9.2 Flooding

- Nationally, floods are the most costly and destructive disasters. Most of the damage caused by Hurricane Katrina was caused by flooding.
- Western Washington is very prone to flooding, and Seattle's flood profile is different from the rest of the state. Seattle has three distinct flooding hazards: riverine flooding, coastal flooding, and urban flooding. Urban and riverine flooding are most common.
- Climate change is projected to cause sea level rise and increase the frequency of heavy rain events, heightening Seattle's future risk of urban and coastal flooding.
- The area in the 100-year floodplains covers South Park and the drainage basins for Thornton and Longfellow Creeks. Flood control structures have been built in all of these areas. Small segments of two high-volume arterials cross the flood plain: SR99 crosses the South Park floodplain and SR 522 cross along three segments of Thornton Creek.
- 2014 Federal Emergency Management Agency (FEMA) data reveals that Seattle has had fewer than ten buildings (including residential) that have had more than one flood loss.

9 2.1 Context

In December 2006, heavy rains overwhelmed the City's drainage systems and water backed up at the top of an embankment in the Madison Valley area. It overtopped the embankment, rushed downhill, slammed into a home and caused one fatality. This event raised awareness about the seriousness of Seattle's flood hazard.

Seattle has over 200 miles of waterfront, making coastal and riverine flooding a natural concern in the area. It is surrounded by Puget Sound and Lake Washington and contains the Duwamish River, a ship canal, and several streams. Moreover, flooding outside Seattle can affect the city. For example, flooding along the Cedar River can decrease water quality to the point where it cannot be diverted for drinking water supply and water stored in Lake Youngs needs to be used instead.

Flooding in Seattle falls into three types:

- **Riverine flooding** – Heavy precipitation causes a river or stream to overflow its banks into the adjoining floodplain. This is the classic flood. Seattle's creeks, especially Thorton and Longfellow, have flooded more often than the Duwamish River, which is managed by the Howard Hanson Dam. Failure of the Howard Hanson dam or the release of large volumes of water from the dam could cause flooding of the Duwamish River.
- **Coastal flooding** – Associated with storms. High tides and wind can push water into coastal areas. Coastal flooding can erode the toes of bluffs and are one factor in landslides. Some areas, like South Park, can experience drainage problems under the same conditions.
- **Urban flooding** – Happens when intense rain overwhelms the capacity of the drainage system. Low lying, bowl-shaped areas like Madison Valley and Midvale are the most likely to flood.

The key factors determining the amount of damage in a flood are the depth and velocity of the water, and the amount of time the water stays above flood level. To project the expected amount of damage, the frequency of high water in a particular area needs to be computed. Usually, this is done by the Federal Emergency Management Agency (FEMA). An area that has a 1% chance of happening in any given year is called a 100-year floodplain. Similarly, a 500-year flood has a 0.2% chance of occurring each year. The elevation and shape of these floodplains, as well as historical and geological records, suggest probable flood depths and velocity.

Riverine floods often develop slowly and give floodplain residents ample time to evacuate. Casualties occur when people cannot or will not leave or try to drive across flooded roadways. Flash floods or dam failures are more dangerous than typical riverine floods because people have less time to escape and are more likely to get trapped. Even small floods can cause heavy structural damage by rotting wooden frames and undermining foundations. More frequently they destroy moveable property and commercial stock.

Riverine floods can also affect city infrastructure when high water cuts transportation routes and pipelines. These lifeline losses can impact people beyond the immediate floodplain. If floodwaters inundate hazardous waste sites or buildings where dangerous chemicals are housed, they also generate secondary incidents such as hazardous material exposures. In New Orleans, flooding from Hurricane Katrina caused a release of 25,000 barrels of crude oil into a neighborhood adjacent to a refinery. 6,500 homes were affected.[521]

The Puget Sound is not considered to have an "open" coastline, where coastal flooding is usually more violent. Storms extend the reach of waves creating floods along the coasts. Storm surges as high as 23 feet have been reported in conjunction with tropical storms. Since they accompany storms, storm surges have enormous destructive potential as winds drive waves ashore at high velocities. Few non-engineered buildings can survive a strong storm surge, especially those constructed of wood. Even stronger structures like port facilities, warehouses, and bridges are vulnerable to coastal floods. Surges are worse when they occur at high tide or king tides, which are extremely high tide events that occur a few times per year when the moon is closest to the earth.

Urban Flooding in Seattle typically occurs during a weather event called an atmospheric river, or colloquially, a "Pineapple Express." An influx of warm air from the tropics or subtropics rapidly raises winter temperatures. The mix of raised freezing levels and increased water vapor can produce heavy precipitation, causing urban flooding.[522] These events typically happen in winter, but have occurred in late fall and early spring as well.

Currently, all levels of government employ structural and non-structural means to reduce flood risk. In the past, structural methods such as the construction of dams, levees and bulkheads were the most common means used. During the 1950s and 1960s, the emphasis began to shift because these structures failed to completely solve the flood problem. Catastrophic flooding, like that on the Mississippi in 1993, led federal authorities to emphasize a suite of non-structural mitigation strategies, such as flood insurance, government buyouts, and more restrictive land use planning.

9.2.2 *History*

Early in Seattle's history, low-lying areas near downtown and at the mouth of the Duwamish flooded. This prompted the construction of landfills and a drainage system downtown and the channeling of the Duwamish. Since that time, there has been no significant flooding downtown or near the mouth of the Duwamish. Because of these changes, listing very early events is irrelevant.

Areas along the city's streams experience periodic, localized flooding, typically limited to the blocks or neighborhoods immediately adjacent to the streams. These streams include Longfellow and Thornton Creeks. However, the depth and current velocity of the floodwaters have been low, and they generally cause only localized structural damage and bank erosion.[523] The record of flooding in these areas is limited, but FEMA data shows problems in November 1978 and January 1986. Limited urban flooding also occurred in the residential area near Thornton Creek during the winter storms of 1996/1997, and again in October 2003.

The South Park neighborhood lies at a low elevation along the Duwamish and is prone to flooding due to backups in the drainage system when there is a combination of heavy rain and high tide. During major storms, runoff can drain directly into the Duwamish. Because the Duwamish is a tidal river, its elevation

rises with the high tide. High stream flow combined with a high tide can push water through pipes that normally drain the neighborhood.

The rivers in eastern King County are prone to severe flooding. Only a few floods in the area have affected Seattle directly, the most significant being on the Cedar River. Major flooding of the Cedar River occurred in 1975, 1990, 1995 and 1996. The flooding led to water quality issues but occurred in the winter when demand for water is low, minimizing impact to customers. Filtration was added to the Tolt system in 2001, so the impact of floods on water supply is no longer a serious concern for that portion of the system.

Both Seattle City Light (SCL) and Seattle Public Utilities (SPU) own and operate facilities located outside of the city limits on the Cedar and Tolt Rivers, the Skagit River, and the Pend Oreille River. Flooding can be a concern in these areas during times of heavy rains and extraordinary snowpack.

December 14-15, 2006. Six landslides of various sizes and approximately 300 flooded homes were reported throughout the city due to intense rainfall (about 2.17 inches in 24 hours) and overwhelmed storm water facilities. Usually, rainfall in Seattle is a few hundredths of an inch per hour. The peak of this storm was a band that ran through the middle of Seattle and produced an inch of rain in one hour.

December 1-3, 2007. Three storms came through the Pacific Northwest, with the last being unusually intense.[524] Four-and-a-half to 5.5 inches of rain fell in north and west Seattle in 24 hours, an all-time record. Seattle experienced flooded roads, sinkholes, and landslides. While this storm brought more rain than the 2006 event, it was spread out over a longer period. Unusually dry weather in the previous month also helped mitigate the risk of landslides.[525]

9 2.3 *Likelihood of Future Occurrences*

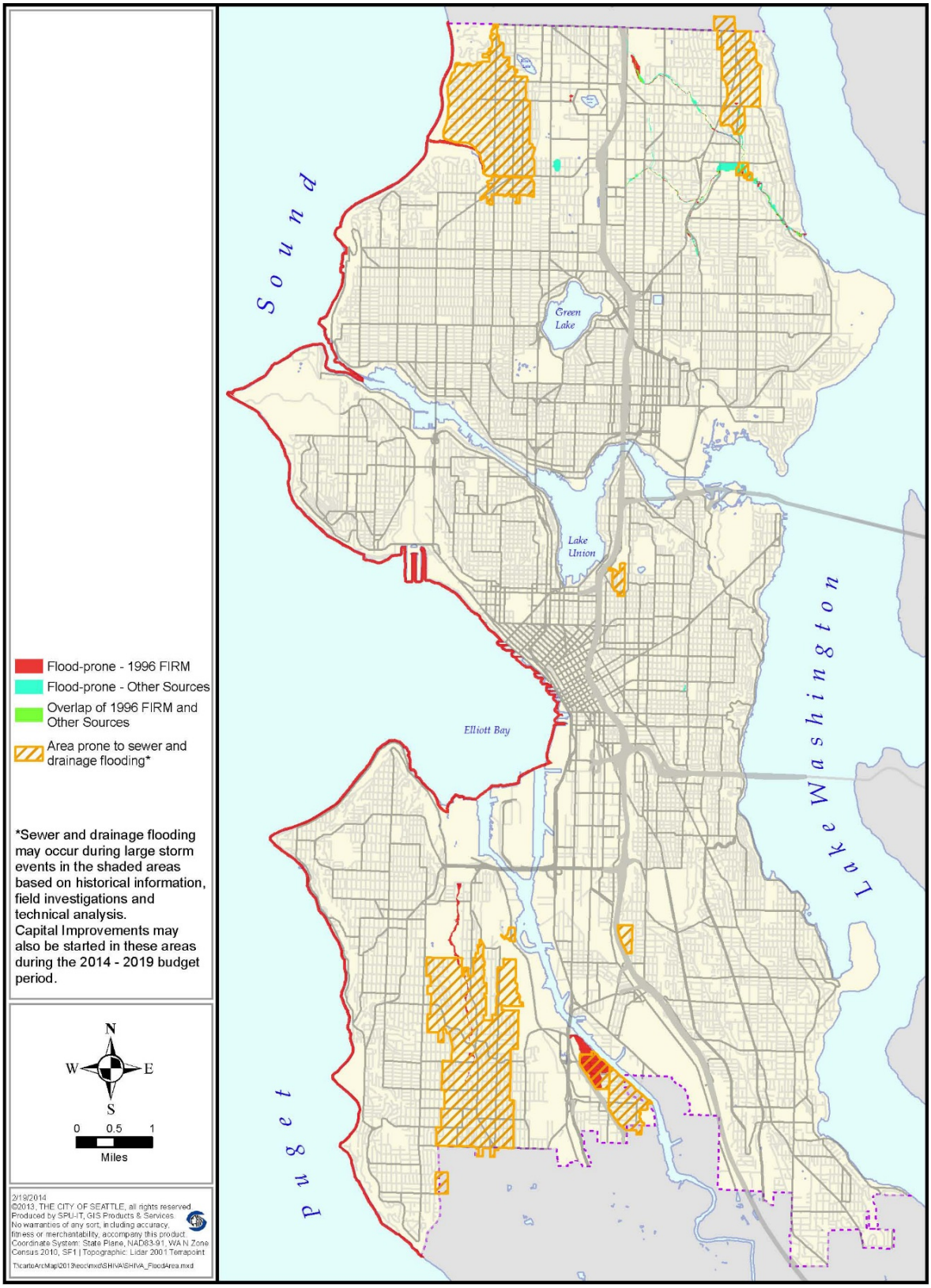
Seattle will experience flooding in the future. The principal unknown factor is the severity of future events. Seattle Public Utilities has examined the amount of rainfall collected in its gauges between 1978 and 2007. It discovered a small but statistically significant trend towards short-duration, high-intensity events. Local meteorology expert, Cliff Mass, analyzed rainfall intensity data and discovered that events like the one on December 14, 2006, have a 1% to 2% chance of occurring each year. These observations are in alignment with the University of Washington's Climate Impacts Group (CIG), who projects that the number of days with more than 1 inch of rain will increase by 6% to 20% by the 2050s.[526] Additionally, CIG projects that coastal flooding will increase due to sea level rise extending the reach of waves in a storm surge.[527] SPU is already upgrading the city's drainage system in critical areas.

9 2.4 *Vulnerability*

The National Flood Insurance Rate Maps and the U.S. Army Corps of Engineers inundation maps indicate areas prone to flooding in Seattle. The latter shows the area affected by a potential break of the Howard Hanson Dam. These maps show that the locations prone to flooding are quite limited. These areas are most vulnerable from November to February when the city receives most of its rain. The City has adopted a variety of structural controls to prevent flooding. It placed a diversion on Thornton Creek and a storm water detention basin on Longfellow Creek. However, each has its limits. The Thornton Creek diversion is effective up to a 100-year flood; the Longfellow basin was only partially effective during the January 1986 flood.[528] In 2014, SPU completed a restoration project along a flood-prone portion of Thornton Creek, which widened the creek channel to handle greater water capacity and enlarged a main culvert.[529]

The Howard Hanson Dam regulates the only large river in the city, the Duwamish. There are two concerns regarding flooding: 1) a flood event in the upper Green River that causes the dam to be over capacity; or 2) a breach or complete failure of the dam. The dam's reservoir can usually contain the runoff from winter storms and spring snow melt. An extremely heavy rain event during the winter

Figure 9-3. Areas with Heightened Flood Risk



months could cause the dam to reach or exceed its design capacity, requiring water to be released. The Army Corps of Engineers has modeled a 500-year flood event (a flood with a 0.02% chance of occurring per year) in the upper Green River. A flood of this magnitude has not occurred since record keeping began. The modeling shows water flows of 25,000 cubic feet per second that would flood parts of the Green River Valley, including Kent.[530] However, by the time the water flow reaches the lower Duwamish in Seattle, flooding is not expected as tidal effects will govern.[531]

The other potential flood scenario would be from a breach or failure of the dam. The Army Corps of Engineers has modeled two scenarios of a dam break. One models a dam break when the reservoir is 10% full, and the other models a dam break when the reservoir is 100% full. In the 10% scenario, the flood could have a large impact upriver, where most of the water would spill over into the Green River Valley.[532] This upriver flooding would relieve pressure on downstream areas like Seattle. In the 100% full scenario, the model shows that flooding could occur in the South Park neighborhood.[533] However, this is a worst-case scenario, and any flooding event will depend on the exact nature of the breach and the water storage level.

In 2009, a void was discovered in the Howard Hanson Dam. Concerns about its strength led to temporary repairs and a reduction in capacity of the reservoir. This means that more water would have to be released from the dam in a heavy storm. At the time, the Army Corps of Engineers, the dam's operator, estimated a 1 in 33 chance of flooding due to releases. Permanent repairs were made to the dam, including a seepage barrier and installation of drains that direct seepage into a drainage tunnel.[534] Other flood control measures include log booms that prevent debris from blocking the spillway and rock installations that prevent erosion of the dam. The Army Corps states that the dam can control water up to a 140-year flood event.[535]

The failure of levees just outside the city limits could produce localized flooding at Boeing Field and SCL facilities, but the Army Corps of Engineers reports that these levees are in good repair.

The Cedar River system, which provides two-thirds of Seattle's water supply, is also vulnerable to flooding. Because of the lack of filtration on the Cedar, diversions from the river are shut down when the water is turbid, and water stored in Lake Youngs is used instead. Since flooding on the Cedar occurs in the fall or winter when demand for water is at its lowest, water from Lake Youngs and the Tolt River system can meet the full needs for water supply.

Coastal problems are another vulnerability. The National Flood Insurance Rate Maps show a coastal flooding hazard directly along the coast but not extending inland. Coastal flooding has occurred in West Seattle and South Park when winter storms coincide with king tides.

Much of Seattle's coastline consists of bluffs with homes built at the top. Coastal storms can erode the toe of these sea cliffs and are a factor in landslides. In parts of West Seattle and Magnolia, homes are built along the shore. These properties are most vulnerable to coastal storm damage.

Many of the low-lying coastline areas, especially the more heavily used parts of the waterfront, are protected by seawalls. In 2017, the City completed major repairs to its aging downtown seawall. The repaired wall is expected to last more than 75 years.

As previously stated, sea-level rise will make coast flooding worse. The projected amount of sea-level rise in Seattle is 4 to 56 inches by 2100, depending on the amount of land movement.[536] The city estimates that the top of the downtown seawall will still be 3 ft above the new water level projections for 2100.[537] Other seawalls could be overtopped if they are not modified or replaced.

Lifeline Exposures:

- The sewer and drainage system is naturally exposed to flooding because it is part of the infrastructure to help control runoff. Sewer and drainage mains run along most of Thornton,

Longfellow and Piper's Creeks; along most of the coast of West Seattle; South Park; Interbay; portions of Magnolia's coast; and Myrtle Edwards Park.

- About a ½ mile of SCL transmission lines run through the Longfellow Creek 100-year floodplain and the northern transmission lines cross the Thornton Creek floodplain.
- Seattle's northern water supply line crosses the Thornton Creek floodplain.

Transportation Exposures:

- Seattle's Puget Sound facing marine terminals are exposed to coastal flooding.
- The BNSF rail corridor, which runs along Puget Sound north of the Ship Canal, is exposed to flooding although landslides are a more common threat.
- Lake City Way and 35th Ave NE in North Seattle are bisected by Thornton Creek.
- Many residential streets in the South Park neighborhood are in the 100-year floodplain. West Marginal Way runs alongside it.
- Beach Drive SW in West Seattle runs along Puget Sound and is exposed to coastal flooding.

9 2.5 *Consequences*

Flooding in Seattle is a regular occurrence, but Seattle's flooding problem is not as severe as the rest of Western Washington. The situation may be changing, however, with climate change projections signaling that urban flooding may become a larger threat. Flooding is frequently part of a larger storm event.

Climate researchers project that Seattle will experience more extreme precipitation events, but there is a large amount of uncertainty in their predictions. In response, Seattle's drainage system is being retrofitted to add surge capacity.

The Duwamish Valley is not likely to flood. Even in the event of a major release of water from the Howard Hanson dam, the river is likely to remain within its banks.

Areas near streams and in natural bowls will be at some risk of localized ponding. The main risk is to property, the majority of which is residential. This residential flooding has a much less pronounced effect on the local economy since the economic base remains unaffected. Nevertheless, a flood could make transportation difficult in the affected areas. The low depth and water velocity of this type of flood mean it is mainly an economic rather than a safety risk.

Coastal flooding in Puget Sound could damage a large area. The most common land use near the shore is residential, but the Port of Seattle and the BNSF Railway might also be affected because of their proximity to the water.

While a Duwamish Valley flood is unlikely, the consequences of a flood would be severe. The dominant land use in the Duwamish Valley is industrial. A flood in this area would cause a severe disruption of the local economy, leading to a decline in tax revenue and a loss of jobs. If firms relocate following a flood, the city could lose some of this income permanently. The Duwamish Valley houses many hazardous materials.

Other severe scenarios include coast erosion caused by coastal flooding extended by sea-level rise. Such events could endanger people living along the shore or near coastal bluffs. The main danger is landslides, which in extreme cases can generate tsunamis.

Lives can also be at risk during flood events, as the fatality that occurred in Madison Valley during the 2006 storm showed. While that case had unique circumstances, with the extra high curb structure acting like a small dam, it is possible for a similar set of circumstances to arise again and put lives in danger.

9 2.6 *Conclusions*

Changes in the landscape, like the dredging and filling along the Duwamish, have reduced the city's risk to flooding. The Howard Hanson Dam maintains further structural protection, and smaller controls work on Longfellow and Thornton Creeks. These structural solutions are backed up by the city's membership in the National Flood Insurance Program that requires buildings within the floodplain to have flood insurance. All of these factors make flooding one of the most well-studied and funded mitigation efforts in the city. Nevertheless, urban flooding incidents and future climate projections point to a hazard that is shifting and exposing new vulnerabilities.