Bluff Recession in the Elwha and Dungeness Littoral Cells, Washington, USA

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Overview

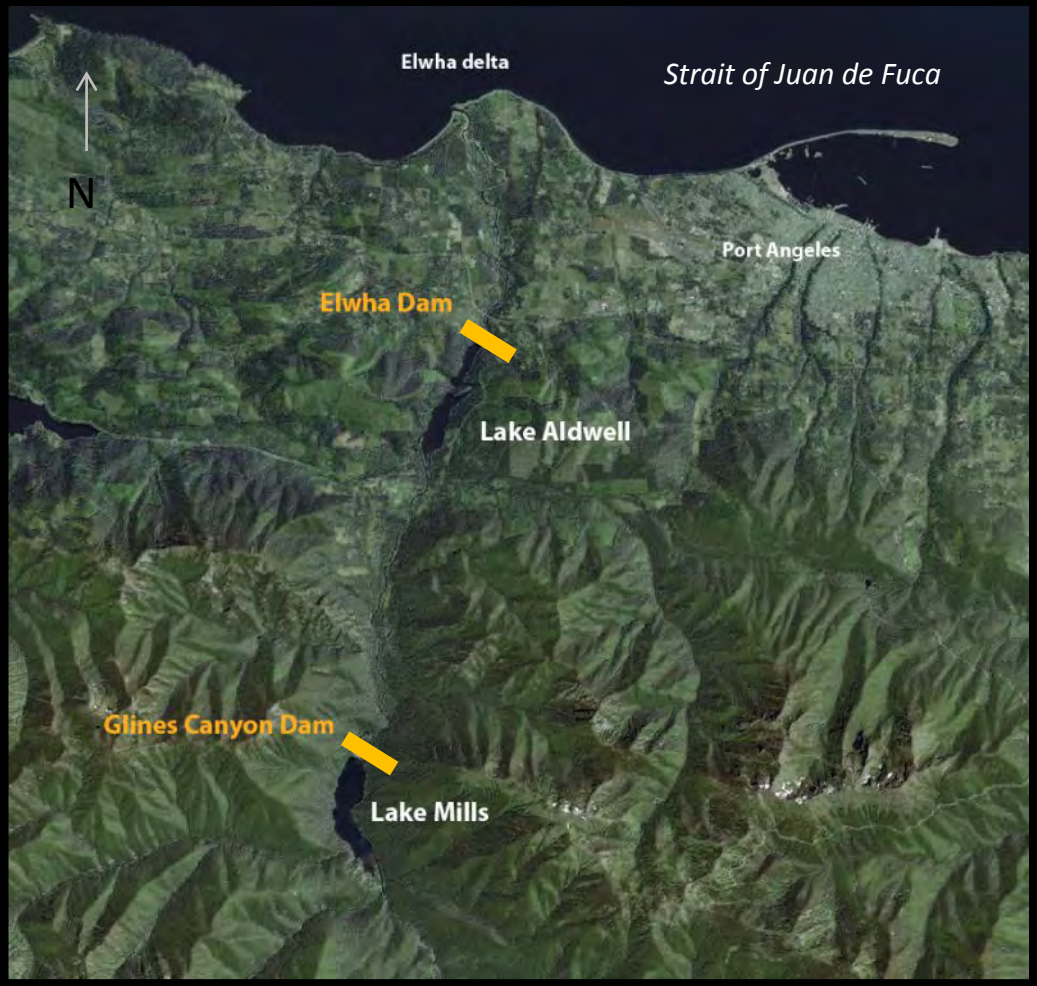
- Elwha River Dams-Effects on Coastal Zone (Littoral Cell)
  - Shoreline Erosion, Ediz Hook (Galster, 1978)
  - Elwha Delta Erosion (Warrick et al., 2009)

- Shoreline Armoring- (Parks, Shaffer & Barry, 2013)
  - Reduced Sediment Supply to Littoral Cell
    - Coarsening of Grain-Size on Beaches
    - Reduced Habitat for Beach-Spawning Fishes

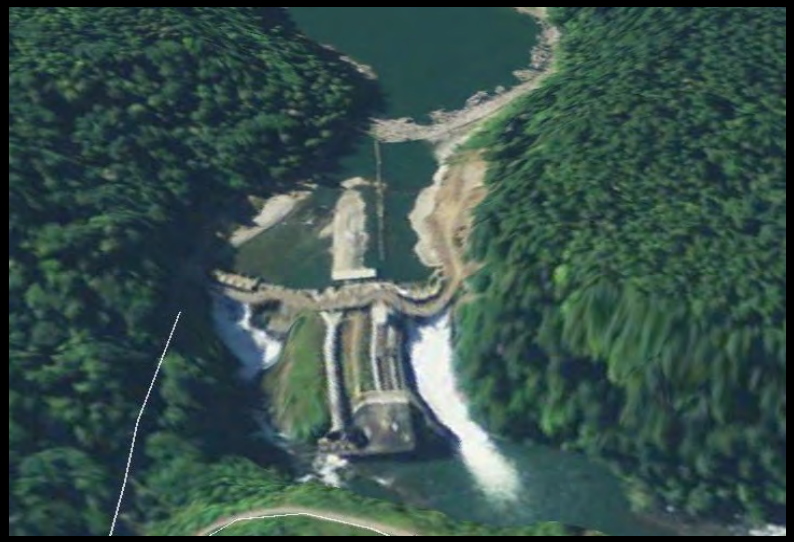
- Littoral Cell Sediment Budgets
  - Elwha River sediment from dam removals
  - Sediment contributed from coastal bluffs (Parks, 2015)
    - Effect of armoring on recession rates and sediment volume.


Strait of Georgia
British Columbia
San Jua Islands
Canada
United States
Victoria
Strait of Juan de Fuca
Puget Sound
Elwha River
Port Angeles
Olympic Mountains
Pacific Ocean
Seattle
Washington
Olympia
British Columbia
Washington
Oregon
Idaho
0 62.5 125 250 375 500
Kilometers

Elwha River


Elwha delta
Strait of Juan de Fuca
N
Port Angeles
Elwha Dam
Lake Aldwell
Glines Canyon Dam
Lake Mills


Elwha River
Watershed
Olympic
National
Park



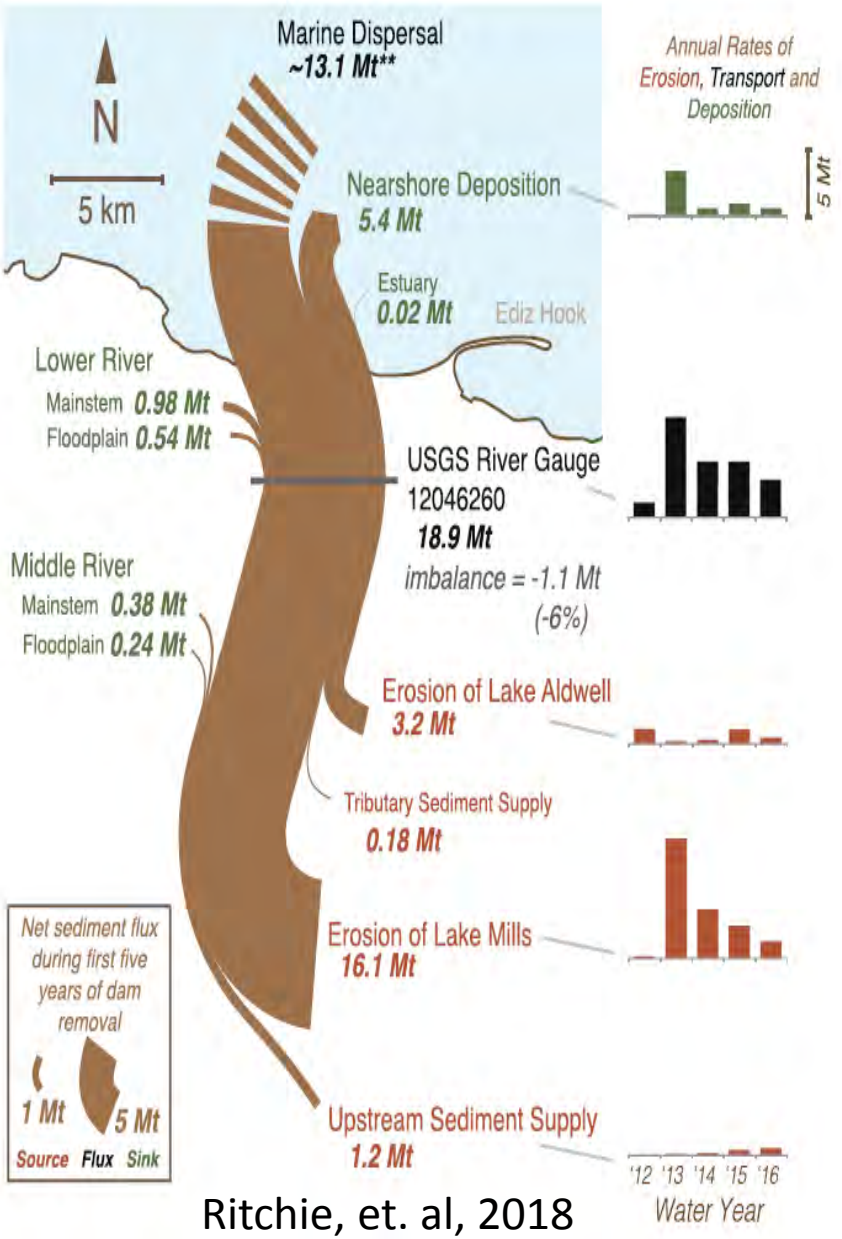
Elwha 2011

Glines 2011

Elwha 2013

Glines 2014

Sediment Contributed from Elwha Dam Removals



Ritchie, et. al, 2018

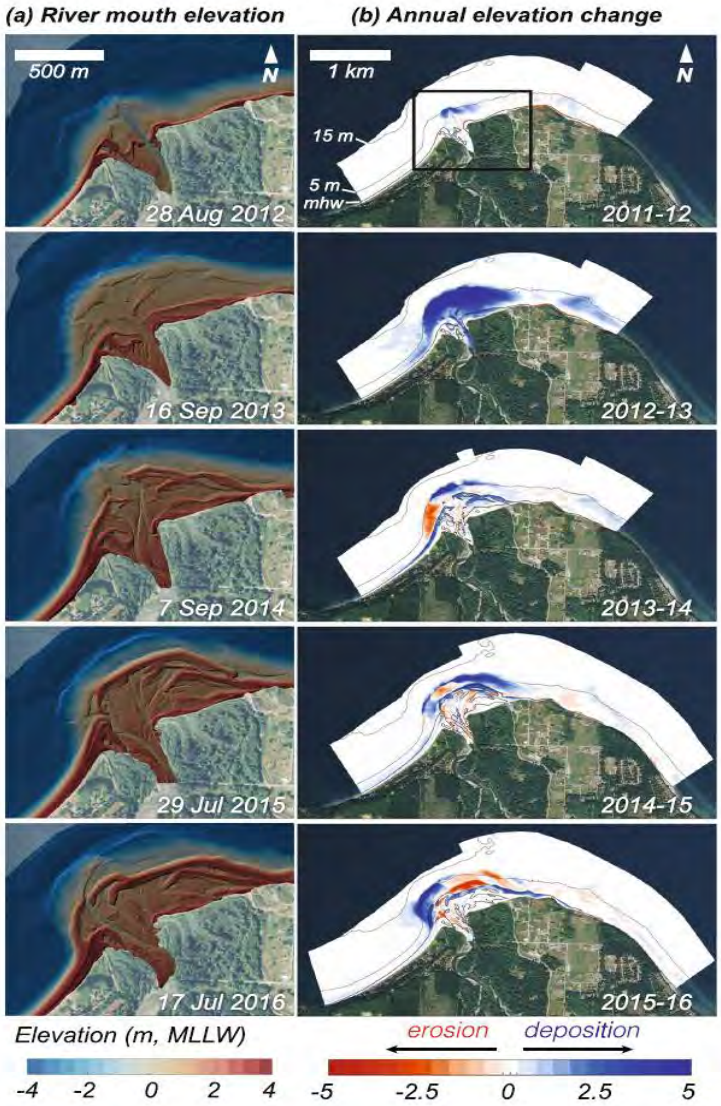


Figure 6. Topographic change of the Elwha River delta during and after dam removal. (a) Shaded-relief elevation maps of the river mouth from annual topographic and bathymetric surveys during the summer season. (b) Maps of annual change in elevation for the broader Elwha River delta. The three thin black lines on each map show contours of the −15 m, −5 m, and mean high water (mhw) elevations. The box in the upper panel shows the extent of the inset shown in (a). Map created with MATLAB Version: 9.2.0.556344 (https://www.mathworks.com). Base map data from the USGS National Map (Map services and data available from U.S. Geological Survey, National Geospatial Program).

Elwha Dam Removals 2011-2014

Delta progradation 32 ha of new subaerial delta.

Beach aggradation 1-2 m west of the delta.

Continued beach erosion east of the delta until 2018.

Research focus has been on the delta.

Special Issue of *Geomorphology*

East et al., 2015

Gelfenbaum et al., 2015

Warrick et al., 2015

Data Synthesis up to 2016.

Ritchie et al., 2018

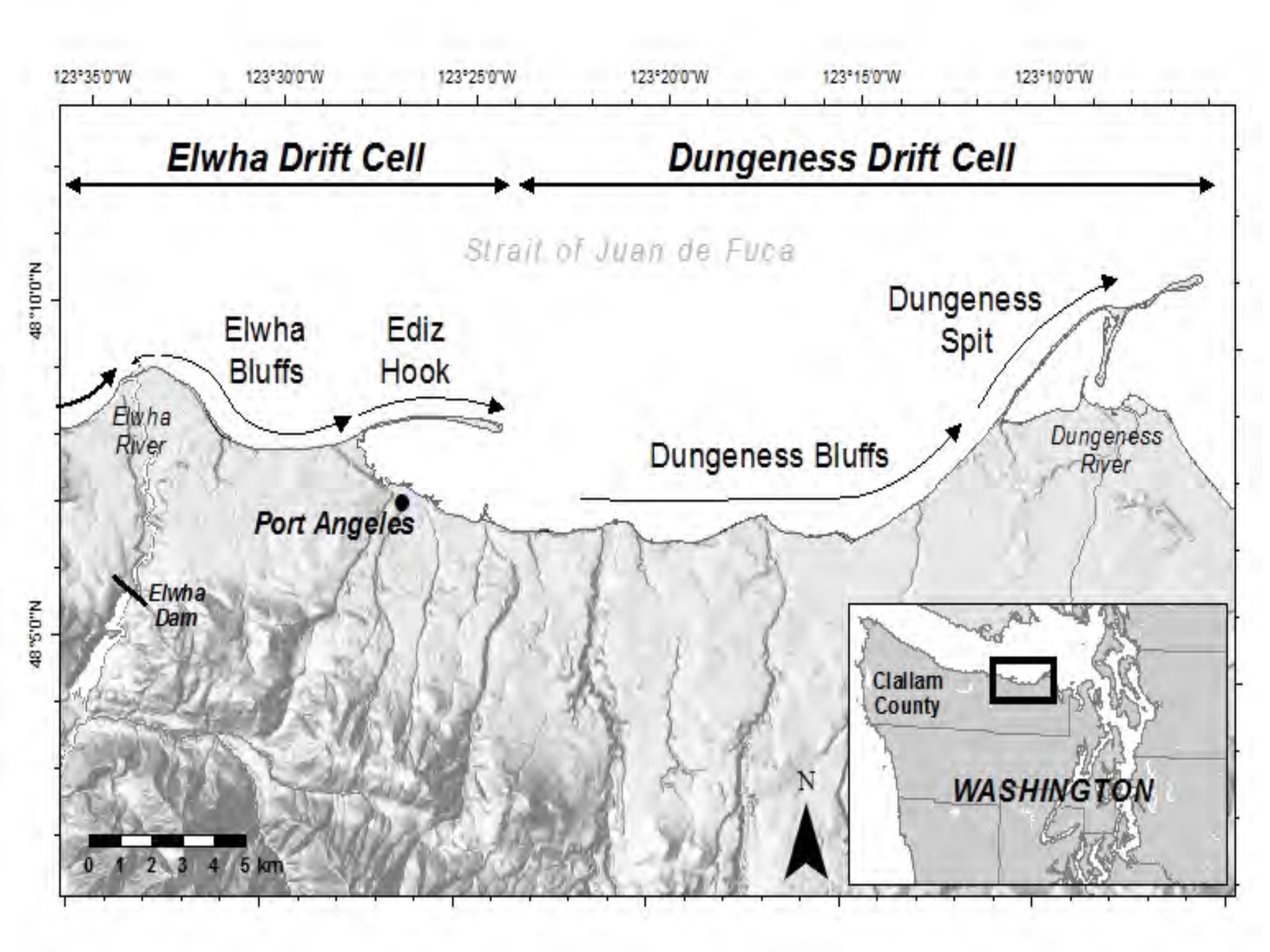
How will Elwha sediments change beaches? in the rest of the Elwha drift cell?

Introduction

- Bluff Erosion- Parks, 2015 *E&EG*
  - Recession Rates
  - Sediment volumes

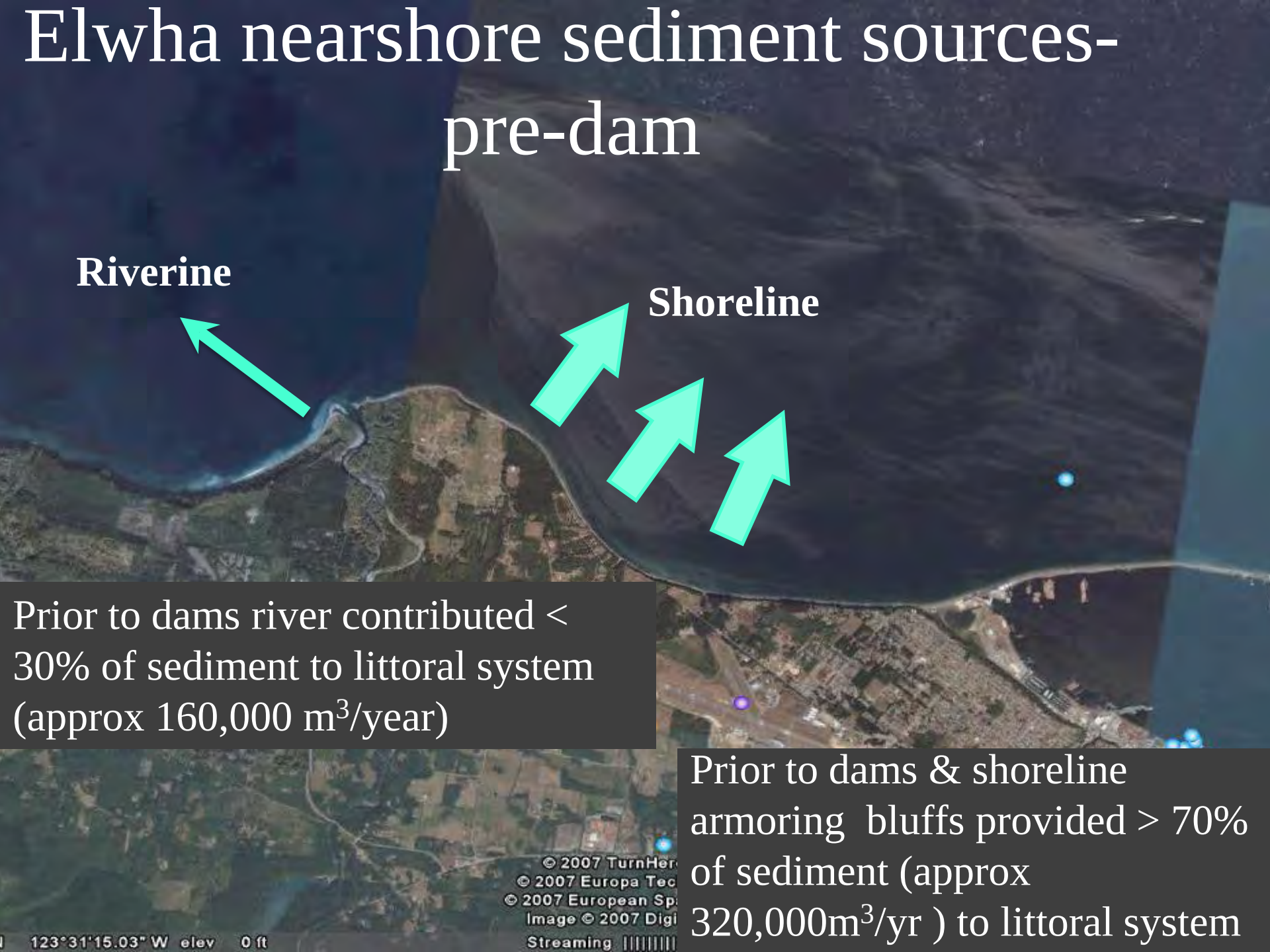
- Beach Topography and Volume Changes before, during and after dam removal.

- BACI (Before After Control Impact)
  - Elwha (Impact)
  - Dungeness (Control)
  - Armored vs. Un-Armored


123°35'0"W
123°30'0"W
123°25'0"W
123°20'0"W
123°15'0"W
123°10'0"W
48°10'0"N
48°5'0"N
Elwha Drift Cell
Dungeness Drift Cell
Strait of Juan de Fuca
Elwha Bluffs
Ediz Hook
Dungeness Spit
Elwha River
Dungeness Bluffs
Dungeness River
Port Angeles
Elwha Dam
0 1 2 3 4 5 km
N
Clallam County
WASHINGTON

Glacial Bluff-Backed Beaches

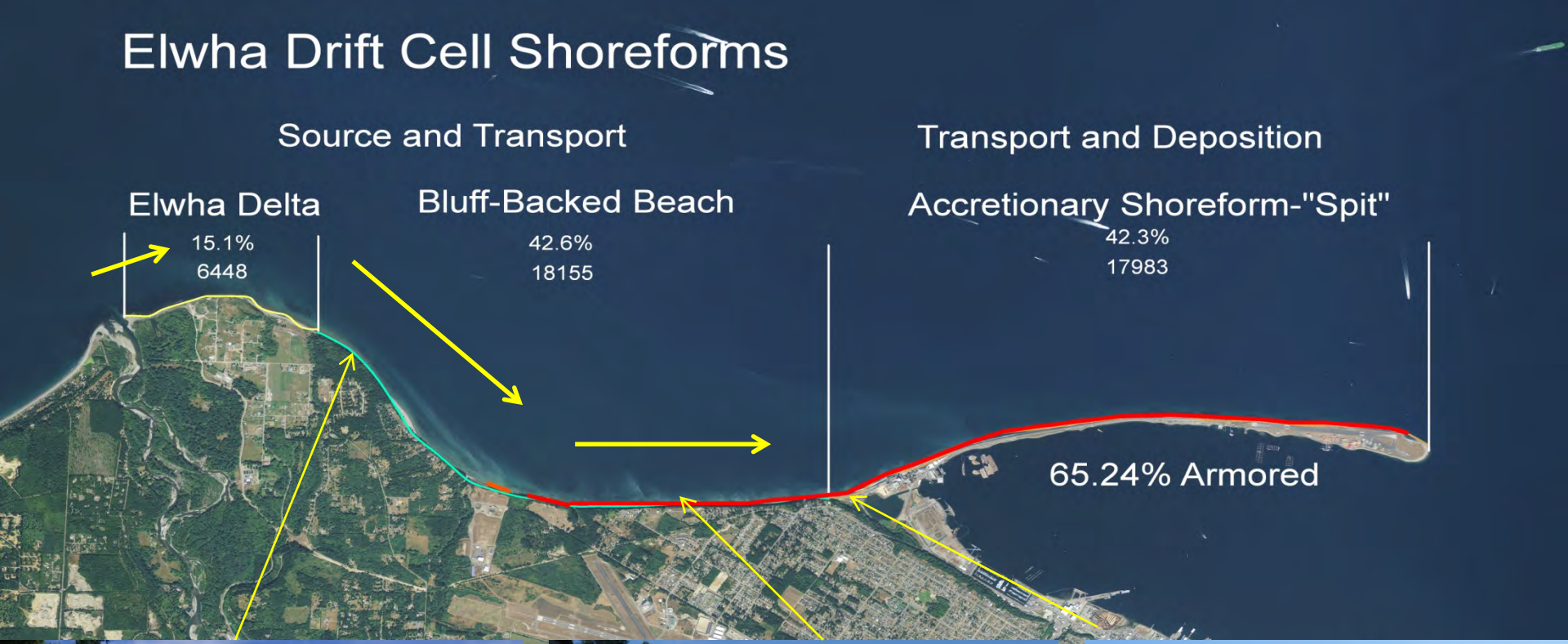
Elwha nearshore sediment sources- pre-dam

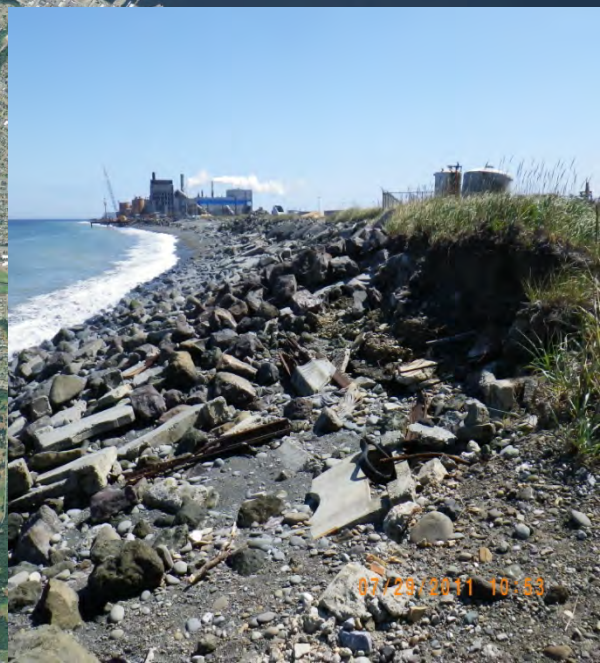


Prior to dams river contributed < 30% of sediment to littoral system (approx 160,000 m^3/year)

Prior to dams & shoreline armoring bluffs provided > 70% of sediment (approx 320,000m^3/yr) to littoral system

Elwha Drift Cell Shoreforms





Historic Anthropogenic Effects on Bluff Recession

American Pipe & Construction installing 57" pipe along bluff about 3,500' west of wye at base of Ediz ook. Note top of pipe is at least 8' below level of beach and is installed right at the toe of the bluff. This was taken some time in 1929.

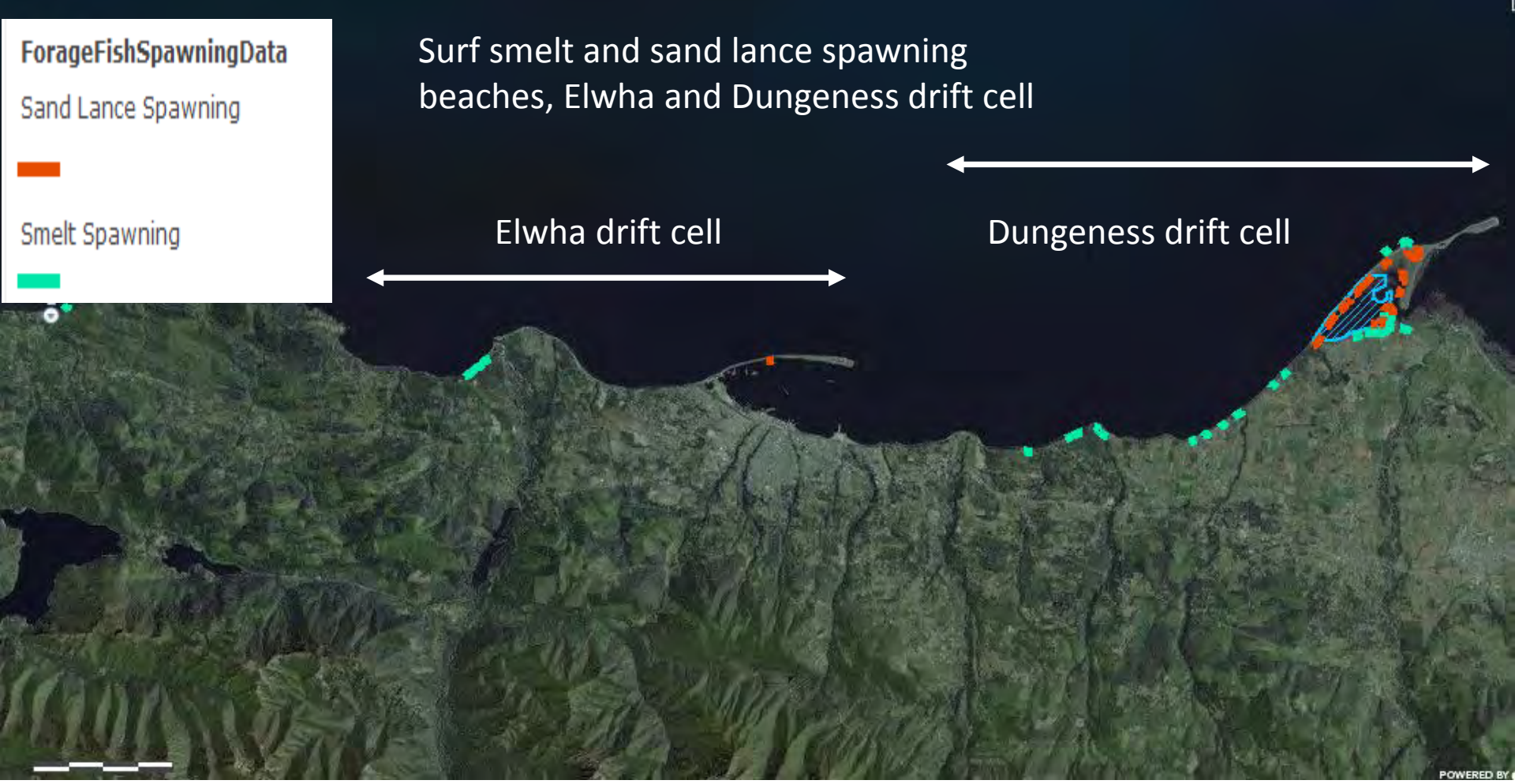
Historic 1929 Industrial Water Pipeline Construction

Elwha Drift Cell

Recent Anthropogenic Effects on Bluff Erosion

How forage fish use nearshore: migration and spawning

Eulachon (candlefish)



* Beach area calculated assuming a 20 foot wide beach

Data source: WDFW http://bit.ly/16eBpJh

Species	Drift cell	Drift cell length (miles)	Total spawning area (square feet)*
Surf smelt	Dungeness	8	404,040
	Elwha	6	66,700
Sand lance			
	Dungeness	8	240,000
	Elwha	6	20,000

Recession Rates Matter!

Tidal Currents

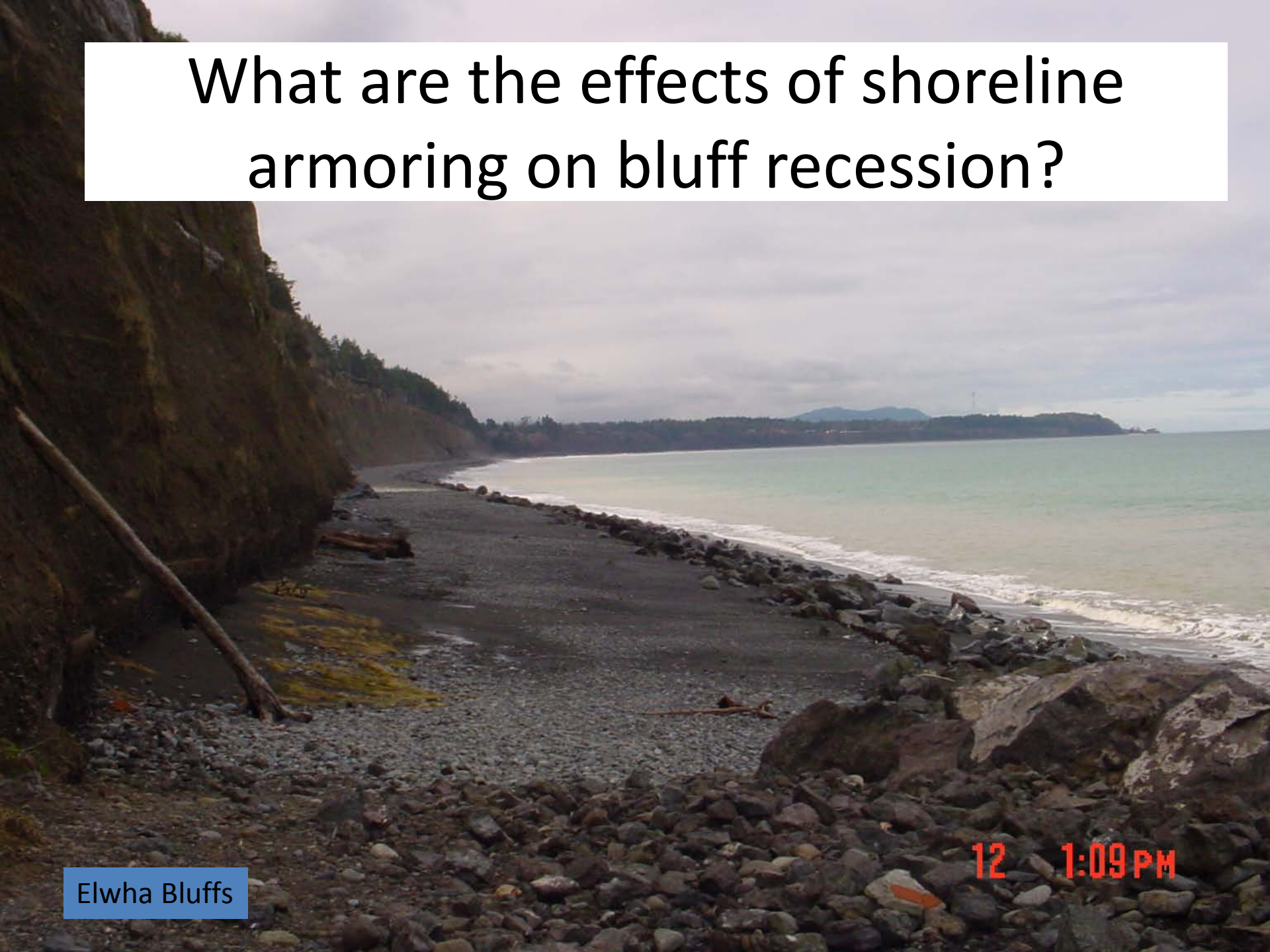
Oblique Wave Approach

PROJECT OBJECTIVES

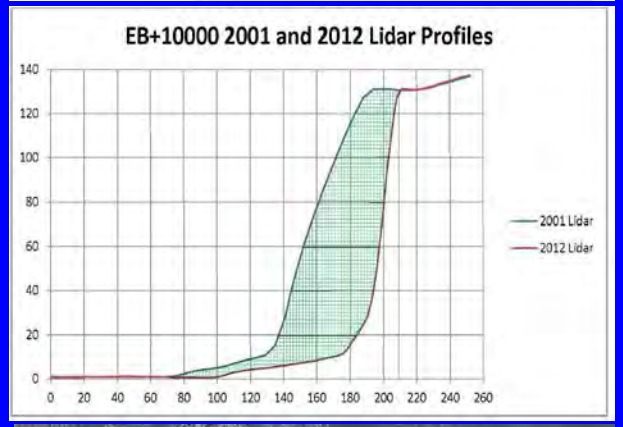
Measure Rates of Bluff Retreat

Estimate Bluff Sediment Volume Contributions

What are the effects of shoreline armoring on bluff recession?

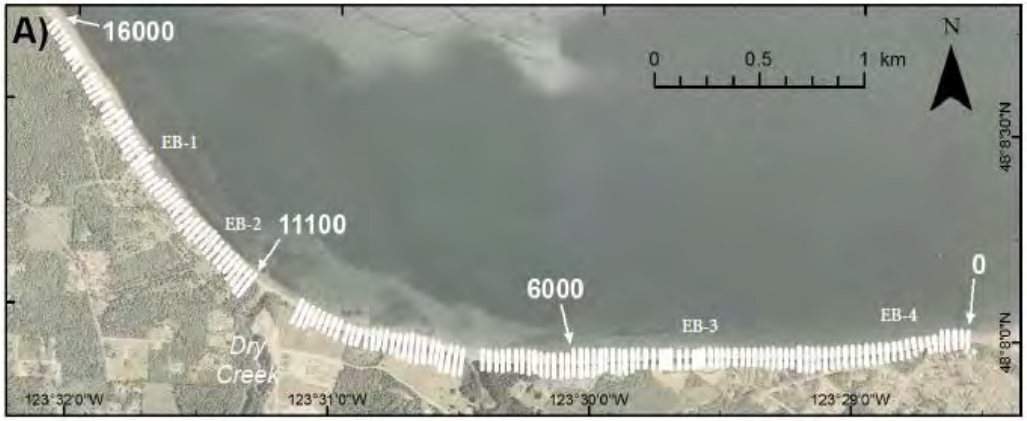


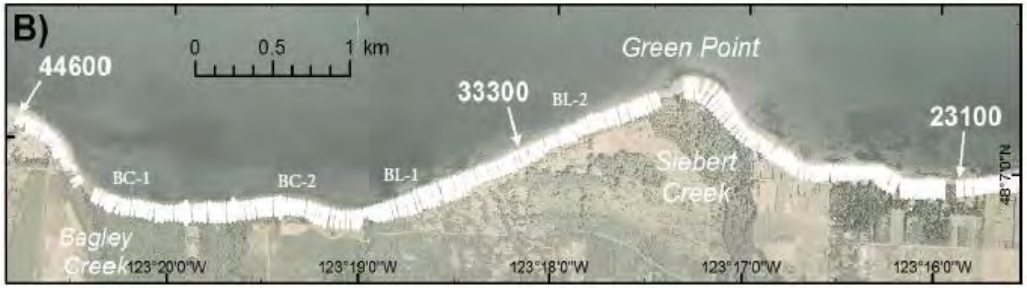
Elwha Bluffs

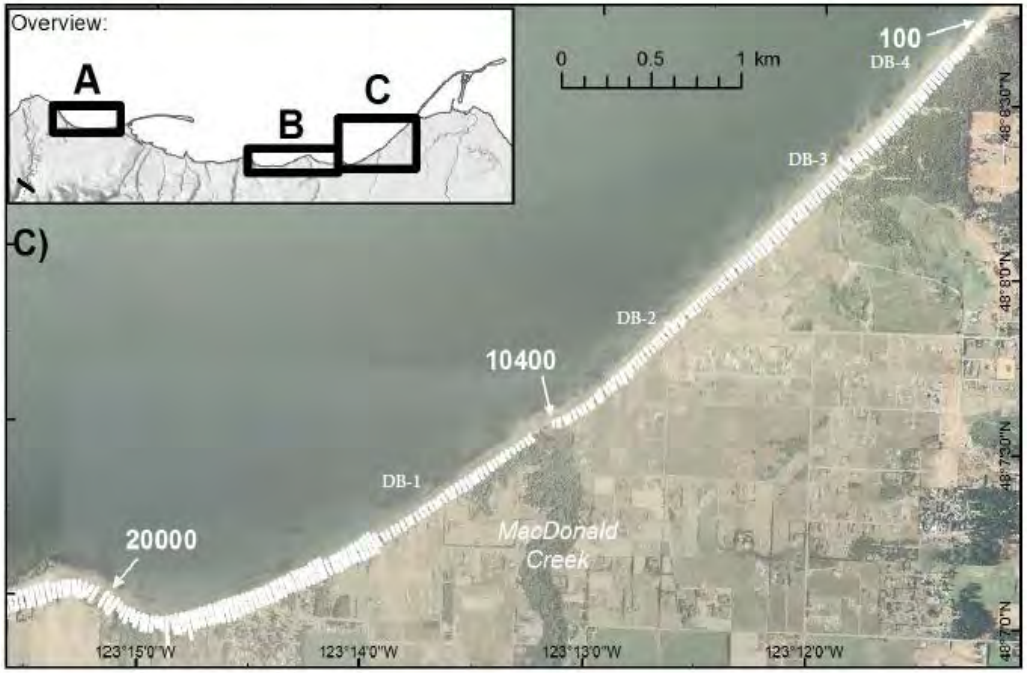


Methods

- Digitized historic aerial photography (1939-2001)
- 2-D Bluff Profiles from Airborne LiDAR Digital Elevation Models (DEMs) 2001-2012.
- 2-D Cross Shore Beach Topography (2010-2013)







Bluff Transects

Elwha N=152

Dungeness N=423

30 m transect spacing

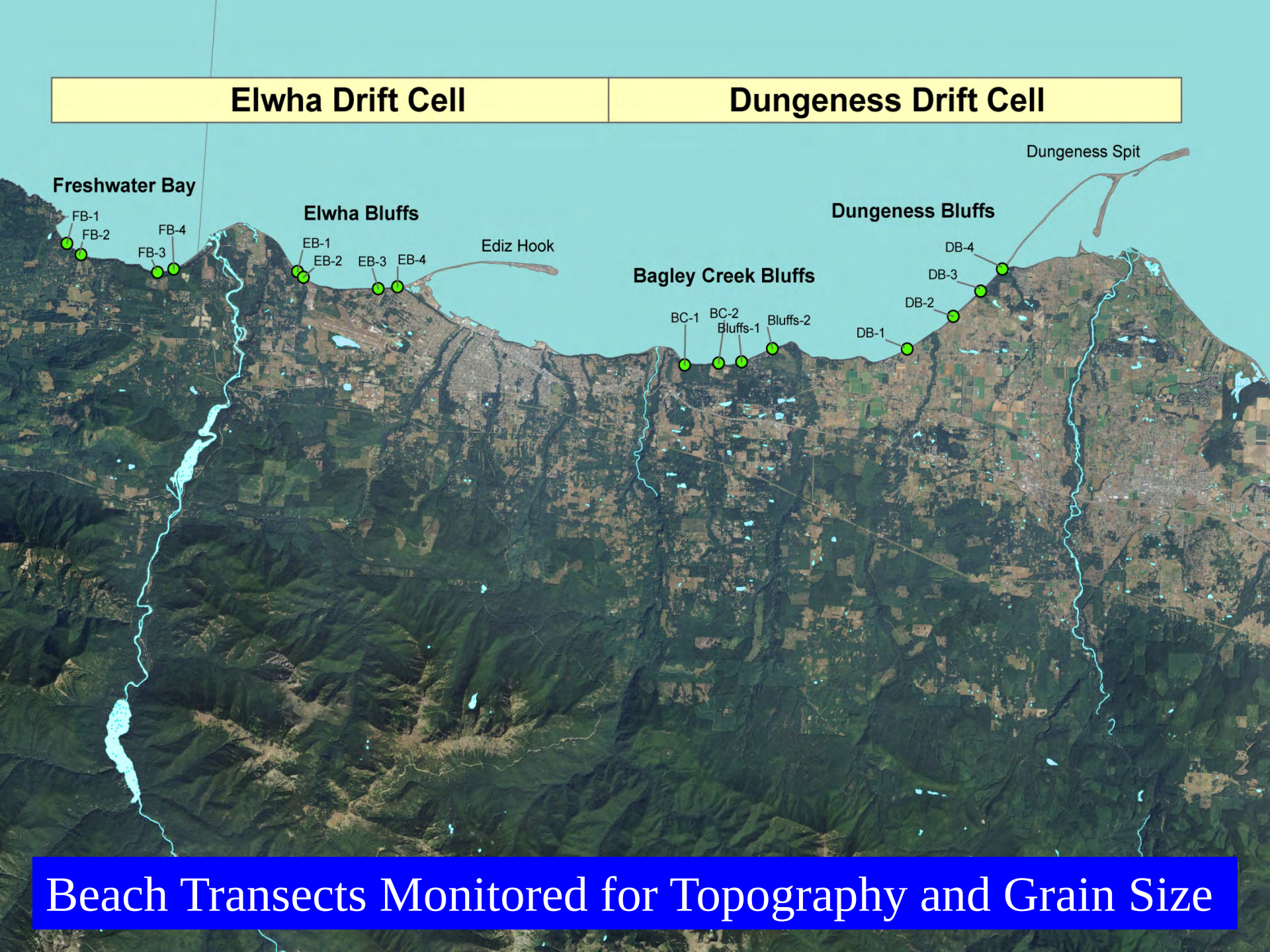
Beach Transects

Elwha N=5

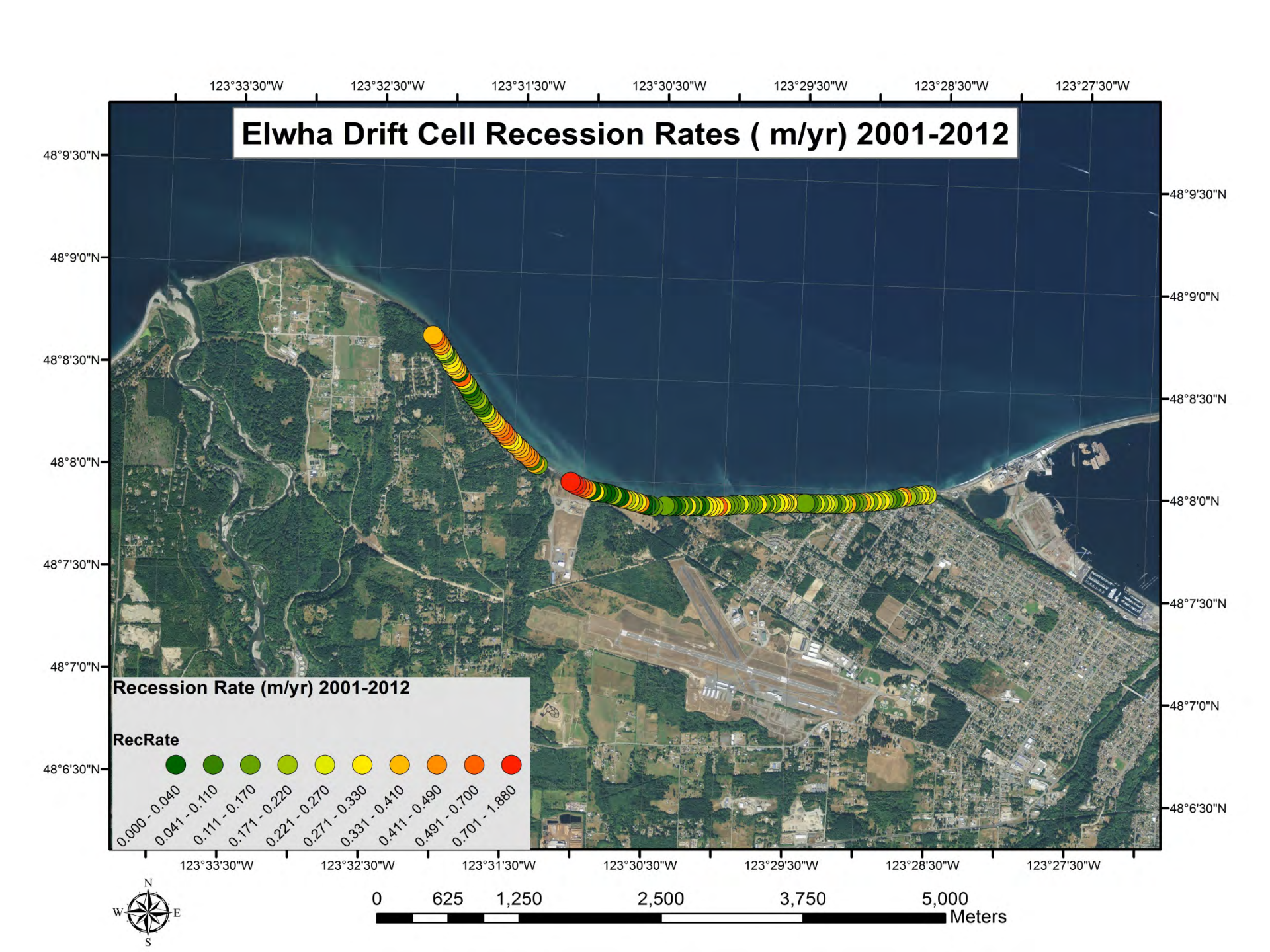
Dungeness N=8

Elwha=4.9 km

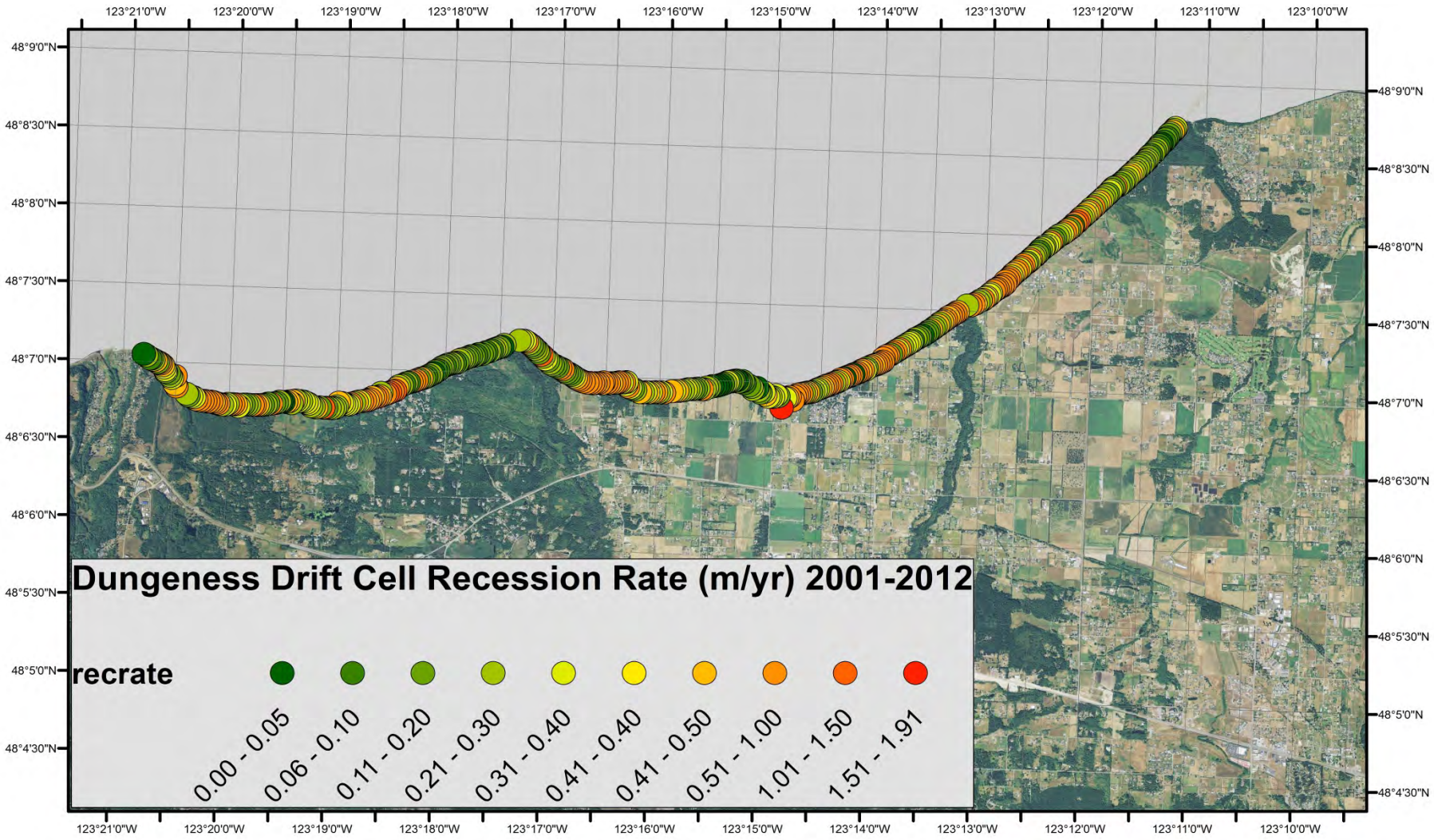
Dungeness =13.6 km



Beach Transects Monitored for Topography and Grain Size


Elwha Drift Cell Recession Rates (m/yr) 2001-2012
123°33'30"W
123°32'30"W
123°31'30"W
123°30'30"W
123°29'30"W
123°28'30"W
123°27'30"W
48°9'30"N
48°9'0"N
48°8'30"N
48°8'0"N
48°7'30"N
48°7'0"N
48°6'30"N
Recession Rate (m/yr) 2001-2012
RecRate
0.000 - 0.040
0.041 - 0.110
0.111 - 0.170
0.171 - 0.220
0.221 - 0.270
0.271 - 0.330
0.331 - 0.410
0.411 - 0.490
0.491 - 0.700
0.701 - 1.880
N
W
E
S
0
625
1,250
2,500
3,750
5,000
Meters

Dungeness Drift Cell Recession Rate (m/yr) 2001-2012



Sediment Volume Armored vs. Unarmored Bluffs

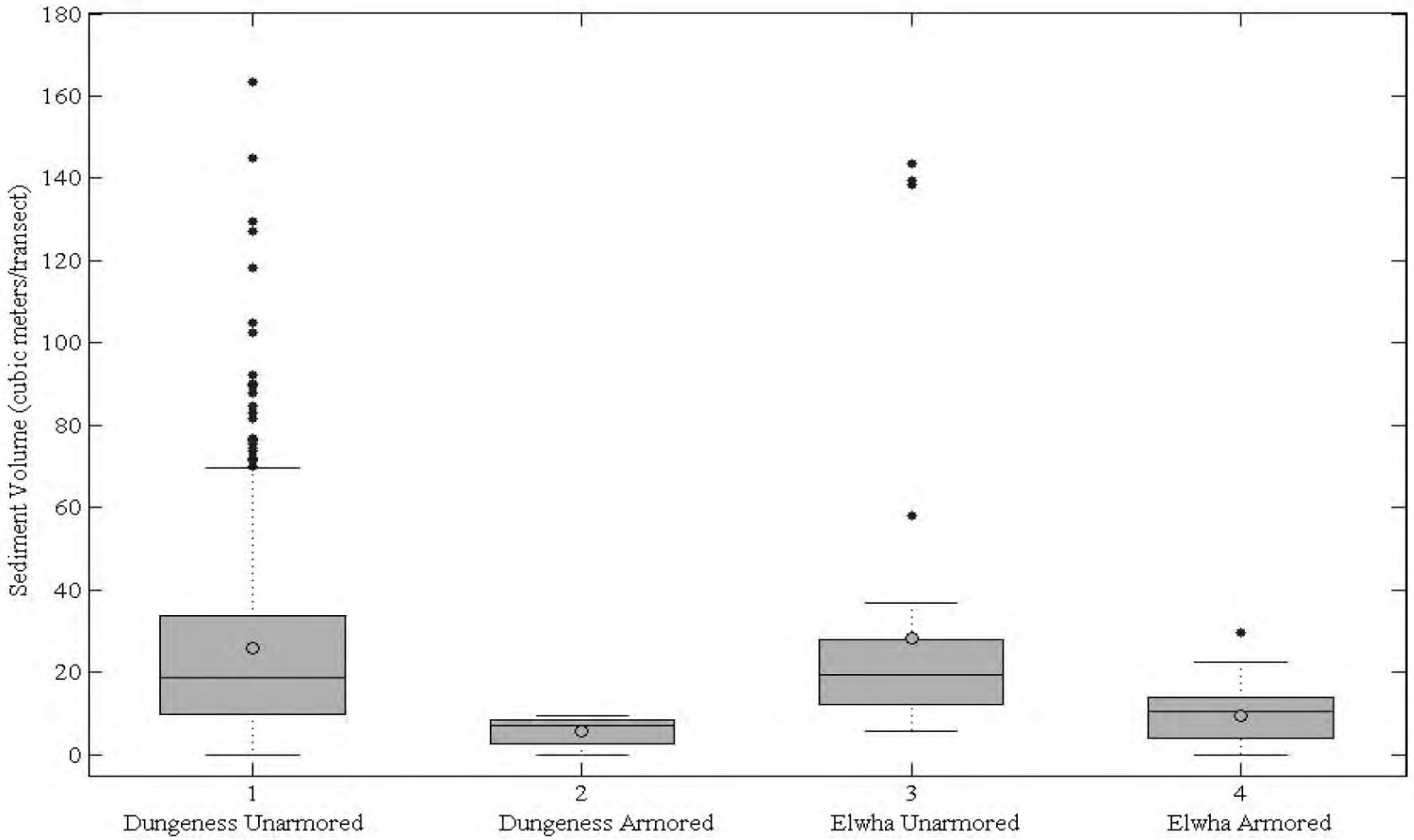


Figure 10. Box plot of sediment volume contributions (m^3/transect) by drift cell and shoreline type (created in ABOXPLOT; Bikfalvi, 2012). The central line within the box represents the sample median, while the circle represents the sample mean. The upper and lower limits of the box represent the 50th percentile of the population and the whiskers the 75th percentile. Dots beyond the upper and lower whiskers represent outliers of the population.

Bluff Recession Conclusions

- Rates of bluff recession 0.26 m/yr-Elwha
  0.36 m/yr -Dungeness Drift Cell.

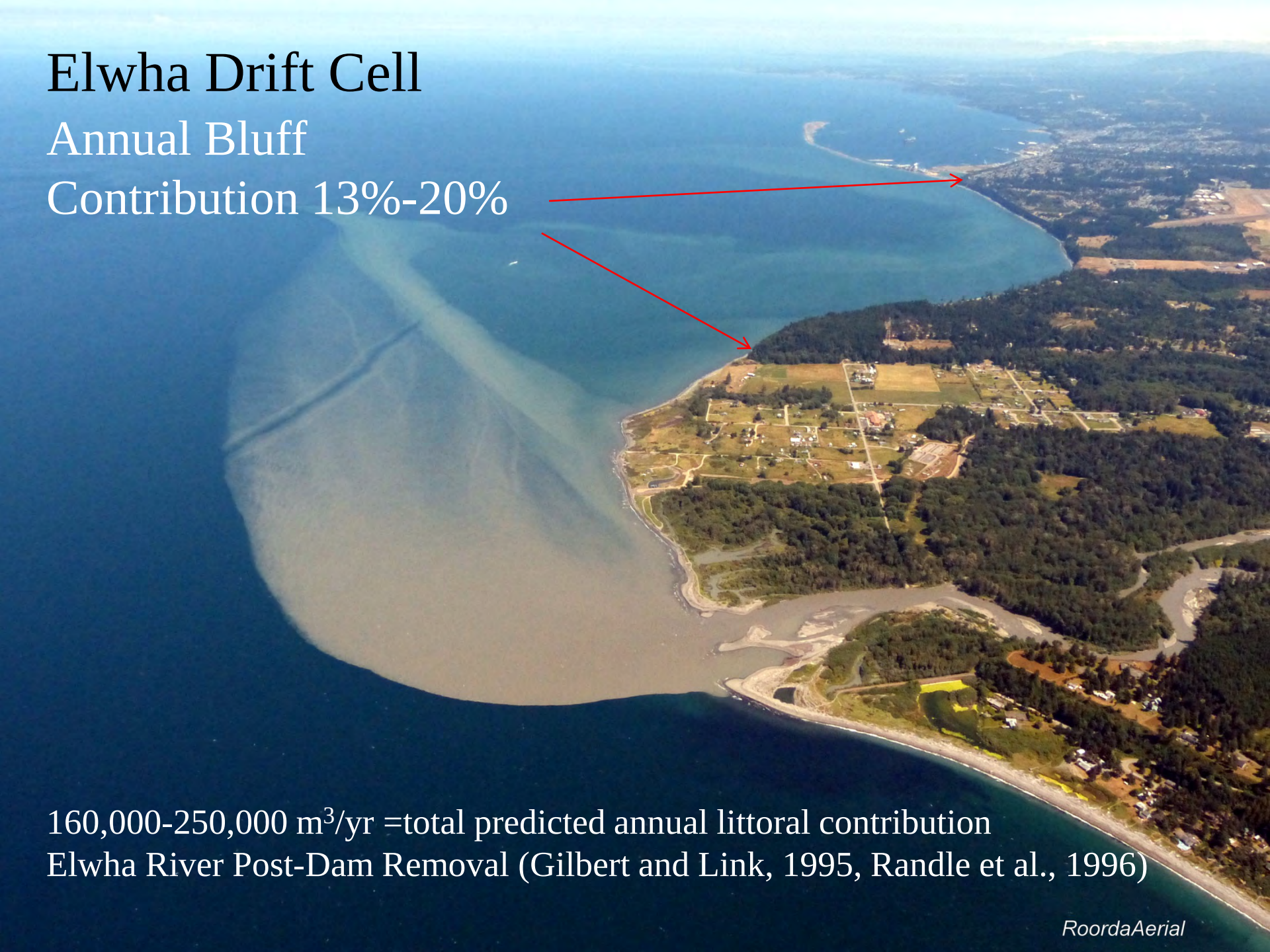
- Dungeness produces two times more sediment volume as Elwha when normalized for drift cell length.

- Shoreline armoring substantially (50%) reduces the rate of bluff recession and sediment delivery to the nearshore.

- Elwha Bluffs produce ~13-20% of annual background sediment production from Elwha River.

Elwha Drift Cell

Annual Bluff Contribution 13%-20%



160,000-250,000 m^3/yr =total predicted annual littoral contribution
Elwha River Post-Dam Removal (Gilbert and Link, 1995, Randle et al., 1996)

RoordaAerial

Implications for Management

- Elwha reservoir sediments are finite.
- Bluffs historically contributed bulk of sediment to beaches.
- Without removing shoreline armoring, the imbalance between sediment supply and transport will cause beaches to coarsen again.
- Dam removal planning should consider the fate and longevity of released sediments in ecosystem processes.

Thank You !

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