevue does not guarantee that the information on this map is accurate or complete. This data is provided on an "as is" basis and disclaims all warranties.

Coordinate System: State Plane, Washington North Zone, NAD83 NSRS2007 (Bellevue)

2.1.1 Energy Shortage or Power/Utilities Failure

Bellevue's energy vulnerabilities depend not only on the security of Bellevue-specific resources, but also on the security of resources for the region. Bellevue is part of larger regional markets for petroleum products, natural gas, and electricity. There are increasing interdependencies among utility sectors. Electric generation is increasingly dependent on the availability and deliverability of natural gas. Telecommunications systems rely on electricity to run. Electric industry communications rely on telecommunications infrastructure.

Energy infrastructure is potentially vulnerable not only to natural hazards but also to cyber and physical attack. Increasing dependence on the internet for energy industry communications and dispatch increases vulnerability to cyber-attack. Energy infrastructure is also prone to physical attack, given numerous sources of public information on its location and importance and the accessibility of energy facilities to the public. Energy security has traditionally been a utility and energy industry responsibility, and access to information (even by energy regulators and emergency personnel) is limited. Bellevue's electric service provider, Puget Sound Energy, is a privately-owned utility regulated by the Washington Utilities and Transportation Commission, and the city's authority is limited by the terms of a franchise agreement with Puget Sound Energy.[7] Security of interstate facilities such as gas pipelines is also an industry responsibility, with some federal oversight.

Factors affecting Bellevue's vulnerability by energy type include:

- Fuel oil:
  - Bellevue is at the end of a long supply-distribution system, heavily dependent on ship or barge delivery that is subject to a variety of economic and weather conditions.
  - Just-in-time inventory practices, coupled with limited in system storage, further exacerbate vulnerabilities to supply disruptions.
  - The regional heating oil reserve can, under certain conditions, be used to relieve regional demand and as such may affect price. But because the reserve is located in Linden, New Jersey and New Haven, Connecticut, the oil is unlikely to be deliverable to Bellevue under emergency conditions.
- Propane:
  - A limited number of suppliers and the majority of product delivered to a single facility greatly increase the vulnerability of propane supplies to disruptions.
- Kerosene:
  - Homes heated with kerosene often have no alternative-heating source. Many kerosene users are lower income households with less capacity to withstand price shocks.
- Natural Gas
  - The regional supply of gas is augmented by the infusion of liquefied natural gas delivered by ship to a Boston area terminal where it is introduced into the pipeline system. This single point of delivery of large amounts of volatile fuel is a significant point of vulnerability.
  - There is limited access to, and knowledge of, interstate pipeline vulnerabilities and security plans.
- Electricity

  - Regional electric generating capacity is increasingly dependent on the availability of natural gas. Most new generating plants are gas-fired. While many of these plants are dual fuel in theory, they do not have dual fuel capability in practice. In the event of a major natural gas supply disruption, there would likely be a significant cascading effect for electricity.
  - Security plans for electric generation plants are a private sector responsibility and are generally proprietary and confidential. They are generally not made available to emergency managers.
- Natural Gas
  - Industry reliance on just-in-time inventory, limited storage capacity, and the expense and regulatory hurdles associated with increased storage capacity leave Bellevue vulnerable to supply disruptions.
  - Performance-based gasoline standards allow more than one type of gasoline blend to meet Bellevue's air quality requirements. Resistance to fuel specifications unique to Bellevue and continued support for efforts to develop regional fuel standards will reduce Bellevue's vulnerability to supply disruptions.

2.1.2 HAZMAT Fixed Facility or Transportation

The City of Bellevue participates in the King County Local Emergency Planning Committee (LEPC) and all hazardous materials that are equal to or greater than established quantities are identified in the Tier Two Emergency and Hazardous Chemical Inventory. Once identification is completed and first responders are trained and equipped, educating the public and effective zoning/land use regulations at the local level can be put in place to minimize the risks associated with any potential release. It is important to continue to develop, update, and test chemical and radiological emergency response plans and maintain equipment and trained personnel in risk areas to protect the populations. All persons involved with the transportation, handling, storage, or use of radiological materials must have adequate training, appropriate protective equipment, and effective procedures to follow in handling and responding to these hazards.

2.1.3 Pipeline

The Olympic Pipe Line Company operates pipelines throughout western Washington that run through Bellevue carrying gasoline, diesel, and jet fuel. British Petroleum (BP) Pipelines, North America, operates the system and the Control Center for operations is in Renton. The Transportation Department maintains a franchise agreement with Olympic Pipe Line Company for operation of its pipelines through Bellevue. The Olympic Pipe Line Company consists of over 400 miles of pipelines extending from refineries in northwest Washington to Portland Oregon. These pipelines carry refined liquid petroleum products: diesel, aviation fuel, (basically a form of kerosene) and gasoline.

Underground high pressure pipelines remove the equivalent of 1,800 tanker trucks from the regions roadways each day and carry 441,000 barrels or 18,700,000 gallons of fuel each day.
The pipeline in Bellevue was initially installed in 1965 and runs from north to south Bellevue from milepost 94.71 to 106.65, approximately 12 miles long. The pipeline is buried between 30 and 48 inches in depth. It is also eight feet deep and encased in steel pipe where it crosses roads and railroad tracks. The pipeline is constructed of carbon steel with walls .281 inches thick and caries a small electrical

charge to reduce corrosion. 60% of the time the pipeline carries gasoline that travels at about four mph producing 5,900 gpm at pressures between 250 and 1440 psi.

The pipeline was created with methods that have led to twelve seam failures during 1988 and 1989. The Office of Pipeline Safety issued two Alert Notices, ALN-88-01 and ALN-89-01. The Alert Notices advised pipeline operators with such pipe in their systems to take additional precautions to limit pressure, to hydrotest, and to assure adequate cathodic protection. Olympic reported 29 instances of corrosion, dents and other "anomalies" in the pipeline through Bellevue in 1996 and 1997. Six of the anomalies were repaired. Seventeen were not inspected because they did not meet guidelines for severity, further research by the City will investigate the status of these repairs.[8] Flow and pressure are controlled by computers in Olympic's Control Center in Renton. Shut down of the pipeline for maintenance or emergency is done by using valve blocks located throughout the system. Olympic uses three types of valve blocks:

1. Clapper Valves only restrict backflow and work immediately without outside manipulation (located at pumping stations only).
2. Hand-Operated Valves (HOV) are shut by Olympic personnel only, in the field. An HOV takes approximately 2 to 8 minutes to shut once the person arrives at the valve site (which can take anywhere from 5 to 60 minutes). The only valves in Kent are HOV's located on the north & south side of the Green River.
3. Remote-Operated Valves (ROV) are controlled by Olympic's Control Center in Renton. It takes approximately 45 to 90 seconds to completely close the valve using a computer-enhanced system.

Since the 1999 pipeline spill and explosion in Bellingham some noted improvements have been made in pipeline safety. Some improvements from an industry standpoint are with regards to corrective action items and integrity management. Some improvements from the State are with regards to a joint agreement between the Office of Pipeline Safety (OPS) and the Washington Utilities & Transportation Commission certifying the state as an "agent" of OPS to administer the interstate program with no enforcement authority. Figure 2 demonstrates the seriousness of a potential spill based on volume in hundreds of thousands of gallons the 16-inch pipe experiences a rupture.

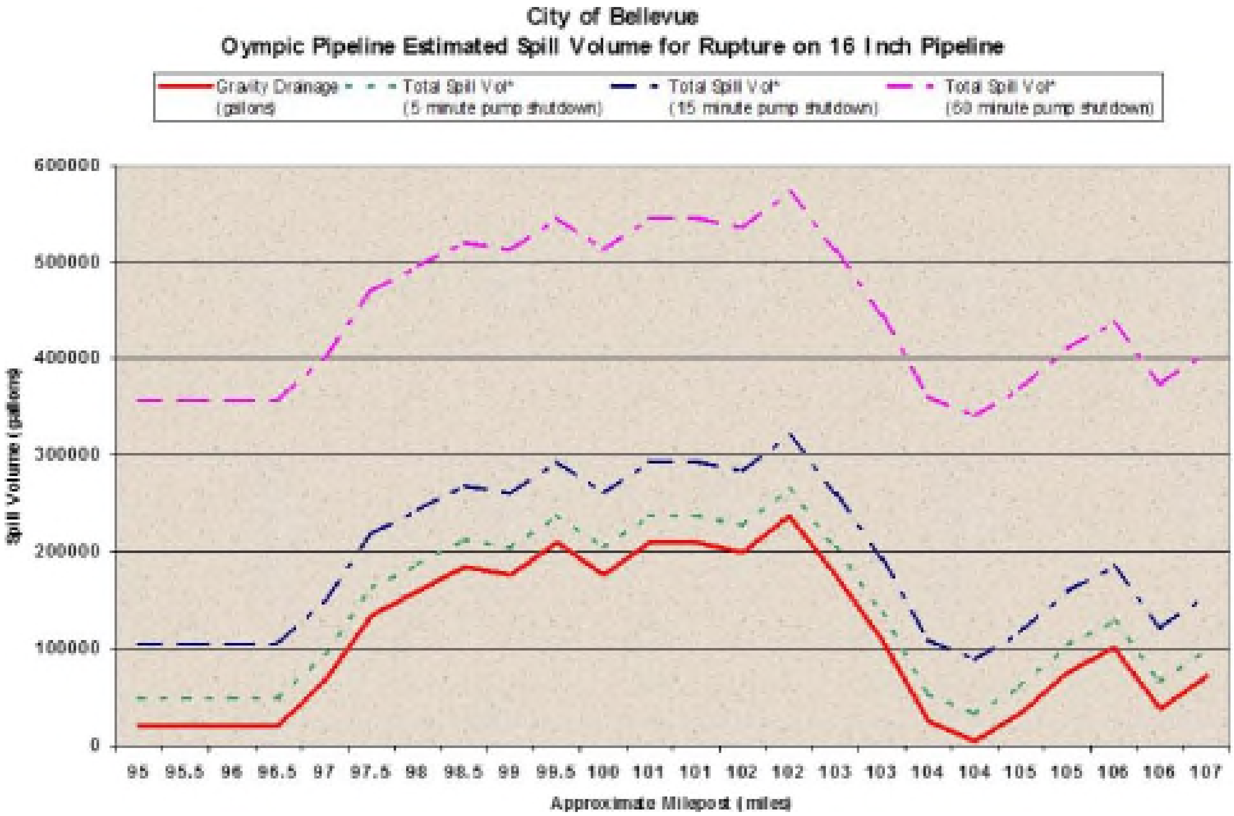


Figure 2. Olympic Pipeline Estimated Spill Volume for Rupture on 16" Pipeline

Bellevue has had a leading role in spearheading improvements in local city's ability to determine franchise rights and monitor safety. The issue of Federal Pre-emption over interstate pipelines prevents local communities from having stronger safety requirement of their own, which could be tailored to the area's unique environment. Issues of testing type and frequency, valve type placement, and improved leak detection remain vague or non-existent within Federal Regulations. There is no industry standard or even agreement as to an appropriate replacement schedule for old pipe. The industry belief is that with proper care and maintenance, a pipeline will last forever despite clear evidence to the contrary.

2.1.4 Abandoned Coal Mine

The area of Cougar Mountain is home to seven coal seams. The 2003 Bellevue Critical Area Update Geologically Hazardous Areas Inventory identified areas at risk from Coal Mine Subsidence as being on the south side of Cougar Mountain and the extreme southern edge of the city (Walsh, 1983). It states that many, but not all of the mine locations and conditions are publicly recorded or documented[9].

The Bellevue Fire Department would respond to a coal mine incident. The Seattle Fire Department has a team trained in tunnel rescue which would be requested to support a mine rescue.[10] Mine rescue teams are private entities that are not legally obligated to respond to requests for assistance. It will take at least five hours to have on site a team trained in mine rescue. The Mine Safety and Health Administration has a local representative who should be able to respond within about 30 minutes.
A sink hole is a type of subsidence consisting of collapse of the ground surface into an underground void in which the surface expression has a characteristic funnel or shaft shape (see Figure 3). This is also referred to as a "collapse pit."

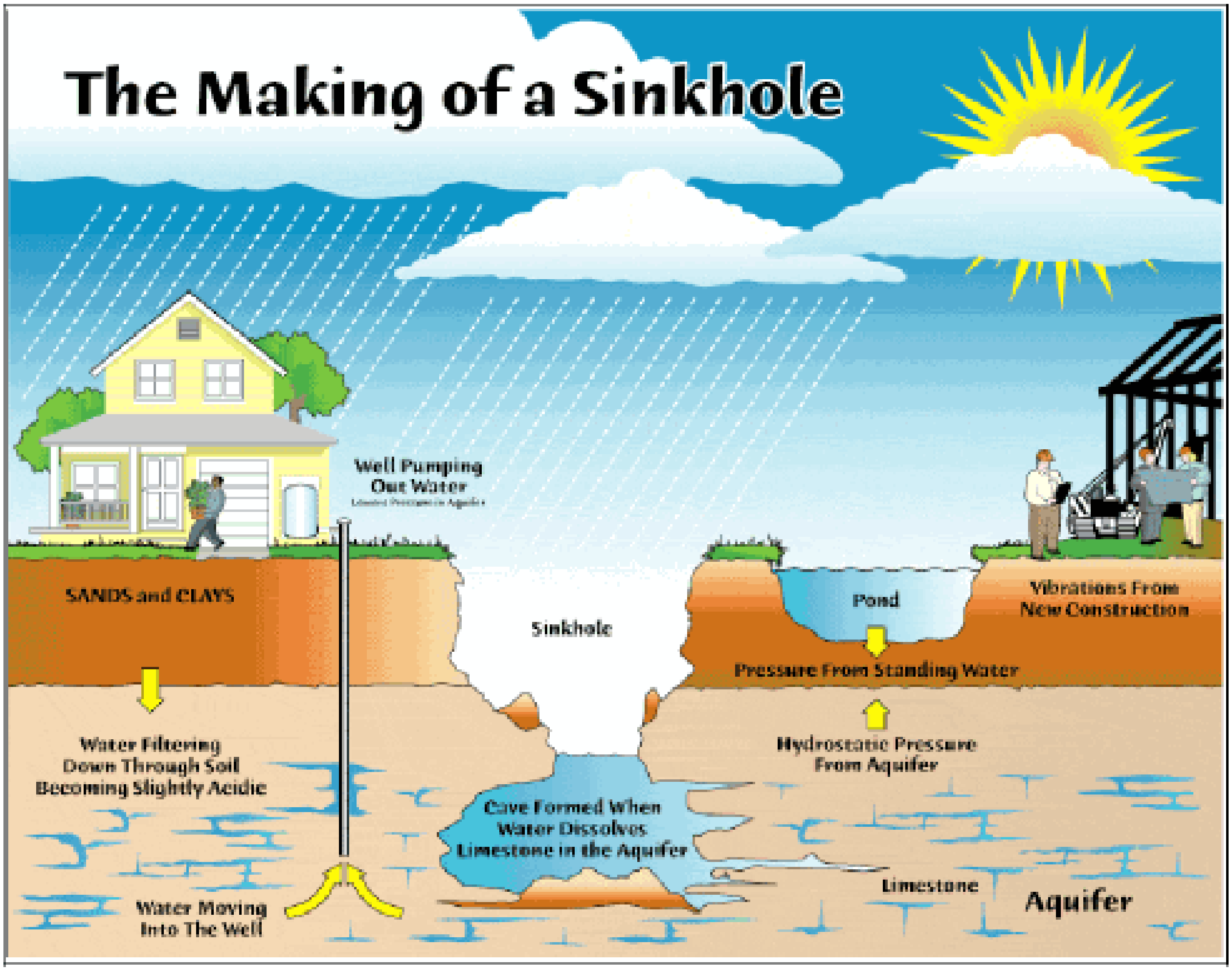


Figure 3. How Subsidence (Sink Holes) Takes Place[11]

Overview of Coal Mine Subsidence (CMS) Zones[12]

The CMA Map delineates areas within the City of Bellevue and associated potential annexation area (sphere of influence) that could be affected by subsidence of abandoned coal mines. The CMA Map defines and identifies CMS Zones based on potential surface tilts and strains and whether there is a potential for sinkhole development. The CMS Zones were developed based on generalized evaluation of available mine maps and records. Direct subsurface information (boring data) on the condition of the mine workings was not available for development of these zones and regulations except for the Newcastle-King Mine. This Newcastle-King Mine information was used to evaluate potential coal mine impacts associated with the existing plat of The Woods. Alternative interpretations of potential subsidence effects could result from site-specific evaluation and analysis based on detailed review of historic data, direct subsurface information, or alternative assumptions.

A surface reconnaissance report and site-specific evaluations are required prior to permitting subdivision or development on any site in a CMS Zone. Methods of analysis shall be described as appropriate. Construction will be permitted in any CMS Zone after elimination of risk to public safety associated with abandoned coal mines, and mitigation of coal mine waste dumps (if any) and potential trough subsidence. There is a potential for sinkhole development, or for other public safety mine hazards. Construction is permitted only after potential public safety mine hazards are investigated and eliminated. A direct subsurface investigation program is required to investigate potential sinkhole development. In addition, if any mine workings could potentially cause trough subsidence at the site, construction is permitted only after a site-specific evaluation of potential trough subsidence and incorporation of project-specific mitigation measures as required for CMS Zone 1.

Areas of Potential Undocumented Workings[13]
CMS Zones are based on an evaluation of documented workings. There is, however, some potential for undocumented workings to exist in the vicinity of outcropping or subcropping seams. The potential for undocumented workings must be evaluated for any property within 100 feet of the subcrop lines of the Jones and Primrose seams between and beyond known coal mine workings, except for construction of attached additions to, or miscellaneous structures accessory to and within 50 feet of, existing residential buildings. The subcrop lines indicating those areas of potential undocumented workings are shown on the Coal Seams Map.

The Primrose seam subcrop through the plats of Forest Ridge Estates Divisions I and II, The Woods, and Forest Park No. 4 has not been shown on the Coal Seams Map because geotechnical exploration and abandoned mine hazard assessments were completed and accepted by the City at the time these plats were developed. Therefore, as no undocumented workings were found by those investigations and subsequent development, the Primrose seam subcrop through those plats has not been shown on the Coal Seams Map so that it is clear that future building permit applications for lots in those plats are not subject to these regulations.

2.2 Occurrences

In Bellevue chemical and petroleum spills occur each year. Although few injuries and no deaths have occurred over the last several years, the likelihood of injury and death remain a possibility. Additionally, the loss of private and public property through contamination is a concern. The potential loss of public property and public safety resources, including PPE and mobile response equipment and of hospitals through contamination remain critical as these resources are minimal at the municipal level and lessening the availability of any of these resources may create an emergency. Beyond the loss of private and public property, there are environmental effects that increase the possibility of the loss or reduced value of land thereby creating an economic loss or quality of life loss to the residents affected. Economic losses may include loss of jobs either through temporary or permanent closures and reduced property values. Radiological may include pollution of the air and under more severe circumstances, contamination of soil and water with radioactive materials. A peacetime nuclear accident may require an extensive response calling for activation of detailed emergency plans dealing with alerting and warning, evacuation and shelter, provision of emergency services, radiological monitoring and testing, and public information.

Other occurrences of a general infrastructure failure in Bellevue include the crane collapse incident in November 2006. The 210-foot tall crane toppled from a construction site at 108th Avenue Northeast killing one person in an apartment complex and causing severe structural damage to three buildings.[14] The reason for the accident was a "catastrophic failure" of the crane. Washington State Department of Labor & Industries later determined after a six-month investigation that the engineering design of the crane caused the failure, and it was not due to operator error.[15] Bellevue Fire personnel led the response of the incident.

Figure 4. November 2006 Crane Failure

Figure 5. November 2006 Crane Debris

The crane failure caused many secondary hazards, such as exposed conduits and wires with water main breaks that produced standing water inside buildings.

2.2.1 Energy Shortage or Power/Utilities Failure

The City of Bellevue experiences minor power outages due to high winds and other forms of inclement weather; however, the disruption in energy sources has varied with the incidents. Most notably are the large-scale severe weather incidents including wind and ice related that have disrupted power for over a week.

2.2.2 HAZMAT Fixed Facility or Transportation

One example of a larger HAZMAT spill was a transportation accident in November of 2011 (see Figure 6). A fuel tanker hit the jersey barrier on northbound Interstate 405 and leaked about 3,500 gallons of fuel onto the highway north of State Route 520. The roadway was cleaned up, but containing fuel that reached surface streets or followed storm drain pipes and culverts to Lake Washington was expected to take longer. The state Department of Ecology and Bellevue Utilities Department were called to mitigate spillage into Lake Washington and evaluate the environmental impact.[16]

Figure 6. November 2011 Fuel Tanker Spill

2.2.3 Pipeline

Over 43 spills have been reported since 1965 totaling almost 821,000 gallons. Olympic Pipeline accounts for 65% of liquid fuel spills in Washington since 1985. The estimate property damage in Washington State is $10,759,357 from pipeline accidents. Other major spills:[17]

- In 2004, a pinhole-sized leak caused by wear unleashed thousands of gallons of gasoline that fueled the Olympic Pipe Line fire and explosion in Renton.[18]
- In 2001, Bellevue conducted emergency bank stabilization due to a landslide caused by the Nisqually Earthquake that threatened to affect the Pipeline. In 2003, Bellevue had to conduct repairs to the roadway above the pipeline due to ground shifting.[19]
- In 2001, water testing caused a pipe break in Renton, spilling petroleum tainted water into a local creek.[20]
- In 2000, a sweeping inspection by state and federal regulators recently found that companies operating 2,500 miles of buried pipeline in the state still aren't following guidelines for rust prevention, leak detection, public education, and timely maintenance and inspections.[21]
- 1996 storms led to the need for Olympic to monitor five potential slide areas at once. March 23, 1996, a mudslide broke the line and 2,000 gallons of diesel fuel spilled into the creek. The Ecology Department fined Olympic $7,000 and criticized the company for being unable to handle several threats of landslides at the same time.

Gasoline is highly flammable and is easily ignited when released into air. Diesel and jet fuel are combustible liquids and produce fewer vapors than gasoline. Petroleum product vapors are heavier than air. Vapors can spread along the ground and collect in low or confined areas, creating a vapor explosion hazard indoors, outdoors, or in sewers. All products have increased volatility and may form explosive mixtures with air when released under pressure from the pipeline as an aerosol. Vapors may travel to source of ignition and flash back. Petroleum products are lighter than water, thus will travel on the surface. Runoff to sewer or storm drain may create fire or explosive hazard. Health hazards via inhalation or contact with material may irritate or burn skin and eyes. Fire may produce irritation and/or toxic gases. Vapors may cause dizziness or suffocation. Runoff may cause pollution.

Figure 7. Scarred Forest from the 1999 Pipeline Explosion in Bellingham

The pipe is made by US Steel via a High Frequency electric resistance welded process. The four cause categories of incidents in liquid pipelines are:

1. Anomalies, such as damage from construction equipment and corrosion, cause 62% of the incident on liquid pipelines. An anomaly is an imperfection in the pipe that if large enough could cause it to become a defect which is generally considered to reduce the failure pressure of the pipe to below the yield pressure of the pipe. The yield pressure is the design strength of the pipe which if exceeded will be on the verge of causing the pipe to permanently enlarge in diameter.
2. Incorrect operation causes 7% of the incidents on liquid pipelines.
3. Malfunction of pressure control equipment causes 5% of the incidents on Liquid pipelines.
4. "Other" Causes such as gaskets, flanges, fittings, etc. cause 27% of the incidents on liquid pipelines.

TABLE B-6 Liquids Pipelines—Cause of Incidents, 1996–2000

Cause	Line Pipe (%)	Tank/Pump (%)
Third-party damage	41	5
Corrosion	21	22
Equipment	4	45
Unknown	11	0
Incorrect operation	6	8
Miscellaneous	1	17
Manufacturer	6	0
Construction/repair	4	1
Weather	3	1
Previously damaged pipe	3	–
Vandalism	0	–
Total	100	100

SOURCE: Trench 2002.

Figure 8. Special Report: Transmission Pipelines and Land Use, a Risk Informed Approach, Transportation Research Board of the National Academies[22]

Factors contributing to pipeline failure include the following:

- **Movement.** The Puget Sound region is seismically active, with hundreds of earthquakes occurring each year. The pipeline transverses multiple strands of faults which have ruptured the surface in the past, and is located in ground made of soft soil or a sandy loam that is susceptible to soil liquefaction during an earthquake. This force is analogous to those that move an unsecured garden house causing lateral forces that strain the pipe. Some communities have reported that the actual pipeline location, when checked by probing, is well outside the supposed location or right-of-way (5-10 feet wide). This outside force can fatigue the pipe producing a partial collapse or buckling of the pipe.
- **Mechanical Damage.** Most commonly caused through third party damage by excavators or utility owners/operators. Although Revised Code of Washington (RCW) 19.122, Underground Utilities provides legislation requiring the use of "one call" system, this does not always occur. Third party damage can introduce dents with gauging leading to pipe failure. The pipeline runs parallel to the Union Pacific tracks also exposing it to mechanical damage should a derailment occur.
- **Internal corrosion.** Corrosion leading to metal loss may cause general thinning of the pipe, pitting of the pipe, crevice corrosion in electric resistance and flash weld seams or stress corrosion cracking.
- **Cracks** in the Seam weld that may be increasing in length and depth from the operational pressure cycles that were created from inclusion on the weld line, inadequate pressure during welding, and excessive trim of the excess metal extruded during electric resistance welding.
- **Gouges.** Gouges without a dent in the body of the pipe that may be due to construction damage. Also, cracks due to fatigue during shipment, stress corrosion cracks, or hydrogen cracks due to the environment that forms at the pipe surface. (Generally, these cracks are oriented along the length of the pipe or axially as this is the direction that is perpendicular to the maximum stress in a pipe or axially as this is the direction that is perpendicular to the maximum stress in a pipe which is due to pressure.)

- **System Failure.** Safety critical devices such as shutdown switches, control valve interlocks, and pressure relief valves. Management of change to pipeline modifications that can impact pipeline flow, surge pressures, as well as the effectiveness of existing safety equipment. Improper tool selection or inadequate data review of inline inspections devices. The type of defect expected must be known or suspected so that the proper tools can be selected to the inspection. Several types of tools generally have to be run in order to inspect the pipe for all of the potential types of defects. Flaws may be missed due to the complex nature of the log interpretation.
- **SCADA Breakdown.** Programming errors entered into the main computer can transfer to the backup system if they are not independent of each other. For safety critical equipment, redundancy does not truly provide increased reliability if such systems can be easily linked to the same failure (mirroring).

2.2.4 Abandoned Coal Mine

In the 1970's two young boys in Issaquah were overcome by mine gas when they entered a freshly opened subsidence crater. The father of one of the two boys and two Issaquah policemen were also rendered unconscious by the fumes. Issaquah Fire using breathing apparatus, were finally able to enter and revive all five persons[23]. In the Newcastle area there have been 200 cases of mine subsidence since studies began in 1978[24]. There also is a coal seam fire in the Cougar Mountain area that has been burning for over 50 years[25]. This location has become a popular attraction for local geocachers, making the possibility of needing to stage mine shaft rescues always present. The coal fire is being monitored by DNR. The City of Bellevue recognizes the danger of coal mine subsidence and has worked to locate and include as a Critical Area, restricting development.

2.3 Recurrence Rate

2.3.1 Energy Shortage or Power/Utilities Failure

Significant power outages occur, on the average, about every five years, affecting as much as 20% of the population.

2.3.2 Pipeline

The potential for damage to the liquid petroleum pipeline by a large earthquake, third party damage, internal failure, terrorist act, or other initiating event presents a risk of release incident. Only through continued training and preparation by response personnel, maintenance on and the practice with equipment, and safety-oriented integrity management principles can this risk be reduced. British Petroleum and their subsidiary, Olympic Pipeline, have responded with a significant improvement to the safety of their system.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

Increased population growth is also reflected in higher demand for outdoor recreation on public lands. Recreation areas, national by-ways, and campground facilities on public lands can be located in proximity to abandoned mine land sites. Use of off-highway vehicles often transpires at abandoned mine land sites amid risks of dangerous shafts, and exposure to contaminants in the soil, water and air. Recreational fishing can place anglers in proximity of abandoned mine land sites, and is impacted by decreased fish population among polluted waters stemming from abandoned mine land sites, and available fish may pose significant uptake of contaminants when consumed.

3.2 Health and Safety of Personnel Responding to the Incident

Fire or explosion; could cause a conflagration to surrounding occupancies and put a tremendous strain on City resources. The Fire department has limited access to foam to handle the blaze; law enforcement to provide traffic and crowd control and possibly evacuations; Public Works in supplying infrastructure expertise, barricading and utility support. Other departments may receive emergency tasking as well to assist with longer term issues of support and recovery. Medical services, both public and private, may be overwhelmed if casualties are high. Movement of product through creeks, rivers and storm drains could cause downstream impacts and widespread fires.

3.3 Continuity of Operations and Delivery of Services

Any type of infrastructure failure, either accidental or intentional, causes impacts to the continuity of operations and delivery of services. The depth and extent of those impacts are based on the scope of the infrastructure failure and the potential secondary hazards that may emerge.

3.4 Property, Facilities, and Infrastructure

The proximity of the pipeline to major highway, and population centers would impact movement and commerce in the region. Effects would be dependent on the type and amount of product (leak or rupture), vapor, fire or both, time of day, weather conditions, and delay in detection or reporting.
The potential for coal mine collapse and land subsidence is influenced by many factors. Primary factors include the height of the mine void, depth and strength of the rock roof, and the type and amount of roof support within the mine (Dunrud 1976; Crowell 1995). In general, the vertical component of subsidence does not exceed the height of the mine void. The potential for subsidence decreases with the strength and thickness of the roof rock due to bridging, which can prevent land-surface subsidence, despite collapse of the mine roof at great depth. The potential for land subsidence increases in weak or fractured rock and where abandoned mines are open to the surface. Rock strength also controls the surface area affected by mine collapse and subsidence. The minimum area of subsidence is determined by the area of roof collapse plus an additional area determined by the friction angle of the rock (an inherent property related to compressive rock strength). A greater area of subsidence will occur above weak rock with a low friction angle. The deterioration of coal or rock pillars and wooden timbers used for roof support in older mines can increase the likelihood of mine collapse, particularly for older mines.

Bellevue developed coal mine hazard maps in 1992 for the City's Coal Mine Area Subdivision, Development, and Building Permit Regulations. Areas within the city limits and within Bellevue's sphere of influence that could be affected by abandoned coal mines are delineated on coal mine area map. The maps delineate two CMS zones based on the potential surface tilts and strains and the potential for sinkhole development. CMS Zone 1 identifies areas of potential trough subsidence. CMS Zone 2 identifies areas of potential sinkhole development above shallow mine workings within 200 feet of the ground surface. Coal mine hazards in Bellevue are managed under the City's Coal Mine Area Subdivision, Development, and Building Permit Regulations. In CMS Zone 1, the risk of property damage from subsidence is mitigated through specialized engineering and construction. Construction is permitted only after a site-specific evaluation of potential subsidence and incorporation of appropriate mitigation measures to reduce calculated surface strain and tilt to below specified tolerances. In CMS Zone 2, the risk of sinkhole development must be investigated and eliminated prior to construction. The CMS Zone designation for a property in CMS Zone 1 may be removed if it is demonstrated by site-specific evaluation of subsidence that magnitudes of potential surface strain and tilt at the property are less than the levels specified. A CMS Zone 2 designation may be changed to CMS Zone 1 if a subsurface investigation demonstrates the absence of coal mine workings or that the coal mine workings, if present, are in a fully collapsed condition.[26]

3.5 Environment

Ground contamination spread over the permeable ground surfaces is a long-term problem. While a concern, there is little that can be done to stop or limit it unless there is a feature of the topography that lends itself to natural containment. This includes paved parking lots with curbs, streets, and natural depressions in the earth. Ground contamination could require a massive clean-up operation lasting several months.

Waterway and storm system contamination can be caused by a rupture of the pipeline near Sunset or Coal Creek that allows product to flow down the banks into the waterway. Creeks create a path for flammable vapors to travel close to highly concentrated business and residential facilities. Some runoff and vapors are contained in areas where there are high banks; areas with low banks do not contain the runoff and vapors. The City of Bellevue has extensive storm drain systems. Many of the storm drains are interconnected and create an ideal path for flammable or combustible liquids as well as the resulting vapors. The spread of product can be undetectable from surface streets until an explosion occurs or a monitoring device is lowered into the storm system. Typical kinds of environmental degradation stemming from abandoned mine land sites include contaminated/acidic surface and ground water and stockpiled waste rock and mill tailing piles.

3.5.1 Water Pollution

Highly acidic water rich in metals is a serious problem at many abandoned mines. Abandoned mines can produce acidic mine drainage for more than 100 years and, consequently, pose significant risks to surface water and ground water. Acidic mine drainage can lower the pH of surrounding surface water, making it corrosive and unable to support many forms of aquatic life and vegetation. Humans may also be affected by consuming water and fish tissue with a metal content.

3.5.2 Air Pollution

Air pollution occurs at mining sites during excavation and transportation. Blowing dust from abandoned mine land sites is a common concern, as many mines are in arid western states. Some sources of dust may be from road traffic in the mine pit and surrounding areas, rock crushers located in pits and in mills, and tailings ponds. The toxicity of the dust depends on the proximity of environmental receptors and the type of ore being mined. High levels of arsenic, lead, and radionuclides tend to pose the greatest risk.

3.5.3 Sedimentation and Sediment Contamination

Surface runoff can carry abandoned mine land-originated silt and debris down-stream, eventually leading to stream clogging. Sedimentation results in the blockage of the stream and can cause flooding of roads and/or residences and pose a danger to the public. Sedimentation may also cause adverse impacts on fish.

3.6 Economic and Financial Condition

The possible economic impact should be of concern because business people and /or residents in the affected area may put pressure on the chief executive regarding access and contingency plans. The effect on business/industry, local commerce, and transportation woes would compound response and recovery issues. Area evacuations would cause a disruption by the large scale movement of people. Although the percentage of people seeking public shelter is typically only about 15-20% of the total evacuated population, shelters must be established. The proximity to senior housing, residential areas, I-90, and 520 would create a heavy burden. This would cause additional problems for emergency officials. Difficulties range from telephone lines overwhelmed with calls to more seriously disruptive activities. These issues arise most commonly with those people displaced into shelters and with the elderly, but they may occur to anyone at any time.

3.7 Public Confidence in the Jurisdiction's Governance

Public confidence could waiver if resolution to infrastructure failure takes longer than anticipated. Much of the infrastructure in the City of Bellevue is privately owned (not owned by the city government). Responsibility falls to the private company to repair the damaged infrastructure, and the City of Bellevue government will support this process. The city government may sustain damage to reputation if the public is unaware that infrastructure is owned by private entities.

4.0 Resource Directory

- Olympic Pipeline Franchise Agreement, Ordinance 6275
  http://mrsc.org/getmedia/355c8960-7a49-4250-be90-d30309951323/b44o6275.pdf.aspx
- Critical Areas Ordinance Update
  https://development.bellevuewa.gov/codes-and-guidelines/code-news/critical-areas-ordinance-update
- Washington Department of Natural Resources Coal Mine Map Collection
  https://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/coal-metallic-and-mineral-resources/coal
- Pipeline Safety Program Incident Database
  https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends
- Abandoned Land Mines Portal
  www.abandonedmines.gov
- Bureau of Land Management, Abandoned Mine Lands
  https://www.blm.gov/programs/public-safety-and-fire/abandoned-mine-lands

[1] Based on 5.13, Hazardous Materials summary from the Washington State Enhanced Hazard Mitigation Plan, 2010. https://mil.wa.gov/other-links/enhanced-hazard-mitigation-plan

[2] Ibid

[3] Based on the Hazard Incident Vulnerability Analysis for Kent, WA.

[4] Pipeline Emergencies Training

[5] Abandoned Mine Land Portal http://www.abandonedmines.gov/ep.html

[6] Abandoned Mind Lands Portal: http://www.abandonedmines.gov/ (Accessed November 25, 2013)

[7] Electric Reliability in Bellevue (Updated May 2010) http://www.ci.bellevue.wa.us/pdf/Transportation/electricreliabilityinbellevue0510.pdf

[8] "Bellevue Urged to Seek Tests of Pipeline March 7, 2000 The Seattle Times http://community.seattletimes.nwsource.com/archive/?date=20000307&slug=4008760

[9] Bellevue Critical Areas Update: Geologically Hazardous Areas Update,

[10] From Draft Mine Rescue Recommendations of the Bellevue Fire Department.

[11] GEOL 105 Natural Hazards, Subsidence-Sink Holes http://geol105naturalhazards.voices.wooster.edu/subsidence-sink-holes/

[12] Critical Areas Ordinance Risk Analysis, Bellevue WA https://development.bellevuewa.gov/codes-and-guidelines/code-news/critical-areas-ordinance-update

[13] Critical Areas Ordinance – 20.25H, Page 80 of 95, June 26, 2006 https://development.bellevuewa.gov/codes-and-guidelines/code-news/critical-areas-ordinance-update

[14] 3 Bellevue buildings damaged in crane collapse; at least one killed https://development.bellevuewa.gov/codes-and-guidelines/code-news/critical-areas-ordinance-update (accessed November 26, 2013)

[15] Washington State Department of Labor & Industries, L&I News, May 11, 2007

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1.0 Introduction

1.1 Definition

1.1.1 Biological Agents

US Code of Federal Regulations Chapter 42 [42 CFR, Section 73.1] defines biological agents as: "Any microorganism (including, but not limited to, bacteria, viruses, fungi, rickettsia, or protozoa), or infectious substances, or any naturally occurring, bioengineered, or synthesized component of any such microorganism or infectious substance, capable of causing death, disease, or other biological malfunction in a human, an animal, a plant, or another living organism; deterioration of food, water, equipment, supplies, or material of any kind; or deleterious alteration of the environment."

1.1.2 Pandemic Influenza

When a new kind of flu virus appears for which there is no immunity and no existing vaccine, it can spread rapidly from country to country. This rapid spread is called a pandemic. Pandemics occur several times each century and can range in severity from the 2009 H1N1 pandemic to the 1918 flu pandemic.[1]

1.2 Types

1.2.1 Biological Agents

Biological agents include bacteria, viruses, fungi, other microorganisms and their associated toxins. They have the ability to adversely affect human health in a variety of ways, ranging from relatively mild, allergic reactions to serious medical conditions, even death. These organisms are widespread in the natural environment; they are found in water, soil, plants, and animals. Because many microbes reproduce rapidly and require minimal resources for survival, they are a potential danger in a wide variety of occupational settings. The following list provides a starting point for information about some of the most prevalent biological agents:

- **Anthrax:** Anthrax is an acute infectious disease caused by a spore-forming bacterium called Bacillus anthracis. It is generally acquired following contact with anthrax-infected animals or anthrax-contaminated animal products.
- **Avian Flu:** Avian influenza is a highly contagious disease of birds which has been prominent amongst poultry in Asia in the past. Despite the uncertainties, poultry experts agree that immediate culling of infected and exposed birds is the first line of defense for both the protection of human health and the reduction of further losses in the agricultural sector.
- **Bloodborne Pathogens and Needlestick Prevention:** OSHA estimates that 5.6 million workers in the health care industry and related occupations are at risk of occupational exposure to bloodborne pathogens, including human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HCV), and others.
- **Botulism:** Cases of botulism are usually associated with consumption of preserved foods. However, botulinum toxins are currently among the most common compounds explored by terrorists for use as biological weapons.

- **E. coli:** E. coli normally inhabit the intestine of humans and animals, but certain strains can cause intestinal and extra-intestinal infections if it enters the blood stream from the small intestine after being ingested from undercooked foods.
- **Foodborne Disease:** Foodborne illnesses are caused by viruses, bacteria, parasites, toxins, metals, and prions (microscopic protein particles). Symptoms range from mild gastroenteritis to life-threatening neurologic, hepatic, and renal syndromes.
- **Hantavirus:** Hantaviruses are transmitted to humans from the dried droppings, urine, or saliva of mice and rats. Animal laboratory workers and persons working in infested buildings are at increased risk to this disease.
- **Legionnaires' Disease:** Legionnaires' disease is a bacterial disease commonly associated with water-based aerosols. It is often the result of poorly maintained air conditioning cooling towers and potable water systems.
- **Mold:** Molds produce and release millions of spores small enough to be air-, water-, or insect-borne which may have negative effects on human health including allergic reactions, asthma, and other respiratory problems.
- **Plague:** Between 2010-2015 there were over 3248 cases of plague reported worldwide (including 584 deaths) according to the World Health Organization. However, there are only an average of 7 cases every year in the US according to the Centers for Disease Control and Prevention. A bioterrorist release of plague could result in a rapid spread of the pneumonic form of the disease, which could have devastating consequences.
- **Ricin:** Ricin is one of the most toxic and easily produced plant toxins. It has been used in the past as a bioterrorist weapon and remains a serious threat.
- **Severe Acute Respiratory Syndrome (SARS):** SARS is a viral respiratory illness causes by a coronavirus, called SARS-associated coronavirus. Since 2004, according to the Centers for Disease Control and Prevention (CDC), there have not been any known cases of SARS reported in the US.
- **Smallpox:** Smallpox is a highly contagious disease unique to humans. It is estimated that no more than 20 percent of the population has any immunity from previous vaccination.
- **Tularemia:** Tularemia is also known as "rabbit fever" or "deer fly fever" and is extremely infectious. Relatively few bacteria are required to cause the disease, which is why it is an attractive weapon for use in bioterrorism.
- **Viral Hemorrhagic Fevers:** Along with smallpox, anthrax, plague, botulism, and tularemia, hemorrhagic fever viruses are among six agents identified by the CDC as the most likely to be used as biological weapons. Many viral hemorrhagic fevers can cause severe, life-threatening disease with high fatality rates.

Medical treatment and equipment needed to treat those exposed varies depending upon on the specific agent. Unlike a typical mass casualty event, few biological agent patients require surgery. In severe cases, the effects of biological toxins may necessitate the use of advanced equipment (e.g., mechanical ventilators) when a patient’s ability to breath is affected.

1.2.2 Pandemic Influenza

Influenza, or flu, is a respiratory infection caused by several flu viruses. Flu viruses are classified as types A, B, and C. Type A has a number of subtypes. Seasonal flu is the term used to refer to the flu outbreaks that occur yearly, mainly in the late fall and winter. Researchers estimate that between 5 and 20 percent of Americans come down with the flu every flu season. Pandemic flu refers to particularly virulent strains of flu that spread rapidly from person to person to create a world-wide epidemic (pandemic).

In nature, the flu virus also occurs in wild aquatic birds such as ducks and shore birds. It does not normally spread from birds to humans. However, pigs can be infected by bird influenza (as well as by the form of influenza that affects humans) and can pass on the flu to humans. In 1997, researchers discovered that a virulent bird influenza had skipped the pig step and had infected humans directly, causing a number of deaths in Asia. These instances of bird flu in humans have raised concerns that if this type of flu could at some point be transmitted between people, a new pandemic would occur.[2]

2.0 Profile

2.1 Extent

Based on Bellevue's location and the population density surrounding it, there are many health centers in the area as compared to other areas in Washington (see Figure 1). This proximity to a variety of health care facilities may account for the general health and wellness of residents in Bellevue.

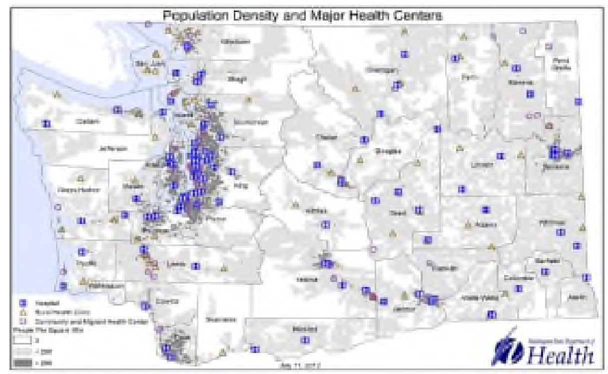
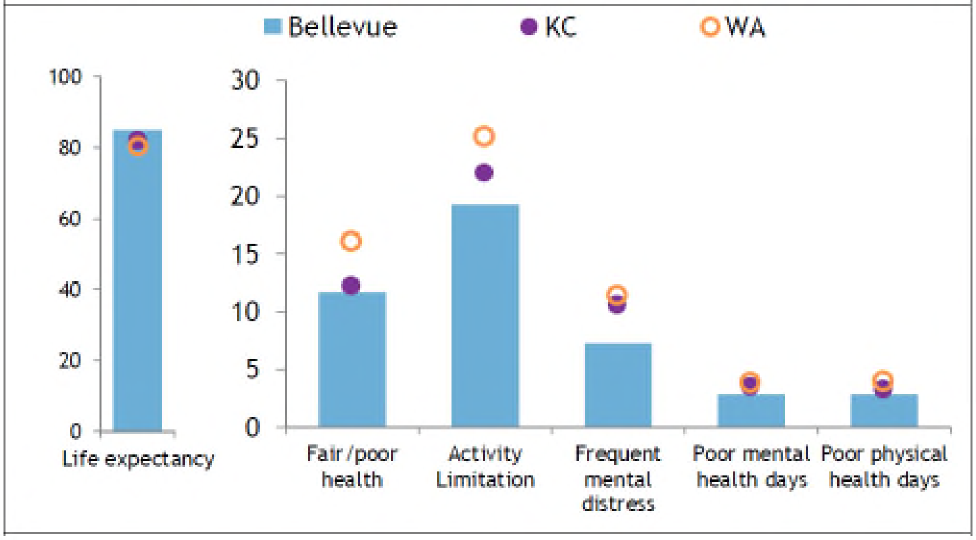


Figure 1: Washington State Population and Health Center Density[3]

The King County City Health Profile for Bellevue was updated in 2016 by the Seattle & King County Public Health Department. This report provides information regarding health indicators for King County and is intended for policy makers, government agencies, and the public. The report includes the following information regarding general health status in the City of Bellevue (see Figure 2).

General Health Status

The World Health Organization defines health as the state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. In this section, we present data on life expectancy and self-reported health status to describe the general health status of the residents.



Indicators	Rate	Rank	Sig	KC	WA
Life expectancy at birth (year)	84.5	24	H	81.8	80.3
Self-reported general health is fair or poor (%)	12	14	N	12.2	16.0
Limited in any way in any activities (%)	19	22	N	22.0	25.1
Had 14+ bad mental health days in past 30 days (%)	7	23	N	10.5	11.4
Days mental health not good in past 30 days (mean)	3	21	N	3.5	3.8
Days physical health not good in past 30 days (mean)	3	19	N	3.2	3.9

Except for life expectancy, the general health status indicators are for adults age 18+.
Data year: Life expectancy: 2010-2014. General health status: (1) area and KC=2010-2014; (2) WA=2011-2014.
Rank: ranking among the 26 King County areas from worst (1) to best (26).
KC: the King County rate; WA: the Washington State Rate.
SIG: whether or not the indicator is significantly higher than (H), lower than (L), or not different from (N) the KC rate.
Data sources: Death certificate and the Behavioral Risk Factor Surveillance System (BRFSS), Washington State Department of Health, Center for Health Statistics.

Figure 2 Bellevue Health Status as Compared to State and County[4]

In the information above, the life expectancy in Bellevue is slightly higher than in King County or Washington State. The other health indicators—poor health, activity limitation, mental distress, poor mental health, and poor physical health—are all below the averages of the county and state, indicating that Bellevue has a higher norm of health than other areas in the region.

2.2 Occurrences

2.2.1 Biological Agents

In the fall of 2001, letters containing anthrax spores were mailed to the news media and congressional officials, leading to the first cases of anthrax infection from an intentional release in the United States. These outbreaks of anthrax infection were concentrated in six locations throughout the country. Anthrax is generally a zoonotic (animal) disease. Humans can become infected with anthrax by handling products from infected animals, by breathing anthrax spores from infected animal products (e.g., wool) and by the intentional manufacture and release of the substance. Deaths in cattle and sheep which coincide with human cases may indicate an anthrax attack. Anthrax is classified as a Category A agent. Category A agents are those that 1) pose the greatest possible threat for a bad effect on public health, 2) may spread across a large area or need public awareness, and 3) need a great deal of planning to protect the public's health.

Sarin was used in two lethal nerve gas attacks in Japan. The first occurred in the city of Matsumoto in 1994. The second attack was on the Tokyo subway system in 1995, which led to the deaths of 19 people and a large number of injuries. Sarin is a man-made chemical, which is classified as a nerve agent. It was originally developed in Germany as a pesticide. Nerve agents are the most toxic and rapidly acting of the known chemical warfare agents. Sarin is a clear, colorless, and tasteless liquid that has no odor in its pure form and can evaporate into a vapor (gas) and spread into the environment.

Ricin is a poison made from castor beans. It is a very stable substance and can be in the form of a powder, a mist, a pellet, and can be dissolved in water or a weak acid. It is only slightly affected by extreme conditions such as hot or cold temperatures. Ricin was found in a US Senator's office in 2004, but did not claim a single victim. Although ricin is easy and inexpensive to manufacture, it is not easily transmitted from one person to another. The toxin is not a living organism, so those exposed are not contagious. The CDC considers it to be a "moderate" threat, and while it can be an agent of some disruption, terrorism experts consider it more an agent of assassination than one of mass destruction.

The one of the largest Washington State *E. coli* O157:H7 outbreak was in 1993, when 477 people were infected from contaminated, undercooked hamburger. In 1994, 11 people were infected from contaminated ground beef and also in 1994, 15 people were infected from contaminated salami.[5]

2.2.2 Pandemic Influenza

Estimates are that a pandemic influenza would cause over 200,000 deaths in the US, with as many as 5,000 fatalities in Washington. Our state could also expect 10,000-24,000 people needing hospital stays and 480,000-1,119,000 people requiring outpatient visits. During a severe pandemic these numbers could be much higher.[6]

The King County Department of Health tracks the occurrences of communicable diseases each year. Along with seasonal flu or a larger-scale pandemic, communicable diseases may cause the same impact to vulnerability and consequences to the City of Bellevue if any disease becomes widespread. Table 1 shows the number of reported cases and the rate for 2012 in King County as a whole. This information is only available at the county level and not specifically for the City of Bellevue.

Table 1. 2012 Occurrences of Communicable Diseases[7]

Disease	Cases	Rate*
Campylobacteriosis	447	22.8
Chlamydia Trachomatis	6763	345.6
Cryptosporidiosis	23	1.2
Giardiasis	170	8.7
Gonorrhea	1527	78.0
Hepatitis A, Acute	10	.5
Hepatitis B, Acute	11	.6
Hepatitis C, Acute	5	.3
Herpes Simplex	742	37.9
Human Immunodeficiency Virus (HIV)	291	14.9
Measles	0	0
Meningococcal Disease	4	n/a
Pertussis	785	40.1
Salmonellosis	219	11.2
Shiga Toxin-Producing Escherichia Coli	71	3.6
Shigellosis	74	3.8
Syphilis (Primary and Secondary)	210	10.7
Tuberculosis	108	5.5
Yersiniosis	23	1.2

*All rates are cases per 100,000 population. Incidence rates not calculated for <5 cases.

2.3 Recurrence Rate

Determining a recurrence rate is very difficult based on the multitude of factors that impact a possible recurrence.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area and the Time of the Incident

In most cases, biological agents cause isolated illnesses that result in relatively few deaths (e.g., annual seasonal influenza) and medical care can be effectively provided at the local level. If the disease calls for specific therapies such as antibiotics, instructions for obtaining and administering drugs should be disseminated thru local health care systems. In rare cases, biological agents can cause disease with high mortality rates and no specific remedies (e.g., Yellow Fever or Avian Influenza). In these cases, instructions should also be disseminated for general supportive care that may be provided by non-medical personnel.

In addition, those exposed to contagious biological agents intentional introduced or novel viruses, could remain functional and asymptomatic for a period of several days, but still be contagious to others. This would limit the ability to track and contain the spread of the disease and could lead to a mass surge of patients inundating hospital systems seeking care once symptoms present themselves, which could have disastrous effects to the delivery of medical care due to shortages of supplies and staff.

3.2 Health and Safety of Personnel Responding to the Incident

Protective clothing, including garments, gloves and booties, also are necessary for the response to a suspected act of biological terrorism to reduce exposures to potential dermal, chemical, and physical hazards. Protective clothing must have physical performance properties adequate for the mission (e.g. tensile strength, puncture resistance, seam breaking strength, abrasion resistance). Protective clothing is used to prevent skin exposures and/or contamination of other clothing. The type of protective clothing needed will depend upon the biological agent, concentration, route of exposure, and anticipated work operations.[8]

Proper decontamination of protective equipment and clothing will ensure that any particles that might have settled on the outside of protective equipment are removed before taking off gear. Decontamination sequences currently used for hazardous material emergencies should be used as appropriate for the level of protection employed and agent encountered. For example, PPE can be decontaminated using soap and water, and 0.5% hypochlorite solution (one-part household bleach to 10 parts water) with an appropriate contact time can be used. Note that bleach may damage some types of firefighter turnout gear (one reason why it should not be used for biological agent response actions). After taking off gear, response workers should shower using copious quantities of soap and water. Bleach should not be used to decontaminate response workers. Note that all NFPA 1994 ensembles are intended to be disposable after a single exposure use.[9]

3.3 Continuity of Operations and Delivery of Services

Depending on the severity of the pandemic continuity of operations and the delivery of services could be impacted. City of Bellevue staff may remain at home due to illness or they are caring for others or because they fear contracting the disease. Therefore, the ability of the City of Bellevue to maintain delivery of services to their constituents could be severely limited. As the incidence of disease increases there could be a loss of operational continuity within individual departments.

3.4 Property, Facilities, and Infrastructure

There should be no direct impact to property, facilities, or the physical infrastructure. Indirect impacts could develop due to lack of maintenance on equipment, property or facilities. However, with severe illness or disease symptoms, many people requiring skilled nursing or hospital care would overwhelm the medical infrastructure.

3.5 Environment

Pandemics do not normally disrupt the environment. As a human disease they infect humans, and in some cases, certain animals. The avian flu H1N5 attacked certain bird populations with a high rate of morbidity and mortality. This is also the case with West Nile Virus which is now moving through the bird population in Washington State. It is possible that other diseases might make the jump between humans and animals, increasing animal illness and death.

3.6 Economic and Financial Condition

Seasonal flu by itself causes considerable economic hardship due to lost productivity, high medical costs, and lost wages. During a pandemic, if the symptoms of the disease are severe, including long periods of illness, or residual, debilitating effects, it could impact the economy of Bellevue. The need to alter or prevent the normal social contacts, called "social distancing," will lead to a further temporary decrease in the financial condition of the community.

3.7 Public Confidence in the Jurisdiction's Governance

A pandemic can shake the confidence of the public across all social groups. As a large portion of the population becomes ill, demands for limited and controlled medical supplies could cause questions to arise concerning the methods of distribution. Inadequate response to the public's concerns about the supplies or the method of distribution could lead to not only lack of confidence, but outright hostility towards both those in power and those who hold the reins of distribution.

An essential element of medical management in such a situation would be to allay panic. This could be done using Public Service Announcements to address the concerns of the public and keep them inform and updated of the changing situation. Immediate use of the media to provide information about the normal course of the disease, the specific signs or symptoms, the situations requiring immediate medical attention or advice, and the procedures for obtaining essential medical supplies would be crucial in maintaining calm and avoiding a mass surge event at local hospitals.

4.0 Resource Directory

- King County City Health Profile: Bellevue, March 2016, Public Health Seattle & King County https://www.kingcounty.gov/depts/health/data/~/media/depts/health/data/documents/city-health-profiles/City-Health-Profile-Bellevue-2016.ashx
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- Seattle-King County Public Health, ESF 8 Hazard-Specific Annex, Pandemic Influenza Plan, Version 17, October 2013 https://www.kingcounty.gov/depts/health/emergency-preparedness/preparing-yourself/~/media/depts/health/emergency-preparedness/documents/pandemic/pandemic-flu-response-plan.ashx
- Washington State Department of Health, E. coli http://www.doh.wa.gov/YouandYourFamily/IllnessandDisease/Ecoli.aspx
- Washington State Department of Health, Pandemic Influenza http://www.doh.wa.gov/YouandYourFamily/IllnessandDisease/Flu/Pandemicflu/PandemicInfluenzaPlan Summary.aspx
- US Code of Federal Regulations Chapter 42 [42 CFR, Section 73.1]
  Centers for the Disease Control (CDC) from 42 CFR Part 72, Appendix A
- Centers for Disease Control and Prevention - Plague https://www.cdc.gov/plague/maps/index.html
- World Health Organization – Plague **https://www.who.int/news-room/fact-sheets/detail/plague**
- Centers for Disease Control and Prevention, Bioterrorism https://www.cdc.gov/healthcommunication/toolstemplates/entertainmented/tips/Bioterrorism.html
- United States General Accounting Office Highlights http://www.gao.gov/highlights/d04152high.pdf#search='anthrax%20incidents'
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- Terrorism Watch & Warning, Surviving a Pandemic Event Fact Sheet http://www.terrorism.com/2013/10/14/surviving-pandemic-event/

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Earthquake Hazard[1]

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1.0 Introduction

1.1 Definition[2]

An **earthquake** is a naturally induced shaking of the ground. It is caused by an abrupt shift of rock along a fracture in the Earth's crust called a fault. Within seconds, an earthquake releases stress that has slowly accumulated within the rock. Sometimes the release occurs near the surface and sometimes it comes from deep within the crust.

Seismic activity is described in terms of magnitude and intensity. Magnitude characterizes the total energy released and intensity subjectively describes the effects at a particular place. While an earthquake has only one magnitude, its intensity varies throughout the affected region.

A **fault** is defined as a fracture in the earth along which rocks on one side have been displaced with respect to those on the other side. Most faults are the result of repeated movement that may have taken place suddenly and/or by slow creep. A fault is distinguished from those fractures or shears caused by land sliding or other gravity-induced ground failures.

A **fault zone** is a zone of related faults that commonly are braided and subparallel, but may be branching and divergent. A fault zone has significant width (with respect to the scale at which the fault is being considered, portrayed, or investigated), ranging from a few feet to several miles.

In 1935, Charles Richter of the California Institute of Technology devised a logarithmic magnitude scale known as the Richter Magnitude Scale. On the Richter scale, magnitude is expressed in whole numbers and decimals. In qualitative terms, an earthquake of 5.0 is a moderate event, 6.0 characterizes a strong event, 7.0 is a major earthquake, and a great quake exceeds 8.0. The scale is open ended but the highest magnitude known to have been calculated was approximately 9.5. On this logarithmic scale, each whole number increase in magnitude represents a tenfold increase in the energy released by the earthquake. Furthermore, a magnitude 6.0 earthquake generates elastic-wave energy that is approximately 30 times greater than that generated by a magnitude 5.0 earthquake, 900 (30 x 30) greater than that of a magnitude 4.0 earthquake, and so forth. This scale was only accurate to describe moderate sized earthquakes, so it was replaced with the Moment Magnitude scale.

Making assumptions on the effects of an earthquake on physical objects based on magnitude can lead to errors because energy released by an earthquake does not always mean intense ground motion. Some earthquakes, like episodic tremor and slip quakes, may have magnitude of 6, but they are unnoticeable without instruments because the energy is released very slowly. The effect of an earthquake on the Earth's surface is called the intensity. In the United States the most commonly used intensity scale is the Modified Mercalli Intensity Scale. This scale, composed of 12 increasing levels of intensity ranging from imperceptible to catastrophic, is an evaluation of the severity of ground motion at a given location measured relative to the effects of earthquakes on people and property (see Table 1).[3]

Table 1. Mercalli Scale and Peak Ground Acceleration Comparison[4]

Mercalli Scale	Potential Damage	Estimated Peak Ground Acceleration depending on ground	
I	None	0.017	
II-III	None	0.017	
IV	None	0.014-0.039	
V	Very Light	0.039-0.092	
VI	None to Slight; United States Geological Survey (USGS)-Unreinforced Masonry-Stair Step Cracks; Damage to Chimneys; Threshold of Damage	0.02-0.05 0.04-0.08 0.06-0.07	0.06-0.13 0.092-0.18
VII	Slight-Moderate; USGS-Moderate Unreinforced Masonry-Significant; Cracking of parapets /Masonry may fail; Threshold of Structural Damage	0.1 0.05-0.10 0.08-0.16	0.10-0.15 0.18-0.34
VIII	Moderate-Extensive; USGS: Moderate-Heavy; Unreinforced Masonry-Extensive Cracking; fall of parapets, gable ends	0.10-0.20 0.16-0.32 0.25-0.30	0.13-0.25 0.35-0.65
IX	Extensive-Complete; USGS-Heavy Structural collapse of some non-seismically designed structures; walls out of plane. Damage to seismically designed structures	0.20-0.50 0.32-0.55 0.50-0.55	0.26-0.44 0.3 0.65-1.24
X-XII	Complete ground failures; USGS- Very Heavy (X+); Structural collapse of most non seismically designed structures; notable damage to seismically designed structures; ground failure	0.50-1.00	

Surface faulting is the differential movement of two sides of a fracture. Surface faulting is an obvious hazard to structures built across active faults. In particular, surface faulting can damage railways and highways and buried infrastructure such as pipelines and tunnels.[5]

A **thrust fault** is a fault with a low angle of inclination in which the upper block moves upward and over the underlying block. These faults result from crustal shortening and are generally associated with intense folding caused by powerful horizontal compression of the crust. The hills of Somerset and Cougar Mountain were created from this folding and horizontal displacement.[6]

1.2 Types

Western Washington is situated in one of the most dynamic seismic locations on the planet. It is located both at the collisional boundary of two tectonic plates, and also, in between the nonmoving mountains of Canada, and unending pressure caused by the rotation of the North American plate into the Pacific Plate. The land is, literally, being compressed between these forces, and the topography is a testament to this process. The energy built up by this process is phenomenal, strong enough to fold miles of earth in this region the way a truck's hood will crumple if it meets a solid object at high speed. The continental plate of the western US is rotating around a fixed region in the Canadian Rockies. This, combined with the Cascadia Subduction zone, creates incredible compression in the Puget Sound Area (see Figure 1).

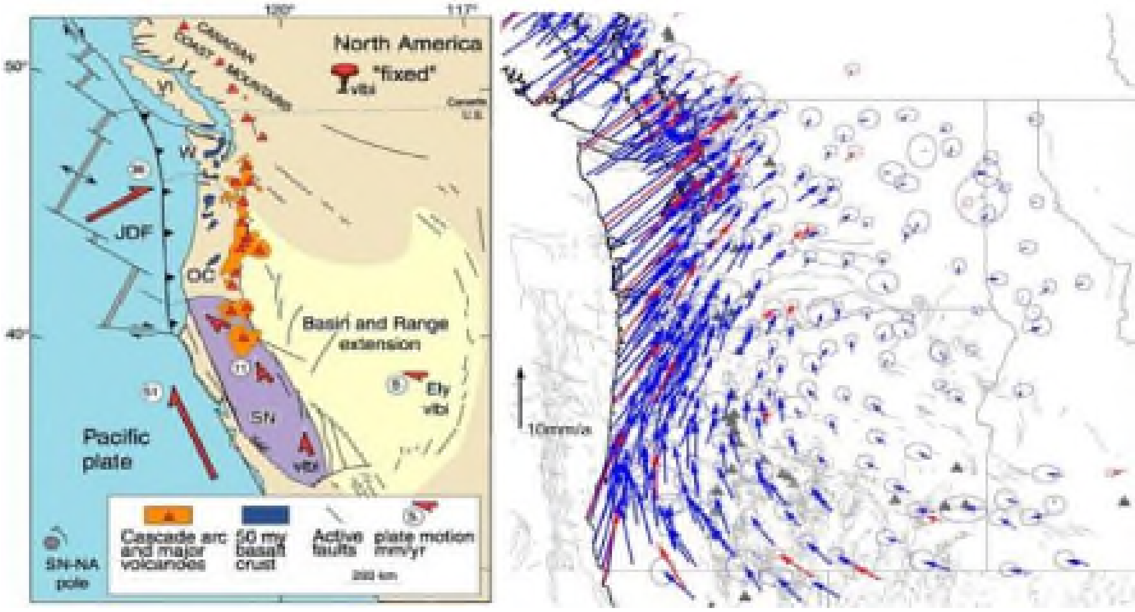


Figure 1. Western US Deforms and Breaks Up into Smaller Crustal Blocks While Continuing to Rotate[7]

The surface of the Earth is not limitlessly flexible though, so in some areas, the relentless pressure led to the surface cracking-in dramatic releases of energy, miles of ground rising 20 feet or more upward and 6 feet forward over seconds. After the pressure was released, it builds again until it causes dramatic shifts forward. This process has been going on over tens of thousands of years. Over the last 2,500 years it has occurred with varying force at least three and maybe four times. The last occurrence is believed be 1,100 years ago. Bellevue is located right over one of the locations where this occurs. Figure 2 shows a cut-away of Cougar Mountain, detailing how the hills are a result of the folding and cracking of surface layer of the Earth. Sometime in the past, the pressure caused the ground to crack and be pushed forward. Multiple times since then, it has been further pushed northward, forcing the ground to the north under and deep below the surface.

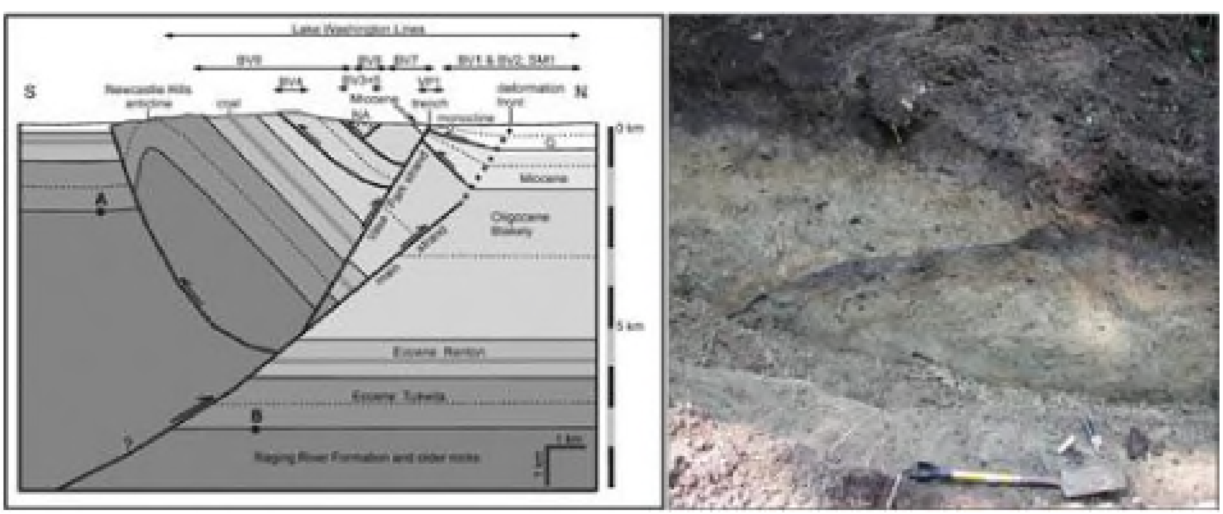


Figure 2. Cutaway of Cougar Mountain Area and Physical Evidence of Previous Faulting Found in Vasa Park, Bellevue[8]

One of the results of the deformation of the ground is that, unlike many other areas, there is very little bedrock upon which to build. The compression of the area has led to most of our flat land actually being large sediment filled basins. These basins have the effect of amplifying the level of ground motion caused by all earthquakes.

Figure 3 shows variations in gravitational attraction in central Puget Sound. The big, bright blue "anomalies" are caused by low-density sediments that fill deep basins. The white-dotted lines are important crustal faults[9].

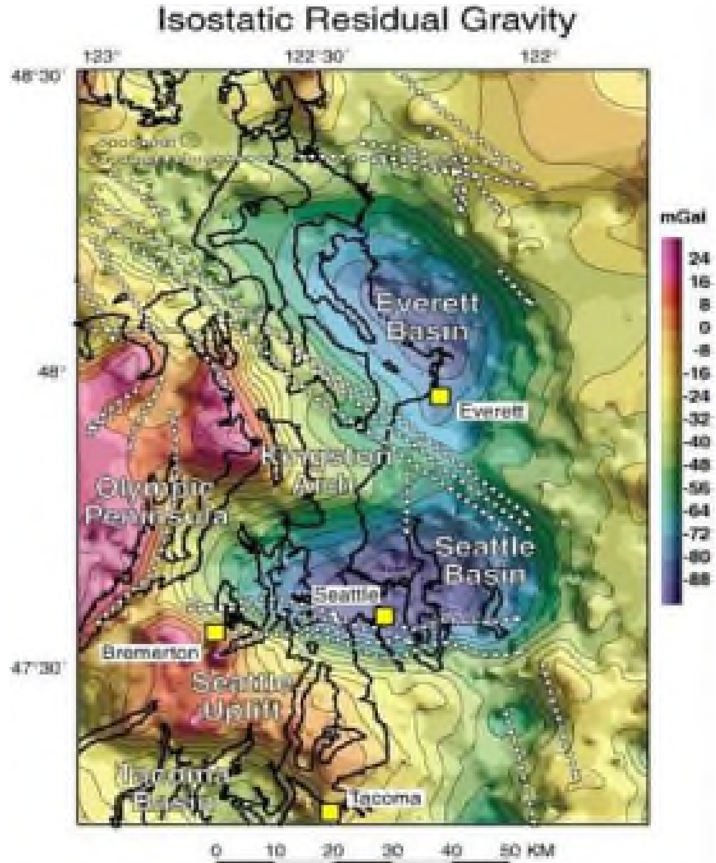


Figure 3. Variations in Gravitational Attraction in Central Puget Sound

The North American Plate, the Pacific Plate, and the Juan de Fuca plate are in constant motion. The Juan de Fuca Plate is being forced under the North American Plate through a process known as subduction. The margins where these two plates converge are known as the Cascadia Subduction Zone. The Cascadia subduction zone is the name for the area where the Juan de Fuca tectonic plate is being forced under the North American Plate (see Figure 4). It stretches 1,100 km from Northern California to central British Columbia, Canada and accommodates 3-4 cm/year of convergence between the Juan de Fuca and North American tectonic plates [Miller et al., 2001; Wang et al., 2003]. This boundary was believed to lie approximately 50 miles offshore, but new information indicates that it may lie inland, about 50 miles to the West of the Bellevue area. It extends from the middle of Vancouver Island in British Columbia to northern California. As it collides with North America, the Juan de Fuca plate slides (or subducts) beneath the continent and sinks into the earth's mantle.

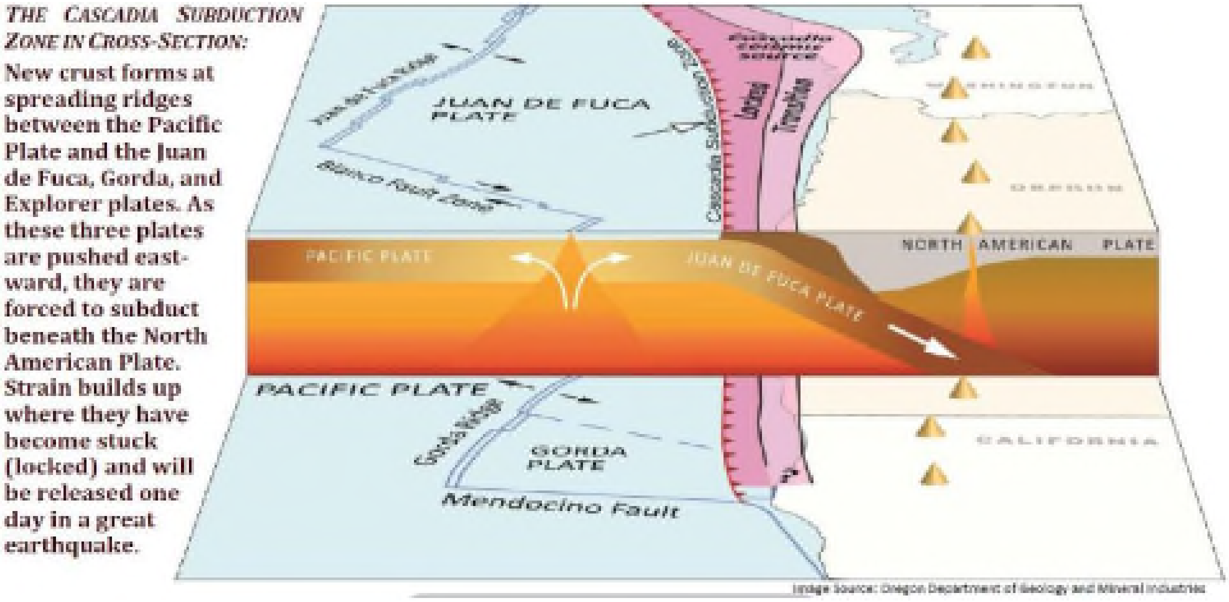


Figure 4. Cascadia Earthquake Sources[10]

The subduction process (see Figure 5) contributes to the three main types of earthquakes discussed below. There is a fourth type of earthquake also caused by the subduction process that is not covered in detail here. It is produced by the movement of magma inside a volcano. These are generally small. Currently, Mt. St. Helens has the best representation of them in the continental United States.

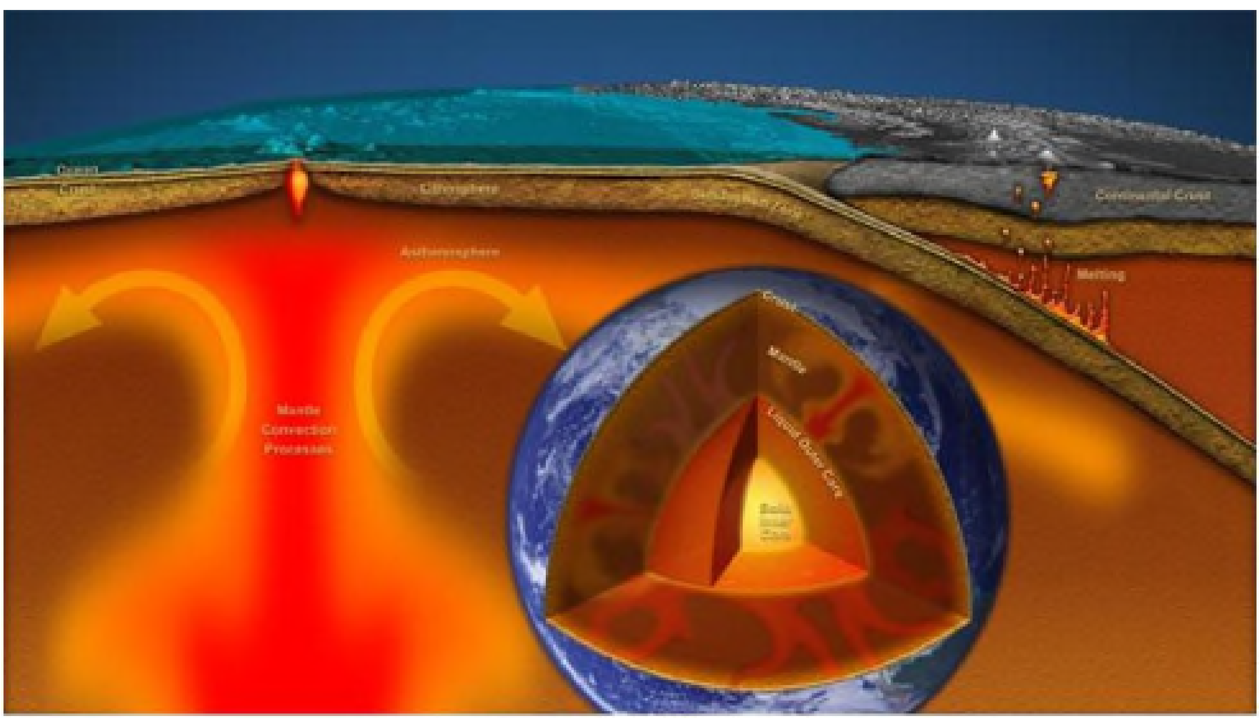


Figure 5. The Subduction Process[11] (Image provided courtesy of the NEPTUNE Project, specializing on studies of the northeast Pacific Ocean off the Washington and Oregon coasts)

1.2.1 Intraplate, Benioff Zone, or Deep Earthquakes

Intraplate earthquakes occur deep within the interior of tectonic plates, in the Pacific Northwest they are caused by bending fracture of the subducting Juan de Fuca (oceanic) plate. They occur within a range of approximately 15 to 60 miles in depth. These deep events typically have few, if any, aftershocks. Intraplate earthquakes are the most frequent large events that strike Bellevue.

1.2.2 Crustal Earthquakes

The Seattle Fault is a thrust fault zone approximately 2-4 miles wide. It extends from the Kitsap Peninsula near Bremerton to the Sammamish Plateau east of Lake Sammamish. Observations at an excavation west of Vasa Park indicate the presence of a surface-rupturing fault in the city. In Bellevue, the northern edge of the fault zone is approximately parallel to I-90. The hills of Cougar Mountain and Somerset represent the 'hanging wall' of the fault, that is, the body of rock that lies above the fault. The Seattle Fault is considered capable of generating a magnitude 7.0 to 7.5 earthquake.

1.2.3 Cascadia Subduction Zone Earthquakes

Cascadia Subduction Zone (interpolate) earthquakes occur less frequently than intraplate, but probably more frequently than large crustal earthquakes. Because Cascadia earthquakes have a very large source (the fault could rupture along its entire length from Vancouver Island to northern California) the ground motion may last for four minutes and be of lower frequency. This can cause a higher level of damage for tall structures. This effect may be amplified by the existence of a sedimentary basin in the region.

1.3 Secondary Hazards

Liquefaction: Soft soils or human-made fills can subside or experience liquefaction or lateral spreading in an earthquake. Liquefaction commonly causes lack of support for structures located on the liquefiable soils. Ground failures are likely: ground cracking or sand boils from layers of and sometimes located a number of meters under the surface. Lateral spreading is landslide that occurs on very shallow slopes due to the liquefiable nature of the soil. Noteworthy liquefaction took place in Green Lake during the 1949 earthquake, and there were examples of it in both the 1965 and 2001 earthquakes. Liquefaction is directly related to the level of soil saturation combined with layers of small loose particles like sand, some gravel, or silt. According to FEMA's Risk Map, approximately 901 structures (2.8% of total structures in Bellevue) have moderate or higher liquefaction susceptibility.

Landslides and Rockfalls: These can be triggered on steep slopes. Earthquakes have caused large and disastrous landslides, including debris flows from volcanoes. Loss of strength in sensitive, clay-rich soils can also cause landslides and other ground failures. This can be especially true during periods when the soils are saturated. In Bellevue, this can go from October through June, depending on the fall and winter weather. See Landslide Hazard.

Dam or lock failure: This is also a possibility during an earthquake. Likely causes are either a fracture of the retention wall or the failure of the soils under the structure. There are no dams directly within Bellevue, but the water level of Lake Washington does depend on locks located to the west. Any dam failure in the region will have an impact on daily life within Bellevue as well.

Tsunamis and seiches: Vertical displacement, co-seismic subsidence, or earthquake induced landslides can all cause tsunamis and seiches[12]; see Tsunami Hazard.

Petroleum Pipeline Break: The Olympic Pipeline, placed underground in 1964, traverses multiple strands of the Seattle Fault Zone with no specific seismic accommodation.

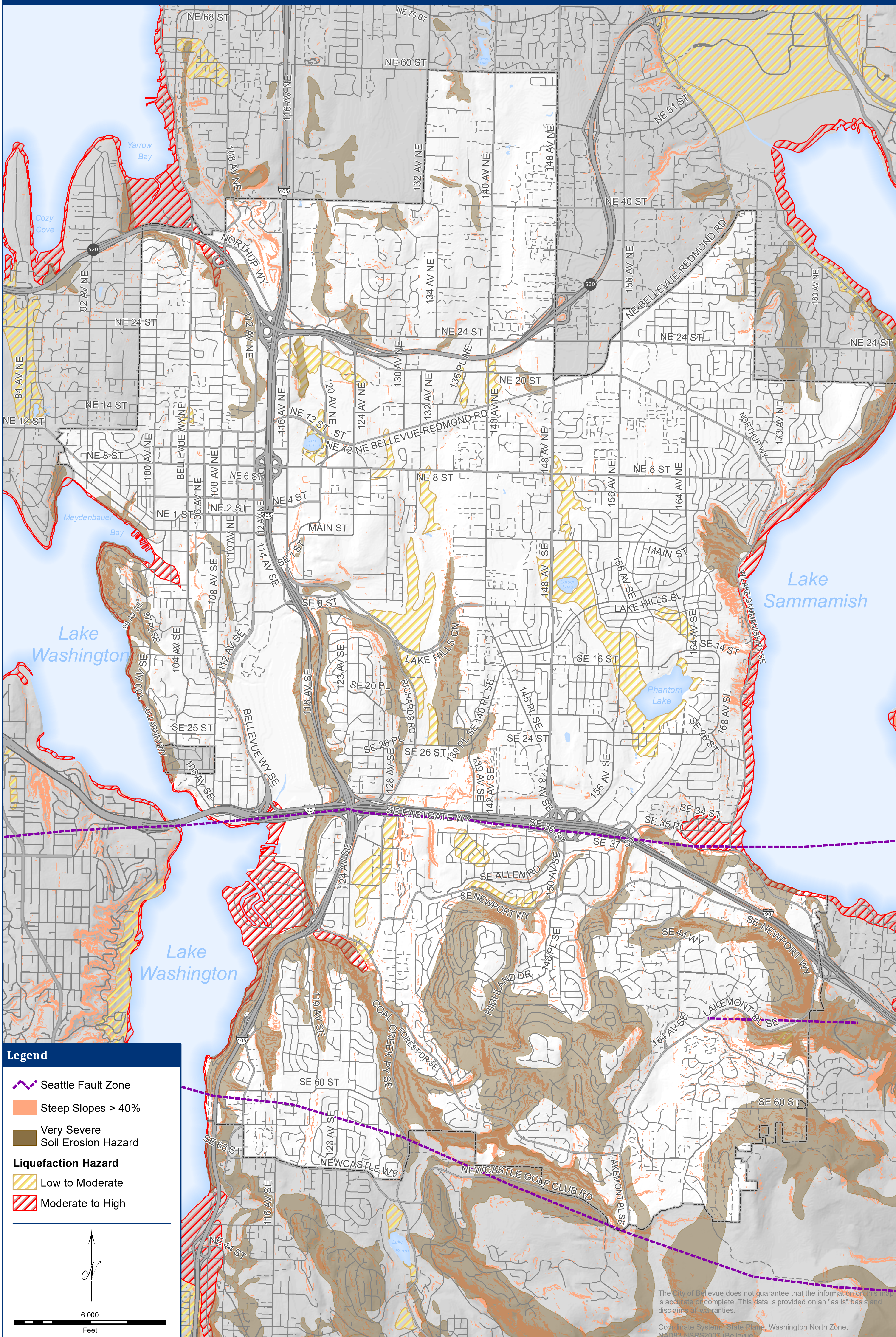
2.0 Profile

2.1 Location and Extent

Earthquakes directly affect the area. While the entire area is at risk from shaking during earthquakes, areas in close proximity to the fault, and areas at risk of liquefaction experience even greater shaking. As illustrated, the majority of liquefiable soils in Bellevue are located in areas where there has been a high level of water flow through historic wetlands and previous flooding. See Figure 6 for the spatial extent of the geological hazards in the City of Bellevue.

Geologic Hazards

City of Bellevue
GIS Services



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2.2 Occurrences[13]

It is considered very likely that we will experience a major earthquake in the next 50 years. Over the last 100 years, a large area of the state has experienced earthquake damage. The majority of the largest earthquakes felt in Washington have occurred in the Puget Sound region between Olympia and the Canadian border, in the Cascade Mountains, and along the Washington-Oregon border. Medium to large magnitude earthquakes (greater than 5.0) have occurred repeatedly in the Puget Sound region (see Figure 7).

In addition, Table 2 lists some of the notable earthquakes felt in the region and is followed by a discussion of occurrences by type of earthquake.

Table 2. Notable Earthquakes Recorded in Bellevue[14]

Date	Location of the Epicenter	Magnitude
July 22, 2001	Nisqually Delta	4.3
June 10, 2001	Satsop	5.0
February 28, 2001 (Federal Disaster #1361)	Anderson Island	6.8
July 2, 1999	Satsop	5.8
1995	South Sound	4.1
1988	Sound Sound	4.1
April 29, 1965	Maury Island, South Puget Sound	6.5
April 13, 1949	Nisqually Delta Puget Sound	7.1
Feb. 14, 1946	Hartstene Island, South Puget Sound	6.3

Figure 7. Puget Sound Occurrences of Earthquakes 5.0 or Greater

2.2.1 Intraplate (Benioff Zone) Earthquakes

The magnitude 6.8 Nisqually earthquake on February 28, 2001 caused extensive non-structural damage throughout the region. Although estimates are still being totaled, to date losses from this event are greater than $350 million statewide. The large earthquakes of 1965 (magnitude 6.5), 1949 (magnitude 7.1), and 1946 (magnitude 6.3) killed 17 people and caused more than $340 million (2002 dollars) in property damage in several counties. Since 1870, there have been six intraplate earthquakes in the Puget Sound basin[15]. Based on the historical record we can say that the actual recurrence rate of events this size is about every 25-30 years.

2.2.2 Crustal Earthquakes

Recent paleoseismic studies of the Seattle fault zone have identified three, or possibly four, ground-rupturing earthquakes in the last 2500 years along a subsidiary strand of the frontal (Seattle) fault on Bainbridge Island, the most recent of which is dated around 1050 calendar years before present (Nelson et al., 2003). Earthquake magnitude near M7 is estimated from this most recent event[16].

2.2.3 Cascadia Subduction Zone Earthquakes

These earthquakes estimated to be in the range of magnitude 8 to 9 appear to have occurred at uneven intervals over the past several thousand years. At least 13 great subduction earthquakes may have occurred in the Pacific Northwest over the past 7,000 years. The most recent great subduction earthquake in Washington State occurred over 300 years ago on January 26, 1700. At this time it appears that the average recurrence rate is about 550 years, however the actual recurrence rate is highly variable with the shortest time period between them being around 100 years, and the longest time span being around 1,100 years[17]. According to the New York Times, new data showed that 80 percent of earthquakes over the past 10,000 years had occurred within 360 years of each other.

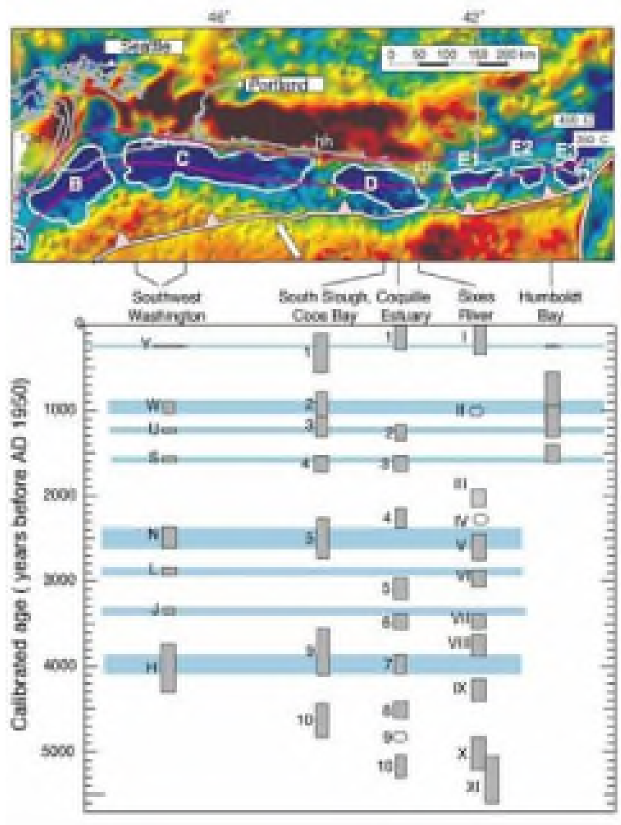


Figure 8. Cascadia Subduction Earthquakes by Plate Segment

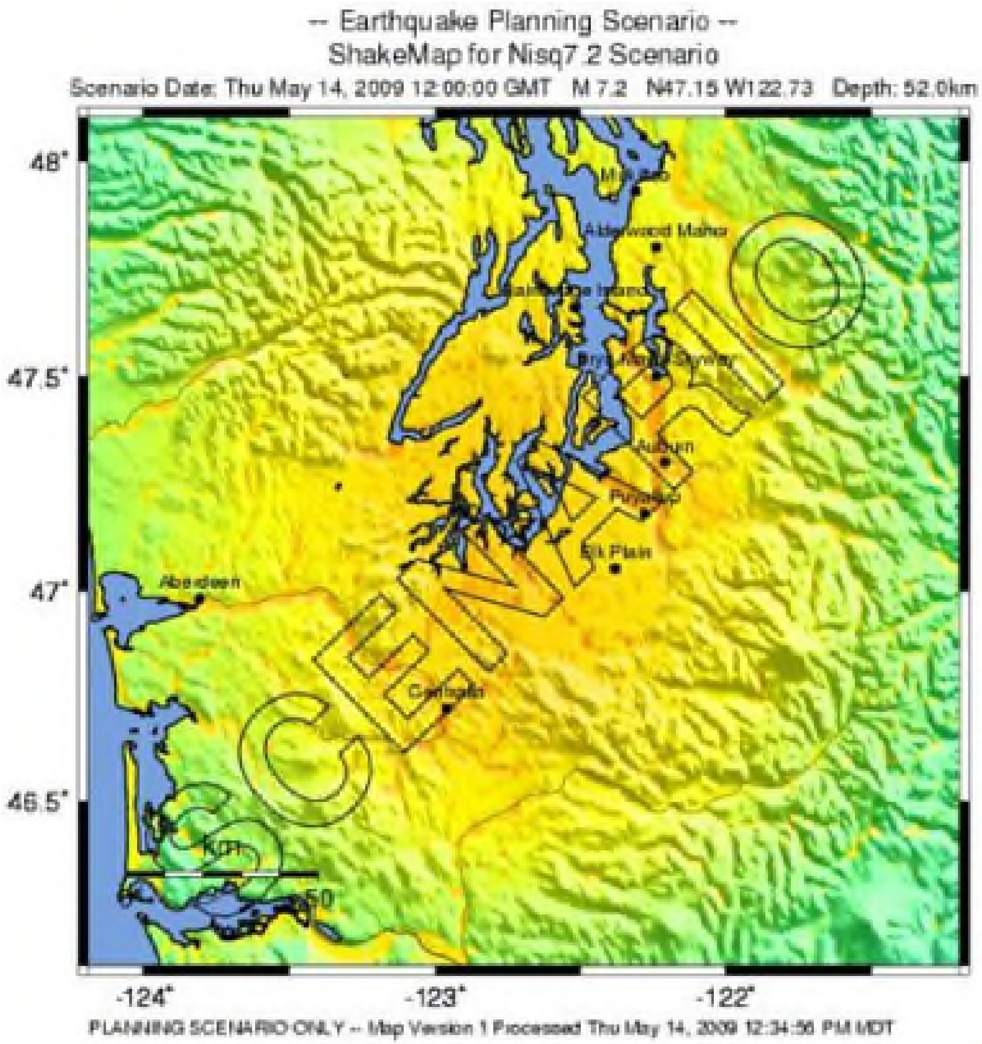
Figure 9 delineates the current understanding of the number of earthquakes by plate segment[18]. Offshore, the segmented fore-arc may correlate with potential seismic segmentation and rupture mode diversity of the megathrust, as recorded by paleoseismic evidence from coastal estuaries and deep water turbidites.

2.3 Recurrence Rate

The following map scenarios are used to identify the three types of earthquakes with varying recurrence frequencies.

2.3.1 Intraplate (Benioff Zone) Earthquakes [19]

Figure 9 shows the area of most extreme damage in an intraplate earthquake scenario. Bellevue would most likely be significantly impacted in this type of earthquake.

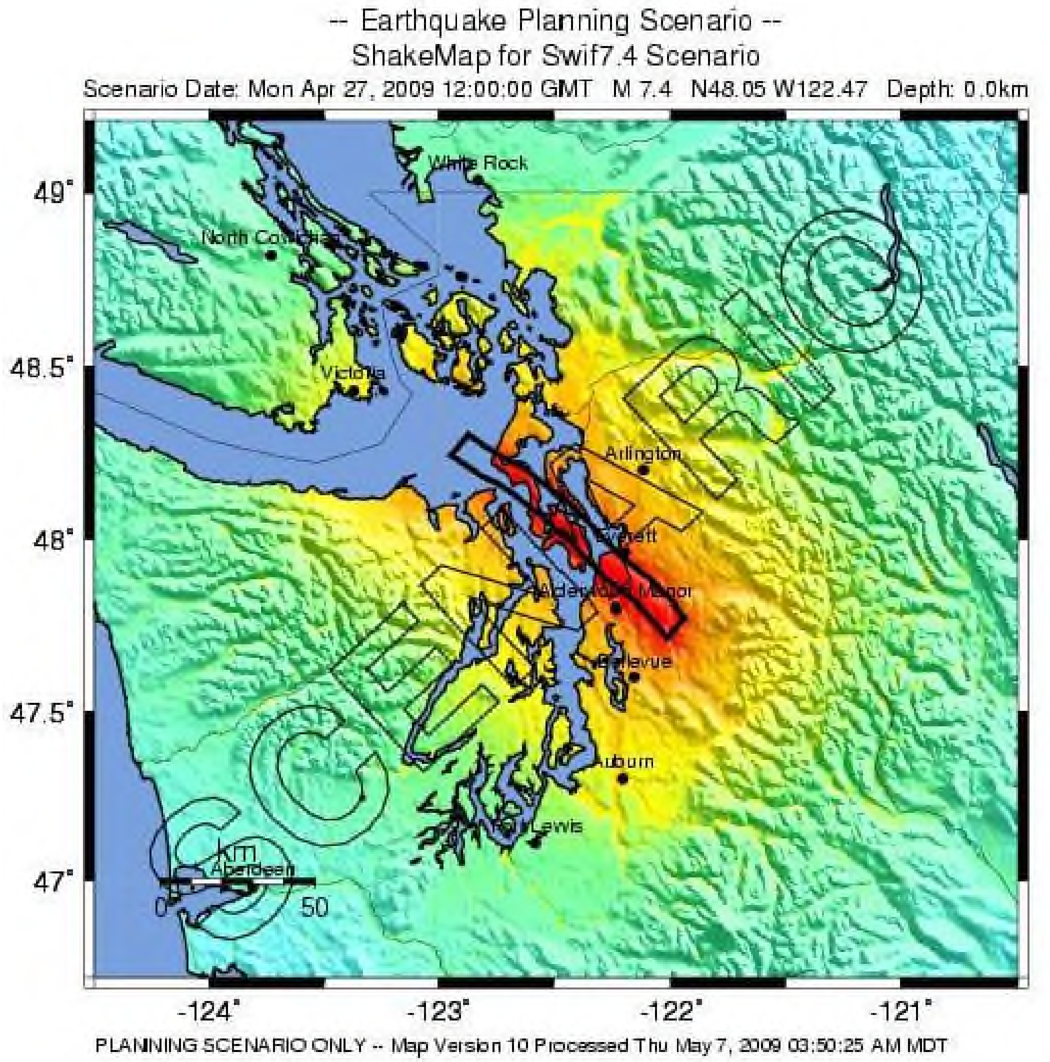


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 9. Deep Slab Earthquake Scenario

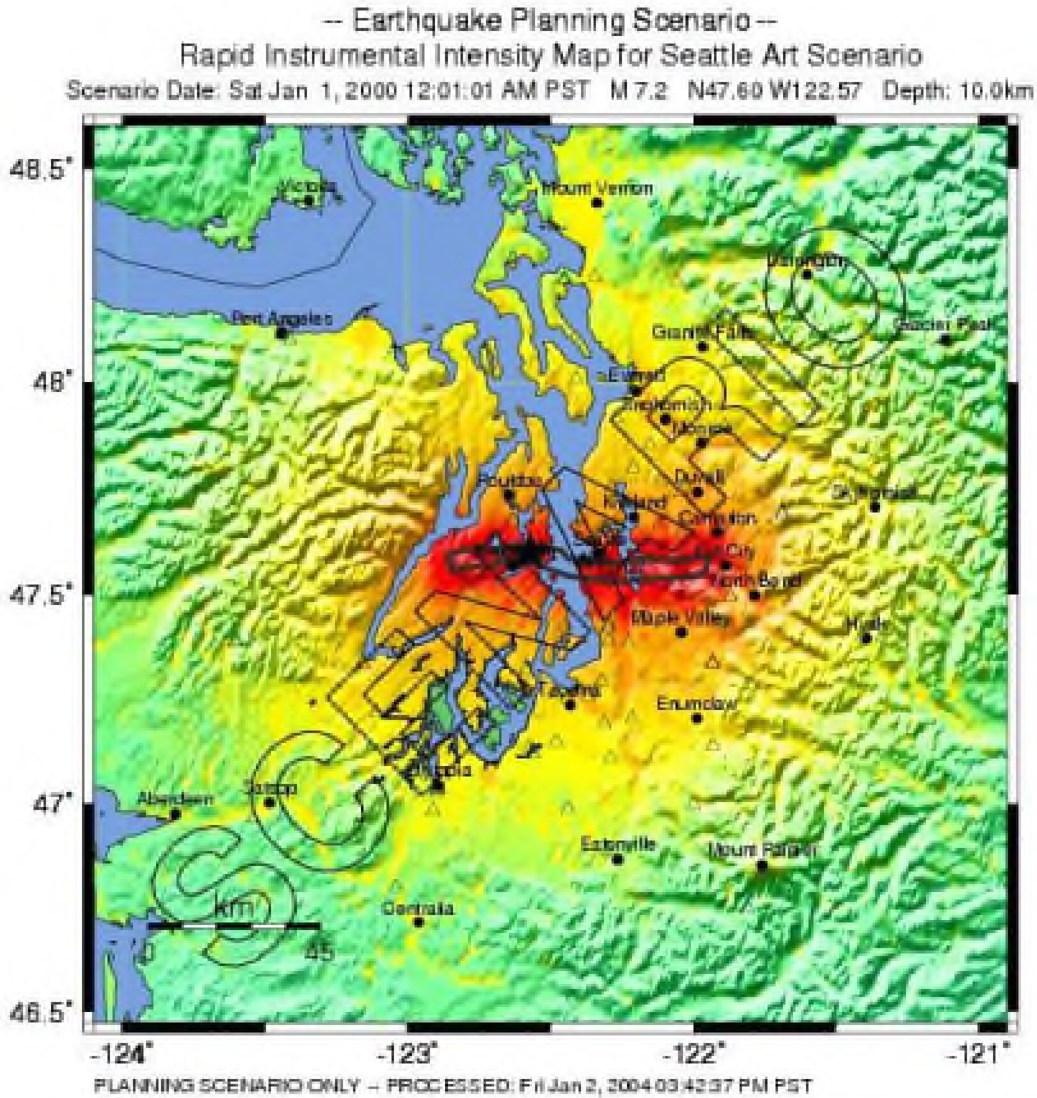
2.3.2 Crustal Earthquake[20]

The Seattle Fault Zone is a reverse thrust earthquake which means that it may be accompanied by vertical and horizontal uplift of the ground to the south of the fault line, and a drop in height of the ground to the north (see Figures 10 and 11).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 10. Intraplate Earthquake Scenario



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 11. Crustal Earthquake Scenario

2.3.3 Cascadia Subduction Zone

This scenario representation was created before the awareness that the earthquake may occur further inland than previously expected. Though the scenario represents strong but not violent or extreme shaking in our area, tall buildings may be more heavily affected because of the long wave pattern subduction zone earthquakes generate compared to other earthquakes. These long waves cause more intense swaying in tall structures. Subduction Zone Quakes may last for up to five minutes, and this can create large scale damage in buildings that would have held up to equivalent shaking but for shorter periods.

All discussion of the impacts of an earthquake should take into account the magnitude, epicenter, and focus of the earthquake. This includes whether it is a subduction quake on the junction of the Juan de Fuca and North American plates off the coast of Washington, a deep earthquake like the 2001 Nisqually quake, or on the Seattle, Whidbey Island, Tacoma fault zones. Other variables outside the obvious impact of magnitude of the quake include weather both before and after the earthquake, the time of day, time of year, and the percentage of older buildings of construction techniques that are not up to current building code standards. For the purposes of this section, preliminary impacts will be from the Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

Depending on the size and location of the earthquake the effect on persons in the impacted area is expected to range from a repeat of the Nisqually quake of 2001 up to those from a hypothetical 6.7 or larger earthquake on one of the major faults in Puget Sound or a large subduction quake located off the coast of Washington (see Figure 12).

The magnitude 6.8 Nisqually Earthquake of February 28, 2001 resulted in one death and approximately 400 recorded injuries, including a dozen that were serious, throughout the Puget Sound Basin. The expectation is that similar quake would produce similar results[21].

Figure 12. Salmon Beach, Tacoma, WA following Feb. 2001 Earthquake

The effects of a surface rupture on the Seattle or Whidbey Island Fault Zone could lead to a much greater loss of life and injuries. Losses are estimated to be equivalent to those from the Kobe quake of 1995. However, in Kobe the fault was 12 miles away. Bellevue is located directly over multiple strands of the fault. Losses in the Puget Sound Basin are expected to top 1,600 fatalities and 24,000 injuries[22]. These estimates are based on one distinct scenario, a 6.7 earthquake on the Seattle Fault with its epicenter in Vasa Park. A variation on this either up or down in the magnitude could have a significant effect on the outcome[23].

In discussing a subduction quake, it must be understood that while the State has experienced quakes of this type possibly as high as magnitude 9, all of them were prior to settlers with a written language entering the State of Washington. Located towards the Washington coast, the earthquake waves will have to travel over 100 miles to reach our location. On the other hand “(T)his particular type of earthquake is especially hazardous to tall buildings, which could lead to significant fatalities in downtown areas.”[24]

In previous large earthquakes, the potential for an outbreak of disease appears to increase. This can be caused by polluted water sources, the eating of spoiled food, and the inhalation of dust kicked up by the quake. In addition, there could be environmental injuries such as hypothermia if the earthquake happened during the winter months.

3.2 Health and Safety of Personnel Responding to the Incident

Responders are subject to several hazards in the response phase of the emergency. Damaged fire stations could prevent fire personnel from utilizing all the equipment with which they are used to responding. Already damaged structures could collapse during search and rescue operations, especially during aftershocks. Response personnel, by the very nature of their work are putting themselves in harm’s way, not just from structural collapse during aftershocks but also from further landslide activity and respiratory problems due to the inhaling of quantities of dust and microbes stirred up by the earthquake. In addition, they can be exposed to bacteria and chemicals in the environment they are working in, sometimes without realizing it. Approximately 80% of Red Cross responders who went to work on Hurricane Katrina response returned home with respiratory infections[25].

First responders frequently have adverse psychological reactions to trauma. Long term psychological impacts were noticed years ago, such as after the collapse of the Hyatt Regency Hotel walkway in Kansas City, Missouri in 1981, and eventually led to the development of Critical Incident Stress Management. Divorce and suicide rates are higher than the normal population in the first responder community and even greater after a major event[26]. “(S)tress is not like a light switch—the images of such tragic events often haunt the responder into his or her home life, piling more pressure on other events. Ill health effects can include high blood pressure, sleep disorders, alcohol or sleeping aid abuse, anger, withdrawal from family members, over protectiveness for family members, and even paranoia.[27,28]”

3.3 Continuity of Operations and Delivery of Services

For a large earthquake impacting Bellevue, continuity of operations will be severely taxed for many if not most of the agencies and jurisdictions located therein. The impacts affecting continuity of operations include:

- Death or injury to staff limiting the number of staff able to fill normal operational duties,
- Inability of staff to respond to their work sites due to road closures from debris on the roads, liquefaction or lateral spreading damaging the roads, and bridges or overpasses damaged closing arterials in particular,
- Staff absenteeism while checking on or taking care of family and handling damage to home or other personal property,
- Damage to communications systems will limit organizations' ability to coordinate their own resources, and it will also limit their ability to pull together a full picture of the damage suffered in their jurisdiction and to request assistance if needed,
- Damage to facilities and equipment, and
- Damage to the water, energy, and sewer systems connected to agency facilities will not allow operations to continue in their normal manner.

Due to the limitations mentioned above, delivery of services will be heavily impacted by a large earthquake. Infrastructure damage or destruction combined with lack of staff will retard delivery of normal governmental services.

Law enforcement operations will be taxed to the maximum. Road closures, prevention of residents entering hazardous areas, control of looting, responding to search and rescue operations, etc. combined with a decrease in available staff due to all the factors listed above will severely limit normal day-to-day operations. Most individual law enforcement officers operate independently of others in their jurisdiction. Since many of them have their equipment with them, including cars, they may be able to assist at least in the area they are at when the earthquake happens.

Fire response will be impacted in a similar vein, however for many of them they will have to report to a station where they can respond from. Between the inability to get to their station and the possibility that the stations and equipment may be damaged or destroyed the response will be compromised. Many fire stations, especially the older ones, even though they have survived previous moderate quakes may not survive a large one. Even if a station is not destroyed or collapsed, a racking of the walls could jam the bay doors closed.

Public works and utilities will not have the ability to have services back up and operational in many cases for days, weeks or, in some cases, for months. Repair of roads, bridges, water and sewer lines, the electric grid and telephone lines and towers will tax these utilities to the maximum. Even with the importation of mutual aid and other assistance from other portions of the state and other states, the service delivery will be slow to develop and spotty at best for some time.

Schools will be unable to fulfill normal expectations. Damage to schools' infrastructure as well as the public infrastructure of roads and utilities will close down schools at least temporarily. Those that might be able to be operational will, in many cases, have to act as temporary shelters for those displaced by the earthquake. Immediately after the earthquake, if school is in session, they may have to house students for days until parents are able to retrieve them.

3.4 Property, Facilities, and Infrastructure

Any large earthquake on the Seattle or Whidbey Island Fault Zones or from many other faults in Washington State will create damage to the property, facilities, and infrastructure either owned by the city or needed to support our economy and residents. This includes damage to buildings, electrical grids, telephone service, including cell operations, water and sewer utilities, port facilities, transportation systems, and both natural gas and liquid fuel pipelines.

A number of factors will determine the effect of ground shaking on the building stock and infrastructure of any area. These include: soil composition, age of the facilities, focus (depth of the quake) or, epicenter (point on the earth's surface directly over the focus), weather previous to the event surface faulting subsidence and uplift.

First, is proximity to the source of the earthquake. The closer to the fault rupture, the greater the effect is on structures. Second, is soil composition. Soft and liquefiable soils will both intensify ground shaking and in the case of liquefiable soils lose structural integrity. Earthquake waves moving along the surface of the ground have different characteristics depending on the soil composition they encounter. These surface waves change when they progress from one soil type to another. They tend to travel slower through soft soils than they do through hard soils or bedrock. Yet the energy contained in the wave stays the same. The result is that as the wave changes speed the amplitude will change in relation to it, increasing in soft soils and decreasing in hard soils. This increase in wave amplitude in soft soils can damage structures, especially unreinforced masonry and pre-1970 tilt up structures[29].

Figure 13. Liquefaction, Niigata Japan, 1964.

When the soil loses structural integrity, liquefaction or lateral spreading may be the result. This is especially prevalent in areas of clay like Newport Shores, or years of flooding, like the Mercer Slough. In cases like this, buildings or portions of buildings built on it may sink[30] (see Figure 13).

Figure 14. Lateral Spreading Along North Deschutes Parkway in Thurston County, March 2001

Secondly, the majority of the building stock that exists in Bellevue was built before current earthquake codes were put into place and before there was much of an understanding of the actual hazard that exists from earthquakes in Washington State. It was only towards the end of the 1980s that geologists began to understand some of the processes that cause earthquakes in the Pacific Northwest. Since that time, both geologic research into our local earthquake hazard as well as engineering studies of building response in earthquakes has shown that some of the older building stock could have major structural problems, possibly to the point of collapse. The 2005 Best Available Science Review recommends requiring structure setbacks for new construction within areas of the Seattle Fault zone delineated as susceptible to surface rupture.

The third and fourth factors that will have a major bearing on the damage done to a community and to its ability to recoup from its losses are the depth of the earthquake (focus) and the location of its epicenter in relation to the city.

An intraplate earthquake located inside the Juan de Fuca Plate as it dives under the North American Plate will be deep enough that the waves it generates will be attenuated or lose some energy as they propagate outwards from the focus. In such a situation, even if the earthquake's epicenter is located in Bellevue the damage will not be catastrophic.

Taking the same size earthquakes, with magnitudes 6.8, 6.5, and 7.3 respectively, and moving them close to the surface could have caused damage similar to the Northridge (6.7), Loma Prieta (7.1), or Kobe (6.8) earthquakes. In each of these cases with the epicenter of the quake, 2001 (Anderson Island), 1965 (Des Moines) and 1949 (Nisqually Delta), deaths and injuries would have been much more prevalent. Buildings would have collapsed, fires would have started, bridges and freeway overpasses would have been more heavily damaged and other lifelines would have been in disarray or out of commission for long periods of time.

This is the scenario that Bellevue faces if there was an earthquake of that size on the Seattle Fault Zone. In addition, any earthquake on a surface fault close to Bellevue, like the Whidbey Island or Tacoma faults, will cause damage in Bellevue although probably to a slightly lesser degree, being further away. It should be noted that there are some portions of the Whidbey Island Fault Zone that are the distance from Bellevue as the Kobe earthquake was from the city.

A subduction zone earthquake will be located further away from Bellevue than the surface quakes mentioned above and so the waves will be attenuated somewhat by the time they get to Bellevue compared to their size on the coast. However, the shaking could run for multiple minutes. This shaking could continue for a much longer time than the historical intraplate earthquakes, and the slow-moving wave of the earthquake would have a larger effect on tall buildings. The most vulnerable structures will be those containing soft soils (both natural and those created by artificial fill) and tall structures built before 1994 (may have brittle welds that have been shown to perform poorly in shaking).

The next factor that can influence the outcome of an earthquake is the weather. The weather previous to the earthquake will have an effect on the eventual outcome. Rain saturating the ground can increase both the potential for earthquake generated landslides and the probability that liquefaction or lateral spreading will occur. This could increase the probability that pipes could break. Lateral spreading under roads, railroad tracks and port facilities would increase disrupting transportation and there could be an increase to building damage due to liquefaction.

The other area that could cause damage is actual surface disruption either from surface faulting, or subsidence and uplift. Fault ruptures breaking the surface can rip buildings apart, destroy bridges, offset roads, break pipelines, destroy sewer lines, and stretch or break transmission lines. The same can be said for subsidence and uplift. Having a building, road or any other piece of infrastructure where a portion of it either rises or falls in relation to the rest will break or destroy it. Actually, any piece of infrastructure either in the ground or on its surface can be broken or destroyed by any of these three effects.

Changes in the ground can affect the water table. Wells may change their water levels or go dry. Stream flows may be altered and on a macro scale landslides or other ground deformation may change the course of streams or rivers.

3.5 Environment

Impacts, or damage, to the environment may be thought of as two different processes. There is direct change to the environment caused by the earthquake. This incorporates all the natural damages such as landslides, coastal uplift, inundation of low lying areas with coastal subsidence and tsunami damage. In contrast, the other process involves the pollution that becomes endemic in the aftermath of an earthquake that strikes an urban area or some part of the infrastructure today.

Concerning traditional environmental changes due to earthquakes, while many times damaging in the short term, many of the changes caused by them are overcome with time as the local ecosystem absorbs them. These types of environmental effects have been happening for as long as the land that is now Bellevue has been around. These types of impacts include:

- Landslides will sometimes block streams or rivers forcing them to reroute, occasionally causing lakes that swamp the local vegetation leaving a ghost forest standing in the water. Landslides can increase erosion affecting fish habitats. They can cause tsunamis that can damage the shoreline.
- Coastal uplift raises sections of the near shore marine environment above the shore line, killing all near shore life in the area raised above the tide line.
- Subsidence dropping areas of low elevation and near shore land so that water now covers land that was recently dry. This can drown plants and animals in newly submerged areas and in some areas lead to saltwater intrusion into the local ground water supply.
- Tsunamis causing local erosion of the beaches, direct damage to plants and animals living on the beach, and possible saltwater damage to non-salt tolerant species away from the beach.

Today, however, there is another type of environmental damage that is the result of human intervention. That is the damage caused by the release of hazardous chemicals and/or large quantities of sewage. These can be released from many different sources including but not limited to industrial plants, pipelines, overturned trucks, damaged ships or barges, railcars and even school chemistry labs.

These impacts to the environment include:

- Air pollution: some chemicals released as gasses can cause immediate damage to plants, animals and humans. Tanks filled with, for example, chlorine, ammonia or any other hazardous gases can harm or kill animals, birds, and plants, not just around the spill but for some distance downwind depending on the chemical involved and the size of the release. The damage will usually be temporary and physical recovery to the environment will begin as soon as the gas dissipates.
- Chemicals that spill either directly into or that could drain into lakes, ponds, streams, rivers, or even drainage ditches could kill or create birth defects in fish and marine mammals. In some areas they would pollute drinking water. Depending on the chemicals involved and their ability to be either absorbed by the environment, or break down quickly the environment may either recuperate quickly or be impacted for years or even decades. Damage to port facilities could create spills into the waterways that tidal currents could spread throughout the coastal areas of Puget Sound causing damage into Kitsap, King, Pierce and Thurston Counties.
- Damage to wastewater treatment facilities, sewers, pump stations, etc. could lead to spills of sewage or the inability of the treatment plant to process waste allowing it to flow untreated into the local environment. This would have the same effect as many other hazardous chemicals, polluting the environment for possibly weeks, but also creating conditions that could with bacterial contamination lead to disease in both animals and humans.
- Spills onto land can, depending again on the type of chemical, either temporarily, as with the case with many caustics or acids or permanently, as with spills of heavy metals or many radioactive materials damage soils. Related to this is the absorption of material by the soil may allow it to pollute groundwater and be transferred for some distance causing damage. Depending on the ability of water and the chemical to leach through the underlying layers of soil, clay, rock, etc., it could eventually reach and pollute the aquifer.

3.6 Economic and Financial Condition

The economic effects from a large damaging earthquake will be extensive and the overall financial condition of most businesses, as well as local governments in King County, will be compromised. Economic factors will be impacted first by the direct damage to homes, businesses and the infrastructure. A number of factors come into play here. First, the housing stock will be affected, and while some people have earthquake insurance, the majority people do not. Most home construction built to contemporary earthquake standards will probably not collapse, however, damage could be extensive to older structures, especially those not connected to their foundations. While assistance will help with reconstruction, there could still be a large gap in what is needed to get families back into their homes.

Looking at the results of other earthquakes both in the Pacific Northwest and California, it can be seen that many businesses' building stock will be damaged. This will be especially prevalent in the areas of soft soils and older building stock. Combining this with the loss of water, electricity, and natural gas means that much of the local industry and businesses will not be able to continue operations in their normal manner. Most will be closed for at least a nominal portion of time. This will mean lost wages. In an escalating sequence of events the wage earner will not be able to buy necessities or pay bills that come due, including mortgages. This can lead to foreclosures and the further displacement of the population.

The loss of the transportation corridors including roads, rail transport and the damage to the Port of Seattle and Tacoma will make it nearly impossible to both import needed supplies and to ship goods to market in the near term. Some of these facilities may take years to recover.

Other economic factors impacting businesses include loss of inventory, or for those businesses that operate on a "just in time" re-supply schedule and do not have an inventory, the loss of their ability to be re-supplied may denote the end of their business.

A contributing factor includes the inability of staff to report to their work. This will be due in some cases to injury, while for others they could be looking after their own homes and families. Another factor leading to staff absenteeism is the damage done to the transportation corridors.

The damage to homes, industry, and other businesses will also have a direct impact on the long term operation of government and the public infrastructure. With the loss of a percentage of the tax base due to damage, and the exorbitant cost of bringing the infrastructure back to normal, there will not be funds available for many of the services that residents have grown to expect. This will have a compounding effect of not attracting other business to the City which then continues to limit the tax base.

3.7 Public Confidence in the Jurisdiction's Governance

How the after effects of the earthquake are handled will have a great deal to do with the public's confidence in the jurisdiction. For smaller size quakes, there should be little or no decrease in the public's confidence about government's ability to act. However, as the size of the earthquake increases and as the parameters that could lead to major damage increase, such as depth, epicenter, rainy weather, etc., the possibility of the public finding fault with local jurisdictions or agencies increases. Local agencies and governments must be able to respond quickly to revive any portions of the infrastructure that have been impacted by the earthquake. The longer the delay in service restoration, the more the public loses confidence in an agency's or government's ability to handle the situation. Since many of the long-term effects of an earthquake have social and economic consequences, the more the public perceives that government is ignoring their plight or unable to respond to it, the more the public will lose confidence in it. Eventually, any perceived lack of ability, or slow response will result in finger pointing and acrimony.

4.0 Resource Directory

- King County Office of Emergency Management
  http://www.kingcounty.gov/safety/prepare.aspx
- Pacific Northwest Seismograph Network
  http://www.geophys.washington.edu/SEIS/PNSN/welcome.html
- Washington State Emergency Management Division
  https://mil.wa.gov/emergency-management-division/hazards/earthquakeWashington State
  Department of Natural Resources
  http://www.dnr.wa.gov/
- Pacific Northwest Seismograph Network: Research in Seismology, Tectonics, and Engineering https://pnsn.org/
- Building Seismic Safety Council
  https://www.nibs.org/page/bssc
- California Division of Mines and Geology
  http://www.consrv.ca.gov/cgs/
- FEMA HAZUS homepage
  https://www.fema.gov/hazus/
- USGS Earthquake homepage
  http://quake.wr.usgs.gov/
- USGS Earthquake Hazards Program
  http://www.earthquake.usgs.gov
- USGS National and regional custom earthquake risk maps
  http://earthquake.usgs.gov/research/hazmaps/interactive/index.php
  http://www.usgs.gov/hazards/

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3 2010, King County Flood District Hazard Mitigation Plan, Web.
4 Ibid page 11-3
5 FEMA Multi-Hazard Identification and Risk Assessment Report: A Cornerstone of the National Mitigation Strategy, 1997, Web.
6 Bellevue Shoreline Management Program Glossary http://www.ci.bellevue.wa.us/pdf/PCD/15.Glossary02.pdf
7 Wells, R.E. Block Rotations and Tectonic Segmentation of Cascadia, Web.
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11 USGS publication. "Earthquake Hazards in Washington and Oregon, Three Source Zones." http://www.ess.washington.edu/SEIS/PNSN/CascadiaEQs.pdf
12 Gonzalez, Frank I., et al. "Puget Sound Tsunami Sources: 2002 Workshop Report." NOAA/Pacific Marine Environmental Laboratory, Contribution No. 2526, 2003. p. 7
13 Modified from PC HIVA (DRAFT), Earthquake Section, September 5, 2002, p. 2. Web.
14 Modified from PC HIVA (DRAFT), Earthquake Section, September 5, 2002, p. 2-3. Web.
15 Earthquakes in Washington, Walsh, Timothy J., et. al., Washington State Department of Natural Resources, Division of Geology and Earth Resources, Web.
16 Nelson, A.R., Johnson, S.Y., Wells, R.E., Pezzopane, S.K., Kelsey, H.M., Sherrod, B.L., Bradley, L., Koehler, R.D., III, Bucknam, R.C., Haugerud, R., and Laprade, W.T., 2002, Field and laboratory data from an earthquake history study of the Toe Jam Hill fault, Bainbridge Island, Washington: U.S. Geological Survey Open-File Report 02-0060, http://pubs.usgs.gov/of/2002/ofr-02-0060/ (March 2003).
17 Earthquakes in Washington, Walsh, Timothy J., et. al., Washington State Department of Natural Resources, Division of Geology and Earth Resources, Web.
18 Wells, R.E Block Rotations and Tectonic Segmentation of Cascadia, Web.
19 USGS 2009, Web.
20 USGS 2000, Web.
21 Hazard Mitigation Survey Team Report for the Nisqually Earthquake, February 28, 2001 , DR-1361-WA, Federal Emergency Management Agency and Washington Military Department, Emergency Management Division, p. 13.
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25 From the State of Missouri's Department of Mental Health PowerPoint slide show "The Psychological Impact of Trauma on Responders" Presenter notes slide 5, presented October 21, 2005 at the FEMA Crisis Counseling Program. Web.
26 Ibid. slide 21.
27 Johnson Sherrard, Linda, Heroes on Call, Occupational Health and Safety, March 2007, Web.
28 For a more in depth look at the long term effects on first responders see Mitchell, Jeff and Bray, Grady, Emergency Services Stress: Guidelines for Preserving the Health and Careers of Emergency Services Personnel, Brady, Prentice Hall Career & Technology, Englewood Cliffs, New Jersey 1990, and Jackson, Brian A. et al., Protecting Emergency Responders: Lessons Learned from Terrorist Attacks, Rand Science and Technology Institute, Proceedings from the Conference December 9-11, in New York City.
29 Field Manual: Post earthquake safety evaluation of Buildings, Second edition, Project Manager: Christopher Rojhan, Applied technology Council, Redwood City, California, 2005, p. 45.
30 Post-Earthquake Safety Evaluation of Buildings, ATC -20 Instruction Slide Show, Project Manager: Christopher Rojhan, Applied technology Council, Redwood City, California, 2005
31 Geotechnical Earthquake Engineering Server (GEES) of the University of Southern California sponsored by the Siting and Geotechnical Systems component of the National Science Foundation's Earthquake Hazard Mitigation program, Web.

Landslide[1]

Table of Contents

1.0 Introduction

1.1 Definition[2]

A landslide is the gravity-driven downslope movement of a sliding mass composed of rock, soil, and vegetation. It can pick up and include anything else that might be in its path whether part of the natural or the developed environment. A landslide occurs when the downslope weight of the slide mass exceeds the strength of the soil along the slip surface, or when the driving force (downslope weight) exceeds the resisting force (soil strength). Factors influencing the stability of a slope include steepness of slope, composition of soil and rock, groundwater conditions, recent precipitation patterns, slope aspect, earthquake, vegetation on slope, and anthropogenic activities (such as land clearing, grading, etc.).

According to Bellevue's Critical Area Ordinance, Landslide hazard areas are defined as areas that contain slopes of 15% or greater with more than 10 feet of rise, which also display any of the following characteristics:

- Areas of historic failures, including those areas designated as quaternary slumps, earthflows, mudflows, or landslides.
- Areas that have shown movement during the Holocene Epoch (past 13,500 years) or that are underlain by landslide deposits.
- Slopes that are parallel or sub-parallel to planes of weakness in subsurface materials.
- Slopes exhibiting geomorphological features indicative of past failures, such as hummocky ground and back-rotated benches on slopes.
- Areas with seeps indicating a shallow ground water table on or adjacent to the slope face.
- Areas of potential instability because of rapid stream incision, stream bank erosion, and undercutting by wave action.

1.2 Types[3]

There are four broad categories of landslides that commonly occur in King County.

1.2.1 Shallow Bluff

Shallow bluff failures occur on the steep Puget Sound marine bluffs. These landslides are limited in area (usually less than 1-2 acres). The removal of vegetation from the marine bluff, usually done to improve views, can lead to serious slope erosion and instability.

1.2.2 Deep Seated Landslides

Deep seated, large landslides can be as large as tens to hundreds of acres, and can occur on slopes with an average slope gradient as low as 15%. These landslides are usually reactivations of older, pre-historic failures and they are typically slow moving.

1.2.3 Debris Flows

Debris flows are the most hazardous to life. They are fast moving, water-saturated masses of soil, rock, and debris (tree trunks, limbs, etc.) that move down steep slopes and channels. Debris flows are typically triggered by intense rainfall and can run long distances when confined to a channel. This type of failure is most common the portions of the Newcastle area and Cougar Mountain. For a more detailed description of this type of landslide and vulnerabilities to it, see the Volcano hazard analysis.

1.2.4 Submarine Landslides

Submarine landslides (landslides that occur primarily underwater) have also occurred in King County in Lake Washington. Large submarine landslides in the Pacific Northwest typically occur on the deltas of major rivers or streams, which can lead to tsunami and seiche. Triggering factors for submarine landslides include:

- Rapid sedimentation resulting in an over-steepened and unstable slope,
- Loss of soil strength due to static liquefaction caused by rapid drop in water level at high to low tide transition,
- Loss of slope support because of bottom current erosion of material at the base of the delta slope,
- Additional loading at top of the delta slope (e.g., artificial fill) increases the downslope weight of the soil (driving force), and
- Earthquake shaking causing loss of soil strength (liquefaction) and increase in downslope force on soil mass.

2.0 Profile

2.1 Location and Extent

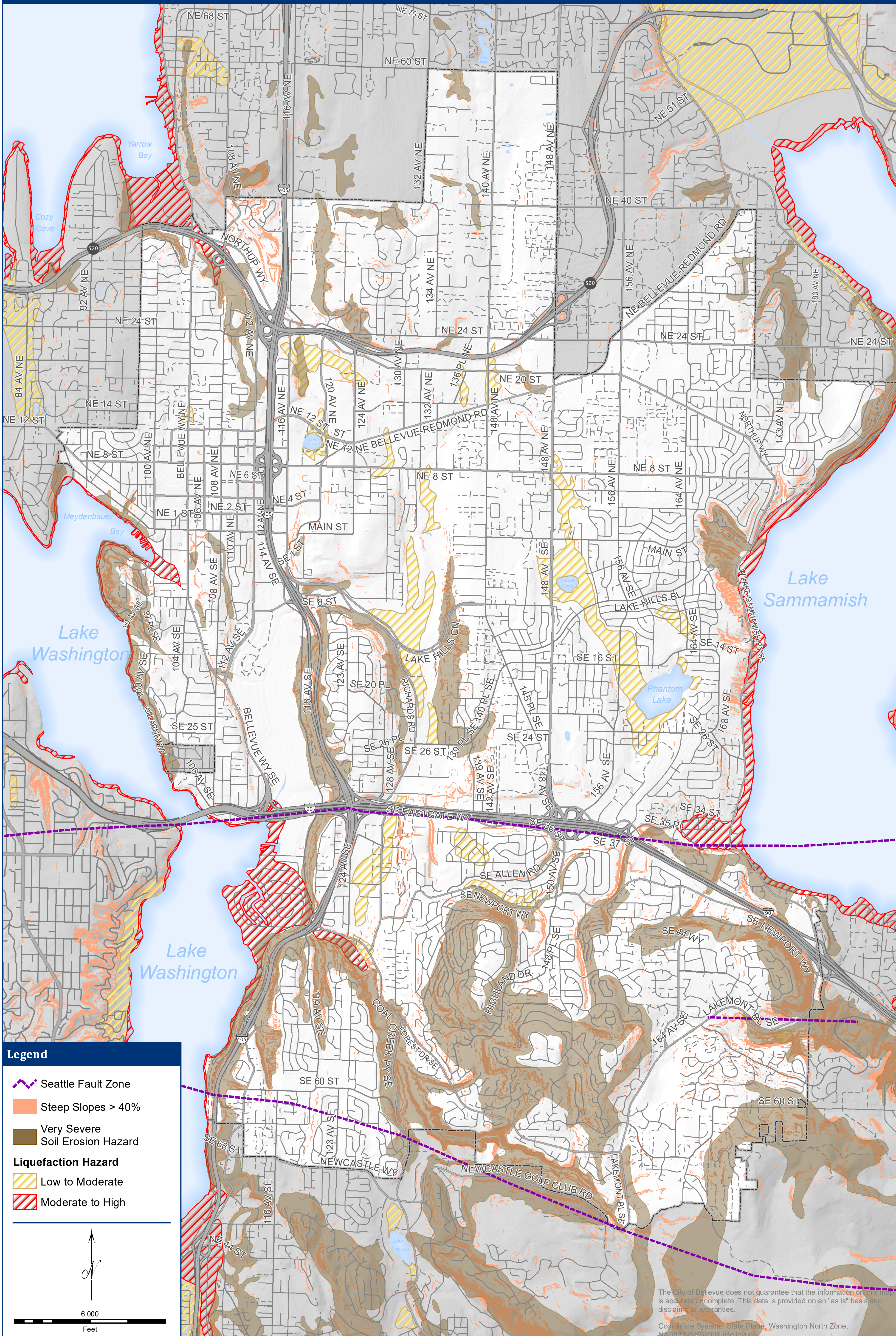
Landslides directly and indirectly affect a small portion of the developed areas in the City of Bellevue (see Figure 1). Two known repeat areas in the City include are West Lake Sammamish Pkwy and 97th Place SE. According to FEMA's Community Risk Profile of Bellevue, approximately 1,774 structures in Bellevue are in Identified Hazard Landslide Areas (approximately 5.4% of total structures in Bellevue).

Landslides and rock falls can be triggered on steep slopes. Earthquakes have caused large and disastrous landslides, including debris flows from volcanoes. Loss of strength in sensitive, clay-rich soils can also cause landslides and other ground failures.

A study of the classes of landslides caused by 40 major historic earthquakes estimates the minimum magnitude of earthquake shaking to trigger landslides and determined that: A greater than 4.0 magnitude earthquake can trigger rock falls, rock slides, soil falls, and disrupted soil slides; A greater than 4.5 magnitude earthquake can trigger soil slides and soil block slides; A greater than 5.0 magnitude earthquake can trigger rock slumps, rock block slides, slow earth flows, soil lateral spreads, rapid soil flows, and subaqueous landslides; A greater than 6.0 magnitude earthquake can trigger rock avalanches, and A greater than 6.5 magnitude earthquake can trigger soil avalanches. The potential landslide impacts of various earthquake incidents is also driven by the location and depth of the earthquake in the location to the City of Bellevue.

Geologic Hazards

City of Bellevue
GIS Services



Legend

- Seattle Fault Zone
- Steep Slopes > 40%
- Very Severe Soil Erosion Hazard

Liquefaction Hazard

- Low to Moderate
- Moderate to High

6,000 Feet

Source: City of Bellevue

Coordinate System: State Plane, Washington North Zone, NAD83 NSRS2007 (Bellevue)

Date: 9/21/2016 File Name: V:\EOC\arcgis\EOCmapSet\EOCMapSet2016\GeologicHazards_11x17_10-2.mxd IT Department

2.2 Occurrences

Topographic and geologic factors cause certain areas of Bellevue to be highly susceptible to landsliding. Ground saturation and variability in rainfall patterns are also important factors affecting slope stability in areas susceptible to landsliding. Strong earthquake shaking can cause landslides on slopes that are otherwise stable. Bellevue has taken steps to reduce the level of development on land prone to landsliding by working to identify areas at risk from landslides and restricting development.

2.2.1 Notable Landslides in Bellevue and King County

There is a history of disruptive landslides in the Bellevue area. Table 1 lists a description of the disruptive landslides from 1977 to current events.

Table 1. History of Bellevue Landslides prior to 2013

Year	FEMA Declaration Number/ WS Incident Number	Description
January 2012	DR-4056	Sever winter storms/weather landslides, mudslides, and flooding—Lake Sammamish Parkway
December 2010	N/A	Landslides, mudslides, and flooding
2009	DR-1817	Severe winter storm, landslides, mudslides, and flooding
2007	DR-1734	Severe storms, flooding, landslides, and mudslides
2006	DR-1682	Severe winter storm, landslides, and mudslides
2006	DR-1671	Severe storms, flooding, landslides, and mudslides
2001	DR-1361	Nisqually earthquake
1997	DR-1172	Severe storms, flooding, landslides, and mudslides
1980	DR-612	Storms, high tides, mudslides, flooding
1977	DR-545	Severe storms, mudslides, flooding

Descriptions of many of these occurrences can be read in the archives of local media located online.

- KIRO Slideshow of 2008 Mudslides in Newcastle area.
- 2007 Story of Bellevue home at risk from slide.
- 1997 Description of a slide that almost pushed a Medina home into the lake.
- A blocked culvert near West Lake Sammamish blocked the road in 1997.
- A second slide in 1997 blocked West Lake Sammamish again.

2.2.2 Prehistoric Landslides

Radiocarbon ages of submerged trees on landslide deposits in Lake Washington, Seattle, indicate that the most recent slides in three separate areas may have occurred simultaneously about 1000 years ago on the south side of Mercer Island. Tree ring crossdating shows seven bark-bearing trees from one of these recent slides and a tree 23 kilometers to the northwest in a probable tsunami deposit on the shore of Puget Sound died in the same season of the same year. The close coincidence among the most recent lake landslides, a probable tsunami, abrupt subsidence, and other possible seismic events gives evidence for a strong prehistoric earthquake in the Seattle region[4].

2.3 Recurrence Rate

Small landslides happen in Bellevue every year. Since few of them have any effect on the residents, they are irrelevant for determining the recurrence rate. Landslides with minor impact are defined as landslides impacting five or less developed properties or causing $1,000,000 or less damage. Significant landslides are those that begin to have a major impact on the fabric of a local community. For the purposes of this plan, they are defined as being six or more developed properties or damages greater than $1,000,000. The probability of recurrence for minor landslides in Bellevue could be ten years or less with the potential for significant slides being 100 years or less. This is based on information from past landslide occurrences and information from local hazard experts.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

Figure 2. Home Damaged by Landslide during January 2012

The impacts include the injury and possibly death to persons in the affected area. Death may result from suffocation from being buried by the landslide or traumatic injury from the impact of sliding material, or the collapse of structures by the landslide. In some areas there is the possibility that a structure could be actually pushed into a water feature like Lake Washington or Sammamish. In these cases, it is possible that a person could be trapped inside the structure and drown as a result of the slide.

The other impact relating to landslides has to do with underwater landslides. In this case, the possibility exists that an underwater landslide could initiate a seiche that could affect the surrounding areas.

3.2 Health and Safety of Personnel Responding to the Incident

Personnel responding to the scene of a landslide must be aware of the potential for more land to collapse while they are attempting to respond to or rescue persons from the slide impact area. Other possible hazards include ruptured gas lines and charged electrical wires. Also, hazardous chemicals associated with the damaged facility could have spilled and be in the environment.

3.3 Property, Facilities, and Infrastructure

Due to their probable location in the less settled portions of Bellevue, many of the landslides will have minimal effect on the developed property. However, in the developed areas there is a danger of roads, railroad tracks, gas, water, and sewer lines either being buried, broken, or in some cases swept away

when undercut by a slide[5]. Private property has the same problem. While many of the landslides will not be large enough to affect large numbers of homes or businesses, many could affect individual parcels of private property. It is also possible that damage to water and gas lines will increase danger from fire.

Figure 3. West Lake Sammamish Road Damaged after Landslide in January 2012

3.4 Environment

The impacts are generally local and would not include large scale damage to the environment. Generally, the slides will affect individual hillsides, possibly blocking rivers or streams. This can cause a backup of water that once it breaks through could cause a flashflood downstream. The possibilities exist that a major slide in a watershed could damage spawning beds or create an obstacle to fish migration. Any landslide that breaks pipelines, sewer lines, etc. or impacts the transportation or storage of hazardous chemicals could cause considerable environmental damage that could take decades to correct.

Figure 4. Hillside and Vegetation Damaged after Landslide in January 2012

3.5 Continuity of Operations and Delivery of Services

Due to the very limited terrain covered by any individual landside in Bellevue, unless the landslide has a major effect on some portion of the infrastructure, its impacts to the continuity of operations for any jurisdiction should be limited. The interruption in the delivery of services should be localized, if at all, and in most circumstances, of short duration. Individual departments or organizations, especially ones with infrastructure tied to the landscape like sewer utilities, water purveyors, and others could have their delivery of services compromised on a very local level but seldom on a large scale. Even a major landslide knocking out the city's water pipeline from north King County would have a workaround from the City's well system that could cover the lack of water until the pipeline was repaired.

There is the potential for a limited number of areas to be temporarily cut off from the rest of the County by landslides. The majority of these are located in the Cougar Mountain, Newcastle, and Woodridge areas. The overall effects would be limited and the roads should be opened within a short period of time. Generally, during normal years, most landslides are taken care of quickly, however in the advent of an earthquake generating a number of landslides throughout the County, as well as other damage affecting the infrastructure; it could be weeks before some areas are accessible for emergency vehicles and crews.

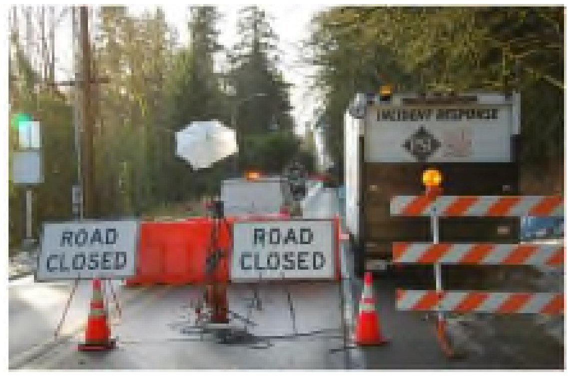


Figure 5. West Lake Sammamish Road Closed after Landslide in January 2012

3.6 Economic and Financial Condition

Due to the very limited terrain covered by any individual landside in Bellevue, the impacts to the economy for any jurisdiction affected should be limited. The biggest potential problem economically could come from a major slide taking out a section of I-405 or I-90. This could impact the transportation of goods into and out of Bellevue for a short time until a work around is established.

There are areas that slide on a regular basis. These are handled yearly with the local budgets and to date have not stressed those budgets. As the City has experienced larger landslides with related impacts, such as the January 2012 landslide on West Lake Sammamish Parkway, state and federal grant funds were requested as part of a larger Washington State Disaster declaration process to support response and recovery costs. If any area of Bellevue were to experience a landslide of the proportions of the slides that affected the Seattle area in 1997, it could cause financial difficulties due to the streets and other utilities affected or destroyed.

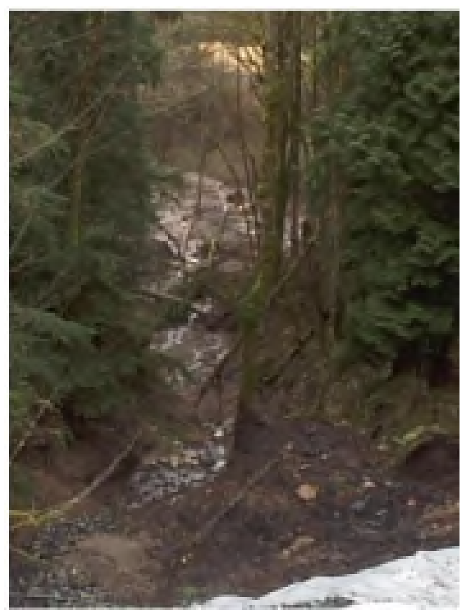


Figure 6. Landslide in the Coal Creek and Newcastle Area December 2010

3.7 Public Confidence in the Jurisdiction's Governance

The majority of landslides that occur each year in Bellevue do not affect homes, businesses, or infrastructure to the extent that there is any lasting impact noticed by the public. That could take a turn in another direction if Bellevue has a landslide that destroys a number of homes or a major arterial that could take months to reopen. If many homes are destroyed and, in particular, if people are killed or injured, there will be questions asked as to why people were allowed to build on unstable slopes.

4.0 Resource Directory

- WA State Department of Ecology: Puget Sound Landslide

  https://ecology.wa.gov/Water-Shorelines/Shoreline-coastal-management/Hazards/Puget-Sound-landslides
- WA State Department of Natural Resources
  http://www.dnr.wa.gov/
- The Landslide Handbook: Guide to Understanding Landslides:
  https://pubs.usgs.gov/circ/1325/
- American Planning Association--Landslide Hazards and Planning
  https://www.planning.org/publications/report/9026862/
- How to do landslide hazard analysis
  http://www.itc.nl/ilwis /
- USGS
  https://www.usgs.gov/natural-hazards/landslide-hazards

[1] Background and specific information for entire Pierce County Landslide Section provided through consultation with landslide hazard expert, Tim Walsh, Washington State Department of Natural Resources.
[2] Modified from Pierce County HIVA (DRAFT), Landslide Section, September 5, 2002, p. 1. Web.
[3] Ibid, p.1, 2.
[4] Science 4 December 1992: Gordon C. Jacoby, Patrick L. Williams and Brendan M. Buckley Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, "Tree Ring Correlation Between Prehistoric Landslides and Abrupt Tectonic Events in Seattle, Washington" GSA Bulletin Vol. 258. no. 5088, pp. 1621 - 16231
http://www.sciencemag.org/cgi/content/abstract/258/5088/1621
[5] Landslides and Landslide Hazards in Washington State Due to February 5-9, 1996 Storm--U.S. Geological Survey Administrative Report-- Debris flow undermining abutment of bridge across the Carbon River on Washington SH-165 south of Carbonado, Washington.

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1.0 Introduction

1.1 Definition

Wave-Induced Hazards on large bodies of water have can create risks to life and property. Damaging waves can be generated by weather systems or ground motion.

Seiches are water waves generated in enclosed or partly enclosed bodies of water such as reservoirs, lakes, bays and rivers by the passage of seismic waves (ground shaking) caused by earthquakes, or atmospheric disturbances, like windstorms, or landslides and underwater landslides. Sedimentary basins beneath the body of water can amplify a seismic seiche. Seismic waves also can amplify water waves by exciting the natural sloshing action in a body of water or focusing water waves onto a section of shoreline.[2]

The term tsunami is a Japanese word meaning "large wave in harbor" and comes from the Japanese observation that such waves tend to be especially large and dangerous after they enter harbors. A tsunami, sometimes called a tidal wave, consists of a series of high-energy waves that radiate outward like pond ripples from the area in which the generating event occurred. They also build in height as they move into shallow water, just before striking the open shore or reaching the heads of bays, and then inundating the low-lying areas near the shore. Often, a quick recession of the water precedes the first wave crest (see Figure 1).

Figure 1. Hawaii 1957, Residents Explore Ocean Floor Moments Before Tsunami, Pacific Tsunami Museum Archive Photos

It is unusual for tsunamis to resemble the icon used to depict them, a towering wave with a breaking crest (see Figure 2). While they can have that form it is more usual for them to resemble a series of quickly rising tides, or a surge of water. When they withdraw they do so with currents much like those of a river. Swift currents commonly cause much of the damage from tsunamis either from impacting objects directly or from the material picked up and transported along with the water, such as logs, cars, or parts of buildings. They also pick up pollutants like oil, gas, sewage, etc. that can cause further damage as well as long term environmental problems.

Figure 2. Hawaii 1949, Wave Overtakes a Seawall Pacific Tsunami Museum Archive Photos http://www.tsunami.org/archivesmore1946.htm . [Internet accessed February, 2007].

1.2 Types

Tsunamis are a secondary hazard, the result of geological events. Typically tsunami and seiches are triggered by earthquakes and landslides, see Earthquake Hazard Sub-Section 4.G2 and Landslide Hazard Sub-Section 4.G3. These sources are discussed below.

1.2.2 Earthquake Source

Sudden raising or lowering of a portion of the Earth's crust during earthquakes generally causes a tsunami. There are signs that Lake Washington had experienced vertical uplift in previous Seattle Fault Zone earthquakes. Upward displacement of the lakebed can cause a tsunami. Ground Motion lakebed or rock fall into an enclosed body of water and displace the water column setting off a series of waves that radiate outward like pond ripples.

1.2.3 Landslide Source

Two distinct landslide situations could result in a significant tsunami affecting local communities bordering Lake Washington or Sammamish: 1) submarine landslides, and 2) slides from adjacent uplands. These slides can be induced by earthquakes.

Subaerial Landslides

The two major geological parameters that control the generation of a water wave from subaerial landslides are the volume of the slide mass and the motion of the mass as it reaches the water body. Some very large prehistoric landslides have been mapped along Puget Sound bluffs; when reactivated, these deep-seated landslides tend to be very slow moving (inches per day) and would not appear to be capable of generating a tsunami. Subaerial landslides that fall into Puget Sound with sufficient volume and velocity and at the appropriate tidal conditions can generate large water waves.

River Delta Failures

Submarine landslides can originate on the delta slopes of major rivers flowing into the Sound, in particular the Nisqually, Puyallup, Duwamish, and Snohomish rivers.

Non-Deltaic Submarine Landslides

Additional landslides originate on steep submarine slopes that are not part of a delta. Away from deltas, submarine areas most susceptible to landsliding may be in the vicinity of faults having Quaternary displacement.

2.0 Profile

2.1 Location and Extent

In Washington State, the Pacific Coast, Strait of Juan de Fuca, and Puget Sound are all at risk from tsunamis. Large lakes, like Lake Washington and Sammamish, experience seiche effects. Tsunamis generated within Puget Sound and seiches on the lakes and southern portions of the Sound indirectly impact Bellevue. Future Coastal Velocity Zone Maps will show the tsunamis and seiche hazard location and extent for the effect on the 520 bridge. Projected increases in sea level due to climate change combined with subsidence in portions of Puget Sound will exacerbate these problems.

2.1.1 Earthquake Source

Earthquake induced tsunamis can occur throughout the Puget Sound, especially with the Seattle Fault Zone or Whidbey Island Fault Zone locations within the County. Any tsunami located within King County could affect the Port. See Figure 3 for a schematic of fault zone locations in the Puget Sound region, with vertical deformation contours for an Mw 7.3 Seattle Fault. The figure also illustrates the vertical deformation for an M 9.1 Cascadia earthquake, and Pacific Northwest peak ground acceleration with 2% probability of exceedance in 50 years.

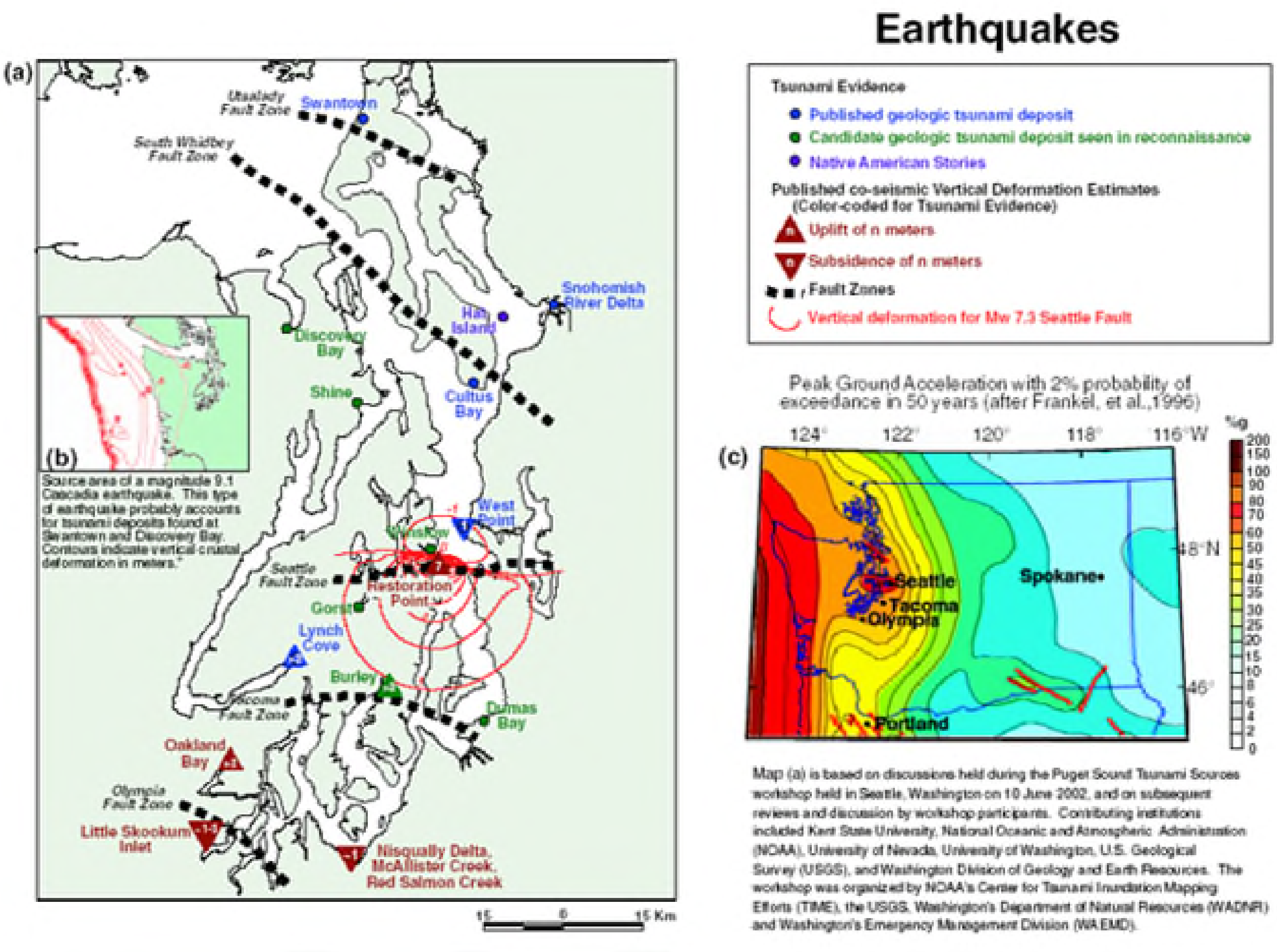


Figure 3 Puget Sound Fault Zone Locations, Vertical Deformations, and Peak Ground Acceleration[4]

A more detailed rendition of the regional faults is shown in Figure 4. In addition, this shows those areas that have a history of uplift and subsidence in previous earthquake events, probably leading to tsunami generation. Displacement along both the Tacoma and Seattle faults happened approximately 1,100 years ago and up to three other times in the last 2,500 years.[4]

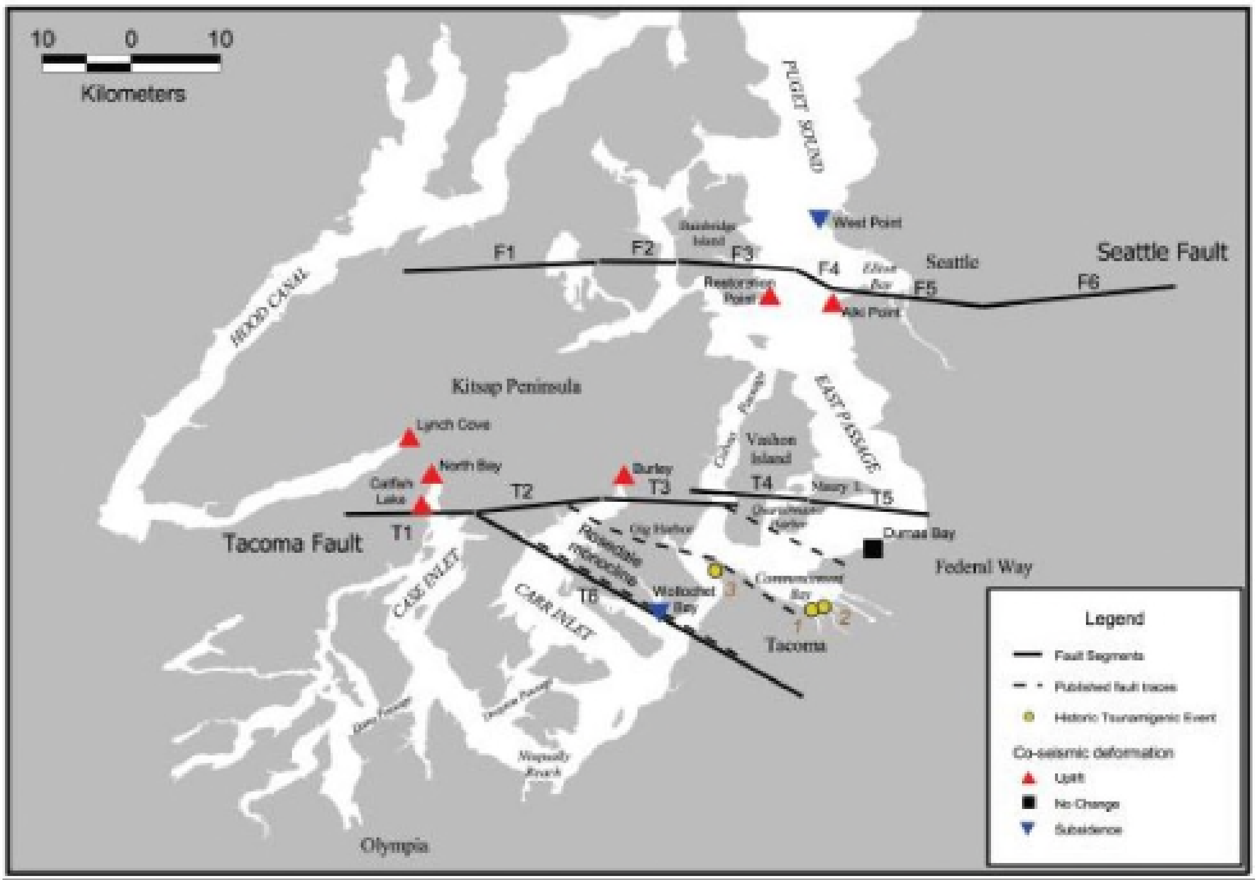


Figure 4. Seattle and Tacoma Faults[5]

Figure 5 identifies the maximum inundation (a, c, e) and maximum wave speeds (b, d, and f) expected for each earthquake source scenario. The Seattle Fault scenario creates the most inundation and highest currents within the study area due to the large displacement of water in the deepest and widest region of Puget Sound.

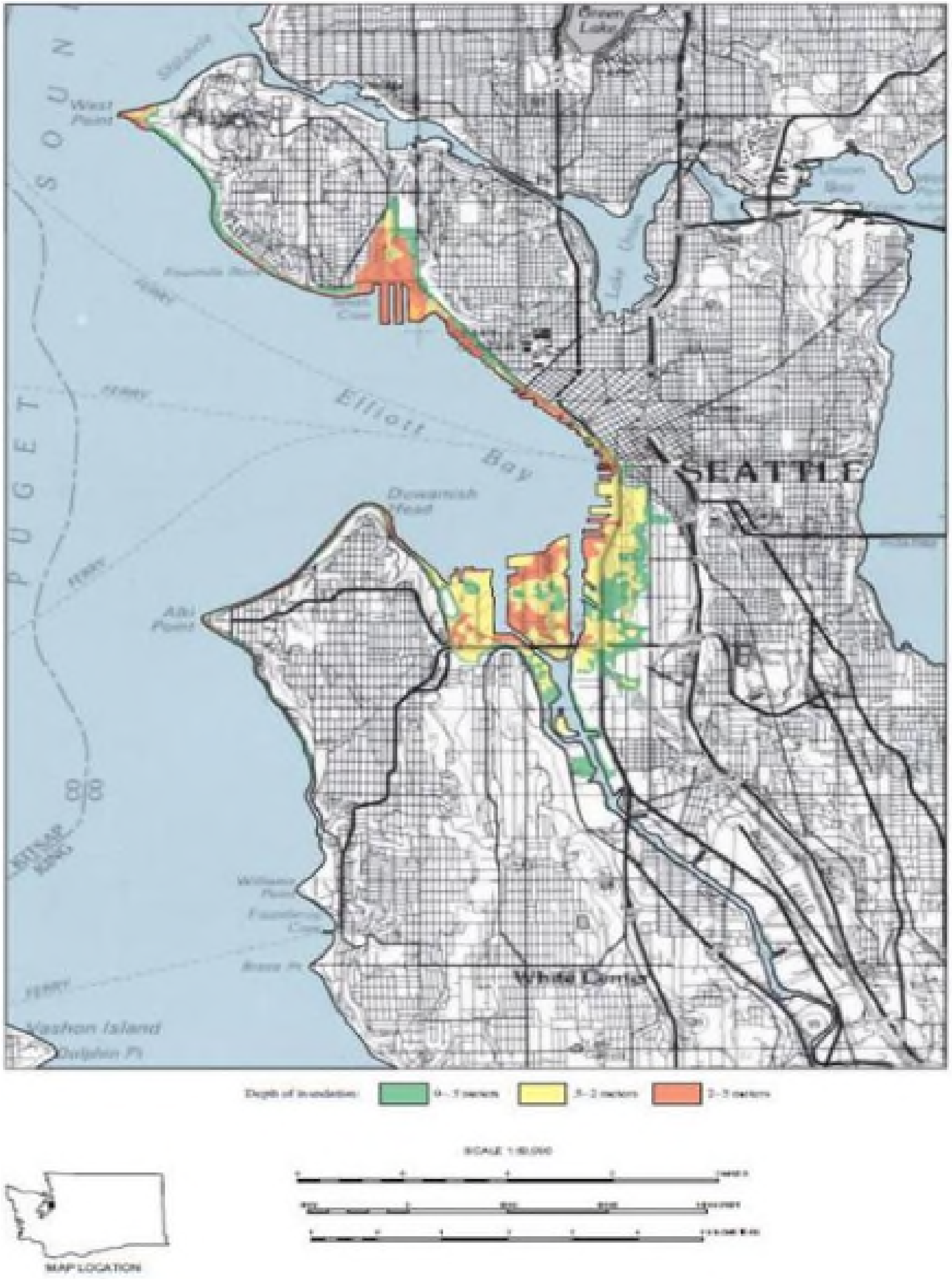


Figure 5. Tsunami Inundation and Current Based on Earthquake Scenario[6]

Earthquakes could also lead to landslide-induced tsunamis, the location and extent of which are described below.

2.1.2 Landslide Source

Subaerial Landslides can occur on most bluffs throughout the waterfront of Lake Washington and Sammamish. Either of these instances can induce a tsunami.

2.2 Occurrences

The recorded history of tsunamis is short and research is currently being conducted to develop a chronicle of past occurrences of tsunamis in Puget Sound. Below is a descriptive narrative of each occurrence organized by the tsunami's source.[7]

2.2.1 Earthquake Source

Although few earthquakes result in tsunamis at Puget Sound, each of the three earthquake sources has demonstrated its capability of generating such waves. A landslide that set off a tsunami in Tacoma Narrows occurred a few days after the 1949 earthquake in the Juan de Fuca plate. The earthquake of ca. A.D. 900 on the Seattle fault caused uplift that triggered a tsunami in central Puget Sound. The Seattle fault quake also caused landslide-generated waves in Lake Washington. Tsunamis from plate-boundary earthquakes probably account for several sand sheets on northwestern Whidbey Island and at Discovery Bay.

It is possible that other cross Sound earthquake sources could also generate a tsunami. However, at this time there has not been much study done on the areas affected by these potential waves. Other potential sources that could generate a tsunami that would impact Bellevue include the South Whidbey Fault and the Tacoma Fault.

2.2.2 Landslide Source

Hillside Landslides

Landslides triggered by ground shaking could result in a significant tsunami affecting the shorelines of Bellevue. Numerous submarine landslides have been mapped within Lake Washington and Lake Sammamish and are thought to have originated both on submarine delta fronts and from adjacent uplands (NOAA 2003). Landsliding is the primary geomorphic process responsible for maintaining the steep bluffs surrounding Lake Washington and Lake Sammamish. Landscape modifications coupled with the possibility of high intensity precipitation place these bluffs at risk of failure in the future.[8]

Our region has experienced local tsunamis in the Puget Sound region caused by a landslide. A tsunami was generated by a landslide at the Tacoma Narrows that occurred three days after the 1949 Ms 7.1 Olympia earthquake. The 1949 tsunami was caused by a landslide on the north end of Salmon Beach, Tacoma (see Figure 6). A 400ft high cliff gave way and slid into the Puget Sound. Water receded 20-25 feet from the normal tideline, and an 8-foot wave rushed back against the beach, smashing boats, docks, a wooden boardwalk, and other waterfront installations in the Salmon Beach area.[9] It moved both directions within The Narrows causing damage at Salmon Beach, Gig Harbor, and as far south as Day Island. Shortly after the earthquake geologists had noticed that cracks had formed at the top of the slope and had notified residents that a slide was possible. Many people evacuated their property and while the slide itself did not damage the homes there was damage from the tsunami itself.

Figure 6. Salmon Beach, Pierce County, 1949--Tsunami Causing Landslide[10]

Native American oral tradition suggests that in 1825, a large subaerial landslide at Camano Head, in Island County at the extreme south end of Camano Island, created a water wave that drowned many people on Hat Island. Because the story does not include ground shaking, this landslide was not necessarily associated with an earthquake.

Submarine Landslides

Unpublished seismic profiling data and mapping indicate that large submarine landslides (see Figure 7) have occurred on submarine slopes in Puget Sound, Lake Washington, and Lake Sammamish that are not associated with large river deltas, but that appear proximal to a number of Quaternary faults that cross the Sound.[11] Future Puget Sound tsunamis are guaranteed by a combination of setting and history. The inland waters and lakes of the Puget Sound lowland cross active faults and contain records of earthquakes and landslides (see Figure 8). From geologic and historical evidence, it is known that some of these events have generated tsunamis.[12]

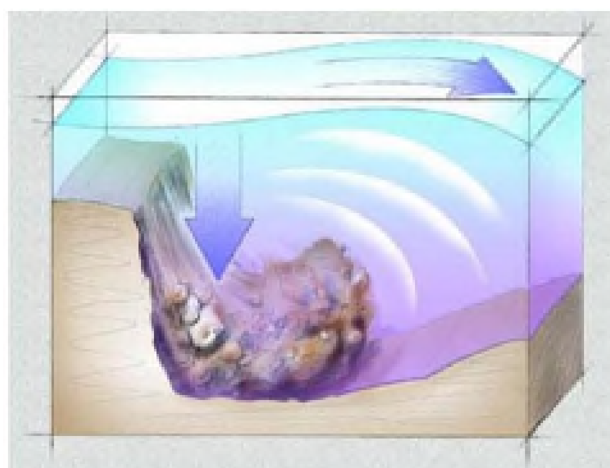


Figure 7. Submarine Landslides Causing Tsunamis

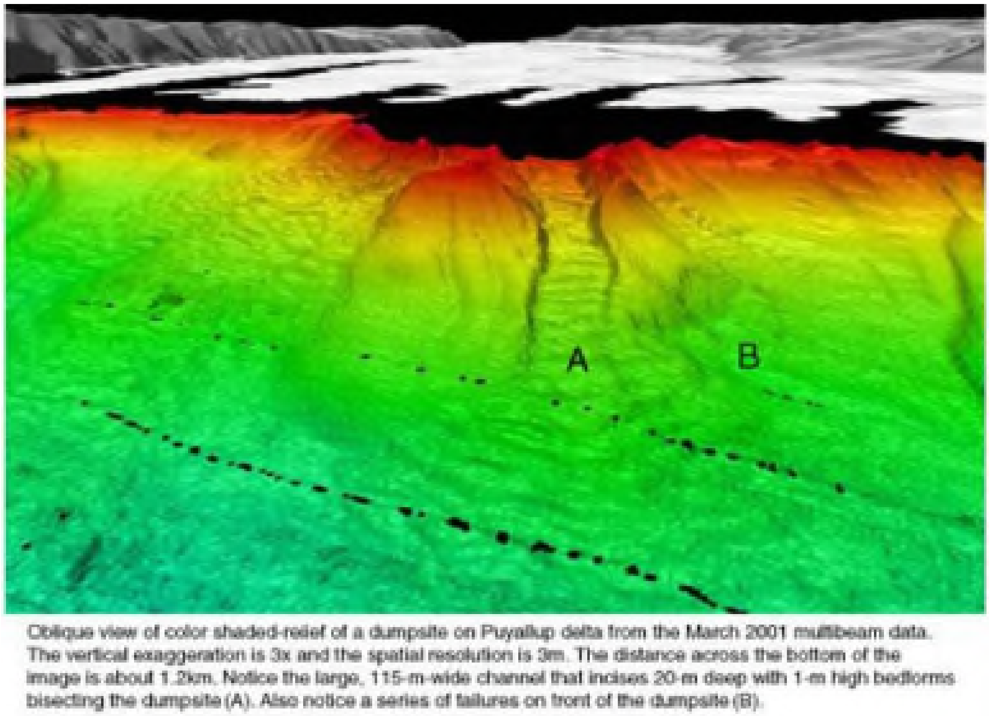


Figure 8. Puyallup River Delta, Submarine Landslides

2.3 Recurrence Rate

Tsunamis have occurred in the region long before there was a written record of their existence. Data from field studies shows that both the Seattle and Tacoma faults that run under Puget Sound had displacement around 1,100 years ago.[13] These would have resulted in tsunamis impacting the coastal areas of the region. Recent locally generated tsunamis from the various sources mentioned above, two submarine and one above water, have impacted the region three times in the last 120 years. The last of these was 65 years ago. This does not mean that the region is overdue for another one. It does, however, point to the erratic nature both of the cause and the recurrence interval. There was earthquake generated tsunamis (1,100 years ago) as well as ones from landslides into Puget Sound (1949) and those from underwater landslides (1,100 years ago, 1894 and 1943). There is too short of a historic record to give a definitive answer for a recurrence rate. Taking these into consideration, until further research can provide a better estimate a tentative recurrence rate of plus or minus 100 years will be used.

Table 1. Recent Earthquake-Induced Submarine Landslides

Recent Earthquake-Induced Submarine Landslides — Pacific Northwest Coast (1866-1964)				
Earthquake/Yr	**Location**	**Wave**	**Casualties**	**Damage**
1964 Alaska	Valdez	30-40 ft	31 dead	Total destruction shore area
1964 Alaska	Seward	30 ft	13 dead; 5 injured	Total destruction shore area
1964 Alaska	Whittier	30-50 ft	13 dead	Total destruction shore area
1949 Olympia	Seattle	None	None	Small slide
1949 Olympia	Olympia (Cooper Spit)	None	None	Small slide

Recent Earthquake-Induced Submarine Landslides — Pacific Northwest Coast (1866-1964)				
Earthquake/Yr	**Location**	**Wave**	**Casualties**	**Damage**
1946 Vancouver Is	Comox Lake	Yes	1 dead	Minor damage to cannery
1866 Olympia	Olympia (Cooper Spit)	10-15 ft	None	Small slide

Puget Sound Tsunami/Landslide Workshop January 2001 http://nctr.pmel.noaa.gov/Ws20010123/

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

The impacts to those in the area hit by a tsunami will depend directly on how large it is as well as its cause. If generated by a landslide into Lake Washington from one of the steep hillsides or cliffs bordering the lake, or an underwater slide, the impacts would be limited compared to one generated by a large earthquake on the Seattle fault. Depending on the location, direction that the wave propagates, time of day and even time of year, fatalities and casualties from any tsunami could be high within the impacted area. However, the method of generating the tsunami could dramatically affect the size of the impacted area. This was the situation with the 1894 tsunami discussed above (see Figure 9).

Figure 9. Damage in Tacoma from the 1894 Tsunami[14]

Mercer Island has a long history of landslides that could potentially trigger a localized tsunami. The 1965 earthquake triggered five major landslides though no tsunamis. A Mercer Island landslide would most likely cause damage to homes or businesses with low bank access to the water, especially those facing a potentially unstable slope.

In contrast, if a seiche is generated from a large earthquake on the Seattle faults, the damage could be severe enough from the seiche itself with deaths and injuries. Evacuation routes could be blocked either by landslides, power lines, or other debris. People could be trapped in damaged buildings along the waterfront and not be able to evacuate before the seiche arrives. In addition, the destruction to the infrastructure from the earthquake could prevent easy evacuation from areas threatened by the waves. In a situation like this, fire, police, and other responders will not be able to adequately rescue or assist residents with the resources normally at hand.

Puget Sound tsunamis could damage both facilities located along the coast and rail cars traveling along the coastal tracks. Many of these contain hazardous materials that could be released into the environment. The resulting spills would contaminate not only the areas initially hit by the wave but also, due to tides within Puget Sound, the coastline King counties. Depending on the chemicals released this could pose a threat to resident's health for weeks or even longer.

It is possible that bridges hit by the seiche could be damaged, either partially or fully destroyed. This would limit the ability of residents of Mercer Island to evacuate and reduce the ability of Bellevue residents based in Seattle to return to their families.

3.2 Health and Safety of Personnel Responding to the Incident

Response personnel located within the affected area will have the same threats as the general population during the actual period of time that the waves are active and dangerous. In addition, first responders, due to the nature of their work, potentially could be repeatedly putting themselves in contact with the hazardous environment consisting of chemical spills, debris, downed power lines in water, etc. as they perform their jobs.

3.3 Continuity of Operations and Delivery of Services

The adverse impact Bellevue for a non-earthquake generated tsunami, in maintaining normal day-to-day operations, will be limited. Damage and response will both be limited due to the small size and localized effect of the tsunami. The exception is for the impact on the region for a large tsunami associated with a major earthquake on either the Seattle or Tacoma fault zone. Computer modeling shows wave action and related currents moving deep into the Duwamish River in Seattle[15] (see Figure 10). Figure 10 identifies the maximum inundation (a, c, e) and maximum wave speeds (b, d, f) for each earthquake source scenario.

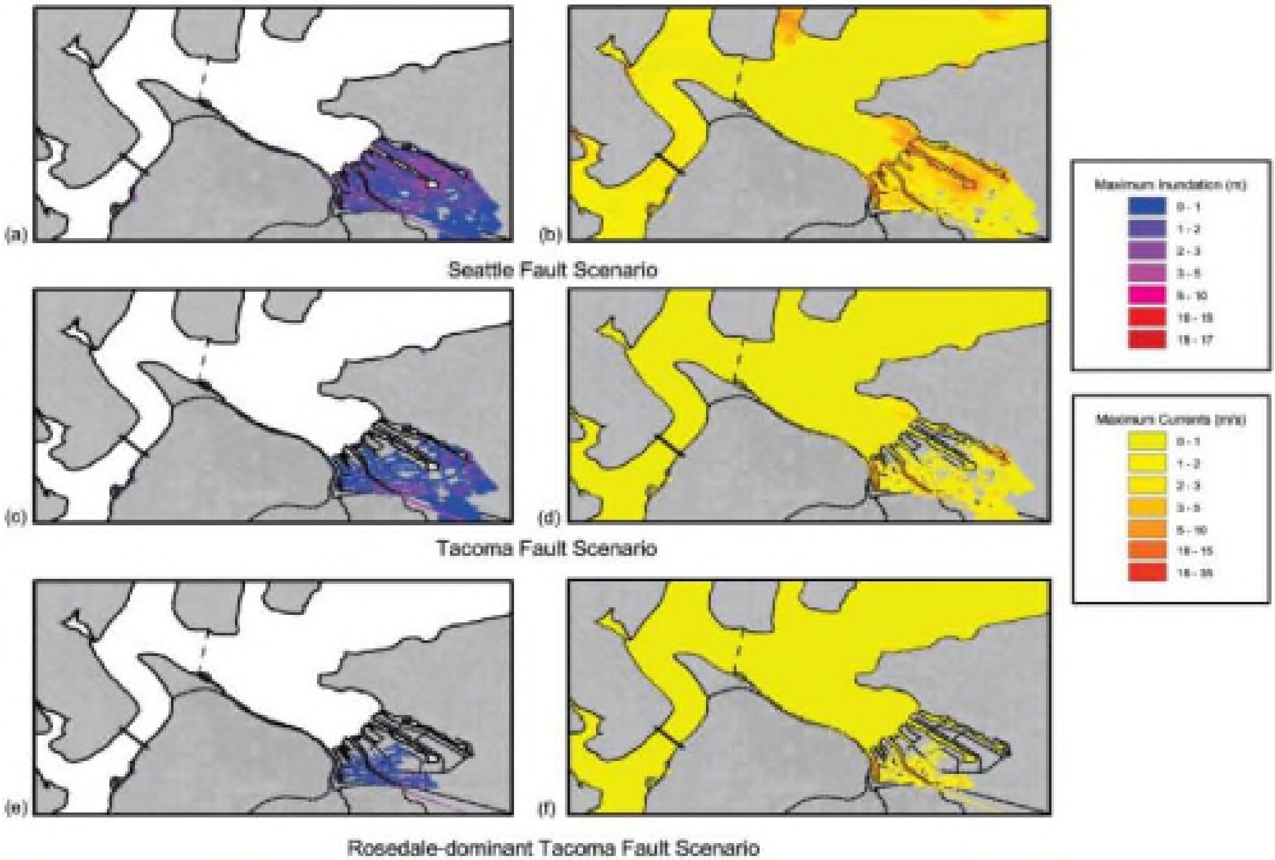


Figure 10. Tsunami Inundation and Current-Based on Earthquake Scenario

Due to the size and area covered during a run up it is probable that one of these tsunamis would impact and damage the infrastructure and equipment in the Port of Seattle and Tacoma and the infrastructure of some other coastal areas. Damage to cranes, docks, and even the Port Administration Building are all possible from a large locally generated tsunami. In this case the Port would not have the ability to maintain normal operations. Damage to the Port of Seattle’s infrastructure and equipment, in limiting its ability to operate at maximum efficiency, will lead to an inability to deliver the services normally provided to the lessees. Such damage could affect the ability of the Port to maintain itself as one of the major ports on the West Coast. An inability to maintain normal service delivery for any extended period of time could result in the loss of companies to competing Ports, either in Tacoma or depending on the type of goods, any other major port on the West Coast.

Mercer Slough and waterfront properties may be at risk of damage. Most likely both of the floating bridges will be damaged. If the bridges are damaged or destroyed, it would have a negative impact on the delivery of services to the community. In addition, there could be damage to City fire facilities, including Marine Response equipment.

Sewage treatment pumping located at or near water have a high probability of damage. In addition, the underside of bridges carries water, gas, and other lines that cross Lake Washington and a high wave could damage these.

Research is still taking place to model the likely impact of lake seiches and tsunamis. Due to local topography, it is likely that populations of Newport Shores, Beau Arts Village, and Meydenbauer Bay may be at risk. Newport Shores is most likely to sustain damage, due to its proximity to the fault, location on clay, and elevation. A tsunami inundating either area could damage or destroy most of the houses, and the marina as well. Damage from the tsunami could damage the roads.

3.4 Property, Facilities, and Infrastructure

Property impacts from a Lake Washington tsunami or seiche could range from minor to extreme. For example, a small tsunami generated by a landslide off the steep hillsides in the southern portion of the Mercer Island would affect only a small population that live right along the water front and a few businesses like the Newport Shores Yacht Club and Marina. In contrast, a large earthquake generated on the Seattle faults could send a tsunami throughout the Lake Washington and Sammamish, up Mercer Creek, inundating businesses there. Damage to the lock to the north could cause further problems maintaining water levels in Lake Washington.

3.5 Environment

The environmental impacts from a tsunami or Seiche striking Bellevue could range from very minor to catastrophic. A small tsunami, like the 1949 wave in Tacoma, would cause environmental damage to habitat and shoreline restoration areas. At the other extreme a tsunami originating from the Seattle Fault could affect the leaking underground tanks that have been identified in Mercer Slough. The action of the waves could carry those chemicals back to Lake Washington.

3.6 Economic and Financial Condition

Small tsunamis similar to 1949 in Tacoma or smaller would have a limited effect on the economic or financial condition of the City. Their area of impact will be restricted because the volume of water displaced is very limited. There could be more damage from the actual landslide than from the tsunami itself depending on where the slide occurs.

A third scenario would be a large Puget Sound tsunami from a quake on the Seattle Fault Zone. The developing tsunami could devastate large portions of the coastal area in the region. In a situation of this magnitude, actual losses from the tsunami itself could be many times that of the other scenarios. The loss of the a major part of the businesses located in the Harbor Island in Seattle, combined with the losses in Magnolia and other areas along the coast would set back the economic base for years. Many businesses and a large part of the industrial base of the County would be damaged. Thousands of jobs would be lost, and tax revenues would drop. It could take years to repair all the infrastructure and only then could the economy begin to rebuild to pre-earthquake/tsunami levels.

3.7 Public Confidence in the Jurisdiction’s Governance

Depending on the amount of damage from a locally generated tsunami or seiche, the public’s confidence in the jurisdictions governance could be sustained or adversely affected. A large tsunami generated by the Seattle fault could cause extensive damage all along the shorelines of Lake Washington and Lake Sammamish, and possibly some distance up Mercer Creek. Even with a case like this, the public's confidence in a jurisdiction would be governed by people's perceptions of how well the response and recovery went. A well-coordinated, visible, response and recovery effort will increase resident confidence in their local government. In contrast, a poorly coordinated one will decrease the public confidence in the local jurisdiction's competence.

4.0 Resource Directory

- King County Office of Emergency Management
  http://www.kingcounty.gov/safety/prepare.aspx
- Washington State Emergency Management Division
  https://mil.wa.gov/tsunami
  Washington State Department of Natural Resources
  https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/volcanoes-and-lahars
- USGS Western Region Coastal and Marine Geology
  http://walrus.wr.usgs.gov/pacmaps/site.html
- Pacific Tsunami Museum
  www.tsunami.org
- USGS Tsunami and Earthquake Links
  http://walrus.wr.usgs.gov/tsunami/links.html
  http://www.usgs.gov/hazards/
- National Weather Service Tsunami Warning System
  http://www.tsunamiwave.info/
- NOAA Tsunami
  https://www.tsunami.noaa.gov/
- Interactive Tsunami Site
  http://www.geophys.washington.edu/tsunami/welcome.html

1 Background and specific information for entire Pierce County Tsunami Section provided through consultation with tsunami hazard expert, Tim Walsh, Washington State Department of Natural Resources.

2 Modified from Washington State Natural Hazard Mitigation Plan (DRAFT), Tsunami Section, Washington State Emergency Management Division. September 5, 2002.

3 *Ibid*. p. 6.

4 NOAA Technical Memorandum OAR PMEL-132, Tacoma, Washington Tsunami Hazard Mapping Project: Modeling Tsunami Inundation from Tacoma and Seattle Fault earthquakes. Venturato, Angie J., et al, NOAA, United States Department of Commerce January 2007, p 3.

5 Ibid. p.3.

6 Tacoma, Washington, Tsunami Hazard Mapping Project: Modeling Tsunami Inundation from Tacoma and Seattle Fault Earthquakes, NOPP Technical Memorandum OAR PMEL-132, Venturato, Angie J. et al., pps. 9-10.

"Due to constraints of the inundation grid, the model does not cover the full extent of wave propagation in the upper Puyallup River; subsequently, the wave reflects off the edge of the grid boundary leading to potentially nonphysical inundation within the City of Fife and Puyallup Nation territory."

7 Gonzalez*,* p. 9-14.

8 Bellevue Washington 2005 Best Available Science Review, Geological Hazards, Web.

9 Tacoma News Tribune, April 18, 1949. p.1 as quoted in Lander, et al. (1993) *Tsunamis Affecting the West Coast of the United States 1806-1992*, NGDC Key to Geophysical Record Documentation No. 29, NOAA, NESDIS, NGDC, 242 pp. Web.

10 Gonzalez. Cover.

11 Gonzalez, Frank I. et al., Puget Sound Tsunami Sources: 2002 Workshop Report, A Joint Special Report: National Oceanic and Atmospheric Administration, Unites States Geological Survey, Washington State Department of Natural Resources, Washington State Military Department Emergency Management Program, June 2003, p.10

12 Modified from Washington State Natural Hazard Mitigation Plan (DRAFT), Tsunami Section, Washington State Emergency Management Division. September 5, 2002.

13 Tacoma, Washington, Tsunami Hazard Mapping Project: Modeling Tsuami inundation from Tacoma and Seattle fault Earthquakes, Venturato, et.al., United States Department of Commerce, National Oceanic and Atmospheric Administration, Office of Oceanic and Atmospheric Research, January 2007, p. 3.

14 Damage to the docks from the 1894 tsunami generated by an underwater landslide in Commencement Bay. Photo from Archives in the Tacoma Public Library, Photo G27.1-099.jpeg

15 Venturato, et al., p.12

Table of Contents

1.0 Introduction

1.1 Definition[2]

A volcano is a vent in the earth's crust through which molten rock (lava), rock fragments, gases, and/or ash can be ejected from the earth's interior[3]. Volcanic hazards within our area include most of the hazards associated with individual volcanoes in the Cascade Mountain Range. Those hazards include ash, landslides, lahars, pyroclastic flows, lava, and acid rain (see Figure 1). Bellevue's direct effects are most likely going to be from ashfall and acid rain, but volcanoes have a number of hazards that have to be considered in any comprehensive emergency management plan in the region. Many of these will only affect areas close to the volcano, but others like lahars and ash can cause damage many miles away.

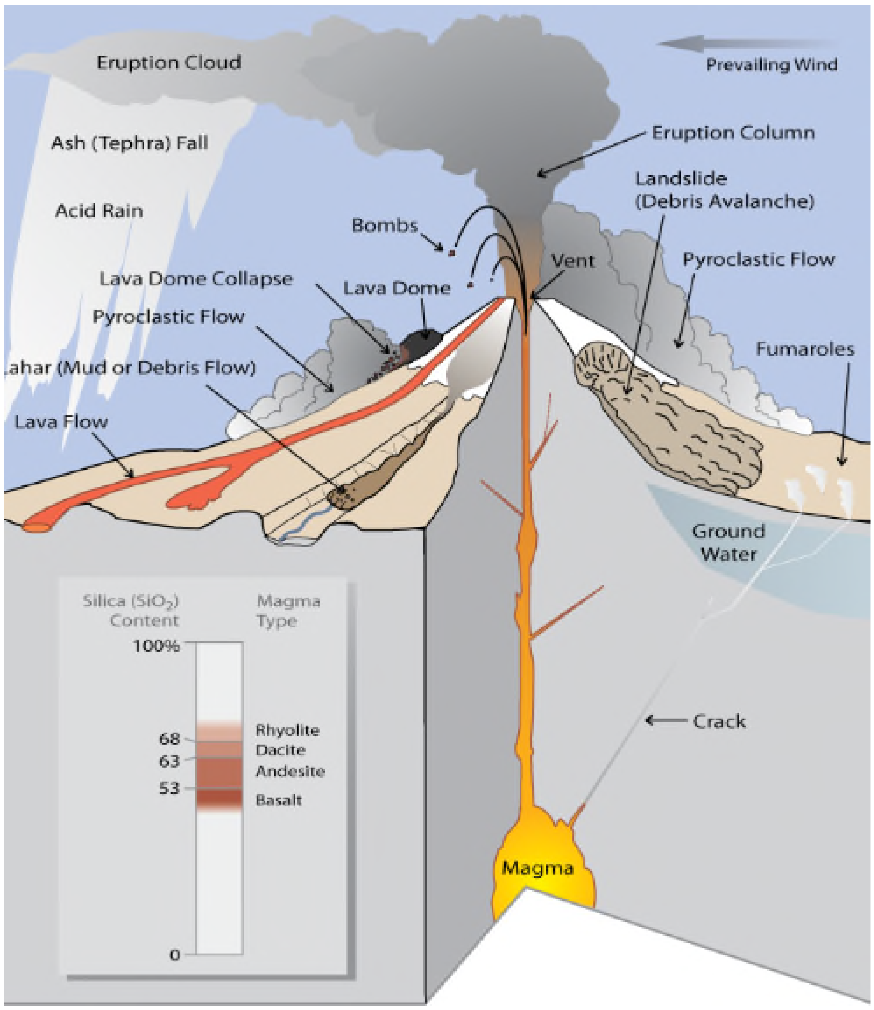


Figure 1. Volcanic Hazards,
https://pubs.usgs.gov/fs/fs002-97/

1.2 Types[4]

Volcanic hazards can occur with or without an actual eruption. The United States Geological Survey (USGS) differentiates volcanic activity into two types. In the case of non-eruptive events (non-magmatic), such as the generation of debris flows, there is generally no movement of magma and there may not be any detectable precursors to the event. Hazards associated with an eruption (magmatic activity) can usually be detected through volcano monitoring, so there is generally some warning prior to a magmatic event.

1.2.1 Non-Magmatic Volcanic Hazards

Debris Flows[5]

Debris flows of glacial ice and rock debris may be set in motion by explosions, earthquakes, and heat-induced melting of ice and snow, or the sudden release of water held within a glacier called a glacial outburst flood. A debris flow is a type of landslide that moves at high speeds; see Debris flow at Tahoma Creek, July 26, 1988[6]. The best recent examples of this are the small debris flows that come off the mountain every few years. The October 2-3, 1947 glacial outburst flood was the largest debris flow since Mt. Rainier National Park was established[7]. Most debris flows at Mt. Rainier are confined to areas either within the park or in a few instances extending to areas just outside the park boundary.

Lahars

Also called mudflows, lahars are a specific type of debris flow associated with volcanoes. They are dense mixtures of water-saturated debris that move down-valley, looking and behaving much like flowing concrete. They involve much greater quantities of material than do the normal debris flows and can cover many square miles of valley bottom with mud and other debris many meters deep. Over 60 postglacial (since the last ice age) lahars have been identified as coming from Mt. Rainier[8].

Lahars come in two types, called cohesive and non-cohesive lahars[9]. Cohesive lahars consist of debris with at least three to five percent clay content. The clay content in a cohesive lahar allows the lahar to resist losing material and transforming from a lahar to a hyper-concentrated stream flow. As such, a cohesive lahar will tend to maintain its integrity as a flow, constant in texture and coherent as a mass over greater distances than does a non-cohesive flow.

Non-cohesive lahars contain less than three to five percent clay, usually around one percent. These lahars tend to be more granular and consist of relatively unaltered volcaniclastic debris. As the flow moves away from the volcano, it tends to deposit material, become diluted and eventually become a hyper-concentrated flow. Essentially the fluid within the flow outruns the sediment, leaving it behind as deposits of rock, gravel, sand, etc.

Toxic Gases

Pockets or clouds of toxic gases may develop on or near both active and inactive volcanoes. Their chemical poisons can cause internal and external burns, or asphyxiation through oxygen starvation. Carbon dioxide, an example of an asphyxiant, is heavier than air and when given off by a volcano can collect in low-lying areas. Carbon dioxide has been collected within the summit caves of Mt. Rainier and a small area of release near Longmire has collected in small depressions in the past and proven hazardous to mice and insects. Other gases that may be present include sulfur compounds, carbon monoxide, chlorine, fluorine, boron, ammonia and various other compounds. With the exception of inside the summit caves these generally are dissipated rapidly by wind[10].

Landslide

Landslides from the sides of the volcano may be large or small, but all can have effects on valleys downstream. Small landslides are common on Mt. Rainier. Large landslides occur occasionally; the last large one was from Little Tahoma Peak (see Figure 2), a subsidiary peak on the side of Mt. Rainier in 1963[11]. Depending on the size of the slide and the consistency and temperature of the material, some of them may transform into lahars.

Figure 2. Landslide from Little Tahoma Peak Covering Emmons Glacier

1.2.2 Magmatic Volcanic Hazards

Volcanic Earthquakes

Often centered within or beneath the volcano, volcanic earthquakes are usually one of three kinds: pre-eruption earthquakes caused by explosions of steam or underground magma movements; eruption earthquakes caused by explosions and collapse of walls inside the volcano, and post-eruption earthquakes caused by the retreat of magma, interior structural collapse and landslides of material from the crater walls and sides of developing domes.

Lava Flows

Lava flows are masses of hot, partially molten to molten rock that flow down slope, generally following valleys. Lava flows from the Cascade volcanoes tend to be short and slow moving due to their high viscosity. The viscosity of lava flows is more dependent on the chemical composition of the material rather than the temperature. Mt. Rainier lava flows have high silica content and tend to be more viscous than do those with low silica content. As such they tend to stay close to the volcano rather than extending down valleys long distances. Many of the Mt. Rainier lava flows in prehistoric times tended to flow down valleys, frequently beside glaciers. These flows now form many of the ridges that surround Mt. Rainier.

Ash/Tephra

Tephra is the general term now used by volcanologists for airborne volcanic ejecta of any size. Table 1 identifies ash types and related sizes.

Table 1. Ash Types and Sizes

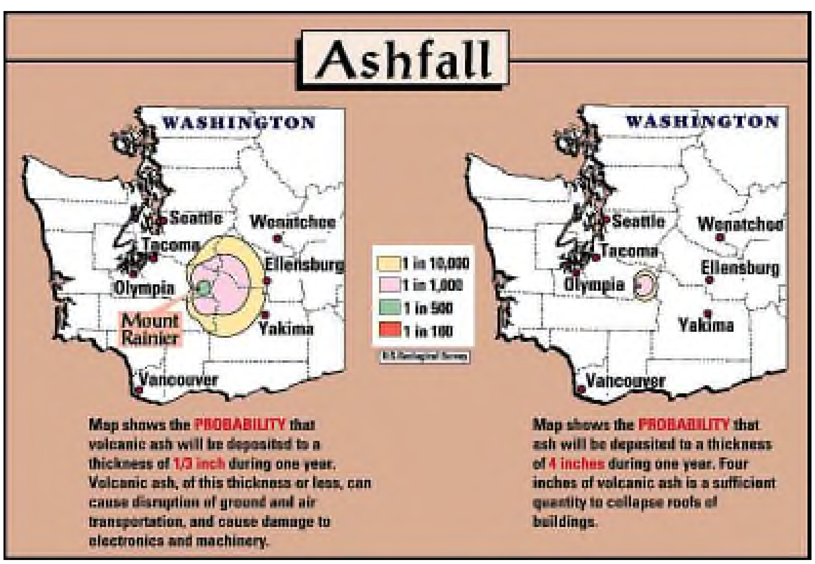
Ash Types and Sizes[12]	
Fine Ash	<1/16 mm
Coarse ash	1/16 mm – 2 mm
Lapilli	2 – 64 mm
Blocks and Bombs	>64 mm

Pyroclastic Flows and Surges

Pyroclastic flows and surges can occur during explosive eruptions. Pyroclastic flows are avalanches of hot ash, rock fragments, and gas that move at high speeds down the sides of a volcano during explosive eruptions or when the edge of a thick, viscous lava flow or dome breaks apart or collapses. Such flows can be as hot as 800 degrees Celsius, and are capable of burning and destroying everything in their paths. Pyroclastic surges are more energetic and thus less restricted by topography.

Lateral Blasts

Lateral blasts are explosive events in which energy is directed horizontally instead of vertically from a volcano. These blasts are gas-charged, hot mixtures of rock and ash that are expelled at speeds up to 650 mph. Lateral blasts vary in size, but large ones are fairly rare.

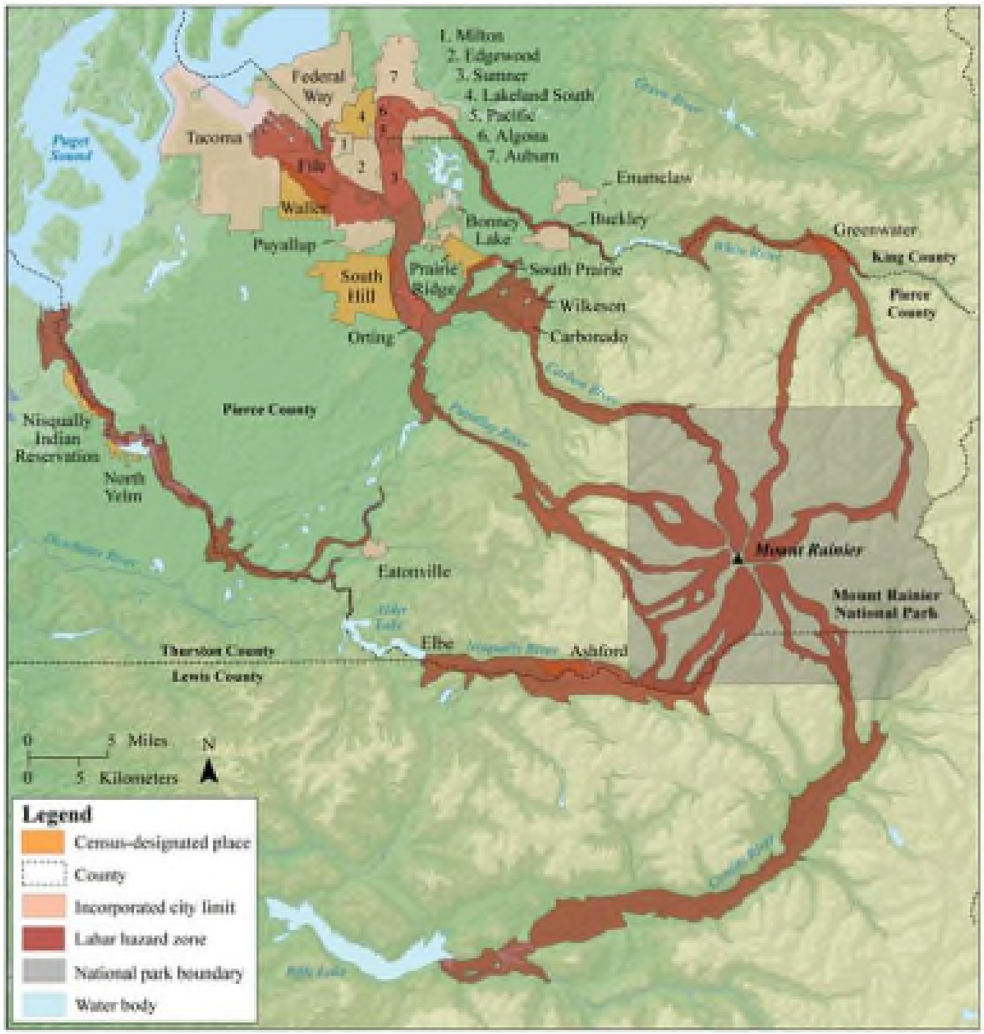


2.0 Profile

2.1 Location and Extent[13]

Bellevue is directly and indirectly affected by volcanic hazards. Figure 3, the Ashfall Probability from Mt. Rainier, shows the potential for ash distribution and Figure 4 shows the lahar, pyroclastic flow, and lava hazard areas in the region.

Figure 4. Lahars, Lava Flows, and Pyroclastic Hazards of Mr. Rainier[14]



As illustrated, the lahar hazard covers a great deal of the Pierce and part of South King County as each of the major river valleys comprises a portion of the lahar run-out zone. USGS volcanologists and Washington Department of Natural Resources (DNR) geologists identify Mt. Rainier as being in an active eruptive window. From the magnitude of past events, they surmise that the consequences of a lahar or debris flow down the populated river valleys will be catastrophic and could potentially result in a tremendous loss of life and property. Over 150,000 inhabitants of the river valleys work and reside on the deposits of prehistoric and historic debris flows.

The area covered by a major lahar will include some of the major population centers, both cities and towns, as well as major transportation routes, both rail and road. These areas include some of the most important industrial economic base for the region, including the Port of Tacoma. Even though Bellevue will not be directly impacted by a lahar, it is obvious that the lahar hazard affects all of the area, albeit indirectly, through transportation changes, loss of income and tax base, population redistribution, etc. Lahars are categorized by both cohesiveness and size. According to best available science, Case M, I, II, and III lahars are outlined below by their recurrence intervals[15]:

- **Case M Lahars—**the largest lahar to occur in the past 10,000 years is the Osceola Mudflow. It formed about 5,600 years ago when a massive debris avalanche of weak, chemically altered rock transformed into a lahar. Osceola deposits cover an area of about 212 square miles in the Puget Sound lowland, extending at least as far as Kent and to Commencement Bay in Tacoma. The communities of Orting, Buckley, Sumner, Puyallup, Enumclaw, and Auburn are wholly or partly located on top of deposits of the Osceola Mudflow. This lahar is at least 10 times larger than any other known lahar from Mount Rainier. Geologists believe flows of this magnitude occur far less frequently than once every 1,000 years. In case of a lahar, these communities are likely to evacuate north towards Bellevue.
- **Case I Lahars—**cohesive lahars originate as enormous avalanches of weak, chemically altered rock from the volcano. They can occur with or without eruptive activity. Most Case I flows have reached some part of the Puget Sound lowland. The Electron Mudflow reached the lowland about 600 years ago along the Puyallup River. Its deposits at Orting are as much as 18 feet thick and contain remnants of an old-growth forest. Average recurrence rate for Case I lahars on Mt. Rainier is about 500 to 1,000 years.
- **Case II Lahars—**usually relatively large non-cohesive lahars, most commonly are caused by melting of snow and glacier ice by hot rock fragments during eruption, but which can also have a non-eruptive origin. More than a dozen lahars of this type have occurred in the past 6,000 years. A few have reached the Puget Sound lowland, including the National Lahar, which occurred about 2,000 years ago. It inundated the Nisqually River valley to depths of 30 to 120 feet and flowed all the way to Puget Sound. About 1,200 years ago, another lahar filled valleys of both forks of the White River to depths of 60 to 90 feet, and flowed 60 miles to Auburn. The average time interval between Case II lahars from Mt. Rainier is near the lower end of the 100 to 500 year range.
- **Case III Lahars—**this class of flows includes small debris avalanches as well as debris flows triggered by sudden, unpredictable release of water stored by glaciers. These debris flows are largely restricted to the slopes of the volcano, rarely moving beyond the National Park boundary; since 1926, outburst floods destroyed or damaged bridges, roads, and national park visitor facilities on about 10 occasions. Glacial outburst floods are unrelated to volcanic activity and typically coincide with periods of unusually high temperatures or unusually heavy rain in summer or early autumn. About three dozen such flows occurred during the 20th century. Case III lahars occur at an average time interval at Mt. Rainier of about 1 to 100 years.

Table 2 Estimated Lahar Travel Times for Lahars 107 to108 Cubic Meters in Volume (Approaching a Case I Lahar in Size[16]) is based on information from geologists at the Cascade Volcano Observatory. It gives a more detailed overview of the lahar hazard from Mt. Rainier. Dr. Tom Pierson of the Cascade Volcano Observatory developed some travel time estimates for the various rivers leading from the volcano. For the Puyallup and Carbon River they are based on the time it takes for the lahar to travel from the point where the lahars are recognized by the monitors that are part of the lahar warning system in those valleys. Because they have no lahar warning system, estimates on the White and Nisqually Rivers are from the actual release of material from the volcanos.

Table 2. Estimated Lahar Travel Times for Lahars 107 to 108 Cubic Meters in Volume

River Basin	Estimated Travel (Time in Hours)
Carbon River	
Carbonado	0.2
Wilkeson	0.3
Orting	0.7
Puyallup River	
Orting	0.7
Sumner	1.1
Puyallup	1.3
Commencement Bay	1.8
Nisqually River*	
Alder Lake	1.0
La Grande	1.5
Haggedorn Road & 526th St	2.0
White River**	
Greenwater	< 1
Mud Mt. Dam overtopping	ca. 2
Note: Travel times on the Puyallup and Carbon Rivers are from Dr. Pierson and are based on the time it would take for the lahar to travel from the lahar recognition points. There are monitors that will pick up a seismic signal from the lahar and broadcast it to the State. Travel times on the Nisqually and White Rivers are from the Pierce County cartography work of Karen Truman.	
*The Nisqually River lahar entering Alder and La Grande Lakes will displace the water column, pushing it over their tops; therefore, travel times downstream from the dams will more closely follow the time patterns of a catastrophic flood.	
**The White River has the Mud Mountain Flood Control Dam on it that can work very well at containing a Case II lahar and most of a Case I lahar. This is why all times below the dam are assumed to be 2 hours or greater. It is dependent on the amount of water behind the dam. It is empty most of the year.	

New studies show that the process of hydrothermal alteration is unevenly weakening the inside of Mt. Rainier. This is a process whereby the interior portions of the mountain are being chemically altered by contact with hot, acidic water. This makes the slopes more susceptible for failure, increasing both the possibility and size of lahars. The slopes above the Puyallup River drainage are weaker than those above other river drainages originating from Mt. Rainier. The potential risk is compounded by the fact that more people live and work in this river valley than other Mt. Rainier drainage areas.

The other volcanic hazard that might directly affect the population of Bellevue is the potential for ash, from an eruption, to cover portions of the region. Mt. Rainier has a long history of ash eruptions. Early lava flows that may precede the development of Mt. Rainier appear to date from no earlier than 2.9 million years ago.

The volcanic cone built up gradually from a sequence of flows that were apparently frequent. Chemical composition of many of the flows shows them to be composed of andesite, with some marginally dacite[17]. Given this type of rock combined with the evidence of ash and breccia, it appears that many of Rainier's eruptions distributed ash over significant areas. An extremely large deposit appears in the record somewhere between 30,000 and 100,000 years ago. This eruption was apparently on the scale of the Mt. St. Helens eruption of 1980 and it is estimated that the volume of ash erupted was around 1 km3. There have been no further eruptions of this size in Holocene times. The potential then for an actual deposition of ash itself from Mt. Rainier is relatively small over much of the County, see Ashfall Map[18] (Figure 5), which includes the probability of a major ash eruption from the volcano impacting the region.

Another possibility is that Bellevue could be affected by ash from other volcanoes in the Cascade chain. This probability, while possible, is also very small; see: Annual Probability of 10 Centimeters or more of Ash Accumulation in the Pacific Northwest[19]. Besides Mt. Rainier, Mt. St. Helens has the highest probability of distributing ash across the region. For any of the volcanoes to do so, including Mt. Rainier, the wind needs to be coming from the right direction.

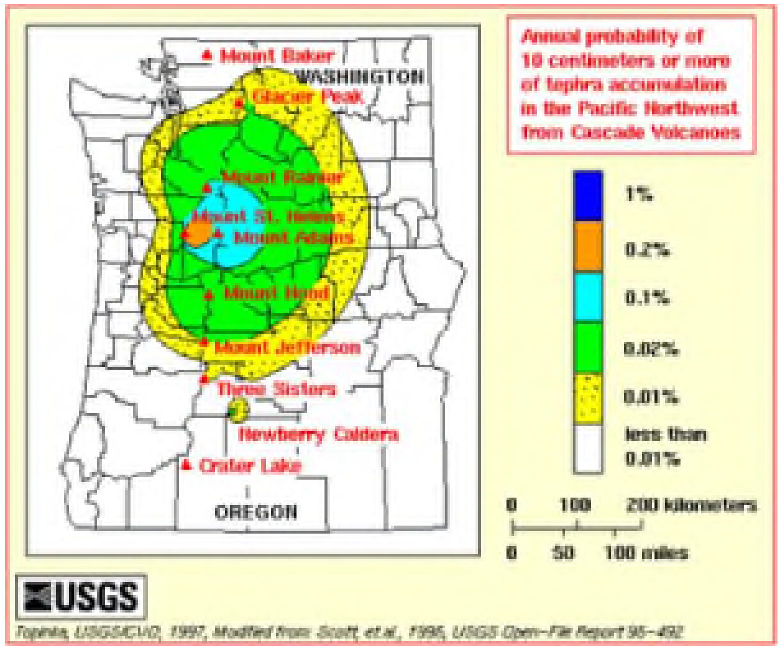


Figure 5. Annual Probability of 10 Centimeters or more of Ash Accumulation in the Pacific Northwest

Throughout the Pacific Northwest, most of the normal wind patterns tend to blow from south, southwest, or west. This takes the ash away from the populated areas of the County. It should be noted that during the 1980 eruptions of Mt. St. Helens, most of King County received some ash, although never a great quantity.

2.2 Occurrences

Cascade Eruptions gives a good idea of how frequently the Cascade volcanoes have erupted in relation to each other[20]. As shown in Figure 6, while Mt. St. Helens has been the most active over the past 4,000 years, many other volcanoes, albeit not all of them, have also been active during this period including Mt. Rainier. While the chart does cover many of the volcanoes in the Cascades, it is not inclusive. It ignores the British Columbia volcanoes like Mount Garibaldi and Meager Mountain. The area of the Cascade Range with the most volcanoes is Oregon. In addition to those listed on the chart, Oregon has a number of others that could erupt and deposit ash throughout the Pacific Northwest. They include,

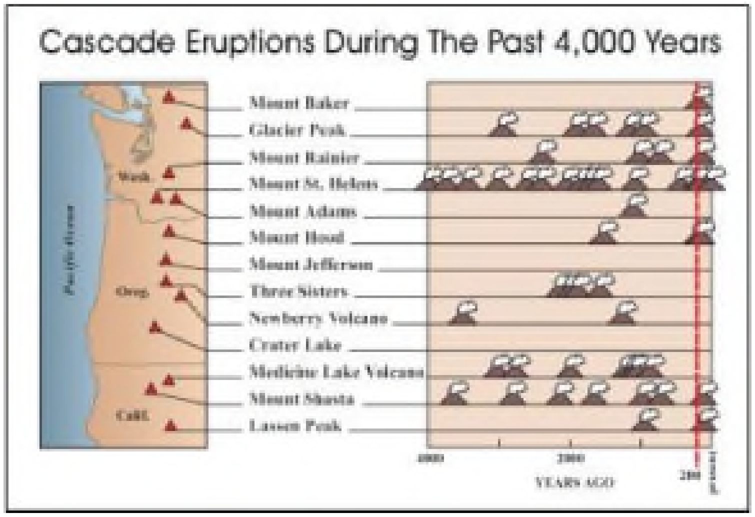


Figure 6. G5-1 Cascade Eruptions

amongst others, Mount Bachelor, Broken Top, Belknap, Mount McLoughlin, Mount Bailey, Diamond Peak, and Mount Thielsen.

During the past 10,000 years there have been 11 identified tephra eruptions, from Mt. Rainier, ranging in size from 0.001 to 0.3 km[21]. In Table 3, notice that none of them begin to come close to the magnitude of ash deposited from the Mt. Saint Helens eruption of 1980[22]. The St. Helens eruption of 1980 deposited approximately 1.01 cubic kilometers of material or a little over three times the amount from the largest Rainier eruption shown on the table[23]. As can also be seen from the table the last eruption putting out ash was around 150 years ago. Mt. Rainier however, had a few small eruptions throughout the 1800s[24]. The table below provides a list of past occurrences of debris flows on the various river valleys in the region.

Table 3. Mr. Rainier Identified Ash, Last 10,000 Years

Type of Flow	Age or Date	Area Reached
Puyallup River Debris Flow History		
Electron Mudflow	530-550 BP*	Puget Sound Lowland, possibly to Puget Sound
Lahar	~ 1000 BP*	Puget Sound Lowland
Round Pass Mudflow	~2,600 BP*	Probably to the Puget Sound Lowland
Lahar runout	< 3400 BP*	Puget Sound Lowland
"Pre-Y" Lahar	< 3500 BP*	Puget Sound Lowland
Lahar runout	>3500 BP*	Puget Sound Lowland
Nisqually River Debris Flow History		
Kautz Glacier/Van Trump Creek Debris Flows	August 2001	Near the Park boundary
Outburst flow on Kautz Creek	1947 AD	Below confluence with Nisqually River
Tahoma Lahar	Post 1480 AD	Below the confluence of Tahoma Creek & the Nisqually River
Lahar runout	< 2500 BP*	At least to Elbe
Lahar runout	< 2500 BP*	At least to Elbe
National Lahar	~ 2200 BP*	Puget Sound
Round Pass Mudflow	~ 2,600 BP*	At least to National
Lahar runout	< 3400 BP*	At least to Ashford
Large lahar runout	< 3400 BP*	Probably to Puget Sound Lowland

Type of Flow	Age or Date	Area Reached
Paradise Lahar	4,500-5,000 BP*	At least to Elbe
White River (including West Fork) Debris Flow History		
Debris Avalanche	1963	Within 1 km of the White River Campground
Gravel-rich flow	~ 1550 AD	At least to Mud Mountain Reservoir
At least one lahar	> 1480 AD	At least 5-10 miles outside of Park boundary
Lahar in West Fork	< 2200 BP*	At least to confluence of forks
Lahar (TBD)	< 2200 BP*	Probably to Puget Sound
Many lahars	< 2200 BP*	Probably to Puget Sound
At least 5 lahars	< 4500 BP*	Probably to edge of Puget Sound Lowland
Osceola Mudflow	~ 5000 BP*	Puget Sound Lowland
Greenwater Lahar	~ 5000 BP*	Puget Sound Lowland
Carbon River Debris Flow History		
Lahar runout	Post 1480 AD	At least 5 km below end of glacier
Lahar runout	Pre 1480 AD	8-10 km beyond end of glacier
*Carbon 14 years before present, working from a base line of 1950		

2.3 Recurrence Rate

While Mt. Rainier had a few small steam or very small ash eruptions during the 1800s, these were not eruptions to cause concern. The same can be said about the small mudflows down Tahoma Creek over the past 40 years, or even the larger Kautz mudflow of 1947. The geologic history of the volcano, as shown in the above tables, shows 11 volcanic ash eruptions over the past 9,000 years. In addition, the history of lahars in the valleys shows their time frames to be variable with some long periods, occasionally over 1,000 years, between them. Research from USGS scientists and others points to an annual probability of 1 in 500 to 1,000 for a significant landslide driven lahar. In addition, the "(A)nnual probability of eruption-triggered lahars is basically the same as the eruption probability because most eruptions will create lahars of some magnitude –1 in 100 to 500, but probably more toward the 500 end.[25]" Taking all this into consideration, the recurrence rate for damaging volcanic activity, be it a damaging ash eruption or a lahar coming down a valley, is estimated to be a 500 to 1,000 year occurrence.

Table 4. Summary of Notable Events on Mount Rainier, 11,000 Years Ago Until Present[26]

Eruptive Period	Age or Date	Event	
Historic activity	A.D. 1980's to present	Several dozen debris flows in river valleys that head on Mount Rainier	
	A.D. 1963	Rock fall avalanche from Little Tahoma Peak	
	A.D. 1947	Debris flow and runout flow of glacial-outburst origin in Kautz Creek	
	A.D. 1930's to 1950's	Multiple debris flows in Nisqually valley	
	A.D. 1910-1927	Rock avalanche on Tahoma Glacier	
	A.D. 11894-1895	Reports of small steam and ash eruptions at summit	
	500 years ago	Rock avalanche-induced Electron Mudflow in Puyallup/Nisqually river valleys; no documented association with volcanic eruptions	
Fryingpan Creek eruptive episode	1,100 to 1,000 years ago	Lahar down Puyallup River at least as far as its confluence with Mowich River	National Lahar in Nisqually River valley sometime between 2,200 and 500 years ago
		Tephra and lahars in White River valley as far as Kautz Creek	
Twin Creeks eruptive episode (Deadman Flats)	1,500 years ago	Tephras and lahars in valleys of the White River and Kautz Creek	
Summerland eruptive period	2,000 years ago	Lava flows formed summit cone, Columbia Crest	
	2,200 years ago	Eruption of Layer C tephra	
	2,200 to 2,600 years ago	Lahar in Nisqually River valley deposits sandy layers	
	2,400 to 2,500 years ago	Eruption of block-and-ash flow in Puyallup River valley; Eruption of tephra layers	
	2,600 years ago	Lahar-Round Pass mudflow descended Puyallup valley to Puget Sound lowland. Part of it descended Tahoma Creek and the Nisqually River	
	2,200 to 2,700 years ago	Multiple lahars in White River Valley	
Osceola eruptive period	4,500 years ago	Eruption of tephra layer B	
	4,700 years ago	Eruption of tephra layer H	
	5,600 years ago	Lahar- Osceola Mudflow in White River's main branch and West Fork extended to Puget sound lowland. Eruption of tephra layer F; Paradise Lahar (part of the Osceola Mudflow) in Nisqually River Valley, extended as far as the community of National	
	>5,600 years ago	Eruption of tephra layer S	
Cowlitz eruptive period	6,700 years ago	Eruption of tephra layers N and D	
	7,200 to 7,400 years ago	Eruption of volcanic bomb-bearing rocks and lahars in White River Valley	
	7,200 to 7,400 years ago	Rock avalanche-induced lahar down the Nisqually River and at Reflection Lakes	
	7,200 to 7,400 years ago	Eruption of tephra layers L and A	
Sunrise eruptive period	11,000 years ago	Eruption of tephra layers L and R	

3.0 Vulnerabilities and Consequences

Impacts discussed here will cover tephra, pyroclastic flows and lahar damage. Unless stated otherwise, lahar damage will be based on the potential for a Case I lahar traveling down the various valleys from Mt. Rainier. It will be assumed that impacts are generic across the four main valleys (Carbon, Puyallup, Nisqually, and White) unless stated otherwise.

Most of the impacts from a lahar will be determined by the volume of the lahar and which valley or valleys it descends. Next is whether there is a recognizable lead up to its initiation. Is it a spontaneous lahar or the result of other developing volcanic convulsions leading to, or part of, an eruption? Other contributing factors include the time of day, time of year, and the clay consistency of the mud. For the purposes of this section we will assume an Electron size and type flow and for most impacts look at the difference between the two basic scenarios of an eruption or magmatic triggered lahar and a spontaneous lahar.

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

3.1.1 Ashfall/Tephra

As mentioned above, most of the tephra or ash from a volcanic eruption of Mt. Rainier should leave western Washington and be deposited east of the Cascades. However, the wind patterns may not always blow that direction. If not, then ash could be deposited over portions of King County. If that is the case then there will be a number of problems that arise.

Thick depositions of ash can collapse buildings. This is especially true if it is raining. A one inch layer of ash weighs between five and ten pounds per square foot. This weight can increase dramatically with rain, because ash will hold the water. The weight can increase to 10 to 15 pounds per square foot, leading to collapse in some cases. Persons inside those buildings have a significant chance of being killed or at least injured by the collapsing structure[27].

A more common hazard is persons located in areas with falling ash can experience eye, nose, and throat problems. Patients with bronchitis, emphysema, and asthma may have increased problems beyond the rest of the population. Breathing similar material in mines and quarries by workers can lead to silicosis over many years. Short term breathing of small quantities of ash particles is not known to cause long term problems. The decrease in visibility and increase in darkness in those areas heavily impacted by the ash will disrupt outdoor activities and, in some cases, cause psychological distress.

Thin ash layers can make roads slick leading to an increase in accidents. It can also clog up air intake systems for automobiles and destroy the engine rendering the car useless for evacuation if necessary.

3.1.2 Pyroclastic Flows

Pyroclastic flows by their nature will cause extensive death and injury to people in the areas inundated by them. In King County, this is restricted to those areas directly associated with the volcano. Park service personnel and tourists in the impacted area will have a very low chance of survival; however pyroclastic flows will not extend very far beyond the boundaries of Mt. Rainier National Park. Any residents or park personnel in the vicinity of a pyroclastic flow will experience the devastating impact and heat created by the flowing hot ash and rock with the usual result of possible death, or if surviving, then major burns and or partial asphyxiation.

3.1.3 Lahars

A lahar coming down one or more valleys from Mt. Rainier has the potential to cause the highest number of fatalities and casualties of any hazard treated in this Plan. The difference in the impact on the population will be highly dependent on whether the lahar was a result of increasing volcanic activity or is spontaneous due to the collapse of a portion of the mountain.

Lahars can be devastating in their consequences. The lahar that inundated the town of Armero in Columbia on November 13, 1985 was relatively small compared to some of the ones that have descended Mt. Rainier. That lahar, from the volcano, Nevado del Ruiz, killed over 23,000 people and injured about 5,000 people[28]. In this case the main wave of mud that demolished the town ranged in depth from 6.5 to 16 feet. There could be a similar percentage of injured and killed in a lahar from Mt. Rainier. The method of destruction, burying entire communities in a flow of dense mud, does not allow most people caught in it a chance of survival.

3.1.4 Magmatic or Eruption Triggered Lahar

The normal situation for lahars from most volcanoes is for there to be some warning that a lahar is possible due to an increase in volcanic activity. With a lahar that begins when the volcano enters an eruptive stage, there will usually be many hours, if not days or weeks of increasing volcanic unrest. During this time, the residents that live in the valley areas surrounding the mountain will be put on a high alert that a lahar is possible. Memories of Mt. St. Helens and the lahar from it should inspire people in the valleys close to the volcano to prepare to evacuate or even self-evacuate early in the eruption process. The more distant from the volcano they live or work, the less preparation there will be overall, even for those who are directly in the path.

As the situation deteriorates, monitoring of the volcano will increase. Any needed warnings from the State, or the Cascades Volcano Observatory will be broadcast to inform and warn residents in the potential paths to prepare for and evacuate, if able, well before any lahar is created. Having a percentage of the people leave the valleys early allows a quicker evacuation when it becomes necessary. A portion of these people may seek shelter in Bellevue.

Much of the response for an early evacuation will depend on the perceived security that individuals' property will have. If local government does not provide adequate security, many people will not leave their property behind, but will rather gamble that they can get out in time if necessary. For those who did leave early, the perception that there is not enough security for their property will bring them back. The other factor that will bring people back is if the volcano does not erupt or send down a lahar over time. People's patience will rapidly wear thin and they will want to move back home.

Overall though, having knowledge ahead of time that the volcano is coming back to life and that a lahar could happen at any time will allow many people to get themselves and many of their belongings out of harm's way before the mud arrives. This could save many lives and a great deal of personal belongings and property.

3.1.5 Spontaneous Lahar

A spontaneous lahar is most likely to happen due to the collapse of a portion of the headwall above the Puyallup Glacier on the west flank of Mt. Rainier. The Mt. Rainier Lahar Warning System composed of sensors to detect the lahar, and radio transmitters to send that information back to Washington State warning points is in place to help prevent a lahar coming down either the Puyallup or Carbon Rivers from taking the communities by surprise.

Having a warning system in place does not mean that everyone will be able to evacuate the valley bottoms in time. The short time between the warning and the inundation of homes, schools, roads and businesses will not allow the entire population to escape. In the upper valley south of the confluence of the Puyallup and Carbon Rivers there could be many fatalities.

A large spontaneous lahar in either the White or Nisqually Rivers would also create an instant problem. Neither of these valleys has a lahar warning system. With no warning system, residents living, working, or recreating close to the mountain in the upper valleys may have only the sound of the lahar coming down the valley to warn them. This would not allow enough time for many of those people to evacuate. Once it has become known to response agencies that a lahar is descending either of these valleys they will be able to put out a notification that might reach people further downstream to allow evacuation. This would be accomplished through use of a telephone notification system that is able to send an informational phone call to each phone in the respective valleys. At the same time an Emergency Alert System message can go out over radio, TV, and all hazard radio addressing the need to evacuate the valleys.

The one good point about both of these valleys is that they have dams that if either empty, as is Mud Mt. Dam most of the year, or low, as Alder Dam frequently is, could contain much of a large lahar lessening the damage and casualties further downstream.

3.2 Health and Safety of Personnel Responding to the Incident

3.2.1 Ash/Tephra

As pointed out above, thick depositions of ash can collapse buildings, and this is especially true if it is raining. Persons inside those buildings have a significant chance of being killed or at least injured by the collapsing structure.

Responders may wind up working for long periods of time in areas with ash. The problems of eye, nose, and throat irritation could impact their ability to work in those conditions. It is not known if this has long term negative consequences. Similar to the effects on residents caught in it, there is no knowledge about the limited quantities inhaled and their long-term effects on the health of rescuers.

Personnel responding to incidents will find that thin ash layers can make roads slick leading to an increase in accidents. Emergency equipment may break and ash can clog up air intake systems and destroy engines for rescue vehicles like helicopters, fixed wing aircraft and automobiles. This is not just a maintenance problem because it could lead to serious impairment of response vehicles.

3.2.2 Pyroclastic Flows

Pyroclastic flow will not reach Bellevue. Bellevue may send responders to help with a regional emergency. With a pyroclastic flow any responders in its vicinity will experience the same devastating impact and heat that residents would, with the same results, probable death, or major burns and/or partial asphyxiation. Those responders attempting any rescue or body recovery will potentially be working in a hot environment, with lots of ash and the potential for further pyroclastic flows that could engulf their position.

3.2.3 Lahars

Because of the enormity of the event, initial response to a lahar will be limited to saving response resources and assisting residents to get to high ground, at the same time keeping themselves safe. What will be a problem for the safety and health of responders is that the lahar will leave residents stranded at various places throughout the valley. They could be on buildings that did not collapse or in trees that were not knocked down or highway overpasses. Essentially, people could be on any structure, tall enough to be above the mud and strong enough to survive being inundated by it. Since the mud will in many cases be too deep to drive or walk through directly, helicopter rescues might be necessary. This has all the dangers inherent in that type of operation. In addition, hazardous chemicals and sewage will contaminate some areas rendering them hazardous to anyone working there. There is also the possibility of more mud flows inundating the valley floor. A contributing factor is rain. Rain could pick up more of the material left in the higher parts of the valley and transport it down to the lower valley and deposit it as a new layer on the earlier flow. This could be especially true if there is rain to wash more of the mud and debris down valley.

During the initial build up to an eruption, when the Cascade Volcanoes Observatory warns about an upcoming event and warns residents that they might want to evacuate, all local police forces will be put in the position of controlling access to those areas deemed hazardous. This could include both the Nisqually and Puyallup Valleys. Irate residents, demanding access to their properties could create hazardous situations for these forces. There could be attempts to push through barricades, threats to officers or others staffing those barricades, or even if the area is shut down for a long period of time, riots.

Responders from public works and utilities will not be able to do any initial work after a major lahar in the lahar zone to restore the damaged area. The lahar will totally block access to the area and would have taken out the utilities and roads; in effect, the entire surface infrastructure. Utilities that were underground to begin with, like pipelines, may be buried under the mud but may still be operational. As the mud solidifies over time, public works and utility providers may be able to work back out into the devastated areas. As they do so they will have to be aware of any hazards that might still be in the environment.

3.2.4 Magmatic or Eruption Triggered Lahar

With the knowledge that the volcano is threatening to erupt, the affected public will know what is happening as the volcano awakens and, in some cases, self-evacuate ahead of time. Close monitoring of the mountain should give the warning points quicker notification when a lahar does begin.

3.3 Continuity of Operations and Delivery of Services

Delivery of services will probably not be curtailed by a volcanic eruption in the area. There can, however, be some differences between the delivery of services, due to cut off transportation and high levels of regional communities needing assistance.

3.3.1 Ash/Tephra

Small ash explosions should not influence the continuity of operations for jurisdictions or agencies in the City unless the wind patterns are perfect for dropping it directly on their service area. Large ash eruptions are different. Due to the amount of material dropped on an area, operations can be strained. Damage to communications equipment, roofs of buildings collapsing, roads closed, etc. can all limit the ability of an agency to maintain day-to-day operations. If the volcano has a large ash eruption and conditions are right to deposit the ash across portions of the area, there could be difficulty finding alternate facilities, getting staff to work and having necessary equipment in operational shape.

However, the probability that this will be the case is relatively low. As mentioned above, Mt. Rainier's eruptions tend to have low quantities of ash and when an eruption does occur the normal wind directions over Bellevue should distribute it to eastern Washington. While possible, it is unlikely that ash, by itself, will dramatically alter or limit the continuity of operations for agencies within Bellevue.

3.3.2 Pyroclastic Flows

Pyroclastic flows, by themselves, should not have any effect on the continuity of operations for the City. Rather, the effects will come from their impact on the glaciers and snow fields located on the mountain. Their melting, from the hot rock, ash, and gas flowing across their surface, could create massive lahars in the valleys below, leading to evacuation of populations toward Bellevue.

3.3.3 Lahars

Any major lahar coming down one or more of the valleys radiating from Mt. Rainier will dramatically alter the regions ability to continue operations. However, depending on the level of preparedness and whether a lahar is the result of the buildup of volcanic activity or of a spontaneous sector collapse the continuity of operations for different jurisdictions or agencies could be very different.

3.3.4 Magmatic or Eruption Triggered Lahar

Lahars triggered by a buildup and release of volcanic energy will have a lead in time, ranging from hours to weeks, for the area to prepare for the likelihood that a lahar may be forthcoming.

For those areas entirely, or nearly entirely, within confines of the flow, things will probably be different. With no offices, possible lack of staff, and no community to administer to which also means no tax base, they could be totally inoperable, even if they were able to initially remove equipment from the valley floor and protect all staff. With no tax base and no residents or clientele, there is no continuity of operations. Bellevue may be in a position to provide a supporting role in the recovery of these areas.

3.3.5 Spontaneous Lahar

For spontaneous lahars the impacts to the valleys, while identical, could have a different impact on the agencies and jurisdictions located there. Those that have operations located in the valley that are unable to get an alternate site to operate from will have all the problems of those jurisdictions and agencies who have a warning but also many others. In addition, they may lose records, staff, and equipment when the lahar overwhelms the valley. Bellevue may be able to play a support role in the recovery of these areas.

3.4 Property, Facilities, and Infrastructure

3.4.1 Ash/Tephra[29]

Ash can collapse roofs, destroy engines, make roads slippery, clog both water and air filtration systems, clog drains, and short out electrical systems. All these can affect the city and its ability to operate on a day to day basis. Depending on the depth and distribution pattern of the ash, individual departments will be more or less impacted by it. With more than one cm of ash having the ability to disrupt traffic by closing down roads combined with the other damage listed above, it could take weeks for the departments to get their individual infrastructures back to normal.

3.4.2 Lahars

Lahars are the primary force damaging regional infrastructure, property, and facilities. They will flatten buildings, destroy equipment, bury roads, take out power lines, destroy sewer pumping systems and flatten buildings. A major lahar coming down any of the river systems from Mount Rainier will damage, destroy or bury all facilities, property, and infrastructure that are above ground in the impacted area, including railroads, highways. The extent of damage will be directly correlated with the quantity of debris the volcano coughs up. Smaller lahars will cause less damage to those areas they cover and they will not cover as much territory as the larger lahar would.

3.4.3 Magmatic or Eruption Triggered Lahar

With a magmatic triggered lahar there will be time to evacuate records, supplies, and equipment from the lahar’s path. How much of the material will actually be evacuated depends on the length of time between when the volcano awakens and finally sends a lahar down valley. This could be from a few hours to many days or weeks. The more time allowed, the more that can be saved.

3.4.4 Spontaneous Lahar

With a spontaneous lahar, there will be very little that jurisdictions can do to protect their facilities, property or infrastructure located in its path. Those with resources further away from the volcano will have a little time once the warning has been disseminated, but it will be too little to make a major difference. Those agencies and jurisdictions will have essentially no time to evacuate anything of value. That which was not protected prior to the initiation of the lahar will be damaged or gone.

3.5 Environment

Environmental impacts will be dramatic and, in some cases, long lasting.

3.5.1 Ash/Tephra

Small ash eruptions will have limited environmental impacts. Large ash eruptions could have dramatic impacts on the environment or ecology of large areas around Mt. Rainier. Because of the prevailing wind patterns under normal circumstances much of the ash will blow to the east impacting the upper White River and much of eastern Washington. In this case, plants and animals in the White River valley could suffocate under the ashfall.

Tephra damage[30] will partly depend on the size of the particles. Large pieces, one to two inches or greater in diameter, can be very damaging. However, lethal impact from falling ash is likely only in the immediate vicinity of the volcano, generally within about six miles of the vent. Animals not protected in this area could be severely injured or killed by the large particles. Further away the finer grains begin to fall and can cause respiratory and eye irritation to animals, burying plants and robbing the animals of their natural food supply. Ash washed down by the rain will tend to add to the rest of the silt in the rivers and some of it will settle out downstream possibly affecting the fish resources, including salmon that return up the various rivers.

A large ash eruption that blows in other than an easterly direction could cause extensive long term environmental damage to much of the region. Having the same types of damage mentioned above but spread over much of the area could take years for some of it to wear off.

3.5.2 Lahars

Lahars are the primary damaging factor associated with local volcanoes. Lahars will destroy and bury any and all plants and animals in their path. They can destroy forested areas and they will silt up rivers and change their channels. They will add pollutants or hazardous chemicals to the environment by the damage they do to manmade structures, vehicles, sewage treatment facilities, etc. The continued addition of mud to the valley bottom by winter rains bringing down more debris from upstream will continue to cause problems for the environment possibly for a few years after the initial mudflow. They may totally destroy salmon habitat and the valley ecology in the areas they cover.

Those that reach Puget Sound could cover the near shore environment with silt and possibility partially fill in Commencement Bay, and/or cover the shallow Nisqually delta and mud flats creating a new surface and killing the creatures that currently make it home.

A new environmental balance will eventually be formed as plants and animals re-inhabit the area covered by the mud. While it may take years for nature to repair the damage, it will eventually reclaim those areas damaged by the lahar.

3.6 Economic and Financial Condition

Economic and financial affects will be of two parts. First, is the damage to property, buildings, inventories and equipment if there is a large ashfall that affects the area. Second, is the loss of revenue due to the inability to get supplies through the damaged area, the loss of markets, the decrease in population and, in some cases, the loss of infrastructure to economically support the area.

3.6.1 Ash/Tephra

The damage to individual businesses, homes, and equipment could cause major financial losses for individuals and businesses throughout the region, but only if the wind does not blow the ash to the east.

3.6.2 Lahars

Lahars have the potential to be the major destroyer of economic viability within the region. Any major lahar coming down one of the valleys from Mt. Rainier or other volcanoes will destroy the homes, businesses and much of the infrastructure within whichever valley it descends.

3.6.3 Magmatic or Eruption Triggered Lahar

As the developing threat from the volcano is recognized by the scientists and they begin to warn the public there will be some time for some people and business to move some of their belongings, records and goods to higher ground. However, no matter how much they are able to save this way the economic recovery will be long and hard. With the destruction of homes and the physical structures of the businesses in the valley, people will have no option except to leave the area and find homes and work elsewhere. This will indirectly affect Bellevue.

3.6.4 Spontaneous Lahar

With a spontaneous lahar, almost no community in the way of the lahar will have the ability to adequately protect its assets. In this case, there could be a total loss of homes and businesses in the impacted area. This is the worst-case scenario. With all buildings, records, inventories, and infrastructure gone, no business will be able to restart immediately at a different location. With the movement away by the population, many of them will have little incentive to even make the attempt at rebuilding in the valley.

3.7 Public Confidence in the Jurisdiction’s Governance

The reputation of the city will probably not be affected by a volcanic eruption. It can be improved by the open distribution of information to the public regarding what is, could, and will happen during a volcanic event.

3.7.1 Ash/Tephra

Good information regarding what needs to be done to prevent or limit damage to property and individuals will allow homeowners, businesses, and other local organizations to prepare for and limit the damage from ash. Any additional programs to assist them in alleviating the problem, such as a community program to clean the ash off roofs, will help.

4.0 Resource Directory

- Mt. Rainier National Park
  http://www.nps.gov/mora/
  http://www.mount.rainier.national-park.com/
- Mt. Rainier Seismicity Information
  http://www.geophys.washington.edu/SEIS/PNSN/RAINIER/rainier.html
- Pacific Northwest Seismograph Network
  http://www.geophys.washington.edu/SEIS/PNSN/INFOGENERAL/volcanoes.html
- USGS Cascade Volcano Observatory
  http://vulcan.wr.usgs.gov/
- Washington State Department of Natural Resources
  http://www.dnr.wa.gov/
- Community Exposure to Lahar Hazards from Mt Rainier, Washington
  http://pubs.usgs.gov/sir/2009/5211/sir2009-5211.pdf
- Alaska Volcano Observatory
  http://www.avo.alaska.edu/avo4/products/hazard.htm
- Smithsonian Institution Global Volcanism Program
  http://www.volcano.si.edu/
- USGS Volcano Information
  http://www.usgs.gov/hazards/
  https://pubs.usgs.gov/fs/fs002-97/
- Volcano Hazard Maps
  http://volcanoes.usgs.gov

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6 Debris flow at Tahoma Creek, July 26, 1988.,USGS Photo Archives, Photo by G.G. Parker, July 26, 1988, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/images.html
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11 Rockfall Avalanche, Mt. Rainer, Washington, Results of the 1963 rockfall avalanche of volcanic debris on Little Tahoma, Mt. Rainer, Washington. There were no witnesses to the event., Geologic Hazards Photos Volume 3 Landslides, Tsunamis, and Volcanoes, Web.
12 www.nsm.buffalo.edu/courses/gly433/Pyroclast.pdf
13 Walder and Driedger, p. 2
14 Hazard zones for lahars, lava flows and pyroclastic flows from Mount Rainier (Hoblitt and others, 1998: US Geological Survey Open file Report 98-428, accessed at http://vulcan.wr.usgs.gov/Volcanoes/Rainier/Publications/FS065-97/FS065-97map.pdf
15 K.M. Scott, P.T. Pringle, and J.W. Vallance, Sedimentology, Behavior, and hazards of Debris Flows at Mount Rainier, Washington, U.S. Geological Survey, Open File Report 90-385, P.80-84
16 T.C. Pierson, Estimated Lahar Travel Times for Lahars 107 to 108 Cubic Meters in Volume (Approaching a 'Case 1' Lahar in Magnitude) in the Puyallup River Valley, Mount Rainier, and Estimated Lahar Travel Times for Lahars 107 to 108 Cubic Meters in Volume (Approaching a 'Case 1' Lahar in Magnitude) in the Carbon River Valley, Mount Rainier, Revised October 11, 2001, U.S. Department of the Interior, U.S. Geological Survey.
17 Swanson, D.A. et al. Excerpt from Cenozoic volcanism in the Cascade Range and the Columbia Plateau, Southern Washington and Northern Oregon: AGU field Trip Guidebook T106, July 3-8 1989 as quoted in an excerpt at http://vulcan.wr.usgs.gov/Volcanoes/PacificNW/AGU-T106/rainier.html
18 USGS, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/Outreach/rainierposters.html
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20 http://vulcan.wr.usgs.gov/Volcanoes/Cascades/EruptiveHistory/cascadeseruptions4000yrs.pdf
21 Mt. Rainier, Active Cascade Volcano, National Research Council, National Academy Press, Washington DC, 1994, pps.42-43
22 Lyn Topinka, Mount St. Helens: A General Slide Set GS9, http://vulcan.wr.usgs.gov/Volcanoes/MSH/SlideSet/ljtslideset.html
23 USGS, http://vulcan.wr.usgs.gov/Volcanoes/PacificNW/AGU-T106/rainier.html
24 Description: Mount Rainier Volcano, USGS Cascade Volcano Observatory, http://vulcan.wr.usgs.gov/Volcanoes/Rainier/descriptionrainier.html
25 Email correspondence from William E. Scott, USGS geologist, David A. Johnston, Cascade Volcano Observatory, 2/26/08
26 A Short History of Mt Rainier http://vulcan.wr.usgs.gov/Outreach/Publications/GIP19/shorthistorymountrainier.pdf
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28 Deadly Lahars from Nevado del Ruiz, USGS Volcano Hazards Program, Colombia, November 13, 1985, http://volcanoes.usgs.gov/Hazards/What/Lahars/RuizLahars.html
29 Materials in this section on tephra are from the Cascades Volcano Observatory website http://vulcan.wr.usgs.gov/Hazards/NRCDefinitions/tephra.html
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Table of Contents

1.0 Introduction

1.1 Description

While climate change today is thought of as being synonymous with global warming, in reality it is a more generic term. Climate change refers to variations in either regional or global environments over time. Time can refer to periods ranging in length from a few decades to other periods covering millions of years. A number of circumstances can contribute to climate change. Included herein are such diverse factors as solar cycles, volcanic eruptions, changing ocean current patterns, or even something as unusual as a methane release from the ocean floor[1].

Today, much of the talk of climate change presupposes a rise in global temperature averages. Over the past 150 years, that good temperature comparisons have been made, there has been an overall increase of approximately 0.7 C. An increasing body of scientific evidence implies that the primary impetus driving climate change today is an increase in atmospheric greenhouse gases. Currently the expanding body of empirical data supports its basic premise that the long term average temperature of the earth's atmosphere has been increasing for decades. This trend is continuing, and the scientific community generally agrees that it will continue for the foreseeable future unless dramatic steps are taken on a global scale to decrease the release of greenhouse gases. Research appears to point to human activities as the main contributing factor. Changes due to human activities are frequently called anthropogenic climate change. In contrast, the United Nations Framework Convention on Climate Change uses "climate variability" for non-human caused variations.[2]

Climate change may create dramatic changes in the local environment of Bellevue. Today, questions revolve around the overall increase in local temperature and its long-term effects. These can be broken down into two categories: 1) natural environment questions and 2) human environment questions. The questions regarding the natural environment include: How will the temperature change over the next few decades? How will the rain and snowfall patterns change during the same time frame? Will this exacerbate other problems in the environment? What new environmental problems will arise? What are the expected changes in the biological life zones? What will be the effect of sea-level rise on the region's coastline? How will climate change impact the ecology of Puget Sound?

Figure 1 reflects a comparison of observed continental and global scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forces. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the center of the decade relative to the corresponding average for 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5-95% range for 19 simulations from five climate models using only the natural forces due to solar activity and volcanoes. Red shaded bands show the 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forces.[3]

If current emissions levels continue, the atmospheric CO_2 concentration is projected to reach 730-1020 ppm by 2100. The current atmospheric concentration of carbon dioxide exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice core measurements.[4]

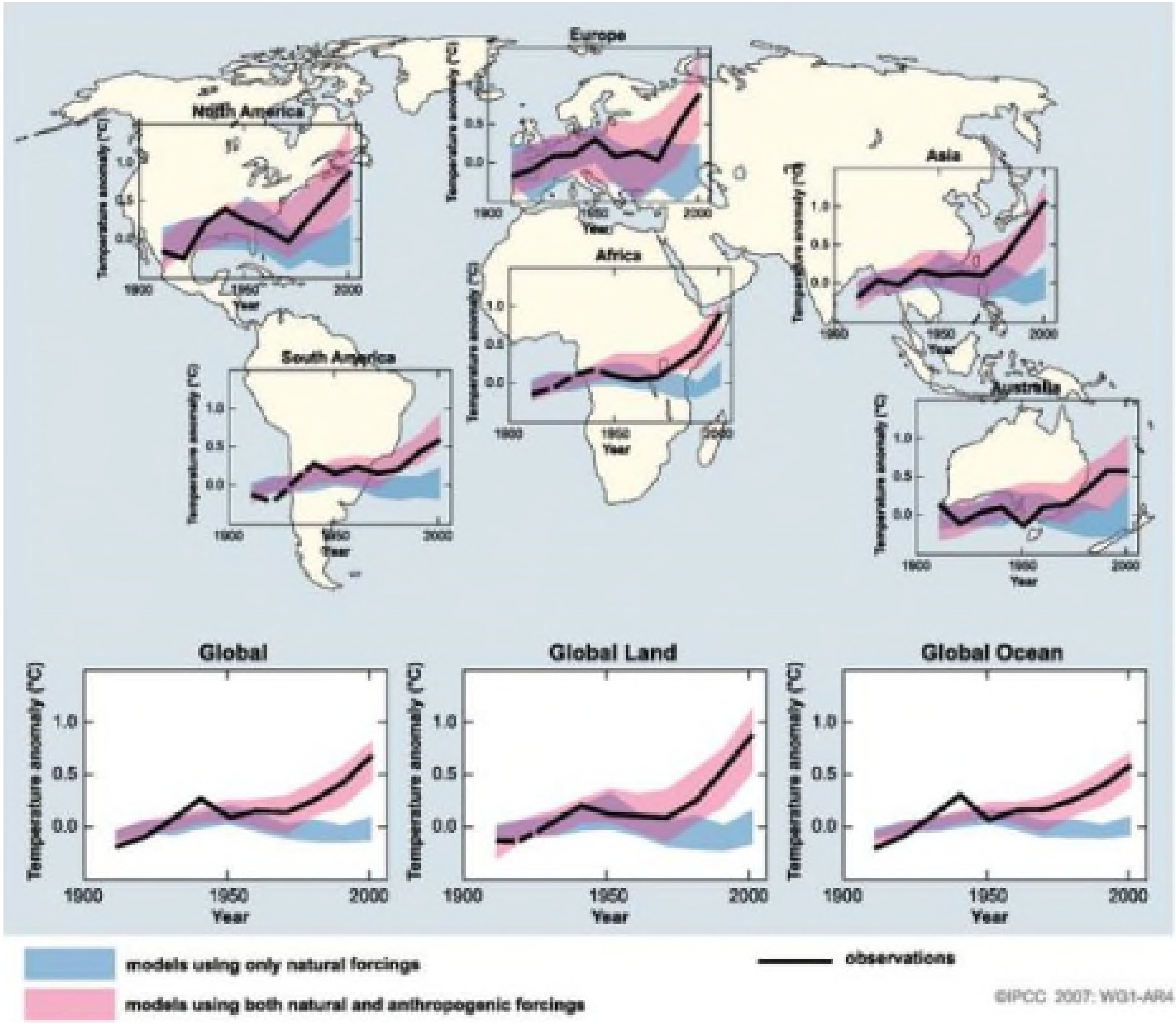

Figure 1. Comparison of Changes in Surface Temperature

The second half asks: How will these changes affect the residents living here? What changes to the infrastructure will be needed to accommodate the expected environmental changes? What lifestyle changes will be necessary? What are the economic consequences of property loss, especially to the port/industrial area? How will individuals, business, and government respond to changes in life style required by the changes in the local environment?

Bellevue has taken steps to address climate change. Some examples include, but are not limited to, the following:

- City of Bellevue joined the King County – Cities Climate Collaboration in 2014 to leverage efforts to reduce the local and global impact of climate change.
- Since 2011, the City of Bellevue government has saved over 14,000 metric tonnes of CO_2 cumulatively as a result of conservation efforts.
- July 2010, Bellevue switches fleet to hybrid vehicles.
- On February 20, 2007 the Bellevue City Council passed Resolution 7517, which adopted the goal of reducing greenhouse gas emissions to 7% below 1990 levels by 2012.
- In August 2007, the City of Bellevue became a signatory to the U.S Mayor's Climate Protection Agreement, joining over 800 communities in all 50 states to affirm its commitment to reduce

greenhouse gas emissions in a manner consistent with the international targets set by the Kyoto Protocol.

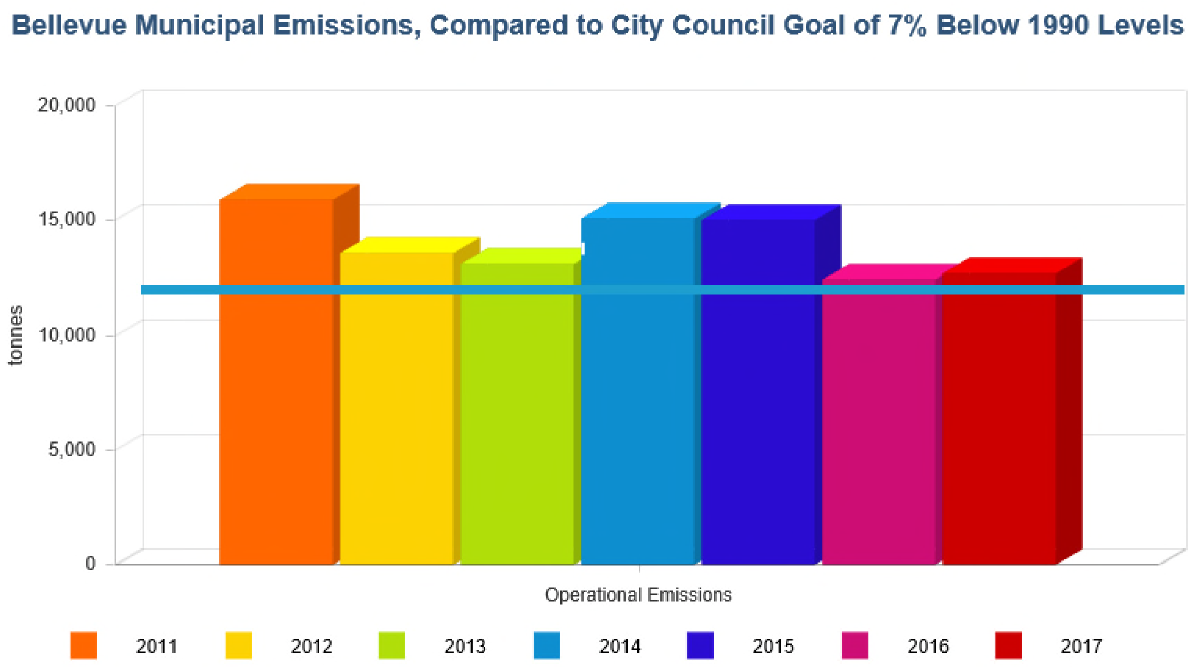

Figure 2. Bellevue Municipal Emissions

In order to implement these resolutions, the City of Bellevue joined more than 400 U.S. local governments and 1000 local governments worldwide in International Council for Local Environmental Initiatives (ICLEI's) Cities for Climate Protection® Campaign. In partnering with ICLEI, Bellevue has committed to ICLEI's Five Milestone Process to fight global warming:

- Milestone 1: Conduct a baseline emissions inventory and forecast,
- Milestone 2: Adopt an emissions reduction target,
- Milestone 3: Develop a Climate Action Plan for reducing emissions,
- Milestone 4: Implement policies and measures, and
- Milestone 5: Monitor and verify results.

1.2 Types

There are two major classifications of climate change:

- Global cooling: a decrease in the average temperature of the earth's atmosphere, especially a sustained decrease sufficient to cause climatic change.
- Global warming: an increase in the average temperature of the earth's atmosphere, especially a sustained increase sufficient to cause climatic change.

2.0 Profile

2.1 Location and Extent

With the primary direction of climate change today being global warming, Washington State and Bellevue will likely experience major changes during the next century. The expected further increases in temperature for Washington State are shown in Table 1. In this table we can see the expected temperature rise broken down by time of year. Such increases will continue to dramatically affect the plants, animals, people and economy of Bellevue. Changing rain and snowfall patterns, life zone migration, and sea-level rise will all create a different region than we have today.

Table 1. Recent and Projected Temperatures for the Pacific Northwest[5]

	1970-99	2020	2040
Annual (increase)	47.0 F	48.9 F 1.9 F	49.9 F 2.9 F
Oct. – Mar. (increase)	36.1 F	37.8 F 1.7 F	38.6 F 2.5 F
Apr. – Sept. (increase)	57.9 F	60.0 F 2.1 F	61.2 F 3.3 F
Notes: Temperatures are averages across the Pacific NW, and may vary significantly from region to region. The table compares observed temperatures for the 1970-99 periods with changes in temperatures averaged across 30 yr periods centered on the 2020s and 2040s projected by 10 global climate models' two emission scenarios. The future temperatures are the averages calculated from changes projected by those climate models for the specified time periods.			

This increase in global temperature is a highly complex issue and involves a number of interrelated issues. Global warming, by itself, is only part of the overall problem, and is actually the result of a number of factors that are all combined into overall environmental degradation. The increase in greenhouse gases, the primary factor blamed for global temperature increase, comes from many divergent sources. Included in the current list are carbon dioxide from modern industry; the burning of fossil fuels; deforestation and cement manufacture; methane from cattle and other animals including such small animals as termites; and gases such as nitrous oxide, chlorofluorocarbons, and a host of other trace gases.

While the increase of atmospheric carbon dioxide (CO_2) is foremost in peoples' minds when they think of global warming, some of the other gases have a much greater effect on global warming for the quantity released than does CO_2. Methane is 20 to 30 times as effective in its ability to absorb infrared radiation as CO_2, and chlorofluorocarbons, while usually associated with the destruction of the atmospheric ozone layer, are also highly contributive to global warming. A single chlorofluorocarbon molecule is 20,000 times more effective as a greenhouse gas than is a carbon dioxide molecule. While a number of these other gases contribute a significant amount to the increase in global temperatures the main culprit for the foreseeable future will continue to be carbon dioxide.

"Emissions of CO_2 due to fossil fuel burning are virtually certain to be the dominant influence on the trends in atmospheric CO_2 concentration during the 21st century."[6] With the advent of the industrial revolution, the quantity of atmospheric CO_2 began to rise. For the 400,000 years prior to the industrial revolution, the atmospheric CO_2 concentrations ranged between 200 and 280 parts per million (ppm). Since the beginning of the industrial revolution, this has increased to today's levels of around 380 ppm and is continuing to increase about 1% per year. By the middle of the 21st century, these levels could reach 500 ppm and by the end of the century, 800 ppm.

Historically, there have been many ways that carbon dioxide has been absorbed by the planet. Plant and animal matter that have been buried in great quantities are eventually transformed into coal and oil. Plant material, especially trees, can absorb large quantities of carbon and the ocean acts as a natural carbon sink. The ocean contains approximately 50 times as much carbon as does the atmosphere. At the same time, human activity continues to add more of it at an ever-increasing rate. Of all the fossil fuel carbon released to the atmosphere, about 48% of it currently ends up in the ocean.[8] This continued absorption of carbon dioxide changes the chemistry of the ocean, eventually affecting all sea life. Computer modeling anticipates that this will increase the acidity of the ocean surface water by a drop of 0.4 pH units.[9] How this will affect the sea life in Puget Sound is still an open question requiring further research.

The pace of some effects of global warming seems to be accelerating. Computer models of climate change from the 1990s appear to be already outdated in their predictions. The slowing of the Ocean Conveyor Belt and the destructiveness of storms appears to be increasing at a rate the models had predicted would happen much later in this century.[10]

2.2 Occurrences

Global climate change has been the norm for essentially the entire life of the planet. It has forced organisms to change with the changing climate either by migrating or evolving to fit the new weather patterns. Those that did not follow either of these paths either died out, or were reduced in their ranges, sometimes forming small insignificant communities perpetually on the verge of extinction.

The last dramatically different climate that we can at least get a partial view of is the last ice age. As much as that climate contrasts with ours, we can see only traces of it today. Knowledge of it has gradually evolved through years of research. The covering of much of North America, Europe, and parts of Asia with ice, in addition to the linking of the North American continent with Asia, the connecting of Malaysia with Sumatra and Borneo, and Australia with New Guinea, is outside the realm of personal experience. It doesn't influence our day to day thinking.

The most recent lengthy episode for which we have detailed written records is the cooling of the Northern Hemisphere during what is called the "Little Ice Age". While there were glacial advances, it was not a true ice age in that it did not last long enough for glaciers to significantly increase the percentage of land they covered. During this 500 to 600 year period temperatures dropped from 1-1.5 Celsius.[11] This drop caused famine, changed disease patterns and led to social upheaval in some areas. In the more recent past, the 25-year temperature decrease from 1940 to 1965, impacted many individuals alive today and shows that even with an overall increase in global temperatures there will be periods when the average temperature will drop for extended periods of time.

While there are wide variations from year to year in global temperatures, the overall trend since the beginning of the industrial revolution has been for a gradual increase. The forecasts are for this trend to continue into the indefinite future depending on the continued release of greenhouse gases, volcanic eruptions, etc. How much of a change in temperature we can expect in the future is one of those debatable questions with estimates ranging from a degree or two up to ten or more degrees Celsius. Even with only a one or two degree increase, there would be tremendous climatic changes.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

The overall impacts from long term climate change are only beginning to be felt throughout Bellevue. Impacts on health would be gradually felt. As the average temperature rises gradually over the next few decades, the incidence of diseases normally associated with warmer climates will increase. There should be a slight decrease in cold related injuries in the winter months and an attendant increase in heat related injuries during the summer months.

3.2 Health and Safety of Personnel Responding to the Incident

Unlike other emergencies, climate change will not have personnel responding to it as if it was an immediate emergency. Health related issues for personnel will be similar to those for the general population.

3.3 Continuity of Operations and the Continuity of Operations and the Delivery of Services

While there will be changes in the environment throughout the area, change will develop slow enough to maintain continuity of operations. It is not expected that climate change by itself will impact the delivery of services on a long-term basis. As the climate changes gradually from decade to decade, governmental offices, response organizations and personnel will gradually adapt to fit the new circumstance. Other changes in the environment, such as population growth, should impact delivery of services more than gradual climate change.

3.4 Property, Facilities, and Infrastructure

Electric generation in Washington is primarily hydroelectric. It relies on a constant supply of water delivered to the dams and generating plants. A decrease in the amount of water locked up in the winter/spring snowpack will impinge on the ability of electric generating plants to meet demand. Increasing demand during the summer for air conditioners, refrigeration units etc., when water levels will be at their lowest will exacerbate this problem. If water resources can no longer fill the need for electric generation, there could be an increase in the use of fossil fuels to generate electricity. This will create more air pollution problems. Brownouts will occur due to an overuse of electricity and heat-related deaths, especially among the elderly, those weakened by disease, and the poor could increase.

3.5 Environment

Continued scientific research today shows major changes on a worldwide scale. They range from gradual sea-level rise to thinning of the arctic ice pack to a change in the amount of ice at mid-latitudes. Changes in the range of insects and the strength of storms are currently forecast for the present and near future.

One of the major problems associated with global warming is the increase in sea-level. Over the past century, global mean sea-level rise has ranged from 1 to 2.5mm/year. In southern Puget Sound, sea-level rise is expected to have the largest global warming rise in the state, about 5mm/year.[12] This is a consequence of rising water levels combined with the gradual subsidence taking place in Puget Sound. Current research on the Sound shows the rate of subsidence in the parts to be 2.4 mm/year[13]. This means that even without any sea-level rise, the land will sink around 9.5 inches over the next century. When we add in the minimum expected sea-level rise of up to 2.5mm/year, this could lead to an effective increase of over 19 inches over the next century. Over the next several years, we should begin to see its effects develop on the local scale. The potential is there to flood ports, tidewater industrial areas, river deltas, coastal wetlands and beachfront properties.

In Bellevue, we may see warmer winters with the snow pack not developing as it has historically. This may lead to drier summers, an increase in forest fire danger, more stress on agriculture, water rationing, and the possible destruction of fish runs. As the climate gradually changes, we can expect an upward movement of lower elevation ecosystems. Those ecosystems, like the sub-alpine and alpine that are located near the top of our mountains, may be pushed up by pressure of other species from lower elevations as the weather warms. This could lead to the extinction of many endemic species which have tenuous holds in these environments. Over time, it could also lead to the migration of plants and animals endemic to areas further south like Oregon and Northern California moving into the Puget Sound basin.

A decrease in river flows and lake levels, especially during the summer months, due to the lack of snow in the mountains is already becoming visible in the lack of glacier ice in the Cascades. Ice volumes have decreased dramatically as can be seen in Figure 2.

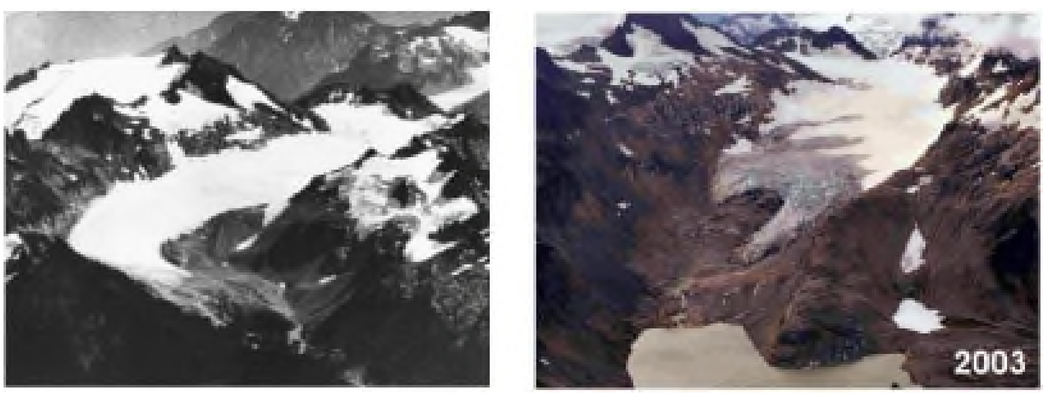

Figure 3. Comparison of the South Cascade Glacier: 1928 to 2003.[14]

The South Cascade Glacier in the North Cascades is one of the glaciers that has been studied for many years and has lost much of its ice volume over the past nearly 80 years; photo on left from 1928 and photo on right from 2003. A lack of permanent ice to feed the rivers when the rest of the snow pack melts in the spring could mean very low water levels in the rivers by the time late summer arrives. This would be offset by the possibility of heavier flows during the fall and winter. The decreased flows during the summer will create warmer rivers that are detrimental to already reduced salmon runs. In addition, the heavier flows during the winter could scour many of the river bottoms decreasing salmon habitat.

On Mt. Rainier, many of the same issues are confronted with the retreat of its glaciers. Over the past 40 years, due to glacier shrinking of the Paradise and Williwakas Glaciers, the Paradise ice caves, a popular spot for tourists to view the underside of a glacier up close, have disappeared. Other glaciers in the park have also retreated, in some cases long distances up valley. The Nisqually Glacier, shown in Figure 3, has retreated approximately one mile upstream since 1912 and evidence in the valley shows that the first chronicle mentioning the glacier in 1857 had the ice considerably further down valley, well below the current bridge across the Nisqually River.[15]

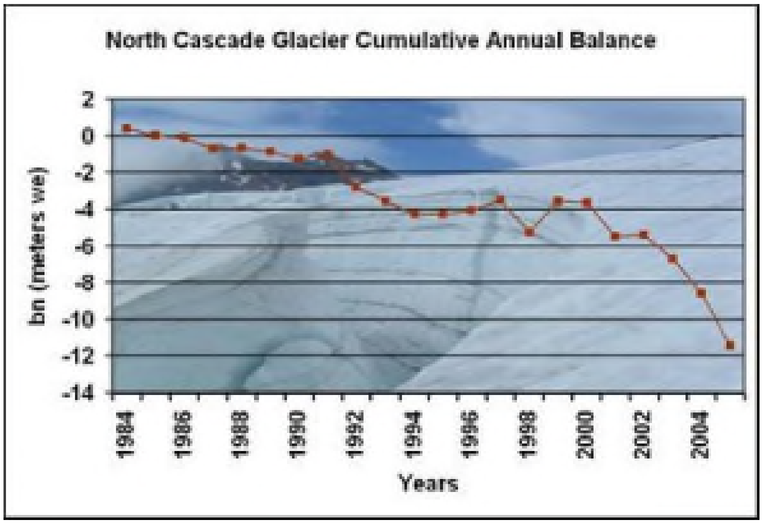

Figure 4. Rate of Recession of Glaciers in the North Cascades. Source: North Cascades Glacier Climate Project.[16]

Other environmental changes might include a loss of forest resources due to changing patterns of precipitation and an increase in temperatures during the summers. Forests could be depleted through changing growth patterns due to weather changes, an increase in insect infestations or an increase in forest fires.[17]

A decrease in the amount of winter precipitation locked up as snow in the Cascades means that a higher percentage of our normal precipitation will be available to cause winter flooding in the region. Currently, the mountain snowpack acts as a natural water reservoir. As the annual snowpack decreases due to warmer winters, the amount of precipitation that normally falls will raise stream and river levels. This could increase the County's flood potential.

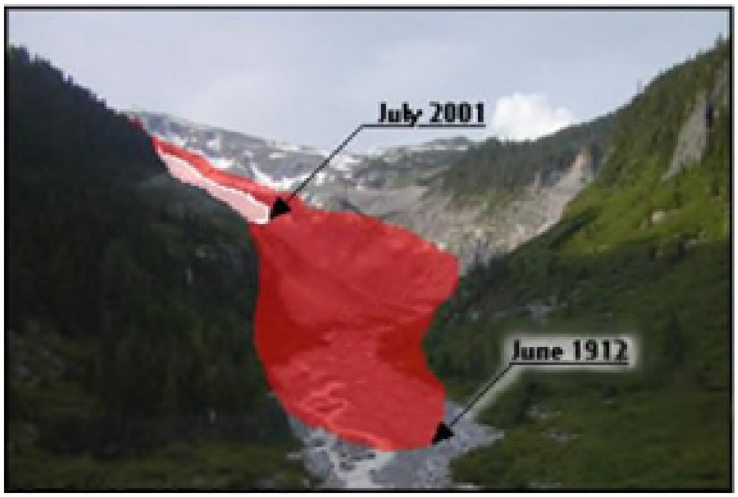

Figure 5. Lower Nisqually Glacier Retreat: 1912 to 2001.[18]

Other potential effects include new diseases - that while endemic to warmer climates could migrate to Bellevue, a longer growing season for some crops, and a change in the recreational possibilities available for both residents and visitors.

3.6 Economic and Financial Condition

The changing climate will affect nearly every portion of the Bellevue's economy.

- Warmer temperatures may reduce the need for electricity and other energy sources for home heating in the winter, but increase it during the summer months when air conditioning needs will increase,
- Agricultural growing seasons should increase, as should their demand for water,
- New agricultural crops that have been grown in warmer climate zones may be added to the state's agricultural base,
- The increase in forest fires due to dryer summers will increase the cost of firefighting,
- The lack of a large snowpack will decrease the amount of available water as the summer progresses, which will create a need for more water storage units to handle the increased need in late summer and early fall,
- Increasing health care costs are expected in the areas of heat related illnesses, asthma, and West Nile Virus,
- With the potential increase in flooding mentioned above, there will be increased costs for responding to and recovering from these floods, and
- The need for more energy efficient solutions to the climate change and global warming issues should increase the options for new business development.

Economic effects will be felt not just due to changes in the surface ecosystems, but also due to changes in the marine environment. Some fish species that used to frequent the waters of Washington are already close to disappearing, such as Pacific Cod. While overfishing assisted in the decline, scientists point to warmer water as a contributing factor in stifling their recovery.[19] The fishing industry has had a difficult time for many years and the declining local species will continue to cause problems for the foreseeable future. However, at the same time that some species are decreasing, others like ocean sunfish, barracuda, sardines, striped bass and lizard fish are beginning to show up in Washington waters.[20] In order to survive, the fishing industry may need to change some of the species that sustain it, moving from the traditional ones to species that are moving into the area.

3.7 Public Confidence in the Jurisdiction's Governance

As the changes in the local environment accumulate over time, the public could begin to demand that any problems that arise be mitigated. It may become difficult convincing residents to accept the costs, including new taxes associated with mitigating the results, preventing damage through controls on land use, or the difficulty of accepting a change of lifestyle that might be required. Frustration could be expressed against local leaders and government agencies.

4.0 Resource Directory

- University of Washington Program on Climate Change
  http://depts.washington.edu/uwpcc/ourprog/ourprogram.html
- Washington State Department of Ecology
  http://www.ecy.wa.gov/
- Office of the Washington State Climatologist
  http://www.climate.washington.edu/events/
- Climate Impacts Group (CIG)
  http://www.cses.washington.edu/cig/
- Intergovernmental Panel on Climate Change
  http://www.ipcc.ch/
- US Environmental Protection Agency
  https://www.epa.gov/climate-research

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[2] Global Warming, Wikipedia, Web.

[3] United Nations Intergovernmental Panel on Climate Change - IPCC (2007). "Climate Change 2007: The Physical Science Basis. Summary for Policy Makers," Web.

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[5] Impacts of Climate Change on Washington's Economy: A preliminary Assessment of Risks and Opportunities, November 2006, Washington Economic Steering Committee and the Climate Leadership Initiative Institute for a Sustainable Environment, university of Oregon for WA. Dept. of Ecology and Dept. of Community, Trade and Economic Development, Washington State, P. 17.

[6] IPCC Special report on Carbon Dioxide Capture and Storage, Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York, New York, 2005, p. 65

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[9] Impacts of Anthropogenic CO2 on Ocean Chemistry and Biology, Tedesco, Kathy, et.al., NOAA Research, Office of Oceanic and Atmospheric Research, Web.

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[12] Climate Variability, Climate Change, and Sea-level Rise in Puget Sound: Possibilities for the Future, Douglas J. Canning, Washington Department of Ecology and JISAO/SMA Climate Impacts Group, U. of Washington, 2001, p.1-2.

[13] Climate Variability, Climate Change, and Sea-level Rise in Puget Sound: Possibilities for the Future, Douglas J. Canning, Washington Department of Ecology and JISAO/SMA Climate Impacts Group, U. of Washington, 2001, p.2.

[14] 1928 to 2000 South Cascade Glacier Photo Comparison, Web. and Web.

[15] Mount Rainier National Park Nature Notes, Volume XV, December 1937, No. 4, Mount Rainier National Park, Web.

[16] North Cascades Glacier Climate Project. 2006. http://www.nichols.edu/departments/Glacier/

[17] Impacts of Climate Change on Washington's Economy: A preliminary Assessment of Risks and Opportunities, November 2006, Washington Economic Steering Committee and the Climate Leadership Initiative Institute for a Sustainable Environment, university of Oregon for WA. Dept. of Ecology and Dept. of Community, Trade and Economic Development, Washington State, P.32-34.

[18] Glacier Research on Mount Rainier, Mount Rainier National Park, Web.

[19] Seattle Post Intelligencer Nov 13, 2003 Online, Web.

[20] Ibid.

Table of Contents

1.0 Introduction

As identified in the Climate Change Hazard Section, larger changes in the atmospheric conditions across the globe, due to climate change, will lead to the potential changes in how we define hazards, identify future recurrence rates, and identify vulnerabilities and related consequences. This is of important note as we document the drought hazard in the City.

1.1 Definition

A drought is defined as "a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious hydrologic imbalance in an affected area."[1] Unlike most states, Washington has a statutory definition of drought (Revised Code of Washington Chapter 43.83B.400). According to state law, an area is in a drought condition when:

- The water supply for the area is below 75% of normal.
- Water uses and users in the area will likely incur undue hardships because of the water shortage.

Drought is a natural part of the climate cycle. However, it can have a widespread impact on the environment and the economy. Both agriculture and certain industries that require a dependable continuous supply of water can be affected by drought. Since the impacts of drought vary highly depending on the local environment, the type of agriculture and industry, and the type of social systems that have developed in an area, people can have very different ideas about drought. This can lead to a wide range of definitions of drought. The two definitions above are both useful in their own way, but are by no means the only possible definitions.

1.2 Types[2]

Because of the wide range of drought definitions available, 'drought' has been grouped into four main categories or types. The first three categories measure drought as a physical phenomenon and the last category measures drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socioeconomic systems.

1.2.1 Meteorological Drought

This type is defined as an expression of precipitation's departure from normal over some period of time. These definitions are usually region-specific, and presumably based on a thorough understanding of regional climatology. Meteorological measurements are the first indicators of drought.

1.2.2 Agricultural Drought

This type is defined as an occurrence when there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.

1.2.3 Hydrological Drought

This type is defined by the deficiencies in surface and subsurface water supplies. It is measured as stream flow and as lake, reservoir, and groundwater levels. There is a time lag between lack of rain and less water in streams, rivers, lakes, and reservoirs, so hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

1.2.4 Socioeconomic Drought

This type is defined as the occurrence when physical water shortage starts to affect people, individually and collectively (see Figure 1). Or, in more abstract terms, most socioeconomic definitions of drought associate it with the supply and demand of an economic good, such as water, food grains, fish, and hydroelectric power.

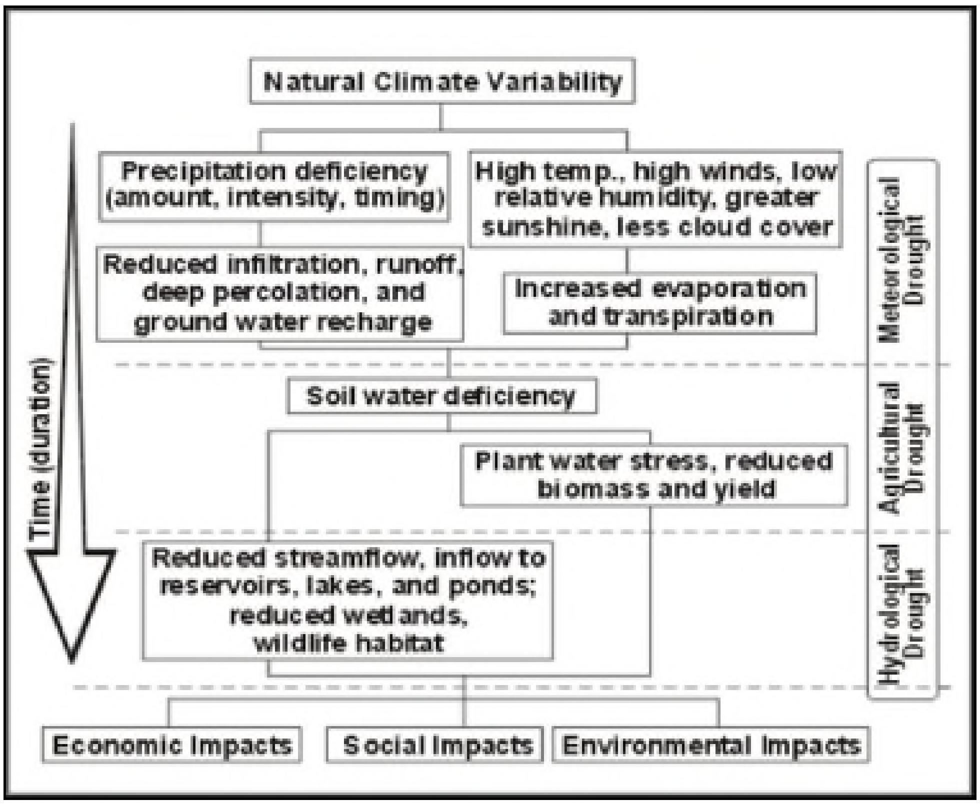


Figure 1. Sequence of Drought Impacts

2.0 Profile

2.1 Location and Extent

Drought directly and indirectly affects all of Bellevue. While the entire region experiences drought, specific natural resources are the most impacted. These resources include, but are not limited to: rivers, creeks, streams, ponds, fish habitat, forests, and other natural resources.

The first noticeable indications of drought, besides lack of rain, are the decrease in soil moisture affecting the agricultural base of the Region. As time progresses, the effects begin to be felt across the community. Normally, available sources of water, like reservoirs and lakes will begin to dry up. Their ability to cover the precipitation deficit can only do so for a limited time. The other option, wells, relies on the amount of ground water and is dependent on the long-term maintenance of the aquifer. Short term drought, from three to six months, usually does not affect these. However, long term drought conditions can affect them, drying up lakes and depressing the water table.

With the ending of drought conditions, the recovery will follow the same pattern. First will be the soil water reserves and the increase in stream flows. Reservoirs and lakes are next to refill, and finally as water works its way down, the groundwater can be replenished. While the soil moisture content may rise rapidly following rain, the replenishing of groundwater may take many months or even years depending on the severity, length of time of the drought, and quantity of new precipitation.[3]

The severity of a drought is measured by the Palmer Drought Severity Index (PDSI) shown in Table 1. Developed by meteorologist Wayne Palmer for the Office of Climatology of the Weather Bureau, it combines temperature and rainfall in a formula to determine dryness. It is most effective in determining both long term droughts and wet periods. Zero (0) is considered normal and the scale diverges from there[4]. The index determines that an area with a -3.0 to -3.99 rating is in severe drought, while an area with -4.0 is in extreme drought.

Table 1. Palmer Drought Severity Index

3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to 0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought

2.2 Occurrences

On average, the nationwide annual impacts of drought are greater than the impacts of any other natural hazard. They are estimated to be between $6 billion and $8 billion annually in the United States and occur primarily in the agriculture, transportation, recreation and tourism, forestry, and energy sectors. Social and environmental impacts are also significant, although it is difficult to put a precise cost on these impacts.

The National Drought Mitigation Center has compiled drought data for the period from 1895 to 1995 using PDSI. According to the data, the Pacific Northwest Basin, an area comprised of the states of Idaho and Washington, most of Oregon, and parts of Montana and Wyoming, has experienced severe to extreme drought multiple times in the last hundred years over a large area (see Figure 2).

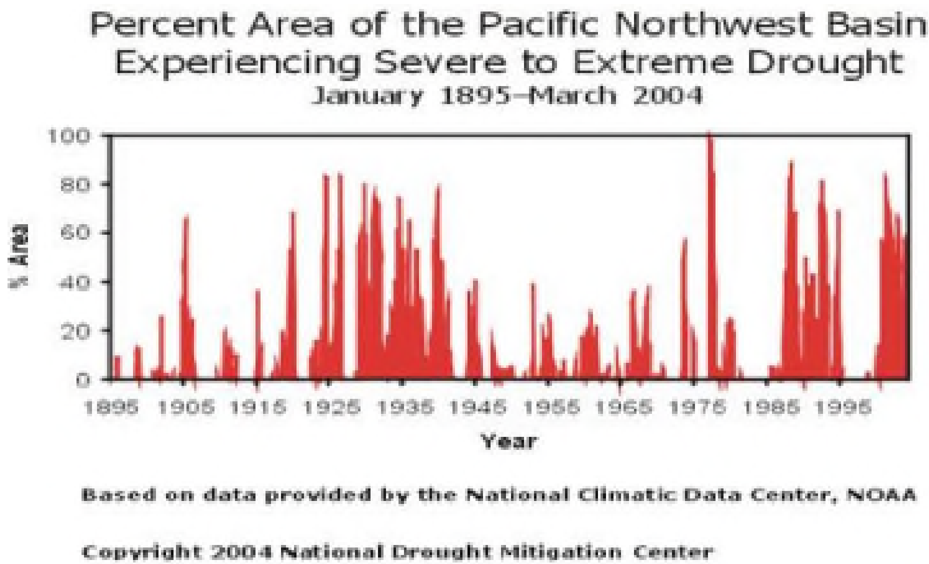


Figure 2. 2% Area of Basin in Drought C1onditions since 1895[5]

Bellevue has experienced severe drought from five to ten percent of the time during the period from 1895 to 1995 (see Figure 3). For the decade from 1985 to 1995, the rate appears to have increased. During this period portions of the Bellevue had severe drought conditions between 10 and 20 percent of the time (see Figure 4).[6]

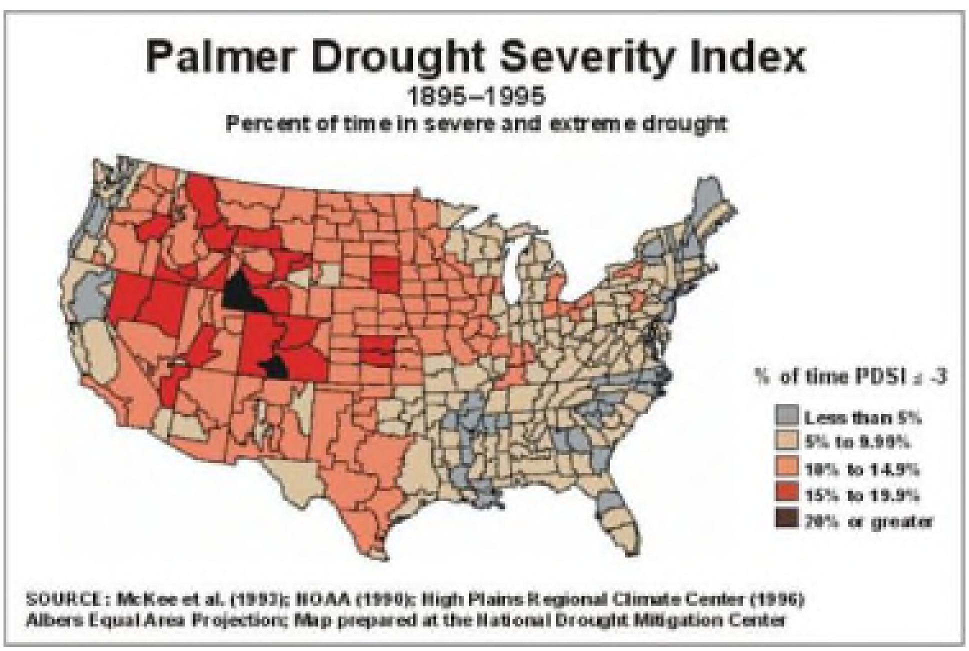


Figure 3. 1% of Time in Severe to Extreme Drought: 1895-1995

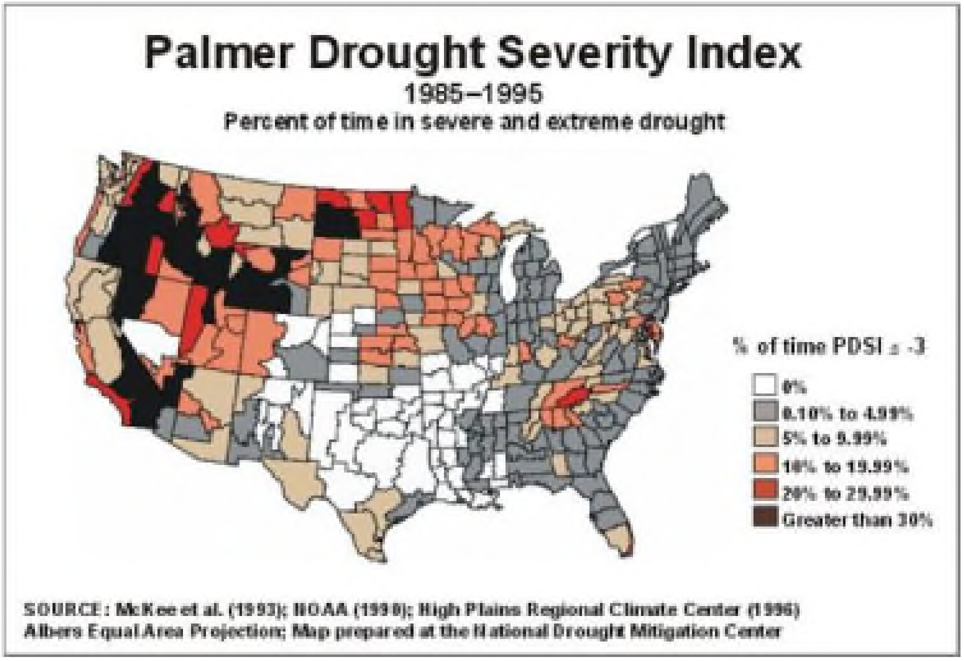


Figure 4. 2% of Time in Severe to Extreme Drought 1895-1995

Historically, droughts have not commonly been considered a problem in the area west of the Cascade Mountain Range. However, Bellevue and other west-side communities have felt the effects of drought many times in the past and will continue to do so in the future. Table 2 catalogues a number of drought periods that have affected Bellevue. Note that several lasted for more than a single season and a few for more than a year.

Table 2. Notable Droughts Affecting King County[7]

Date	Description
November 2004 – Summer 2005	The winter of 2004-2005 was the driest winter in recorded history with record low snow packs of only 26% of average and stream flows as low as 22% of average. The droughty conditions culminated in a February with no measurable precipitation in many parts of the state. Washington State declared a Drought Emergency on March 10, 2005.[8]
January – March 2001	The second driest winter on record in 106 years and second worst drought in State History. Stream flows approached the low levels of the 1976-1977 drought.
October 1976 – September 1977	The worst drought on record. Stream flows averaged between 30% and 70% of normal. Temperatures higher than normal resulted in algae growth and fish kills. Bellevue experienced severe-extreme drought conditions from 10-20 percent of the time.
April 1934 – March 1937	The longest drought in the region's history with PDSI maintaining values less than -1.[9] The driest periods were April-August 1934, September-December 1935, and July-January 1936-37.
July – August 1930	Drought affected the entire state. Most weather stations

Date	Description
	averaged 10% or less of normal precipitation.
June 1928 – March 1929	Most stations averaged less than 20% of normal rainfall for August and September and less than 60% for nine months.
July 1925	Drought occurred in Washington State.
July – August 1921	Drought in all agricultural sections of Washington State.
August 1919	Drought and hot weather occurred in Western Washington.
July – August 1902	No measurable rainfall in Western Washington.

2.3 Recurrence Rate

Scientists at this time do not know how to predict drought more than a month in advance for most locations. Predicting drought depends on the ability to forecast precipitation and temperature. Anomalies of precipitation and temperature may last from several months to several decades. How long they last is dependent on interactions between the atmosphere and the oceans, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influence of weather systems on the global scale.

Based on the State's history with drought from 1895 to 1995, as shown in Figure 3 above, the state as a whole can expect severe or extreme drought at least five percent of the time in the future. Table 2 shows that since the beginning of the 20th Century, there have been ten droughts with significant effects on Bellevue. However, only four of those have happened in the past 71 years with gaps of 39 and 24 years. This implies that Western Washington, including Bellevue, can expect severe or extreme drought from five to ten percent of the time. This is too short a period to make a definitive statement as to whether this is a change in frequency or not. To conservatively cover the variance, we are defining the recurrence rate as being 50 years or less for the drought hazard in Bellevue.

The future intensity and patterns of drought Bellevue could be altered due to the expected changes in the global climate. Warming trends that will deliver less snow to the mountainous areas and threaten the possibility of drier summers could have a dramatic impact on drought in Bellevue. The dwindling level of the average annual snowpack will decrease the available water for agriculture, the environment, residents, businesses, and industry all leading to more frequent drought conditions. For a further discussion of this, see the Climate Change Hazard.

3.0 Vulnerabilities and Consequences[10]

Depending upon its severity in Bellevue, drought typically does not result in loss of life or damage to property, as do other hazards. However, it can be a contributor to the development of other hazards disasters like forest fires or crop diseases.

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

In Bellevue, based on historical precedent, drought will not by itself cause a decrease in the health and safety of its residents. Rather damage will be done to the environment, business, agriculture, etc. However, problems frequently associated with drought can cause a decrease in the health and/or safety of local residents. These would include:

- High temperatures leading to heat related injuries including some deaths,
- Mental and physical stress which can lead to a susceptibility to other diseases such as heart disease,
- Low moisture content in the forest leading to an increase in the number of forest fires threatening homes, residents and firefighters,
- Conflicts between residents and government over water usage, and
- Conflicts between residents over water usage.

3.2 Health and Safety of Personnel Responding to the Incident

There should be no extra health or safety impacts from drought beyond those for the general public. Individual hazards exacerbated by the drought, such as an increase in wildfires, by themselves threaten the health and safety of responders; however they are not a direct result of the drought.

3.3 Continuity of Operations and Delivery of Services

Drought on the scale experienced in Bellevue should not affect the ability of agencies to continue operations. While services to the public for some operations may have to be cut back, the actual ability of agencies to continue operations in some form should not be compromised. Delivery of services to the public will probably not be considered a problem for most local law enforcement agencies. Any increase in public tension regarding limiting the use of water or caused by layoffs from industry dependent on water should be within the ability of departments to handle.

For fire operations, however, it would be dependent on two factors: 1) the actual quantity of water available and 2) the dryness of the environment. If the drought is extreme enough and long lasting to the point that fire flow is affected, fire departments and districts will not be able to fulfill their mission in relation to fire suppression. Related, is the general dryness of the environment. As the water supply decreases, the probability of large scale fires, wildland, urban, or on the wildland/urban interface become more probable. An increase in the number of fires as well as their size could tax the ability of departments to respond, causing them to rely on mutual aid or going to state mobilization. In either case, their operations will continue, albeit with support from outside agencies and possibly at a reduced level.

The ability to maintain service at a level required by the public can be threatened during drought for many utilities. Both electric and water utilities rely on a steady supply of water throughout the year. The foundation of northwest electricity is hydroelectric, and without a steady supply of water supplying the dams, utilities will either have to cut back production, possibly causing brownouts, or buy expensive power from other areas that have an excess. Much of this supply originates in the mountain snowpack that normally exists in the Cascades and Olympics, or in the case of the Columbia River, an area incorporating portions of seven states and one Canadian province (see Figure 5).[11]

Figure 5. Columbia River Basin

Bellevue water purveyors receive their water either from mountain watersheds or wells locally supported by the purveyor. Short term drought has caused limited problems in the past, usually rectified by volunteer water rationing. As the population grows and the demand for water to support that population increases the need for more extreme measures may also increase.

Lack of rain will directly affect the aquifer that many of the water purveyors rely on. Changes in the aquifer may require the drilling of new wells. Small water purveyors with wells that run dry and no intertie with another system may have to temporarily bring in water either by truck or in bottles to supply customers.

Lack of rain will also be responsible for a decrease in the quantity of water flowing in the Cedar and Tolt Rivers. While Bellevue has a number of wells, they are private. The longer a drought continues the stronger its effects will be felt not only the supply from the Rivers, but also on the aquifers that could act as a backup. Eventually the point could be reached where in order to get water to the residents not only would voluntary rationing happen, but some mandatory controls would have to be put in place with fines for violators. Such controls would also affect industry. Many industrial processes require a quantity of water. To distribute enough water to residents for health reasons, and critical infrastructure like fire hydrants and hospitals, some industry may have to either reduce or suspend operations.

3.4 Property, Facilities, and Infrastructure

Drought is a slowly developing problem with little immediate impact on any property, public facilities or the infrastructure. Many built up properties, such as buildings, highways, transmission towers, and so on will not be adversely affected by drought in any form. As a drought progresses however, from a short-term inconvenience to a long term problem, certain portions of the infrastructure will begin to be affected. The lack of water in the reservoirs, streams and rivers will restrict its uses. For example, the need to use it for agriculture will conflict with the need to maintain an adequate flow for fish that will also conflict with the needs of some industries for a continuous supply and the need of the public for drinking, cooking and bathing water.

The decreasing levels in reservoirs used for hydroelectric generation puts limits on the output of electricity through two problems. First, drought limits the amount of water available for generation. Without water behind the dams, they cannot generate power. Second, the amount of electricity generated depends on the pressure of the water on the turbines or how much head there is behind the intakes to the turbines. So, as the water level behind the dams drops the pressure turning the turbines decreases. The result is that the dams are not getting as much electricity generated per cubic foot of water from a low water level as you do from a high water level.

The water distribution system could also be impacted. Water purveyors may find their normal sources drying up. Water from the Cedar and Tolt Rivers, currently used by the Bellevue and Seattle, may no longer be adequate or dependable. As the water table drops, shallow wells distributed throughout the region mostly with small water purveyors may begin to dry up. Most of these do not have interties with other purveyors. The result could be that they will have to bring in outside resources to assist with getting an adequate supply to residents.

3.5 Environment

The environment that makes Bellevue an enjoyable place to live, work, and play has its basis in the rainfall that supports the diverse ecosystems that exist across the city. Based as it is on an abundance of water, the environment could be the most adversely affected portion of the area by a drought, especially long-term drought. Impacts on the City environment include:

- A reduction in viable habitat for fish and wildlife,
- As the environment becomes more stressed, there will be an increase in both plant and animal diseases, and
- An increase in wildfires.

3.5.1 Habitat Reduction

Many of the plants, fish and wildlife native to the area are used to periods of moderate drought, which happens irregularly in Western Washington. However severe drought could stress the various environments or individual species within those environments. A decrease in rain and snow will not be uniform across any individual biotic zone and so the effects from a drought will not be universal throughout King County. In some areas they could be much worse than in others.

The most obvious immediate impact from drought is on fish populations. Drought can have a variety of negative impacts on salmon and other fish populations at several points of their life cycles. Drought can dramatically affect the ability of fish to thrive and reproduce. Streams that lack a continuous source of water tend to dry up leaving only pools for the fish to live in until the next rain brings a new flow of water down the channel. Many fish are sensitive to an increase in water temperature and a low stream flow can allow the water temperature to rise well above normal. According to the Washington Department of Fish and Wildlife: The downstream migration of juvenile salmon in the spring is linked to the surge in stream flows created by runoff from melting snow in the mountains. With mountain snow packs either well below average or completely gone, there could be some change on out-migration patterns as young fish attempt to reach saltwater to continue their life cycle. Adult salmon can have difficulties reaching upstream spawning grounds if river flows remain below normal.

Some salmon species spawn in channel margins, side channels and smaller tributaries. Spawning would have to occur in mainstream waters if those other areas are unavailable because of low flows. This could make salmon nests, known as redds, and the eggs incubating in them, more susceptible to bed scour during the fall and winter. In other cases, instream flow can drop after the salmon spawn. Salmon nests are then dewatered and the eggs within them are lost. Impacts of drought can result in depressed salmon runs three to five years later, when those fish would be returning as adults.

Warmer-than-normal stream temperatures and low dissolved-oxygen levels in isolated pools can lead to fish deaths both in wild populations and at WDFW fish hatcheries. Just as reduced water levels affect wild spawners, reduced water supply can lead to warmer water temperatures and thus result in increased fish disease, treatment costs and fish mortality. Some of the likely causes of problems are fungal and bacterial diseases, which can kill fish or lead to fewer fish eggs.

Many of our hatcheries depend on a clean and consistent source of water. So, during a drought, hatcheries can be at risk because of lack of water of sufficient quality and quantity to rear fish. WDFW sometimes might be required to pump water from wells, which adds significant costs to operations.[12] However, it must also be pointed out that while drought may be detrimental to some species, it may not be detrimental to all. "During droughts, the in stream habitat conditions can actually be favored for some fish species, such as certain minnows and darters, and fry and fingerlings of larger species. Drought conditions allow these fish to compete with other fish, such as larger predators, which may be favored at higher flows. The result is a more robust and diverse fish community."[13]

The impact on wildlife can also be dramatic and can vary considerably across the County. With topography ranging from sea level to over 6,500 feet there is a wide range of plants and animals that inhabit different areas. The United States Department of Agriculture (USDA) developed climate zones (also called hardiness zones) based on temperature for the entire United States. These zones are based on the mean of the lowest temperature recorded each year. King County is divided into various climate zones (see Figure 6). Since these zones are based on temperature, other factors need to be taken into account when looking at the effects of drought on the County.

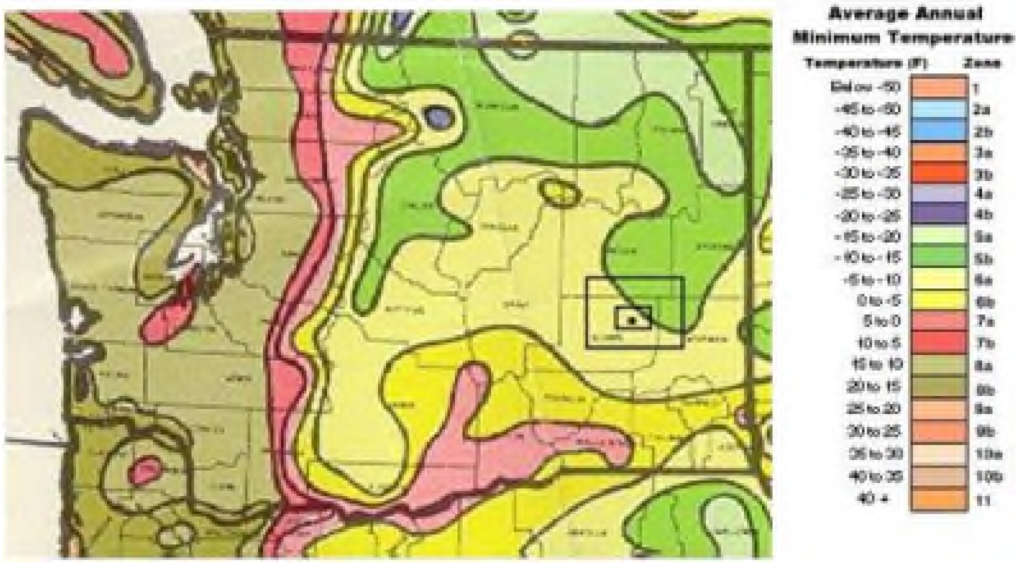


Figure 6. USDA Climate Zones – Washington State[14]

Eastern King County, as can be seen from the USDA Climate Zones map, has a very different range of temperatures from western King County. Temperatures are cooler and because of the rise in elevation precipitation is much higher. This creates a different series of zones called life, or biotic zones. These zones are not just related to temperature, but include precipitation, are very variable, contain different animal and plant species and generally are located at different elevations.

A number of different categorizations of life zones have been utilized or defined over the years. Some more detailed and others simpler. The one shown here has been in use for over 50 years, and is a variation of one first developed in the late 1800s. King County has four of the seven Washington State biotic zones established within it[15]. These include:

- **Coast Forest Zone**: This zone encompasses the lowlands of King County up to the foothills of the Cascades and climbing their lower slopes until it meets the
- **Mountain Forest Zone**: This zone is also called the Canadian Zone. It includes the evergreen forests that range up to approximately 5,000 feet where it meets the
- **Sub-Alpine Zone**: This zone includes the species that exist near tree line and ranges from 5,000 to 7,000 feet in elevation. As the trees peter out to tundra and snow the zone is called the
- **Alpine Zone**: This zone includes all terrain above timberline along the highest portions of the Cascade crest.

The marine climate associated with these zones provides the moisture to maintain them. Within the different zones the various species of plants and animals are more or less tolerant of drought conditions. Animals that have an association with water resources, like amphibians (frogs, salamanders, etc.), ducks, geese, herons, and many others, will find their habitats drying up and will not have their normal food source available. Waterfowl and other birds have the ability to move elsewhere, however, many smaller non-flying species do not. They, in turn, may attempt to migrate. While some may be successful, others will not.

Deer and elk will find their normal food sources decreasing and may have to change their normal migration patterns. Voles, mice, and others will find their populations decreasing, a situation that can put stress on the predators that rely on them. As water sources dry up animals will tend to congregate near water sources that are still viable. This concentration leaves many of them vulnerable to predators also congregating at the water source.

The result of extended drought in particular, is a total change in the distribution of the flora and fauna. This can push many species into conflict with people as they leave their normal habitats and migrate into more populated areas. The change in habitat limiting food and water can push some marginal species into localized decline or even eliminate them from the local environment, resulting in a decrease of biodiversity.

3.5.2 Plant and Animal Disease

Maritime forests, like we have in Western Washington, in drought conditions tend to become stressed. Initial effects will be to the tree root system. Lack of water in the top 12-18 inches of the soil will begin to dry up and kill the root hairs that normally take up water. This causes a water deficit in the tree. Trees stressed like this are unable to grow properly, begin to lose their resistance to disease and also become susceptible to attacks by insects.[16] This can lead to wide areas having diseased or dead trees, all of which can increase the potential for wildfire.

Research into the effects of drought on local environments shows that it can alter the effects of other disasters, a recent example is the loss of wetlands due to drought. The weakening and killing of marsh grass by drought allowed periwinkle snails to further destroy the wetlands along the Gulf Coast. This loss of coastal wetlands exacerbated the destructive tendencies of Hurricane Katrina. “It’s important to note that drought was the trigger that initiated these events – and because drought stress is becoming more extreme with global warming, events like this could become both more frequent and intense.”[17] In drought conditions, the lack of water and food supply will put extra stress on wildlife. Because of this stress, the combination of dehydration, hunger and in some cases heat, many animals may become susceptible to disease.[18]

3.5.3 Wildfire

The heavy forest growth, and resulting duff, existing on the west side of the Cascades has the potential during prolonged drought of creating conditions conducive to wildfires. Once started, the steep terrain combined with the heavy load of fuel can make these fires hard to put out. As with a wildfire in any part of the state, a large-scale wildfire within King County could leave a lasting impression on the local environment that may not rebound for years if not decades or longer. Animal and fish habitat would be destroyed. The loss of the forest canopy would eliminate the shade needed for many species of both plant and animals. Streams would be polluted with burnt material and there would be an increase in erosion leading to silt deposits that could destroy fish habitat.

In contrast, it must be understood that while fire is destructive, it opens up new environmental opportunities. Forests go through a cycle of growth, decay, and destruction. Fire is a natural part of the forest ecology. Previous attempts to eliminate all fires proved counter-productive for a healthy environment. Burning the understory in many cases increases the health of a mature forest. The newly burnt landscape would allow the introduction of other species, tolerant of the open spaces and increased sunshine. Many plants are intolerant of the deep shade that exists in the heavily forested areas. These newly burned areas allow them an opportunity to thrive. With them will come animals that thrive on those particular plants. The result is a new ecological niche will have been created.

The impact of drought on the environment and Bellevue will follow a sequence of events. These begin with relatively minor inconveniences and as time progresses can get much worse leading to major environmental degradation. This can eventually lead either directly or as a result of fire to major changes in the local ecosystems that exist within Bellevue.

3.6 Economic and Financial Condition

Drought will impact the population in Bellevue. Most previous periods of drought have been, at their worst, an inconvenience. However, a prolonged severe drought could impact the agricultural and industrial basis of the local economy. Economic impacts become apparent as we move from a strictly meteorological drought to an agricultural drought. Crops are damaged due to lack of water. Damaged crops and closed national forests mean that retailers begin to lose business. Layoffs can begin leading to financial and mental, stress on individuals and families.

Damaged crops may lead to a decrease in food quality as well quantity, causing more food importation. This yields higher costs for the distributors and therefore higher food prices for consumers. Bellevue services and companies that rely on a large supply of water for manufacturing goods could have a similar predicament in that as supplies of water dwindle they may have to cut back some processes and also lay off workers with consequences down the chain of distribution. A lack of water in the rivers and streams will result in lower levels behind dams used for hydroelectric power generation. Power bought from other sources will be costlier than that locally generated. These costs will eventually be passed on to the consumer.

Recreation will also be affected. As a drought intensifies, recreation resources will be closed to the public. Dry conditions creating fire danger will limit the use of National Forest and both State and National Park lands. Communities acting as entry points to the recreation areas would be affected by the National Forest and Park closures. As lakes dry up and the flow in rivers and streams decrease, water recreation will also diminish. Boat ramps and docks may be high and dry. Recreational fishing could be curtailed.

3.7 Public Confidence in the Jurisdiction's Governance

Public dissatisfaction with government regarding drought response can erode confidence in local governments. This is especially true if a portion of the public feels that it is being denied a legitimate share of the water available. Required rationing, while necessary, must be scrupulously carried out to ensure that no bias is felt by others, especially the low or middle-income portions of the population. If this is not done, it can lead to a lack of confidence in either local utilities or local government or both. Eventually, this can lead to unrest.

4.0 Resource Directory

- Seattle Office of the National Weather Service
  https://www.weather.gov/
- Washington State Comprehensive Emergency Management Plan, Annex Z2, Drought Contingency Plan https://fortress.wa.gov/ecy/wrdocs/WaterRights/wrwebpdf/dcp/wa-droughtcontplan-finaldraft.pdf
- Western Regional Climate Center
  http://www.wrcc.dri.edu
- National Drought Mitigation Center
  http://drought.unl.edu
- Extreme Heat Fact Sheet
  https://www.fema.gov/media-library-data/20130726-1622-20490-2694/extremeheatfactsheet_final.pdf
- National Weather Service Climate Prediction Center
  http://www.cpc.ncep.noaa.gov
- Snow and Ice – National Snow and Ice Data Center
  https://nsidc.org/

[1] What is meant by the term drought? Referenced by the National Weather Service, Western Region Headquarters from Glossary of Meteorology , 1959 edition. http://www.wrh.noaa.gov/fgz/science/drought.php The current edition lists it as "A period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance." Web.

[2] The drought types are taken from the National Drought Mitigation Center (NDMC), School of Natural Resources, University of Nebraska, Lincoln, 2006, https://drought.unl.edu/Home.aspx

[3] What is Drought: Understanding and Defining Drought., The National Drought Mitigation Center (NDMC), https://drought.unl.edu/Home.aspx

[4] The Palmer Drought Severity Index, NOAA's Drought Information Center, NOAA, Web.

[5] National Drought Mitigation Center, http://www.drought.unl.edu/whatis/palmer/pacnw.gif --05/2005

[6] What is Drought: Historical Maps of the Palmer Drought Index., National Drought Mitigation Center, Web.

[7] Much of this table was taken from the Washington State 2001 Hazard Identification and Vulnerability Assessment, Washington State Military Department, Emergency Management Division, April 2001, p. 7.

[8] Washington State Hazard Mitigation Plan, Washington State Military Department, Emergency Management Division, Web.

[9] Pierce County Hazard Identification and Vulnerability Analysis, Pierce County Department of Emergency Management, September 2002, p. 18.

[10] Ibid.

[11] Columbia River Basin, Department of Ecology, 12/16/02, Web.

[12] Drought Planning, Washington Department of Fish and Wildlife, https://wdfw.wa.gov/conservation/drought/impacts.html

[13] Young, Leroy, Fjsh Habitat and Flow: What's the Connection? AQUATIC RESOURCES SECTION IN THE COMMISSION'S DIVISION OF ENVIRONMENTAL SERVICES, Web.

[14] The Climate Zone Map was from http://growingtaste.com/usdamap.shtml

[15] C.P. Lyons, J.M. Dent & Sons Trees, shrubs and flowers to know in Washington, , Canada, Limited, Toronto, 1977, pp7-11.

[16] Terrell, Cindy The Damaging Effects of Drought, monograph published by the Morton Arboretum., July 1, 2005, Web.

[17] Research: Snails were overlooked contributors to marsh destruction, University of Florida News,12/15/05, Web.

[18] National Drought Mitigation Center, Web.

Table of Contents

1.0 Introduction

As identified in the Climate Change Hazard Section, larger changes in the atmospheric conditions across the globe, due to climate change, will lead to the potential changes in how we define hazards, identify future recurrence rates, and identify vulnerabilities and related consequences. This is of important note as we document the flood hazards in the City.

1.1 Definition[1]

A flood is a general and temporary condition of partial or complete inundation of normally dry land areas from:

- The overflow of inland or tidal waters,
- The unusual and rapid accumulation or runoff of surface waters from any source, or
- Mudflows or the sudden collapse of shoreline land.

Special Flood Hazard is land within a floodplain that has a 1% or greater chance of flooding in any given year as calculated in the Storm and surface Water Utility Code, Chapter 24.06 BCC. It is sometimes referred to as the “100-year” floodplain. Development in Special Flood Hazard areas in Bellevue is regulated by LUC 20.25H – Critical Area Overlay District.

Riparian Corridor is an ecologically distinct area bordering rivers and streams.[2] Bellevue’s flood hazards are urban stream/groundwater. The rapid urbanization of Bellevue has increased its risk from large-scale flooding and development has increased the amount of impervious surfaces and the volume of flood water. In 1977, the estimated 100-year occurrence flow was estimated to be 420 cubic feet per second and by 1997 this had increased to 950 cubic feet per second[3].

1.2 Type

1.2.1 Urban Stream

The most severe flooding on Bellevue’s major streams and creeks results from low to moderate elevation (500 to 1,400 feet) runoff occurring in conjunction with a prolonged moderate- to high-intensity rainfall event. This situation can be worsened if there is preexisting snow conditions at these elevations in the City, leading to what is referred to as a rain-on-snow event. Accumulating snowfall usually occurs for brief periods (one to three days) and can be followed by accelerated warming from warm Pacific frontal storm systems arriving from the tropics and containing a significant amount of precipitation, also known as atmospheric river of moisture or “pineapple express”. Rain-on-snow events typically result in a sharp rise in flow that can quickly yield flood stages (see Figure 1). The rise in peak flow can occur quickly, making consistent monitoring of river flow gages essential during the flood season.[4]

Flooding can occur in Bellevue when runoff exceeds the conveyance capacity of natural and manmade drainage systems. Surface water runoff[5] volumes in urban stream channels, closed depressions (potholes), roadway ditches, culverts and conveyance pipe systems typically exceed the available conveyance and storage capacity of such systems during the fall, winter, and early spring wet seasons (see Figure 2). This typically occurs with moderate- to high-intensity storms that can last for several days or occur in succession over a period of weeks. These events are characterized as rainfall of three inches or more in a 24-hour period. Urban area flooding generally occurs gradually and allows time for property owners to identify an impending flood situation and prepare for it. In some areas, however, flooding can occur rapidly and may leave little time for preparation.

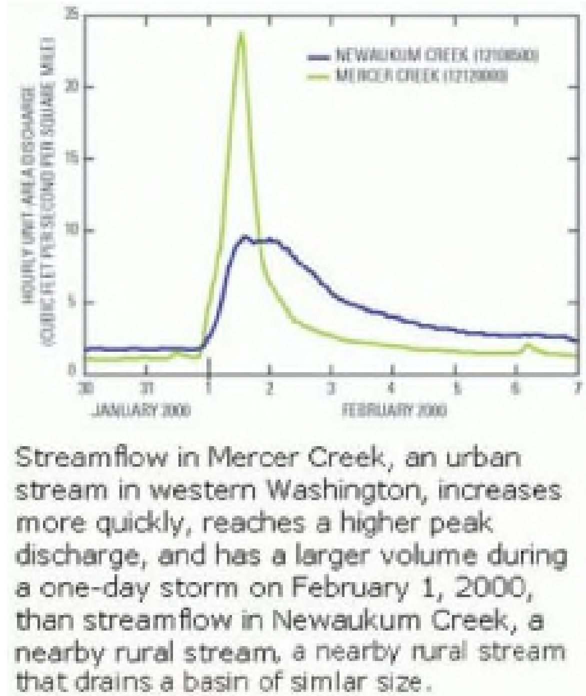


Figure 2. Mercer Creek Stream Flow

In some cases, debris can accumulate in stormwater collection systems and reduce the capacity of the system to convey flow. Such a reduction in capacity can lead to more frequent flooding events. Regular maintenance, however, can ensure that the stormwater systems function as designed. Urban stream flooding is exacerbated by rain-on-snow events. During the winter months, these events usually result in widespread flooding along streets, streams, ditches, culvert pipe systems, and storm drains. Conditions in the basins can change rapidly and the onset of flooding can occur at an accelerated rate.

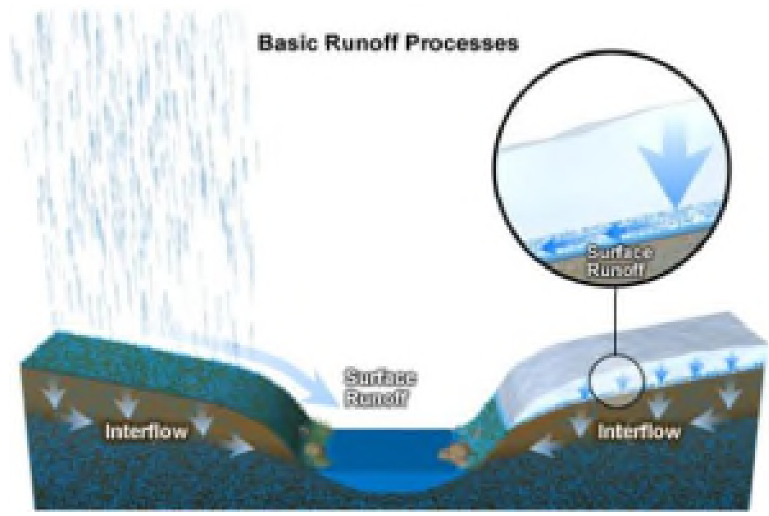


Figure 1. Major Sources of Surface Runoff

1.2.2 Groundwater Flood

Groundwater flooding is associated with a large amount of cumulative rain over several storms or consecutive rainy seasons. High groundwater may occur weeks after the last significant rainfall and can also shift locations as groundwater levels change throughout the region. This type of flooding may last for several weeks or even months.

1.3 Secondary Hazards

Secondary hazards of ongoing flooding include possible contamination of drinking water, interruption of gas and electrical services, potential transportation issues if arterial passageways are impacted (which may further impact food supply delivery), and soil instability due to over-saturation.

2.0 Profile

2.1 Location and Extent

Bellevue is divided into two major drainage basins—Lake Washington and Lake Sammamish—and 26 watersheds or basins. A watershed or basin is the land area that drains to a particular body of water, such as a stream or lake. These watersheds range in size from the Wilkins Creek watershed at 900 acres to the Coal Creek watershed at about 4,000 acres (see Table 1).

Table 1. Bellevue's Major Basins, Storm Drainage Basins Containing Streams, and Stream Names[6]

Regional Stream Inventory Basin	City of Bellevue Storm Drainage Basin	Primary Streams	Total Length Streams	% Piped	Total Impervious Area
East Lake Washington	Yarrow Creek	Yarrow Creek	24,026	22%	28.8%
	Meydenbauer Creek	Meydenbauer Creek	2,408	29%	52.9%
	Lakehurst Area	Lakehurst Creek Newcastle Beach Creek 60th Street Creek 64th Street Creek	11,411	29%	36.3%
Kelsey Creek	Mercer Slough	Mercer Slough	23,419	15%	35.3%
	Kelsey Creek	Kelsey Creek	55,169	12%	41.8%
	West Tributary	West Tributary	17,791	15%	44.3%
	Goff Creek	Goff Creek	9,684	23%	30.3%
	Valley Creek	Valley Creek	15,566	15%	32.3%
	Sears Creek	Sears Creek	3,326	43%	64.2%
	Richards Creek	Richards Creek	12,180	12%	45.0%
	East Creek	East Creek	12,739	15%	48.4%
	Sturtevant Creek	Sturtevant Creek	23,419	15%	35.3%
	Sunset Creek	Sunset Creek	12,193	21%	44.1%
Coal Creek	Coal Creek	Coal Creek	77,187	5%	24.7%
	Newport Area	Newport Creek	4,715	3%	38.1%
West Lake Sammamish	Ardmore Area	Ardmore Creek	14,894	8%	42.4%
	Wilkins Creek	Wilkins Creek	1,742	0%	40.9%
	North Sammamish Area	Idlywood Creek Sunich Creek Unnamed Creek Unnamed Creek Weona Park Creek	6,778	18%	33.2%
	Phantom Creek	Phantom Creek	4,046	7%	38.3%

Regional Stream Inventory Basin	City of Bellevue Storm Drainage Basin	Primary Streams	Total Length Streams	% Piped	Total Impervious Area
	Vasa Creek	Vasa Creek	18,614	19%	40.3%
	South Sammamish Area	Reservoir Creek Unnamed Creek Sunrise Creek	17,884	20%	30.9%
Lewis Creek	Lewis Creek	Lewis Creek	48,520	10%	28.2%

Bellevue has 235 properties located within the 100-year flood plain defined by FEMA. According to modeling conducted by the King County Flood Control District, in a 100 year flood event, residents of Bellevue could face $10,162,000 in damages to buildings and property. Bellevue has undertaken considerable effort to manage storm water since 1994. Recent activity has included increasing storage capacity of a regional pond, replacing culverts and conducting levee improvements near the I-405 corridor.[7]

Known areas for flood response according to the City of Bellevue Transportation Department include the following areas, which are natural flood basins: 148th Ave SE and Larsen Lake; 148th Ave SE and SE 8th St; SE 7th Pl, east of Lake Hills Connector; NE 21st St, east of 140th Ave NE; 156th Ave SE, north of SE 16th St; and SE 30th St, east of Richards Rd.

2.1.1 Urban Stream/Groundwater Flood Hazard

Urban stream/groundwater flooding occurs when runoff exceeds the conveyance capacity of natural and human made drainage systems (see Table 2). It typically occurs with moderate- to high-intensity storms that can last for several days or occur in succession over a period of weeks. Floodwater can be high and flooding can last for several days until rainfall and saturated soil moisture conditions subside.

Table 2. Bellevue Flood Plains

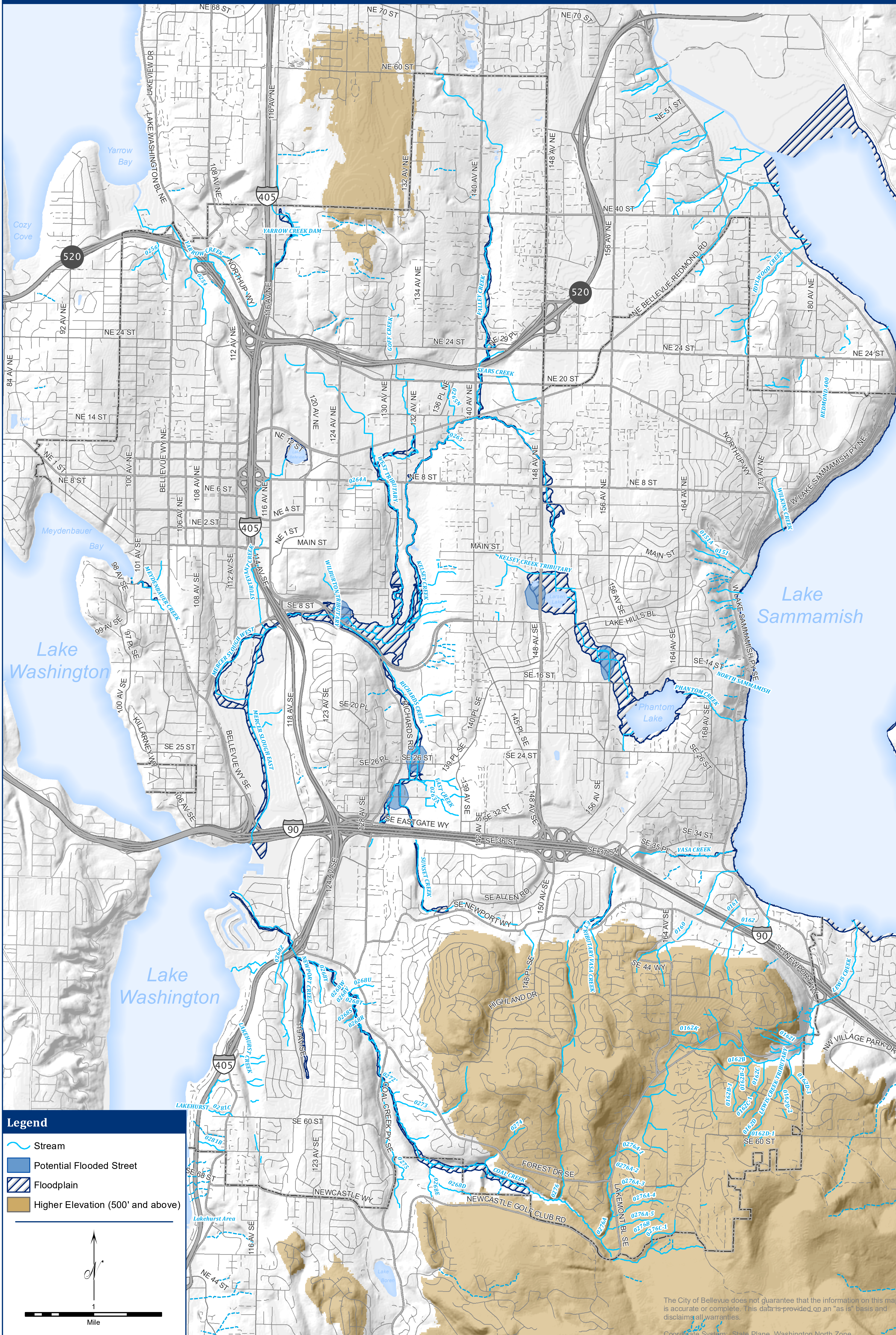
Stream Name	Stream Basin	City Storm Drainage Basin	Channel Type
East Creek	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
262 (East Creek)	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
East Creek Tributary 1	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
East Creek Tributary 2	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
0263A Tributary 2	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
0263A Tributary 3	Mercer Slough/Kelsey Creek	East Creek Basin	Flood plain
Kelsey Creek Tributary 9 (0265N)	Mercer Slough/Kelsey Creek	Kelsey Creek Basin	Flood plain
New Castle Beach Creek	New Castle Beach Creek	Lakehurst Area	Flood plain
New Castle Beach Creek Tributary	New Castle Beach Creek	Lakehurst Area	Flood plain
Kelsey Creek	Mercer Slough/Kelsey Creek	Mercer Slough Basin	Flood plain
Meydenbauer Creek	Meydenbauer Creek	Meydenbauer Creek Basin	Flood plain

Stream Name	Stream Basin	City Storm Drainage Basin	Channel Type
West Tributary	Mercer Slough/Kelsey Creek	West Tributary Basin	Flood plain
0264A	Mercer Slough/Kelsey Creek	West Tributary Basin	Flood plain
Yarrow Creek	Yarrow Creek	Yarrow Creek Basin	Flood plain

Figure 3 maps the flood plain boundaries when Bellevue experiences flooding hazards, along with other meteorological hazards in the City of Bellevue.

Meteorological Hazards

City of Bellevue
GIS Services



Date: 9/21/2016 File Name: V:\EOC\arcgis\EOCmapSet\EOCMapSet2016\MeteorologicalHazards_11x17_10-2.mxd IT Department

2.1.2 Repetitive Loss Areas

FEMA defines a repetitive loss property as being a National Flood Insurance Program (NFIP) insured property that since 1978, regardless of changes in ownership, has experienced any of the three following[8]:

- Four or more paid losses greater than $1,000,
- Two paid losses in excess of $1,000 within any 10 year rolling period since 1978, and
- Three or more paid losses that equal or exceed the current value of the insured property.

Bellevue has only two locations that FEMA considers repetitive loss.

2.2 Occurrences

2.2.1 Description of Flooding

Bellevue is a participant in FEMA's NFIP. Residents of communities participating in the NFIP can obtain lower cost flood insurance coverage in return for the participating communities meeting FEMA's minimum criteria for flood plain management under the Community Rating System.

Bellevue is rated five out of ten on the FEMA Community Rating System program; that rating allows Bellevue residents to realize discounts on their flood insurance coverage. There are 236 flood insurance policies issued in Bellevue for a total value of $69.4 million. There have been 56 losses claimed over $800,000 dollars have been paid out in claims. Two of the claims were substantial, meaning the claim exceeded 50 percent of the value of the home (see Table 3).[9]

Table 3. Flood Hazard Related Incidents before 2013

Federal Disaster	Notes
Washington State #10-3912—12/12/2010	Urban flooding with over 3 to 4 inches of rain falling in the City and Western Washington in a 24 hour period. An estimated 11 residents had flood damage in the City and an estimated $400,000 in emergency response costs and damage were documented including a large landslide in the Coal Creek Drainage.
DR-1817-WA—1/30/2009	Over $500,000 assistance provided to Bellevue
DR-1734-WA—12/1-17/2007	Flooding throughout most of W. Washington. $521,561.35 Public Assistance provided to Bellevue.
DR-1671-WA--11/5-6/2006	Localized flooding in Bellevue and street closures
DR-1499-WA--10/2003	Surface flooding
DR-1159-WA--12/96-2/1997	Ice storm, snow and flood. Stafford Act assistance - $83 million, SBA $31.7 million
DR-1100-WA--1-2/1996	Three deaths in Washington. Stafford Act disaster assistance provided – $113 million. SBA disaster loans approved - $61.2 million
DR-1079-WA--11-12/1995	100-year flood at Alderton on the Puyallup and 50-year flood

Federal Disaster	Notes
	at La Grande
DR-896-WA--12/1990	Stafford Act assistance provided $5.1 million
DR-883-WA--11/1990	Stafford Act assistance provided $57 million
DR-852-WA--1/1990	Stafford Act assistance provided $17.8 million
DR-784-WA--11/1986	Two deaths. $11 million in private property damage and $6 million in public damage
DR-545-WA--12/1977	16 counties were declared. Very heavy rain in the upper Nisqually caused significant damage.
DR-492-WA--12/1975	13 counties flooded
DR-328-WA--2/1972	King, Pierce and Thurston counties flooding
DR-185-WA--12/1964	Wide ranging flooding affected 19 counties in both eastern and western Washington

2.2.1 Coal Creek Watershed

Coal Creek

Coal Creek is located along the southern limit of the City of Bellevue. The headwaters of Coal Creek originate in the steep terrain of Cougar Mountain at an elevation of about 1,400 feet. The creek flows for approximately seven miles through a series of steep, narrow ravines before entering Lake Washington along the eastern shoreline at Newport Shores. The drainage basin for the creek is roughly 4,550 acres and contains one large tributary – Newport Hills Tributary. The watershed is within the shared jurisdiction of the City of Bellevue, King County and the City of Newcastle.

Extensive coal mining activities took place in the basin beginning in the late 1800s. The mining activities resulted in changed stream courses, channelized reaches, and mine tailing dumped along stream banks (McDonald 1987; Kerwin 2001). Headwater streams of the south fork of Coal Creek originate from a caved-in section of mine that seems to combine with an extensive mine drainage system (Skelly and Loy 1985).

Urban development within the basin in the last century has further altered the creek's natural hydrologic characteristics, increasing the frequency, duration, and peak of flood events, stream bank erosion, and streambed sedimentation (Kerwin 2001). The channel was diverted southward in the late 1940s, then northward again in the late 1950s, because of the construction of an airstrip in the delta area of the stream. In the 1960s, as a feature of the residential development, two large canals were excavated just south of the stream mouth to allow moorage and waterfront amenities for inland properties. The stream has also been crossed several times by large municipal water and sewer mains.

A comprehensive basin plan for Coal Creek was produced by the City of Bellevue and King County in 1987. As part of this planning effort, a hydrologic model was developed. It was found that base flows in Coal Creek are augmented by approximately ten percent by flows from mine tunnels. Coal Creek was also found to have extensive sedimentation problems from stream bank erosion and the occasional catastrophic failure of tailing slopes that remain from the old coal mining activities in the creek's headwaters and landslides of the steep slopes above the creek. Since 1997, the City of Bellevue has maintained two sediment retention ponds in the system, one immediately upstream of Interstate Highway 405 and another immediately upstream of Coal Creek Parkway. While the sediment ponds are helping to control excessive delta formation through the reduction of large particles, smaller particles and fine silts and clays remain suspended and wash downstream (Tetra Tech/KCM 2005). As a result, the ponds provide no protection for spawning and rearing habitat (Kerwin 2001).

Currently, land use in the Coal Creek basin is predominantly single-family and multi-family residences and parks, including the Cougar Mountain County Park in the headwaters and Coal Creek Regional Park (Kerwin 2001). The basin has 15 percent impervious area within the 100-foot riparian area surrounding the creek.[10]

Newport Creek

Gradients on Newport Creek range from moderate to very high (over 40%). Approximately seven percent of Newport Creek is contained in culverts; overall, the basin has a moderate rating for channel and flow modifications. Log wires on upper Newport Creek have created upstream barriers and resulted in several isolated pools.

Coal Creek basin has the highest amount of undisturbed riparian corridors in Bellevue due to the extensive system of parks and open space in this basin. Total impervious area within 100 feet of the streams in the Coal Creek drainage basin is approximately 15%; however, total impervious area within 100 feet of Newport Creek is only 2%.

Yarrow Creek

Channel modification varies from high to low throughout Yarrow Creek; some reaches of the stream are completely piped, while others remain open channel. The basin has a moderate level of channel and flow alteration. Overall, approximately 22% of the Yarrow Creek system is contained in culverts. One culvert in a downstream reach (approximately river mile 0.2)

Channel types in the Yarrow Creek basin range from floodplain in lower reaches to moderate gradient, mixed control in upper reaches. The basin, however, has extensive lengths of stream in culverts, a moderate level of total impervious area, and a moderate amount of riparian constraints.

Meydenbauer Creek

Meydenbauer Creek is highly urbanized, flowing through commercial and multi-family land uses before flowing into Lake Washington at Meydenbauer Bay. It is a low-gradient stream (gradients ranging from 0-2%) with few riffles and a predominantly sandy substrate with a silt layer in some places.

Two reaches of Meydenbauer Creek are largely piped, and approximately 29% of the total stream length is contained in culverts. The stream is blocked at approximately river mile 0.2 by a culvert. The stream also has a high ratio of storm drainage network to open channel, and an overall poor rating for channel and flow modifications. Meydenbauer Creek’s riparian corridor has been highly modified by residential development and road crossings. Total impervious area within 100 feet of the stream corridor is approximately 36%.

2.2.2 Lakehurst Basin

In the Lakehurst basin, four streams drain directly to Lake Washington. The northern stream, Newcastle Beach Creek located in Newcastle Beach Park, has gradients ranging from low to high with only small piped sections. Lakehurst Creek has a relatively constant moderate gradient in its upper 3,000 feet, averaging approximately 3-4%, while in the lower 1,000 feet of this stream gradients are high. The southern streams (60th and 64th Street Creeks) are seasonal, with gradients ranging from 10-19%. (The Watershed Company, 2001).

Overall, with the exception of Newcastle Beach Creek, some reaches of all of these streams have been piped. In the basin overall, approximately 29% of total stream length is contained in culverts, but the ratio of storm drainage network to open channel is moderate, resulting in a moderate rating for the level of watershed alteration.

2.2.3 Kelsey Creek Watershed

The Kelsey Creek basin comprises approximately 10,870 acres and has several streams draining west into the east channel of Lake Washington at Interstate 90. The basin includes over 19 miles of open stream encompassing Mercer Slough, Sturtevant Creek, Kelsey Creek, Valley Creek, the West Tributary, Goff Creek, Richards Creek, East Creek, and Sunset Creek. The main stem of Kelsey Creek originates in the Phantom and Larsen Lake wetlands. Historically, the creek originated from Phantom Creek and Phantom Lake, but early pioneers redirected the Phantom Lake outlet to Lake Sammamish in the late 1880s (KCM 1993).

Land use in the Kelsey Creek Basin is predominantly single-family residential (37%), particularly in the Sunset Creek, Valley Creek and Goff Creek storm drainage basins. The Richards Creek basin contains the highest percentage of multi- family residential land use, while the highest percentage of commercial land use is located in the Sturtevant Creek and Sears Creek basins. The Kelsey Creek basin has 22% open space, 13% multi-family residential, 13% public roads, 8% commercial/office, 6% institutional/ government, less than 1% industrial and mixed use (Kerwin 2001). Kelsey Creek Park, within the central part of the City of Bellevue encompasses 150 acres of forest and wetland habitat.

The Mercer Slough area has the highest percentage of open space and has the lowest amount of impervious surface. Impervious surface cover is highest in the Sturtevant Creek and Sears Creek basins and the lowest in the Mercer Slough area. Nineteen culverts and a number of concrete and rock weirs in the basin are partial water passage barriers.

The Kelsey Creek basin area is considered to have reached built-out conditions and future development will be predominantly redeveloping existing properties. An analysis of vegetation in 2000 found 7% forest canopy, 38% green vegetation, and the rest of the watershed in un-vegetated land cover such as impervious area and bare soils.[11]

Sturtevant Creek

Sturtevant Creek flows along and under I-405 before entering Mercer Slough. Gradient in this stream is low. Channel and flow modifications are high in this basin; approximately 45%of the stream is in culverts, and the ratio of storm drainage to open channel is approximately 20. The two longest culverts span 37% of Sturtevant Creek's total length. Many other culverts, some perched, create barriers to upstream migration. Headwater segments near Lake Bellevue were observed in 2001 to contain little water (The Watershed Company, 2001).

West Tributary

Habitat on the West Tributary ranges from slow moving, beaver-dammed reaches to pool-riffle sequences downstream. Channel and flow modifications in this stream are moderate, with approximately 15% of the stream in culverts and a ratio of drainage network to open channel of five.

Richards Creek

Richards Creek downstream of the Lake Hills Connector is a low-gradient depositional area with limited spawning habitat. Upstream of the Lake Hills Connector to SE 26th Street, Richards Creek is a low-gradient wetland/beaver dam system. One reach of this stream of approximately 725 feet is piped. Overall, the stream has a moderate level of channel and flow modifications.

East Creek

Lower segments of East Creek have been heavily channelized around roadways and property boundaries, but the upper segments of the stream flow largely through deciduous forested areas. Wood and tree roots from the riparian buffer contribute to moderate pool formation in the upper segments. Stream gradients in East Creek system are very low to very high, ranging from 14.4% in the headwaters to 0.7% in lower reaches. There are seven culverts in the upper reaches. On tributaries, culverts and channelization have modified habitat (The Watershed Company, 2001). The stream has a moderate level of watershed alteration; while only 12% of the stream is contained in culverts, it has a ratio of drainage to open channel of 17.

Sunset Creek

Sunset Creek flows through the commercialized I-90 corridor and residential neighborhoods before entering Richards Creek. Gradient in Sunset Creek ranges from 2-7%, with the highest gradients located in the middle reaches. Four major culverts with a combined length of over 2,000. Pool formation in portions of the stream has been aided by woody debris. Overall, Sunset Creek has a moderate level of channel and flow modification; while over 20% of the stream is contained in culverts, the ratio of drainage to open channel is 9. In the coming year there is a flood mitigation project that will work to improve the flood protection of Sunset Creek.

Goff, Valley, and Sears Creek

Goff Creek, Valley Creek, and Sears Creek stream gradients range from low to high; substantial portions of all of these streams have been piped. The level of channel and flow modification is high in Sears Creek, with over 43% of the stream in culverts and a high ratio of drainage network to open channel. Sears Creek is channelized in its lower 1,000 feet before passing through a culvert upstream; vegetative cover and in stream structural complexity is lacking in this reach of stream. A 1,200-foot section of vegetated riparian corridor is located upstream of this section, with better in stream habitat structure (The Watershed Company, 2001).

Approximately 23% of Goff Creek has been placed in culverts, while 15% of Valley Creek is in culverts; both of these streams have a moderate level of channel and flow alteration. Goff Creek contains a 1,000-foot long culvert at Bellevue-Redmond Road. There is ample flow in this stream for fish use (The Watershed Company, 2001). Substrate in much of Valley Creek consists of gravel and pool-riffle sequences. There is also a 1,000-foot long culvert on this stream in the vicinity of the golf course (The Watershed Company, 2001).

2.2.4 West Lake Sammamish Basin

Phantom Creek

Phantom Creek flows through a wooded ravine below Phantom Lake. Upstream of the lake, the stream consists of a narrow, sediment-filled channel with low flow. Phantom Creek has a moderate rating for flow and channel modifications; approximately 7% of the stream is contained in culverts, while the ratio of drainage network to open channel is 9. Nearly half of all stream length in the basin exceeds 12% gradient. In addition, approximately 20% of the streams are in culverts. There is a critical culvert under West Lake Sammamish Parkway, and approximately 15% of the stream contains gradients exceeding 12%. Overall, Phantom Creek has a high gradient, confirmed channel type.

Vasa Creek and South Sammamish Basin

Vasa Creek, the longest stream system in the basin, includes a variety of conditions and gradients, from steep headwater reaches with bedrock substrate, to reaches with gravel substrates, to low- gradient reaches downstream of I-90 near Lake Sammamish. Portions of this stream have been piped. Approximately 7% of the stream is constrained by culvert (a good rating), while the basin has a moderate rating for the ratio of drainage network to open channel.

Ardmore, North Sammamish, and Wilkins Creek Basins

Salmonids have not been documented in remaining streams in this basin, including the Ardmore, North Sammamish, and Wilkins Creek basins. Habitat in Wilkins Creek is limited by steep gradient, limited flow, and barriers from Lake Sammamish. Lack of water has also been documented as a limiting factor (The Watershed Company, 2001)

2.2.5 Mercer Creek

Mercer Creek is one of the most studied creeks in the country, due to a partnership between the city of Bellevue and the United States Geological Survey (USGS) in the eighties to determine the issue of urbanization on stream flow. The study determined that the increase of impervious surfaces increased the likely stream for hundred-year flood from 420 cubic feet per second in 1977 to 950 cubic feet per second by 1997 (see Figure 4). This increase has been reflected in the annual peak flow recordings for Mercer Creek as well (see Figure 5).

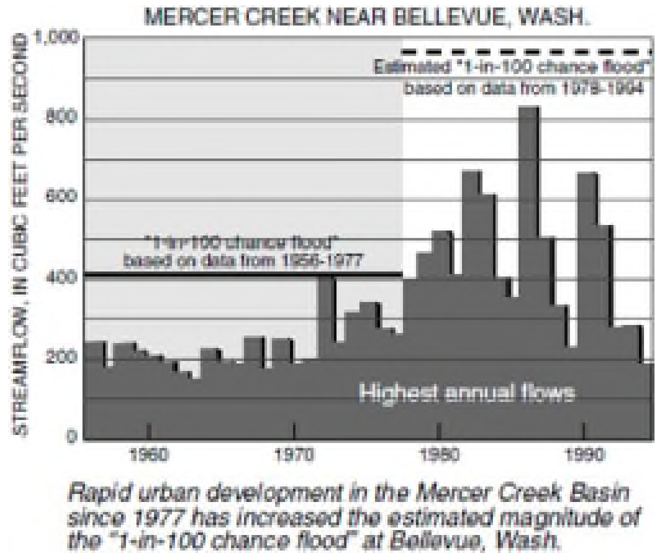


Figure 4. 1-in-100 Chance Flood for Mercer Creek

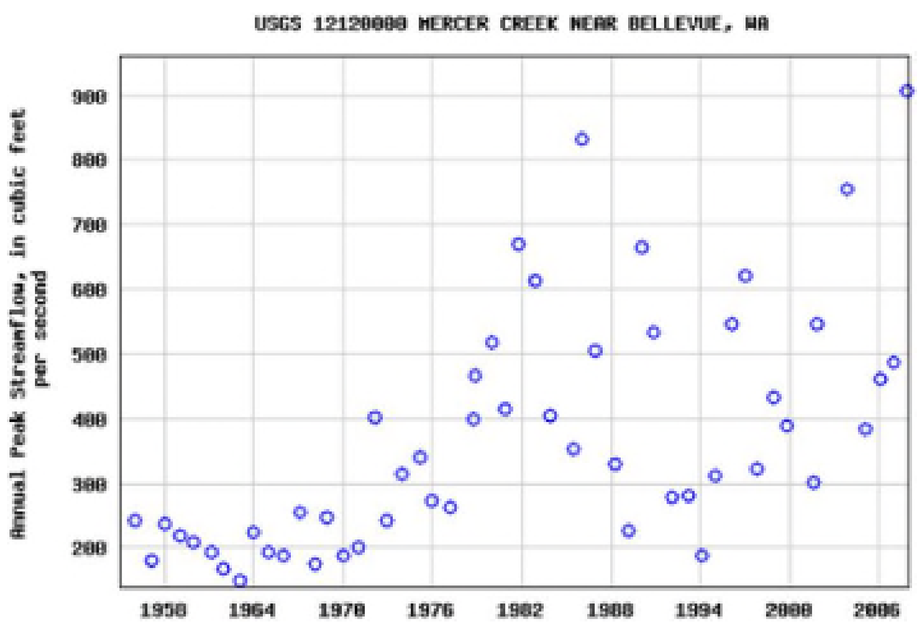


Figure 5. USGS Fact Sheet 229-96 "100 Year Flood"
https://pubs.usgs.gov/fs/FS-229-96/pdf/FS_229-96.pdf[12]

2.3 Recurrence Rate

Since 1990, King County floodplains have been declared a federal flood disaster area 11 times. According to University of Washington scientists, climate change is projected to increase the frequency of flooding in most western Washington river basins. Floods in future years are expected to exceed the capacity and protective abilities of existing flood protection facilities, thereby threatening property, lives, major transportation corridors, communities and regional economic centers.[13] Figure 6 shows the trend of the largest storms in Bellevue during the past three decades.

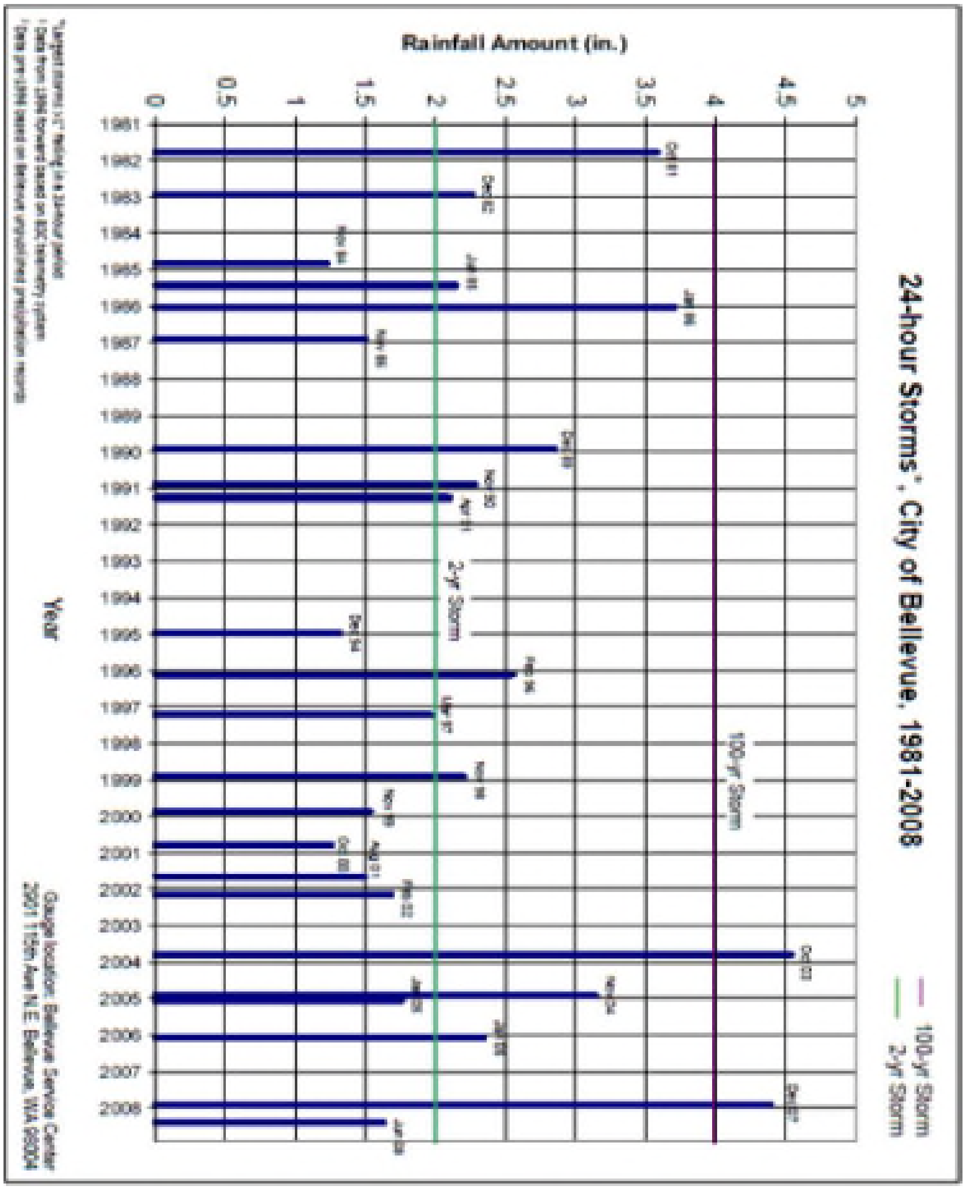


Figure 6. Rainfall: Largest Storms from the 1982 to 2008[14]

Table 4. Summary of Bellevue Regional Pond Characteristics

Summary of Bellevue Regional Pond Characteristics, 2009 Regional Pond	Vol. @ Overflow (ac-ft.)	Tributary Area (ac)	Tributary EIA (ac)	Total Vol./ac Tributary EIA 1 (ft.)	Stage @ Overflow (ft., NGVD)	Q @ Overflow (cfs)	Overflow Return Period (yrs)	Notes
Kelsey Creek Pond (133) 2	32.0	1594	476	0.18	247.9	110.0	20.0	Larsen Lake is upstream
Larsen Lake Pond (149) 2	54.0	833	207	0.26	253.4	23.0	1.5	
Lower West Trib. Pond (164S) 2	8.0	1423	517	0.07	109.2	85.0	5.0	Goff Creek and Upper W. Trib. ponds are upstream
Goff Creek Pond (164N) 2	8.0	1268	427	0.07	113.4	53.0	2.0	Upper West. Tributary pond is upstream
Upper West Trib. Pond (165) 2	22.0	463	238	0.09	131.2	39.0	10.0	
Valley Creek Pond (197) 2	15.0	1298	288	0.05	198.5	37.0	5.0	
Overlake Pond (179N) 2	12.0	514	312	0.05	246.6	55.0	25.0	Commissioners Pond Upstream
Commissioners Pond (179S) 2	2.7	269	116	0.02	282.4	37.0	5.0	
Total Kelsey Basin 2	153.7	6470	2040	0.08				
I-405 Pond (Coal Creek Basin) 3	19.5	4550			72.5	585		
Lakemont (Lewis Creek Basin) 4	31.6	252.4	85.1	0.37	634.6 5			

1 From Northwest Hydraulic Consultants, 2002. Hydrologic Study of Kelsey Creek Basin, Bellevue, WA.
2 Volume includes all upstream regional pond storage. EIA = Effective Impervious Area, or impervious area that drains directly to the storm drain system and streams.
3 From Jensen, Bruce, 2004. I-405 Rating Curve Development, Entranco, Inc., Bellevue, WA.
4 From City of Bellevue, 2002. Lakemont Stormwater Filtration Facility, Operations and Maintenance Manual, Volume 1: Procedures Manual.
5 Emergency spillway overflow elevation.

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

Flooding kills individuals throughout the United States every year. While that has not been a major problem in Bellevue over the years, it could happen with any major flood that happens in Bellevue. During the fall and winter flood season, rivers and streams are comprised largely of cold rain and some snow, depending on preexisting conditions. They are, therefore, very cold. In addition, air temperature in the winter during flood season can also be in the thirty-degree range, although not usually below that during floods. The result is that persons caught in flood waters can drown not just from direct action of the flood but also as a complication of hypothermia.

Other problems that can compromise a person's health can develop after the flood waters have receded. Mold will grow in wet material, be it clothing, bedding, the walls of a house or the insulation under a floor. Sewage and hazardous chemicals may be present in homes, cars, or just as a layer coating peoples' property. Water and food may be contaminated. Heat and electricity may be off for some time. All of these will contribute to a decrease in not just the quality of life for individuals, but also their current and long-term health.

3.2 Health and Safety of Personnel Responding to the Incident

Response to flooding is response in hazardous conditions. Whether one is attempting swift water rescue, adding sandbags to dikes, or cleaning up debris after the waters have receded, an individual is working in a hazardous environment. Impacts to responding personnel are similar to what can affect the residents residing or working in the flood area. They include death from drowning and/or hypothermia, and either death or injury from trauma. Long-term environmental hazards such as hazardous chemicals, sewage, etc. can cause illness, either acute or chronic.

3.3 Continuity of Operations and Delivery of Services

Continuity of operations for most jurisdictions within Bellevue will not be compromised due to flooding. However, those that have their main administration or critical components of their operations within the flood zone could find their operational continuity at risk. If files, paper or electronic, are damaged or destroyed, an organization may not be able to: contact clients; assign work; complete scheduled jobs; meet deadlines; access, track, and pay accounts; or pay staff. Without a Continuity of Operations (COOP) Plan that takes these issues into account, they may not be able to continue normal operations.

The delivery of services by the local departments within Bellevue is directly related to the degree of damage by the floods, to improved property, the infrastructure, and the areas in which the damage occurs. A flood that closes roads, either with water over the road or a washout, temporarily eliminates the ability of a local jurisdiction to repair other damaged infrastructure, respond to emergencies in the affected area, or deliver the other normal goods and services expected of it. Flooded electric substations, downed lines, contaminated wells, and broken pipelines all have the same impact. In all of these cases the delivery of services will be at least temporarily halted. Damage to facilities, equipment, or files all could impact the delivery of services to residents from individual jurisdictions or agencies.

3.4 Property, Facilities, and Infrastructure

Flooding is one of the major causes of damage to and destruction of property, facilities, and infrastructure throughout the country and it is no different Bellevue. Individual property has been destroyed in most major floods to hit the County. Over time this has included homes, equipment, and transportation vehicles of various types.

Flood waters can damage or destroy a jurisdiction's facilities. Buildings can be flooded. Equipment, electronic or mechanical, can be ruined or in some cases made inaccessible due to flood waters. Files, electronic or paper, can be destroyed. Both water and the contaminants it carries can either damage or permanently ruin equipment. Flood waters can erode land containing infrastructure such as roads, power lines, natural gas, fuel, water pipelines, and sewage control facilities. It can breach levees, erode revetments, and destroy bridges. Water overtopping dams can cause damage to the dam's structure. Material carried by the flood waters, if not screened out or removed can cause damage to the hydroelectric generating components of a dam.

3.5 Environment

The impacts to the environment from a major flood could include: erosion of stream or river banks; loss of plants and animals; and contamination from chemicals, sewage, etc. picked up, transported and deposited by the flood. The contamination of both the river and the flooded landscape from the various chemicals and debris picked up from farms, homes, and businesses along the river is a serious problem. Industrial chemicals, oil and gas, sewage, old tires, etc. can all pollute the landscape where they come to rest as the water recedes. Some of these materials may take years, decades or even longer to break down and become harmless. Until that happens they can continue to degrade the environment where they have come to rest, in some cases leaching back into the water course or into ground water spreading contamination away from the site. Without cleanup, this may continue for years.

However, from an environmental standpoint, not all flooding of rivers is bad. Floods are endemic in these valleys and the low areas of the Bellevue They have changed the course of rivers, flooded low areas, uprooted or drowned vegetation, all as part of the natural environment. Areas where the river has changed course, frequently during floods, and moved away from, form oxbow lakes that attract water fowl and other animals. Where the river once ran the river, gravels gradually develop a layer of topsoil forming meadows and allowing willows, alders and other open area bushes and trees to thrive. These species attract a growing diversity of animal life which continues to change, as the forest itself changes progressing from open area species to taller trees like Douglas fir and, eventually, to shade resistant types like Western Hemlock.

Flood waters traditionally have replenished the soil. In bringing down silt from higher elevations and depositing it across the landscape in the flat areas of the Bellevue it adds a new quantity of nutrients to the soil that is already there. This contributes to the fertility of the valley floors aiding the growth of both natural vegetation and agricultural products.

Another development that occurs with flooding is the creation of snags within the river channel itself. As the river erodes the banks, trees become uprooted, fall into the river and either create coverage for fish at that spot or in many cases are transported by the flood down river and later are snagged creating more fish habitat.

3.6 Economic and Financial Condition

Economically, the after effects will depend directly on how much damage was done to local businesses, the local tax base, and the local infrastructure. While an individual home damaged by a flood can be devastating to an individual or family, it has very little effect on the overall economic condition of the community. However, when a large number of homes and businesses are damaged or destroyed it can negatively alter the tax base decreasing the ability of the local jurisdiction to pay, not just for infrastructure repair and community restoration, but also for the normal day to day programs that make the community a viable area in which to live and work. Related to this is the possibility that people may need temporary relocation assistance. If homes are not repairable, families may have to look for alternate housing.

Damage to the business and industry sector does not only affect the tax base, but also removes jobs from the local economy. The loss of jobs can escalate into other problems. The unemployed may either move away, go on unemployment, or be forced to take a lower paying job, all of which further decreases the financial stability of the community. If the loss of financial stability is not corrected, there are other social problems that arise. Those out of work can develop a loss of self-esteem that can lead to an increase in crime, alcohol and drug abuse, spouse abuse, and an increase in medical problems.

Flooding may damage the infrastructure by undercutting and washing out transportation corridors such as roads, bridges and train tracks, downing power poles, damaging pipelines, filling sewer lines with silt, and damaging levees and revetments. The time taken to repair these can take from weeks to years depending on the amount of damage and the available resources to repair them. This damage to the infrastructure will slow down the economic recovery for the jurisdiction. It can limit the reopening of businesses. It can force those that may have had no damage and operate on a just-in-time supply system but cannot get inventory, to close, at least temporarily. For some of these, the lack of commerce and therefore loss of income can prove critical. With creditors needing pay and no revenue stream, some may not be able to recover and could close permanently. Grocery stores, restaurants and food delivery systems may lose product because of the lack of power. Large chains can recover, but small independent businesses may not. Those that have a system of backup power should do much better than those that do not.

In summary, the economic viability of the community will depend on not just how much damage is done, but also on how quickly the infrastructure can be repaired, how prepared businesses are to operate in the post disaster environment, how prepared residents are for the flood and its after effects, and how well local governments and organizations can respond to the needs of the public for support, cleanup, and, if necessary, relocation.

3.7 Public Confidence in the Jurisdiction’s Governance

The reputation of any individual department within Bellevue or the public’s confidence in the city is highly dependent on the public’s perception on how well the response and recovery were handled during and after the flood. A response that either shows or gives the impression that the city is prepared and responsive to the public’s needs and that it manages a recovery to get services back and damage repaired in a timely manner will enhance a city's reputation. If, however, the perception develops that the response is incompetent, slow to react, or ignores the needs of its residents, then the reputation of the city and the confidence in its abilities will decline.

4.0 Resource Directory

- King County Flood Control District
  http://www.kingcountyfloodcontrol.org/default.aspx
- King County Department of Emergency Management
  http://www.kingcounty.gov/safety/prepare.aspx
- Bellevue Utilities Department
- https://utilities.bellevuewa.gov/
- Washington State Department of Ecology
  http://www.ecy.wa.gov/
- Western Regional Climate Center
  http://www.wrcc.dri.edu
- Corps of Engineers Northwest Division
  http://www.nwd-wc.usace.army.mil
- Copies of FIRMs, FISs, DFIRMs, Digital Q3 Flood Data, and FHBMs
  https://msc.fema.gov/portal/home
- National Flood Insurance Program: Flood Hazard Mapping
  https://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping
- Flood Safety Rules
  http://www.nws.noaa.gov/floodsafety/
- Floodplain Management Association
  http://www.floodplain.org

[1] Modified from PC HIVA, Flood Section, September 5, 2002, p.29. Web.

[2] Guidelines for Bank Stabilization Projects in the Riverine Environments of King County, 1993 http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/biostabl/PDF/9305BnkStbCh2.pdf

[3] Hyndman, D Natural Hazards and Disasters, Cengage Learning, 2008 pg 308 http://books.google.com/books?id=8jg5oRWHXmcC&pg=PA308&lpg=PA308&dq=%22mercer+creek%22+bellevue&source=bl&ots=d16mcDt8q2&sig=juD-6-3sJ3kaAiV8zHmnbe2ZD0E&hl=en&ei=ETZbTPq3MYG88gahnZH5AQ&sa=X&oi=bookresult&ct=result&resnum=6&ved=0CCQQ6AEwBQ#v=onepage&q=%22mercer%20creek%22%20bellevue&f=false

[4] Closed Depression flooding occurs where water collects in low-lying areas with little to no drainage capacity. Once flooding occurs, it can last for the remainder of the wet season until evaporation or slow infiltration lowers the water level. (PC HIVA).

[5] The Comet Program, NWA, Web.

[6] Bellevue Critical Area Update, Stream Inventory, 2003

[7] King County Flood Control District Hazard Mitigation Plan https://www.kingcounty.gov/services/environment/water-and-land/flooding/flood-control-zone-district/local-hazard-mitigation-plan-update.aspx

[8] Pierce County Flood Risk Assessment – Draft, June 2007, Pierce County Public Works & Utilities Water Programs, TETRA TECH/KCM, p. 1-6.

[9] Bellevue Planning Commission Study Session, April 14, 2010 http://www.ci.bellevue.wa.us/pdf/PCD/2010-04-14BlPCminutes.pdf

[10] King County Stream Monitoring Program: Coal Creek http://green.kingcounty.gov/wlr/waterres/streamsdata/watershedinfo.aspx?Locator=0442

[11] King County Water Quality Monitoring, http://green.kingcounty.gov/wlr/waterres/streamsdata/watershedinfo.aspx?Locator=0444

[12] USGS Fact Sheet 229-96 “100 Year Flood” https://pubs.usgs.gov/fs/FS-229-96/

[13] King County Flood Control District Website FAQs, Web.

[14] Citywide Data and Reports: Streams, Water and Land Use, Web.

Table of Contents

1.0 Introduction

As identified in the Climate Change Hazard Section, larger changes in the atmospheric conditions across the globe, due to climate change, will lead to the potential changes in how we define hazards, identify future recurrence rates, and identify vulnerabilities and related consequences. This is of important note as we document the severe weather hazards in the City.

1.1 Definition[1]

Severe weather includes a variety of meteorological phenomena that are detrimental to residents and or infrastructure in Bellevue. These atmospheric disturbances are usually characterized by strong winds frequently combined with rain, snow, sleet, hail, ice, thunder, and lightning. This definition includes unusual weather disturbances such as tornadoes or waterspouts, which appear infrequently in the region. In addition, any heavy fall of snow or rain might be considered a severe storm in its own right. Secondary hazards or impacts that can result from severe storms include flooding, landslides, power outages, and closed transportation routes limiting emergency response, pollution, and environmental damage.

For the purpose of this Plan, this hazard will not cover rain storms. Since the primary hazards that occur from heavy rain are flooding, landslides and erosion, the effects of rain will be covered in the separate Flood Hazard and Landslide Hazard sections.

1.2 Types

1.2.1 Hail

Hail storms occur when freezing water in thunderstorm clouds accumulates in layers around an icy core. Hail can cause damage by battering crops, structures, automobiles, and transportation systems. While Bellevue does get occasional hail storms, they seldom include hail stones large enough to cause major damage. However, when hailstones are large,[2] especially when combined with high winds, damage can be extensive.

1.2.2 Ice Storms

Ice storms occur when rain falls out of the warm, moist upper layer of atmosphere into a below freezing, drier layer near the ground. The rain freezes on contact with the cold ground and other surfaces. It accumulates on exposed surfaces such as trees, roads, houses, power lines, etc. The accumulated weight of this ice, especially when accompanied by wind, can cause damage to trees and utility wires. Ice storms are usually of short duration from several minutes to a few hours. However, the danger left behind will last until a rising temperature allows for thawing.

1.2.3 Snowstorms

Snowstorms or blizzards, which are snowstorms accompanied by high wind and/or poor visibility, occur occasionally in Bellevue. A snowstorm including warmer moist air from the Pacific Ocean, overrunning existing cold, subfreezing air could continue to drop snow for several days.

1.2.4 Tornadoes

Tornadoes are the most violent weather phenomenon known. Their funnel shaped clouds rotate at speeds up to 300 miles per hour or more, and large ones may affect areas from one-quarter to three-quarters of a mile or more in width, see Table 1.[3] They may travel for some distance although seldom more than 15 miles. Tornadoes are produced by strong thunderstorms. Such thunderstorms can also produce large hail, heavy rain and strong sustained winds over a larger geographic area. Tornadoes and Funnel Clouds do occasionally occur in the area, though they are usually small.

Table 1. Fujita Tornado Scale

SCALE	WIND EST. (MPH)	TYPICAL DAMAGE
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains were overturned; most trees in some forested areas were uprooted; heavy cars were lifted off the ground and thrown some distance.
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261-318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur.

This scale is now also supplemented with an enhanced scale, Enhanced Fujita Scale[4], that incorporates damage indicators and degree of damage.

1.2.5 Windstorms

There are four main types of Windstorm tracks that impact the Pacific Northwest and Bellevue as identified in Figure 1.

Two basic windstorm patterns have emerged in King County: the South Wind Event and the East Wind Event. South wind events are generally large- scale events that affect large portions of not only King County, but also most of Western Washington and possibly Western Oregon. In occasional cases, they may even affect areas as far south as Northern California. In contrast, East Wind Events are more limited. High pressure on the east side of the Cascade Mountain Range creates airflow over the peaks and passes, and through the funneling effect of the valleys, the wind increases dramatically in speed. As it descends into these valleys and then exits into the lowlands around Enumclaw and Buckley, the wind can pick up enough speed to damage buildings, rip down power lines, and destroy fences. Once it leaves the proximity of the Cascade foothills, the wind tends to die down rapidly, causing little damage to the rest of the County.

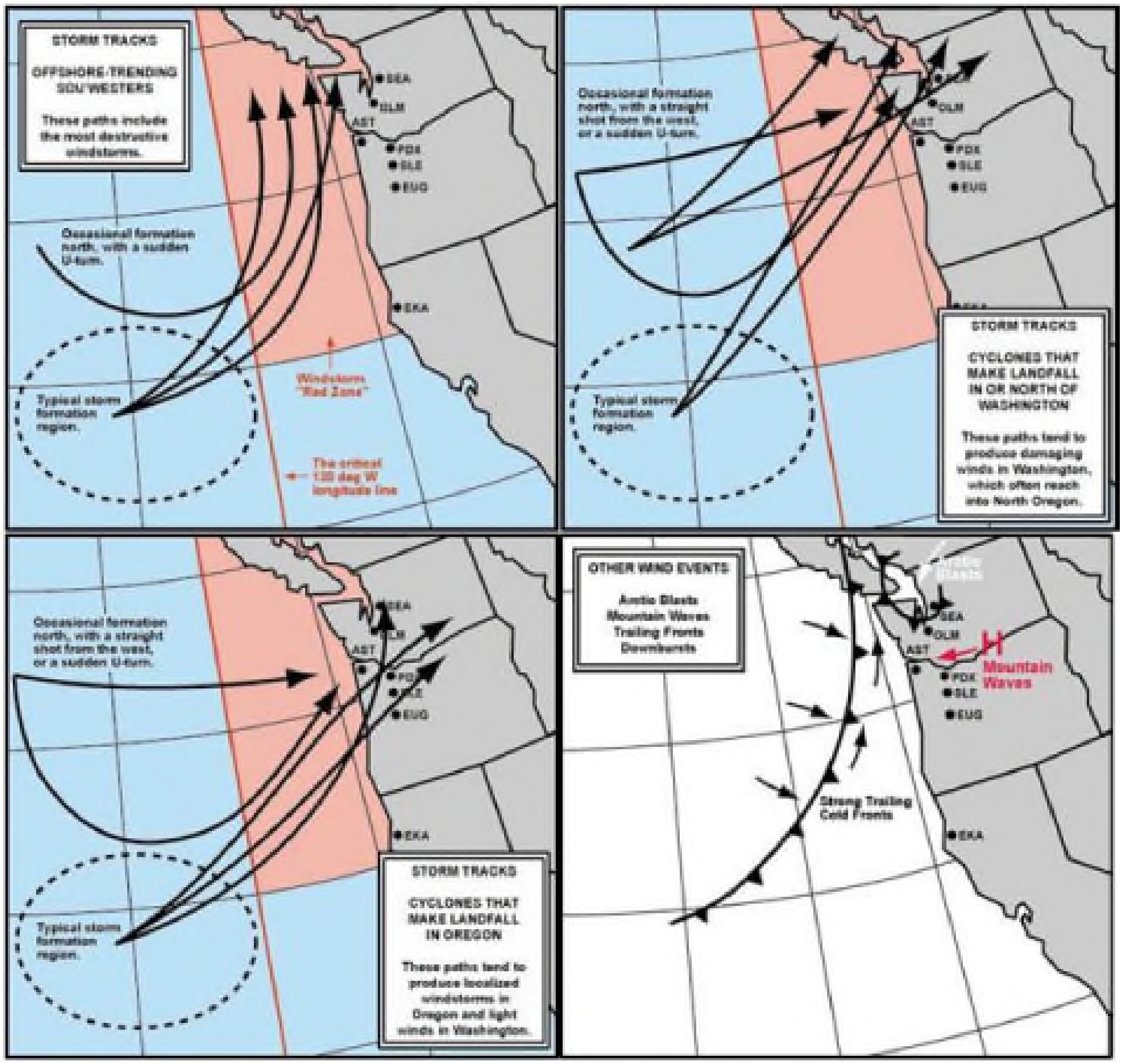


Figure 1. Windstorm Tracks[5]

2.0 Profile

2.1 Location and Extent

Severe weather of all types directly and indirectly affects the all of King County. Due to variations in geographic location and elevation, certain areas of the area are more vulnerable to certain types of severe weather, including: windstorm, snowstorm, and ice storm. Maps are currently available that depict wind events. Windstorms directly and indirectly affect all of Bellevue. The map shows the level of tree cover, trees have the ability to amplify the effect of wind and the extent of severe windstorms with predominant wind direction.

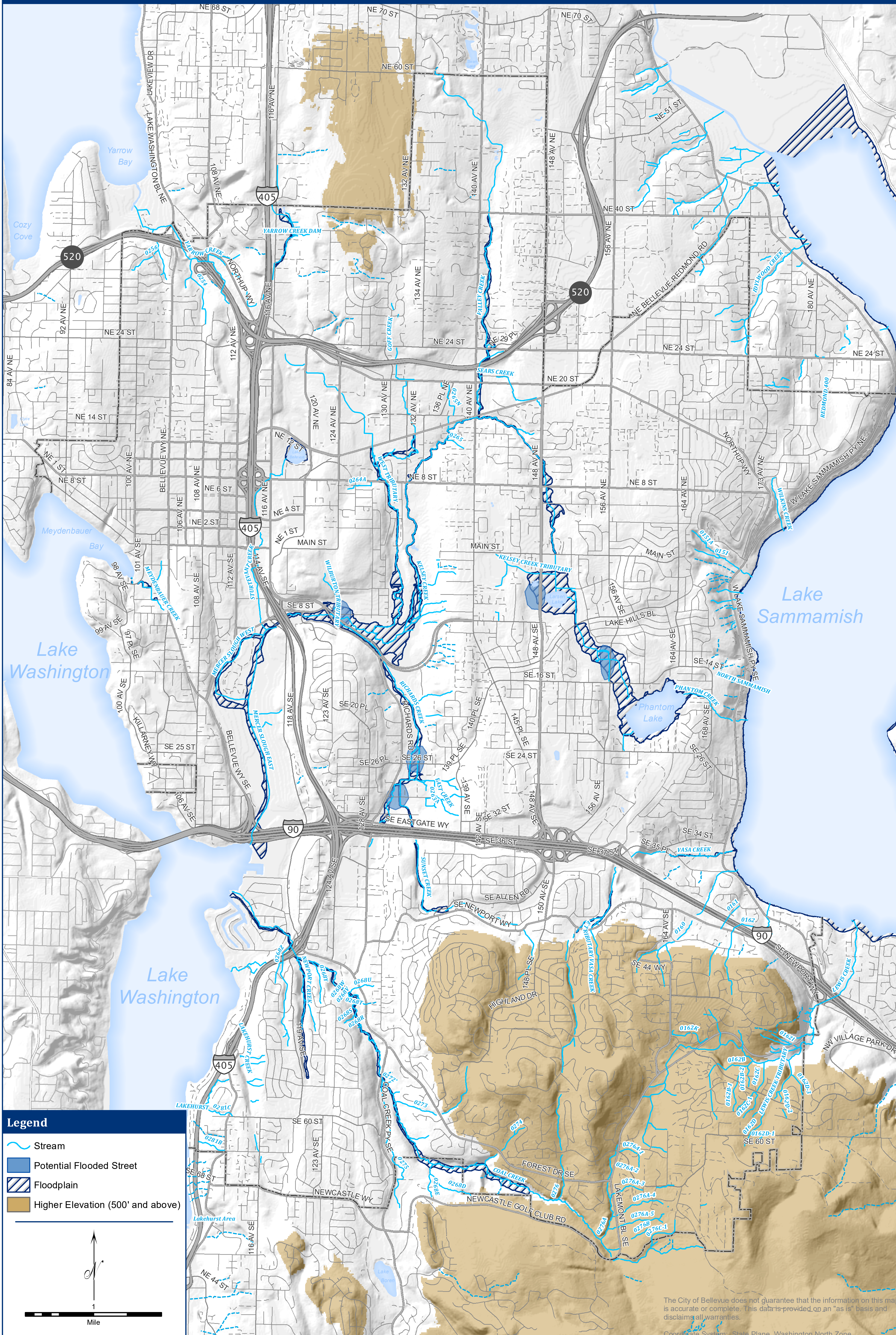
One important ingredient in the recipe for severe weather in the City is related to the Puget Sound Convergence Zone. The zone sets up when northwest winds in the upper atmosphere become split by the Olympic Mountains, then re-converge over Puget Sound, causing updrafts (see Figure 2). Those updrafts can lead to convection and then rain showers or more severe weather. This zone can enhance severe weather in the Puget Sound and slide north and south increasing or decreasing the location and extent on severe weather incidents.

Figure 2. Puget Sound Convergence Zone

Figure 3 identifies a number of Meteorological Hazards that impact the City of Bellevue. These hazards include: potential flood hazard areas and areas of elevation great than 500ft.The wind hazards are currently not incorporated into this map. Figure 4 identifies the snow response priority routes in the City of Bellevue.

Meteorological Hazards

City of Bellevue
GIS Services



Date: 9/21/2016 File Name: V:\EOC\arcgis\EOCmapSet\EOCMapSet2016\MeteorologicalHazards_11x17_10-2.mxd IT Department

2.2 Occurrences

Historically, over the years Bellevue has had a number of instances of severe weather. While not all of these have caused major long-term problems, they all have disrupted people's day-to-day activities and posed a burden, especially on the poor and those with reduced mobility. Table 2 lists some of the other notable severe weather in King County.

Table 2.Severe Weather Events in King County 1958 - 2013

Date	Type	Deaths or Injuries	Property Damage
01/2012 16th-22nd	4-6 inches of Snow, Followed by .5 to .75 inches of inches	None	Unknown
Description: Record or near-record snowfall and ice impacted most of Western Washington. -12—0112 State Incident Number. Landslide on Lake Sammamish Parkway damaged 3 homes.2 yellow tag and 1 red tag.			
11/22/2010	4-8 Inches of Snow	None	Unknown
Description: Record or near-record snowfall impacted most of Western Washington.			
12/2008	Record Snowfall	None	Unknown
Description: Record or near-record snowfall impacted most of Western Washington for over a week, this was accompanied with a prolonged period of arctic air in place. Incident became FEMA Disaster #DR-1817 and the City received Stafford Act Public Assistance Grant Funding to support Recovery Efforts.			
12/14/2006	High Wind (60-75 mph)	None	$750,000
Description: In Washington, peak winds reached 80 to 90 mph along the coast and elsewhere 60 to 75mph. A few locations had gusts as high 85 mph in the interior. The windstorm, the strongest since the 1993 Inauguration Day Wind Storm, blew down thousands of trees and knocked power out to close to 1.5 million customers in western Washington. The strong winds damaged major transmission lines, power poles and other power utility infrastructure. Trees also fell onto houses, street signs, streetlights, parked cars, fences, railings and rooftops. 90 % of the City of Bellevue lost power. City EOC was activated for 7 days. Incident became FEMA Disaster #DR-1682 and the City received Stafford Act Public Assistance Grant Funding to support Recovery Efforts.			
1/2004	4-10 Inches of Snow	None	Unknown
Description: Record or near-record snowfall impacted most of Western Washington. A very cold air mass in place was overrun by a large warm pacific frontal system causing road closures, and the shutdown of some government s and businesses for the incident.			
08/03/1999	Lightning	None	$650,000
Description: Over 1000 lightning strikes were recorded in a four-hour period. One man was struck by lightning while standing under a tree, and another man while standing in water next to his boat. At its peak, the storm knocked out power to about 20,000 customers.			
04/03/1997	Lightning	None	None
Description: A woman holding an umbrella was struck by lightning.			
12/29/1996	Ice/snow/rain	None	$31.5 M
Description: The December 26—31 ice/snow/rain storm caused about $315 million in insured and uninsured damage (in all of Washington). The storms directly or indirectly claimed 16 lives and sparked a state of emergency in 30 counties. Seattle normally averages 1.44 inches of precipitation between Dec. 26 and Jan 2. It received 8.35 inches during those eight days. The total number of customers without power at one time was nearly 300,000and some people went a week without power. The damage affected people for weeks. Incident became FEMA Disaster #DR-1159 and the City received			

Date	Type	Deaths or Injuries	Property Damage
Stafford Act Public Assistance Grant Funding to support Recovery Efforts.			
12/12/1995	High Wind (40 -55 mph)	None	None
Description: In western Washington, peak winds reached 78 mph at Harbor Island in Seattle. Bellevue experienced scattered power outages and trees downs. At a high point 15 roads were blocked by trees or downed power lines in the City. The 520 Bridge was closed for half a day. The Communication Center received approximately 1400 calls during the incident. Incident became FEMA Disaster #DR-1079 and the City received Stafford Act Public Assistance Grant Funding to support Recovery Efforts.			
01/08/1995	Freezing Rain	None	None
Description: Several reports of icy roads due to early morning, freezing rain were received from the east side of the county were several cars slid off the roads due to slippery conditions.			
12/30/1994	High Wind	None	None
11/01/1994	High Winds	None	None
Description: Winds were reported 45 to 55 mph in some areas along the Puget Sound with numerous power outages due to fallen tree limbs on power lines.			
03/21/1994	High Winds	None	None
08/23/1993	Lightning	1	None
Description: A jogger struck by lightning while running in the 5100 block of West Lake Sammamish Parkway never regained consciousness and died 17 hours later.			
05/17/1989	Thunderstorm Wind	None	None
10/22/1985	Thunderstorm Wind	None	None
06/08/1972	Hail (1.50 in.)	None	None
12/22/1971	Tornado (F0)	None	$25,000
12/23/1969	Thunderstorm Wind	None	None
12/12/1969	Tornado (F3)	None	$250,000
08/18/1964	Tornado (F0)	None	None
09/28/1962	Tornado (F1)	None	$250,000
03/03/1956	Thunderstorm Wind (80 knots)	None	None

2.3 Recurrence Rate

Based on the previous history of severe weather that has impacted Bellevue and information from the National Weather Service,[6] the probability of recurrence for the severe weather hazard in Bellevue is determined to be a five years or less occurrence.

2.3.1 Hail

To date the various hail storms in the City have caused limited damage to some property. The only reported hail storm with hail large enough to have caused extensive damage in the past was located in the Cascades. Minor hail storms which do not cause major damage happen on almost a yearly basis somewhere in the County. Since large hail is such a rare occurrence, it is an estimated 100 year or fewer occurrences.

2.3.2 Ice Storms

The record shows a few significant ice storms in the past 100 years. The probability of recurrence is estimated as a 25 years or fewer occurrence.

2.3.4 Snowstorms

Snowstorms of consequence are estimated as a 10 year or less occurrence.

2.3.5 Tornadoes

While not as frequent as windstorms, there have been six recorded tornadoes in the past 110 years. Given this frequency, the probability of recurrence is estimated as 25 years or less.

2.3.6 Windstorms

Wind has played a prominent role in the history of emergencies and disasters impacting the community. Major events have occurred 12 times during the past 70 years and caused millions of dollars' worth of damage (see Figure 5). Bellevue can expect some wind-related problems on an annual basis, although few of these cause extensive damage. Based on the historical frequency of large windstorms, the probability of recurrence is estimated as 10 years or less.

Figure 4. Tacoma Narrows Bridge, November 7, 1940 Windstorm[7]

3.0 Vulnerabilities and Consequences

3.1 Health and Safety of Persons in the Affected Area at the Time of the Incident

As can be seen above, the impacts from severe weather can be largely dependent on the type of incident. Since the severe weather can range from snowstorms to tornadoes each one is factored out in this section.

3.1.1 Hail

Over the years, hail has not been a major factor in Bellevue. While injury and even death to people and animals that are in the wrong spot at the wrong time can occur, the size of hail that impacts Bellevue is usually too small for that to happen. While the damage to cars and other items out in the weather can be dramatic, direct impacts to people are usually limited to minor stings and bruises. However, should a hailstorm with large hail stones occur, individuals could be injured and in rare instances killed.

3.1.2 Ice Storms

Direct impacts on the general public from ice storms can include cold related injuries like hypothermia, or injury and death from accidents. Accidents can occur either through falls due to ice on walkways or on the ground, or auto accidents due to the ice on the roads. In addition, overloading on trees or utility wires can cause limbs or wires to break. These can fall either on individuals, automobiles, or homes causing damage or traumatic injuries or in the case of downed utility wires fires could start or individuals could be electrocuted.

Individuals on home-based life support systems could be adversely impacted by the power outages if they do not have a backup power system. A combination of cold and lack of power will force many people to find alternate ways of cooking and heating. Those who attempt to cook or heat with barbecue grills or hibachis run the risk of carbon monoxide poisoning.

3.1.3 Snowstorms

Direct impacts on the general public from snowstorms can include cold related injuries like hypothermia or frostbite. This can be especially prevalent in the older population and those who lose heat and power for extended periods of time.

Access to normal businesses, health facilities, government offices, etc. can all be compromised due to snow. In many cases the hills and slopes of many of the roads and streets restricts individuals' movements. This remains the case until such time as road crews are able to either plow or sand the roads and streets. There is an increase in injuries and deaths from accidents and in some cases increases in heart attacks from individuals attempting to shovel snow away from walkways and driveways.

Depending on the depth of the snow, the length of time it stays around, and the number of downed tree limbs, or trees in lines, road closures could isolate some individuals; possibly for days (see Figure 6).

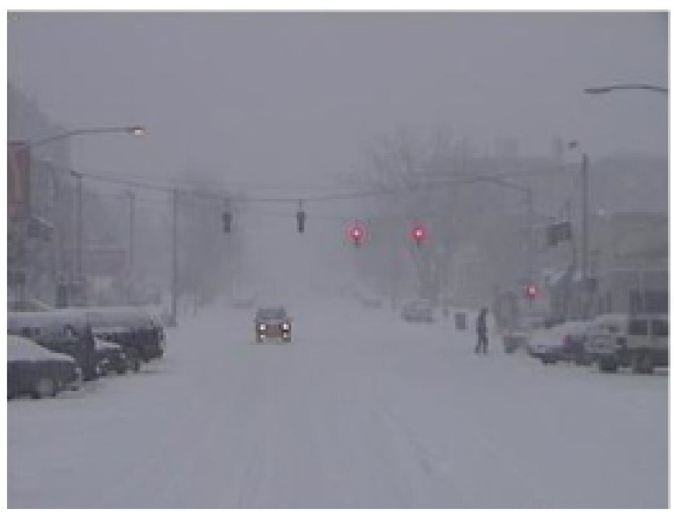


Figure 5. Snowstorm, January 2004

Individuals on home based life support systems could be adversely impacted by the power outages if they do not have a backup power system. A combination of cold and lack of power forces many people to find alternate ways of cooking and heating. Those who attempt to cook or heat with barbecue grills or hibachis run the risk of carbon monoxide poisoning.

3.1.4 Tornadoes

Most tornadoes that have historically impacted the Puget Sound have been rather small. The exception in the region is the October 1899 tornado in Pierce County. The results of any tornado can be devastating to those caught in one. However, the number of people injured or killed and the number of houses, businesses, community facilities, etc. destroyed or damaged varies dramatically depending on the size of the tornado, where it touches down, and how long it is in contact with the ground.

Members of the community caught in a tornado can expect that many of them could have major injuries or be killed by the tornado. Flying debris and collapsing buildings are the main cause of injury and death.

3.1.5 Windstorms

Windstorms are one of the emergencies that impact all of Bellevue on a regular basis. Some are much more damaging than others. For those like the Hanukkah Eve Windstorm of 2006, see Figure 7[8], the impact on the public can be very severe. Over 80% of Bellevue was without power for a period.[9]

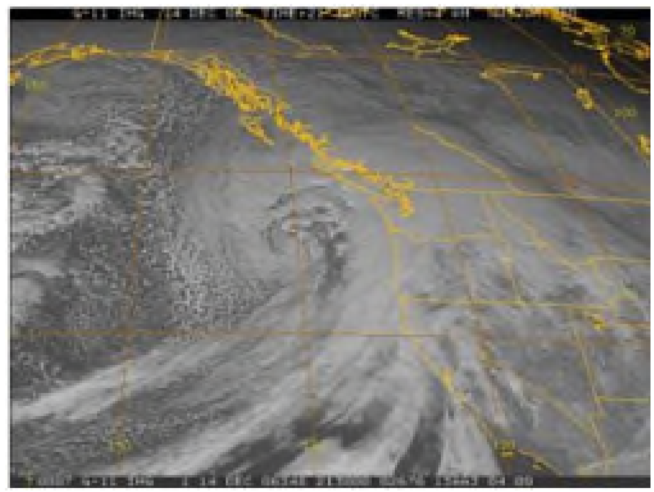


Figure 6. Satellite Image, Hanukkah Eve Windstorm

Individuals can be hit by flying debris or falling limbs and trees. During past windstorms cars have been crushed and houses split by falling trees.

Figure 7. December 15th 2006 Windstorm Damage on SE 42nd St and 156th Ave SE

Individuals can suffer injury or death. Downed wires have been known to electrocute individuals, as happened in Gig Harbor in the Hanukkah Eve Windstorm of 2006 (see Figure 8).

Large numbers of power lines down, combined with trees and limbs on roads can keep fire, medical and law enforcement personnel from responding to individual incidents. During heavy wind first responders may have to wait until the wind abates before being able to respond to calls. Individuals on home based life support systems without a backup power system could be adversely impacted by the power outages.

With power outages sometimes lasting for days there are individuals who attempt to cook or heat their homes with a barbecue or hibachi. For these individuals and families the buildup of carbon monoxide can be fatal.

3.2 Health and Safety of Personnel Responding to the Incident

3.2.1 Hail

First Responders have very similar safety and health concerns to those of the general public regarding hail. While injury and even death to people and animals that are in the wrong spot at the wrong time can occur, the size of hail that impacts Bellevue is usually too small to cause major damage. Hail storms here will result in first responders seeking shelter for the short period of time the hail is falling. There should not be any different result for the first responders than for the general public. Just as the general public injuries are usually limited to minor stings and bruises, so are the first responders.

3.2.2 Ice Storms

First Responders can expect similar injuries as the general public. These could include cold related injuries like hypothermia, or injury and death from accidents. Accidents can occur either through falls due to ice on walkways or on the ground, or in response vehicles due to the icy roads. In addition, over loading on trees, utility wires, etc. can cause breaks and limbs or wires can fall either on individuals, automobiles, or buildings causing damage or traumatic injuries, or in the case of downed utility wires fires could start or individuals could be electrocuted. Road crews will have to be careful of downed lines and work in conjunction with utility workers to open roads.

3.2.3 Snowstorms

First responders operating in the hazardous environment of a snowstorm, have the potential to get cold related injuries if they are not adequately protected from the elements. Due to the amount of time spent on snow covered roads responding to storm related problems, they also have a potential for traffic accidents.

3.2.4 Tornadoes

During the actual tornado itself, responders are like any other resident. They are as likely as anybody else to be injured or killed by the storm. The Greensburg Kansas tornado, see Figure 9, gives a good impression of what can happen as a tornado passes through a community. Once the tornado has passed, however, they will enter the area where the damage has occurred. With a large tornado this puts them in a hazardous area. They could be exposed to live electric wires, hazardous chemicals, and unstable debris.

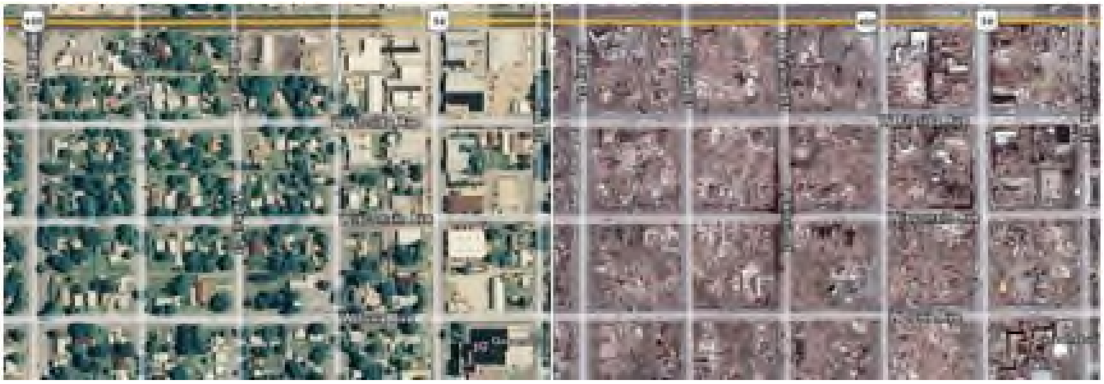


Figure 8. Before/After Tornado Damage, Greensburg, KS, May 4, 2007[10]

3.2.5 Windstorms

First responders will be putting themselves in harm's way throughout windstorm incidents. They can be hit by flying debris or falling limbs and trees as well as coming in contact with downed power lines. Their response vehicles have been crushed and over the years there are the occasional injuries. In the aftermath of the windstorm, first responders by the nature of their work are putting themselves in harm's way by clearing roads, restringing wire, and cutting trees.

3.3 Continuity of Operations and Delivery of Services

3.3.1 Hail

Hail has not traditionally caused more than the most minor slowdown of any public services within the boundaries of Bellevue. Due to the shortness of the normal hailstorm and the size of the normal hailstones, it is not expected to disrupt any organizations continuity of operations or the delivery of services to the public for more than a short period of time. Should there be an increase in size of the hail stones and an increase in the length of the storms, damage might begin to appear on equipment, facilities and people.

3.3.2 Ice Storms

While ice storms themselves tend to last only a few hours at the most, the after effects can last for days. The actual problem with iced roads, falling branches, and other types of damage will continue until the temperature warms enough for the ice to melt. In a situation where the temperature remains below freezing for a long period of time, there may be continuity of operations problems for some local jurisdictions or agencies. The inability of agencies that have a very small staff to staff their operations if roads are closed due to ice or downed power lines could cause their operations to lapse for short periods. For most jurisdictions, however, the closing of roads and the related damage will slow down rather than stop normal operations.

An ice storm can slow down, and in some cases, halt the delivery of services over the entire city and for any jurisdictions or agencies located within its borders. The loss of power from the breaking of lines has in the past, and will again, affect thousands of customers. Ice coated streets do not allow the normal movement of emergency vehicles of any type within their normal response times, so the delivery of all types of services will be slower than normal or even non-existent until such time as the streets are once again passable. Delivery of services will rapidly improve once the temperature warms and the ice begins to melt.

3.3.3 Snowstorms

Normal amounts of snow in the populated portions of Bellevue have a limited effect on the continuity of operations of most Departments in the City. Most, if not all, are able to maintain operations of some sort through the few inches of snow that is normal in the City (see Figure 10).

A snowstorm equivalent to the late December 2008 multiple storm system snow incident inhibits movement enough that some organizations would be totally unable to operate. Such a storm can almost shut down the entire city and, depending on the ensuing temperatures, governmental agencies, schools, businesses and services might be shut down for days.

Snow covered streets do not allow the normal movement of vehicles of any type. For light snow, there could be minor slowdowns in the delivery of services. For heavy snow, jurisdictions and agencies could all get behind in their normal operations. With a very heavy snow fall, especially when combined with wind, the delivery of all types of services will be slower than normal or even non-existent until such time as the streets are once again passable. Delivery of services will rapidly improve once the temperatures have risen and the roads have been plowed and are open to traffic. Even with the roads opening up, the electric utilities could take several days to get all the lines back up in all the outlying areas of the city.

Figure 9. Snowplows Clear Bellevue Streets

3.3.4 Tornadoes

A small tornado touching down in Bellevue should not impact the continuity of operations for any of the entire city. It is possible that a small tornado could directly damage a city facility, including City Hall. In that case, their continuity of operations would be impacted. This is, however, unlikely.

A very large tornado on the scale of the one in 1899, by damaging a large area could damage or destroy a large proportion of the city. That could either physically or administratively limit continuity of operations. Having the administrative offices destroyed, possibly along with the staff being injured or killed, would make the normal day-to-day operations difficult to maintain. Combining this with broken pipes in the destroyed buildings, phone and electric lines down, streets covered with debris and possible fires from broken gas lines would increase the difficulty of maintaining the continuity of operations.

Within the area directly impacted by the tornado the delivery of services is directly related to the size of the tornado. Small tornadoes will have little to no effect on service delivery, while a large one, because of the amount of damage done, could completely take out service delivery to the impact area. This would include blocking roads, and breaking gas, water and electric lines. Within the damaged area, it would take time to rebuild the damaged homes and businesses and begin to reconnect them to the damaged utilities.

Due to the localized nature of the tornado, the delivery of services to the rest of the city should be minimally impacted. The main exception to this could be electric. The damage to the power infrastructure could have a direct effect on surrounding neighborhoods, businesses, and jurisdictions, all of which could experience power outages over a very broad area, until such time as the power companies can make repairs and restore services.

3.3.5 Windstorms

Operations for most if not all of the departments of the City should be able to continue, albeit at a reduced level in some cases. Damage to the administration, infrastructure and a reduction in response are very possible consequences of a major windstorm. However, its operational structure would probably not entirely shut down for any department. Damage to administrative facilities and operational equipment would put various organizations in a bind in so far as maintaining their normal support to the public, but would not totally shut down their operations.

The impacts to the delivery of services could impact the entire city or in some cases, only a portion of it. This is largely dependent on the type of windstorm. With heavy winds there could be extensive debris on the roads, broken lines and if some buildings are damaged, there could be broken water or gas pipes.

Figure 10. December 15th, 2006 Windstorm Damage at Northrup Way and East of NE 10th St

With a south wind event, essentially, the entire populated area of the county will be impacted. This is equivalent to the Columbus Day windstorm of 1962 or the Hanukkah Eve Windstorm of 2006. In these two cases, there was major damage to the trees and power lines (see Figure 11). Many roads were totally closed and some people were without power for over 10 days. In situations like this, the local jurisdiction is not capable of maintaining an adequate delivery of services. In order to bring the services back up to their normal level, they will possibly have to staff the recovery operations for weeks.

3.4 Property, Facilities, and Infrastructure

3.4.1 Hail

Large hailstones can damage property, facilities, and some infrastructure like electrical transformers, etc. However, in Bellevue, the size of hail that has fallen historically has caused minimal damage, if at all, to any of the jurisdictions' facilities or infrastructure in the city.

3.4.2 Ice Storms

Ice storms can cause damage to public and private property, jurisdictions' facilities and local infrastructure. Overloaded tree limbs breaking off and landing on cars, buildings, and equipment can cause significant damage. Overloaded wires can break causing fires. Ice on roofs adding extra weight can cause damage, especially on lightly built structures. A 50-foot conifer can accumulate as much as 99,000 pounds of ice during a storm[11], and when combined with wind, may topple causing much more damage than it would have otherwise.

3.4.3 Snowstorms

Typical Bellevue snowfall of a couple of inches does not normally cause much damage to the facilities, property, or infrastructure, around the city. It slows down traffic and causes an increase in traffic accidents, but little more. In contrast, an unusually heavy storm like the January 16, 1950 storm could cause extensive damage to facilities, equipment and infrastructure. In a case like this, power lines could come down, equipment could be damaged, and facilities could have extensive damage from excessive weight on roofs.

3.4.4 Tornadoes

Depending on the track and size of the tornado, it could devastate the facilities and infrastructure. The last few tornadoes to strike King County have been relatively small and have not caused appreciable damage to the facilities or infrastructure of any jurisdiction in the county. If a tornado the size of the Greensburg Kansas tornado of May 4, 2007 were to strike Bellevue, we would have extensive damage to property, facilities, and infrastructure. Descriptions of the 1899 tornado to hit Pierce and Lewis counties appear to put it in the same category. That tornado destroyed old growth forest with trees up to four feet in diameter and left a path of destruction 300 to 600 yards wide and 50 miles long. A repeat of that event passing through the populated portions of the Bellevue could destroy or damage some major pieces of infrastructure in addition to family homes and businesses.

Figure 11. Impacts to Property and Infrastructure

3.4.5 Windstorms

The impacts to facilities, property and infrastructure include downed power lines, closed roads, see Figures 12 and 13[12], damaged or destroyed equipment and facilities can be extensive from major windstorms.

Power loss may occur to portions of the Bellevue for over a week after a major windstorm. This means that traffic lights will be out at crossings and emergency facilities without generator backup will not be able to function. Having many roads covered with debris would virtually shut the city down. Response vehicles and facilities may have trees or branches fall on them. Blowing debris, such as parts of roofs, fences, metal signs, and even sand can all cause damage to property and equipment. Strong wave action from windstorms can erode shoreline areas.

3.5 Environment

3.5.1 Hail

Environmental impacts are some of the more serious effects resulting from hailstorms in Bellevue. Hail tends to cause extensive damage to crops and other plants. It can abrade or tear leaves; break stalks, stems or branches; destroy blossoms; and bruise fruit. All this will cause short-term environmental damage. However, due to the normally small size of hail in Bellevue, this damage seldom lasts more than one year.

Figure 12. December 14th, 2006 Windstorm Kelsey Creek Shopping Center

3.5.2 Ice Storms

Ice storms cause environmental damage by placing an excess amount of weight on plants that can break the limbs off large trees, crush small shrubs, and injure or kill animals. Conifers are a little more resilient to the effects of the ice than are deciduous trees and can accumulate large quantities of ice. When combined with wind, however, they then can topple with considerable force. Icing can further damage plants by sealing the leaves, stems, and buds from the air, suffocating these parts. When the ice sheet covering the ground persists for a lengthy period it can also suffocate some plant species.

Animals that are accustomed to snow cannot dig through the ice to reach their normal food supply and so starve. Some become encased in ice themselves and die[13]. With enough time, the environment will regain its normal vitality, but depending on the amount of damage done it could take from a few months to several years.

3.5.3 Snowstorms

Light snowstorms have very little impact on the environment. The plants and animals that are endemic to the area are used to this type of winter weather. With a heavy snowfall, broken limbs from trees will be one of the most visible signs of damage. If the snow remains deep for an extended period of time, some large animals may starve to death being unable in deep snow to cover enough terrain to find food. Regardless of the initial damage done by the storm, the scars on the environment will usually disappear in a matter of months.

3.5.4 Tornadoes

Tornadoes, by their very nature, can destroy everything in their path. The 1899 tornado, according to news reports, cut a 300 to 600 yard swath through forest, ripping up trees four feet in diameter. A repeat of a tornado of that size could cause even more environmental damage today. In 1899, it tore through forest and farms. While the environment suffered the loss of many trees, it began to repair itself immediately. New vegetation would have filled in the open areas and eventually the forest would have recovered.

The environment that the tornado would travel through has changed considerably. Forests have been logged and are now in at least their second if not third re-growth. Instead of a few farms spread apart you have a modern metropolitan area. A tornado that touches down in the wrong area could destroy oil storage tanks, and hundreds of other hazardous chemical storage sites. All the material, especially hazardous materials that are transported on the highway system or through the port by ship or rail, would be at risk of being spilled. Many of these could cause drastic long term environmental damage possibly lasting for many decades. Spills into the rivers or Commencement Bay could decimate fish populations for years.

3.5.5 Windstorms

The impacts include downed trees and limbs. In some cases, entire stands of trees can blow down in a single windstorm, see Figure 14. A single tree falling at any one point is a very minor environmental problem that will not even be noticed. However, a full stand of trees falling together leaves a scar that will take decades to regrow. Loss of forest increases erosion, and increased erosion leads to more silt in the rivers. Fallen trees can block streams or cause log jams on rivers that can cause the water to back up with possible flood consequences.

Along coastal areas strong winds, especially when combined with high tides can erode beaches. The wave action can undercut hillsides that extend down to the water increasing the possibility of landslides.

Wind damage to homes, businesses or industry can cause further environmental damage through the release of hazardous chemicals. Natural gas lines can be broken, leading to fire. Very strong winds can tip over trucks or cause the driver to have an accident leading to a spill. Depending on the quantity and type of chemical the spills will be more or less damaging.

Figure 13. Trees Downed from a Storm

3.6 Economic and Financial Condition

3.6.1 Hail

Economic impacts from hail, even the relatively small hail that occasionally falls here in Bellevue, can be dramatic. Economic damage may come about if the hailstones are large enough to damage cars, or equipment being used outside and building exteriors.

3.6.2 Ice Storms

The economic or financial impact of an ice storm can be extensive. Damage to facilities due to the weight of the ice can be in the millions of dollars. Closed roads and power outages, either due to ice and debris on the road, downed power lines, or damage to electrical power facilities will cause closure of businesses. This can lead to lost revenue for the business and lost income for employees. Damage to homes and personal property can also be high, leading to residents incurring increased debt.

3.6.3 Snowstorms

Most snowstorms to strike Bellevue have a very limited impact on the local economy. They are more of a short-term inconvenience than anything else, melting off in a few hours or a day. However, a major storm that knocks out electricity and closes roads, schools, and businesses could have a major impact on the local economy (see Figure 15). The inability of retail outlets to maintain a certain level of commerce, restock, and in some cases lose stock from either damage from the cold or exceeding expiration dates on perishables could cost them millions of dollars. When employers close their business even for a few days, the ripple effects include not just lost goods but lost wages for employees. With lost wages, the employee becomes unable to pay bills. If this goes on for very long, the lost wages make it difficult for the worker to pay the normal day-to-day bills, much less support the retail economy.

Figure 14. I-405 During the January 2012 Snowstorm

3.6.4 Tornadoes

A small tornado hitting the unpopulated areas of Bellevue would have negligible economic or financial consequences for the city. In contrast, a large tornado moving through an industrial area, a populated area, or an area with a concentration of businesses could devastate the local economy. This would be especially true if a large number of businesses or the industrial base of the city were affected. Homes and some businesses could be rebuilt and be up and running within a year or so. Larger scale projects like malls or the port industrial complex could take many years to rebuild and restaff.

3.6.5 Windstorms

The economic and financial aspects of a windstorm can be extensive. Local damage to homes and businesses can run into the millions of dollars. When business or industry is damaged there can be extensive loss of employment. This leads to individuals and families not being able to make their bill payments, including rent or house payments. People unable to work will need assistance, which puts a burden on the taxpayer. If the situation does not resolve itself the jurisdiction could eventually have some people leave the area.

3.7 Public Confidence in the Jurisdiction's Governance

3.7.1 Hail

Hailstorms should not cause any loss of confidence in Bellevue.

3.7.2 Ice Storms

The reputation of local jurisdictions and agencies in the wake of an ice storm is partly dependent on the weather itself. A heavy ice storm that maintains below freezing temperatures for a long period of time will continue to tax local resources throughout that period. Residents will become more adamant in demanding relief from power outages and other storm related problems. In contrast, an ice storm that does its damage and then melts quickly allowing for a rapid recovery will not damage the confidence of residents in the local jurisdictions or agencies.

3.7.3 Snowstorms

Small snowstorms will have little if any impact on the residents' confidence in local agencies or jurisdictions. With large storms depositing a great deal of snow throughout Bellevue, two factors will affect peoples' perceptions on the competency of the local jurisdiction. The first is how fast the roads are brought back to being passable and the second is how quickly their electricity is returned. If these two things are brought back to normal quickly, confidence in the local entity will be high. If, on the other hand, things are slow and the perception develops that not enough is being done, then confidence in the local jurisdiction will falter and it will develop a reputation for either incompetence or not caring about the residents it serves.

3.7.4 Tornadoes

In the wake of a tornado the confidence in any individual entity will be based on how quickly it responds to the needs of the affected community. People know that tornadoes are extremely damaging and there are not many of them that actually form in Bellevue. A tornado, by its very nature, is more localized in its damage. Rather than being a county-wide phenomenon, the path of destruction will be well defined. Any jurisdiction directly impacted by the wind should be able to begin recovery operations immediately. If assistance is needed, and it hasn't been for the last few tornadoes, it would be available from nearby agencies and jurisdictions on short notice.

If the perception, real or not, is that any agency or jurisdiction is not responsive to the needs of the community affected by this incident, then there will be a decrease in confidence in that organization. If, on the other hand, the entities involved act quickly to get the community back on its feet, its reputation should not be hurt.

3.7.5 Windstorms

The Hanukkah Eve Windstorm of 2006 that impacted all of Western Washington provides a good example of the results of communities attempting to pull together to resolve the problems that arose. It can be used as a template to see what reaction the public will have to the work that public entities will have done in attempting to bring the community back to normal.

Initially, the public is very supportive of the actions of first responders. However, as time goes on and there are still pockets of homes or businesses without electricity or phone service, the people who live in these areas will begin to lose faith in the abilities of the local entity. They begin to wonder why they do not have services and while other people do. Eventually, they begin to feel that the local jurisdiction has either forgotten about them or that they are considered to not be important enough to warrant a quick response. If a jurisdiction cannot overcome these fears, they can escalate into confrontations between individuals and those working to restore services.

4.0 Resource Directory

- King County Department of Emergency Management
  http://www.kingcounty.gov/safety/prepare.aspx
- Seattle Office of the National Weather Service
  https://www.weather.gov/
- Western Regional Climate Center
  http://www.wrcc.dri.edu
- Office of the Washington State Climatologist
  http://www.climate.washington.edu/
- Coastal Zone Management Programs by State
  https://coast.noaa.gov/
- National Severe Weather Laboratory Estimates the Likelihood of Severe Thunderstorm Hazards in the United States
  http://www.nssl.noaa.gov/hazard
- National Weather Service Climate Prediction Center
  http://www.cpc.ncep.noaa.gov

[1] This entire section has been modified from PC HIVA, Storms Section, September 5, 2002, pp.41-45. Web.

[2] The largest hailstone in US history was a 7" wide chunk of ice slightly smaller than a soccer ball. It is referenced in National Geographic News on August 4, 2003, Web. In contrast the heaviest hailstone recorded comes from northern India on March 10, 1939 and weighed 7.5 lbs. It is referenced on the Multi-Community Environmental Storms Observatory website.

[3] Developed in 1971 by T. Theodore Fujita of the University of Chicago, NOAA Storm Prediction Center, http://www.spc.noaa.gov/faq/tornado/f-scale.html

[4] The Enhanced Fujita Scale http://www.spc.noaa.gov/efscale/

[5] The Storm King, Windstorm Events Roughly Broken Down by Track Type, Web.

[6] Phone conversation with Ted Buehner of the National Weather Service, NOAA, Department of Commerce, Seattle office, March 6, 2008.

[7] Bridge midsection crashing into the waters of the Tacoma Narrows, November 7, 1940. Bashford and Thompson Photo. PH Coll. 290.36 University of Washington Libraries. Manuscripts, Special Collections, University Archives Division.

[8] NOAA Satellite Photo of Hanukkah windstorm approaching the Washington Coast, 12/13/06.

[9] History Link Essay http://www.historylink.org/index.cfm?DisplayPage=output.cfm&FileId=8042

[10] Photos from before and after of Greensburg Kansas, Google Earth and May 2007 CATF3 photo

[11] Ice Storms: Hazardous Beauty, Keith C. Heidorn, PhD, The Weather Doctor, December 2001, Web.

[12] Photo by Luke Meyers, Aftermath of February 2006 Windstorm.

[13] Ice Storms: Hazardous Beauty, Keith C. Heidorn, PhD, The Weather Doctor, December 2001, Web.