Wyckoff: Climate Change Vulnerability Assessment (3/31/2016)

EPA recognizes that the climate is changing and that we need to consider climate change impacts in our programs and we need to identify adaptation strategies to mitigate those impacts. To assist Superfund site managers in completing a vulnerability assessment and identify adaptation strategies for their sites, EPA developed several technical fact sheets[1].

The fact sheets address contaminated site remedies involving source containment systems, remedies for contaminated sediments, and for groundwater contamination. The fact sheets provide general information and layout a process for considering climate change impacts. However, because of the different local or regional climate and weather regimes and the individual nature of each contaminated site, the process for considering climate change impacts and potential adaptation measures is most effective through the use of site-specific strategies.

Wyckoff

The site includes the former Wyckoff Company wood-treatment facility, a former shipyard and subtidal/intertidal sediments in Eagle Harbor. The former wood-treating facility, located at the mouth of Eagle Harbor, operated from 1903 to 1988. This facility and a former shipyard are the major sources of widespread sediment contamination in the 500-acre harbor.

About 2,000 people live within one mile of the site. The nearest residence is located less than a quarter-mile away. Land use in the area is largely residential and commercial. The harbor is heavily used by recreational boaters, "live-aboards," and ferry transport to and from Seattle. A local citizen group receives funding under EPA's Technical Assistance Grant Program to support community involvement at the site.

Vulnerability Assessment

The goal of the vulnerability assessment is to help site managers and the public understand how climate change may impact the cleanup goals established for the site. A vulnerability assessment consists of several steps:

1. Identify the climate change threats of greatest concern for the site.
2. Identify the major site components that could be impacted by the climate change threats.
3. Characterize the potential sensitivity of those site components from the climate threats and the potential for increased exposure to human health and the environment or damage to equipment or infrastructure.
4. Prioritize which climate change impacts pose the greatest threat to human health and the environment or damage to equipment and infrastructure.

The following evaluation focuses on the vulnerability assessment. Identifying the possible adaptation measures and which options will be implemented will occur late. Each of the steps identified above are discussed below.

[1] https://www.epa.gov/superfund/superfund-climate-change-adaptation

Climate Change Threats

The major climate change threats evaluated for Wyckoff include:

- Sea Level Rise
- Precipitation
- Temperature

Sea-Level Rise

Over the period 1901-2010, global mean sea level rose by about 7.5 inches (6.7 to 8.3 inches)[2]. In the Puget Sound, sea level is rising at most locations in or near Puget Sound. At the Seattle tide gauge, one of the longest-running gauges in Puget Sound, sea level rose by about 8.6 inches from 1900 to 2008 [3]. Although sea level is rising at most locations, records show a decline in sea level for the northwest Olympic peninsula, a region experiencing uplift. At the Neah Bay tide gauge, for example, relative sea level dropped by about −5.2 inches from 1934 to 2008[4].

Global mean sea level rise will continue to rise during the 21st Century and will likely increase between 10.2 to 32.3 inches for 2081 to 2100 relative to 1986-2005 depending on a range of potential emission scenarios[5]. The Puget Sound region is projected to experience continued sea level rise throughout the 21st century, increasing the potential for more frequent coastal flooding and increased erosion. These changes, which have significant implications for human, plant, and animal communities, will be most pronounced for places such as Seattle, where land elevations are subsiding [6].

There have been several sea level rise projections for the Seattle area. It is anticipated that the projections for Seattle are applicable to the Wyckoff site since it is just several miles from Seattle. The projections in Table 1 and Figure 1 come from several sources.

1. The USACE initiated a project to assist project managers evaluate the potential impact to their civil works projects around the country[7]. The project provided a systematic approach for evaluating the vulnerability of specific sites and developed a sea level change curves to assist project managers.
2. The second source included is from a 2012 National Research Council Report [8] for the Coasts of California, Oregon, and Washington. The report provided projections for several points along the coast including Seattle.
3. The third source is from the 2015 State of Knowledge Report for Climate Change in Puget Sound completed by the Climate Impacts Group [9].

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[2] Intergovernmental Panel on Climate Change. 2013. Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis Summary for Policymakers

[3] Mauger,G.S., J.H.Casola, H.A.Morgan, R.L.Strauch, B.Jones, B.Curry, T.M.BuschIsaksen,L. Whitely Binder, M.B. Krosby, and A.K.Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Section 4: Sea Level Rise. Report prepared For the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D.

[4] IBID.

[5] IPCC. 2013

[6] Mauger, G.S. et al, 2015.

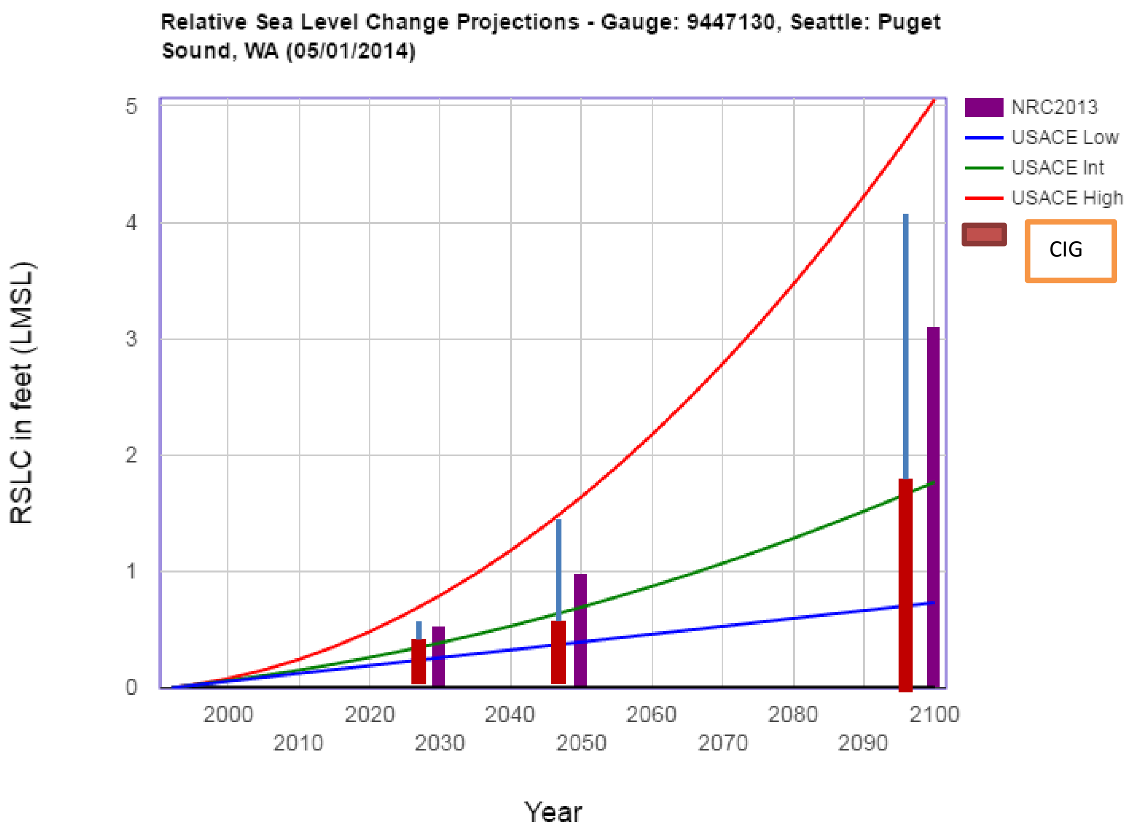
[7] http://www.corpsclimate.us/ccaceslcurves.cfm (accessed March 3, 2016). Gauge: 9447130. Seattle: Puget Sound. Located near Coleman Dock in Seattle.

[8] (NRC 2012) National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Committee on Sea Level Rise in California, Oregon, Washington. Board on Earth Sciences Resources Ocean Studies Board Division on Earth Life Studies The National Academies Press.

Table 1: Relative Sea Level Rise Change Projections (Inches)

Year	USACE Low[10]	USACE Intermediate	USACE High	National Research Council[11]	Mauger et al[12]
2030	3.1	4.7	9.5	6.4	3 (-2 to 9)
2050	4.7	8.3	19.7	11.8	7 (-1 to 19)
2100	8.8	21.2	60.7	37.3	24 (4 to 56)

Figure 1: Relative Sea Level Rise Projections for Seattle



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[9] (Mauger, G.S. et al. 2015) Mauger,G.S., J.H.Casola, H.A.Morgan, R.L.Strauch, B.Jones, B.Curry, T.M.BuschIsaksen,L. Whitely Binder, M.B. Krosby, and A.K.Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared For the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D.

[10] http://www.corpsclimate.us/ccaceslcurves.cfm . Gauge: 9447130. Seattle: Puget Sound. Located near Coleman Dock in Seattle. The USACE low scenario represents the historic rate of sea level change. The intermediate and high scenarios represent projected increases in sea level change and is corrected for the local rate of vertical land movement.

[11] NRC. 2012.

[12] Mauger, G.S. et al, 2015

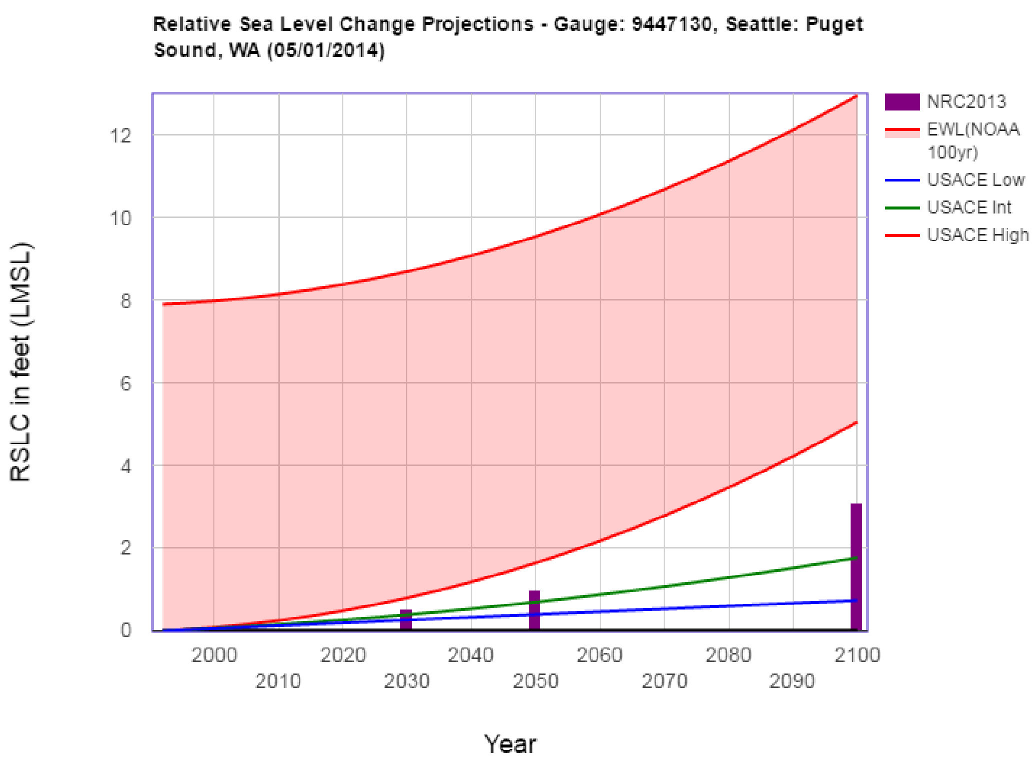
As can be seen from Table 1 and Figure 1 there are difference in the projections depending on which scenarios is selected. The choice of which scenario to select needs to be made on a case-by-case basis depending on several factors including the anticipated time horizon for the project, the sensitive of the projections to the plans and designs for the project, and other factors such as economic costs and benefits, and environmental impacts.

Along with sea level rise it is important to consider the existing conditions at the site related to extreme water levels. The sea level rise will need to be added to these existing conditions to better understand how they might impact the site. The USACE tool provides information on the extreme water levels. Table 2 and Figure 2 provide information based on the Seattle gauge for projected sea level rise for the three USACE scenarios plus the 100 year recurrence interval for extreme water levels.   There are also options for the 1,2,10, 20, and 50 year recurrence interval for extreme water levels. The 100 year extreme water level from NOAA for this area is 7.9 feet.

Table 2: 100 Extreme Water Levels plus Sea Level Rise Projections (feet)

Year	USACE Low	USACE Intermediate	USACE High
2030	8.2	8.3	8.7
2050	8.3	8.6	9.6
2100	8.6	9.7	13.0

Figure 2: 100 Extreme Water Levels Plus Projected Sea Level Rise: Seattle



Precipitation and Temperature

The current and projected precipitation rates for the area are included below. The current precipitation events, especially the more extreme events are important to consider when designing the project and to compare against the projections for future precipitation.

Table 3 includes information on precipitation magnitude and frequency estimates from two sources. The first source is NOAA's Atlas 2 precipitation-frequency (isopluvial) maps published in the early 1970s. These have historically been used in hydrologic analysis and design. The second source are precipitation magnitude-frequency estimates more specific to the City of Seattle that were developed for the City of Seattle stormwater design manual.

Table 3: Precipitation Magnitude and Frequency Estimates

Event	NOAA Precipitation Estimates[13] (Inches)	City of Seattle Estimates[14] (inches)
10-year,24-hour event	3.0	2.9
50-year, 24-hour event	4.0	3.8
100-year, 24-hour event	4.5	4.1

Table 4 provides information on the highest precipitation events recorded since 1981 at the Wyckoff site.

Table 4: 10 Highest Daily Precipitation totals from 1/1/1981 to 3/2/2016

Date	Precipitation Amount [15](inches)
12/3/2007	4.14
10/21/2003	3.79
1/19/1986	2.72
12/12/2010	2.72
11/23/2011	2.56
1/7/2002	2.54
11/26/1998	2.22
1/302006	2.21
12/4/2007	2.21
11/24/1990	2.2

[13] Hydrometerological Design Studies Center – NOAA National Weather Services.. http://www.nws.noaa.gov/ohd/hdsc/

[14] City of Seattle Stormwater Manual. September 2015. Appendix F: Hydrologic Analysis and Design. Average Estimates for 17 SPU Gauges from Attachment 2: Precipitation Magnitude-Frequency Estimates for SPU Rain Gage Locations. http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2145420.pdf

[15] PRISM – Northwest Alliance for Computational Science and Engineering. http://www.prism.oregonstate.edu/

Precipitation and Temperature Projections

I used three main sources for temperature and precipitation projections.

1. USGS National Climate Change Viewer
http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp
2. Climate Impacts Group, State of Knowledge Report for Climate Change in Puget Sound
https://cig.uw.edu/resources/special-reports/ps-sok/
3. EPA Climate Ready Water Utilities Program. http://www.epa.gov/crwu/view-your-water-utilitys-climate-projection-scenario-based-projected-changes-map

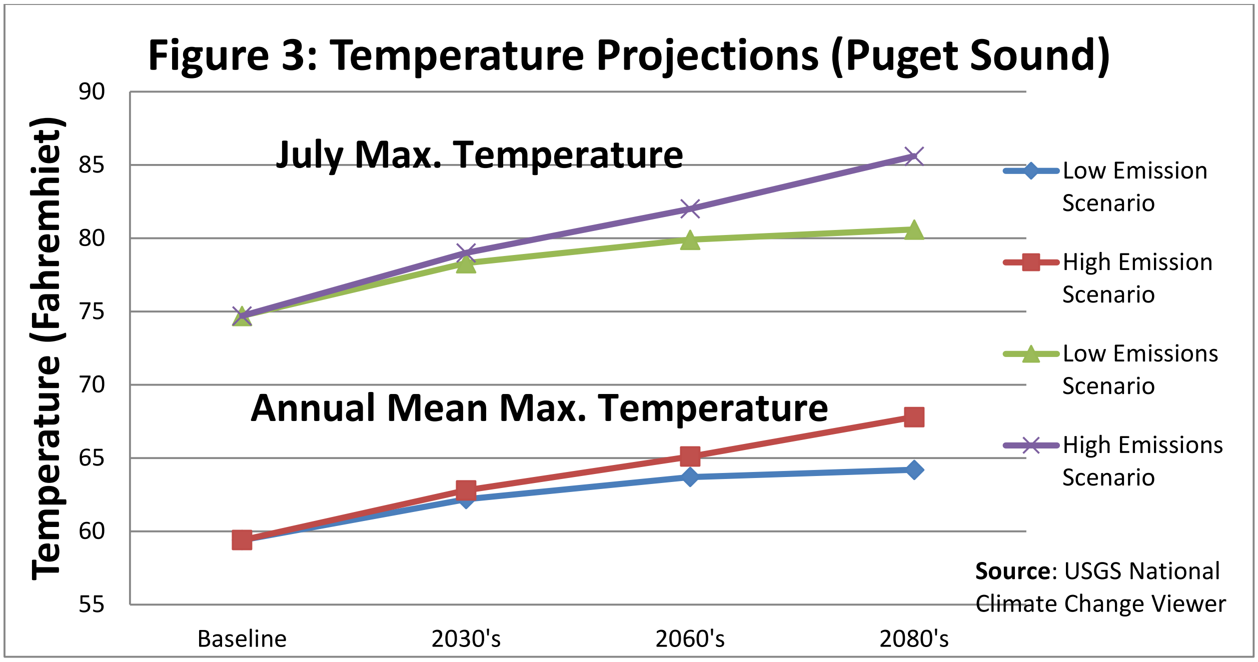
USGS National Climate Change Viewer
The USGS National Climate Change Viewer allows users to visualize projected changes in climate (temperature and precipitation) and the water balance (snow water equivalent, runoff, and soil moisture) for any state, county, and USGS Hydrologic Unit. The viewer provides a number of useful tools for exploring climate change such as maps, climographs, and histograms. For Wyckoff, I used the Puget Sound watershed as the hydrologic unit for evaluation. The table below contains information on temperature and precipitation.

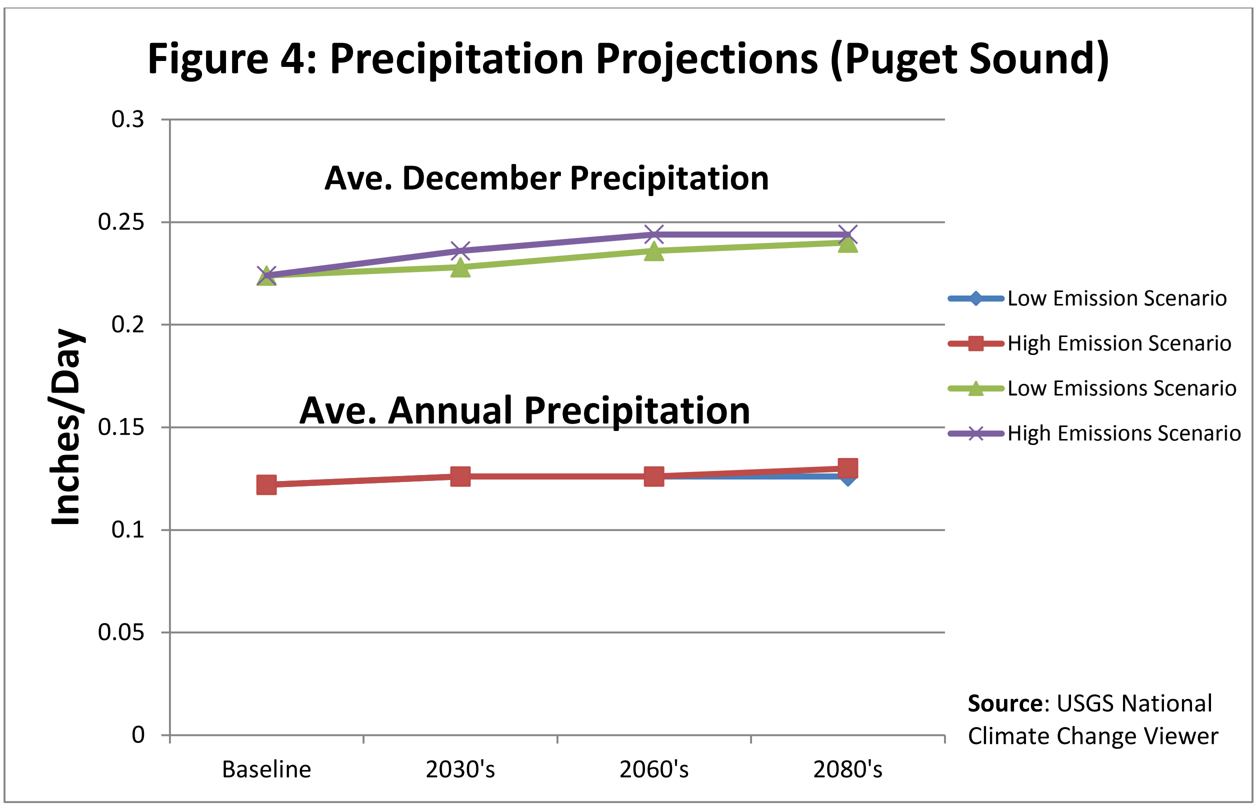
Table 5: Projections for Temperature and Precipitation for the Puget Sound[16]

Dates	Annual Mean Max. Temperature (Fahrenheit)	July Max. Temperature (Fahrenheit)	Ave. Annual Precipitation (inches/day)	Ave. December Precipitation (inches/day)
1950-2005	59.4	74.7	0.122	0.224
2025-2049	62.2-62.8	78.3-79.0	0.126 – 0.126	0.228 – 0.236
2050-2074	63.7-65.1	79.9-82.0	0.126 – 0.126	0.236 – 0.244
2075- 2099	64.2-67.8	80.6-85.6	0.126 – 0.130	0.240 – 0.244

Low values use low emission scenario (RCP 4.5) and high values use high emissions scenario (RCP 8.5)

[16] Alder, J. R. and S. W. Hostetler, 2013. USGS National Climate Change Viewer. US Geological Survey http://www.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T.





CIG: State of Knowledge Report: Temperature and Precipitation

State of Knowledge: Climate Change in Puget Sound is a comprehensive synthesis report summarizing relevant research on the likely effects of climate change on the lands, water, and people of the Puget

Sound region. For temperature and precipitation the report concludes (more details are included in Table 6 and Figures 5 and 6):

> *Puget Sound is experiencing a suite of long-term changes that are consistent with those observed globally as a result of human-caused climate change. These include increasing air temperatures, a longer frost-free season, nighttime warming, and a possible increase in the intensity of heavy rainfall events. Continued increases in average annual and seasonal Puget Sound air temperatures are projected as a result of climate change, as well as increases in extreme heat. Projected changes in annual precipitation are generally small, although summer precipitation is projected to decrease and heavy rainfall events are projected to become more severe. Natural variability can have a strong effect on trends – as evidenced by recent regional cooling – and will continue to influence shorter-term (up to several decades) climate trends in the future.*

Table 6: Projections for Temperature and Precipitation for Puget Sound[17]

Dates (relative to 1970 -1999)	Change in Average Annual Air Temperature (Fahrenheit)	Change in Average Summer Air Temperature (Fahrenheit)	Change in Temperature of Hottest Day (Fahrenheit)	% change in Average Annual Precipitation	% Change in Average Winter Precipitation
2040-2069	4.2 – 5.5 (2.9 to 7.1)	5.1 – 6.8 (3.3 to 9.7)	6.5 (4.0 to 10.2)	4.2 – 5.0 (-1.9 to 13)	9.9 – 11.0 (-1.6 to 21)
2070-2099	5.5 – 9.1 (2.3 to 17)	6.4 – 11.0 (4.6 to 15.0)	9.8 (5.3 to 15.3)	6.4 – 6.9 (-0.2 to 10)	11.0 – 15.0 (1.3 to 23)

Low values reflect use of low emission scenario (RCP 4.5) and high values reflects use of high emissions scenario (RCP 8.5)

[17] (Mauger, G.S. et al. 2015)

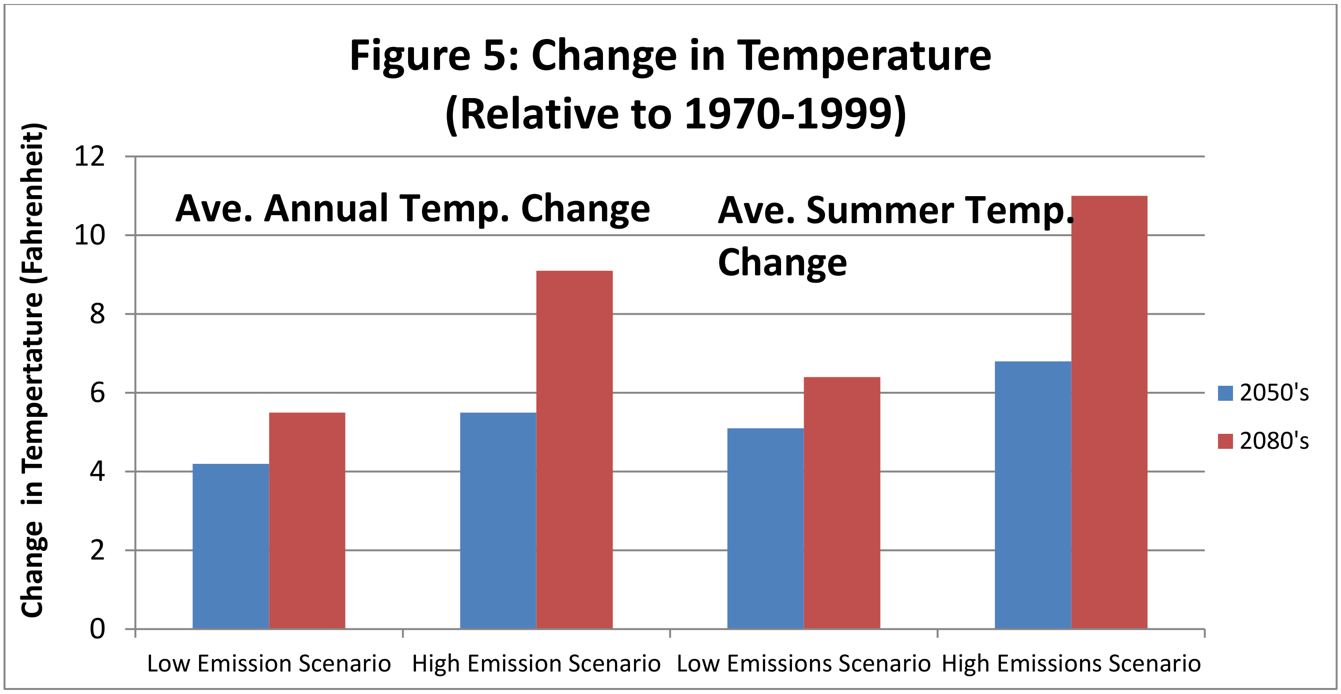


Figure 5: Change in Temperature (Relative to 1970-1999)
Change in Tempertature (Fahrenheit)
Ave. Annual Temp. Change
Ave. Summer Temp. Change
0
2
4
6
8
10
12
Low Emission Scenario
High Emission Scenario
Low Emissions Scenario
High Emissions Scenario
2050's
2080's

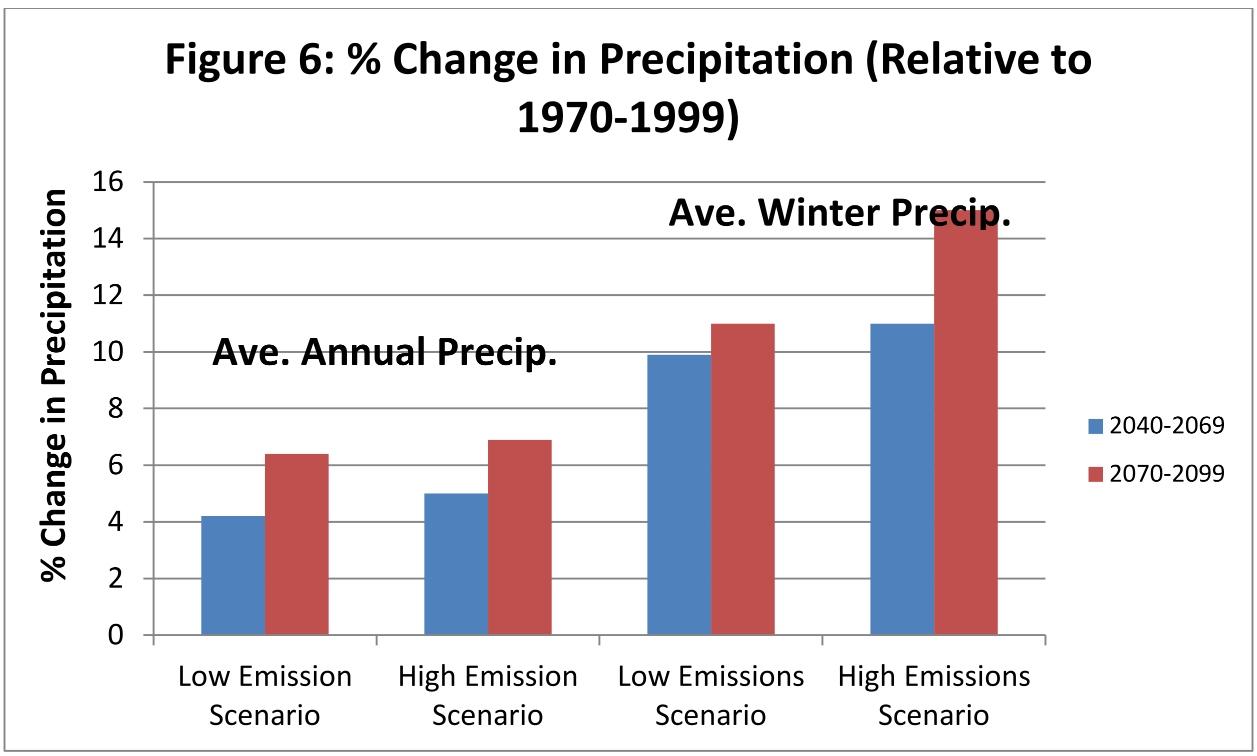


Figure 6: % Change in Precipitation (Relative to 1970-1999)
% Change in Precipitation
Ave. Annual Precip.
Ave. Winter Precip.
0
2
4
6
8
10
12
14
16
Low Emission Scenario
High Emission Scenario
Low Emissions Scenario
High Emissions Scenario
2040-2069
2070-2099

Projected Precipitation Extremes

Heavy precipitation events are projected to increase and are expected to exceed the range of variability shortly after mid-century. Projected changes in western Oregon and Washington precipitation extremes for 2070 – 2099 relative to 1970-1999 for a high emission scenario (RCRP 8.5) are[18]:

- 22% (range 5% to 34%) change in annual 99% percentile of 24-hour event
- Increase of number of day exceeding the historical 99th percentile of 24-hour precipitation from
    - 2 days/year for 1970 -1999
    - 8 days/year for 2070 to 2099

A second source of information is from EPA's Climate Ready Water Utilities program[19]. The projected climate conditions are from a climate station located in Keyport,WA. The projection is for the percent change in the total precipitation expected during a 100 year storm event. The base period is 1981-2010.

- Period 2026-2045. 3% to 9% increase in total precipitation for a 100 year event.
- Period 2051-2070. 6% to 17% increase in total precipitation for a 100 year event.

Site Components and Sensitivity to Climate Threats

Site Components

The main site components that could be impacted by climate change include:

- Retaining wall
- Plant Cover system
- Liner (if there is one)
- In-water cap
- Runoff and stormwater control systems
- Electrical and mechanical systems
- Groundwater

Sensitivity of Site Components to Climate Threats (what if analysis)

Table 7 characterizes the potential impacts for each component and the potential for increased exposure to human health and the environment or damage to equipment and infrastructure based on projections discussed above for 2050. Table 8 does the same analysis for 2100.

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[18] (Mauger, G.S. et al. 2015)

[19] EPA Climate Ready Water Utilities Program. http://www.epa.gov/crwu/view-your-water-utilitys-climate-projection-scenario-based-projected-changes-map

Table 7: Potential Impacts to Site Components: What if Analysis for 2050

	How does this impact:						
What if by 2050	**Retaining wall**	**Plant Cover System**	**Liner**	**In-water cap**	**Runoff & stormwater**	**Electrical systems**	**Groundwater**
SLR increases by 2 feet							
Average annual temperature increased by 5 degrees F							
Average summer temperature increased by 6 degrees F							
24 hour, 100 year event increased from 4.5 to 5 inches							

Table 8: Potential Impacts to Site Components: What if Analysis for 2100

	How does this impact:						
What if by 2100	**Retaining wall**	**Plant Cover System**	**Liner**	**In-water cap**	**Runoff & stormwater**	**Electrical systems**	**Groundwater**
SLR increases by 3 feet							
Average annual temperature increased by 7 degrees F							
Average summer temperature increased by 10 degrees F							
24 hour, 100 year event increased from 4.5 to 6 inches							

Prioritization

Qualitative Prioritization of Impacts (this step would look at the impacts to the different components and prioritize which areas are the most vulnerable and need to be considered in the design phase of the project.