Pacific Northwest NATIONAL LABORATORY

Impacts of a Cascadia Subduction Zone Earthquake on Water Levels and Wetlands of the Lower Columbia River and Estuary

Matthew Brand, Heida Diefenderfer, David Jay,

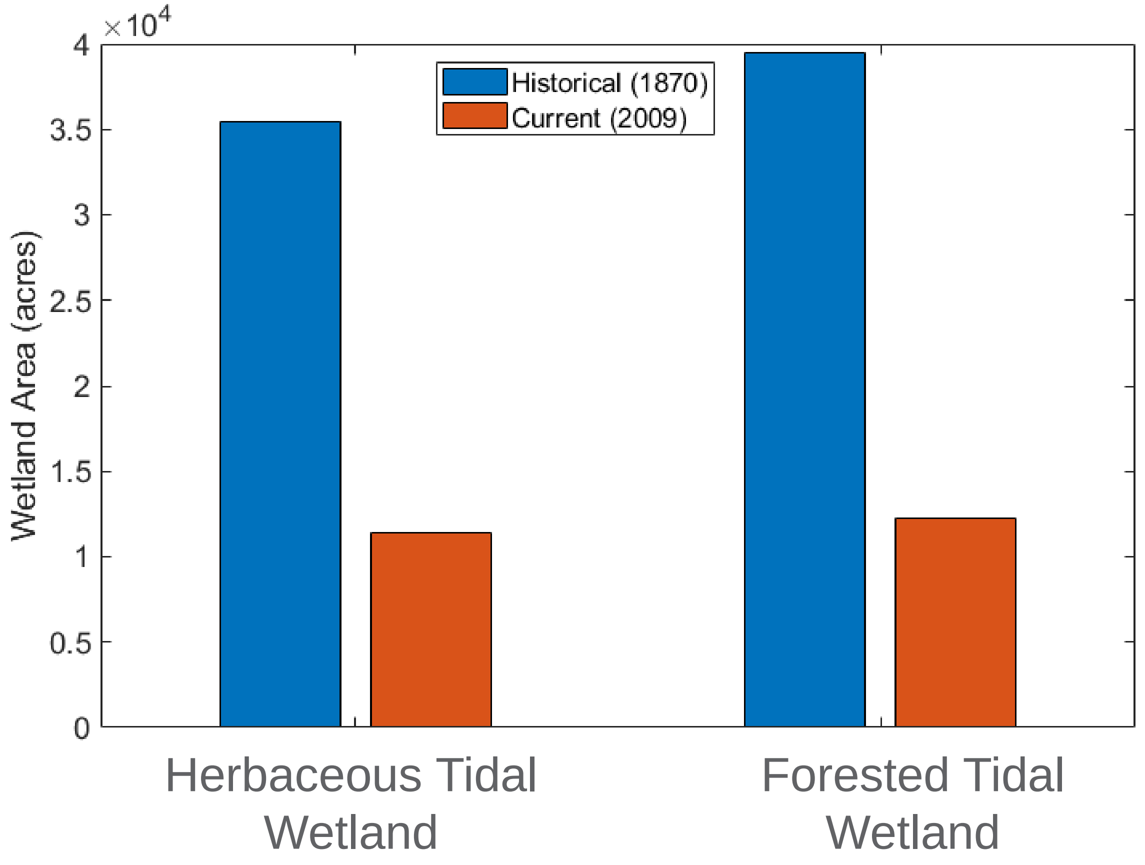
Stefan Talke, Amy Borde and Maggie Mckeon

Postdoctoral Scholar
Coastal Sciences Division
Thursday, May 18th, 2023

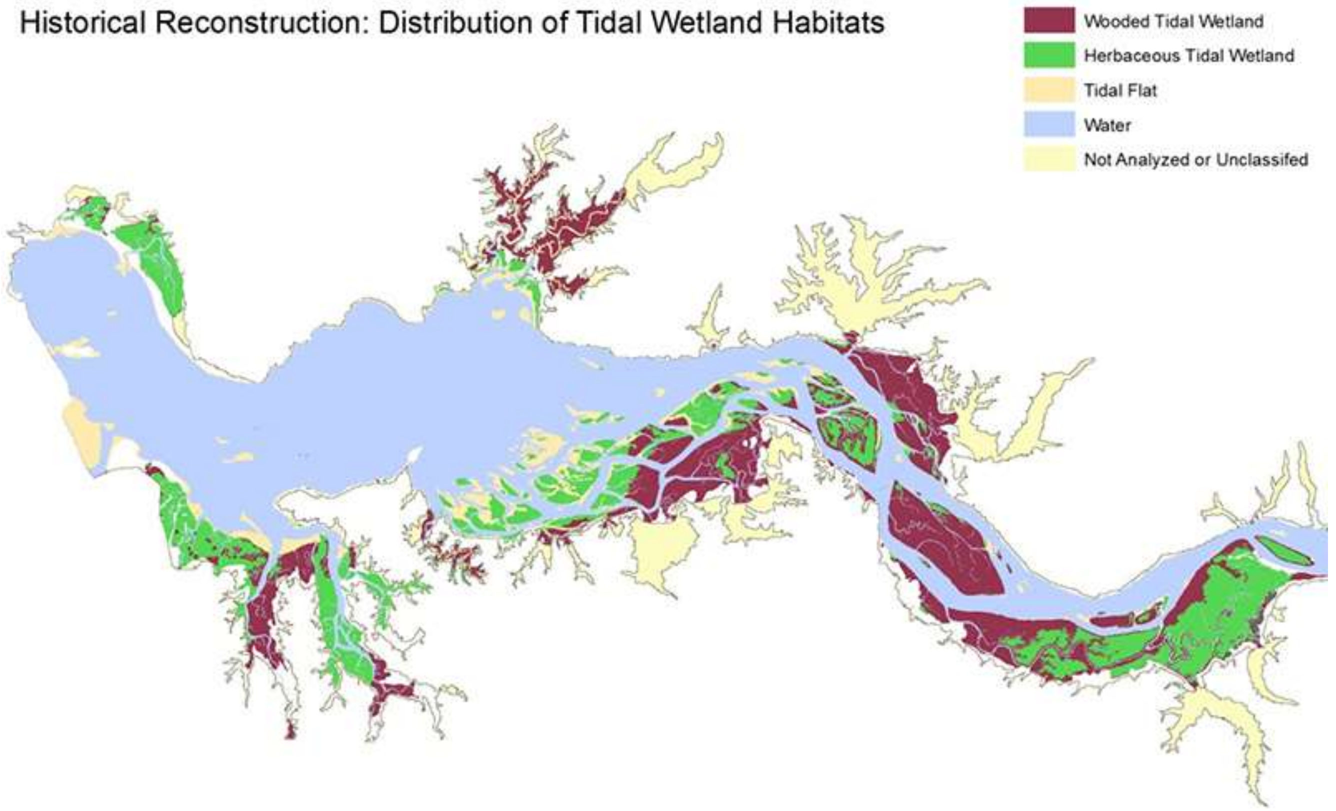
U.S. DEPARTMENT OF ENERGY BATTELLE

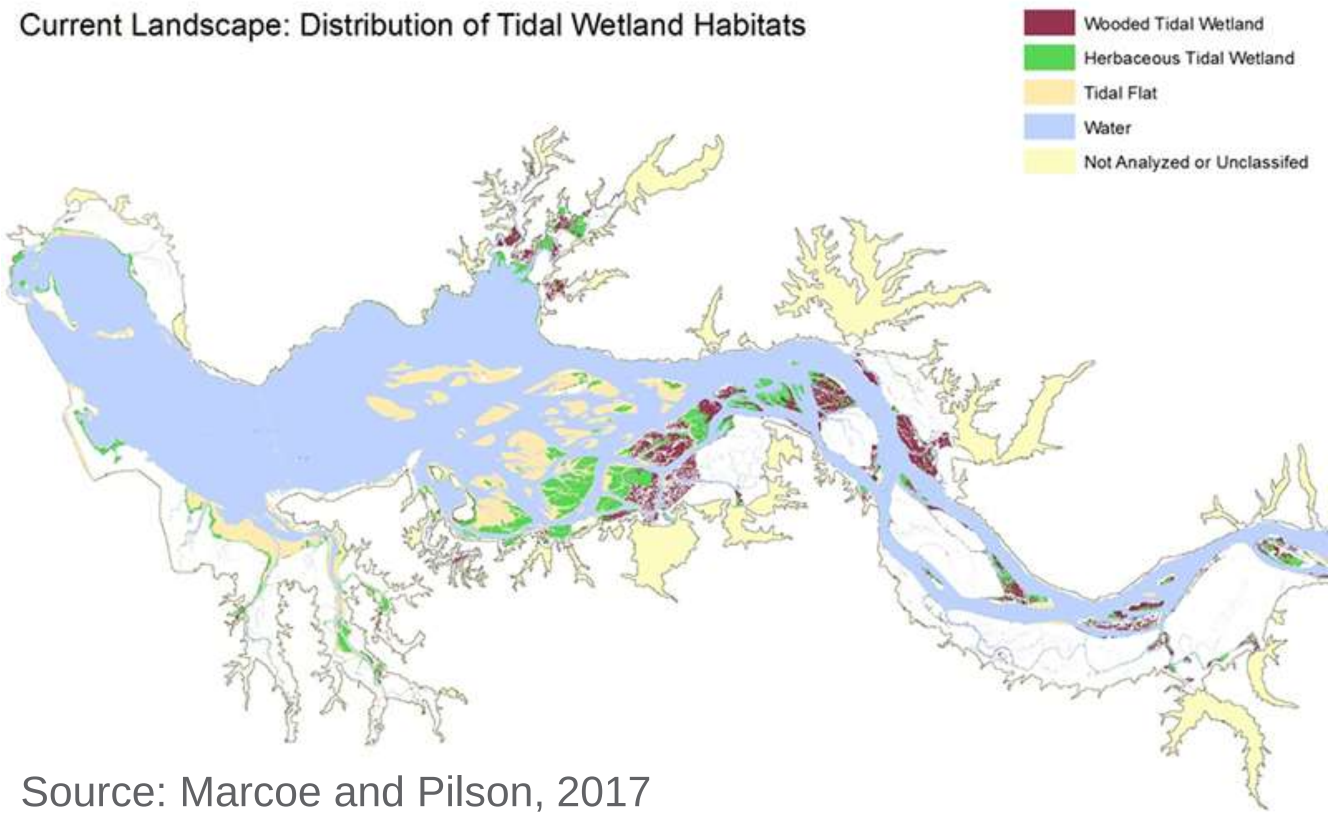
PNNL is operated by Battelle for the U.S. Department of Energy

Motivation



Source: Littles et al., 2022



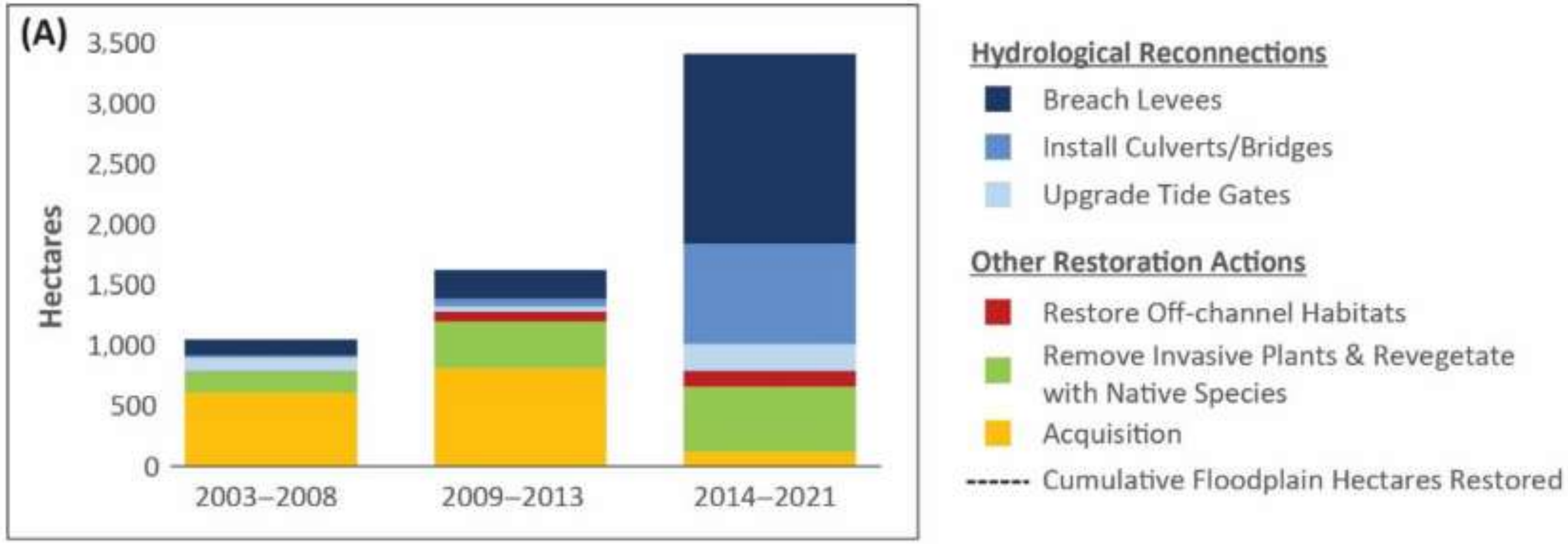


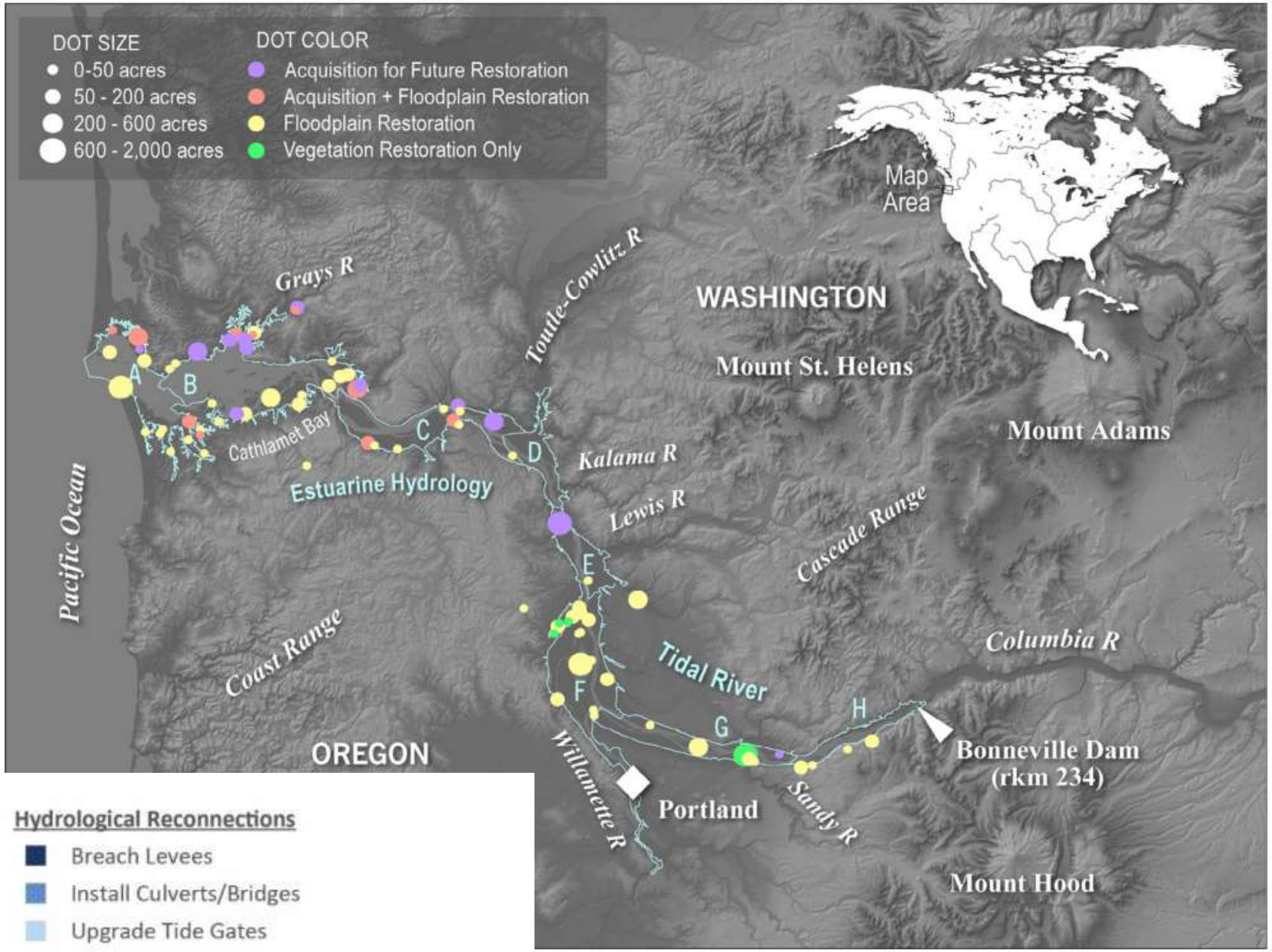
Source: Marcoe and Pilson, 2017

Pacific Northwest
NATIONAL LABORATORY

Motivation

- We are making great progress towards restoring tidal wetlands on the CR
- SLR/CC represents an obvious threat to restoration activities, but occurs on timescales > decades
- There is another threat to wetland restoration much more abrupt, and potentially more damaging to tidal wetlands not yet widely discussed…





Source: Littles et al., 2022

Cascadia Subduction Zone Earthquake

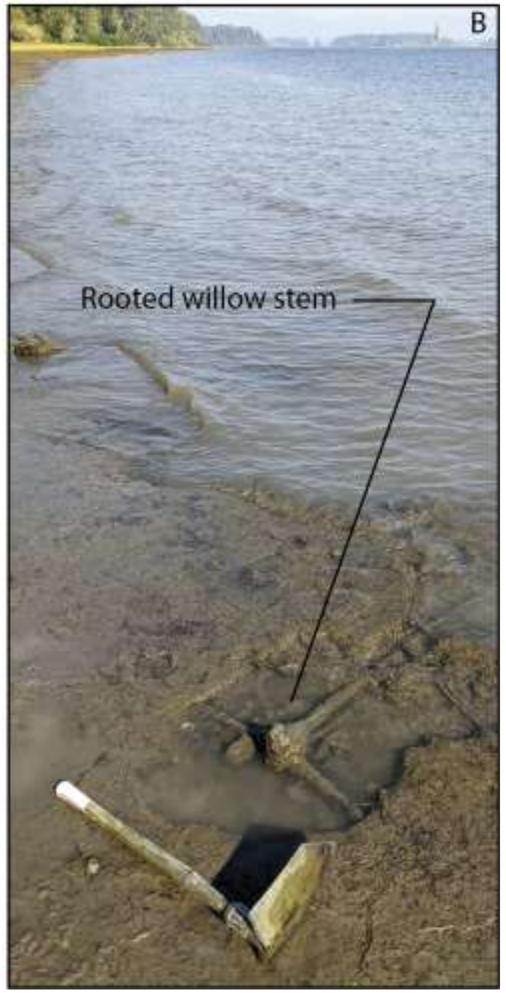
Photos courtesy of Jim O'Brian

Evidence for Great Holocene Earthquakes Along the Outer Coast of Washington State

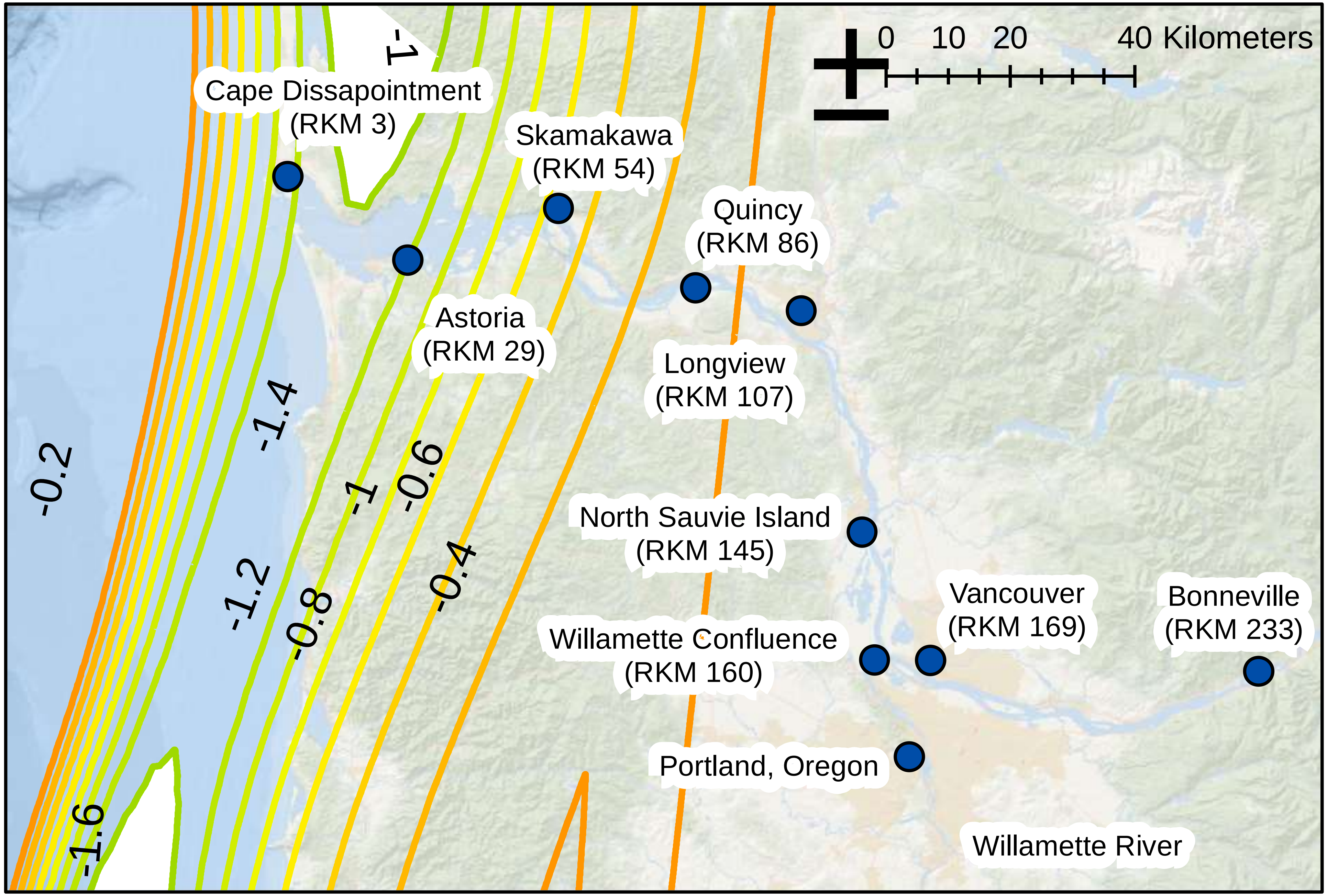
BRIAN F. ATWATER

Intertidal mud has buried extensive, well-vegetated lowlands in westernmost Washington at least six times in the past 7000 years. Each burial was probably occasioned by rapid tectonic subsidence in the range of 0.5 to 2.0 meters. Anomalous sheets of sand atop at least three of the buried lowlands suggest that tsunamis resulted from the same events that caused the subsidence. These events may have been great earthquakes from the subduction zone between the Juan de Fuca and North America plates.

Stumps at the Neskowin Ghost Forest – photograph by user: RocketSams on Wikipedia



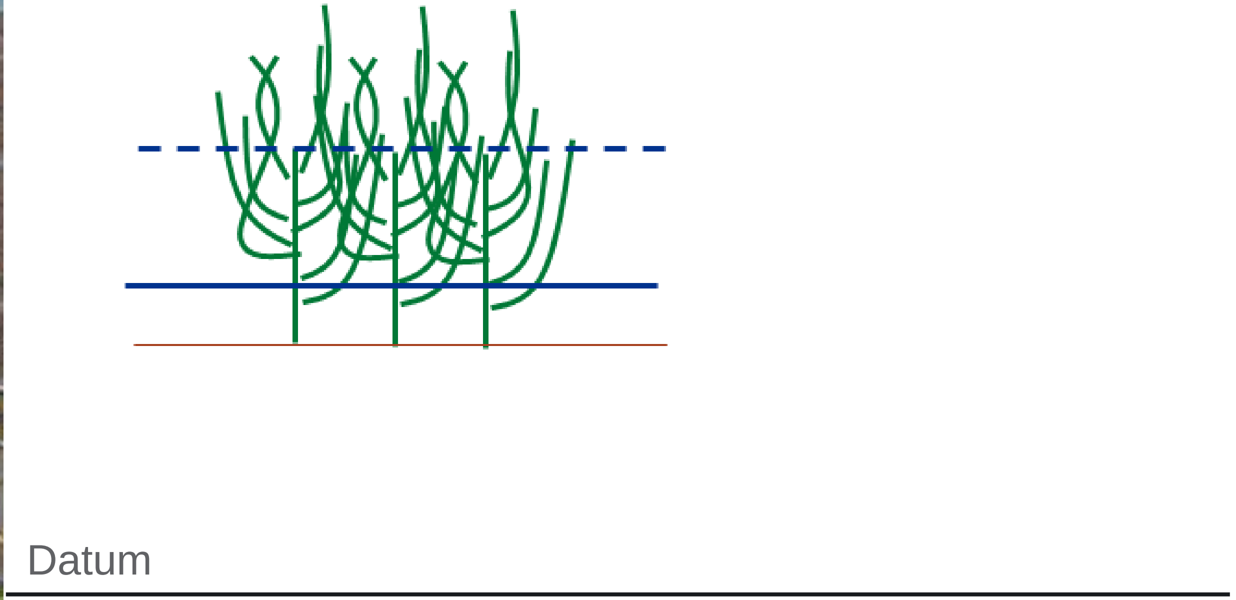
Cascadia Subduction Zone Earthquake: Subsidence

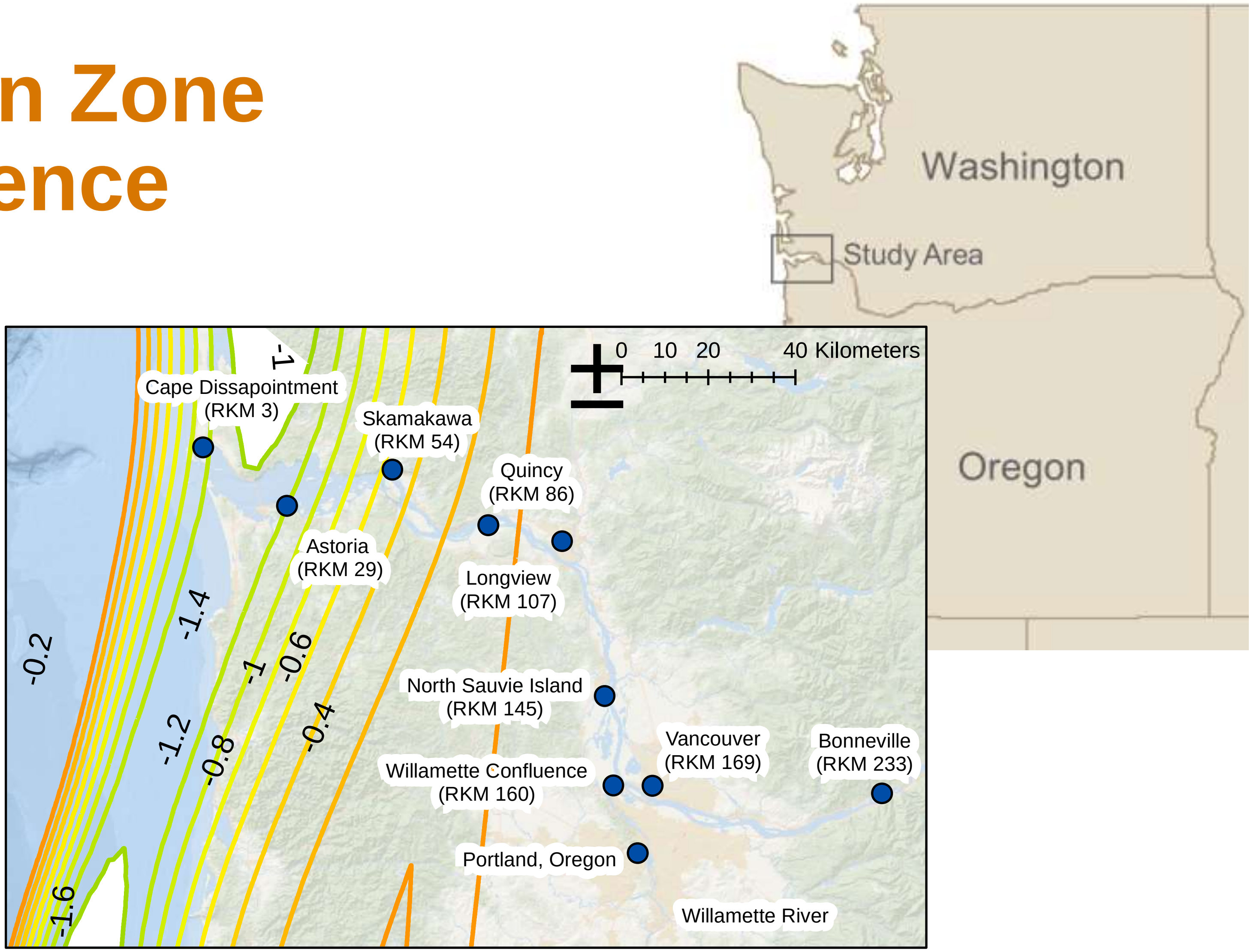


Land subsidence estimates from DOGAMI Open-File Report O-13-06

Cascadia Subduction Zone Earthquake: Subsidence

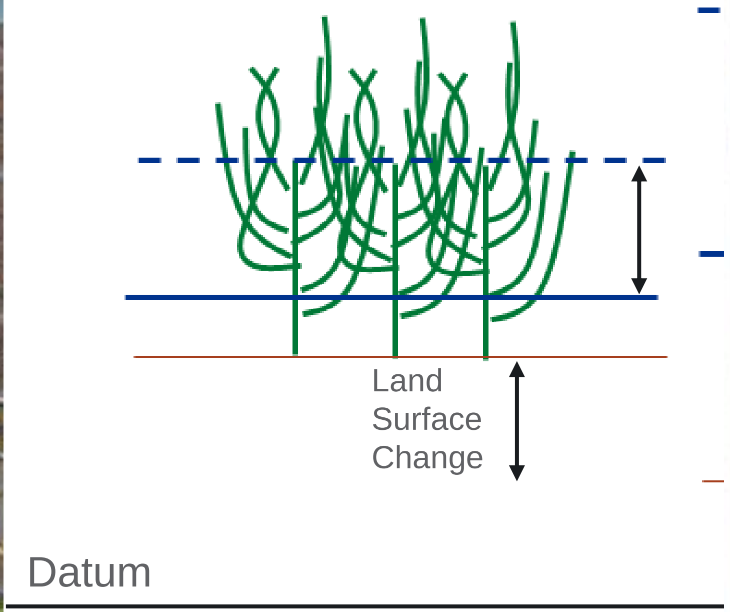
Pre-Earthquake

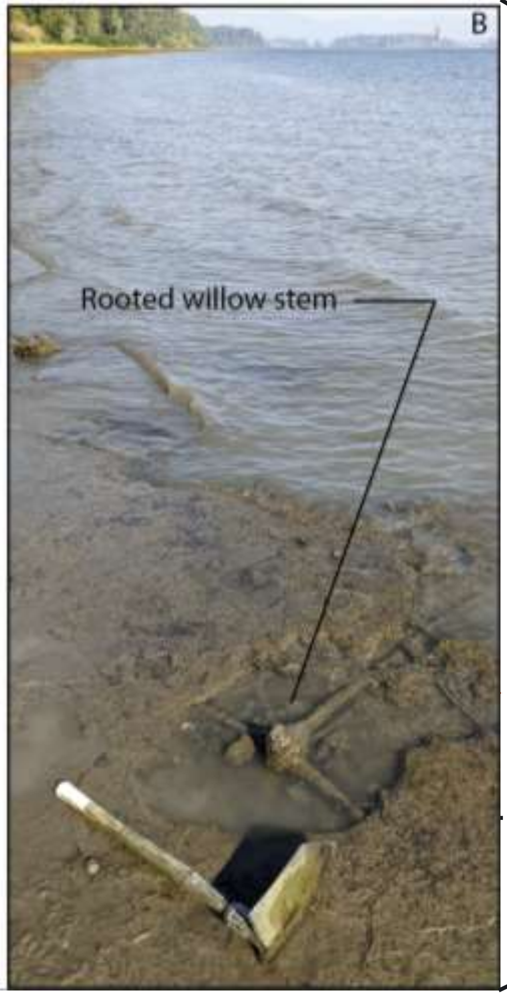


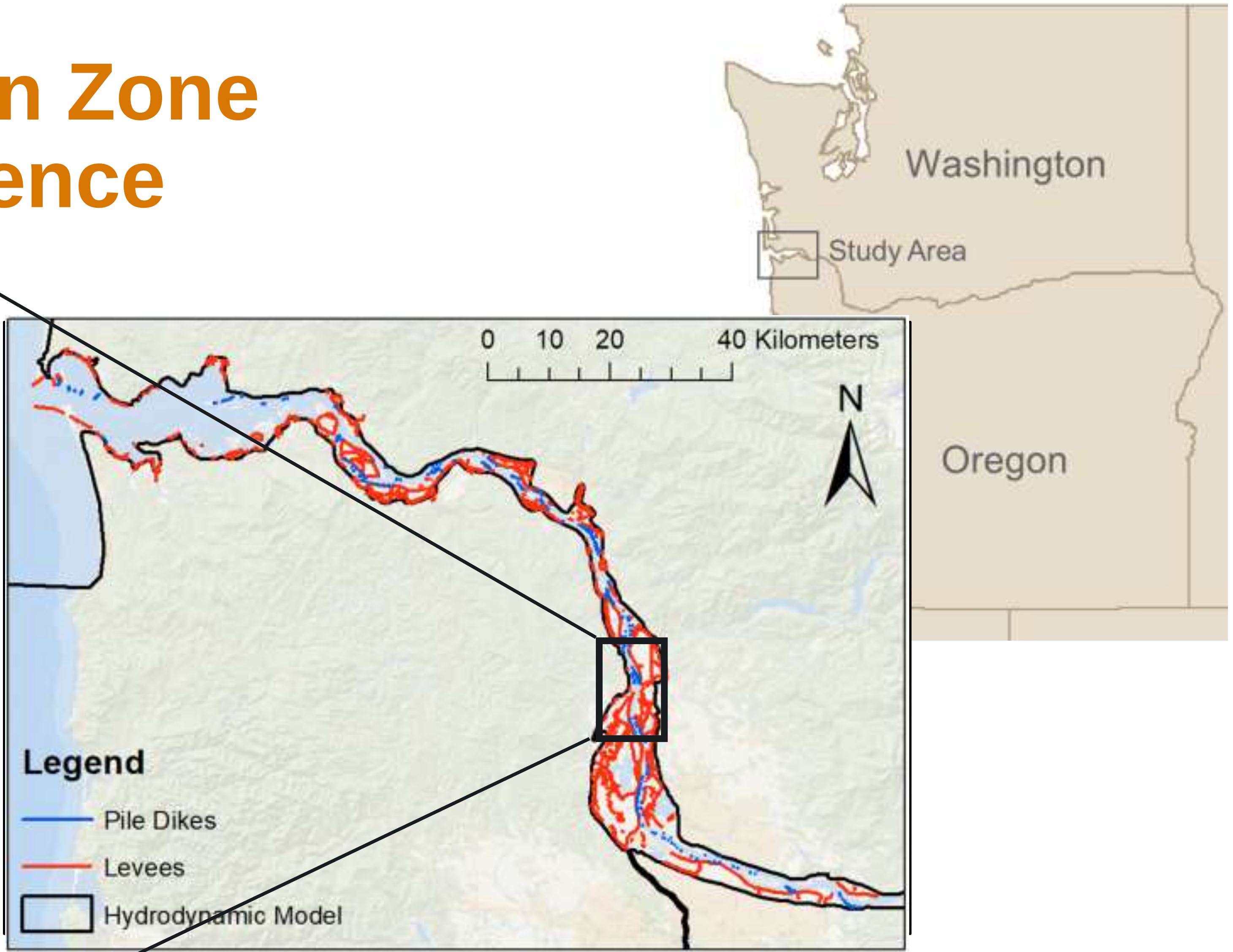


Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Cascadia Subduction Zone Earthquake: Subsidence





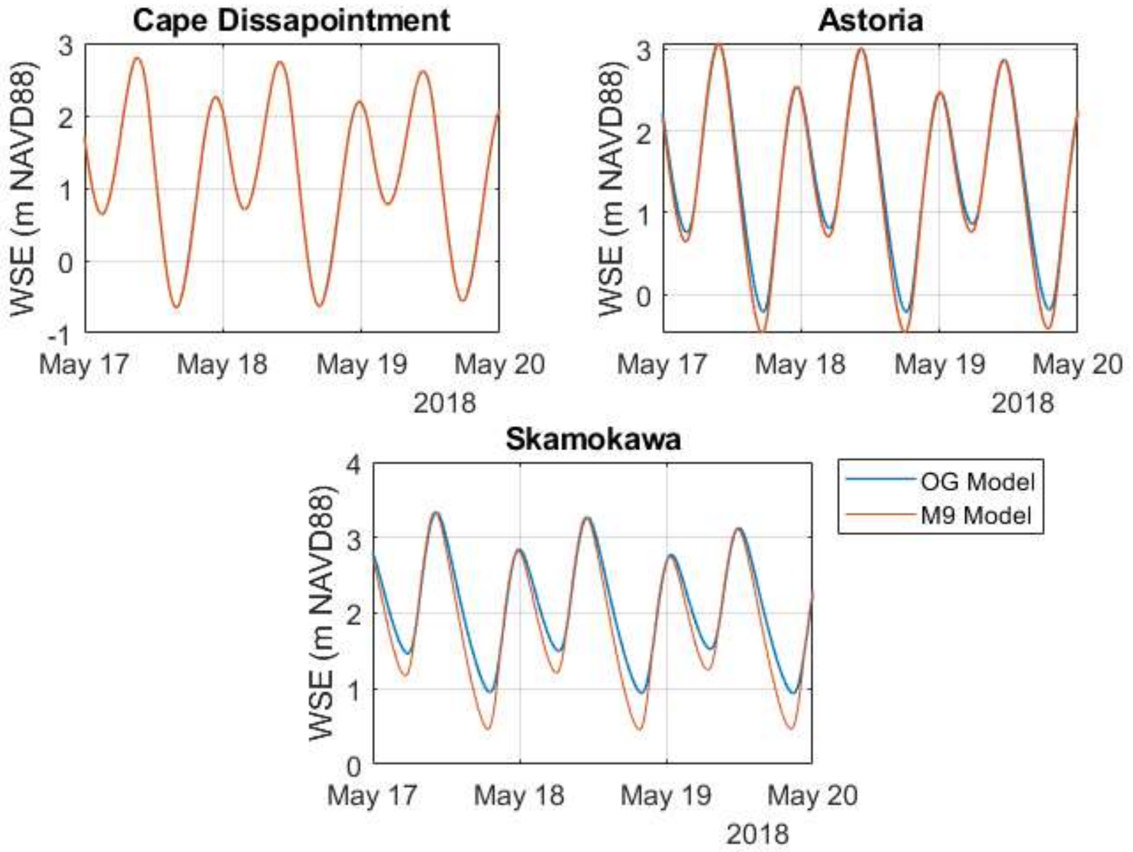


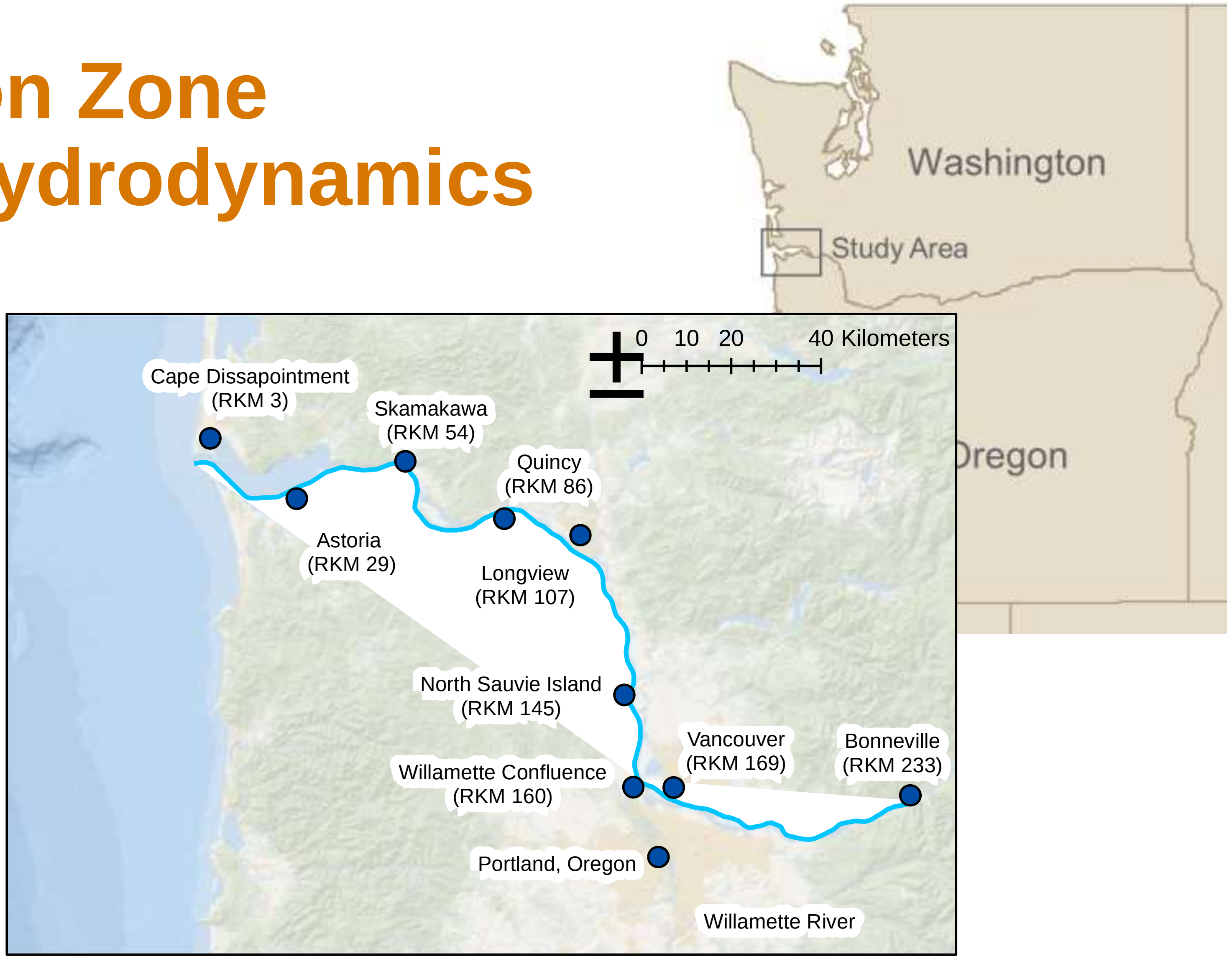
Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Three Scenarios:

- **M9** - subsidence
- **M9+IF** – subsidence and infrastructure failure
- **M9+IF+LQ** – subsidence, infrastructure failure, and liquefaction

Cascadia Subduction Zone Earthquake: Tidal Hydrodynamics

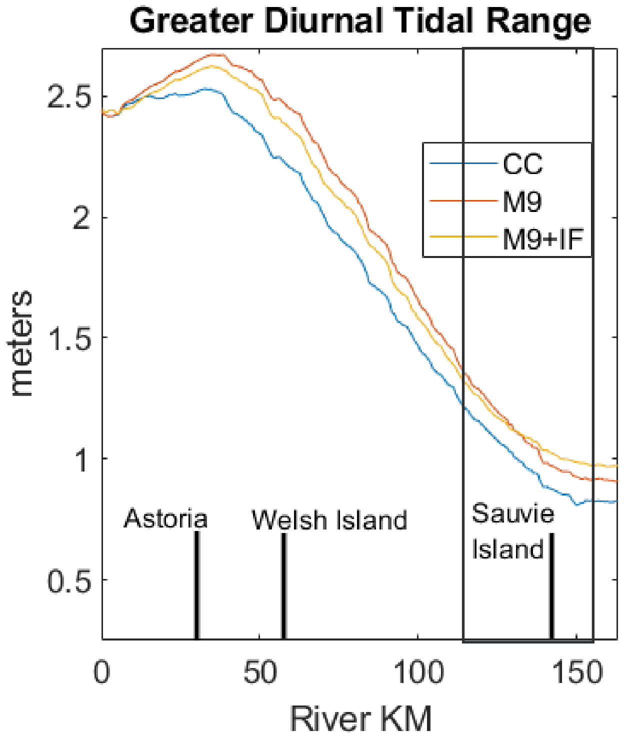


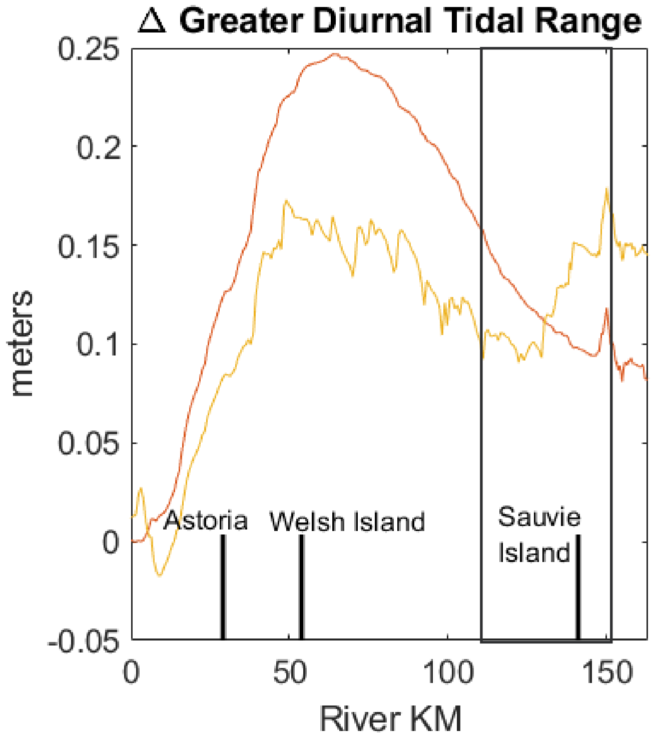


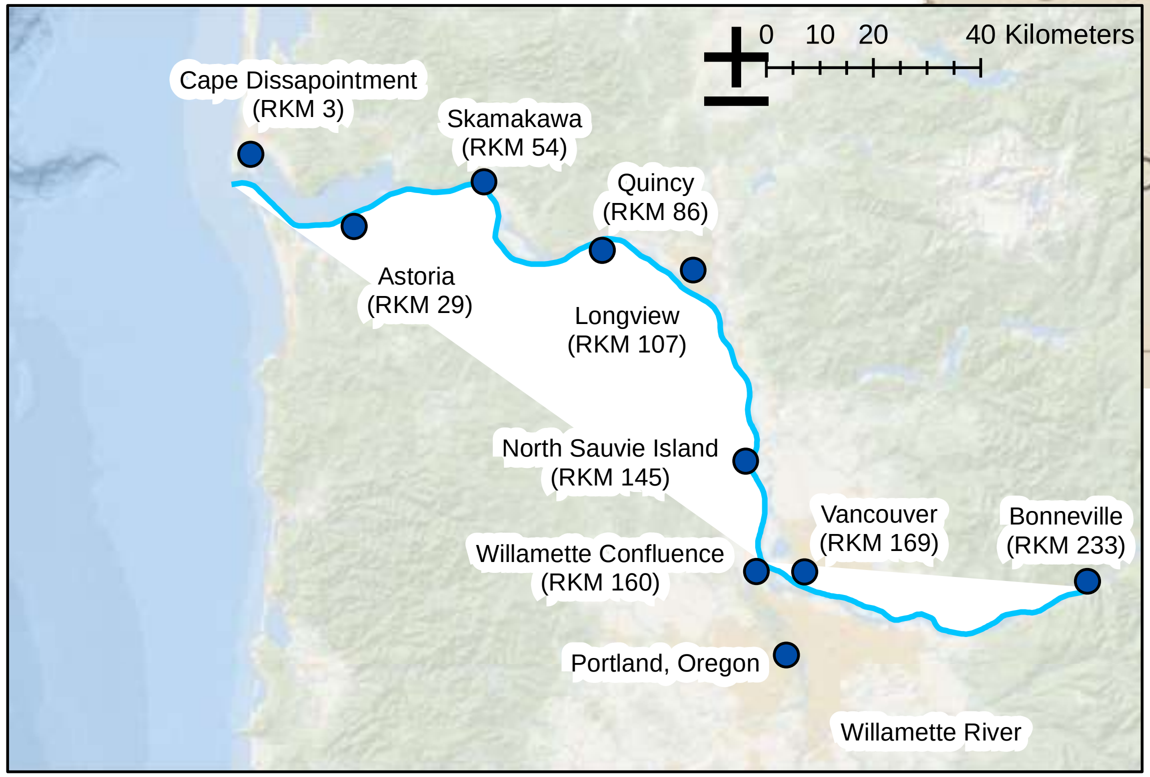
Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Changes to tidal range are largely driven by lowering of MLLW, and magnitude of changes increase upstream

Cascadia Subduction Zone Earthquake: Tidal Hydrodynamics





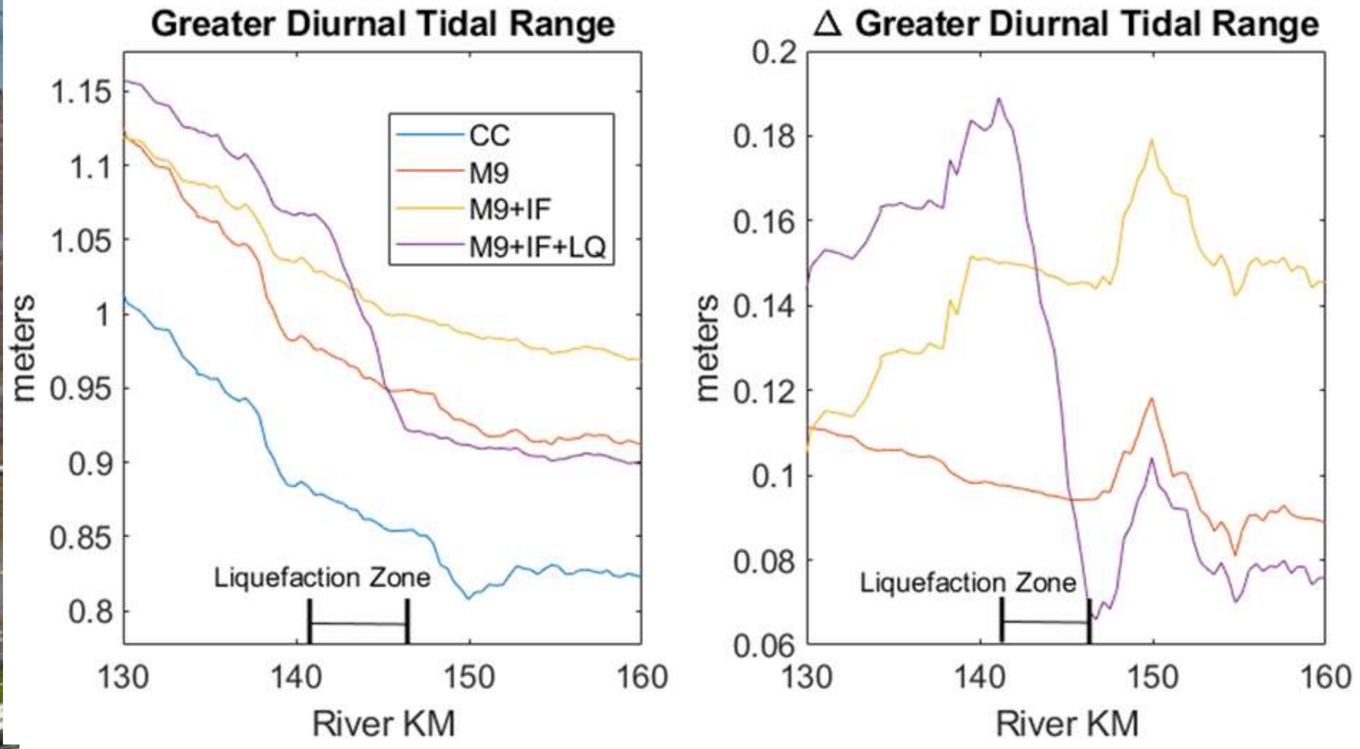


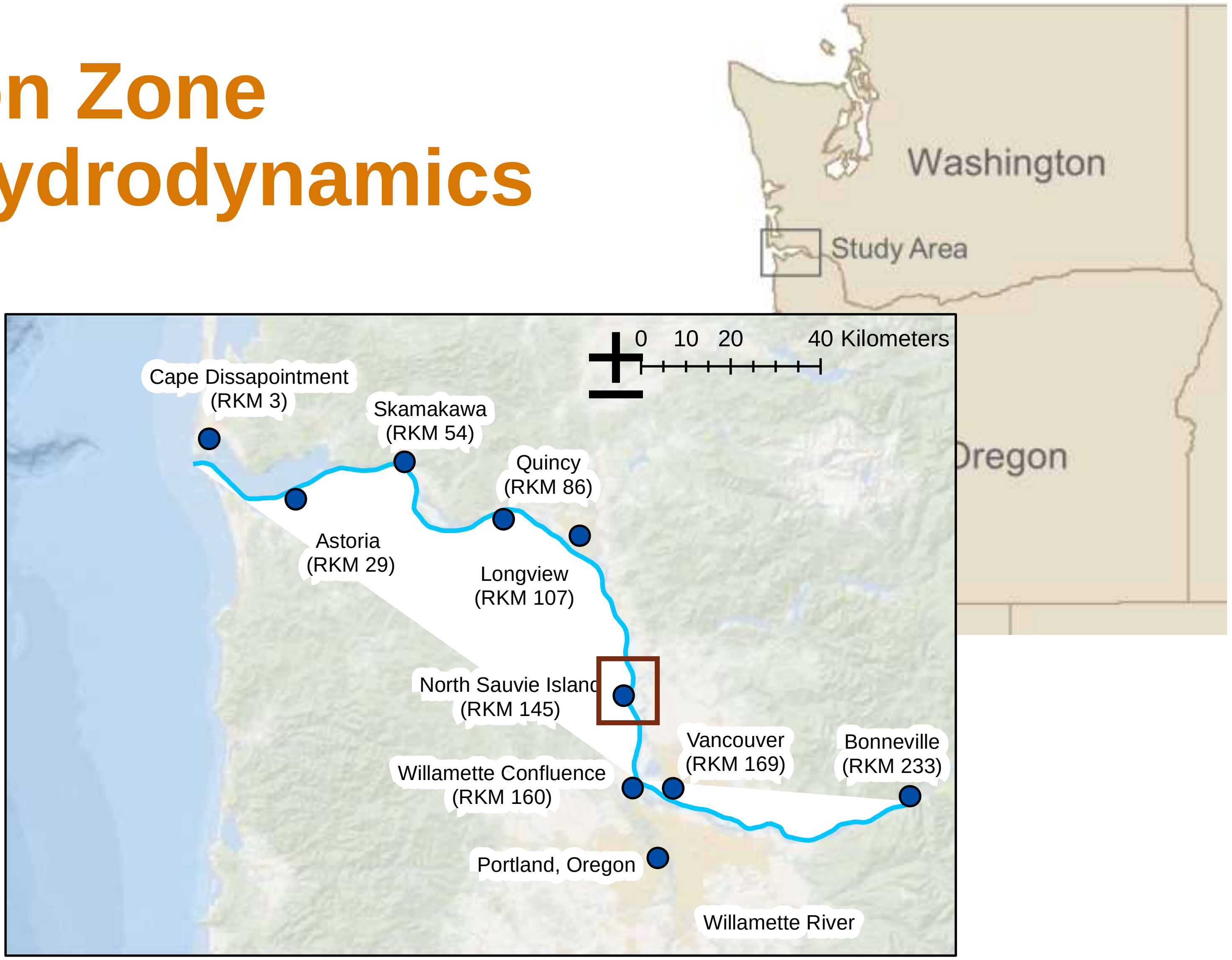
Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Changes to tidal range are largely driven by lowering of MLLW

Infrastructure failure results in tidal dampening compared to M9 alone

Cascadia Subduction Zone Earthquake: Tidal Hydrodynamics



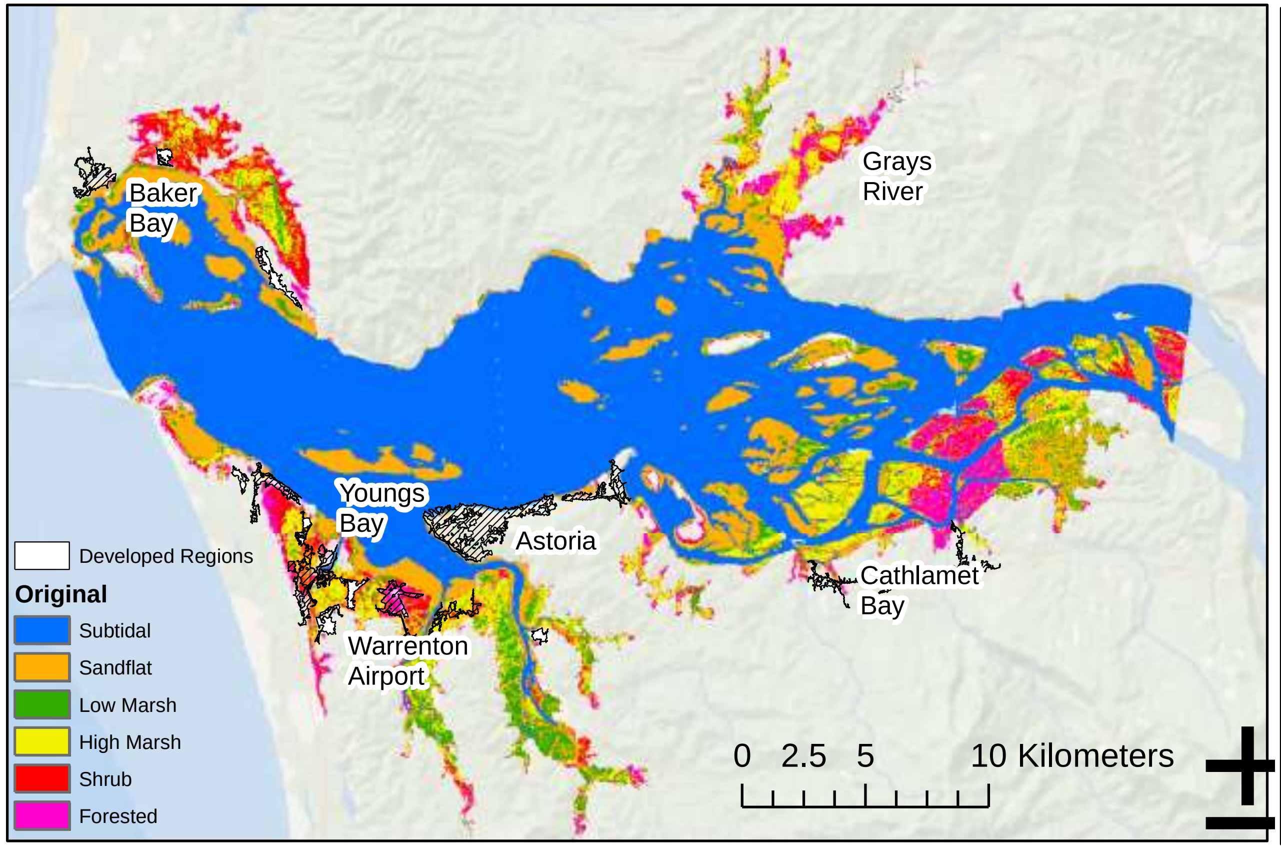


Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

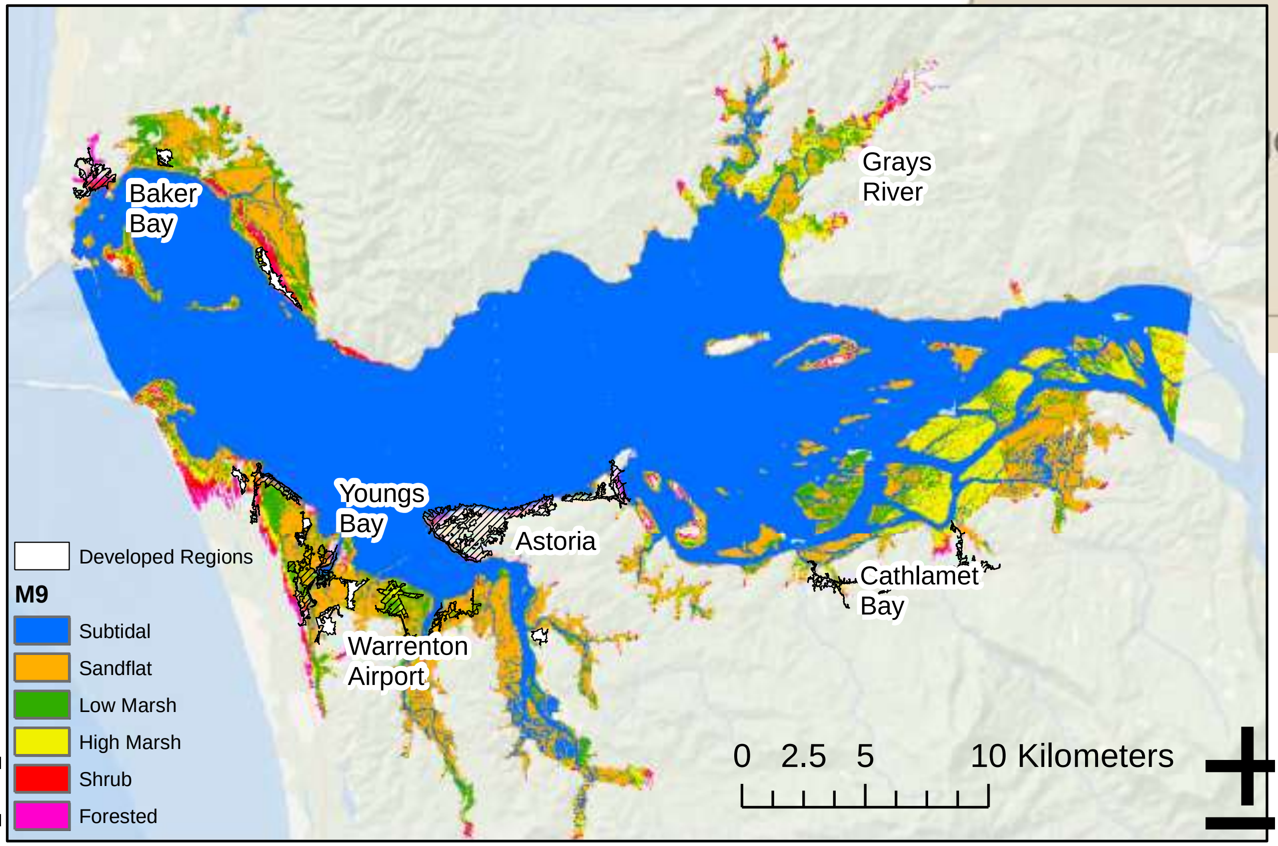
Liquefaction causes reflection of the tidal wave, locally increasing tidal range downstream and decreasing range upstream

Cascadia Subduction Zone Earthquake: Habitat Changes

Current Conditions



M9 Earthquake



Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Broad scale lowering of habitats (>90%)

Cascadia Subduction Zone Earthquake: Habitat Changes

	Habitat Proportion (hectares)	
Habitat Type	CC	M9
Subtidal (SUB)	28,929	36,402
Sandflat (FL)	7,127	6,966
Low Marsh (LM)	2,625	3,115
High Marsh (HM)	5,237	3,510
Shrub (SH)	2,478	830
Forested (FOR)	2,763	954
All Habitat Sum	49,159	50,823
Intertidal Habitat Sum	20,230	14,421

↑ +26%
↓ -2.2%
↑ +18%
↓ -33%
↓ -66%
↓ -65%
↑ +3.4%
↓ -29%

Intertidal Habitats (-2.2% to -65%)

Dynamic changes (i.e. "how much intertidal habitat converts to a lower type?) indicate >90% of intertidal habitats will be impacted

Changes to:
Land Surface Elevation
Tidal Hydrodynamics
Habitat

Cascadia Subduction Zone Earthquake: Habitat Changes

	Habitat Proportion (hectares)		
Habitat Type	CC	M9	
Subtidal (SUB)	28,929	36,402	+26%
Sandflat (FL)	7,127	6,966	-2.2%
Low Marsh (LM)	2,625	3,115	+18%
High Marsh	[illegible]	[illegible]	

idal Habitats

Habitat

Geophysical Research Letters

RESEARCH LETTER
10.1029/2022GL099115

Key Points:
- ^{14}C, excess ^{210}Pb, and Bayesian statistics can produce decadal age-depth models over the last ~300 years
- Following the 1700 CE Cascadia Subduction Zone earthquake high marsh reestablishment took ~200 years in Netarts

Supporting Information:
Supporting Information may be found in the online version of this article.

Correspondence to:
E. K. Peck,
erinpeck@udel.edu

Recovery Rate of a Salt Marsh From the 1700 CE Cascadia Subduction Zone Earthquake, Netarts Bay, Oregon

Erin K. Peck[1,2], Thomas P. Guilderson[3], Maureen H. Walczak[1], and Robert A. Wheatcroft[1]

[1]Earth, Ocean, & Atmospheric Sciences, Oregon State University, Corvallis, OR, USA, [2]Plant & Soil Sciences, University of Delaware, Newark, DE, USA, [3]Ocean Sciences, University of California Santa Cruz, Santa Cruz, CA, USA

Abstract Since the 1700 CE Cascadia Subduction Zone earthquake and associated coseismic subsidence and tsunami, vegetated intertidal habitats have reestablished across Pacific Northwest estuaries, yet timescales and mechanisms of recovery are uncertain. We investigated the timescale of salt marsh reestablishment in Netarts Bay, Oregon following the 1700 CE earthquake using a combination of excess ^{210}Pb, ^{14}C, stratigraphic constraints, and Bayesian age-depth modeling. Coseismic subsidence lowered the area to low/mid marsh, which persisted for 200 years before transition to modern high marsh. The modern high marsh now appears in dynamic equilibrium with modern sea level rise. In addition to serving as a methodological proof of concept for dating the past 300 years, these results provide insight into intertidal morphodynamic response to large perturbations along tectonically active margins.

"Through a combination of different age dating techniques and statistical analyses, we determined that the reestablishment of a salt marsh in Netarts Bay, Oregon took ~200 years."

Key Findings and Q&A

- A Cascadia Subduction Zone rupture event will result in significant changes to habitat distributions throughout the Columbia River Estuary
- Marshes will subside to lower elevations
  - >90% will convert to lower elevations
- Recovery rates specific to the CRE are unknown, and likely to be different from historical rates
  - Recovery rates from nearby areas suggest ~200-year recovery period
  - ~75% reduction in sediment loads to CR from historical values – reduces marsh building capabilities
  - Sea-level rise and changes to flows are conflating factors
- How can we design restoration projects that are “climate AND earthquake resilient?”

Thank you