9.4 Water Shortages

- In 2018, Cape Town, South Africa, became dangerously close to running out of water. Reservoirs were dry, causing the city to impose extreme water restrictions, including a 50-liter limit per person per day.[556] The restrictions have postponed a water shortage crisis for now, but Cape Town's experience shows how drought, climate change, and water management practices can lead to a water shortage even in a large, well-established city.
- A water shortage occurs when the demand for water exceeds supply. It can be caused by the onset of a drought or sudden infrastructure failure, such as a major pipeline failure or treatment plant shutdown.
- Peak demand for water for people and businesses occurs in the summer. Replenishment of the city's reservoirs does not occur until the spring, when snow accumulated during the winter melts and runoff from rains is stored. Low winter snow accumulation followed by hot summer weather or later-than-normal return of fall rains can cause a shortage.
- It is extremely unlikely that Seattle would run out of water. To avoid failure of the water supply, a series of increasingly severe usage curtailments would be enacted to ensure that Seattle would have enough water for essential functions. "Phased Curtailments" occur in four stages: Advisory, Voluntary, Mandatory, and Emergency. While the curtailments would mitigate a greater disaster, they would have increasingly severe impacts on residents and businesses.
- The City of Seattle supplies water to people and businesses within the city limits and to many customers in King County and southwest Snohomish County through wholesale water deliveries. It depends on its two Cascade watersheds, the South Fork Tolt and Cedar Rivers, for its water supply. Both of these reservoirs are managed for instream flows for fish.
- Wells in the Highline area provide limited supplemental back-up for peak loads and emergencies.
- Decreasing demand has mitigated the pressure on the water supply. Total water consumption has gone down despite increases in population in the area served by SPU. Since the early 1990s, conservation programs, plumbing code changes and pricing have all contributed to reduced water use in the region.
- Maintaining public health is the highest priority in managing a water shortage. In extreme conditions, shortages can result in a degradation of water quality, reduction in the flow of water available for firefighting or sufficiently low pressure that water cannot reach certain areas.
- In an Emergency Curtailment, both stringent restrictions and surcharges will be imposed. Such restrictions would be an economic burden on businesses that are heavy water users and customers without the means to pay for surcharges.

9 4.1 Context

Water shortages develop when the supply of water cannot meet demand. The cause can be either a decreased supply, a rise in demand, or both. They are not the same as droughts, which are prolonged periods without precipitation. Shortages often develop as a result of drought but can also be caused by overconsumption or structural failures such as pipeline breaks.

Seattle uses water for direct consumption, e.g., drinking, washing and watering lawns, and to generate electricity. Both types of consumption are cyclic. Water use peaks in the summer with demand determined by the heat and dryness of the weather. Power consumption peaks during the winter. The extent of its demand also depends on the weather. The colder the winter, the more power required.

Seattle Public Utilities (SPU) manages reservoirs in the Cascade Mountains to provide water supply for consumption and fisheries, as well as to provide flood management and hydropower generation. During the spring, SPU captures runoff from melting water from the winter snowpack and rainfall and stores the runoff in city-owned reservoirs. Water remains there until the demand increases and releases from storage are required. During peak demand, water is drawn from the reservoirs at a greater rate than it is being replaced. This yearly cycle of recharge and draw-downs is the city's "water-budget." For Seattle's drinking water supplies, the end of the yearly drawdown cycle is dependent on the timing of fall rains, which is uncertain and is not forecasted well in advance. If the "water-budget" is not renewed each year, Seattle could face a multi-year water shortage.

SPU draws most of its water for direct consumption from two watersheds in the Cascade Mountains — the South Fork of the Tolt River and the Cedar River—and from well fields in the Highline area. The Cedar supplies two-thirds of the city's water, while the South Fork of the Tolt supplies one-third. The amount of water in these rivers is dependent on the yearly levels of snowpack in the mountains. The Highline wells provide water in emergencies and peak water use periods.[557] This water is delivered to Seattle's retail customers and SPU's wholesale customers through large diameter pipes. Unlike an electric utility that is connected to a regional and national power grid, Seattle must rely on its own watershed resources. There is on "water grid" that can provide water from outside sources in a shortage.

As for power, Seattle City Light (SCL) gets most of the power it generates from dams on the Skagit and Pend Oreille Rivers. When the amount of water in the reservoirs drops, SCL cannot generate as much power. When peak demand exceeds supply, SCL buys power from other sources, mostly the Bonneville Power Administration. Most of these demand peaks are anticipated so the utility can buy power ahead of time or swap power with another utility. The real costs occur when water shortages are unforeseen, and the City must make emergency purchases.

Droughts are slow-onset or "creeping" disasters because their effects accumulate slowly over time. Even with modern forecasting tools, there is always some uncertainty about when to adopt water restriction measures. Water resource managers are never sure if they are overreacting whenever usage restrictions are requested preemptively. This doubt can cause managers to delay action until a drought is well underway. There are three different types of droughts that affect the Seattle regional water supply. Winter/spring drought from low accumulations of snow in the mountains, summer drought from dry conditions and hot temperatures, and fall/early winter drought from delayed fall rains. SPU and SCL, with real-time information about snowpack, can typically forecast supply for the summer and manage resources accordingly. They cannot, however, predict the end of the drawdown cycle and timing of fall rains.

To respond to a water shortage, SPU uses four levels of water use curtailments: advisories, voluntary restrictions, mandatory restrictions, and emergency curtailments. As a shortage worsens, SPU enacts progressively stringent restrictions.

SPU uses several data and forecasting tools to monitor water resources.[558] They work with USGS to monitor stream flows and the Natural Resources Conservation Service (NRCS) to monitor snow. Additionally, SPU monitors daily weather forecasts and 30- and 90-day multi-season climate outlooks. They also track El Niño/La Niña conditions. SPU uses an in-house reservoir management and stream flow forecast model which is updated hourly with meteorological and hydrological data. It can simulate the current snowpack, soil moisture, aquifer storage, and stream flows of the watersheds. It allows SPU to analyze future reservoir operating scenarios.

Nationally, per capita water use has decreased by nearly 30% since 1975 despite a growing population and economy. While the population that is served by SPU has steadily risen since 1975, water demand leveled off during the 1980s then dropped off sharply in 1992 after a severe drought and mandatory

curtailment measures. Since then, the combined effects of higher water rates, the 1993 state plumbing code, conservation programs, and improved system operations have kept both billed and total consumption significantly below pre-drought levels.

Water consumption further declined between 2000 and 2005 due to additional conservation efforts represented by the regional 1% Conservation Program, significant increases in water and sewer rates and an economic slow-down. Between 1990 to 2016, annual water consumption decreased about 28%, while population increased by 28%. SPU currently serves 1.4 million retail and wholesale customers in King and Snohomish counties. Average water consumption in 2015 was 121 million gallons per day (mgd).

Peak water demand has fallen even more than annual average demand since the 1980s. In the 1980s, hot summer weather could produce peak day consumption of over 325 mgd, compared with only 270 mgd in 1994 when temperatures reached 100 degrees. Ten years later, during the two very hot, dry summers of 2003 and 2004, peak day consumption reduced further, barely reaching 250 mgd. Between 2005 and 2010, average peak day consumption has been around 200 mgd.

Droughts do not necessarily cause water shortages. However, they can contribute to shortages. The most common measure of drought intensity is the Palmer Drought Index that describes dryness. The values usually range from -4 (extremely dry) to +4 (extremely wet). The values are a function of precipitation and temperature that are obtained by comparing current local scores with average scores for the area. One significant drawback is that it underestimates the role of water stored in snowpack.[559]

Breaks in the pipeline distribution system or events that force SPU to shut down the water system preemptively, such as a failure at one of the water treatment facilities, can also cause shortages. Pipeline breaks or other infrastructure failure often result from other disasters like earthquakes, floods and explosions, but they can occur as a result of mechanical failure or human error. More information on water pipe breaks can be found in the section on infrastructure failures. A major contamination incident could cause a water shortage. A detection of harmful bacteria such as E. Coli could call for a temporary shutoff to certain affected areas.

9 4.2 *History*

Water shortages are a regular occurrence in the region's history. This section reviews the significant shortages to reveal the duration, severity and cause. Drought conditions are cited as an indirect and imperfect measure of the shortage. Some short-term shortages were caused by pipeline breaks, none of which precipitated an immediate health danger in the city or prompted water rationing.

1919. A hot, dry summer.

1928/29. Rain was 20% of normal. This was the longest recorded drought in Washington at that time. It exacerbated the 1930 drought.

1930/31. Moderately dry weather occurred in Western Washington. The Palmer Drought Index hovered in the -3 range.

1938. A record dry growing season in Western Washington at the time. The state studied the minimum stream flows necessary to preserve fish life. Stream flows are still an issue and complicate the regulation of reservoir levels.

1941-1945. During March and April 1941, the Palmer Drought Index was -4, then hovered between -3 and -1.5. Temperatures west of the Cascades were usually above normal.

1952/53. Puget Sound was hit with dry weather beginning in January and continuing through April 1953. The worst came during the winter when the Palmer Drought Index reached -4. The state ordered power cuts for hydroelectric dams.

1965/66. King County recorded Palmer Indices of roughly -1.5 from June 1965 to December 1966.

1967. The summer was dry with no significant rain from the third week in June to the first week in September.

1976/77. Precipitation was 57% of normal in Seattle. For three months, the Palmer Drought Index was in the -4 range. Hydroelectric power generation dropped 47%. City Light had to make emergency power purchases at highly inflated prices. As a result, it had to increase its debt and put a surcharge on electric bills.[560]

1987. Hot, dry summer weather increased water demand, causing a rapid drop in reservoir levels. Mandatory restrictions were adopted. Consumption dropped by 10%.

November 1987. The Tolt pipeline broke, temporarily dropping the supply reaching customers by 30%. This impacted 10,000 customers, but only for several hours. Water was rerouted through the Cedar River pipeline, placing additional demands on the Cedar River Reservoir. Voluntary restrictions dropped consumption by 5%. Luckily, November had low demand and the Cedar River pipeline was able to completely supply the city.

1988. The level of Cedar River Reservoir fell below its outlet. The Seattle Water Department responded by installing emergency pumps to extract water. The pumps were left at the site and used again in 1992.

August 1988. The Tolt pipeline broke during a period of peak use, threatening 100 suburban customers with loss of service or low water pressure. The public was asked to curtail all unnecessary water use. The goal was a 30% reduction, but only 18% was achieved. The outage lasted several days.

1992. Scarce winter rains prompted emergency measures to avoid severe reservoir depletion. Enforced mandatory restrictions reduced water consumption by 25- 30%. Additional emergency pumps installed in 1988 at Cedar River Reservoir were used. The silver lining to the 1992 shortage is that per capita water consumption remained low even after the shortage ended.

2001. Snowpack appeared to be very similar to that of 1992. Water supply forecasts made through the end of the year looked dire until a late snowfall occurred in March.[561] Snowpack in SPU's watersheds ended up peaking at 75% of normal and reservoirs were full or nearly full by June. Nonetheless, with a state-wide drought emergency in effect, SPU asked customers starting in early April to voluntarily reduce water use by 10%.

2002. Fall rains came later than normal. SPU had to mobilize pumps on Morse Lake. SPU entered into the voluntary curtailment stage and warned customers that water restrictions could occur if the weather continued to be dry. No further restrictions were imposed.

2005. The worst snowpack in 60 years at SPU's watersheds, causing SPU to enter into the advisory stage. Effective reservoir management and some late spring/early summer rainfall brought reservoirs back to near normal levels. By early July, the advisory was lifted.

2015. A new record-low snowpack occurred in the state, with a historic hot and dry summer. The Governor declared a state-wide drought emergency by mid-May. Even though reservoirs were operated to store more than their typical capacity in anticipation of the drought, SPU entered into the voluntary curtailment stage, asking their customers to decrease water consumption by 10% (which was achieved). Regional water supply conditions returned to normal in November.

Based on significant past events, shortages seem to occur once every five to ten years. In most cases, water shortage response actions were implemented prior to or during the summer. The extent of losses is difficult to determine. The most severe shortages were the result of either low snowpack or dry fall conditions.

9 4.3 Likelihood of Future Occurrences

In the long-term, climate change has the potential to affect the water supply system but is not the only factor that could contribute to future hydrologic changes. Land use, land cover, and reservoir management can all affect streamflow and water availability. The University of Washington Climate Impacts Group (CIG) projects that average spring snowpack in the Cascade Mountains will continue to decline by 42 to 55% by 2070 to 2099.[562] They also project that decreased snowpack and early spring melting will contribute to peak streamflow occurring earlier in the year. Summer streamflow is projected to decrease by at least 24% by 2080.[563] The main implications will be that Seattle's water resources will be more reliant on variable rain than mountain snowpack, and SPU may face more frequent temperature-driven droughts due to low snowpack and/or early snowmelt leading to an extended summer dry season.[564]

Demand is the critical variable. Total consumption and demand is falling, despite population growth, but consumption can still spike, especially in summer months during periods of high heat. These periods are predicted to increase with climate change. If a low snow year is followed by a hot summer, Seattle's water supply will face at least a short-term challenge. SPU forecasts that demand will increase gradually to 147 mgd by 2039, and then decline to stay relatively flat at 137 mgd through 2060.[565] Despite the forecasted increase, SPU states there is less than a 10% probability that Seattle will need a new water supply source before 2060.

The challenges are different for SCL. The CIG forecasted changes to hydropower in the Columbia Basin, where Seattle gets most of its power. It projects that annual production will decline slightly, with increases in the winter offset by declines in the summer.[566] The authors caution that, in the near term, annual production will be more influenced by other factors, like El Niño/La Niña events, than climate change.

Historically, SCL's peak demand is in the winter when stream flows are also at their peak. Demand in the summer is checked by the low market penetration of air conditioning systems locally. Based on American Housing Survey data, only 33.7% of Seattle-area homes have air conditioning. However, central air conditioning is becoming more commonplace in newly constructed apartments. Seattle has seen a fourfold increase in apartments offering air conditioning over the past decade.[567] While this trend may appear to signal increased future energy demands, newly constructed apartments are so energy efficient that overall demand is still expected to decrease.[568] Population increases will lead to a growth in demand for heating, even as per capita demand goes down due to warming winter temperatures. Taken together, these projections suggest that adaption to climate change will be easier in the winter than the summer.

9 4.4 Vulnerability

The main direct vulnerability in urban areas in a water shortage are financial, as water restrictions and/or price increases are put in place to lower demand and protect supply. Both drinking water and power could be affected. It is unlikely that restrictions and price increases would become so severe that there would be public health or public safety impacts. Water is still a cheap commodity in the U.S. and only about 10% is used for direct human consumption.

The history of water shortages shows that the power and water supply systems have different vulnerabilities to drought. Their water demands differ, and Seattle's reservoirs are located far enough apart that precipitation can be significantly different at each location.[569] Often, only one system is affected by dry weather.

Overall, the water system seems to have a higher probability of being affected than the power system. The water system cannot supplement supplies from outside the immediate region; SCL's power system can, as it has access to the regional power supply.

The heaviest water users are affected the most by water shortages. Commercial customers have traditionally been the biggest consumers, but many have succeeded in sharply reducing consumption. Some heavy users remain, such as landscapers and greenhouses.

Maintaining stream flows for salmon is also a challenge for the utilities. To create these flows, SPU and SCL must let water bypass their facilities during the spring when the reservoirs are most easily replenished and, in the fall, when water is being drawn from storage. During dry years, the amount of water they release can cause water reserves to drop significantly.

Wildland fire is becoming a more prominent threat to the water system. Climate change is projected to increase wildland fire risk even west of the Cascade Mountains.[570] Fires that occur near the watersheds can degrade surface water supplies by increasing turbidity, impacting aquatic species, and reducing reservoir storage.[571] SPU maintains a wildland fire crew that works with the Washington Department of Natural Resources to protect Seattle's watersheds from fire. This is particularly important for the Cedar River, which SPU does not filter.

SPU and SCL are publicly owned utilities, and any increased costs from water shortages are often be transferred to their customers in the form of higher rates. SPU rates are projected to increase at 5.2% annually for six years, beginning in 2018.[572] Seattle's low and fixed income residents will be the most vulnerable to rate increases.

A water shortage could indirectly expose Seattle residents to harm if it contributes to power failures, if low stream flows suppress power production at a time of peak demand, or to fires if water pressure is low or vegetation is dry.

9 4.5 Consequences

Seattle has a water shortage risk that is likely to increase with climate change; however, an even bigger driver will be demand. With good planning, it will be possible to boost supply or enact conservation measures to address demand increases. Climate change impacts can be mitigated through system adaptations and good reservoir management.

While Seattle will certainly face water shortages in the future, these will probably be on the same order of magnitude as previous shortages. Seattle's water supplies seem secure. On the power generation side, the situation seems more challenging, but the likelihood that a water shortage will cause rolling blackouts seems remote. It is more likely that power rates will increase.

With the effects of climate change on top of regular yearly and decadal fluctuations, a severe multiyear drought could have serious consequences for Seattle and extend beyond economic impacts into the public safety and health spheres. Most of these effects are likely to stem from indirect factors such as wildland fire, power failure, and heat exposure risk. Even under the maximum credible scenario, Seattle is better off than some cities that are truly facing a crisis as their entire supply is threatened.

9 4.6 Conclusions

Experience suggests that Seattle Public Utilities and Seattle City Light can manage shortages effectively. Since droughts require little in the way of emergency equipment, pose little immediate danger to public health, and have a crisis period that lasts for weeks or months, there seems to be little reason to activate the Emergency Operations Center. As with other "creeping" hazards, the City does not presently have a system in place for prolonged multi-department emergency management. Nevertheless, the current system could be used for interdepartmental city involvement to assist the utilities in managing a severe shortage emergency caused by infrastructure failures.