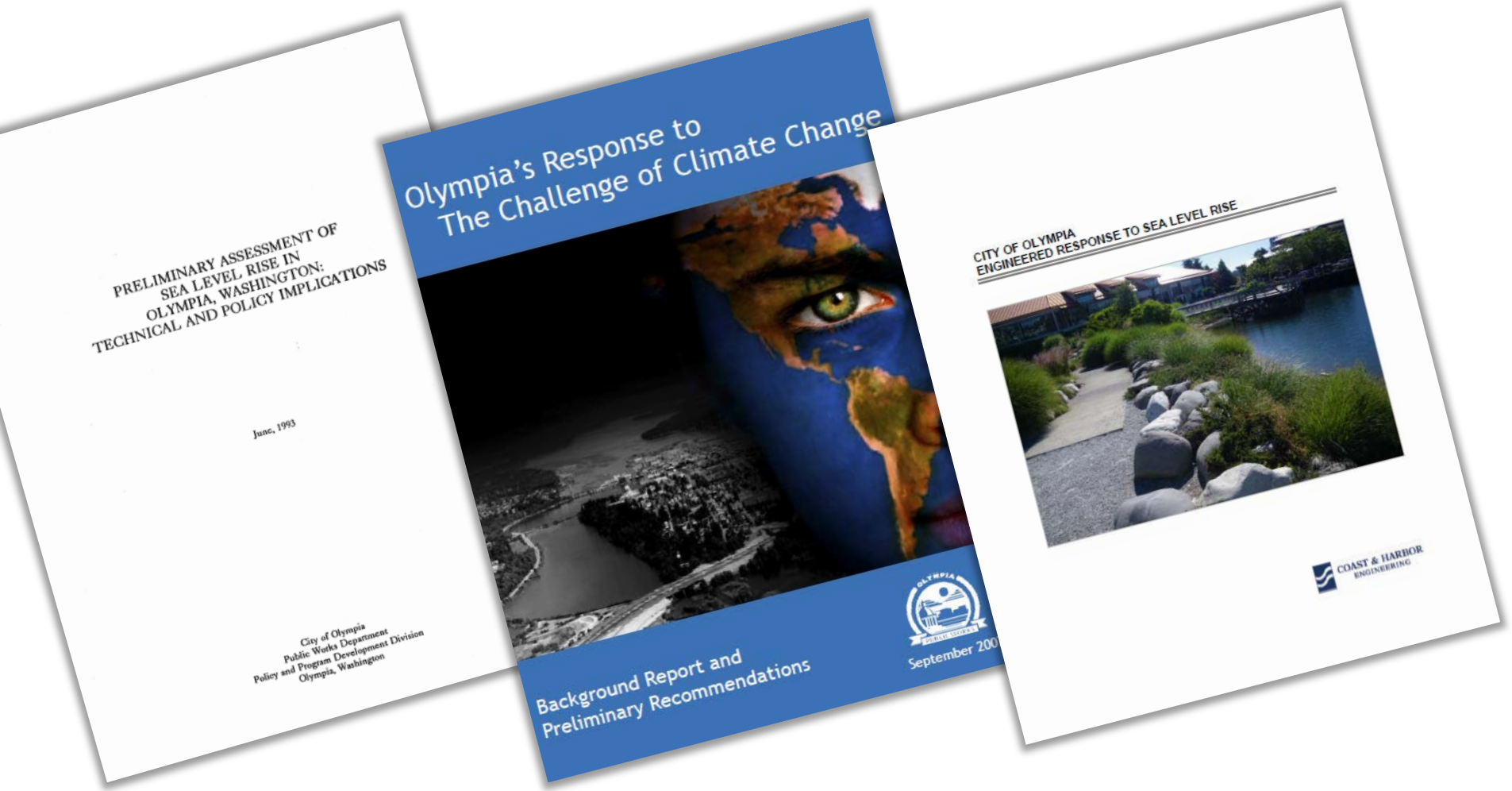
Utility Advisory Committee
Sea Level Rise Update

March 10, 2016…17.6 Foot Tide

Now is the time to develop a vision and strategy for adapting to sea level rise

May 5, 2016

Climate Change and SLR in Olympia



City Policy 2010

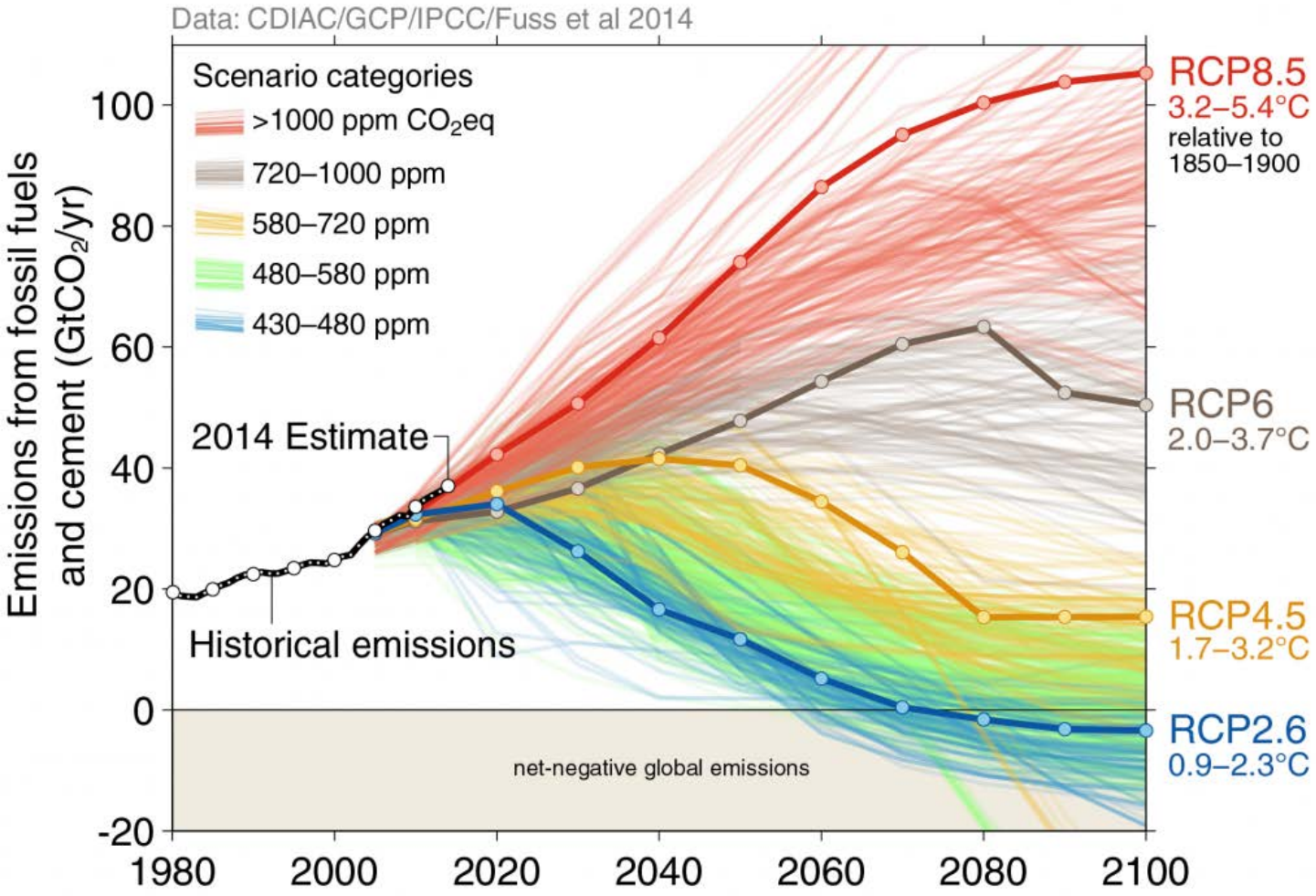
- Protect downtown.
- Understand the implications of 50 inches of sea level rise.
- Use opportunities for new public and private investments to prepare for sea rise.
- Seek opportunities to maintain control of valuable shoreline.

Comprehensive Plan

GU11: The City uses best available information to implement a sea level rise management plan that will protect Olympia's downtown.

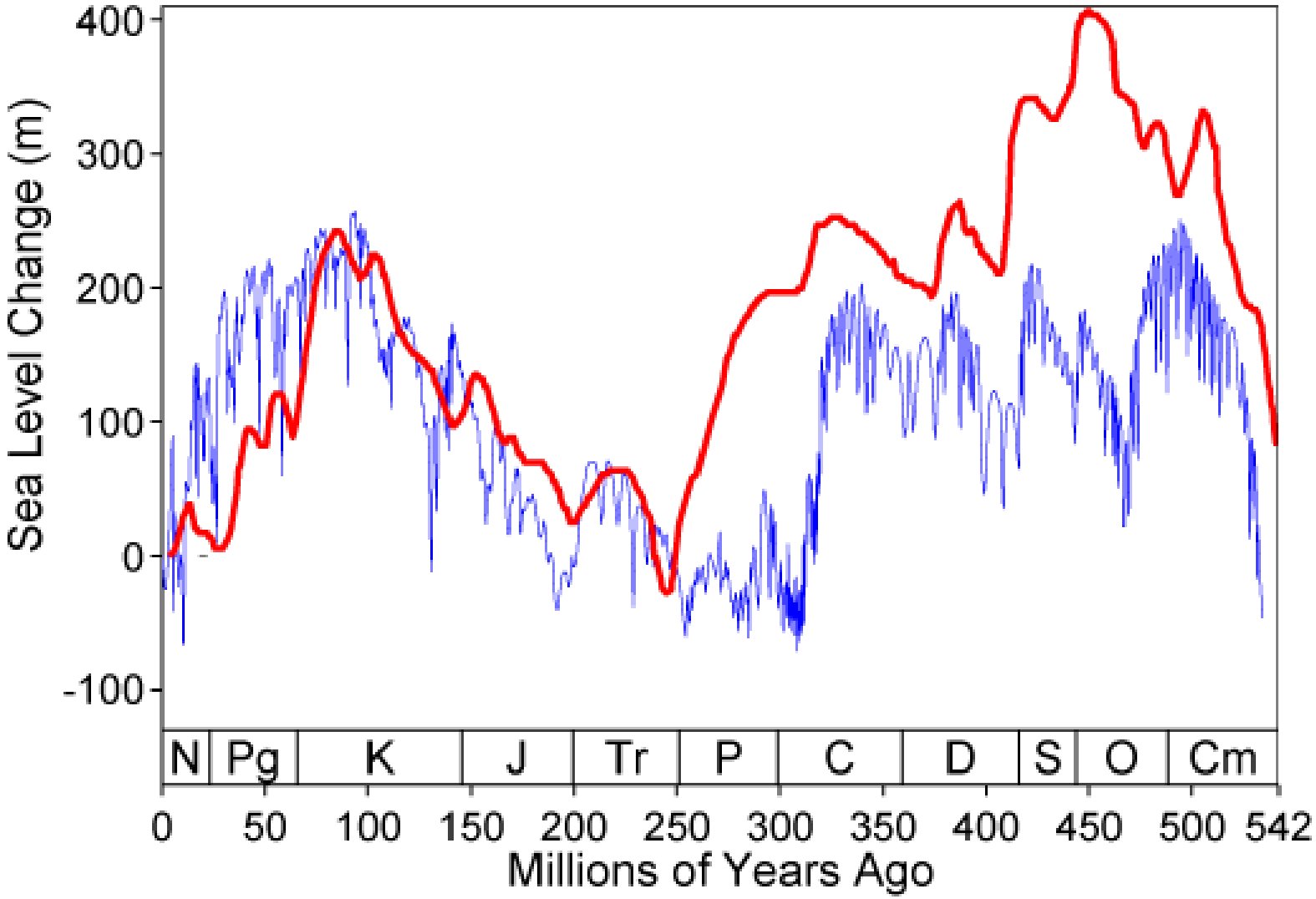
- Develop a robust sea level response plan
- Maintain public control of downtown shorelines
- Use best available science
- Partner with government entities and key stakeholders
- Engage the community
- Require development to incorporate sea rise response measures

Climate Change



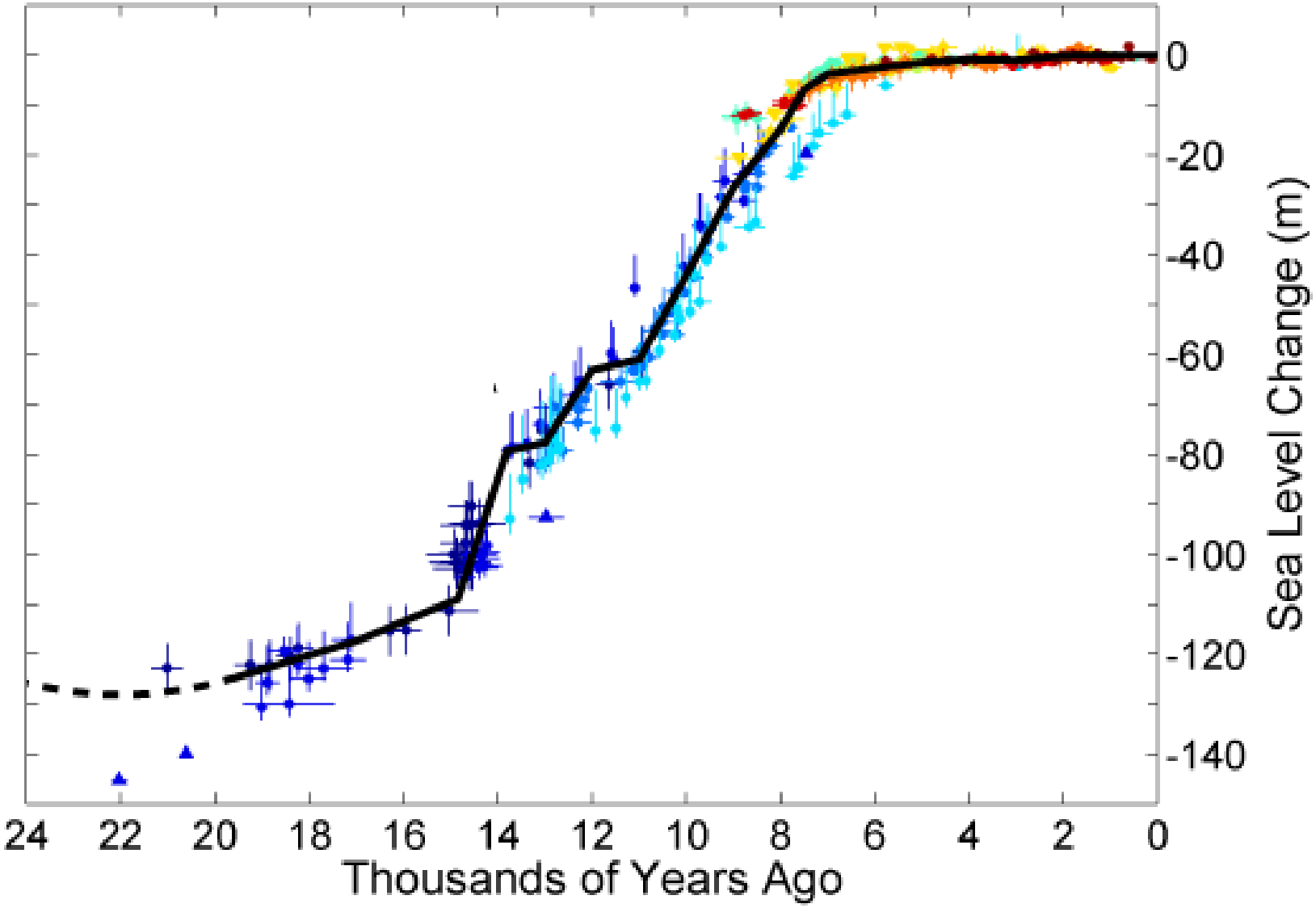
Climate Change

Sea Level Fluctuations

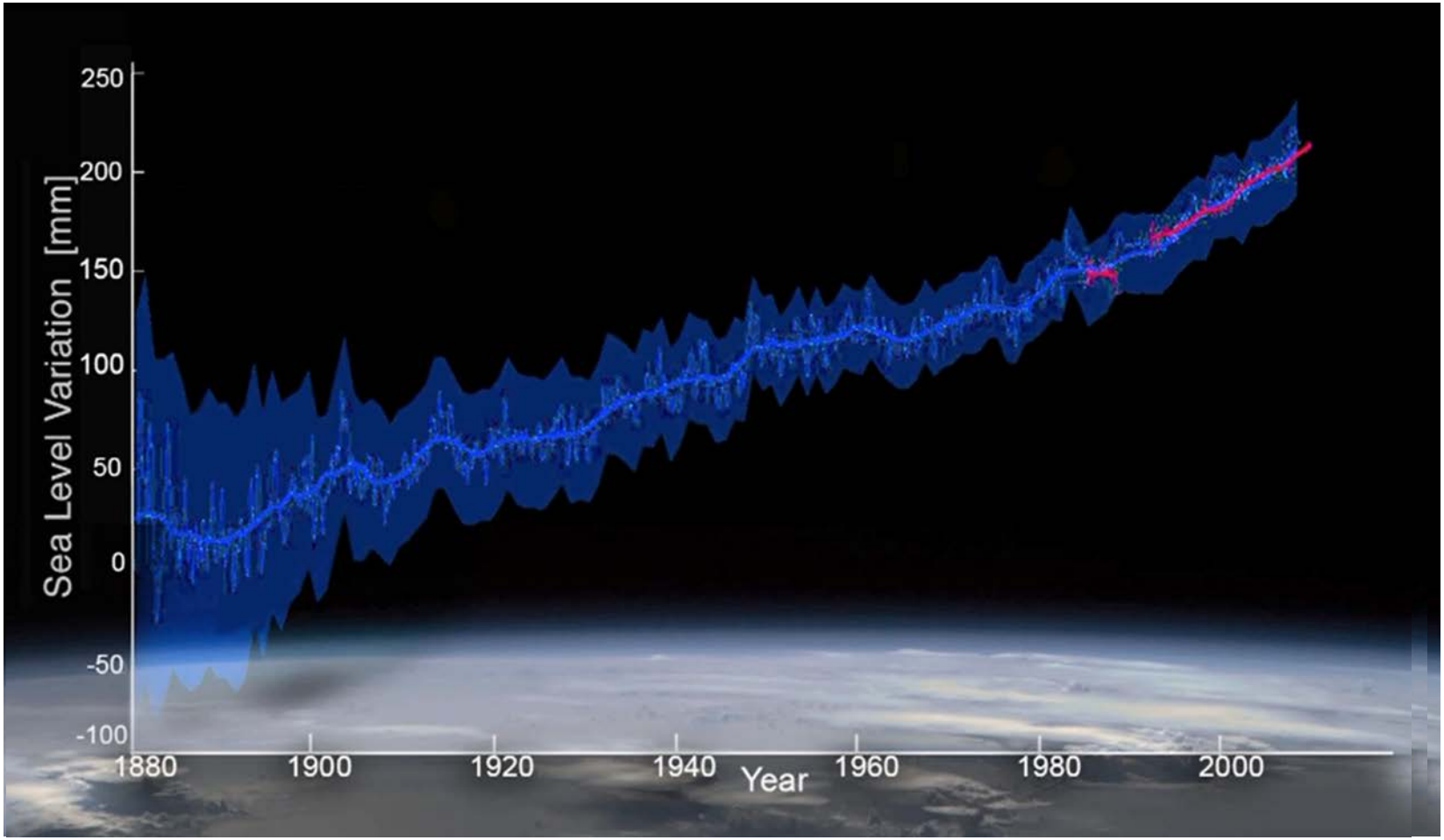


Global Warming Art project

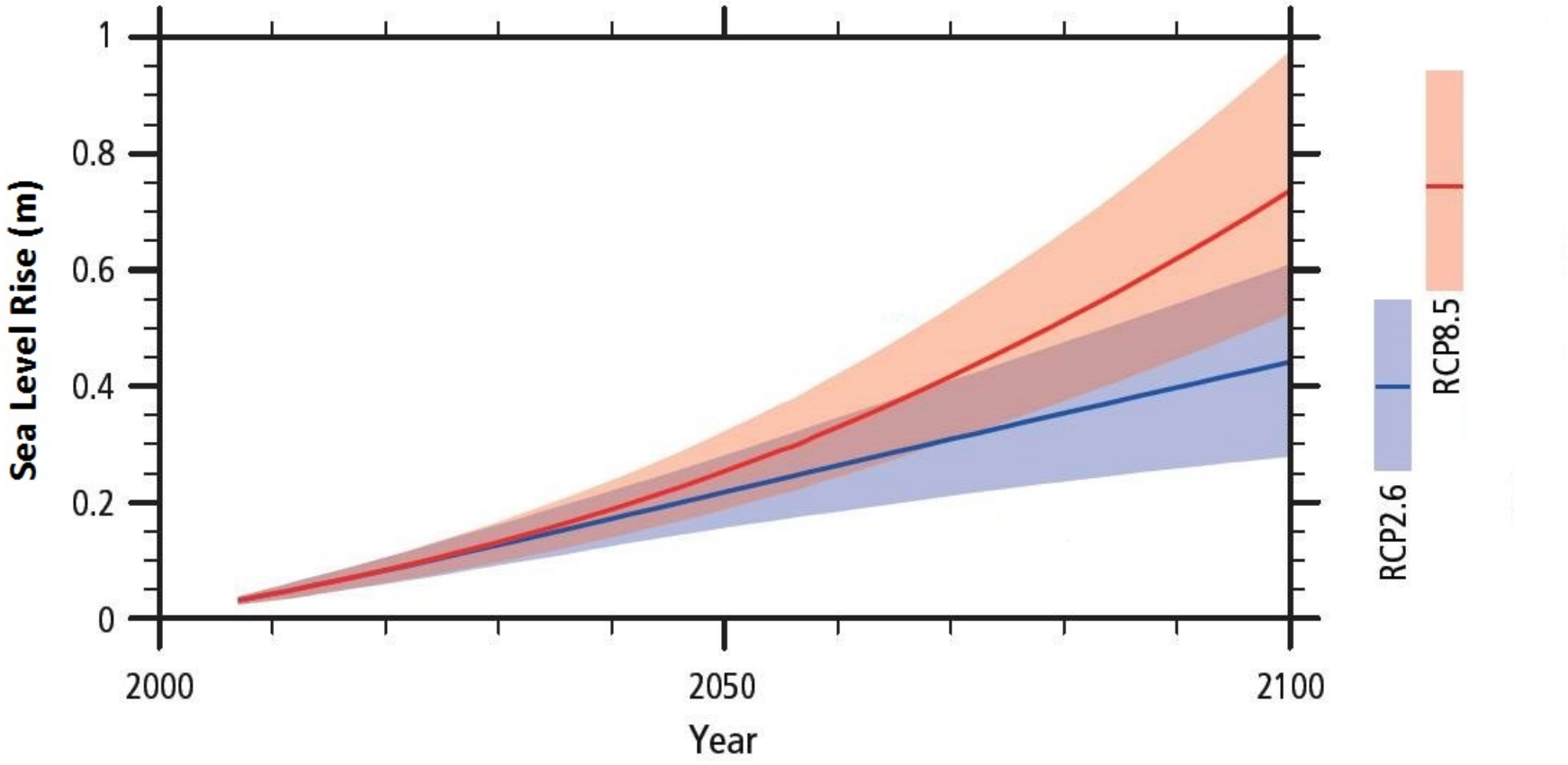
Post-Glacial Sea Level Rise



Sea Level Trends



IPCC Sea Level Rise Scenarios



IPCC 5th Assessment Report (2013)

Recent Headlines

'Drastic' Antarctic melt could double global sea-level rise

Scientists nearly double sea level rise projections for 2100, because of Antarctica

Greenland's Ice Sheet Is Melting So Fast Right Now, Scientists Thought It Was an Error

Costs rise faster than water, according to sea level rise study

Antarctica Meltdown Could Double Sea Level Rise

A new model suggests ice loss could raise sea levels further, faster

RIMS 2016: Sea Level Rise Will Be Worse and Come Sooner

Sea-level rise may last twice as long as human history to date

'A dire prediction' on melting ice sheets and rising sea levels

Experts: The sea level is rising, and coastal cities better be ready

It's not just Antarctica — why Greenland could also melt faster than expected

Sea Level Rise Could Look Much Worse by 2100

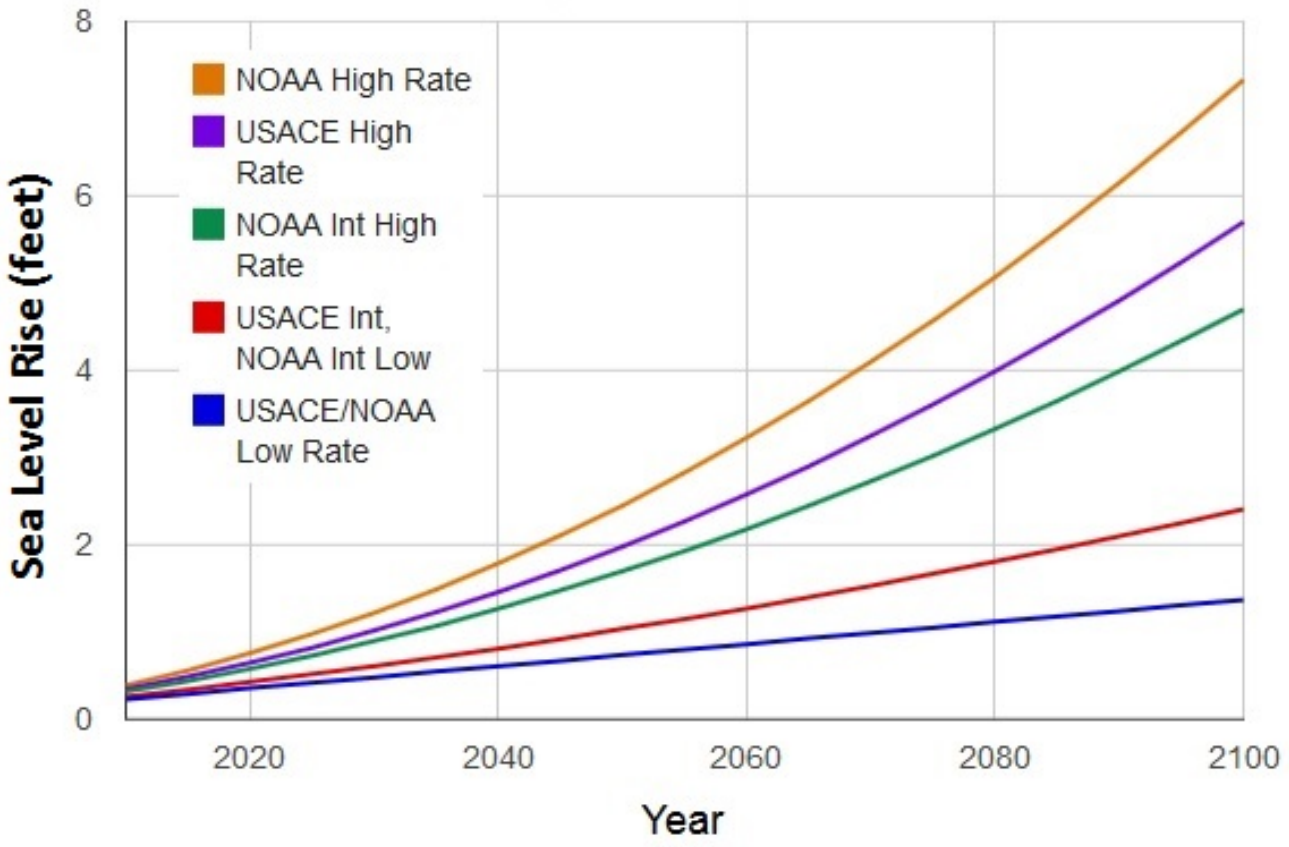
New research doubles previous predictions if greenhouse gas emissions go unchecked.

Greenland's massive ice sheet is melting freakishly early

By Associated Press April 14, 2016 | 11:04am

'A dire prediction' on melting ice sheets and rising sea levels

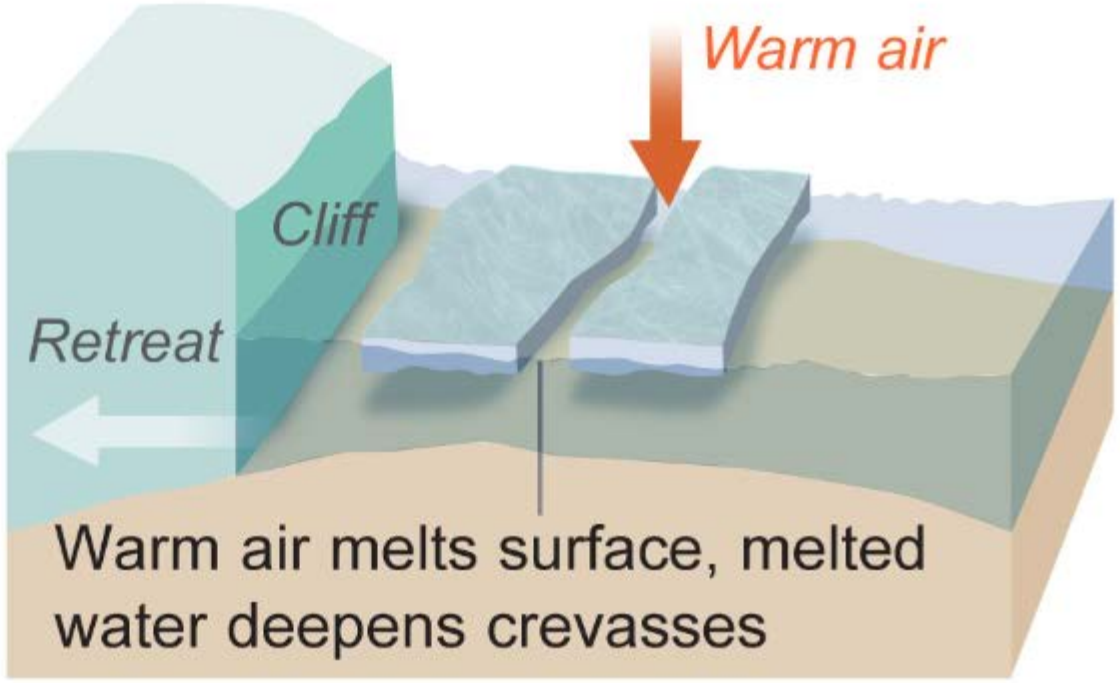
Other Sea Level Rise Scenarios



Antarctica

How marine ice sheets retreat from above

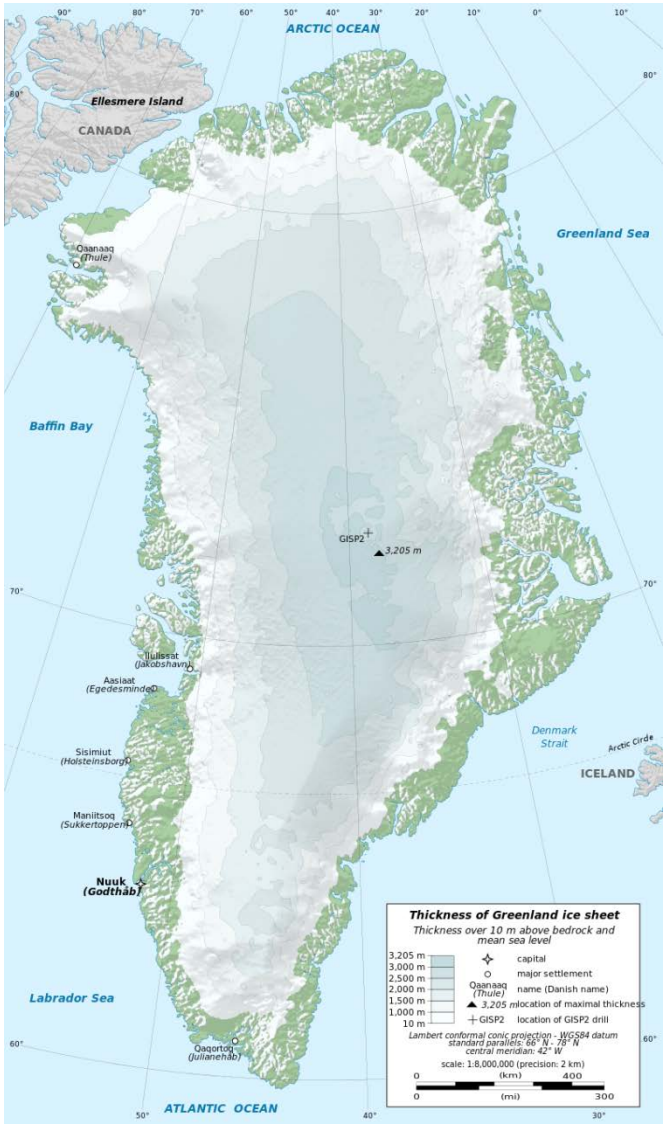
Warm air melts surface and floating ice disintegrates, exposing large cliffs which fail under their own weight.



Sources: Robert M. DeConto and David Pollard

Raoul Rañoa@latimesgraphics

Greenland


ARCTIC OCEAN
Ellesmere Island
CANADA
Greenland Sea
Qaanaaq (Thule)
Baffin Bay
GISP2
3,205 m
Ilulissat (Jakobshavn)
Aasiaat (Egedesminde)
Denmark Strait
Arctic Circle
ICELAND
Sisimiut (Holsteinsborg)
Maniitsoq (Sukkertoppen)
Nuuk (Godthåb)
Labrador Sea
Qaqortoq (Julianehåb)
ATLANTIC OCEAN
Thickness of Greenland ice sheet
Thickness over 10 m above bedrock and mean sea level
3,205 m
3,000 m
2,500 m
2,000 m
1,500 m
1,000 m
10 m
capital
major settlement
name (Danish name)
3,205 m location of maximal thickness
GISP2 location of GISP2 drill
Lambert conformal conic projection - WGS84 datum
standard parallels: 66° N - 78° N
central meridian: 42° W
scale: 1:8,000,000 (precision: 2 km)
0
(km)
400
0
(mi)
300

Recent Quote

"Recent data that has been collected but has yet to be made official indicates sea levels could rise by roughly 3 meters or 9 feet by 2050-2060, far higher and quicker than current projections."

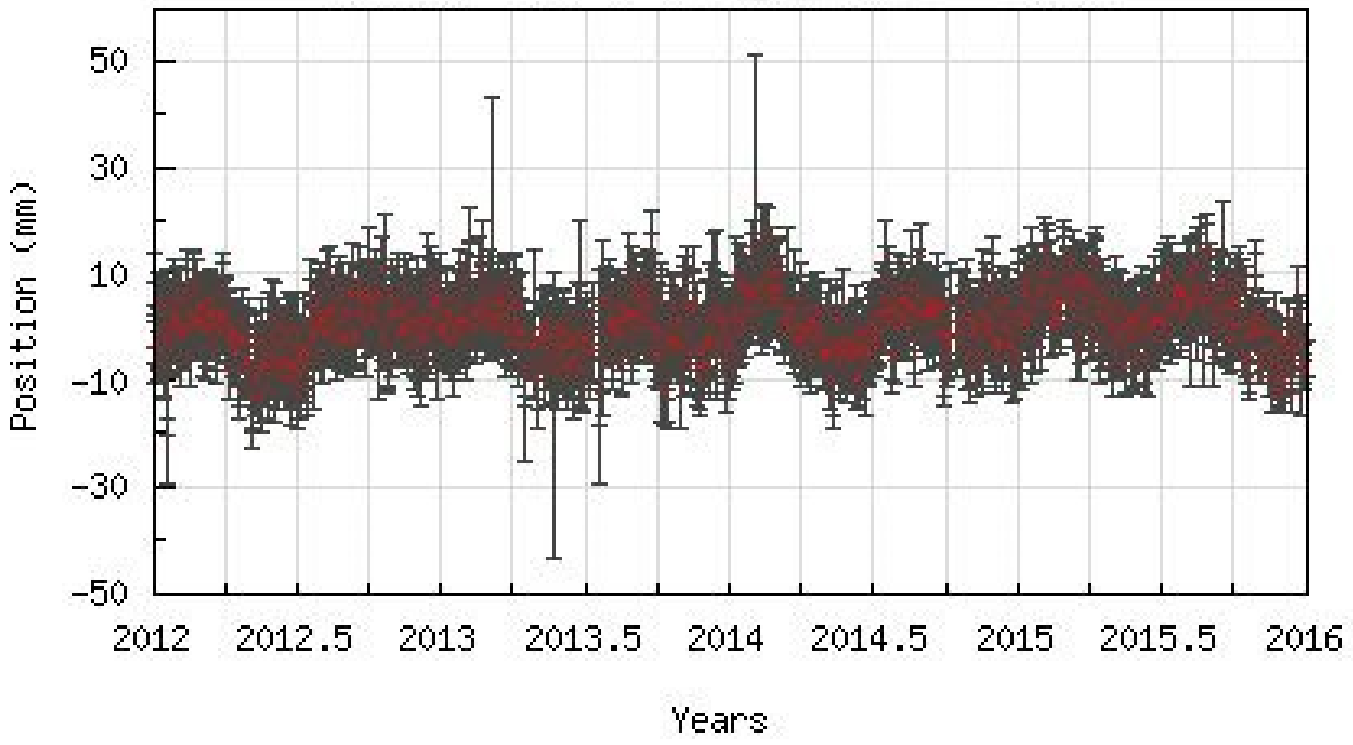
- Margaret Davidson, NOAA's senior advisor for coastal inundation and resilience science and services at RIMS 2016

Sea Level Rise Commitment Beyond 2100

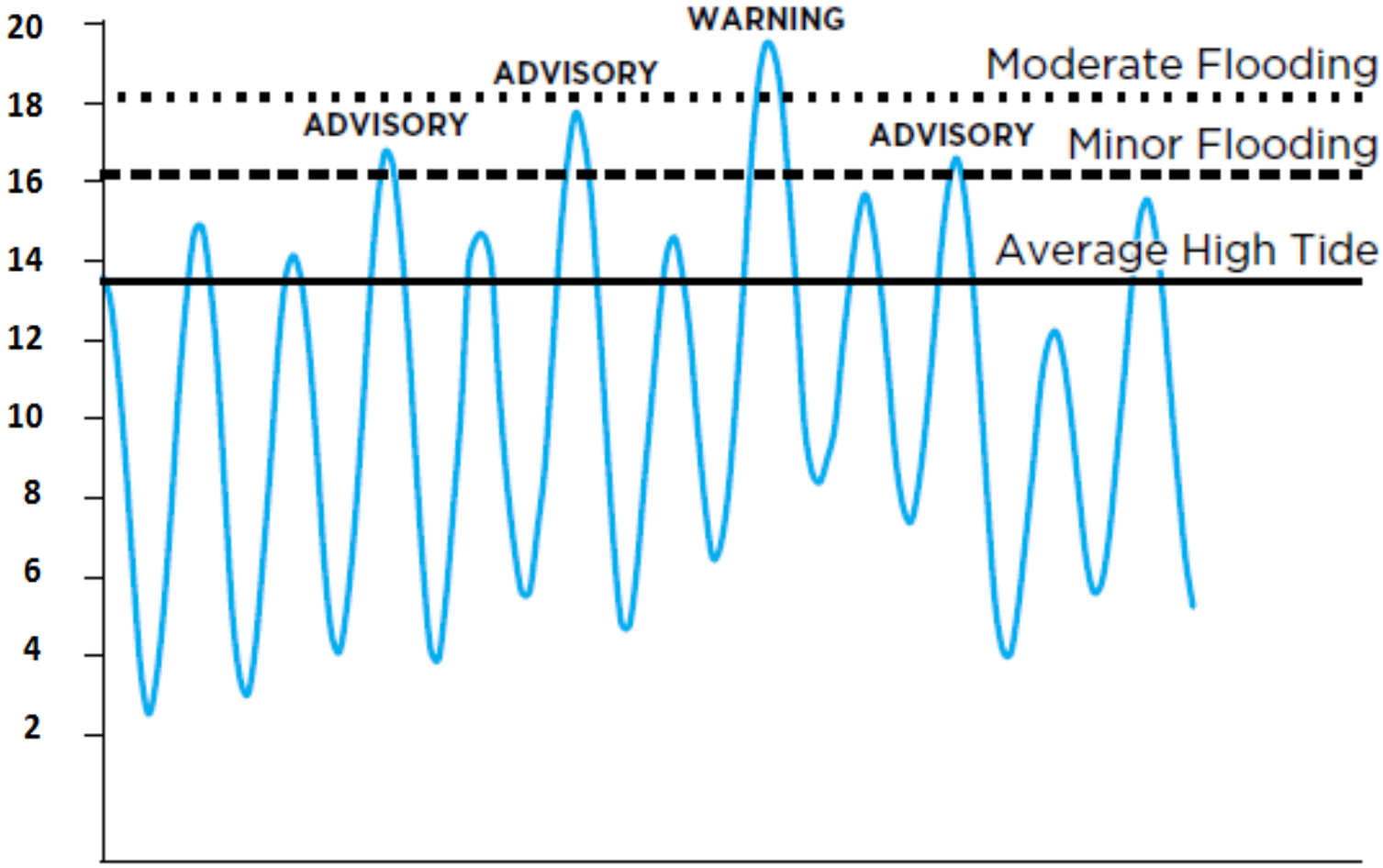
- Carbon emissions through 2015 have committed us to 4 feet of sea level rise
- Maintaining current carbon emissions through 2100 commits us to 23 feet of sea level rise
- Reducing carbon emissions starting in 2020 commits us to almost 8 feet of sea level rise
- Even with climate change limited to $2^{O}C$ by tough emissions cuts (Paris Agreement), sea levels would rise 16 feet by 2500 and >80 feet by 4015

Vertical Land Movement

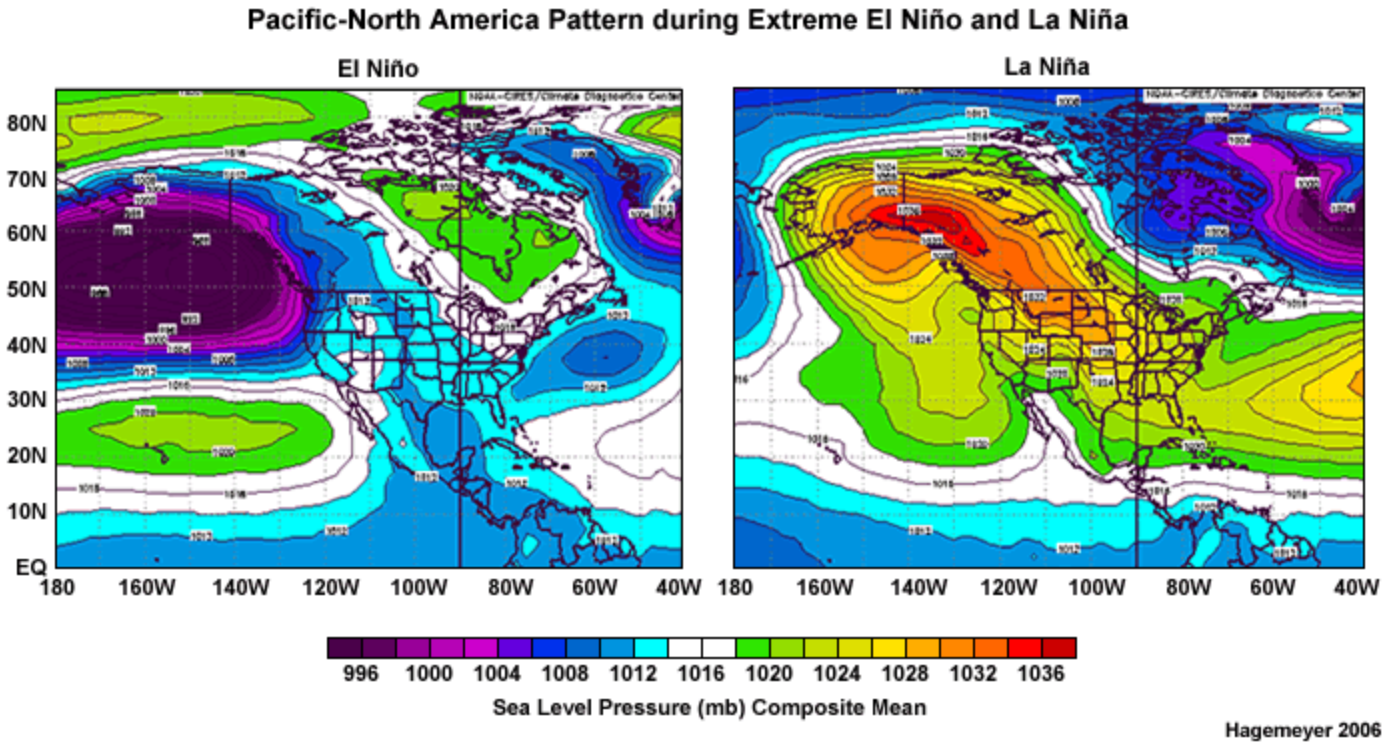
Downtown Olympia appears to be subsiding 0.9 in/decade



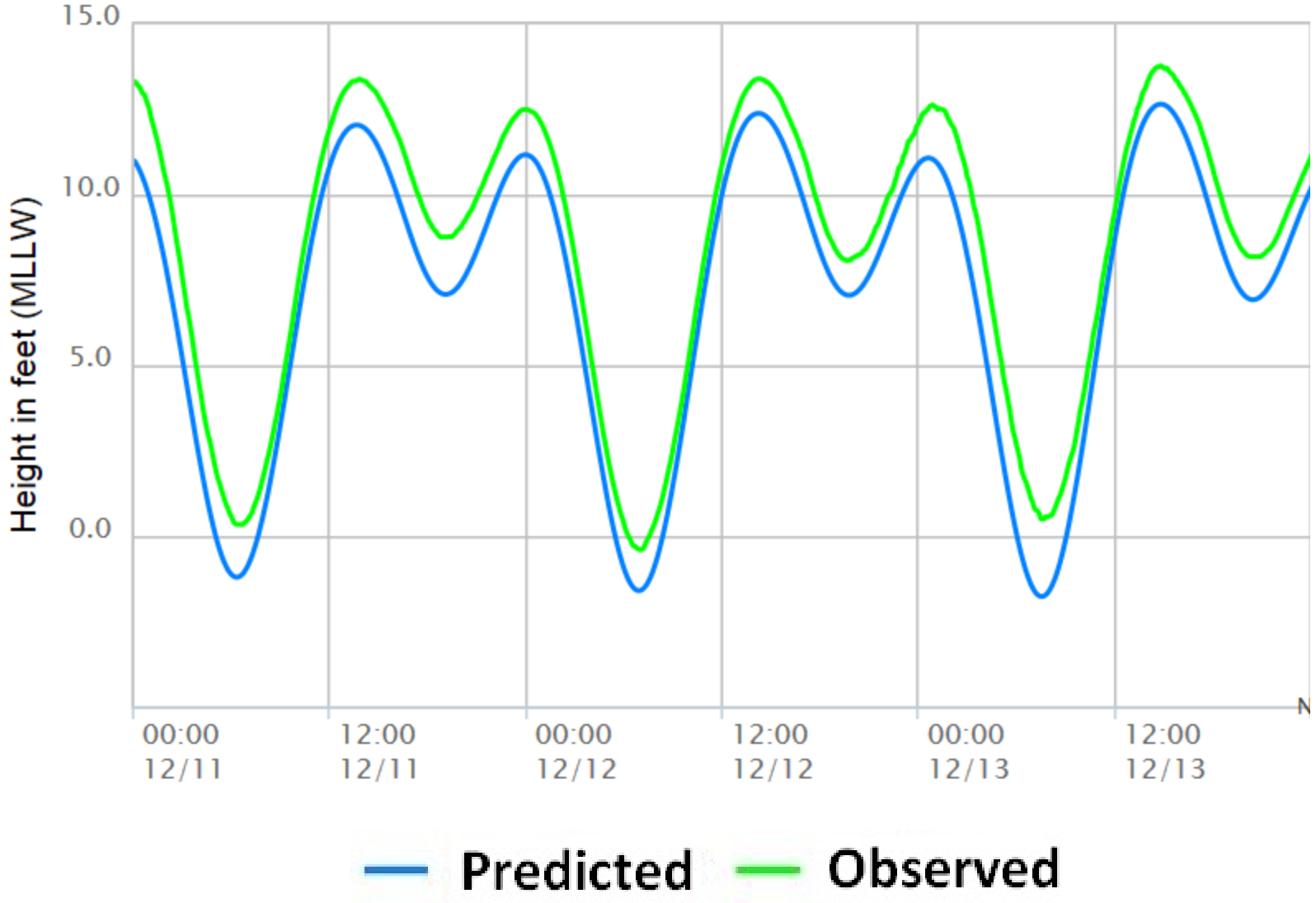
Flooding is Periodic



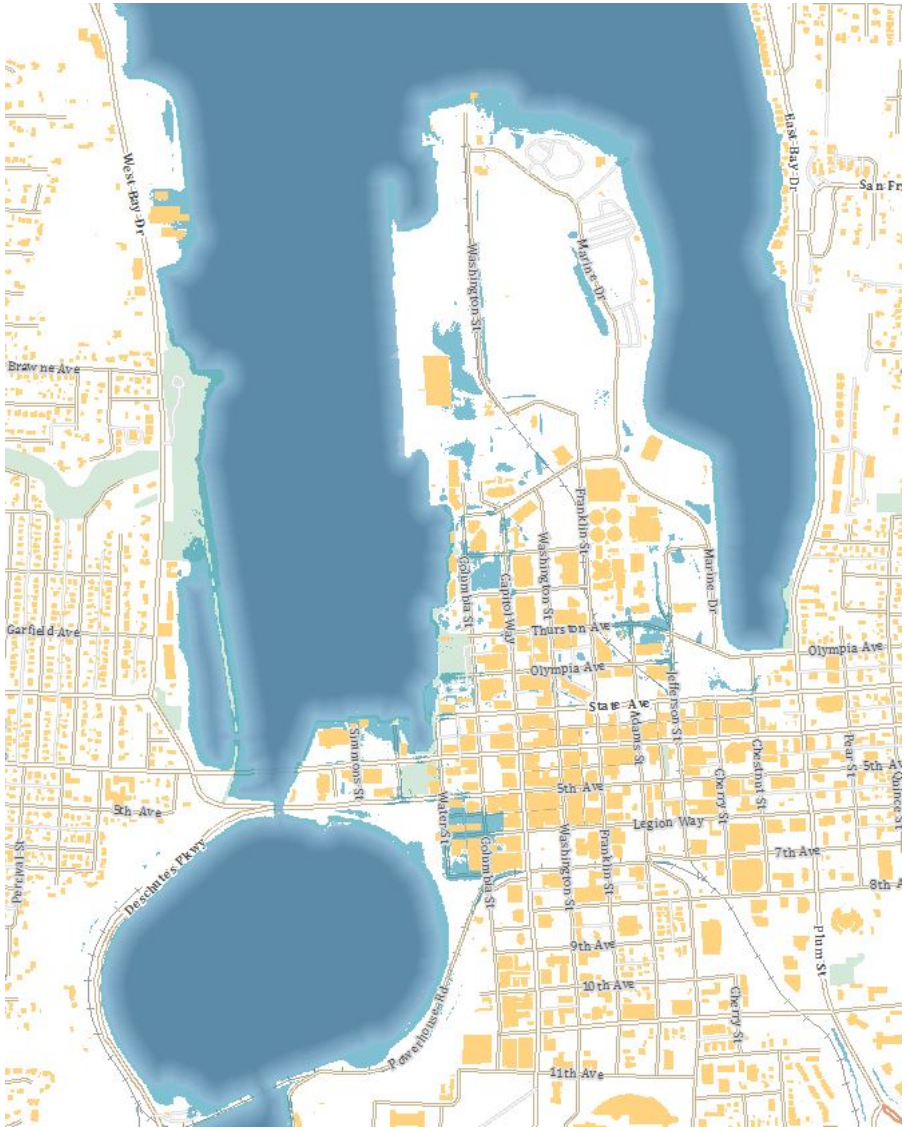
Importance of El Nino events



Atmospheric Pressure



100-yr Flood Zone

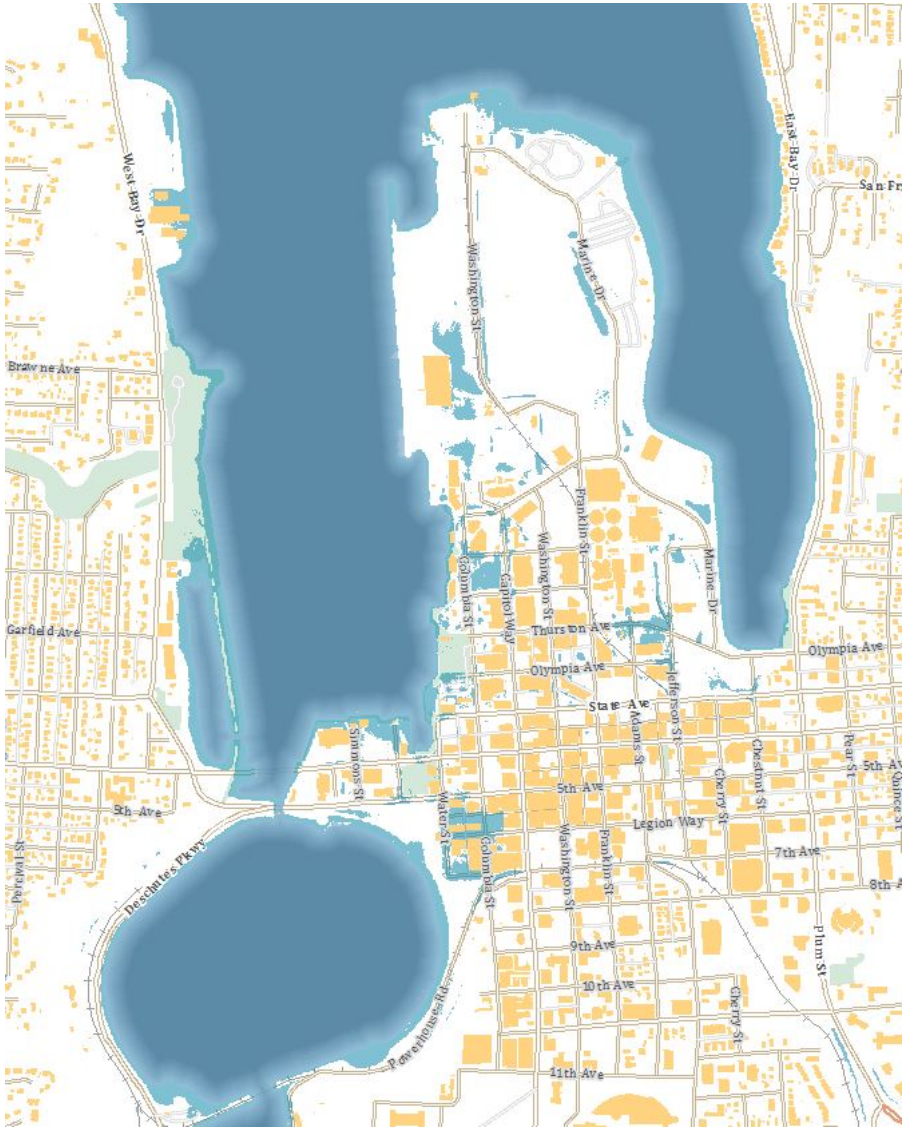


- 14 feet NAVD88 = 18 feet MLLW

- Nuisance flooding 1 time per year
- Current 100-year flood 1% chance/ year

- ~ 55 acres inundated
- ~ 150 buildings affected
- ~ 122 LOTT catch basins affected

2011 City Study 100-yr Flood Zone

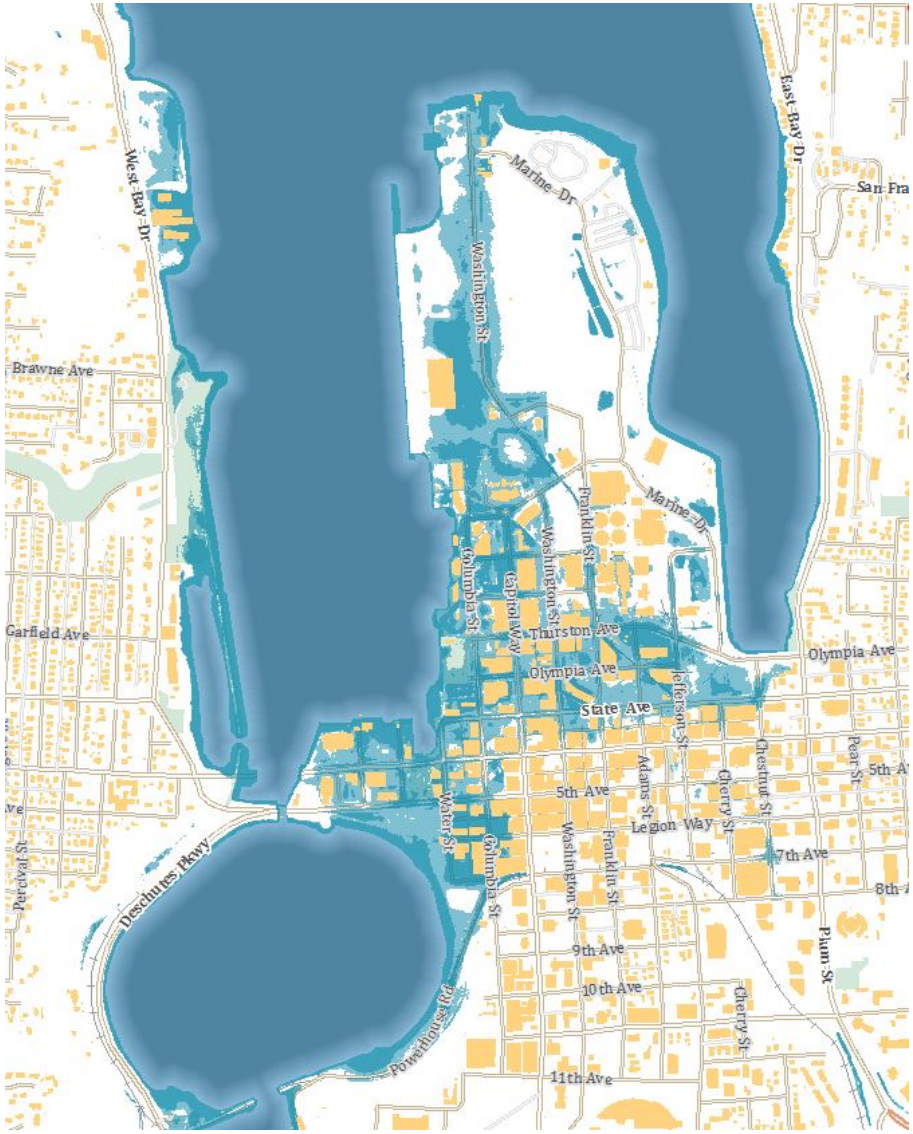


- 14.8 feet NAVD88 = 18.8 feet MLLW

- Nuisance flooding 1 time per year
- Current 100-year flood >2% chance/year

- ~ 143 acres inundated
- ~ 150 buildings affected
- ~ 178 LOTT catch basins affected

1 foot SLR 100-yr Flood Extents



- 15 feet NAVD88 = 19 feet MLLW

- Nuisance flood - 30 times/year
- Current 100-yr flood - 1 time/ year

- Forecast
  - 2100 – IPCC Low
  - 2045 – IPCC High
  - 2075 – NOAA Low
  - 2025 – NOAA High

- ~ 163 acres inundated
- ~ 261 structures affected
- ~ 195 LOTT catch basins affected

2 feet SLR 100-yr Flood Extents

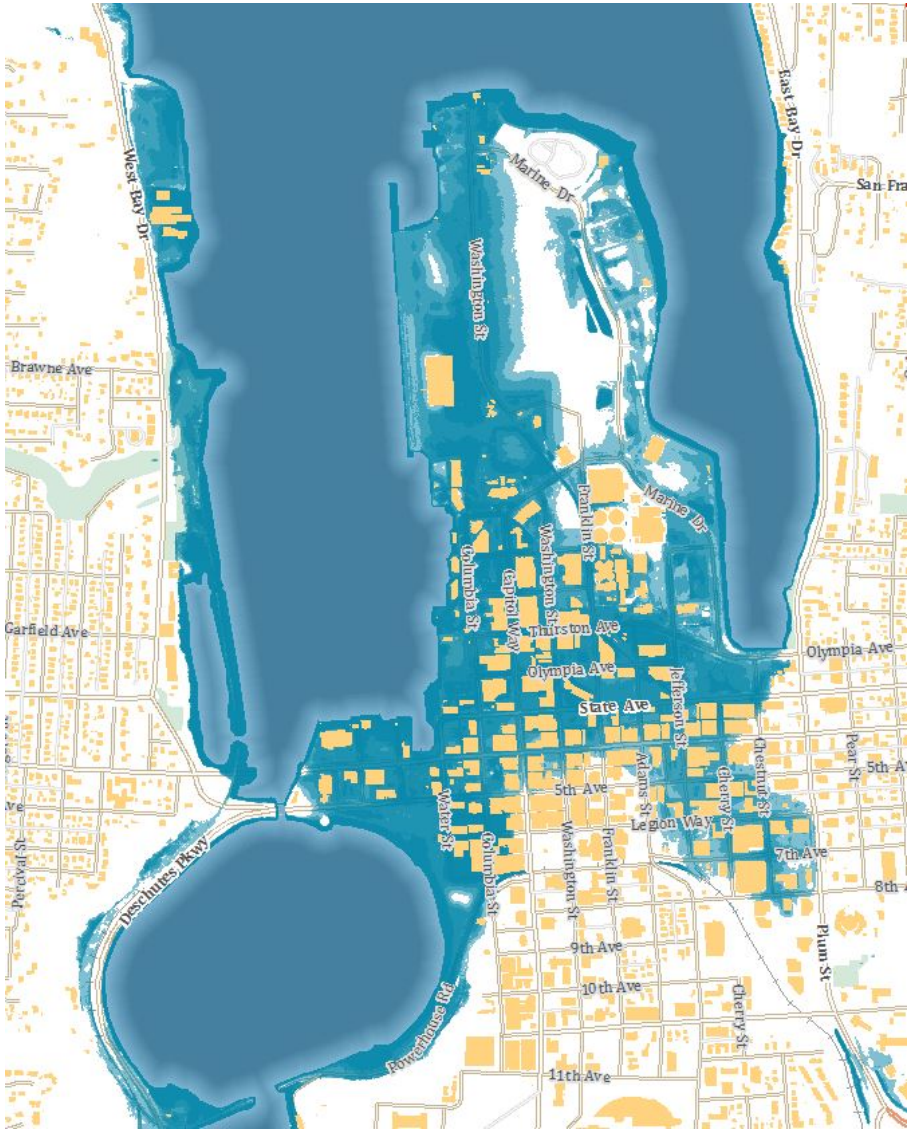
- 16 feet NAVD88 = 20 feet MLLW

- Nuisance flood - 160 times/year
- Current 100-yr flood - 30 times/ year

- Forecast
  - >2100 – IPCC Low
  - 2090 – IPCC High
  - >2100 – NOAA Low
  - 2042– NOAA High

- ~ 252 acres inundated
- ~ 328 structures affected
- ~ 231 LOTT catch basins affected

3 feet SLR 100-yr Flood Extents



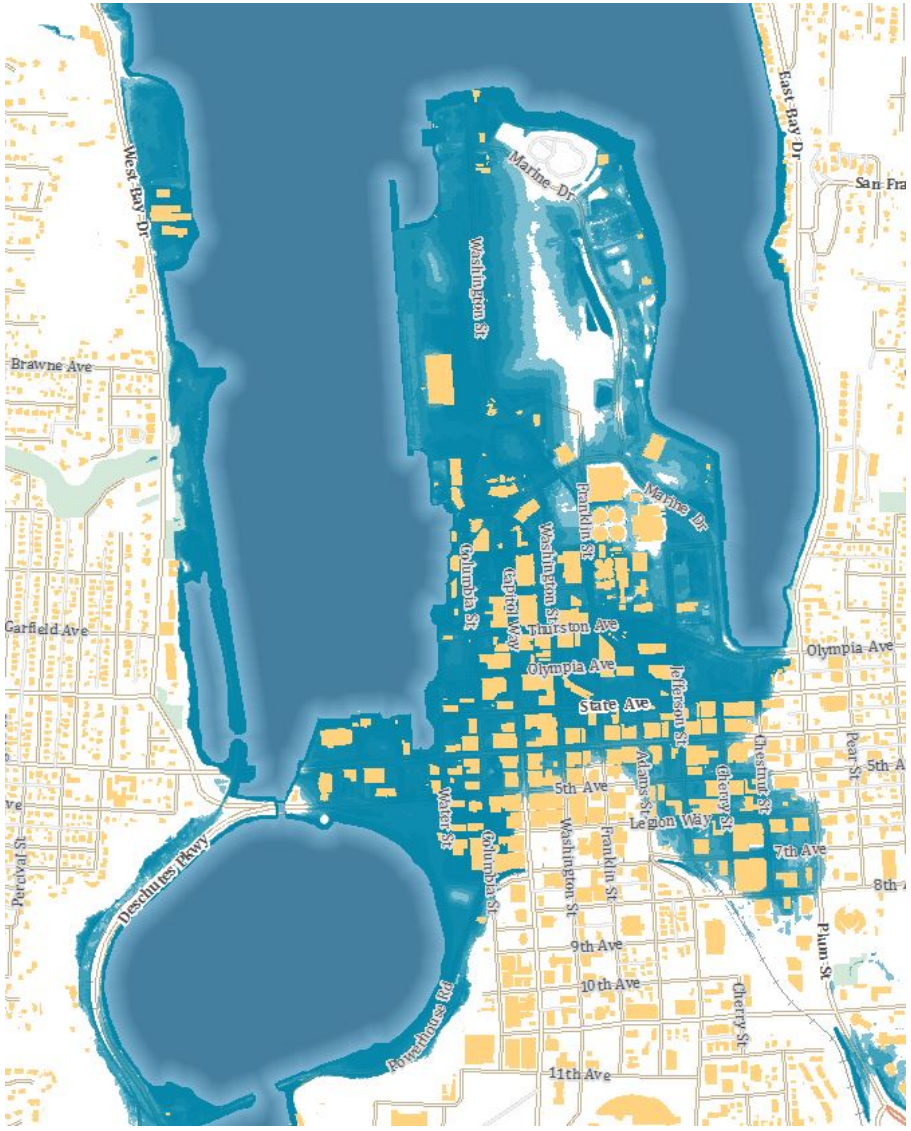
- 17 feet NAVD88 = 21 feet MLLW

- Nuisance flood ~ 350 times/year
- Current 100-yr flood ~ 160 times/year

- Forecast
  - >2100 – IPCC Low
  - 2100 – IPCC High
  - >2100 – NOAA Low
  - 2058 – NOAA High

- ~ 322 acres inundated
- ~ 368 structures affected
- ~ 255 LOTT catch basins affected

4 feet SLR 100-yr Flood Extents



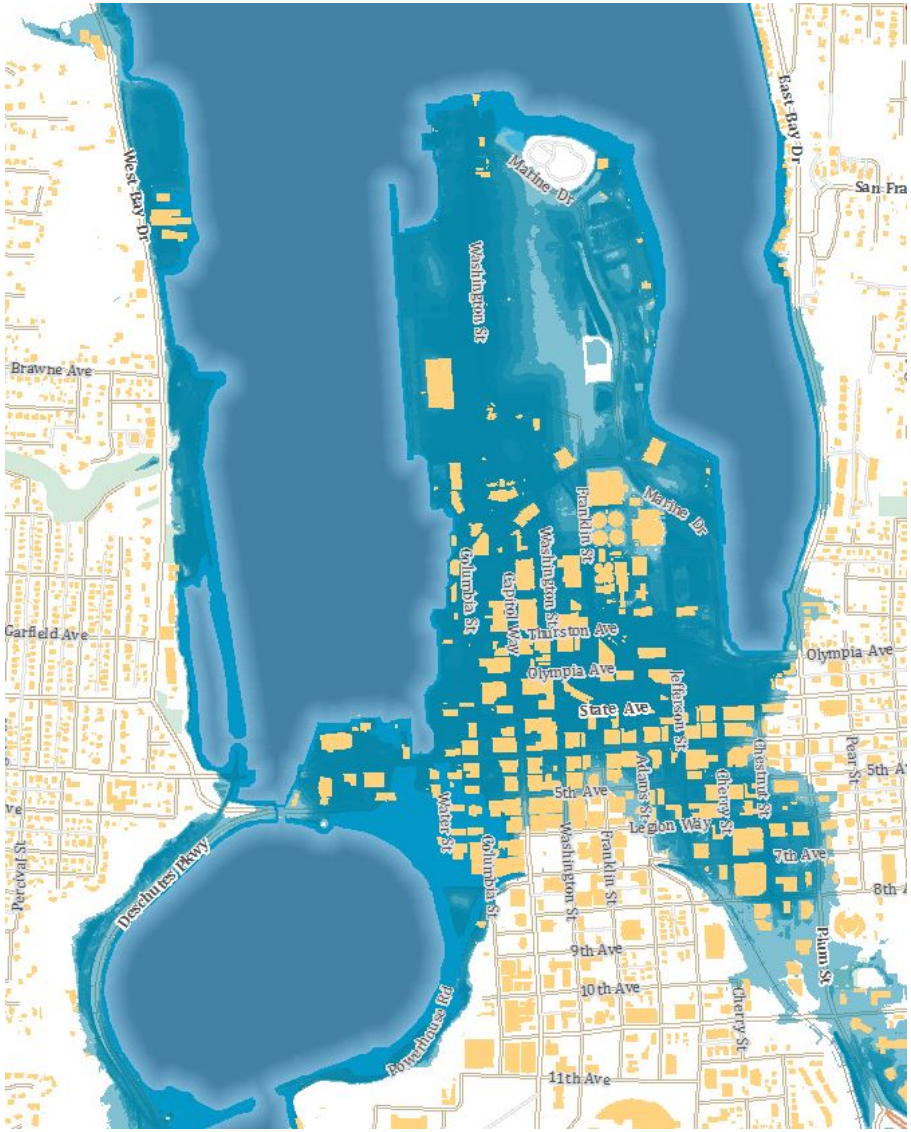
- 18 feet NAVD88 = 22 feet MLLW

- Nuisance flood ~ 440 times/year
- Current 100-yr flood ~ 350 times/year

- Forecast
  - >2100 – IPCC Low
  - >2100 – IPCC High
  - >2100 – NOAA Low
  - 2058 – NOAA High

- ~ 368 acres inundated
- ~ 402 structures affected
- ~ 269 LOTT catch basins affected

8 feet SLR 100-yr Flood Extents



- 22 feet NAVD88 = 26 feet MLLW

- Nuisance flood ~ every day
- Current 100-yr flood ~ every day

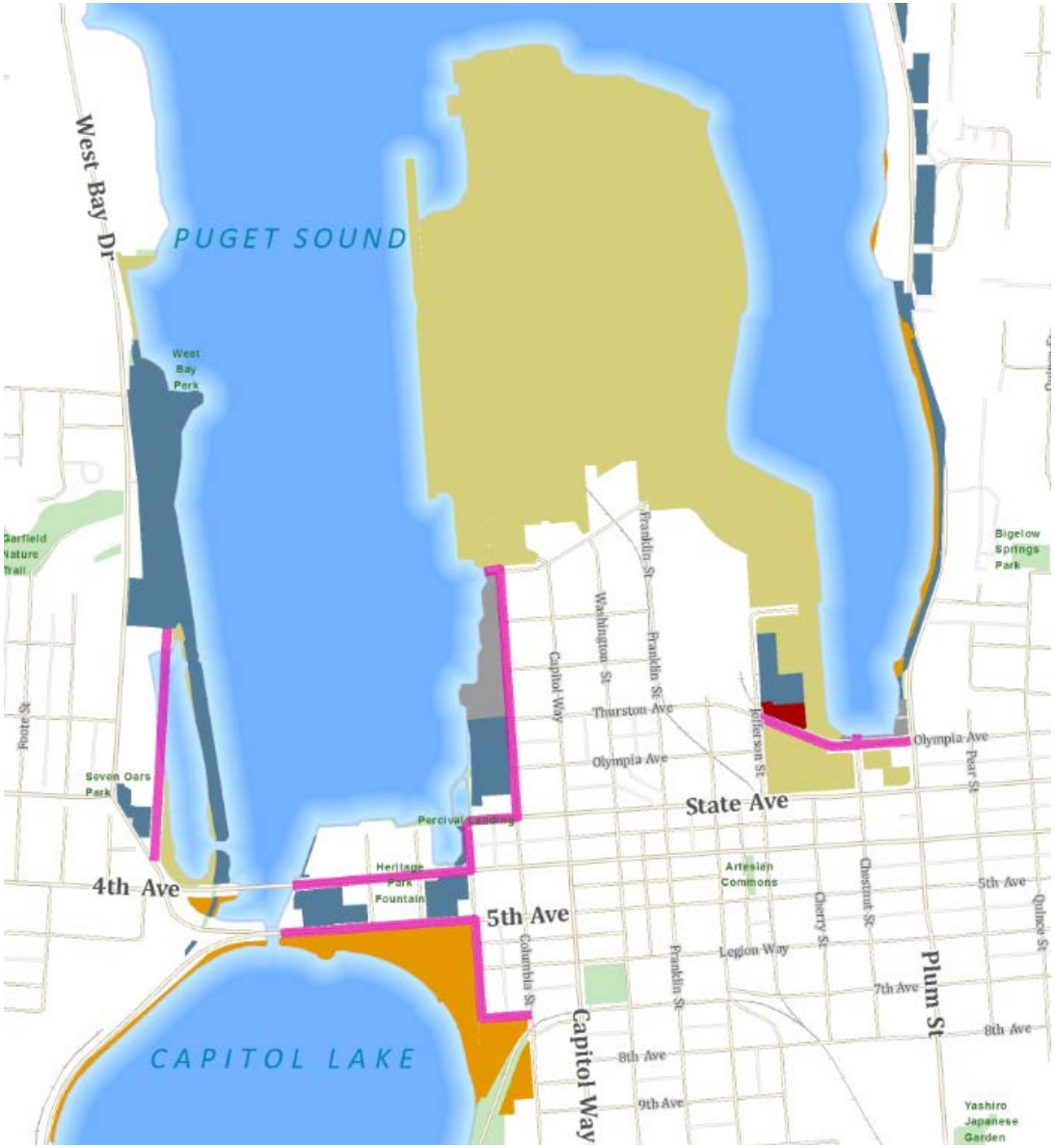
- Forecast
  - >2100 – IPCC Low
  - >2100 – IPCC High
  - >2100 – NOAA Low
  - 2100 – NOAA High

- ~ 534 acres inundated
- ~ 520 structures affected
- ~ 309 LOTT catch basins affected

20 feet SLR 100-yr Flood Extents

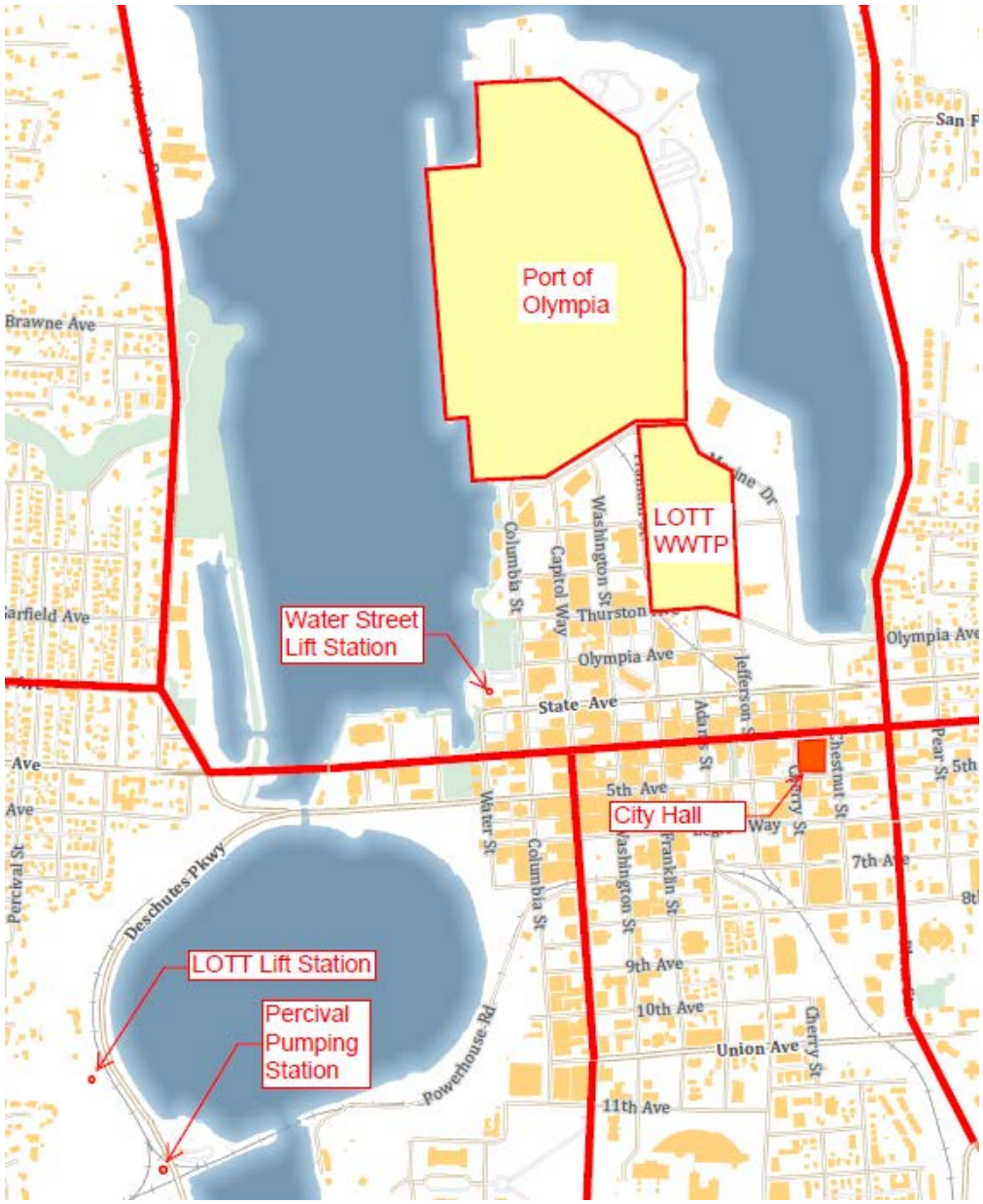
- 34 feet NAVD88 = 38 feet MLLW
- Nuisance flood ~ every day
- Current 100-yr flood ~ every day
- Forecast
  - 2500
- ~ 652 acres inundated
- ~ 680 structures affected
- ~ 316 LOTT catch basins affected

Shoreline Ownership



- Right of Way
- Port of Olympia
- City of Olympia
- LOTT
- Washington DNR
- Washington DES

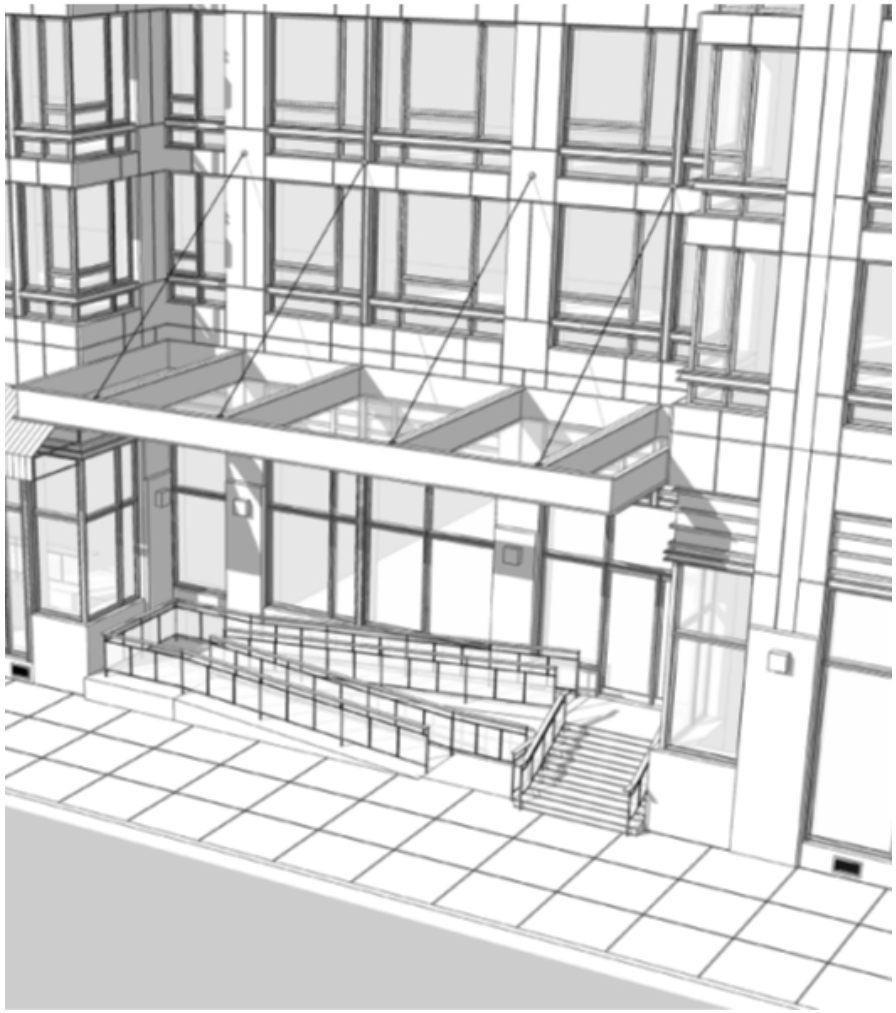
Key Infrastructure



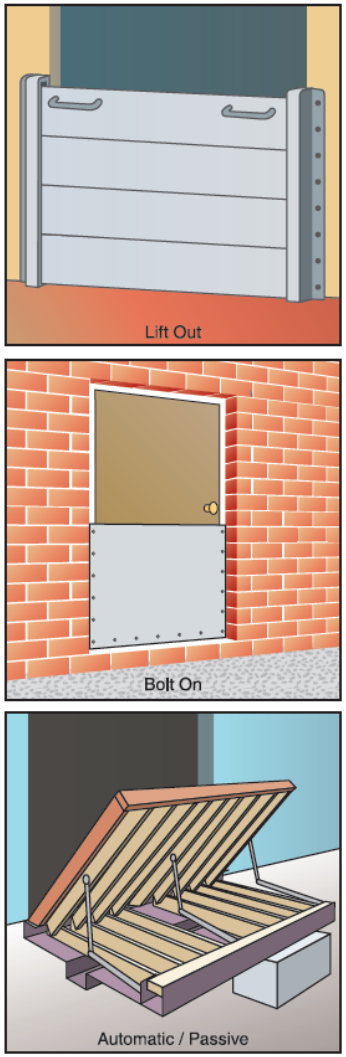
Adapting/Protecting

- Elevated/ flood-proofed buildings
- Storm drainage modifications
- Flood barriers
- Elevated landscapes
- Flood walls
- Elevated roadways
- Downtown regrade
- Marine flood barrier

Elevated/ Flood-proofed Buildings



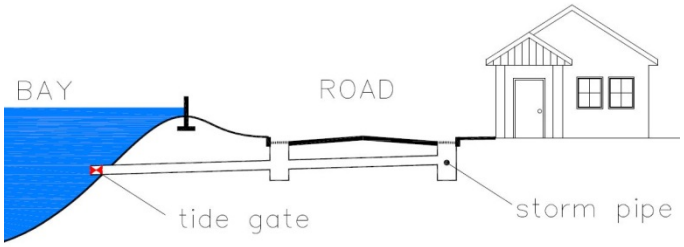
New Buildings

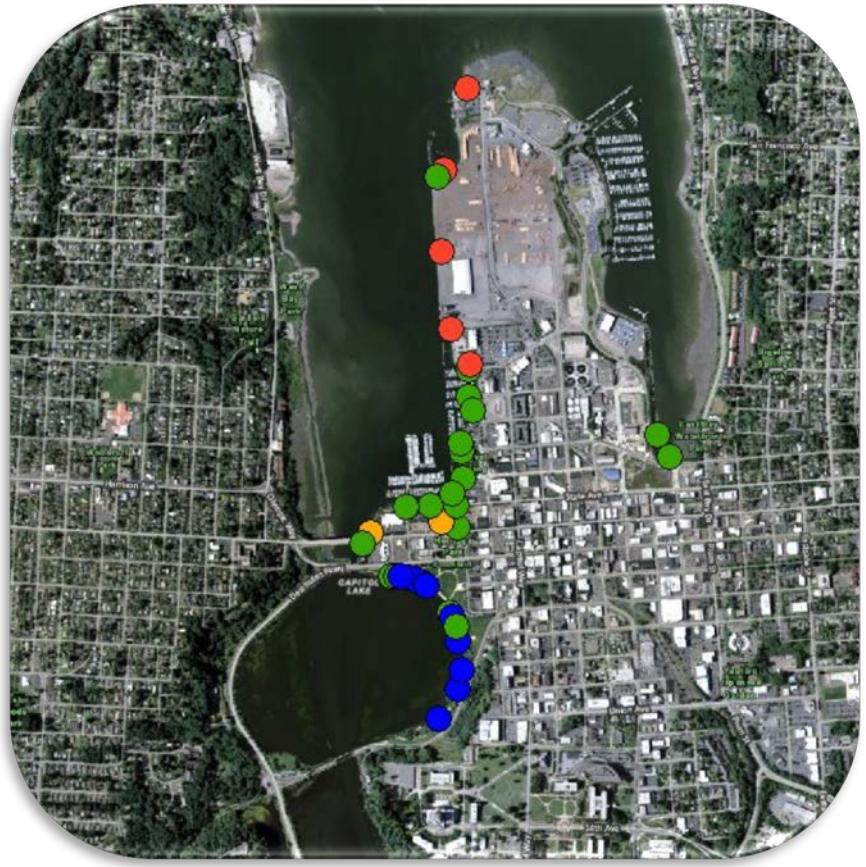


Existing Buildings

Storm Drainage System

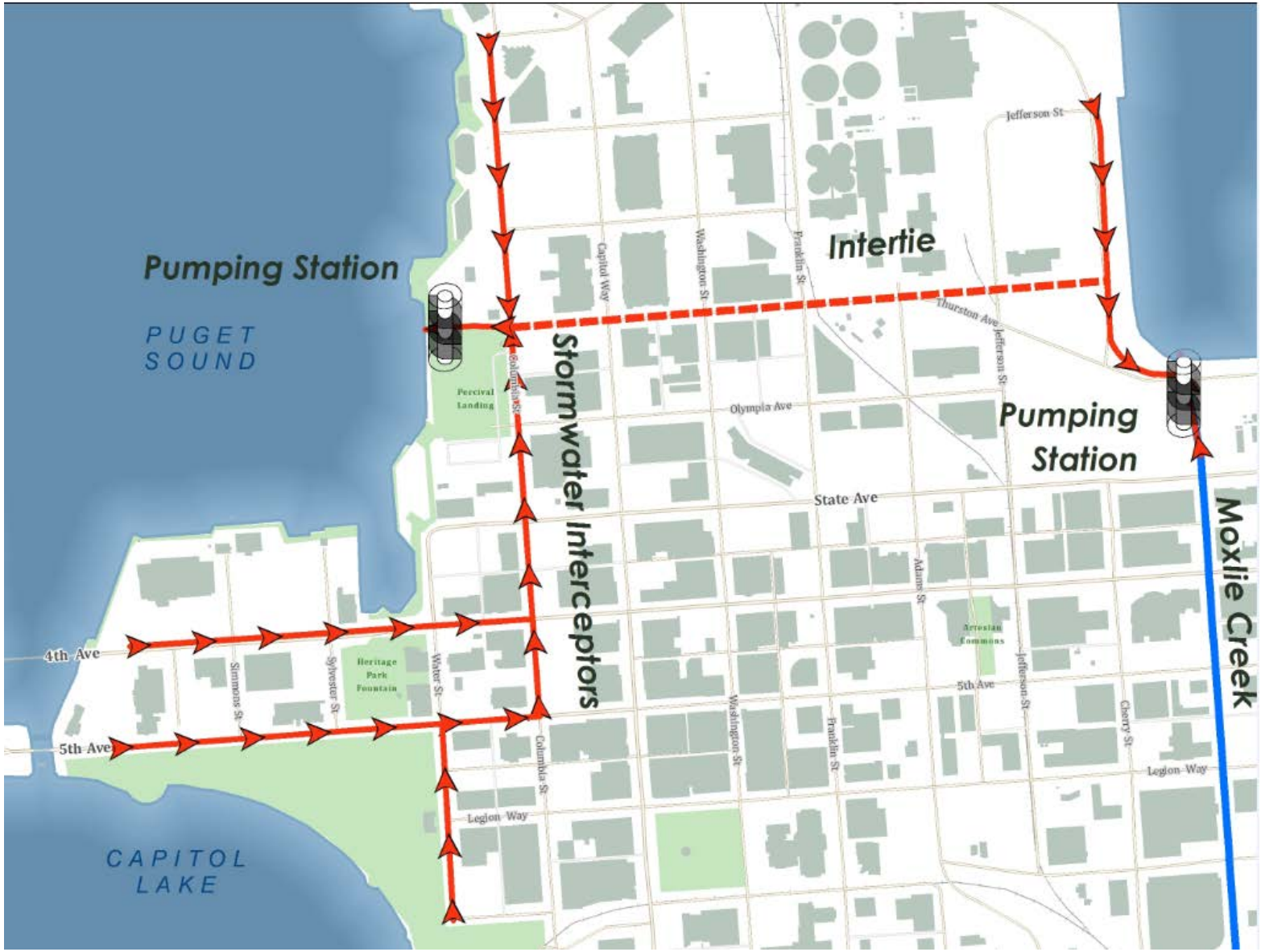
Backflow flooding at Budd Bay Cafe



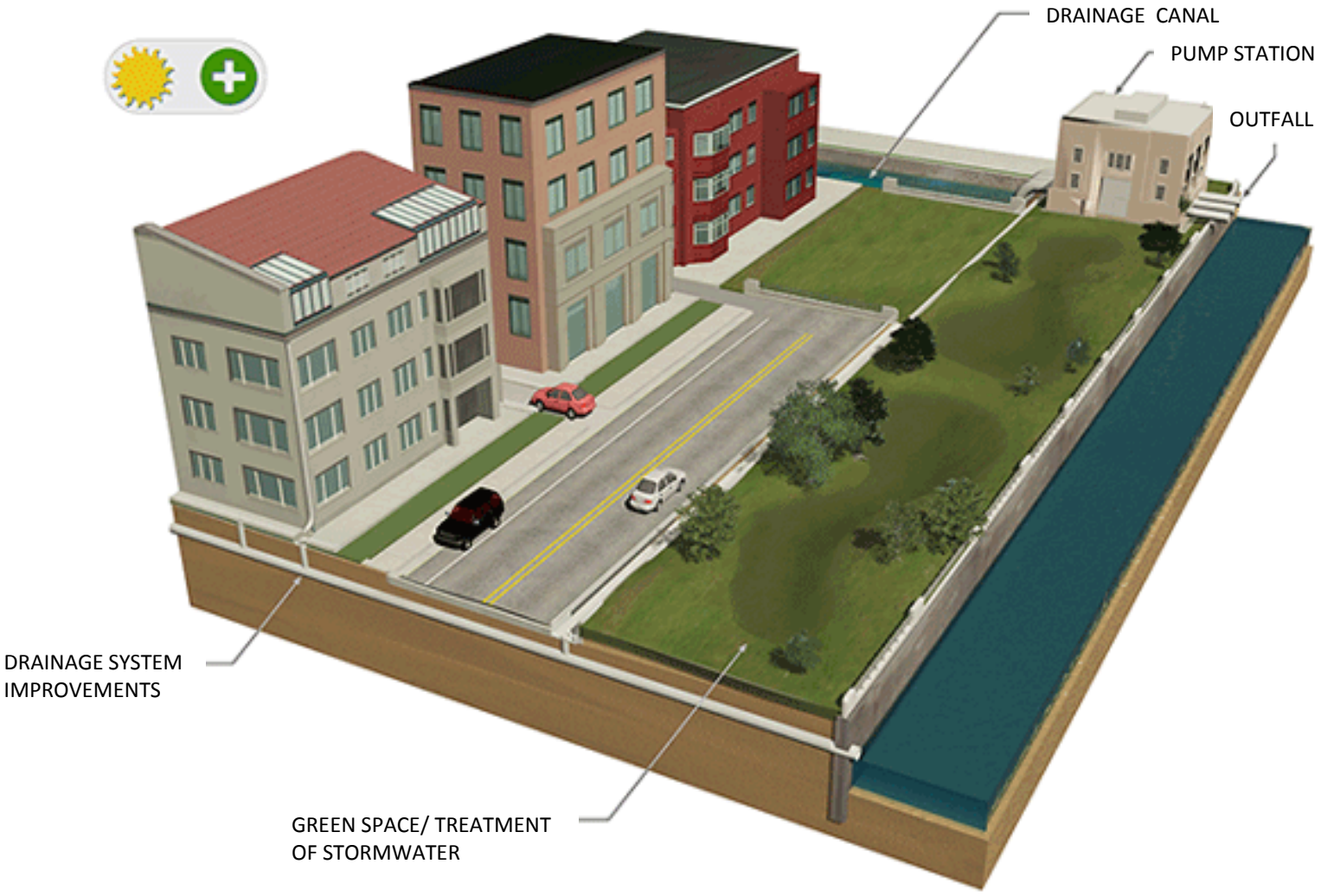


Stormwater Outfalls

Storm Drainage System



Storm Drainage System



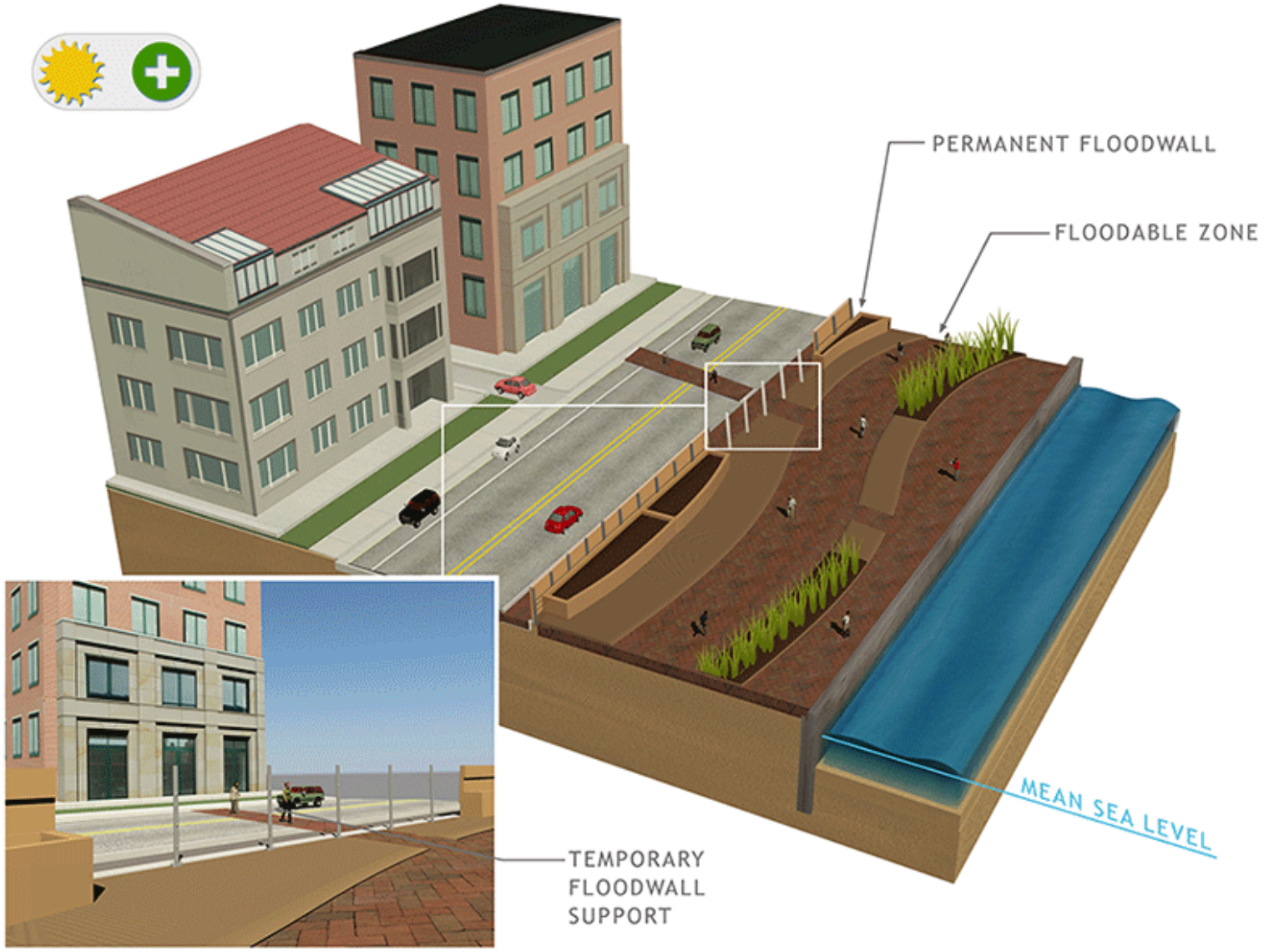
Flood Barriers

Elevate Landscapes

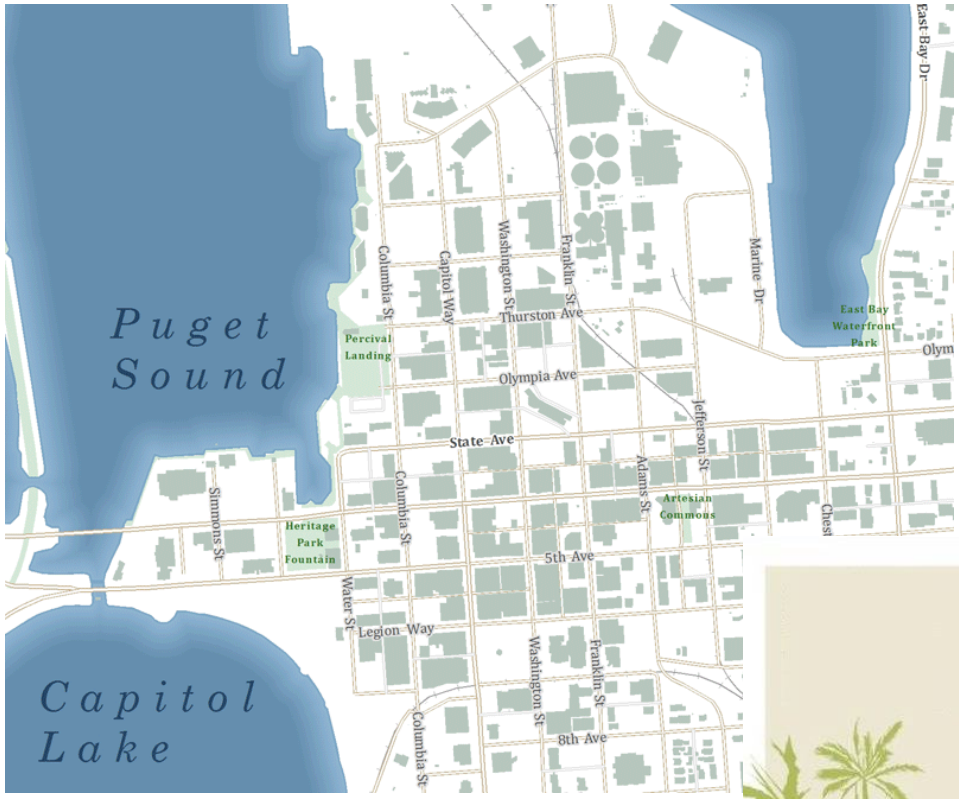
Heritage Park

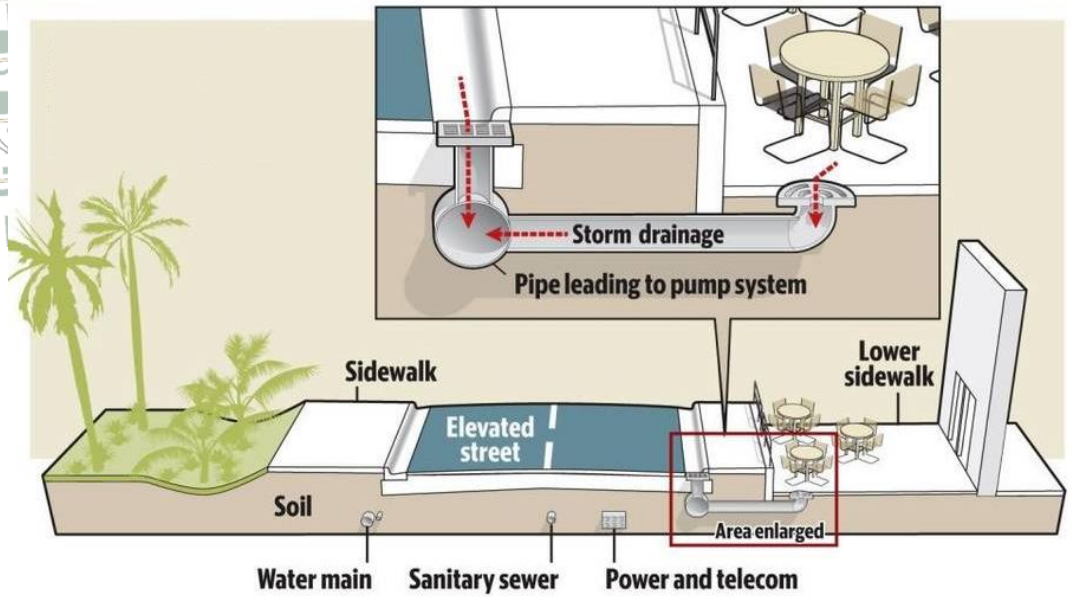
Planter Box Flood Barriers

Flood Walls

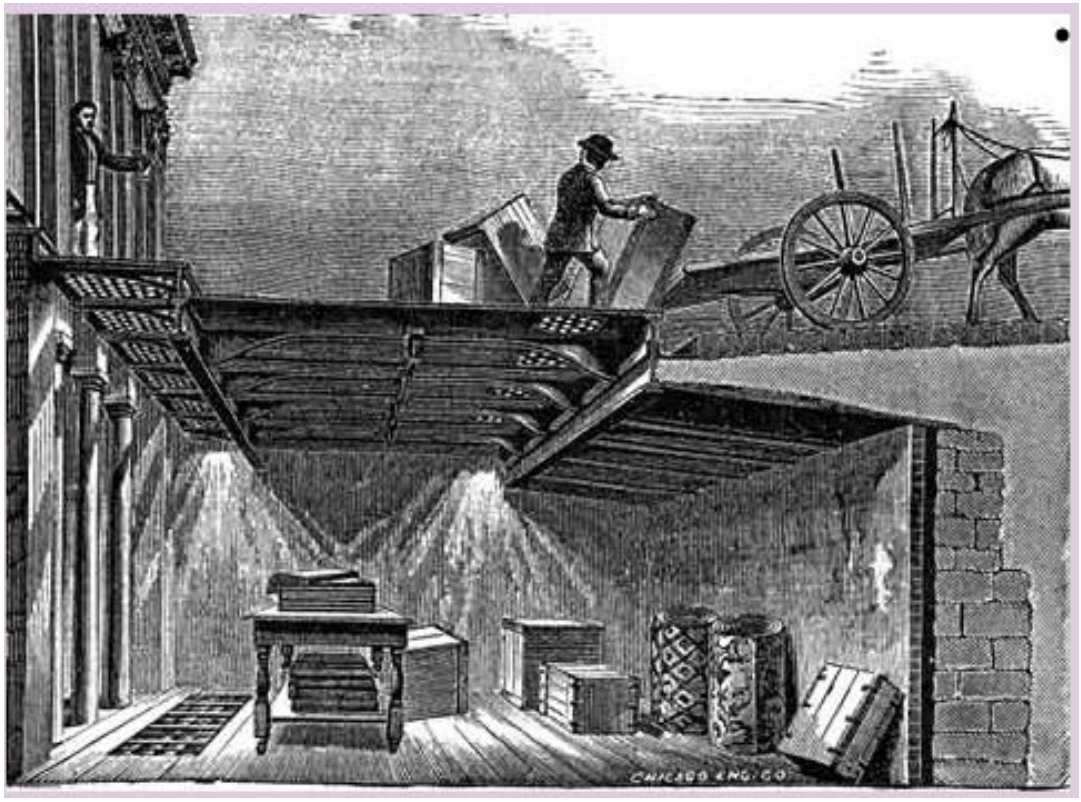

PERMANENT FLOODWALL
FLOODABLE ZONE
MEAN SEA LEVEL
TEMPORARY
FLOODWALL
SUPPORT

Elevated Roadways

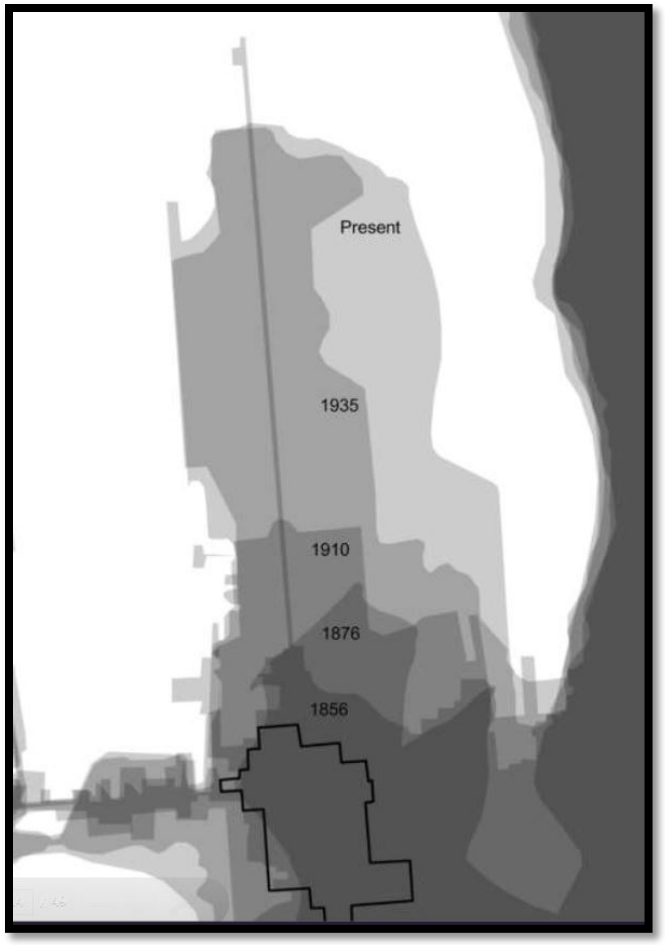




Downtown Regrade

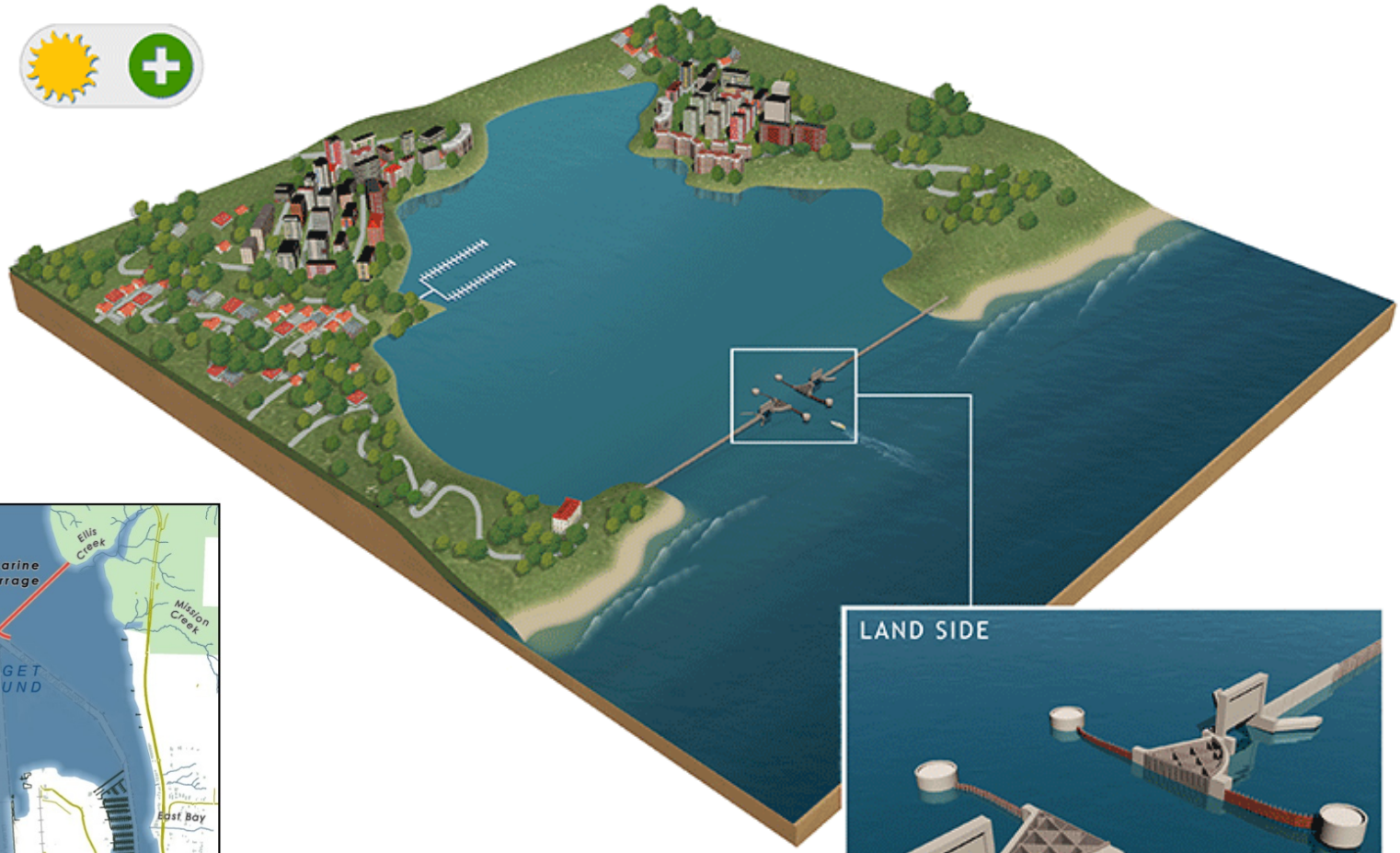


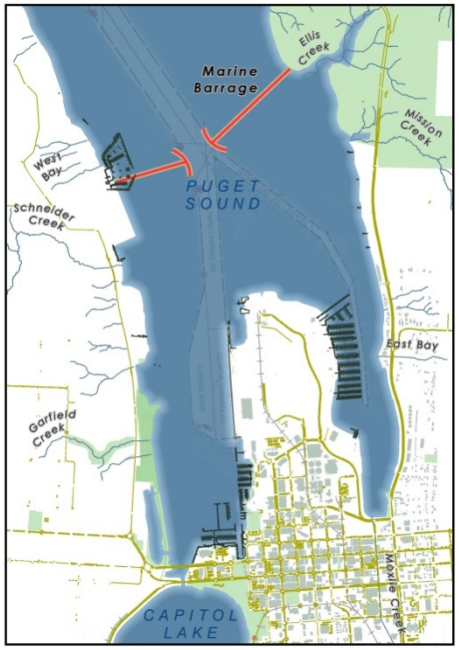
Seattle Pioneer Square Regrade

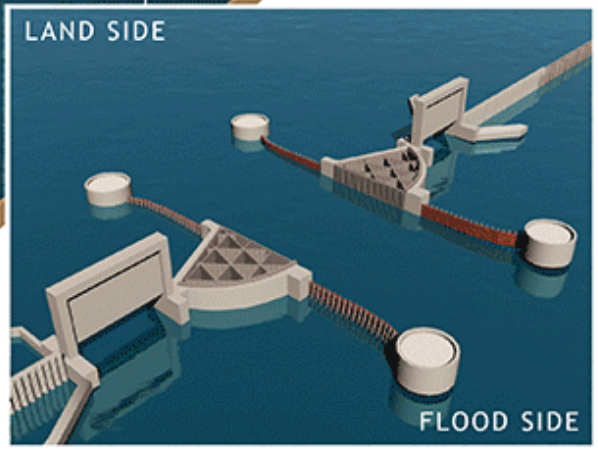


Previous Fill

Marine Flood Barrier







Questions to be answered…..

- How high and how long to plan for and when?
- What elevation is it feasible to protect to before filling?
- Which zones are priorities and which aren't feasible to protect?
- What will sea level rise protection look like?
- How can sea level rise be equitably funded?
- Is the cost shared by everyone?

Next Steps

- Complete proposed capital projects
- Perform public outreach in concert with the Downtown Strategy
- Revise code to establish minimum floor elevations for downtown structures
- Develop inter-agency partnerships
- Identify financial needs and funding sources
- Return to the UAC in October for further discussion and work on the scope for a Sea Level Rise Program plan

Sea Level Rise

Eric Christensen,

Water Resources Engineering and Planning Manager, 570-3741, echriste@ci.olympia.wa.us

- In the next few decades, the greatest cause for concern will be an increase in the kind of flooding that the region already experiences due to waves, storm surge, El Nino events, and very high tides. When planning for this period, an emphasis should be placed on preparing for more common and more severe extreme events.
- Starting around mid-century, the Bay/Inlet may become more vulnerable to regularly occurring inundation of certain locations and assets, some of which are being planned and built today. As a result, this longer-term risk of inundation should be a consideration in today's decision-making.
- The most vulnerable sectors in the community include stormwater management, wastewater collection, shoreline parks and public access, transportation facilities, commercial buildings, the Port, and ecosystems (though limited in the urban setting).

- Upgrading coastal flood defence infrastructure will involve long lead times relating to both planning (time to obtain the financial and political support to carry out the upgrade or replacement) and implementation (time to source the company and materials to carry out the work) of schemes. For example, plans for building the Thames Barrier were started soon after the notorious 1953 North Sea flood, but the Barrier was not operational until 1982 - nearly 30 years later!

  Read more at: http://phys.org/news/2016-09-sea-level-uk-coastal-defences.html#jCp

- With increasing scientific knowledge, acceptance and mechanisms that would allow adaptation to sea-level rise to potentially occur, one would think that adaptation would be straight forward to implement. Not so. Instead of hard and fast numbers, we are faced with wide ranges of uncertainties from different sources, making decision making challenging. What are we adapting to, and when will it occur?

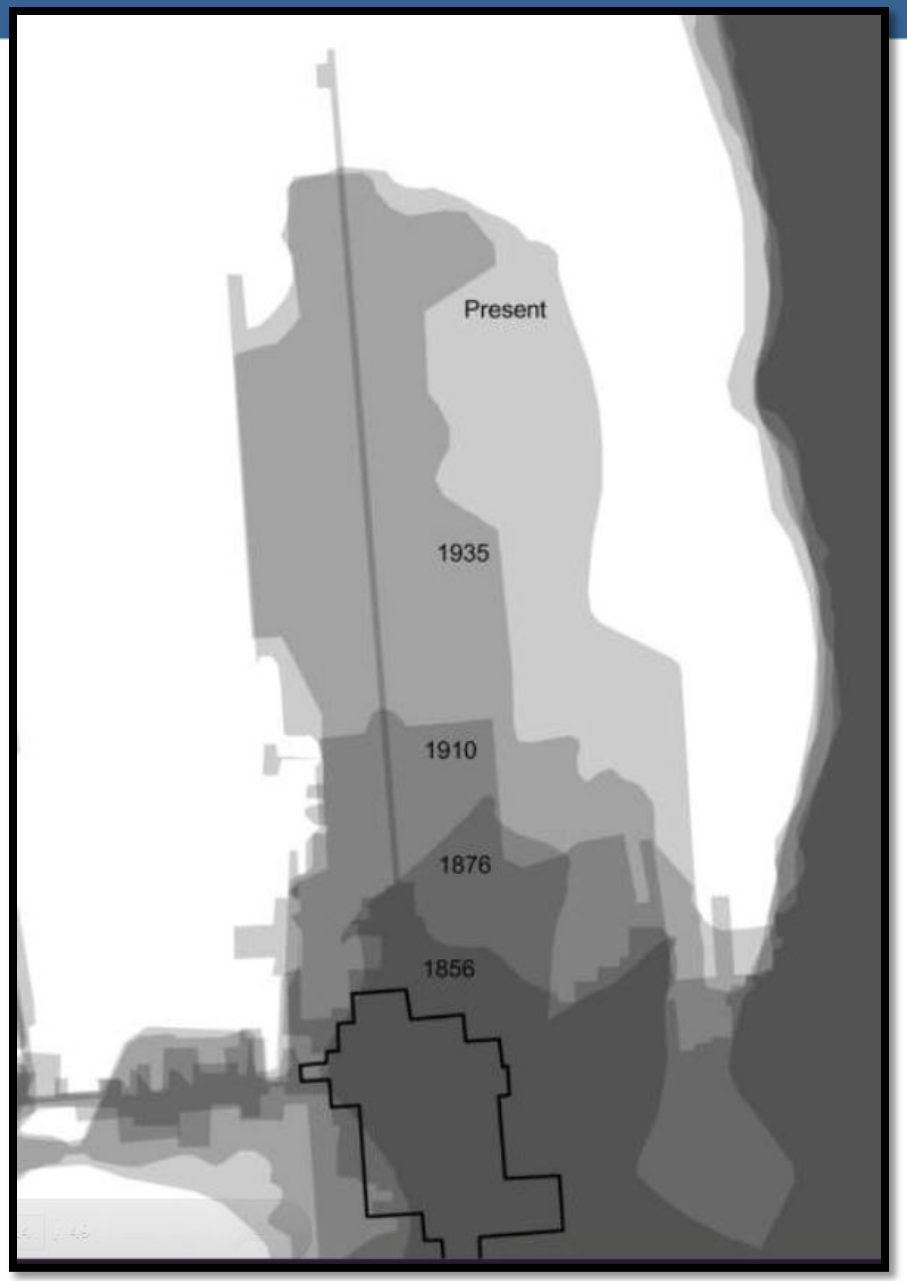
- Unfortunately, CO2 emissions linger in the atmosphere for centuries, and today's CO2 levels have already committed Earth to dangerous sea-level rise. About 99 percent of all freshwater ice resides in two ice sheets: one in Antarctica and one in Greenland. Both are expected to melt if humanity's CO2 output isn't curbed quickly, but the question is when — and how much damage we still have time to prevent.
- The Greenland ice sheet is smaller and melting more quickly. If it completely melted, sea levels would rise by about 6 meters (20 feet). The Antarctic ice sheet has been more buffered from warming so far, but it's hardly immune, and would raise the ocean by 60 meters (200 feet) if it melted. (Estimates vary widely on how long these ice sheets might survive — while most expect they'll take centuries or millennia to melt, a controversial 2015 paper suggested it could happen much more quickly.)
- Sea levels have naturally risen and receded for billions of years, but they've never risen this quickly in modern history — and they've never had so much human help. It's unclear what effect they'll have on our species, but what is clear is that our descendants will still be dealing with this problem long after we're all gone. Giving them a head start on a solution is the least we can do.
- "With all the greenhouse gases we already emitted, we cannot stop the seas from rising altogether, but we can substantially limit the rate of the rise by ending the use of fossil fuels," says Anders Levermann, a climate scientist at Columbia University and co-author of the new study on future sea-level rise. "We try to give coastal planners what they need for adaptation planning, be it building dikes, designing insurance schemes for flooding or mapping long-term settlement retreat."
- As another recent study pointed out, any policy decisions made in the next few years and decades "will have profound impacts on global climate, ecosystems and human societies — not just for this century, but for the next ten millennia and beyond."

- Hazardous waste sites are highly vulnerable to **flooding and inundation** as storage tanks in the area could be opened or moved, or motors and pumps could be impaired thus releasing contamination into flood waters or area soils.
- In all scenarios, storm sewers are highly vulnerable to **flooding and inundation** in the Bay due to higher sea levels, a condition that would result in localized flooding in very low-lying inland areas.

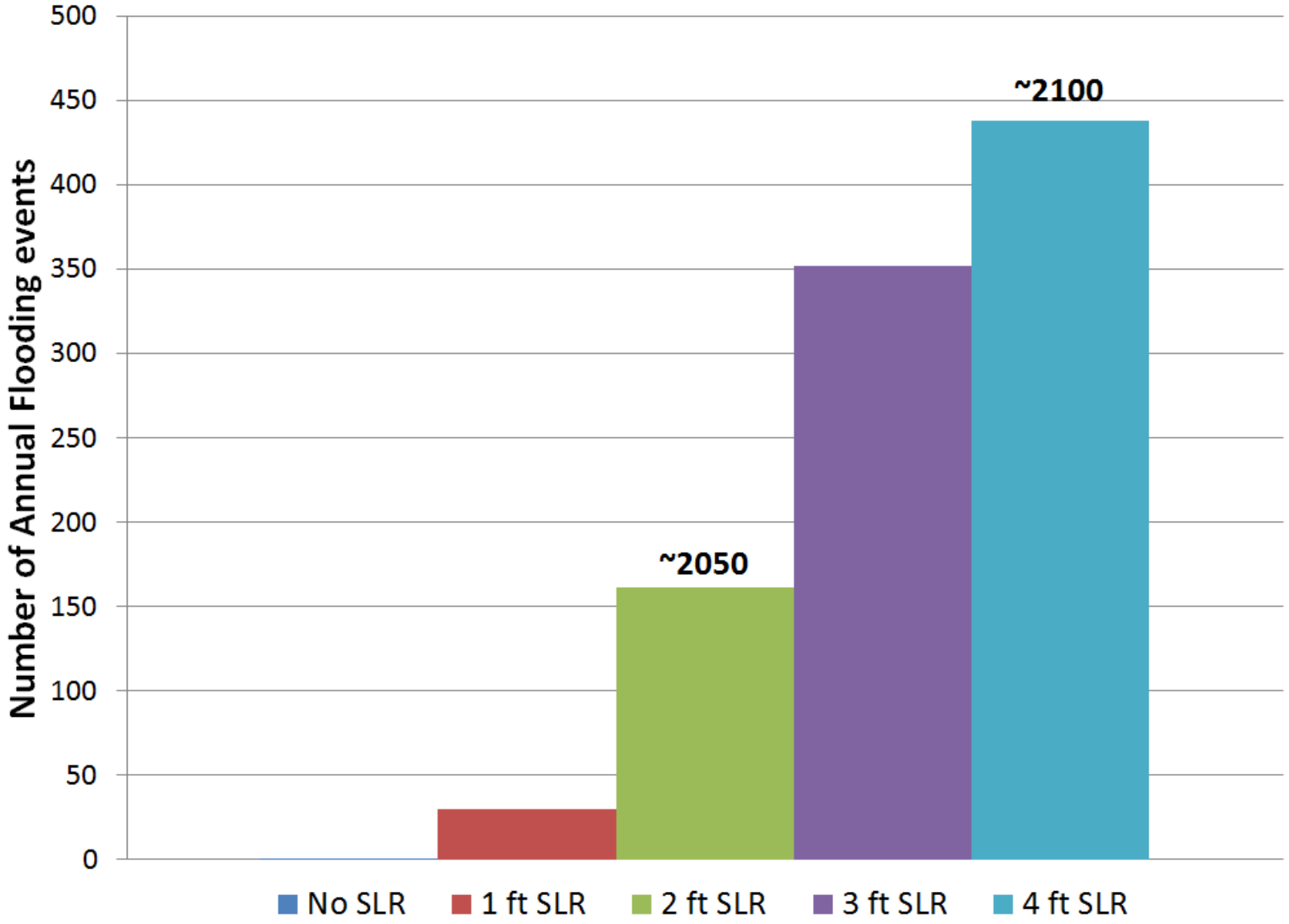
- Sanitary sewers in low-lying locations downtown will be vulnerable to **floodwater inflow** which could exceed their capacity, potentially resulting in discharge of wastewater to Budd Inlet
- The entire wastewater collection system in the planning area will be vulnerable to **inundation** impacts.
- From ICICLI San Diego

- Davidson said recent data that has been collected but has yet to be made official indicates sea levels could rise by roughly 3 meters or 9 feet by 2050-2060, far higher and quicker than current projections. Until now most projections have warned of seal level rise of up to 4 feet by 2100. - Margaret Davidson, NOAA's senior advisor for coastal inundation and resilience science and services
- http://www.insurancejournal.com/news/national/2016/04/12/405089.htm

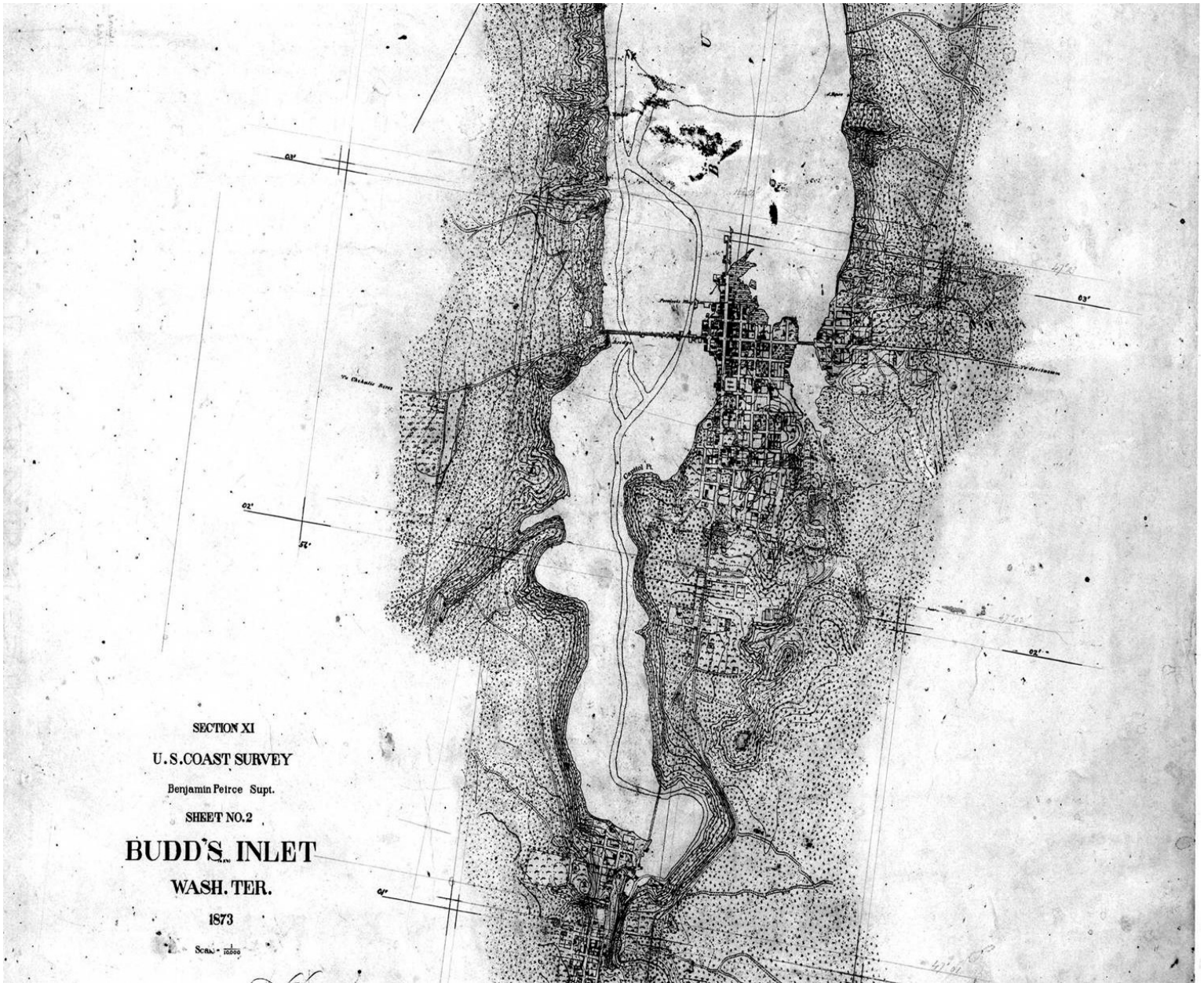
Downtown Fill



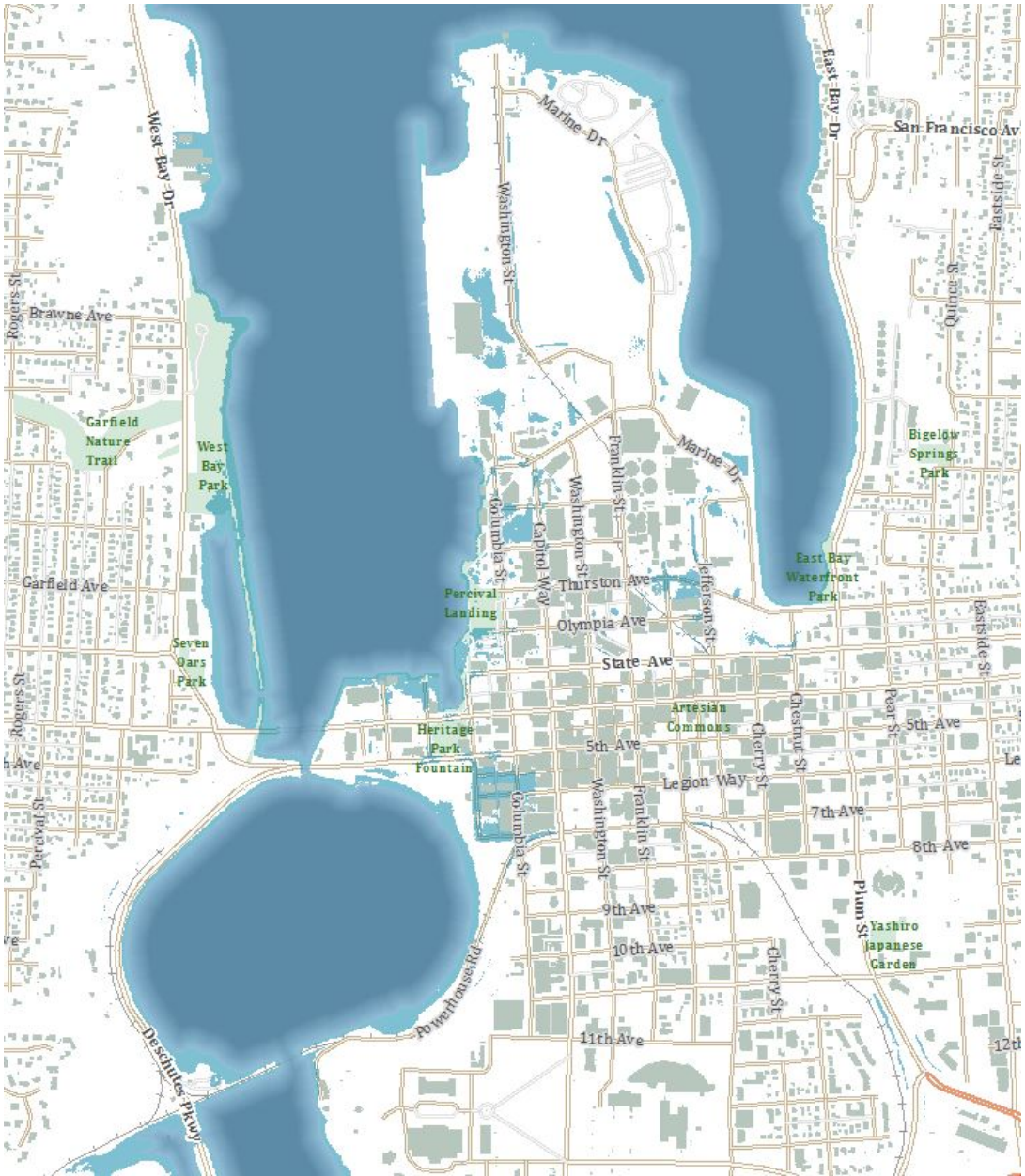
Annual Nuisance Flooding



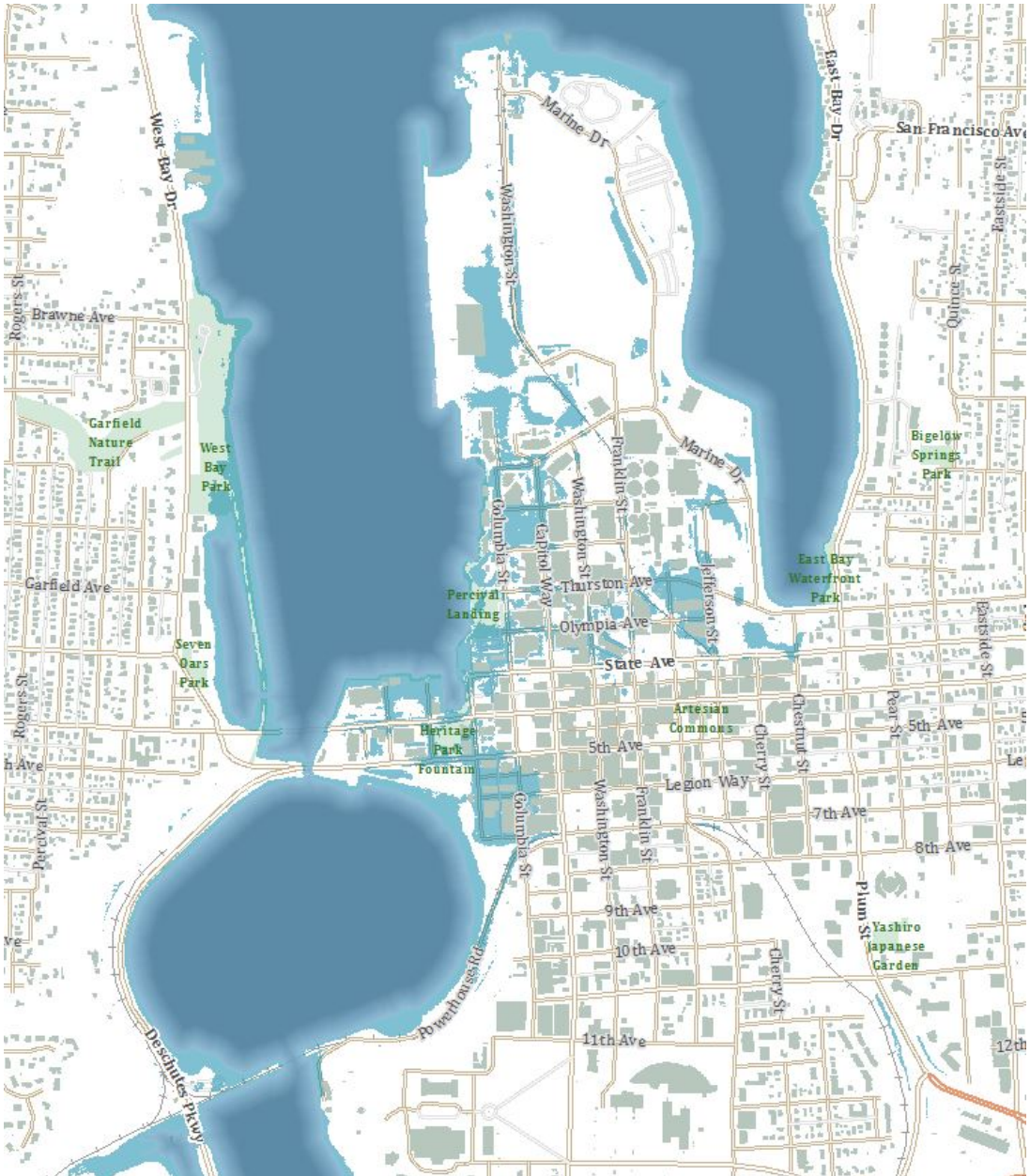
Historic Shoreline



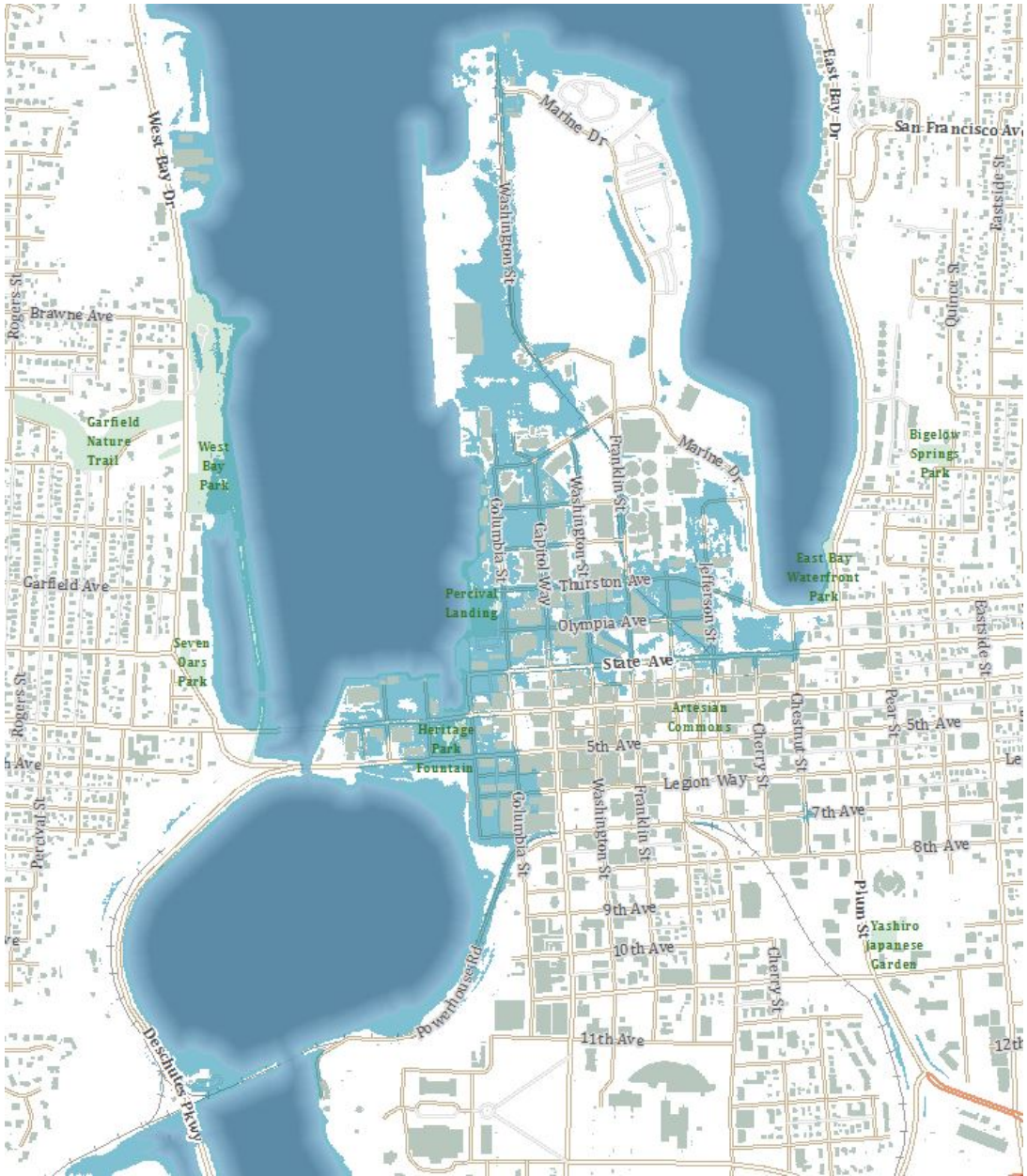
Current 1% Flood



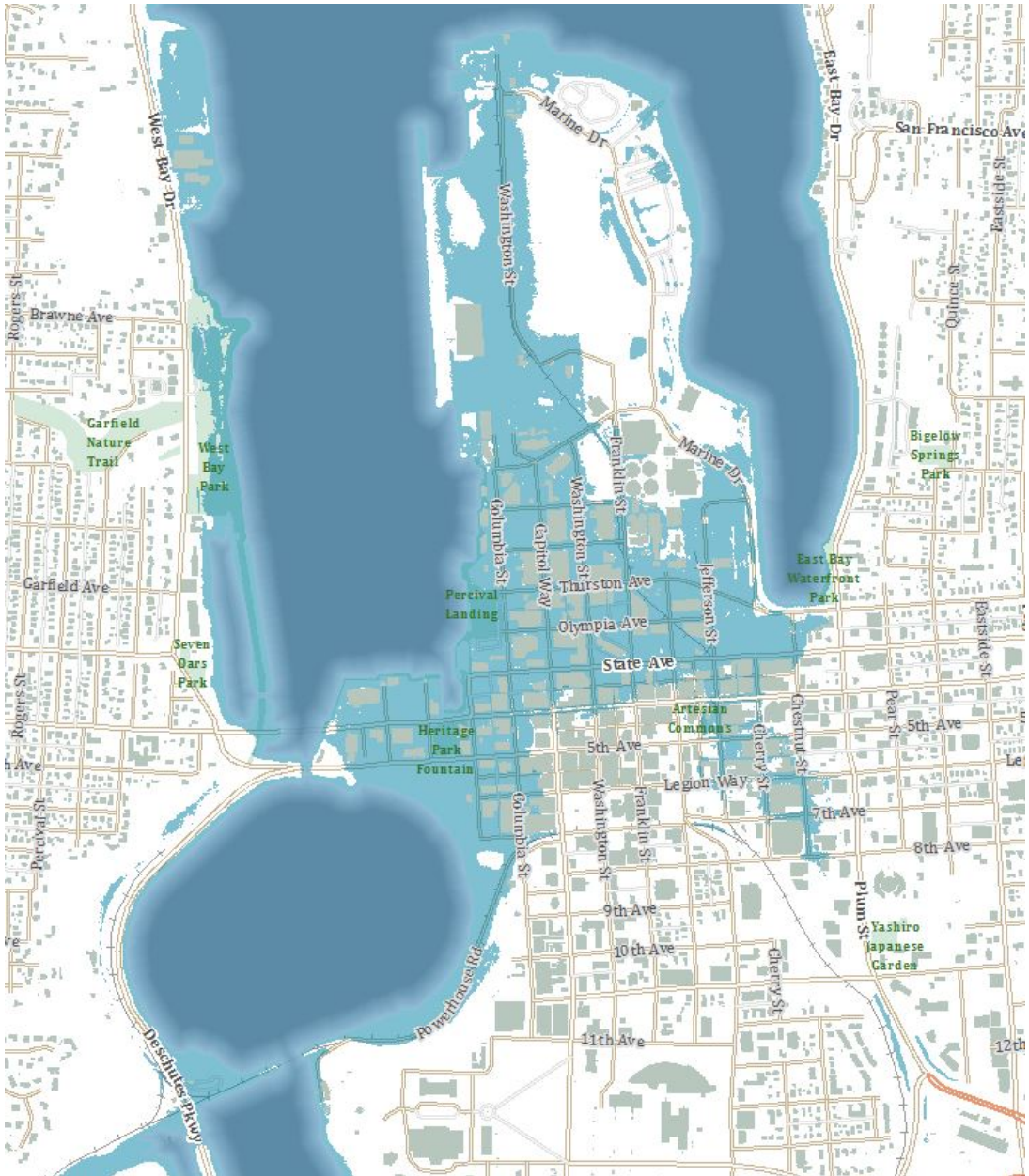
1% Flood with 6 inches SLR



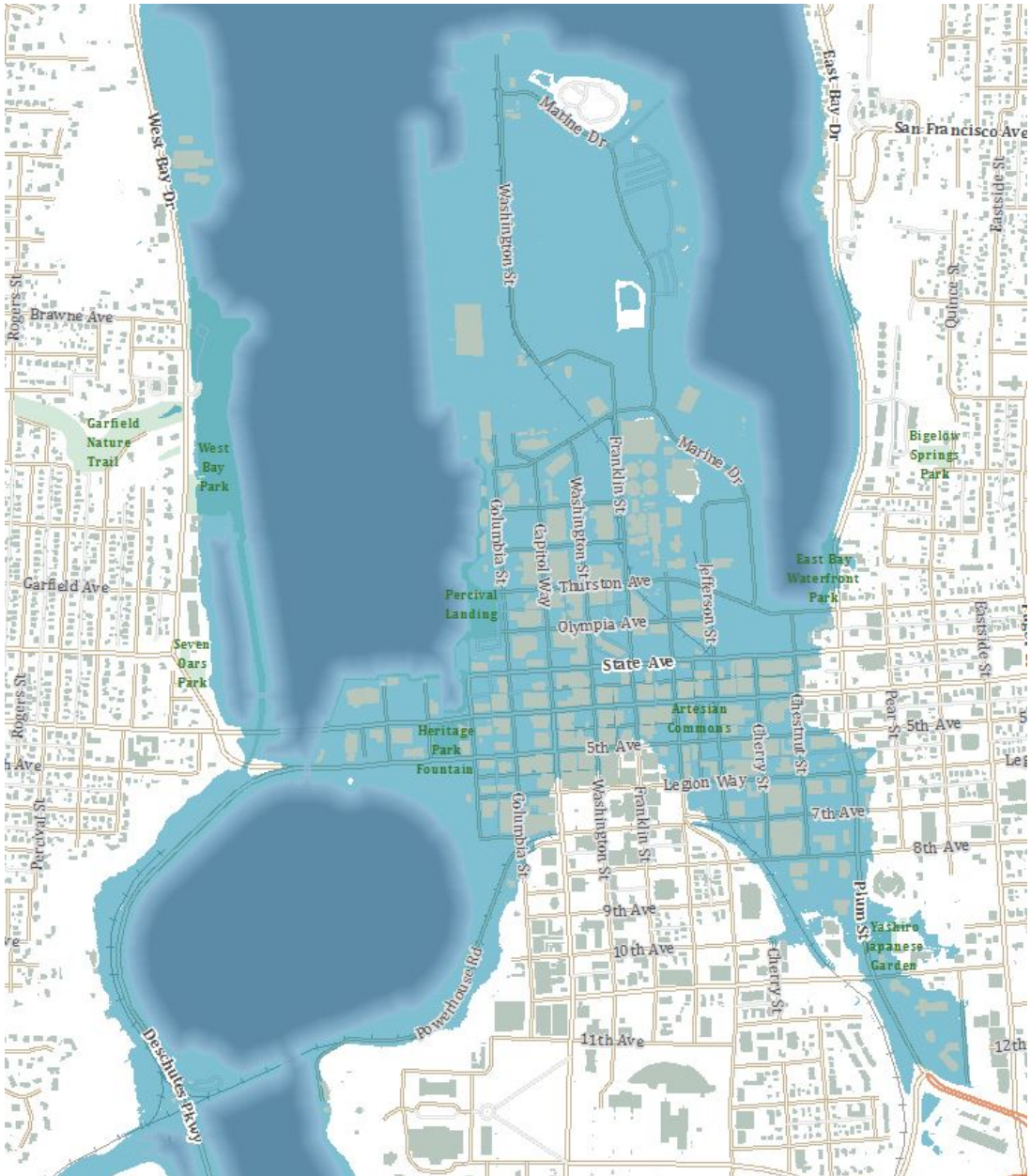
1% Flood with 1 foot SLR



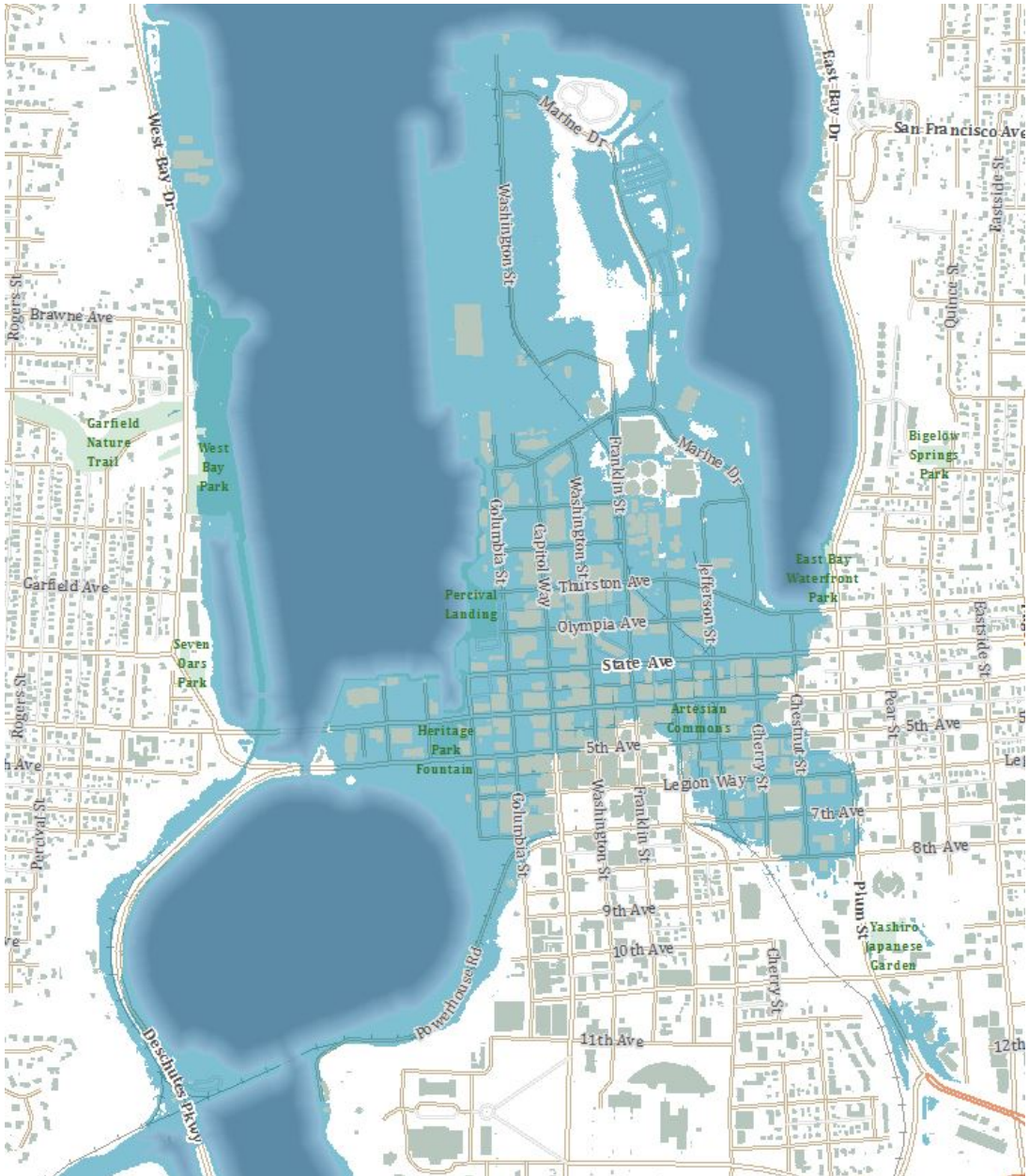
1% Flood with 2 feet SLR



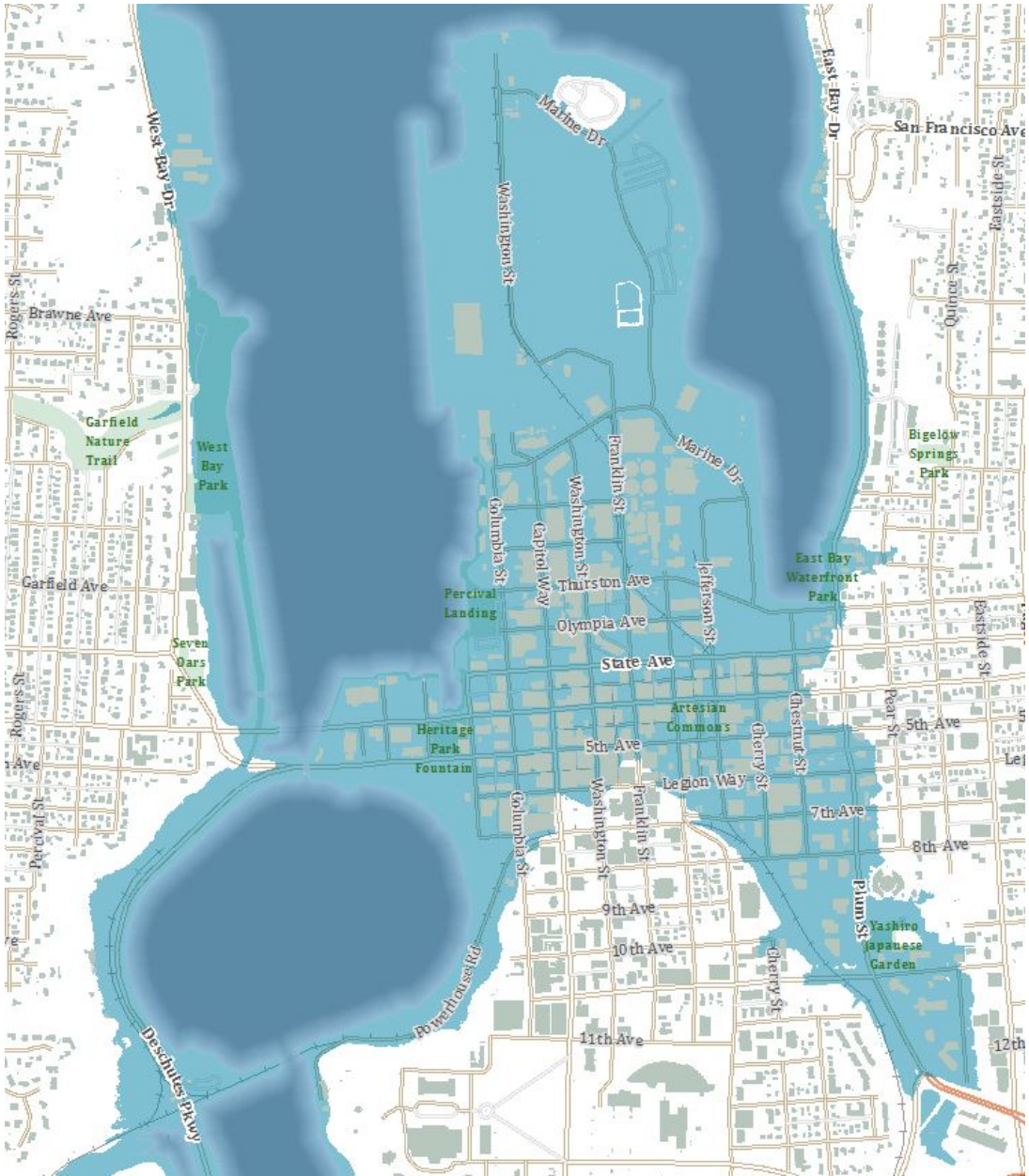
1% Flood with 3 feet SLR



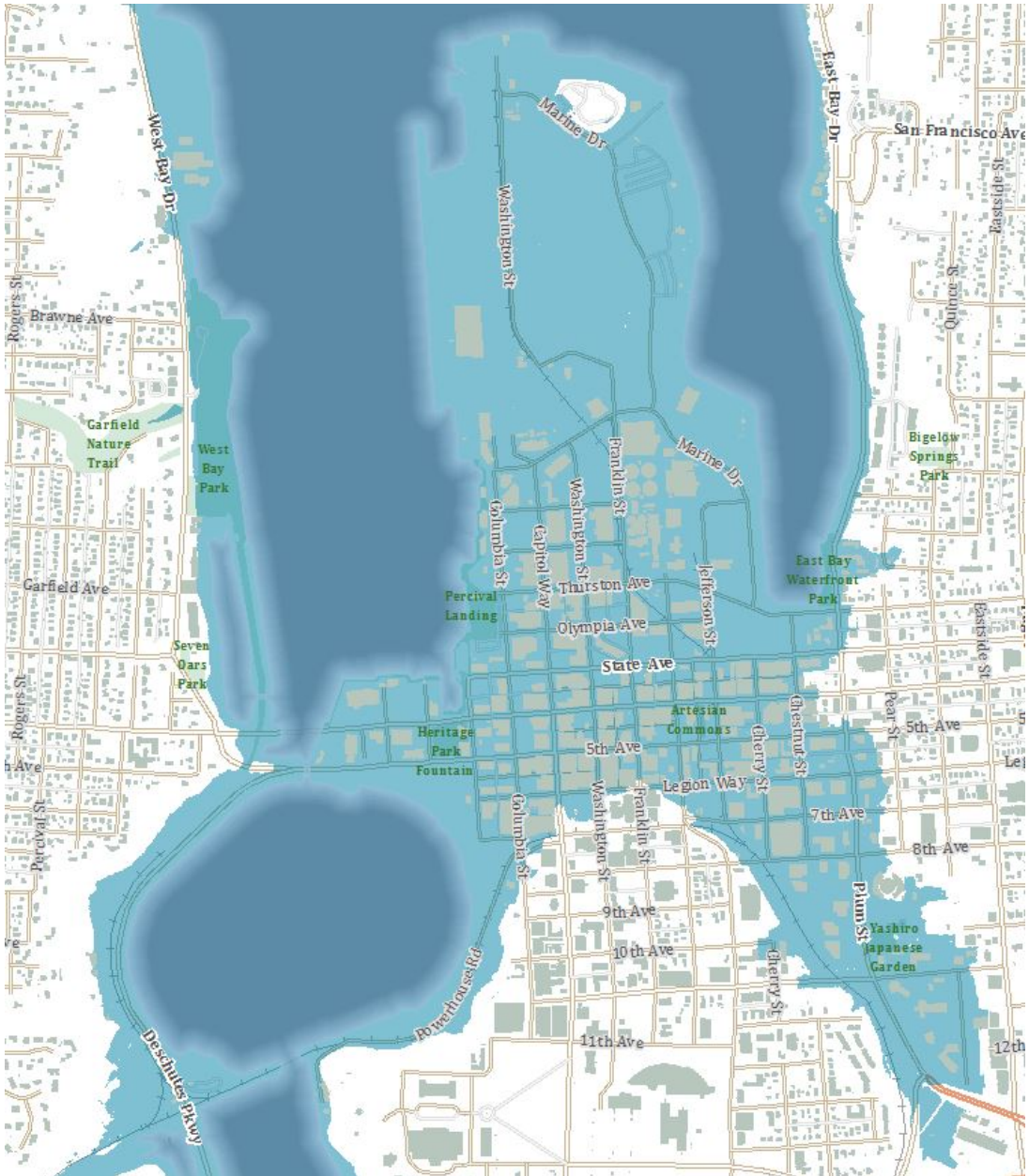
1% Flood with 4 feet SLR



1% Flood with 6 feet SLR



1% Flood with 8 feet SLR



1% Flood with 8 feet SLR