



Western Washington University  
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Salish Sea Ecosystem Conference

2018 Salish Sea Ecosystem Conference  
(Seattle, Wash.)

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Apr 6th, 10:45 AM - 11:00 AM

## Guidelines for mapping sea level rise and uncertainty

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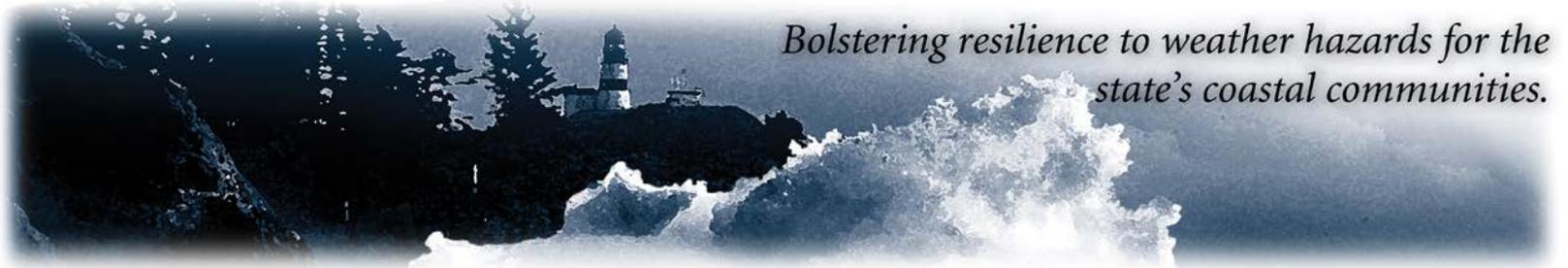
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Norheim, Robert and Mauger, Guillaume, "Guidelines for mapping sea level rise and uncertainty" (2018). *Salish Sea Ecosystem Conference*. 514.

<https://cedar.wwu.edu/ssec/2018ssec/allsessions/514>

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*Bolstering resilience to weather hazards for the  
state's coastal communities.*

## THE WASHINGTON COASTAL RESILIENCE PROJECT

# Guidelines for Mapping Sea Level Rise and Uncertainty

Robert Norheim and Guillaume Mauger

Climate Impacts Group, University of Washington

# Coastal Resilience Project Partners



City of Tacoma  
WASHINGTON



WASHINGTON STATE DEPARTMENT OF  
**FISH & WILDLIFE**



**King County**

Funding provided by NOAA Regional Coastal Resilience Grants Program

# Mapping Coastal Inundation

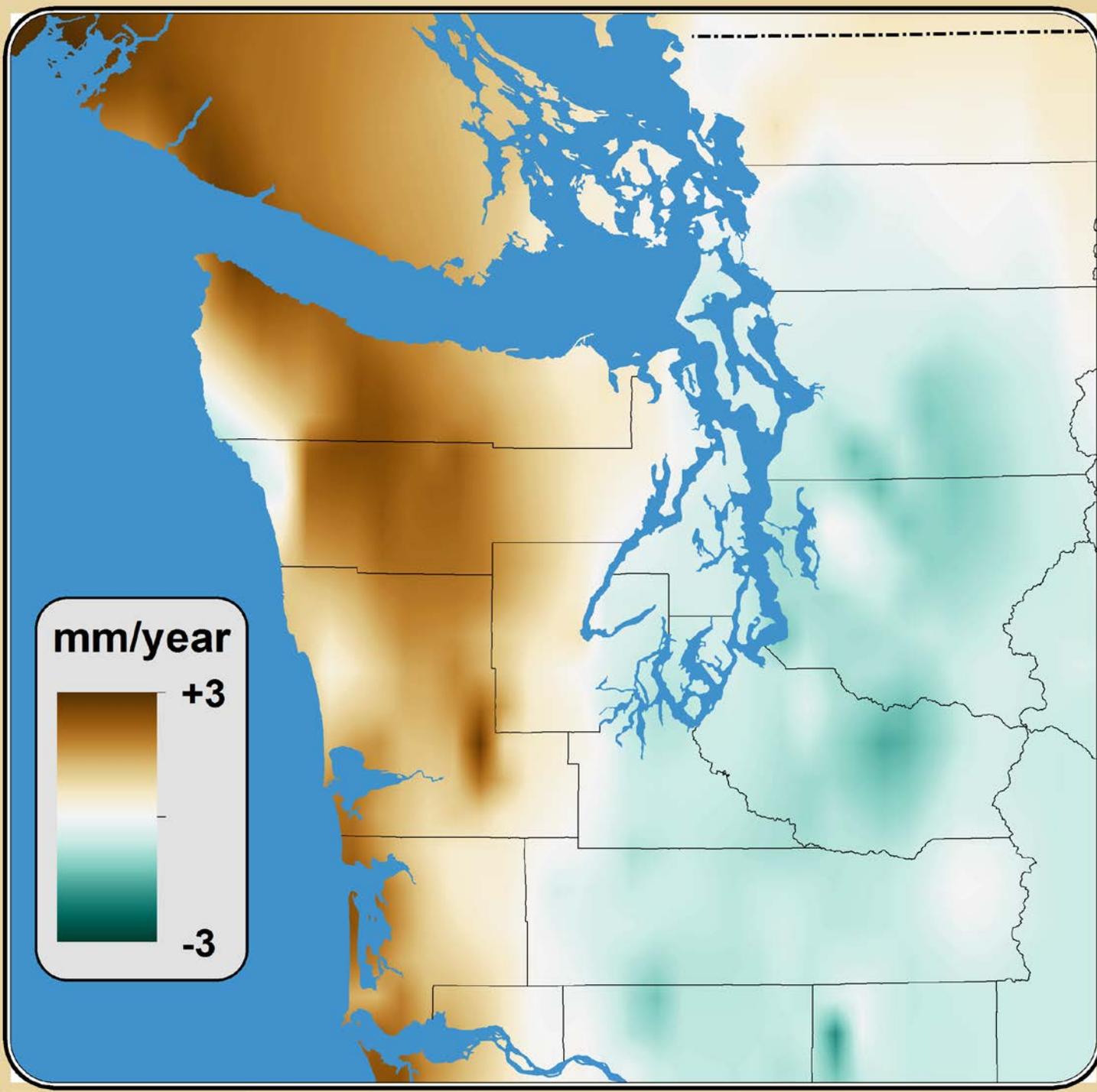
- NOAA's Office of Coastal Management provides excellent guidelines, data, and training for mapping inundation
- Our project adds to this
  - Local relative sea level rise projections
  - Advice on choosing which projections to use
  - Recommendations for local elevation data
  - Instructions for preparing the elevation data
  - Recommendations on symbolization

*This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PC-01J22301 through the Washington Department of Fish and Wildlife.*

# Relative Sea Level Rise

- Sea level rise (SLR) varies spatially due to many factors
  - Ocean currents
  - Wind patterns
  - Gravitational potential
- SLR can be mitigated or enhanced by vertical land motion (VLM)
  - Tectonic forces
  - Post-glacial (Isostatic) rebound
  - Sediment compaction
  - Groundwater pumping
- $SLR + VLM = \text{Relative Sea Level Rise}$

# Vertical Land Motion





# Probabilistic Projections: Relative SLR in Seattle

		Most Likely to Occur		Lower Likelihood of Exceedance		
		Central Estimate (50%)	Likely Range (83-17%)	Very Unlikely (10%)	Exceptionally Unlikely (1%)	Project Upper Limit (0.1%)
20-year period centered on:	Green House Gas Scenario					
2050	RCP 2.6	0.7	0.5 – 1.0	1.0	1.4	2
	RCP 4.5	0.8	0.6 - 1.0	1.1	1.4	2
	RCP 6.0	0.8	0.6 - 0.9	1.0	1.3	1.9
	RCP 8.5	0.8	0.6 – 1.1	1.1	1.5	2.2
2100	RCP 2.6	1.7	1.1 – 2.3	2.6	4.3	7.6
	RCP 4.5	1.9	1.3-2.5	2.8	4.4	7.6
	RCP 6.0	1.9	1.4-2.5	2.8	4.4	7.8
	RCP 8.5	2.3	1.7-3.1	3.4	5.1	.6
2150	RCP 2.6	2.4	1.5 – 3.6	4.2	8.5	16.4
	RCP 4.5	3.0	1.9-4.3	4.9	8.9	16.7
	RCP 6.0	*	*	*	*	*
	RCP 8.5	3.9	2.8-5.4	6.1	10.4	18.7

*Projections are expressed in **ft.** relative to 1990-2010 avg.*

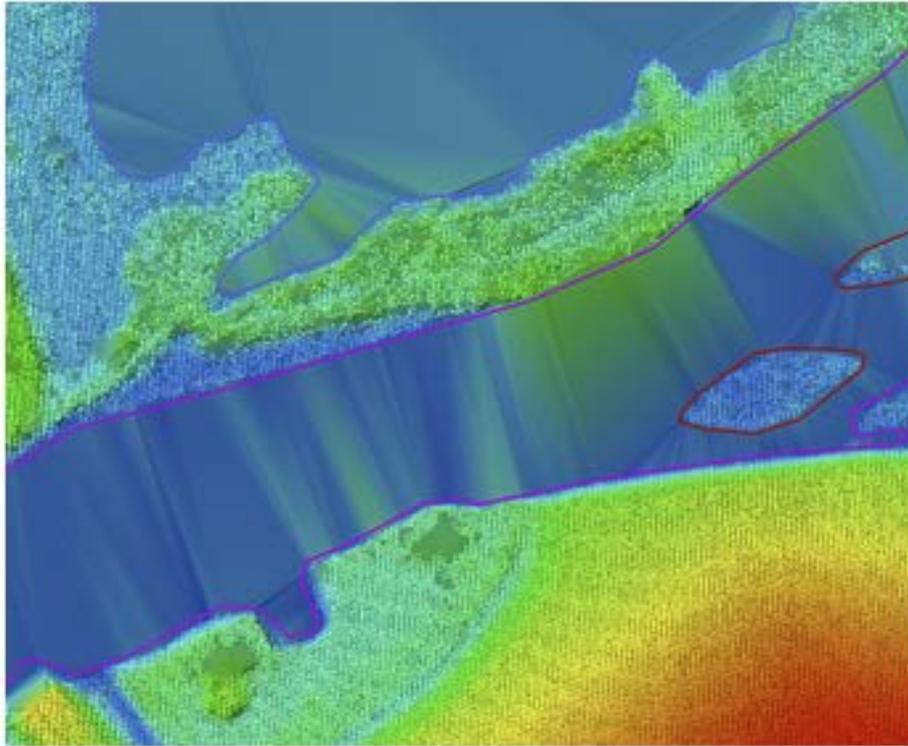
# Elevation data

- Central estimate of RSLR is about 2 feet by 2100
- Elevation data with excellent vertical accuracy and resolution is essential to mapping inundation
- Lidar data ideal for this purpose
- Lidar data available for most of the Washington coast from the Puget Sound Lidar Consortium
- Data also available from the WA DNR Lidar Portal

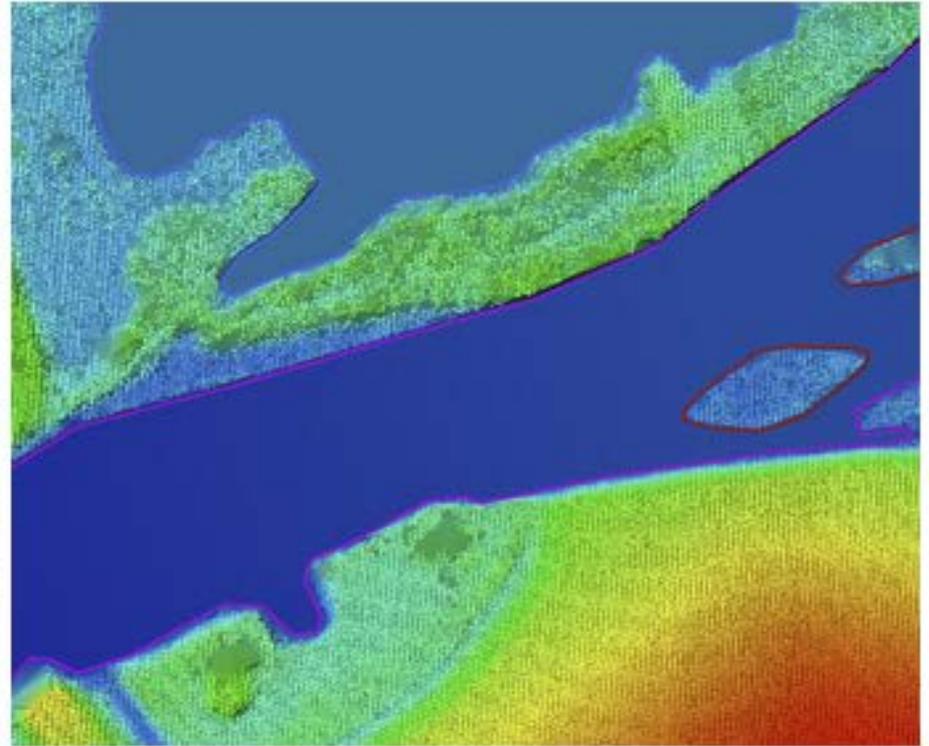
# Preparing elevation data

- Hydraulic continuity
  - Low-lying inland areas may or may not be hydraulically connected to the sea
  - Dykes, levees, culverts, stormwater infrastructure: not accurately represented in DEM
  - Need to correct DEM with accurate elevations
  - Alternatively, map inundation and look for low-lying areas, then determine whether connected hydraulically
- Hydro-flattening
  - Lidar DEM may average heights across narrow bodies of water
  - Need accurate coastline geodata to correctly mask DEM

# Hydro-flattening example



*Figure 1. Sample - Hydro Flattening Not Applied*



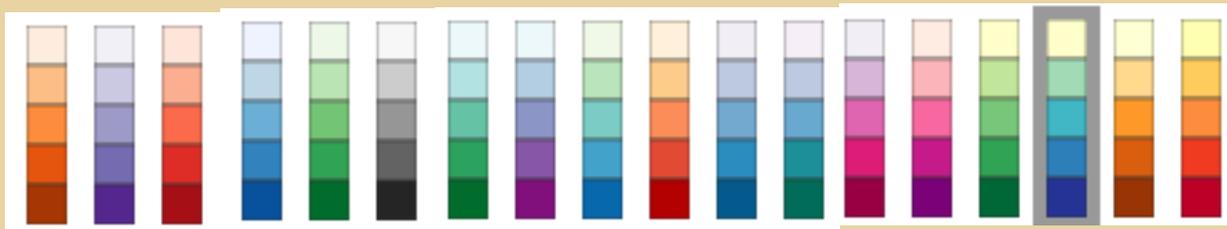
*Figure 2. Sample - Hydro Flattening Applied*

# Vertical datums

- To map coastal inundation, RSLR is added to high tide (mean higher high water, MHHW)
- MHHW is a tidal datum -- locally specific
  - Accuracy depends on distance from tide gages
- Digital elevation models (DEM) from lidar surveys are based on mean sea level on NAVD88, an orthometric datum
- Need to create a MHHW surface based on NAVD88
- NOAA's VDATUM tool accomplishes this
- NOAA provides a MHHW surface for the entire USA excluding Alaska

# Map symbolization

- Different attributes of RSLR projections can be mapped
  - Decade, Greenhouse Gas Scenario, Probability of Exceedence, Inundation Depth
- Best to map an even number of scenarios
  - Users tend to use central scenario if odd number shown
- Ordered numerical data: use sequential color scheme
  - Light to dark represents “less” to “more”
  - Examples from ColorBrewer2:



# Mapping Sea Level Rise

## Port of Tacoma

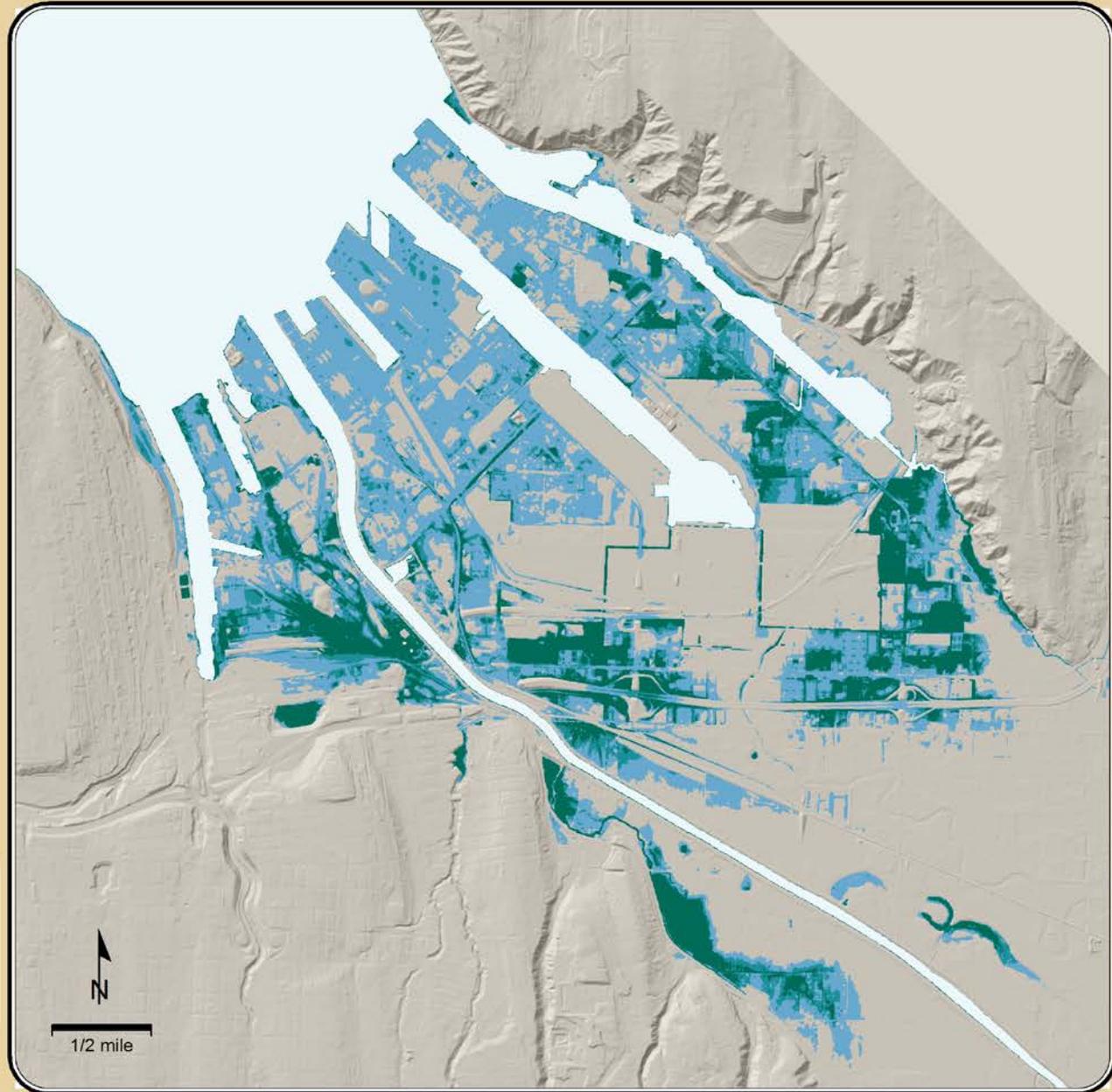
### Symbology Examples

### Varying Greenhouse Gas Scenario

50% Probability of Exceedence  
2200



RCP 2.0 RCP 4.5 RCP 8.5



# Mapping Sea Level Rise

Port of Tacoma

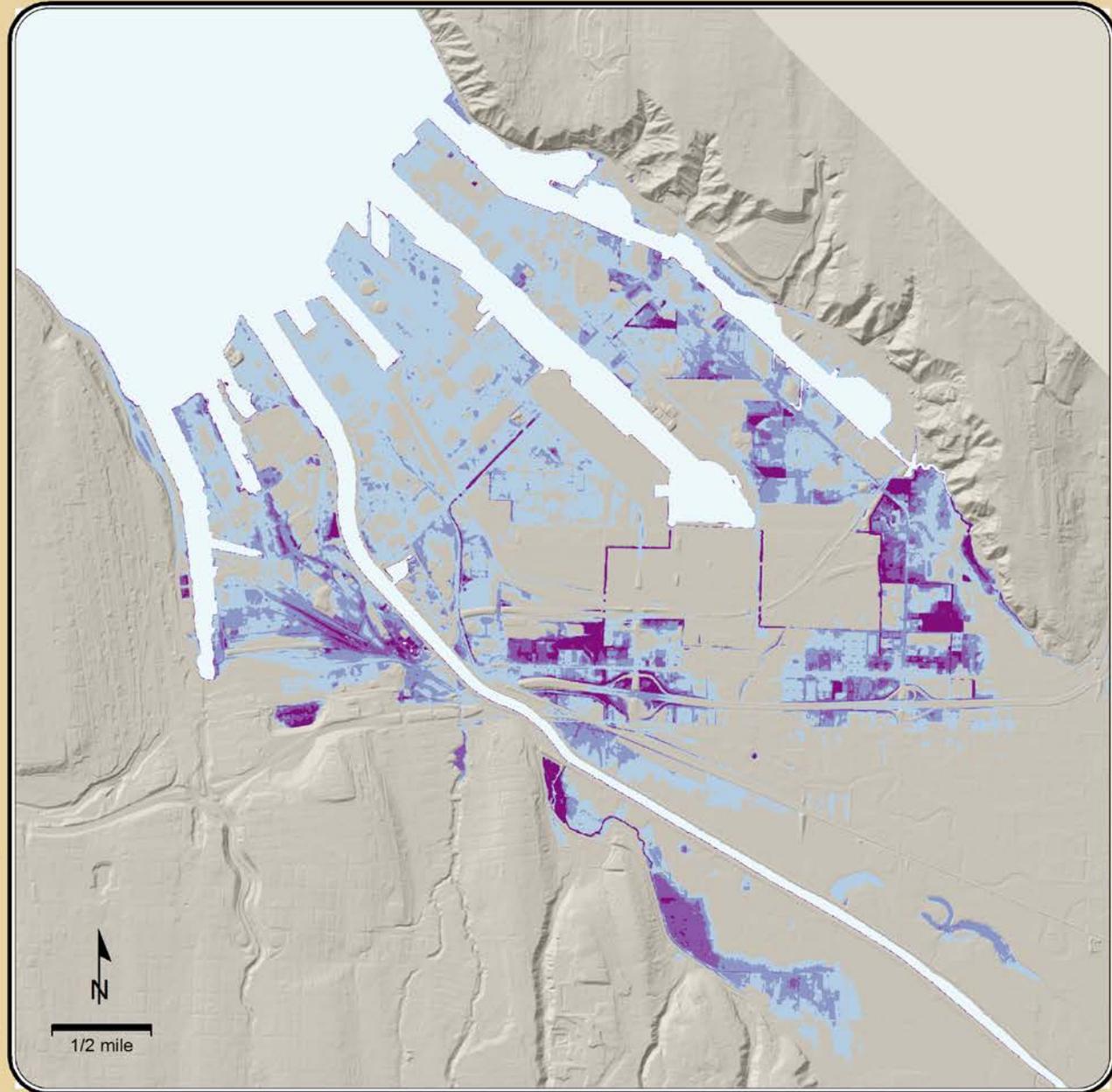
Symbology Examples

Varying Year

10% Probability of Exceedence  
RCP 8.5



2050 2100 2150 2200

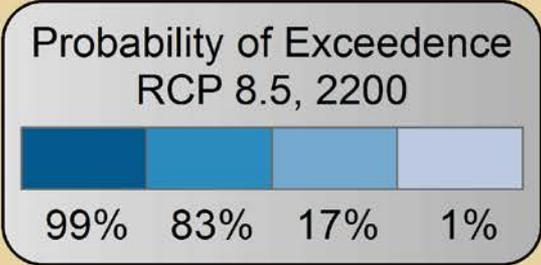
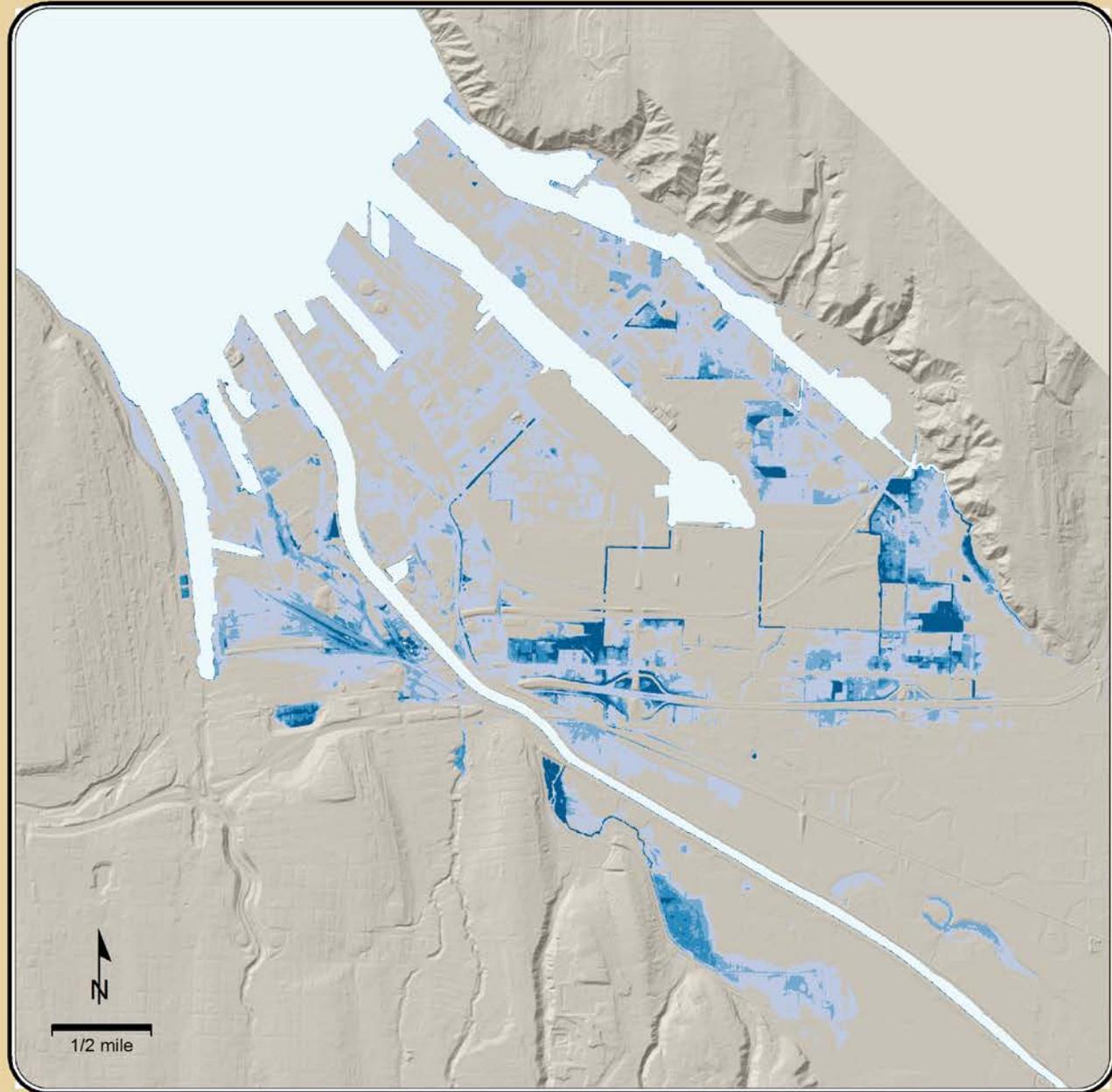


# Mapping Sea Level Rise

Port of Tacoma

Symbology Examples

Varying Probability  
of Exceedence



# Mapping Sea Level Rise

Port of Tacoma

Symbology Examples

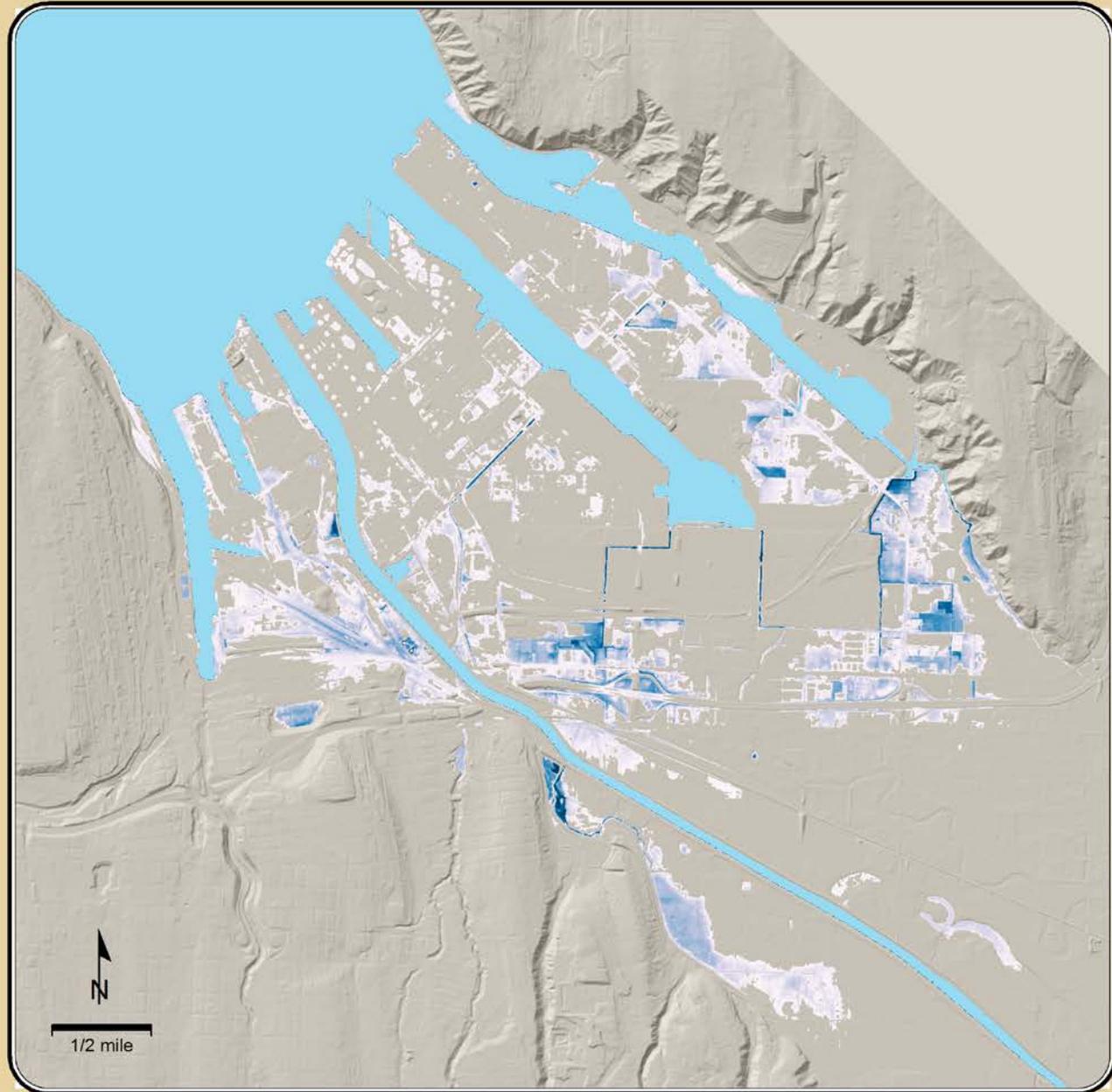
Inundation Depth

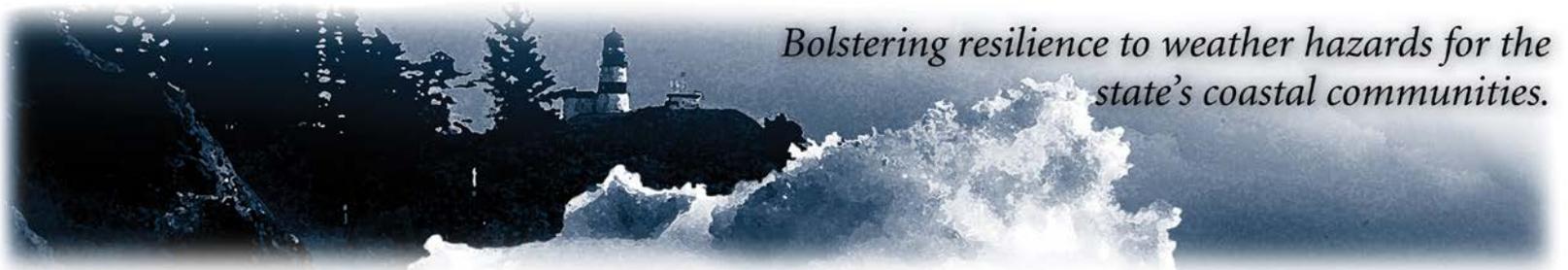
1% Probability of Exceedence  
RCP 4.5/6.0, 2100



0'

14'



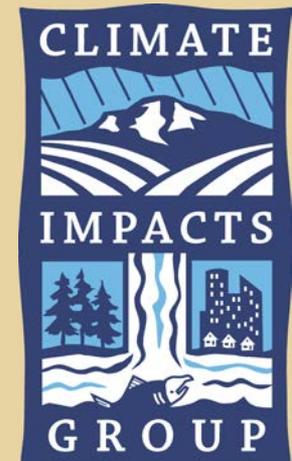


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## THE WASHINGTON COASTAL RESILIENCE PROJECT

# W

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