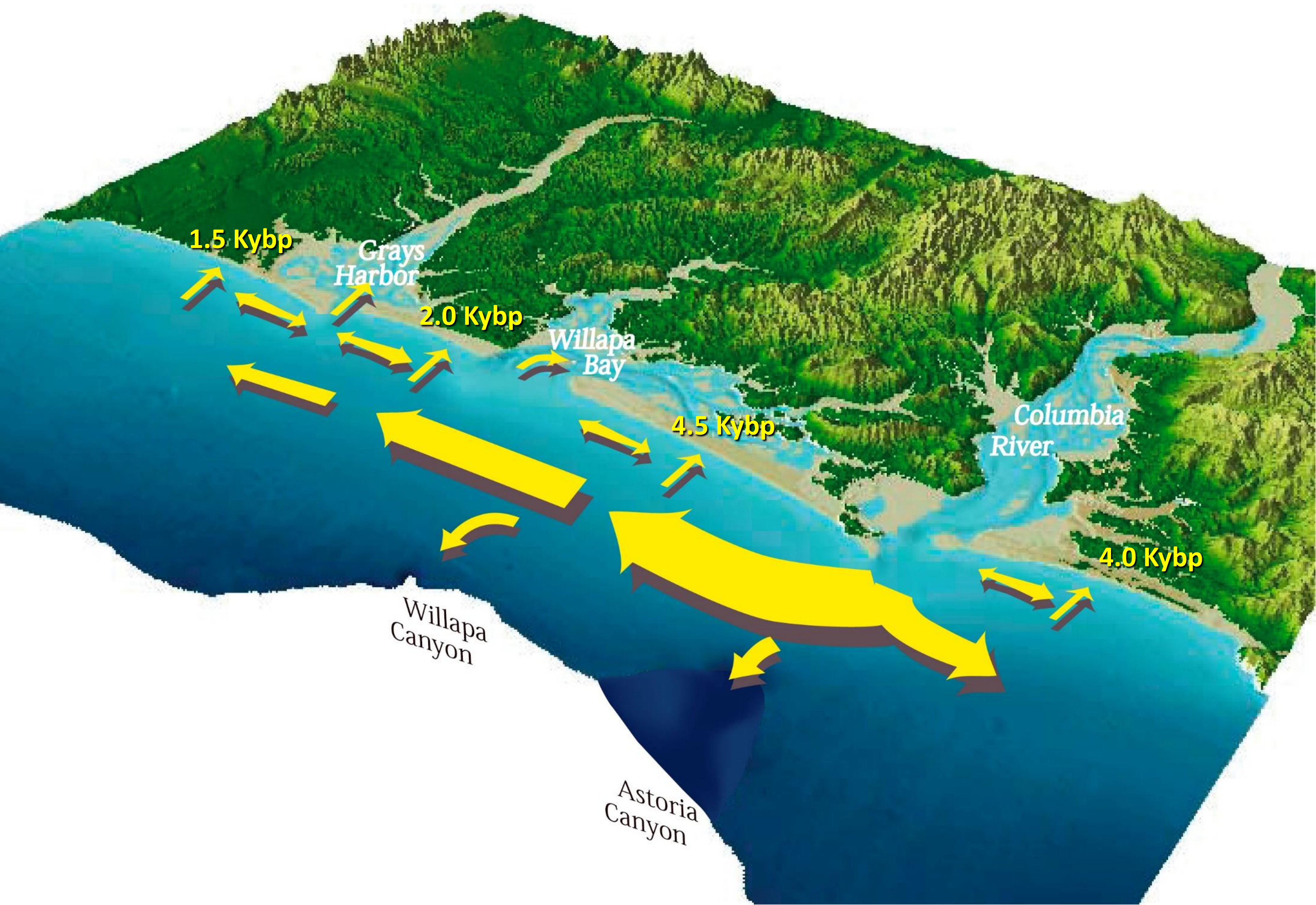
Overview of Washington Coastal Erosion

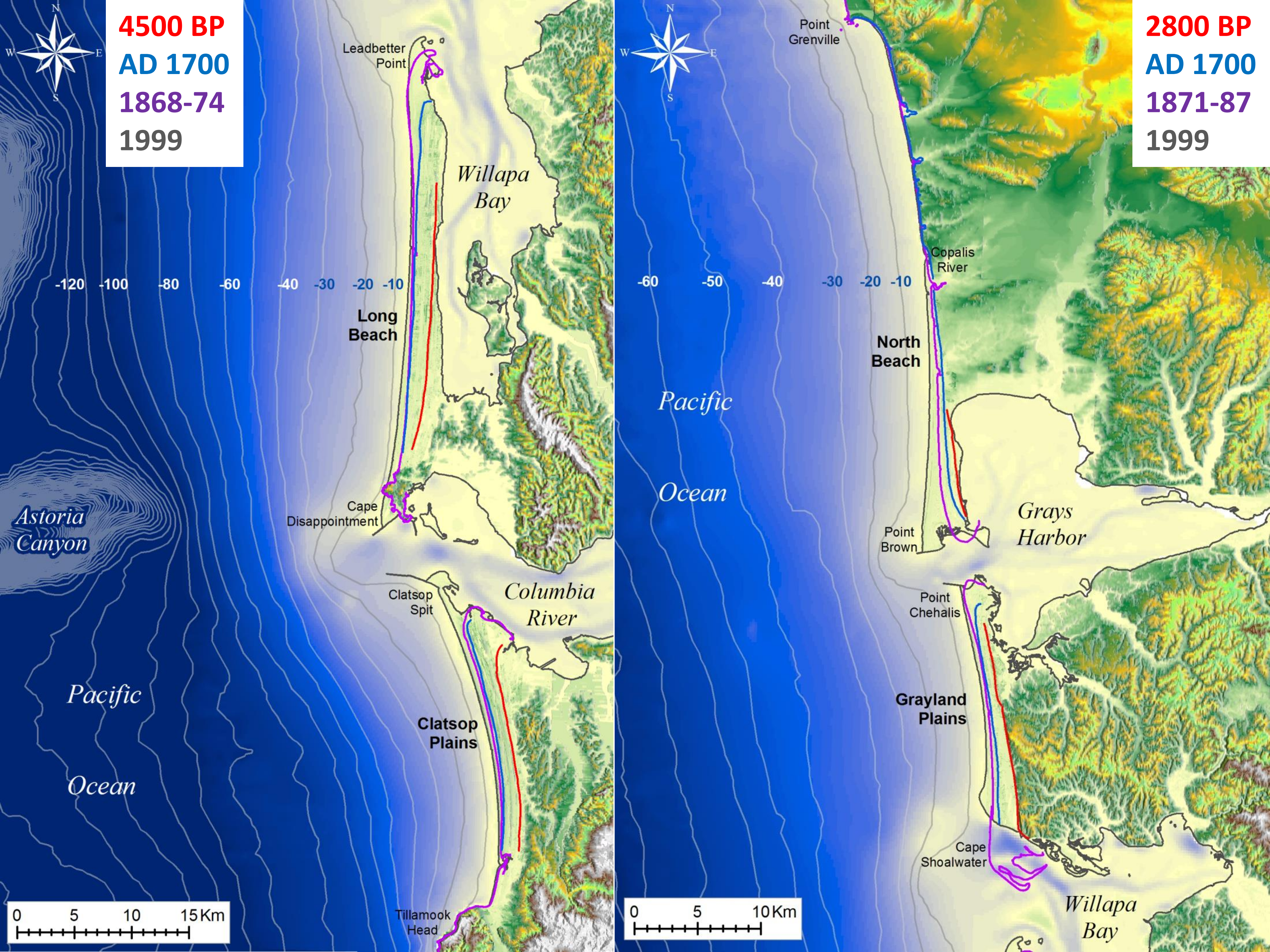
George Kaminsky, Washington Department of Ecology

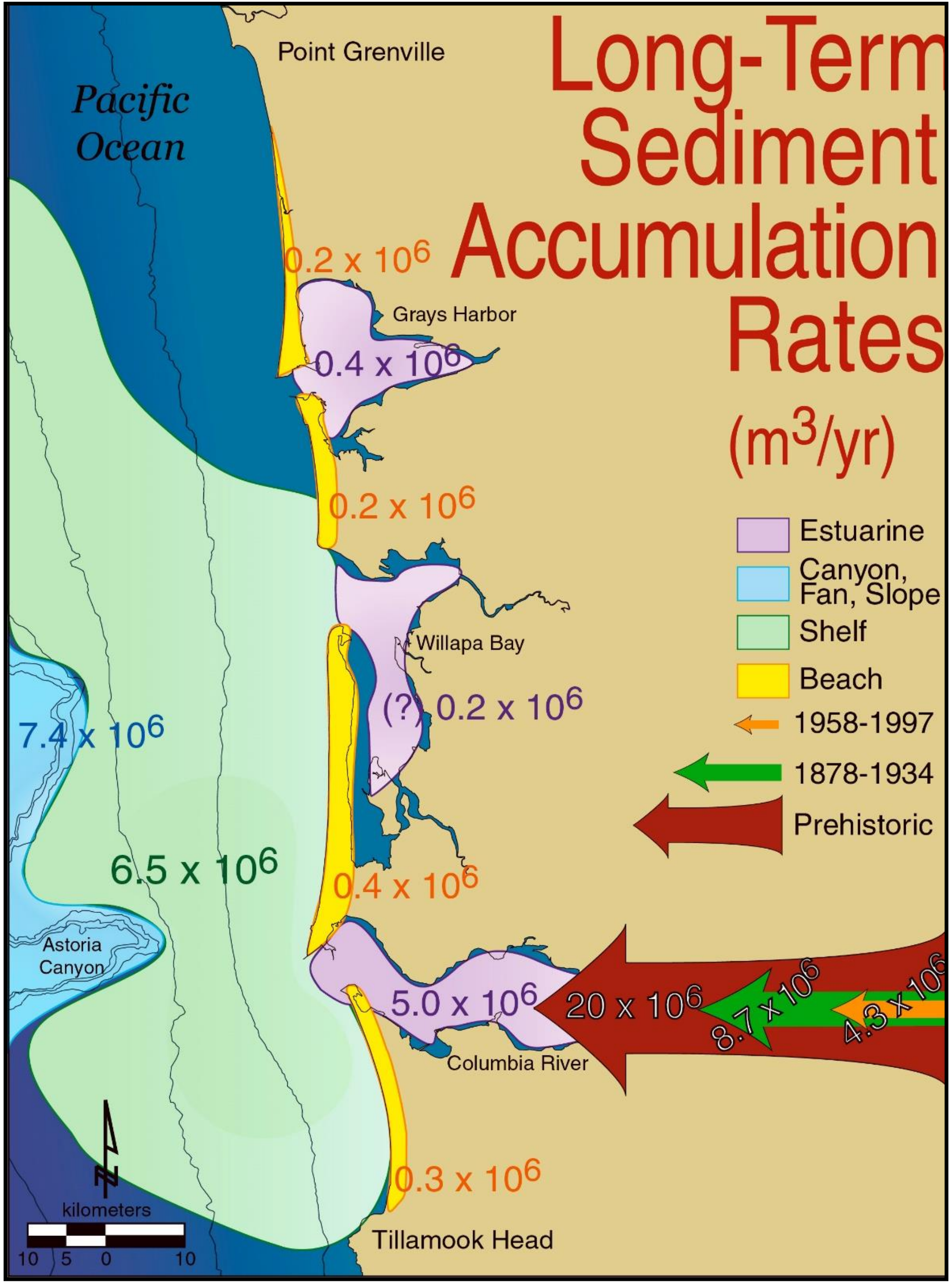
Quantities and Conversions

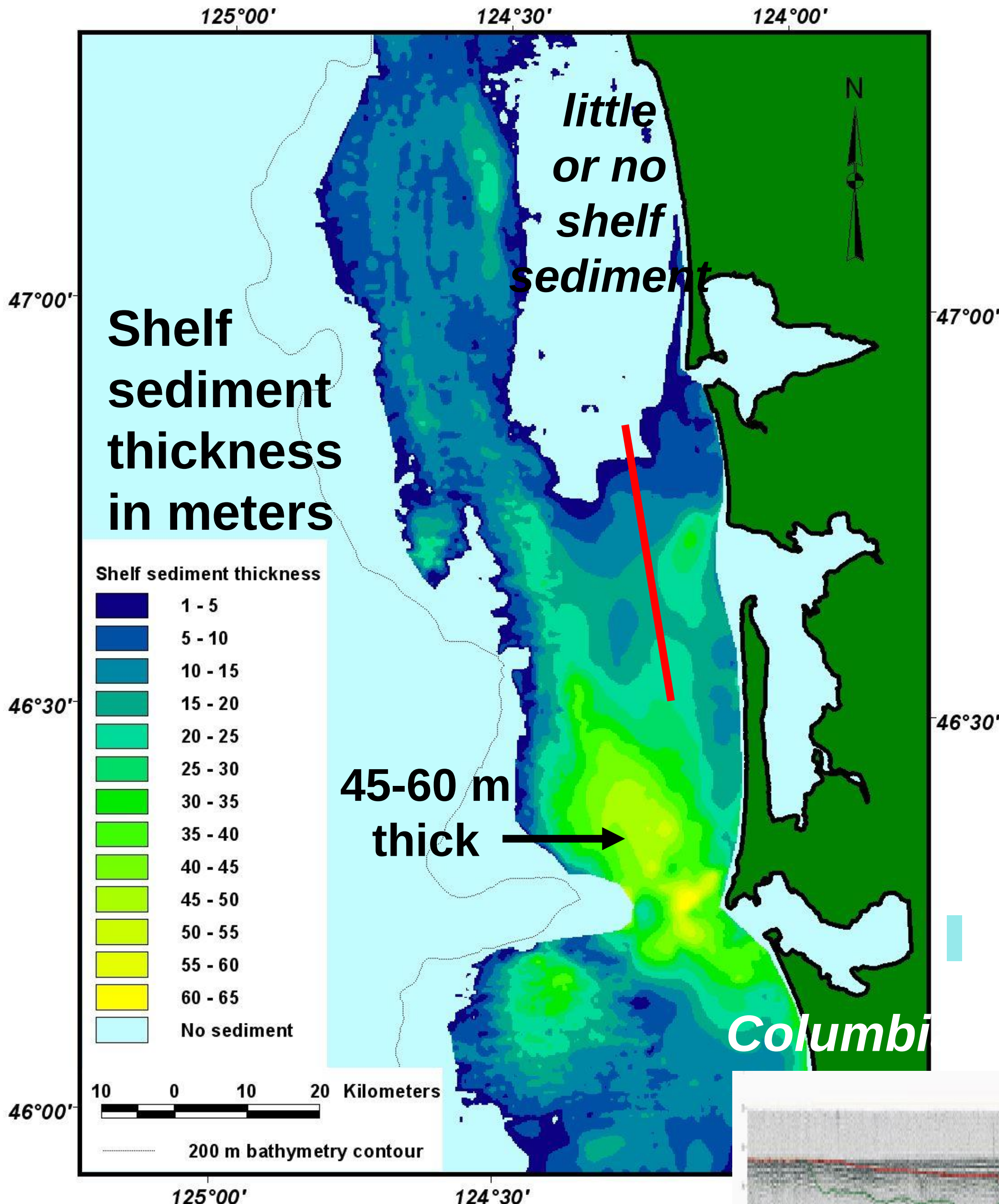
- Roughly 1.5 million cy/yr of sand is in transport along the southwest Washington shoreline and generally moves northward.
- Beach erosion at project areas varies from 26,000 cy/yr at Ocean Shores, to 63,000 cy/yr at Westport, to 65,000 cy/yr at Benson Beach (recently 292,000 cy/yr)
- Typically nearshore beneficial use of dredged material includes roughly 2 Mcy/yr at MCR and 0.5 Mcy/yr at MGH
- Sand placement projects typically vary from tens of thousands of cy to on the order of 500,000 cy.
- 1 dump truck carries roughly 12 cy
- 1 cubic meter = 1.31 cubic yards
- 1 meter = 3.28 ft = 1.09 yards

Columbia River Sediment Dispersal



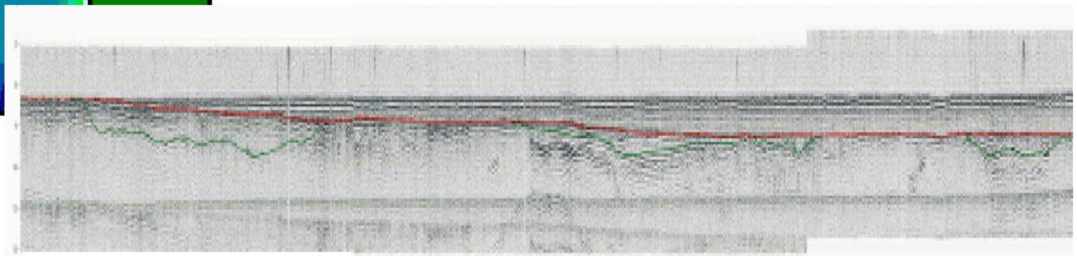

4500 BP
AD 1700
1868-74
1999
Leadbetter Point
Willapa Bay
-120
-100
-80
-60
-40
-30
-20
-10
Long Beach
Cape Disappointment
Astoria Canyon
Columbia River
Clatsop Spit
Clatsop Plains
Pacific
Ocean
Tillamook Head
0
5
10
15 Km
2800 BP
AD 1700
1871-87
1999
Point Grenville
Copalis River
-60
-50
-40
-30
-20
-10
North Beach
Pacific
Ocean
Grays Harbor
Point Brown
Point Chehalis
Grayland Plains
Cape Shoalwater
Willapa Bay
0
5
10 Km

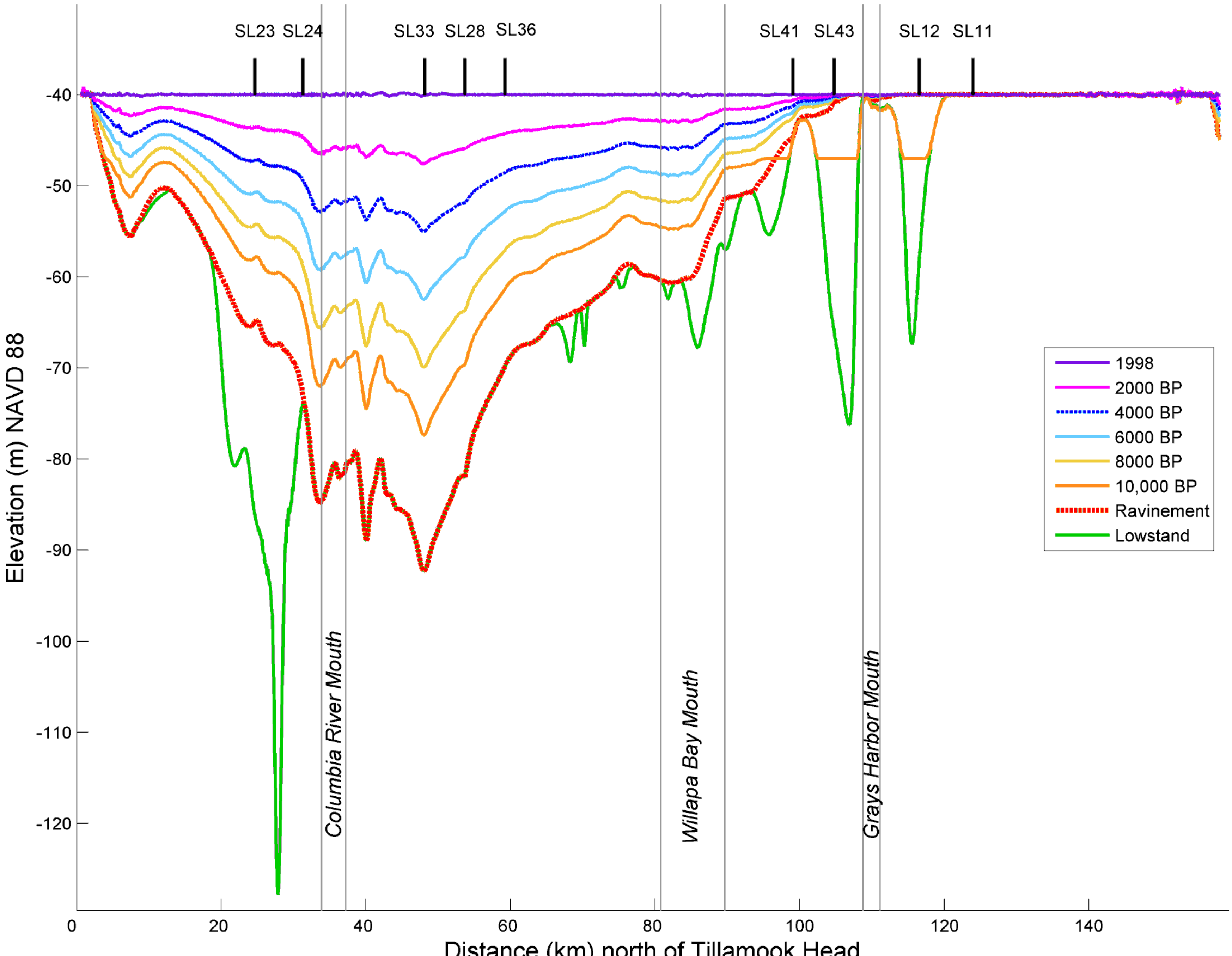

Long-Term Sediment Accumulation Rates
(m3/yr)
Point Grenville
Pacific Ocean
0.2 x 10^6
Grays Harbor
0.4 x 10^6
0.2 x 10^6
Willapa Bay
(?) 0.2 x 10^6
7.4 x 10^6
6.5 x 10^6
0.4 x 10^6
Astoria Canyon
5.0 x 10^6
20 x 10^6
8.7 x 10^6
4.3 x 10^6
Columbia River
0.3 x 10^6
Tillamook Head
kilometers
10 5 0 10
Estuarine
Canyon, Fan, Slope
Shelf
Beach
1958-1997
1878-1934
Prehistoric



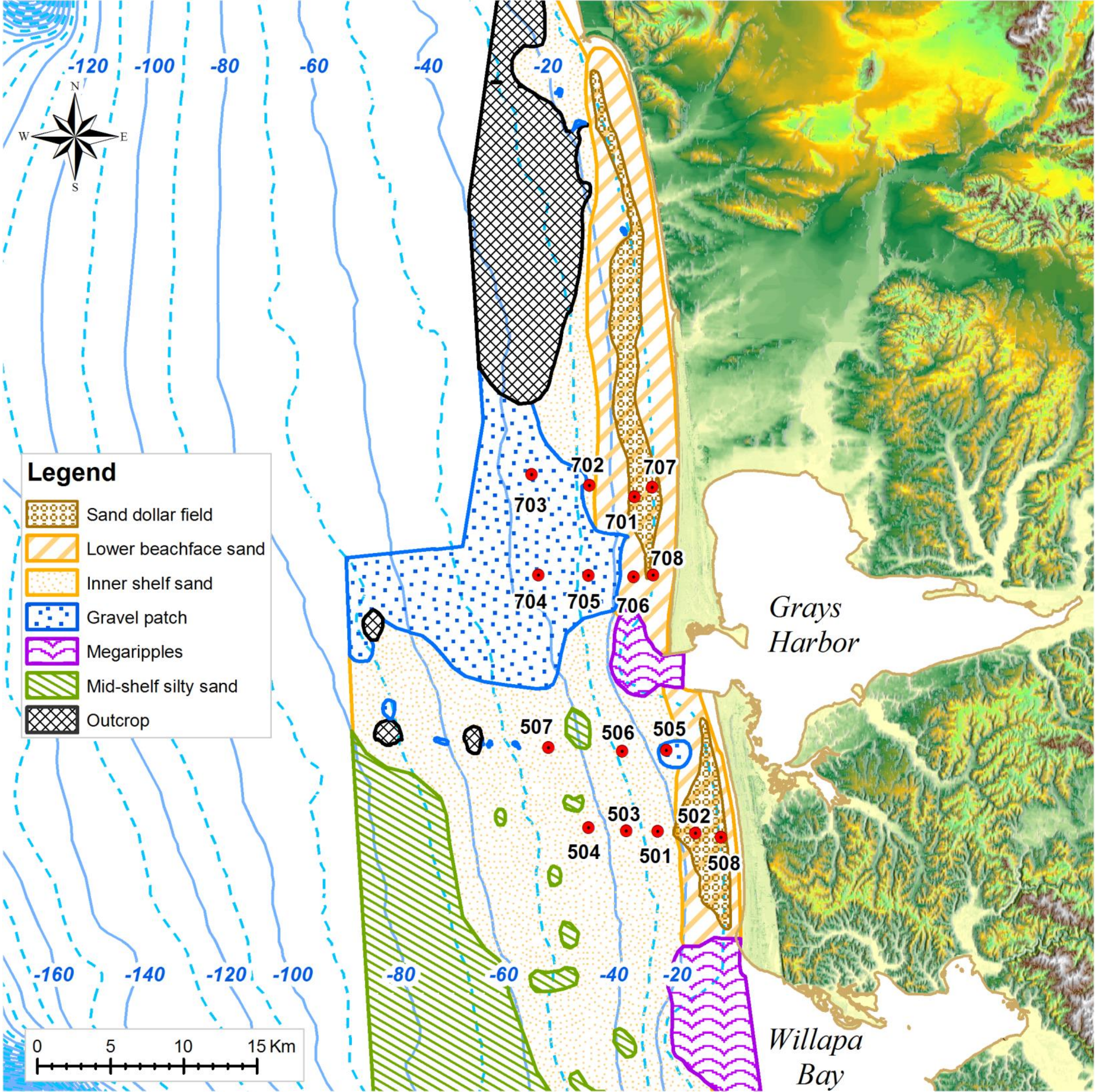
A thick tongue of shelf sediment extends to NNW from the mouth of Columbia River (thickest between 50-100 m isobaths)

Sediment 'thins' to the north, so expect barriers & shelf deposits to vary alongshore

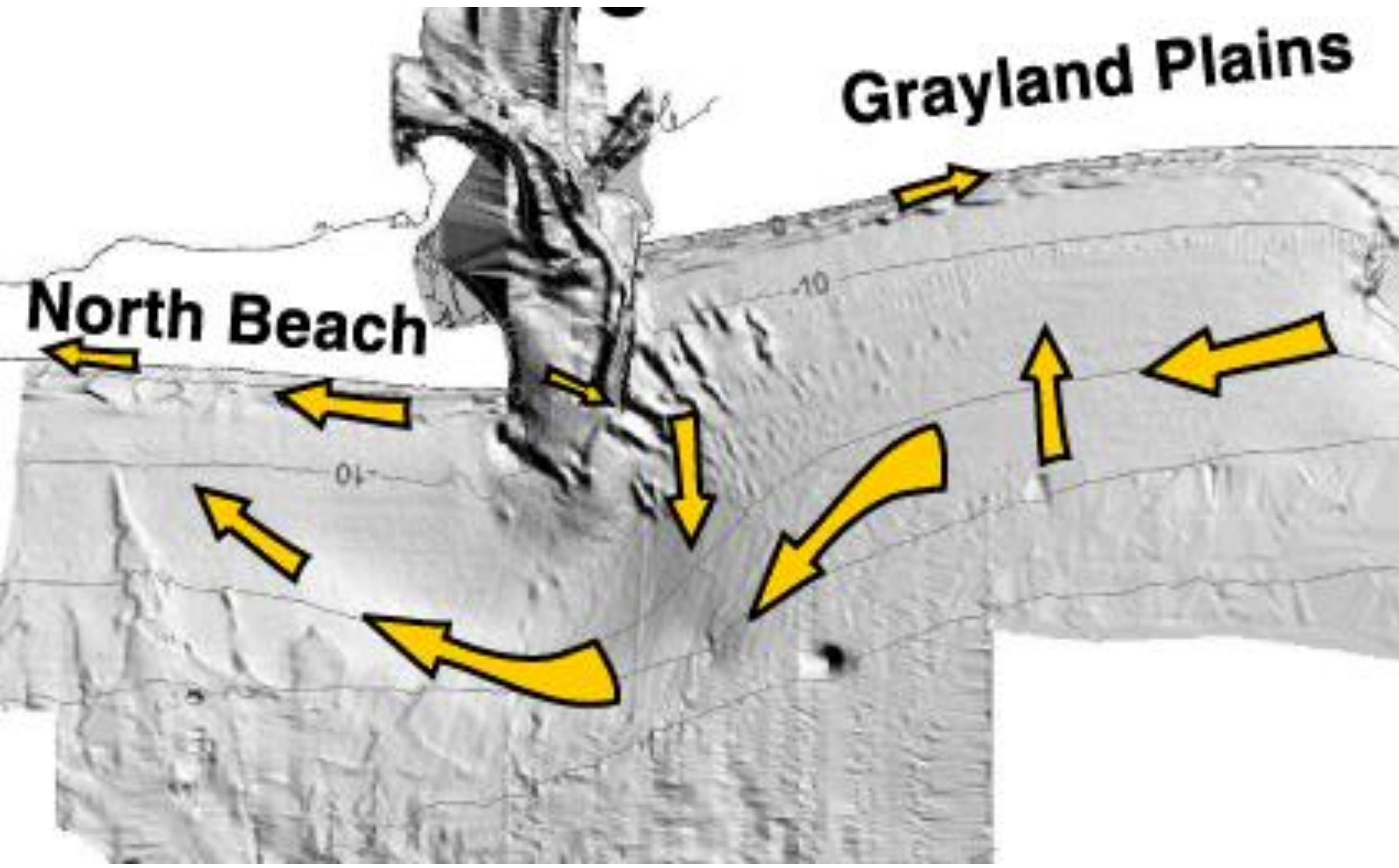




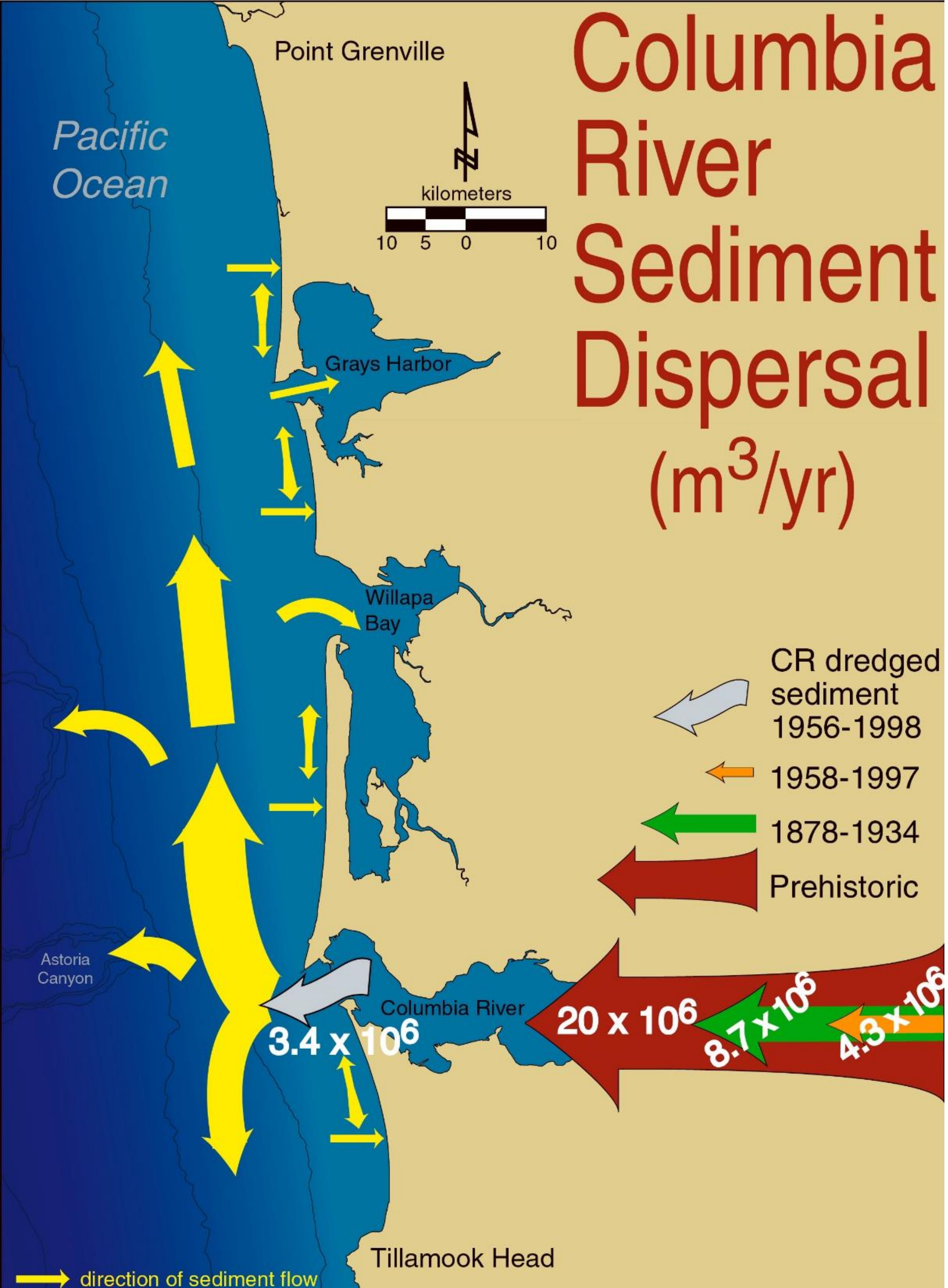
SL23
SL24
SL33
SL28
SL36
SL41
SL43
SL12
SL11
Elevation (m) NAVD 88
-40
-50
-60
-70
-80
-90
-100
-110
-120
0
20
40
60
80
100
120
140
Distance (km) north of Tillamook Head
Columbia River Mouth
Willapa Bay Mouth
Grays Harbor Mouth
1998
2000 BP
4000 BP
6000 BP
8000 BP
10,000 BP
Ravinement
Lowstand



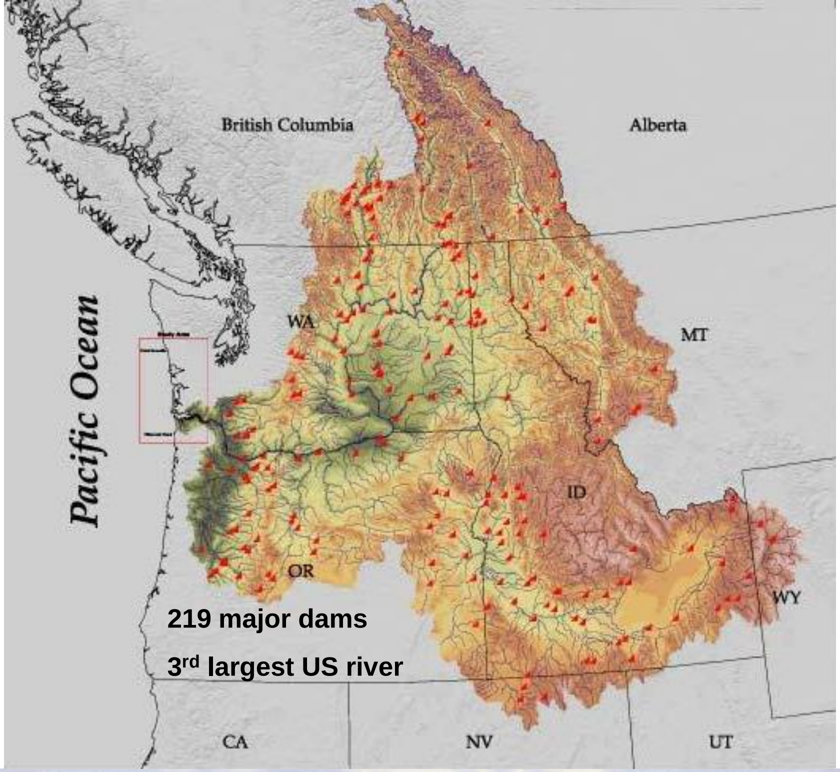
-120
-100
-80
-60
-40
-20
N
W
E
S
Legend
Sand dollar field
Lower beachface sand
Inner shelf sand
Gravel patch
Megaripples
Mid-shelf silty sand
Outcrop
702
707
703
701
708
704
705
706
Grays Harbor
507
506
505
503
502
504
501
508
-160
-140
-120
-100
-80
-60
-40
-20
0
5
10
15 Km
Willapa Bay

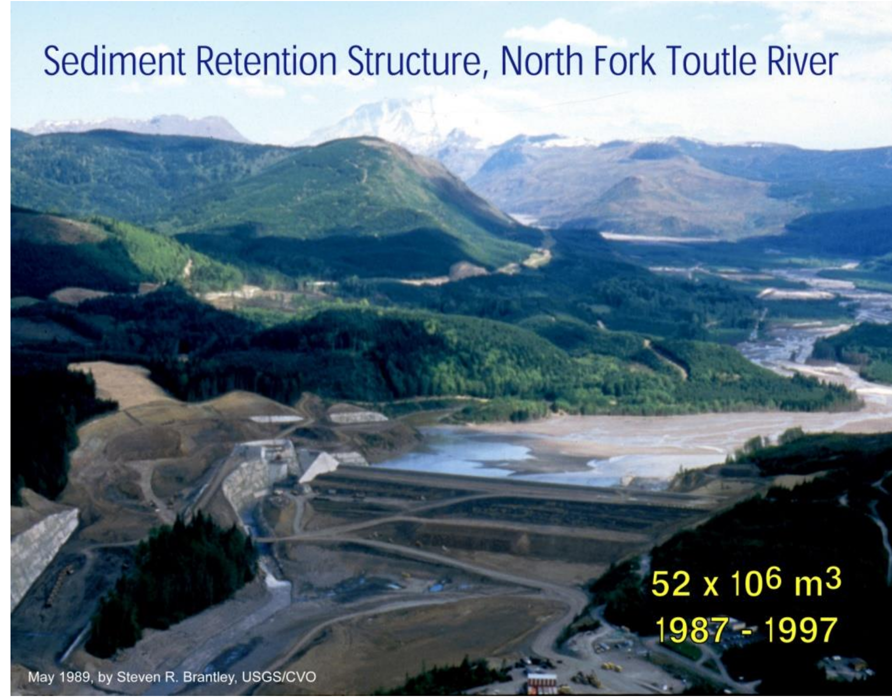


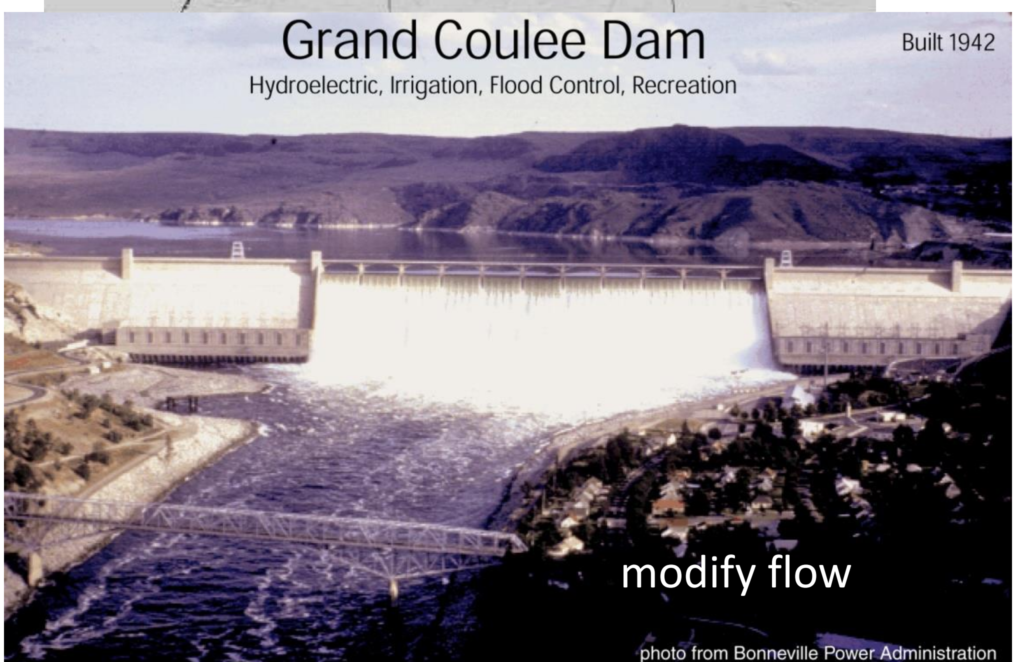
Grayland Plains
North Beach
-10
-10

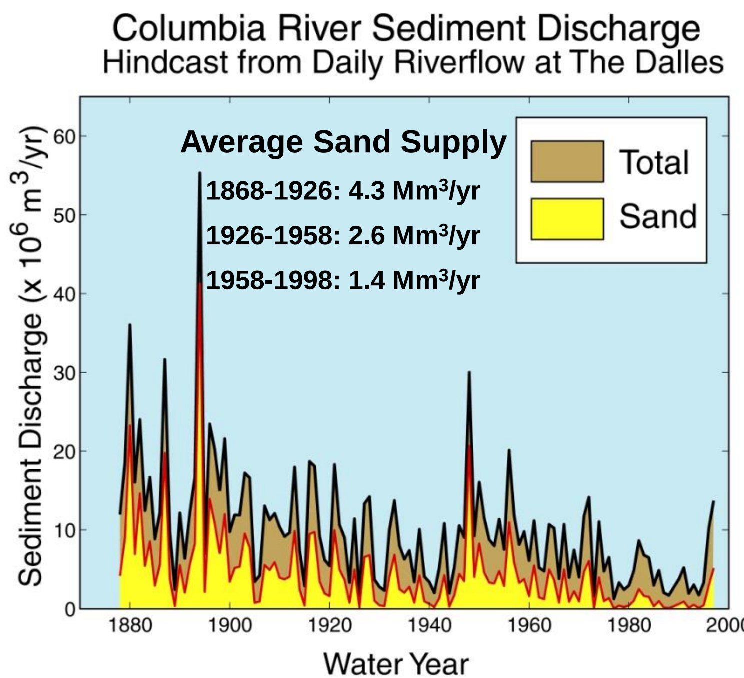


- Modern rate of sediment supply from river is less than 1/4 of prehistoric rate
- Decrease in sediment supply due to dams trapping sediment and reducing peak flows that flush sand out of river


British Columbia
Alberta
Pacific Ocean
WA
MT
ID
OR
WY
CA
NV
UT
219 major dams
3rd largest US river

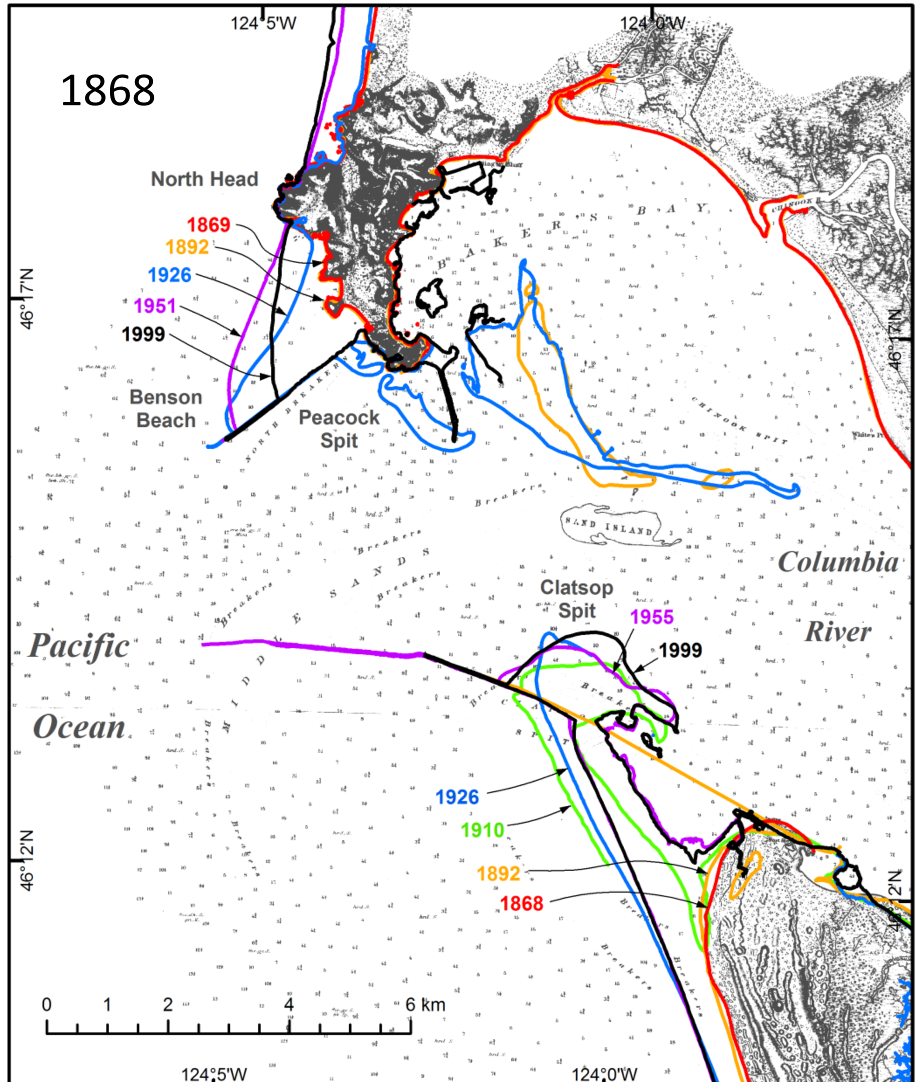

Sediment Retention Structure, North Fork Toutle River
52 x 10^6 m^3
1987 - 1997
May 1989, by Steven R. Brantley, USGS/CVO


Grand Coulee Dam
Built 1942
Hydroelectric, Irrigation, Flood Control, Recreation
modify flow
photo from Bonneville Power Administration


Columbia River Sediment Discharge
Hindcast from Daily Riverflow at The Dalles
Average Sand Supply
1868-1926: 4.3 Mm3/yr
1926-1958: 2.6 Mm3/yr
1958-1998: 1.4 Mm3/yr
Total
Sand
Sediment Discharge (x 10^6 m^3/yr)
Water Year
0
10
20
30
40
50
60
1880
1900
1920
1940
1960
1980
2000

Columbia River
Jetty Construction and Shoreline Change

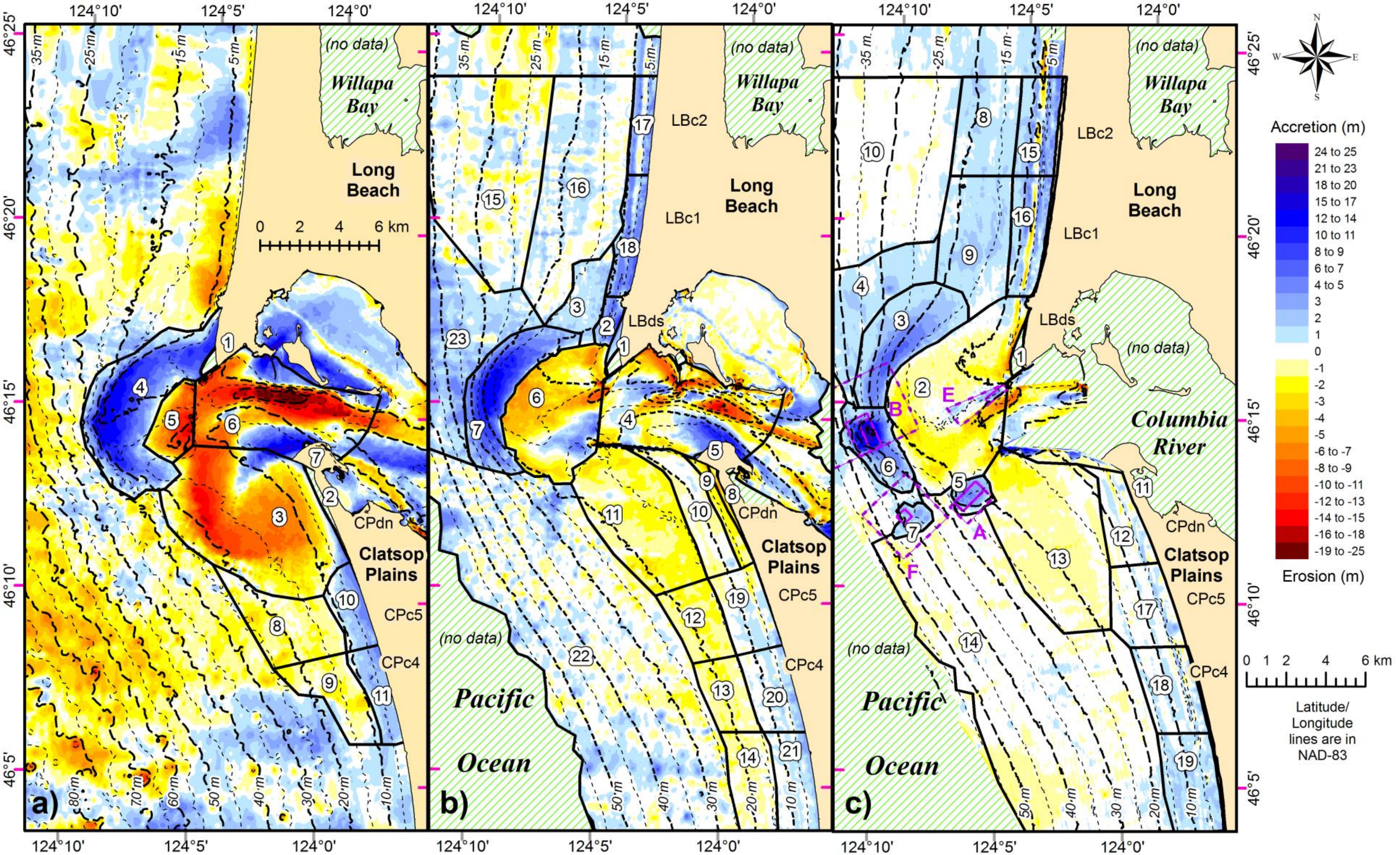
- Inlet width = 3.2 km
- Inlet shoals dispersed seaward
- Single entrance channel forms
- Shoreline progradation up to 2.5 km (north) and 4.5 km (south)



North Jetty
1913-1917

South Jetty
1885-1895
1903-1913

Mouth of Columbia River Bathymetric Change

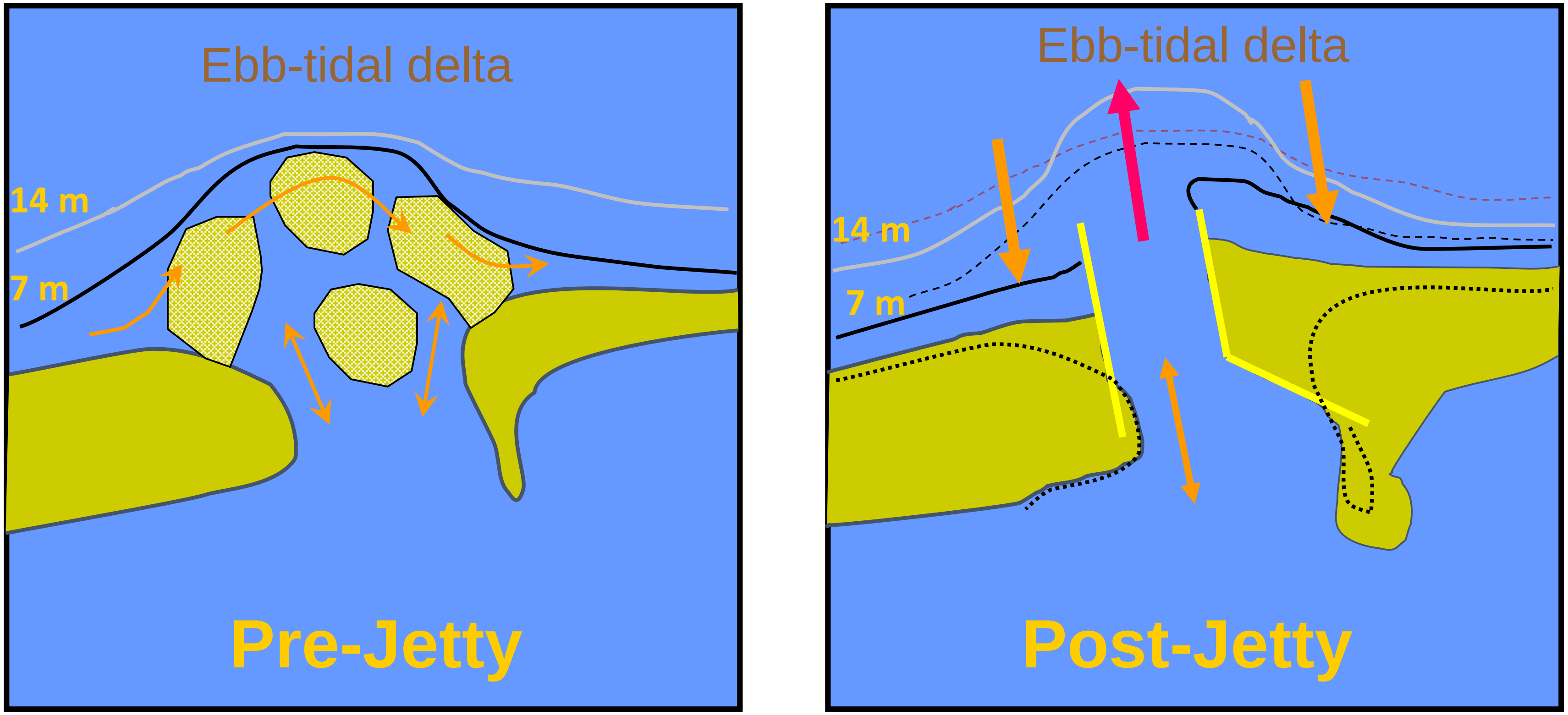


1868-1926

1926-1958

1958-1999

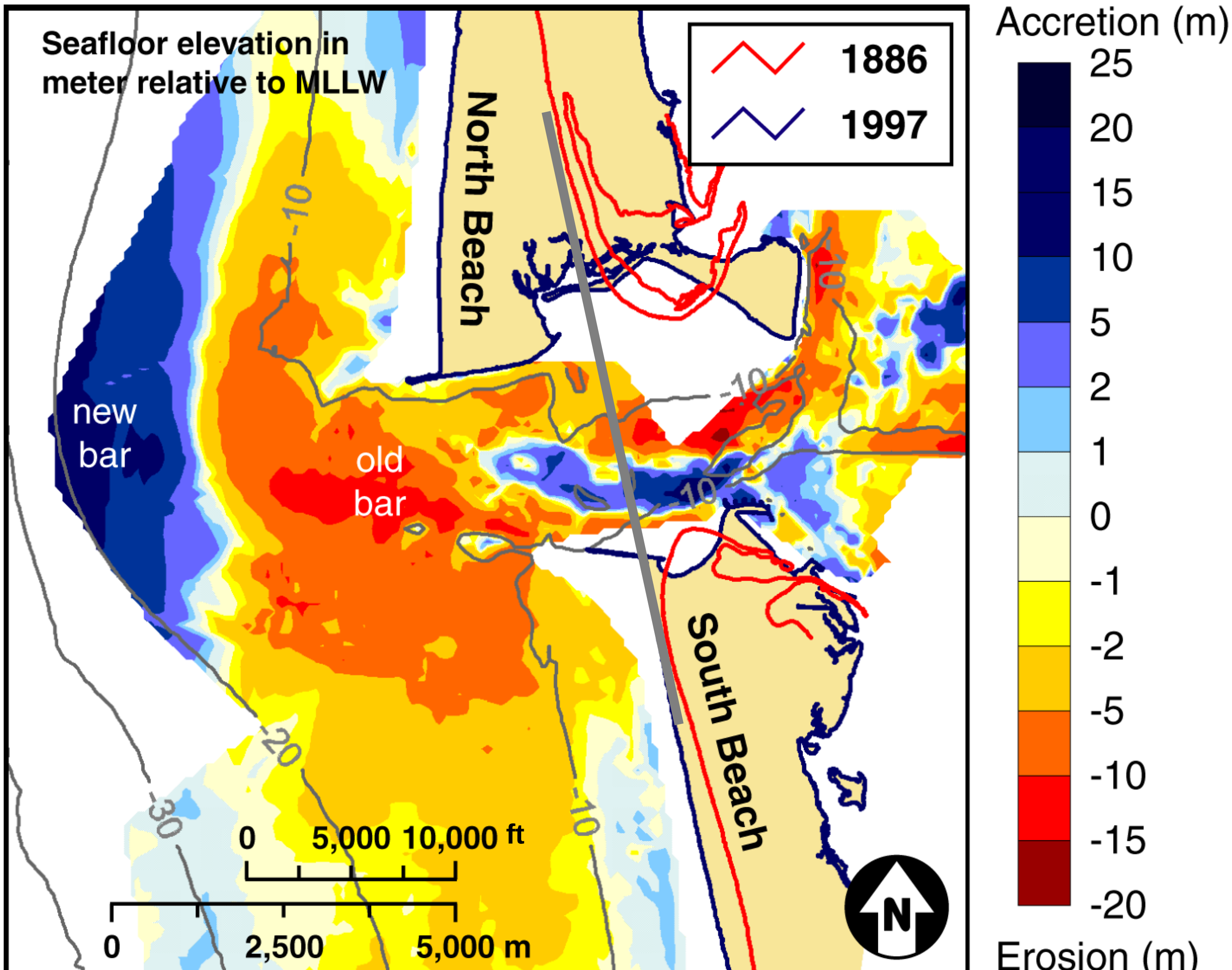
Morphology Change Caused by Jetties

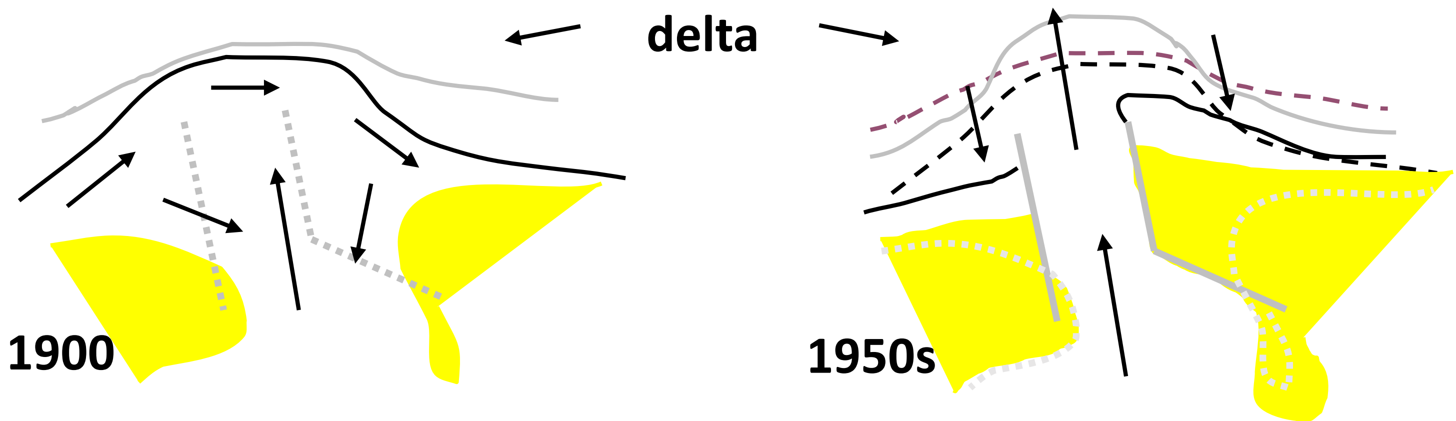


- Several shallow channels
- Shallow ebb-tidal delta
- Attached sub-aqueous shoals
- Alongshore sand bypassing

- Single deep channel
- Deep ebb-tidal delta
- Shoals migrate onshore
- Reduced sand bypassing

Grays Harbor Entrance Change 1886-1999





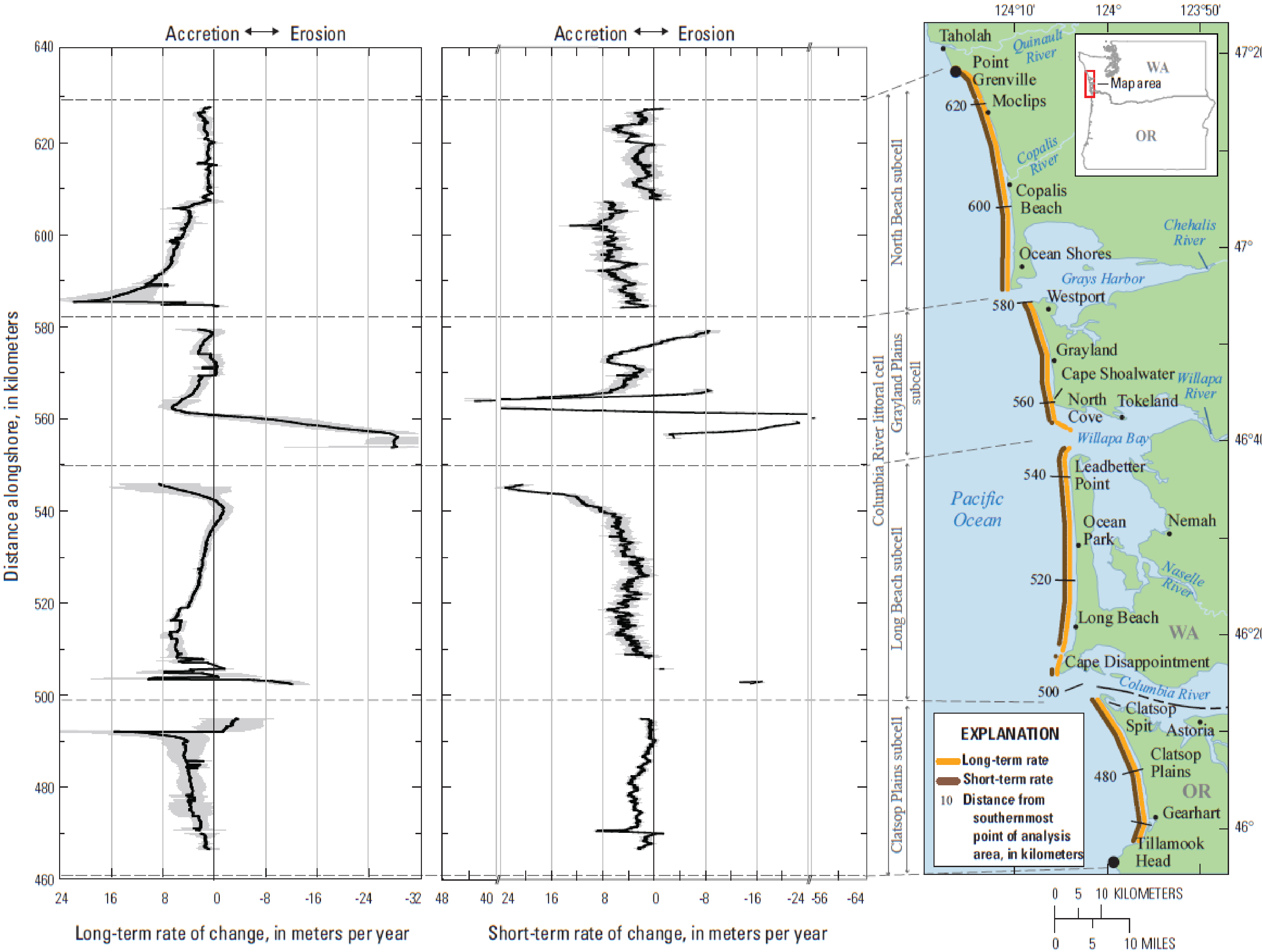
- Early 1900s: jetty construction at Grays Harbor and Columbia River entrances
- Delta flanks moved onshore, causing accretion of the adjacent beaches; centers migrated offshore
- Sediment transport away from the deltas caused the beaches to accrete up to 20 km away
- In recent decades the sand supply has diminished; shorelines adjacent to the jetties stopped accreting or began eroding

Key Points

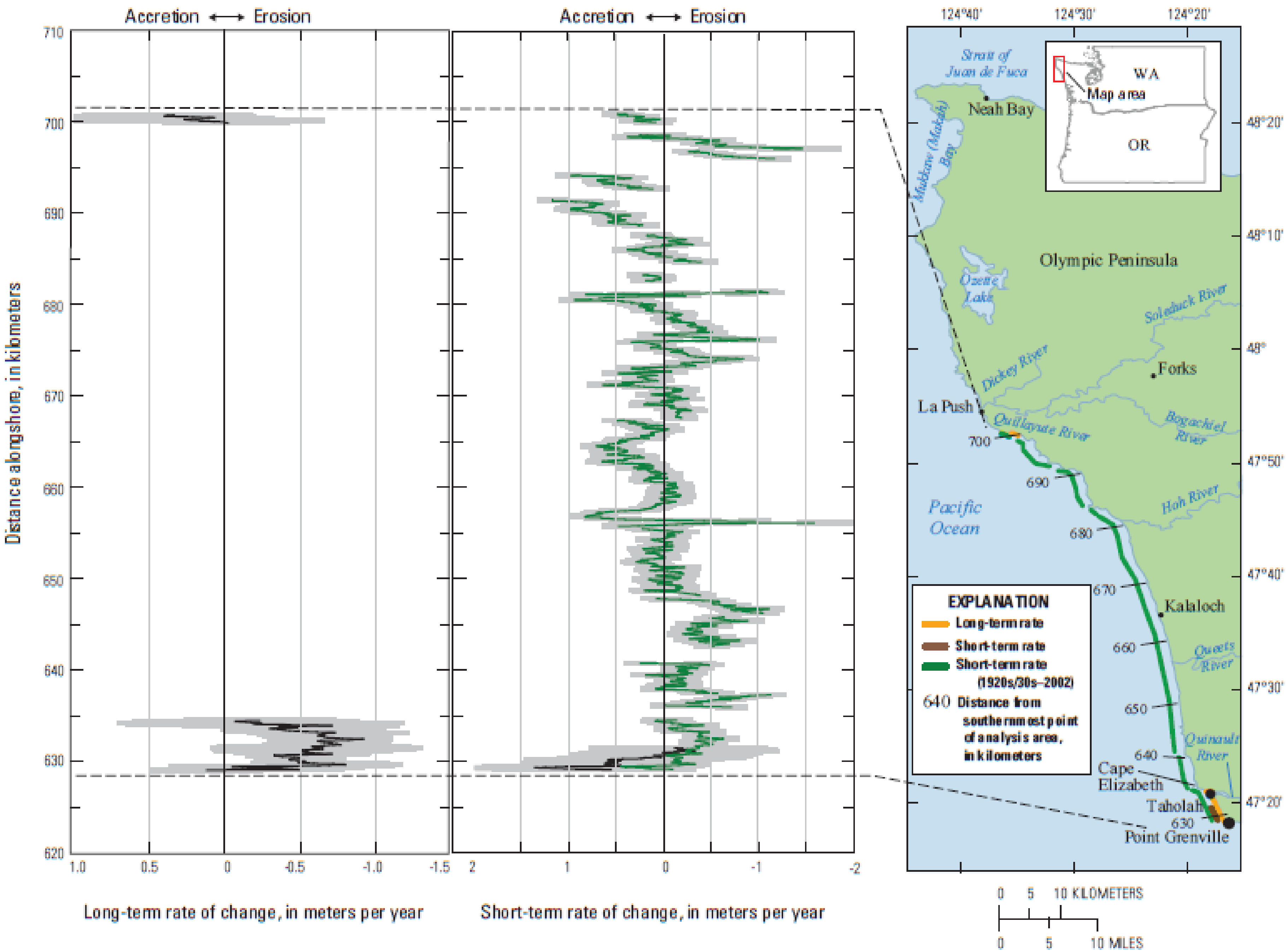
- For thousands of years, the shorelines along the Columbia River littoral cell were accreting slowly and uniformly due to a large supply of Columbia River sediment.
- Jetty construction at the beginning of the century caused ebb-tidal delta changes leading to rapid shoreline accretion at the southern end of the North Beach sub-cell.
- The jetties have affected shoreline changes along distances greater than 20 km away over several decades.
- In the last several decades, shoreline accretion has slowed or stopped in the southern portion of the North Beach sub-cell, as a result of reaching the holding capacity of the North Jetty.
- Much of the Grayland Plains shoreline within Grays Harbor County trends toward erosion.

Implications

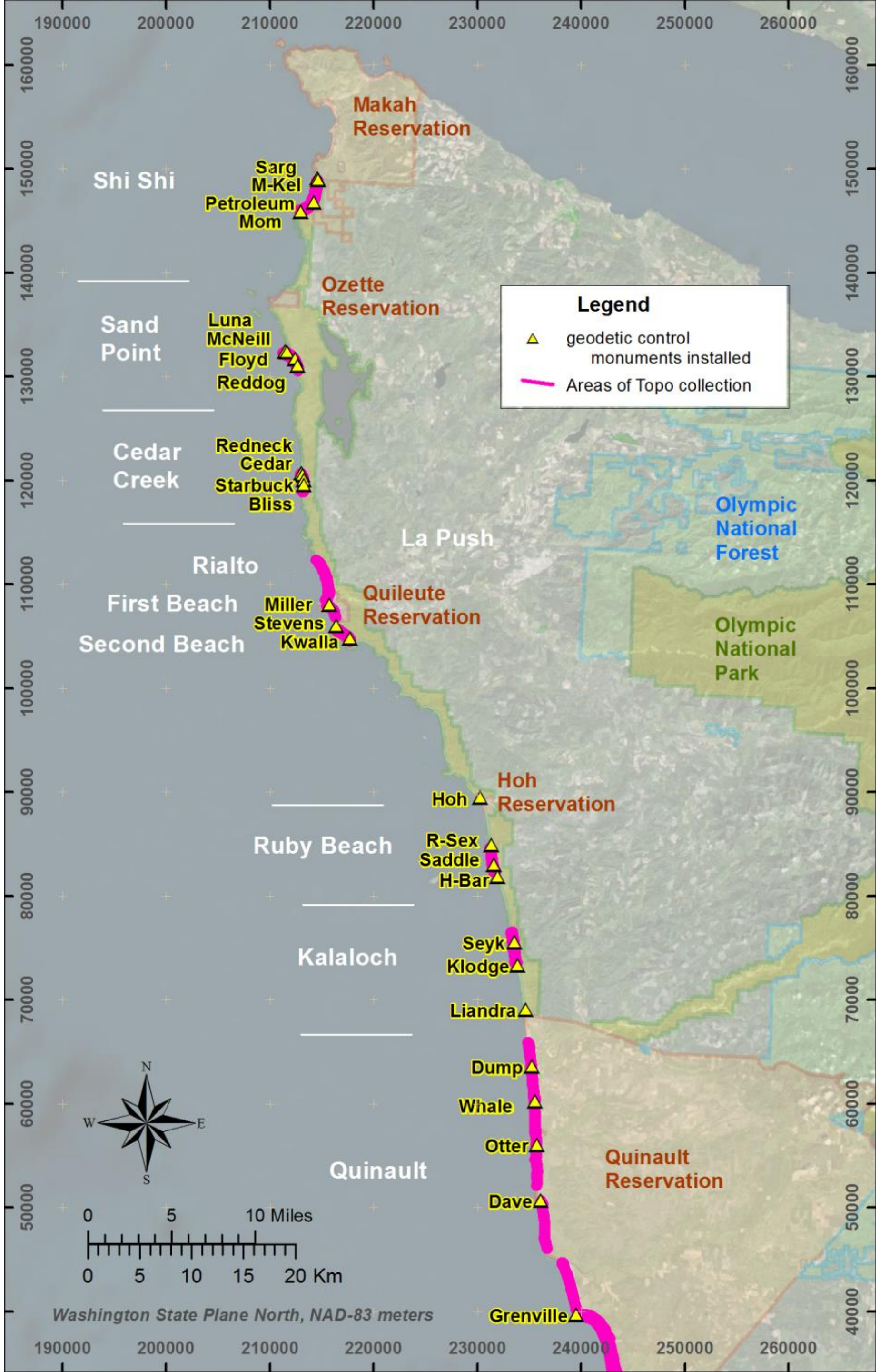
- Sediment sharing between adjacent coasts has been significantly reduced, resulting in a downdrift offset shoreline.
- Ocean Shores has benefited by seasonal reversal in sediment transport, building out the shoreline to nearly the end of the North Jetty.
- Recent shoreline recession is related to reduced sediment supply from the ebb delta and the condition of the jetties.



Accretion ⟷ Erosion
Accretion ⟷ Erosion
Distance alongshore, in kilometers
Long-term rate of change, in meters per year
Short-term rate of change, in meters per year
North Beach subcell
Grayland Plains subcell
Long Beach subcell
Clatsop Plains subcell
Columbia River littoral cell
Taholah
Point Grenville
Moclips
Quinault River
Copalis River
Copalis Beach
Ocean Shores
Chehalis River
Grays Harbor
Westport
Grayland
Cape Shoalwater
North Cove
Tokeland
Willapa River
Willapa Bay
Leadbetter Point
Pacific Ocean
Ocean Park
Nemah
Naselle River
Long Beach
Cape Disappointment
Columbia River
Clatsop Spit
Astoria
Clatsop Plains
Gearhart
Tillamook Head
WA
OR
Map area
EXPLANATION
Long-term rate
Short-term rate
10 Distance from southernmost point of analysis area, in kilometers
124°10'
124°
123°50'
47°20'
47°
46°40'
46°20'
46°
0 5 10 KILOMETERS
0 5 10 MILES



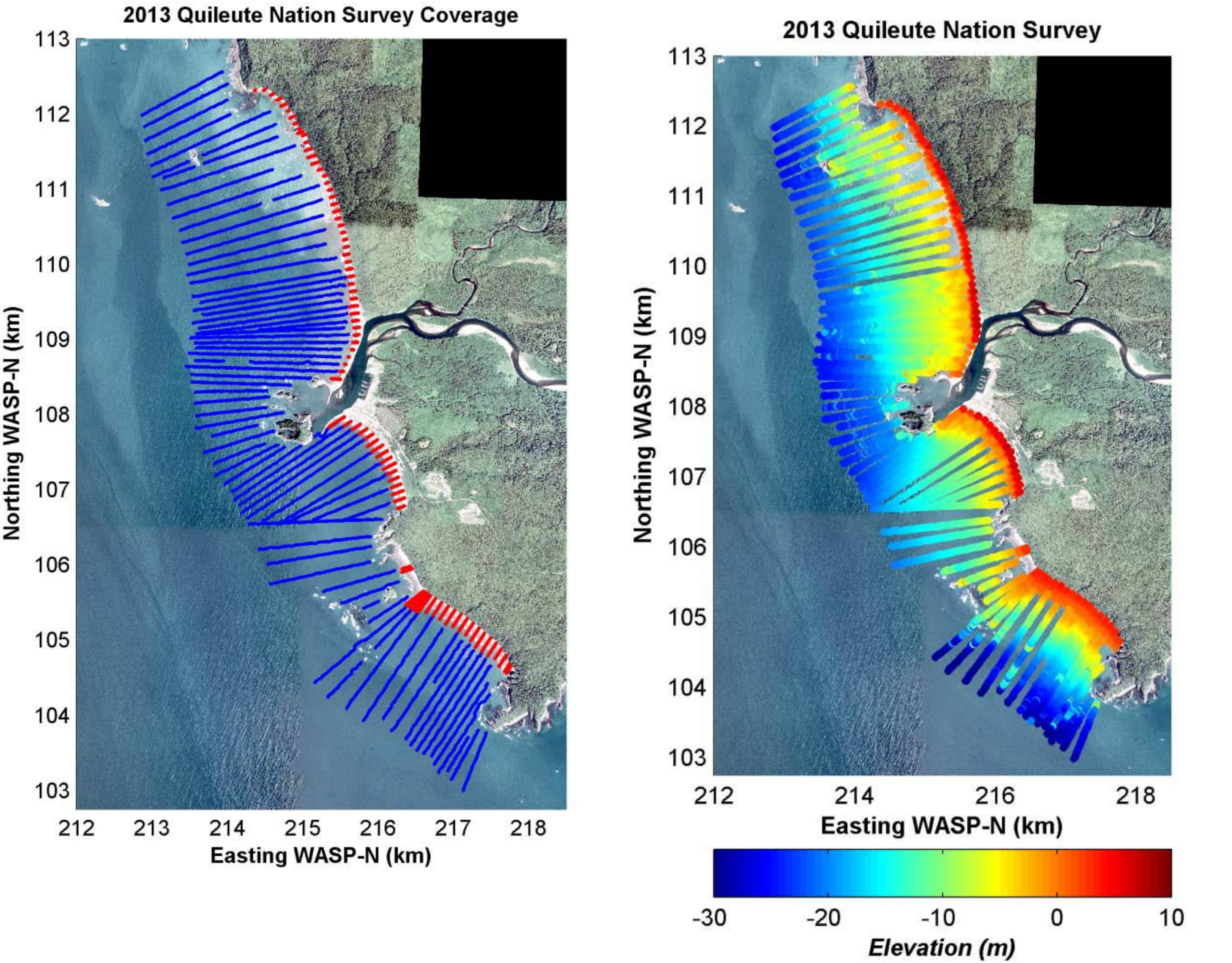
Accretion ⟷ Erosion
Accretion ⟷ Erosion
Distance alongshore, in kilometers
710
700
690
680
670
660
650
640
630
620
1.0
0.5
0
-0.5
-1.0
-1.5
2
1
0
-1
-2
Long-term rate of change, in meters per year
Short-term rate of change, in meters per year
124°40'
124°30'
124°20'
48°20'
48°10'
48°
47°50'
47°40'
47°30'
47°20'
Strait of Juan de Fuca
Neah Bay
Mukkaw (Makah) Bay
WA
Map area
OR
Olympic Peninsula
Ozette Lake
Soleduck River
Forks
Dickey River
La Push
Quillayute River
Bogachiel River
700
690
680
670
660
650
640
630
Pacific Ocean
Hoh River
Kalaloch
Queets River
Quinault River
Cape Elizabeth
Taholah
Point Grenville
EXPLANATION
Long-term rate
Short-term rate
Short-term rate (1920s/30s–2002)
640 Distance from southernmost point of analysis area, in kilometers
0 5 10 KILOMETERS
0 5 10 MILES



Olympic Coast Geodetic Control and Beach Profiles
Marine Spatial Planning
2012

Beach profile sites (Ian Miller)

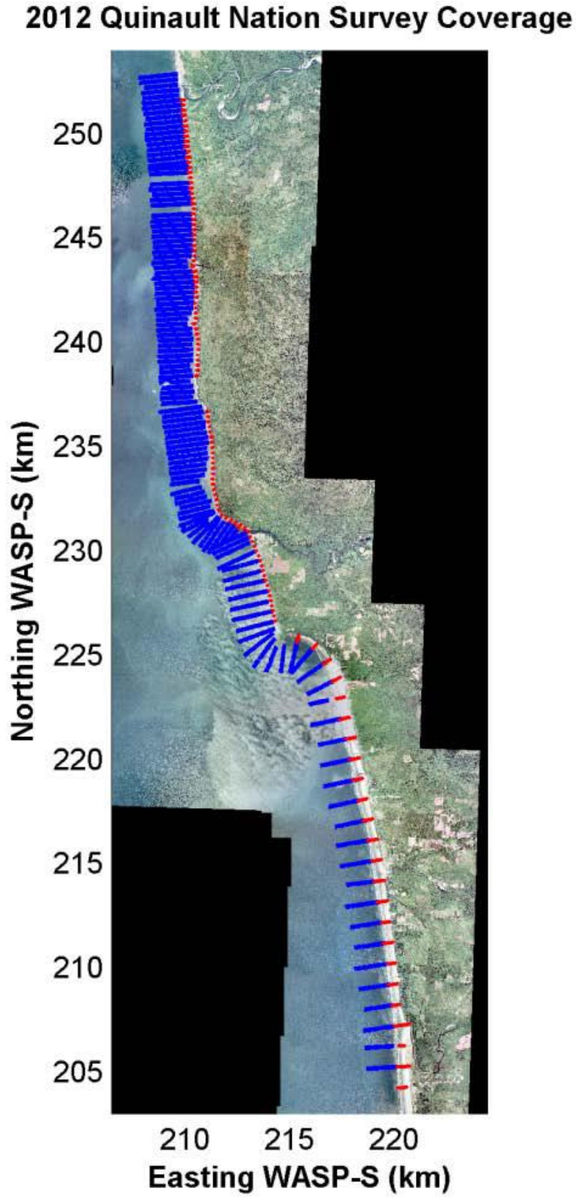
- Hobuck Beach (2 surveys since June 2018)
- Norwegian (~25 surveys since 2013)
- Rialto (~25 surveys since 2013)
- First Beach (6 surveys since 2013)
- Second Beach (3 surveys since 2015)
- Kalaloch (~15 surveys since 2014)

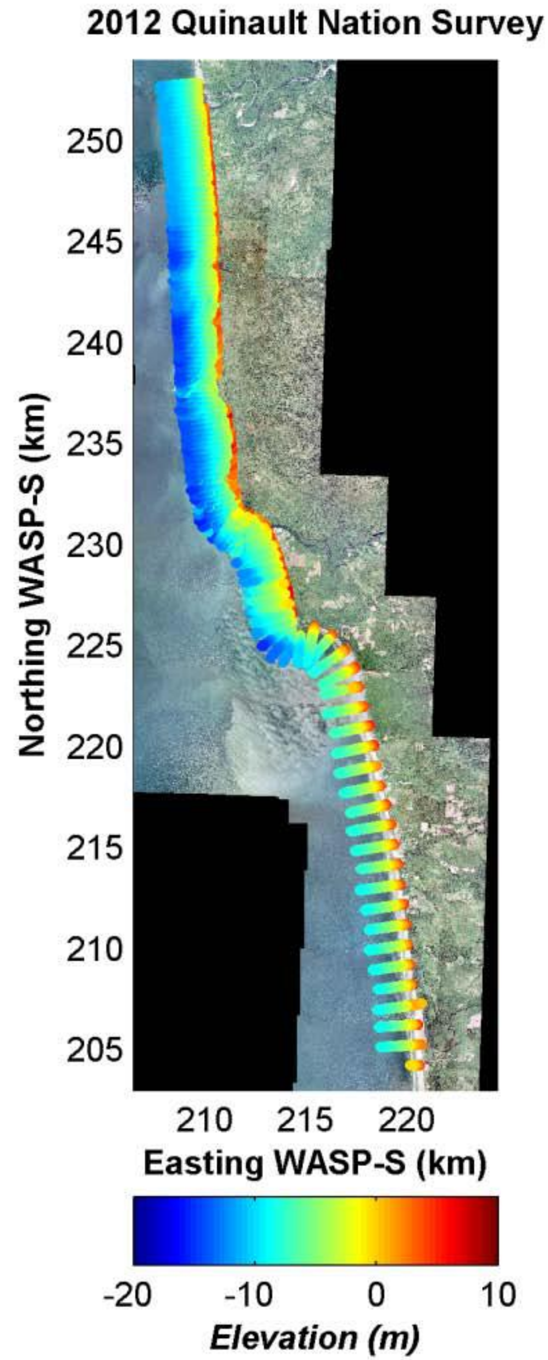


2013 Quileute Nation Survey Coverage
Northing WASP-N (km)
Easting WASP-N (km)
113
112
111
110
109
108
107
106
105
104
103
212
213
214
215
216
217
218
2013 Quileute Nation Survey
Northing WASP-N (km)
Easting WASP-N (km)
212
214
216
218
-30
-20
-10
0
10
Elevation (m)

Quinault Coast Beach Profiles and Nearshore Bathymetry

July-Aug 2012

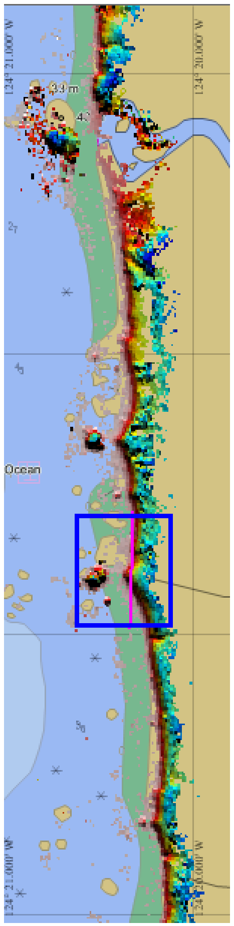


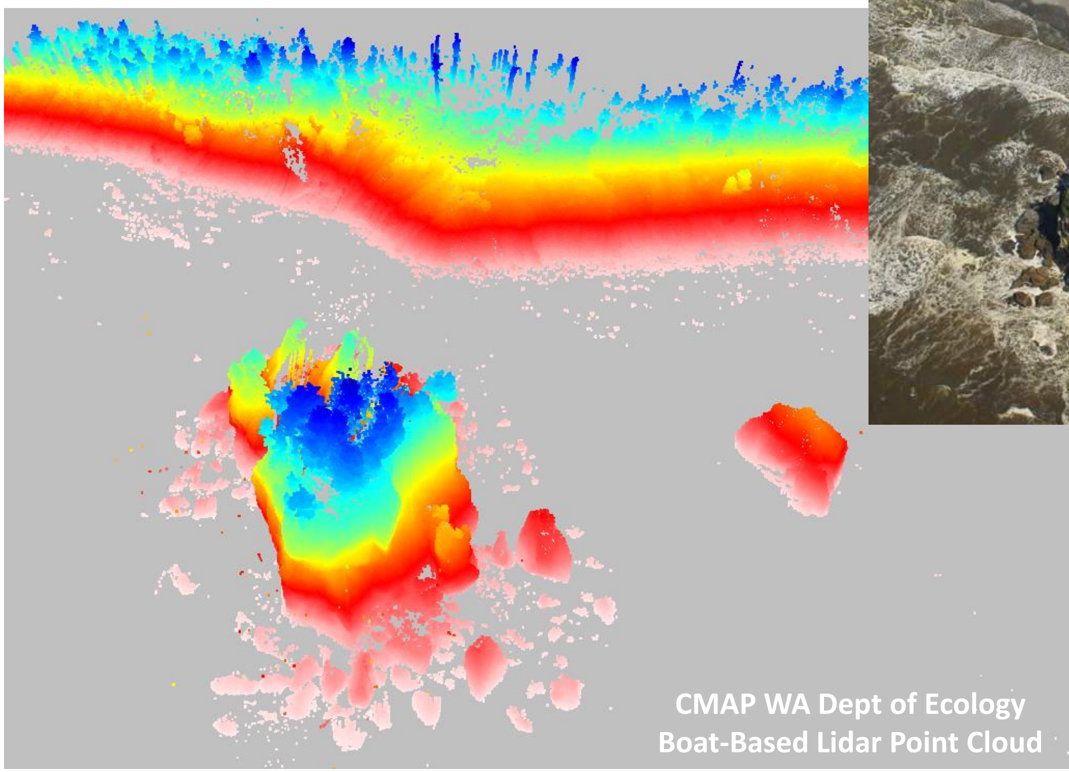


Coastal LiDAR at Quinault Indian Nation for Marine Spatial Planning

24-25 June 2013

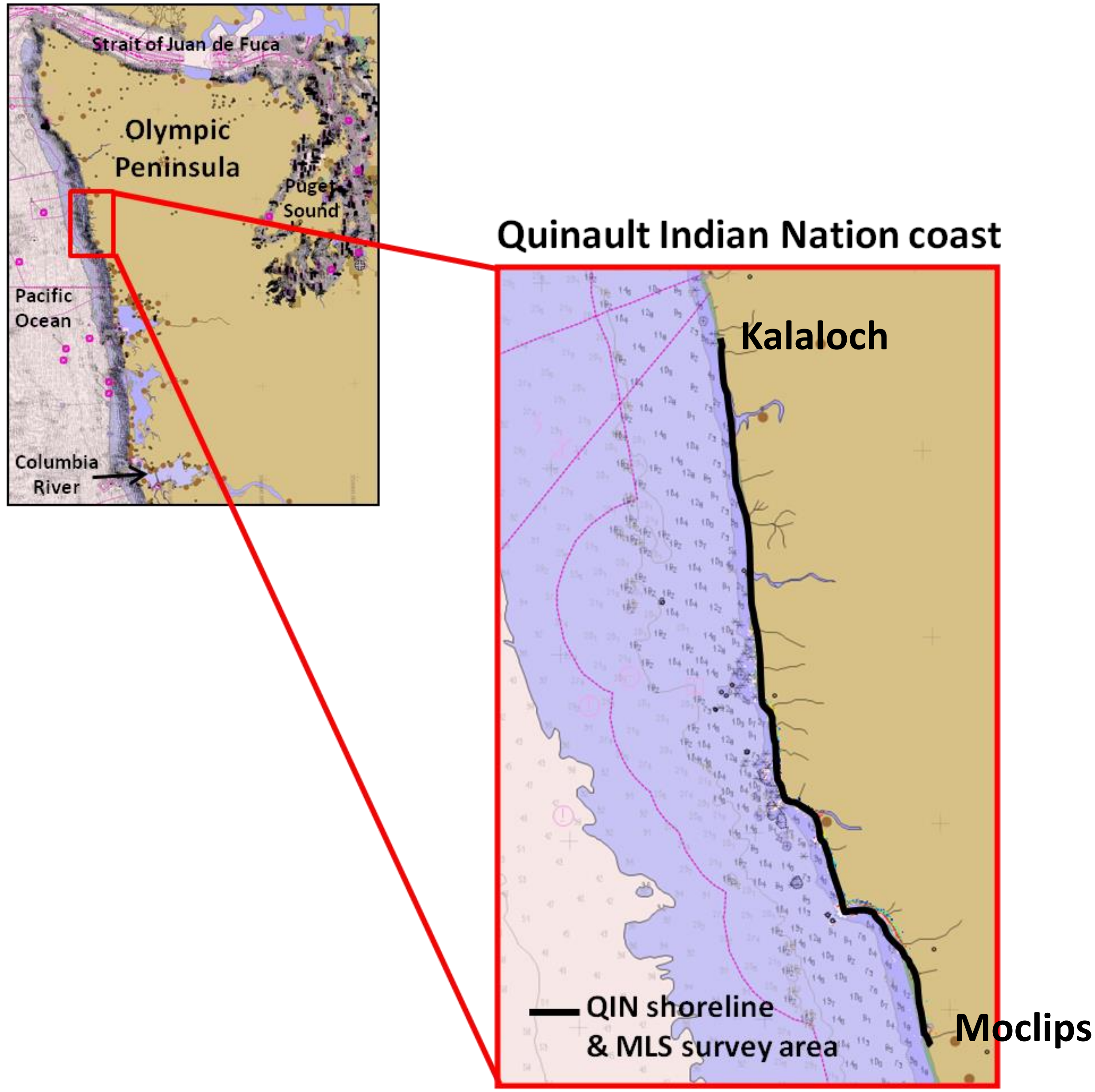
Little Hogsback, Quinault Indian Nation





Coastal LiDAR at Quinault Indian Nation for Marine Spatial Planning

24-25 June 2013



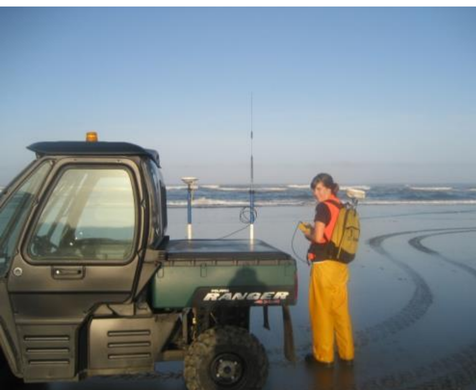
Coastal LiDAR at Quinault Indian Nation for Marine Spatial Planning

24-25 June 2013

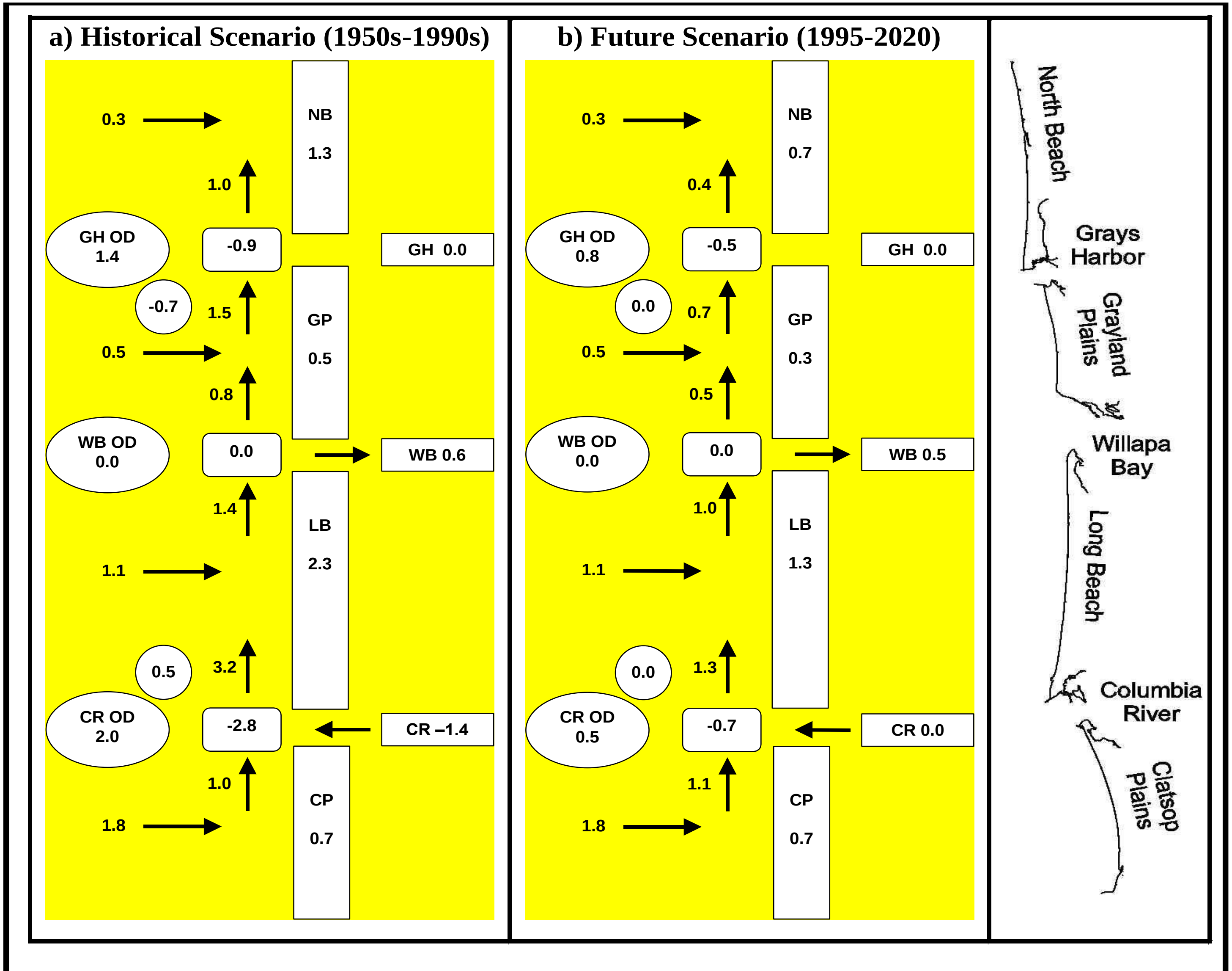
Columbia River Littoral Cell (CRLC) Coastal Morphology Monitoring

RTK-GPS ATV surface maps, beach profiles (to wading depth), and CPS nearshore bathymetry

Quarterly beach profiles since summer 1997

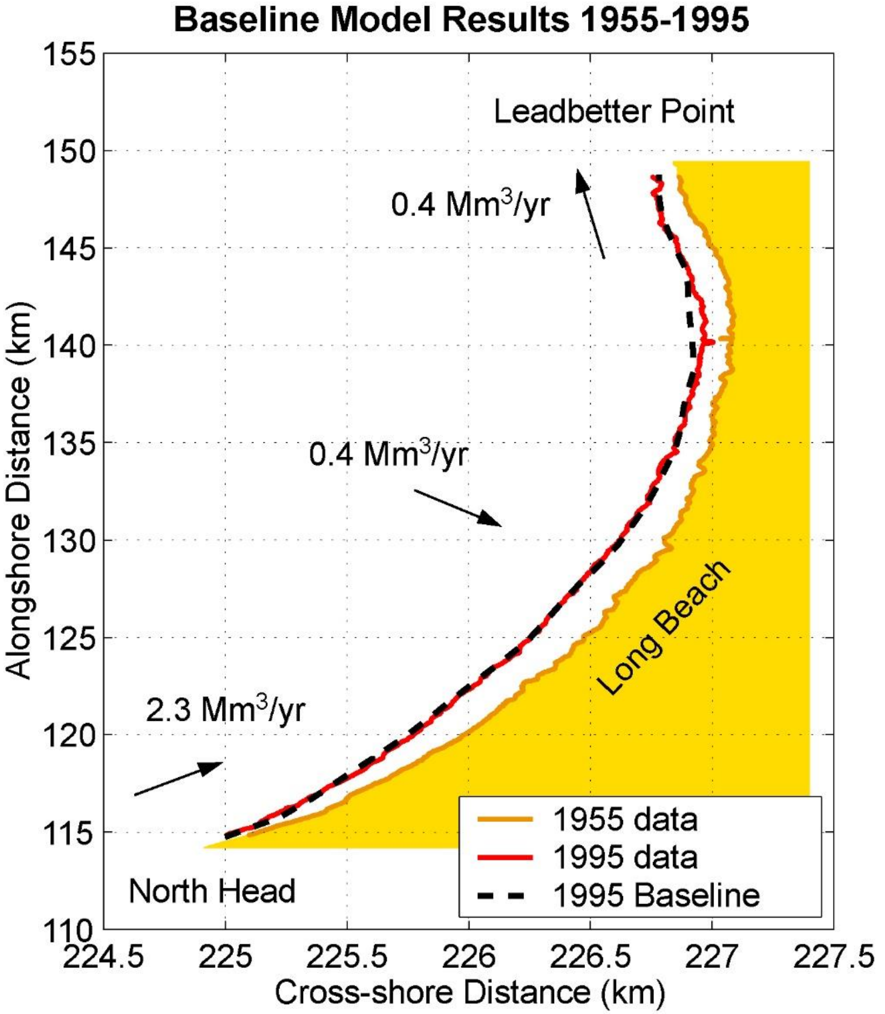


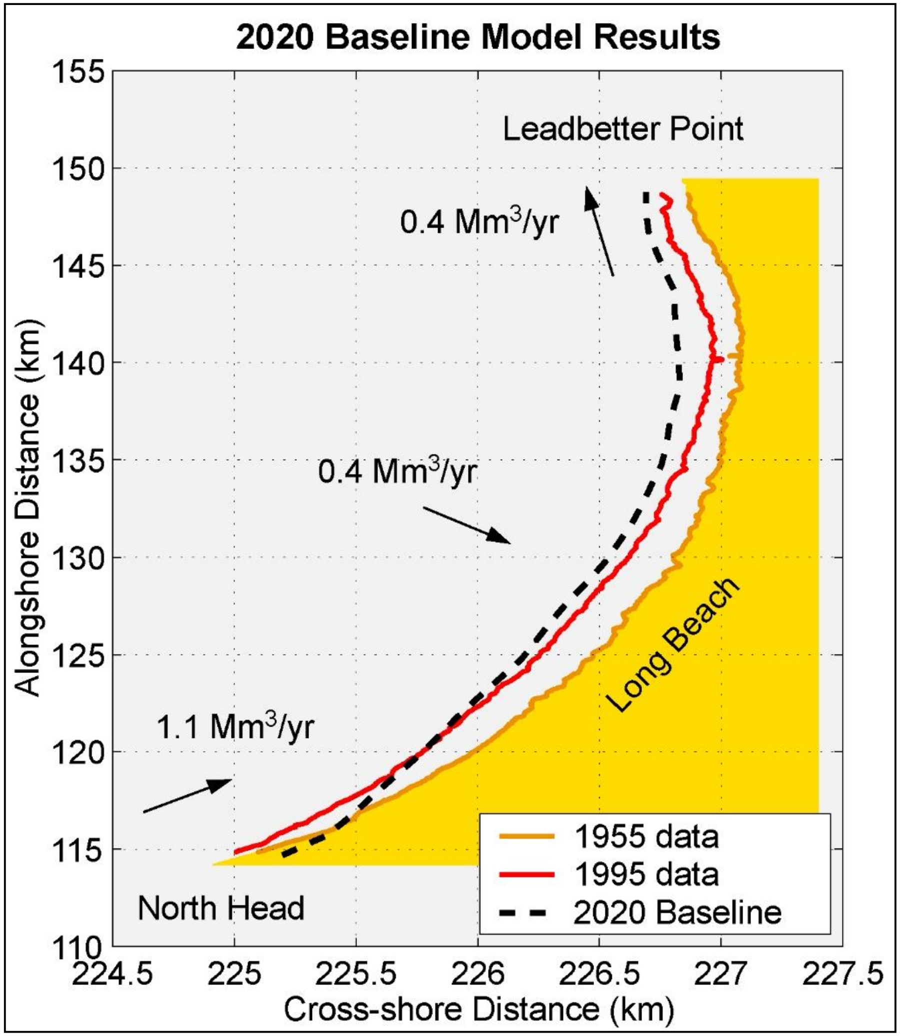
CRLC Sediment Budget



sediment flux in Mm^3/yr

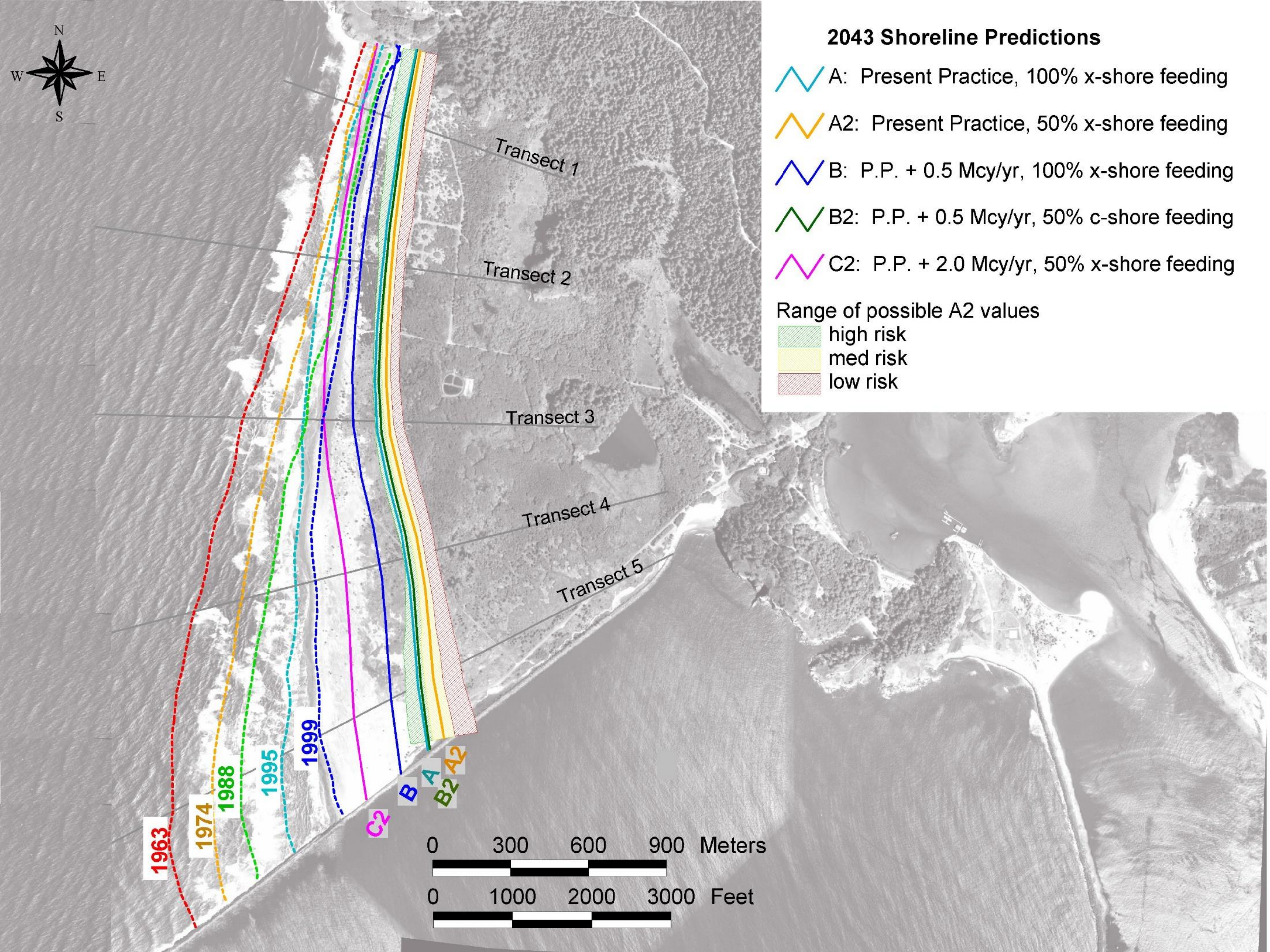
Model Calibration - Prediction



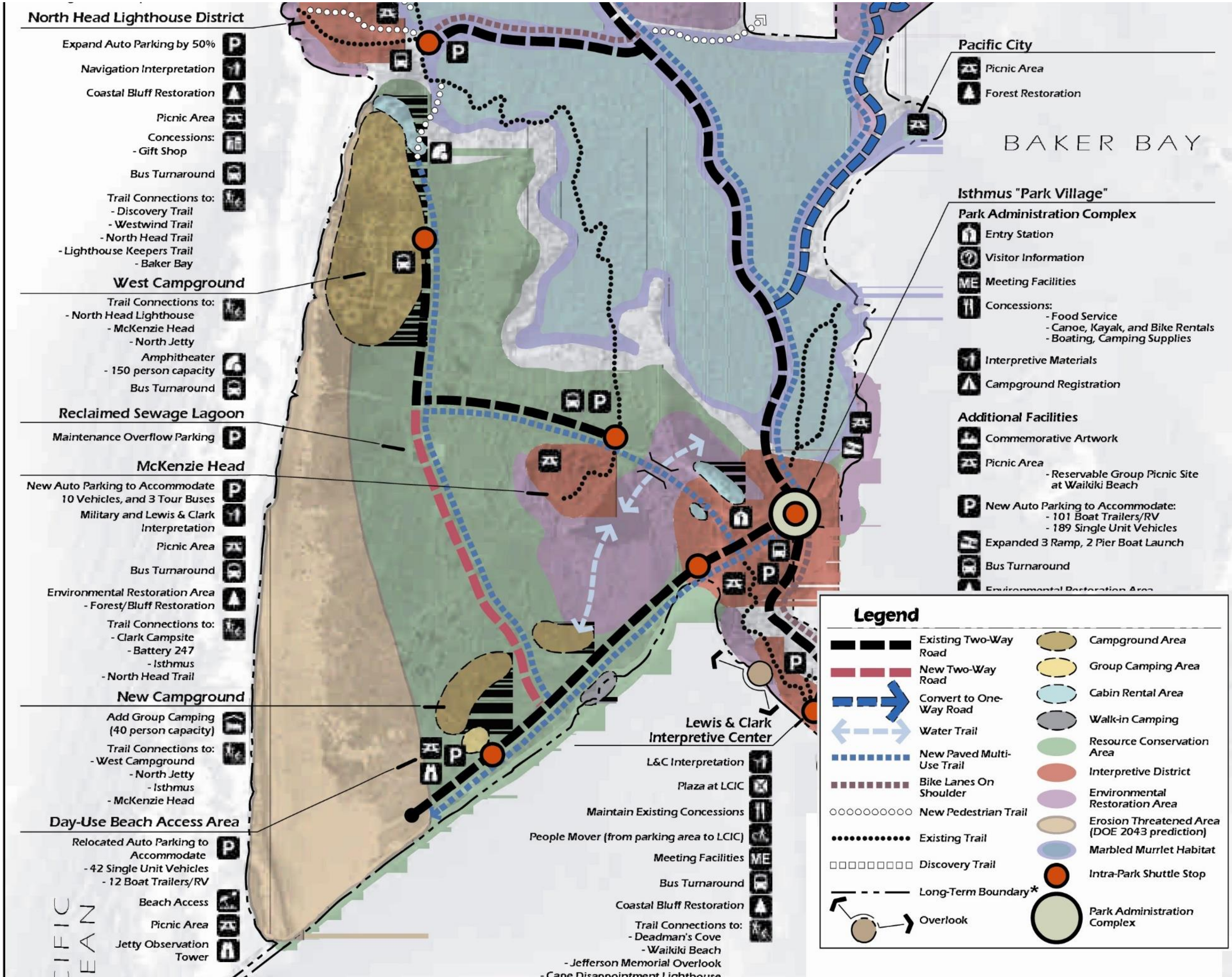


2.2 Mm^3/yr to maintain LB in future

1.6 Mm^3/yr: 250 m retreat; No supply: 640 m retreat



2043 Shoreline Predictions
A: Present Practice, 100% x-shore feeding
A2: Present Practice, 50% x-shore feeding
B: P.P. + 0.5 Mcy/yr, 100% x-shore feeding
B2: P.P. + 0.5 Mcy/yr, 50% c-shore feeding
C2: P.P. + 2.0 Mcy/yr, 50% x-shore feeding
Range of possible A2 values
high risk
med risk
low risk
N
W
E
S
Transect 1
Transect 2
Transect 3
Transect 4
Transect 5
1963
1974
1988
1995
1999
C2
B
A
B2
A2
0 300 600 900 Meters
0 1000 2000 3000 Feet

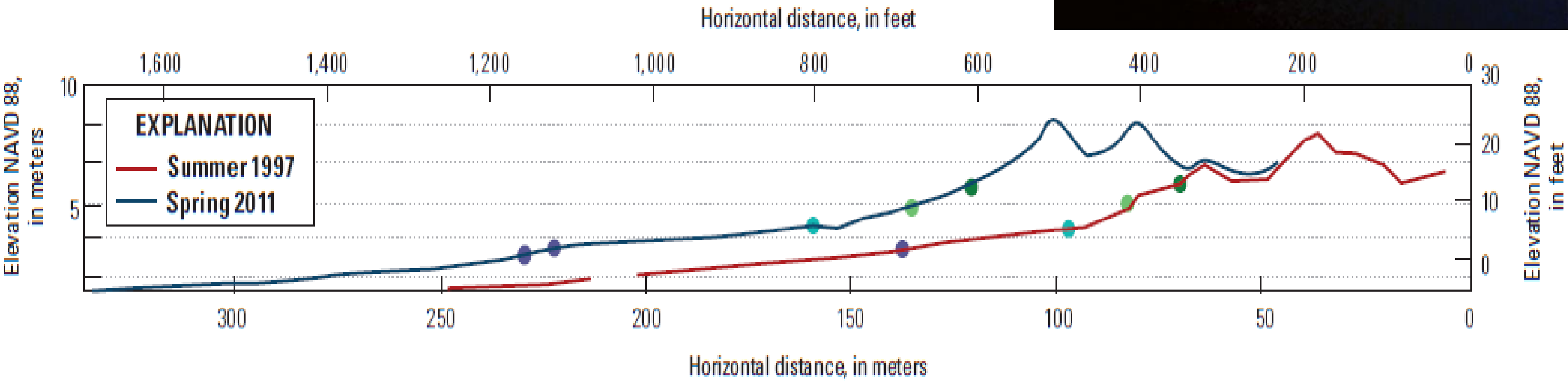

North Head Lighthouse District
Expand Auto Parking by 50%
Navigation Interpretation
Coastal Bluff Restoration
Picnic Area
Concessions:
- Gift Shop
Bus Turnaround
Trail Connections to:
- Discovery Trail
- Westwind Trail
- North Head Trail
- Lighthouse Keepers Trail
- Baker Bay
West Campground
Trail Connections to:
- North Head Lighthouse
- McKenzie Head
- North Jetty
Amphitheater
- 150 person capacity
Bus Turnaround
Reclaimed Sewage Lagoon
Maintenance Overflow Parking
McKenzie Head
New Auto Parking to Accommodate
10 Vehicles, and 3 Tour Buses
Military and Lewis & Clark
Interpretation
Picnic Area
Bus Turnaround
Environmental Restoration Area
- Forest/Bluff Restoration
Trail Connections to:
- Clark Campsite
- Battery 247
- Isthmus
- North Head Trail
New Campground
Add Group Camping
(40 person capacity)
Trail Connections to:
- West Campground
- North Jetty
- Isthmus
- McKenzie Head
Day-Use Beach Access Area
Relocated Auto Parking to
Accommodate
- 42 Single Unit Vehicles
- 12 Boat Trailers/RV
Beach Access
Picnic Area
Jetty Observation
Tower
Pacific City
Picnic Area
Forest Restoration
BAKER BAY
Isthmus "Park Village"
Park Administration Complex
Entry Station
Visitor Information
Meeting Facilities
Concessions:
- Food Service
- Canoe, Kayak, and Bike Rentals
- Boating, Camping Supplies
Interpretive Materials
Campground Registration
Additional Facilities
Commemorative Artwork
Picnic Area
- Reservable Group Picnic Site
at Waikiki Beach
New Auto Parking to Accommodate:
- 101 Boat Trailers/RV
- 189 Single Unit Vehicles
Expanded 3 Ramp, 2 Pier Boat Launch
Bus Turnaround
Lewis & Clark
Interpretive Center
L&C Interpretation
Plaza at LCIC
Maintain Existing Concessions
People Mover (from parking area to LCIC)
Meeting Facilities
Bus Turnaround
Coastal Bluff Restoration
Trail Connections to:
- Deadman's Cove
- Waikiki Beach
- Jefferson Memorial Overlook
- Cape Disappointment Lighthouse
Legend
Existing Two-Way Road
New Two-Way Road
Convert to One-Way Road
Water Trail
New Paved Multi-Use Trail
Bike Lanes On Shoulder
New Pedestrian Trail
Existing Trail
Discovery Trail
Long-Term Boundary*
Overlook
Campground Area
Group Camping Area
Cabin Rental Area
Walk-in Camping
Resource Conservation Area
Interpretive District
Environmental Restoration Area
Erosion Threatened Area (DOE 2043 prediction)
Marbled Murrlet Habitat
Intra-Park Shuttle Stop
Park Administration Complex

Columbia River Littoral Cell – Long Beach

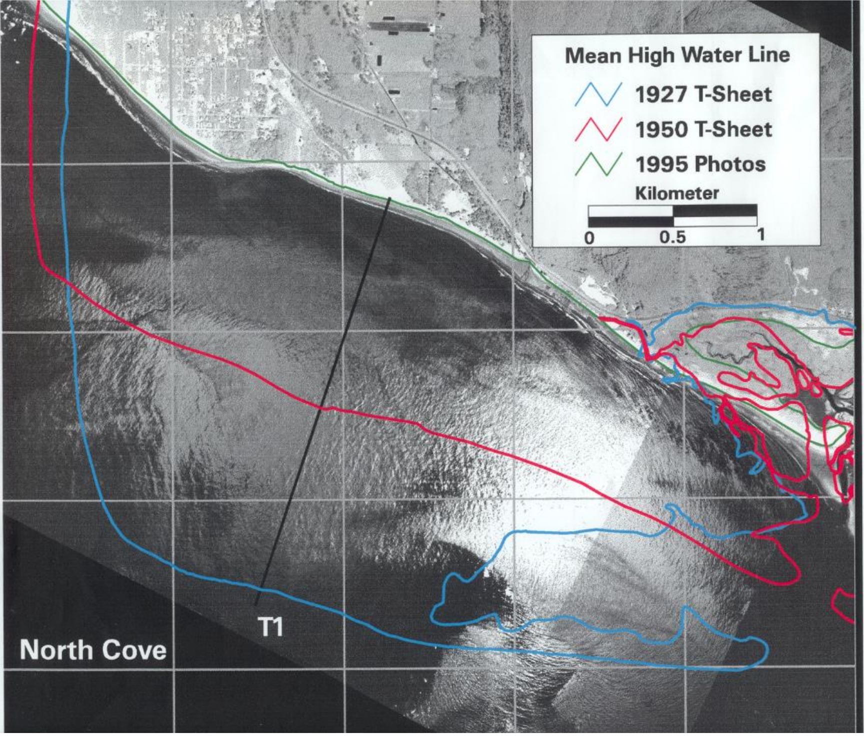
- Beach erosion is tied to Columbia River sediment supply.

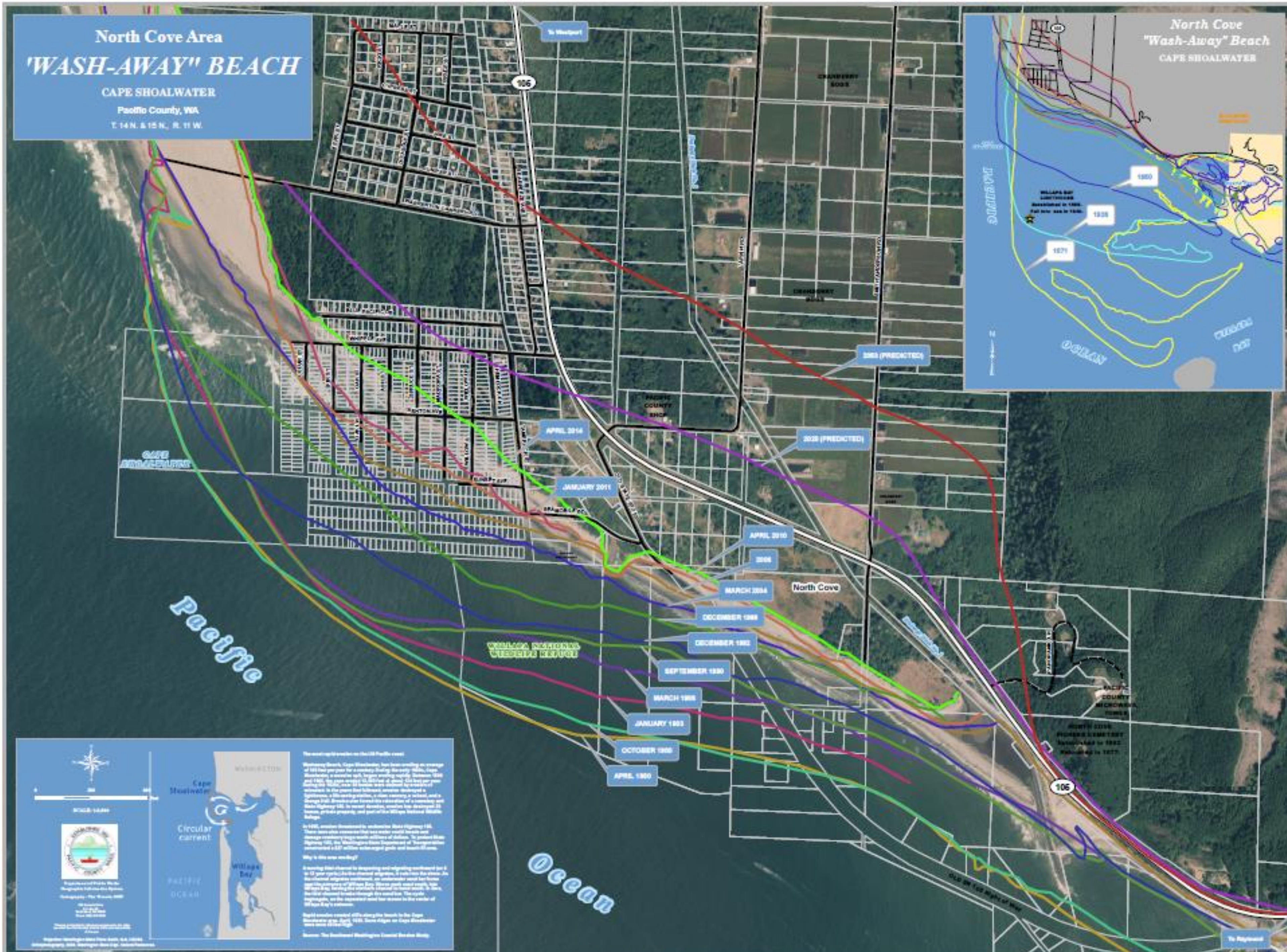
- The beach closest to the Columbia River has eroded most rapidly.

- Beach accretion continues northward at lower rates in the south and higher rates in the north.

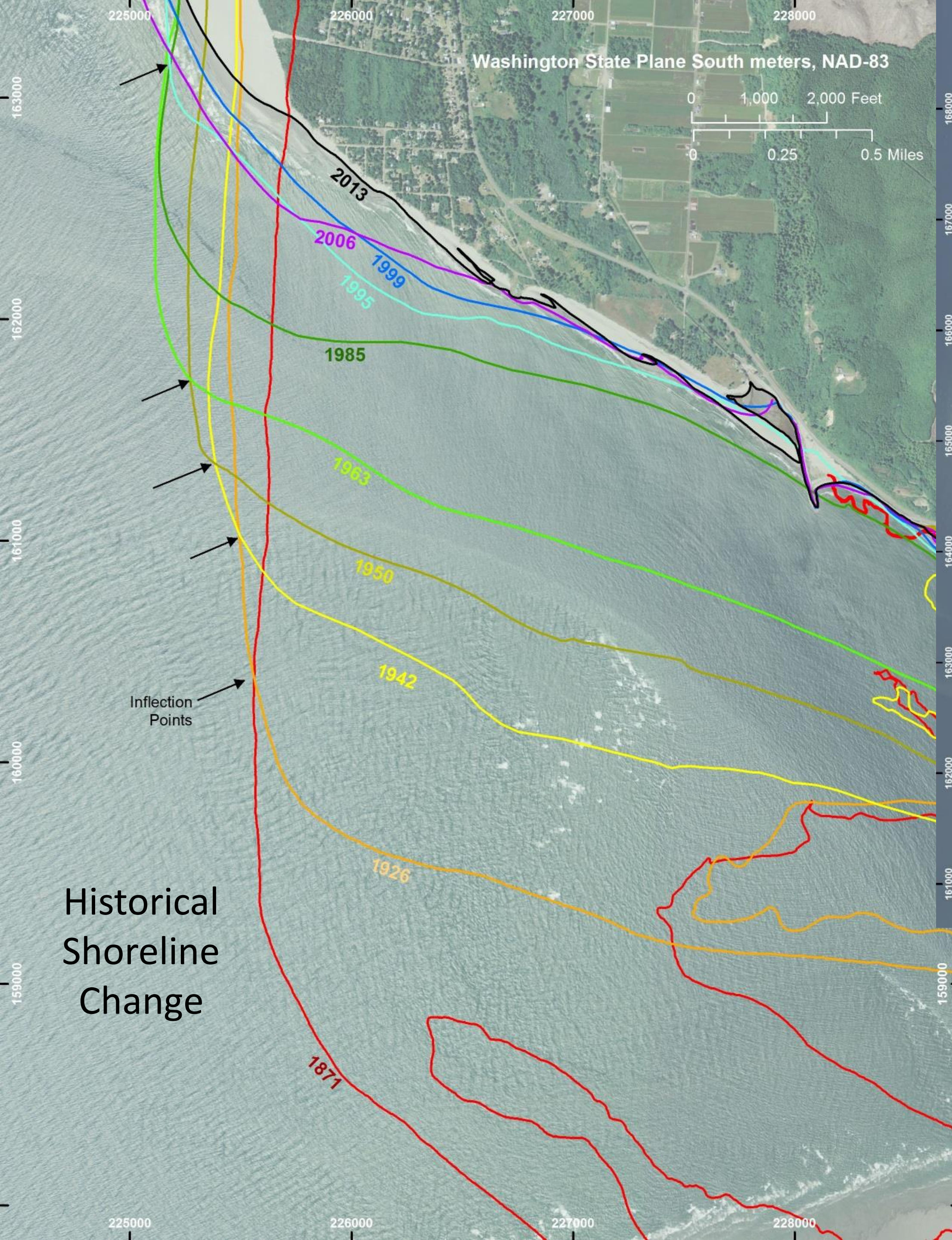


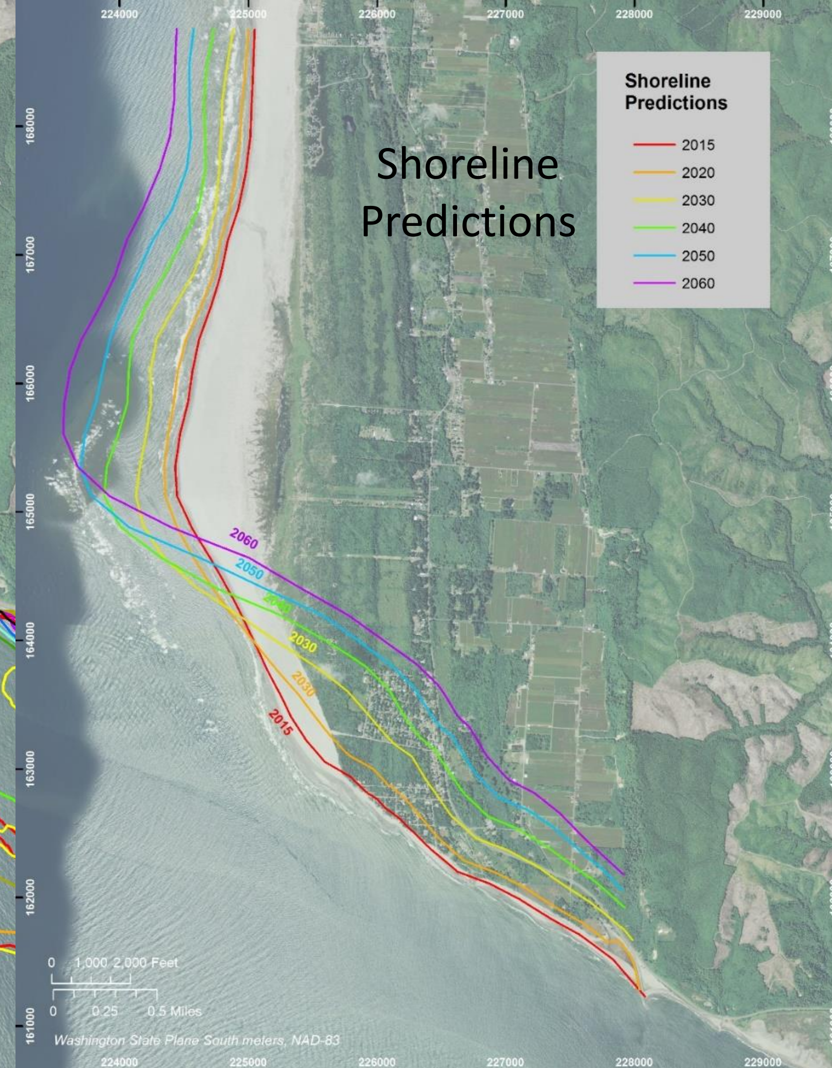
North Cove, WA





North Cove Area
'WASH-AWAY" BEACH
CAPE SHOALWATER
Pacific County, WA
T. 14 N. & 15 N., R. 11 W.
To Westport
106
CRANBERRY BOGS
North Cove
"Wash-Away" Beach
CAPE SHOALWATER
1950
1935
1971
OCEAN
2060 (PREDICTED)
2030 (PREDICTED)
APRIL 2014
JANUARY 2011
APRIL 2010
2006
MARCH 2004
DECEMBER 1999
DECEMBER 1992
SEPTEMBER 1990
MARCH 1986
JANUARY 1983
OCTOBER 1980
APRIL 1980
North Cove
PACIFIC COUNTY SHOP
Pacific
Ocean
Cape Shoalwater
Circular current
Willapa Bay
PACIFIC OCEAN
To Raymond


Historical Shoreline Change
Washington State Plane South meters, NAD-83
0 1,000 2,000 Feet
0 0.25 0.5 Miles
Inflection Points
2013
2006
1999
1995
1985
1963
1950
1942
1926
1871
225000
226000
227000
228000
163000
162000
161000
160000
159000

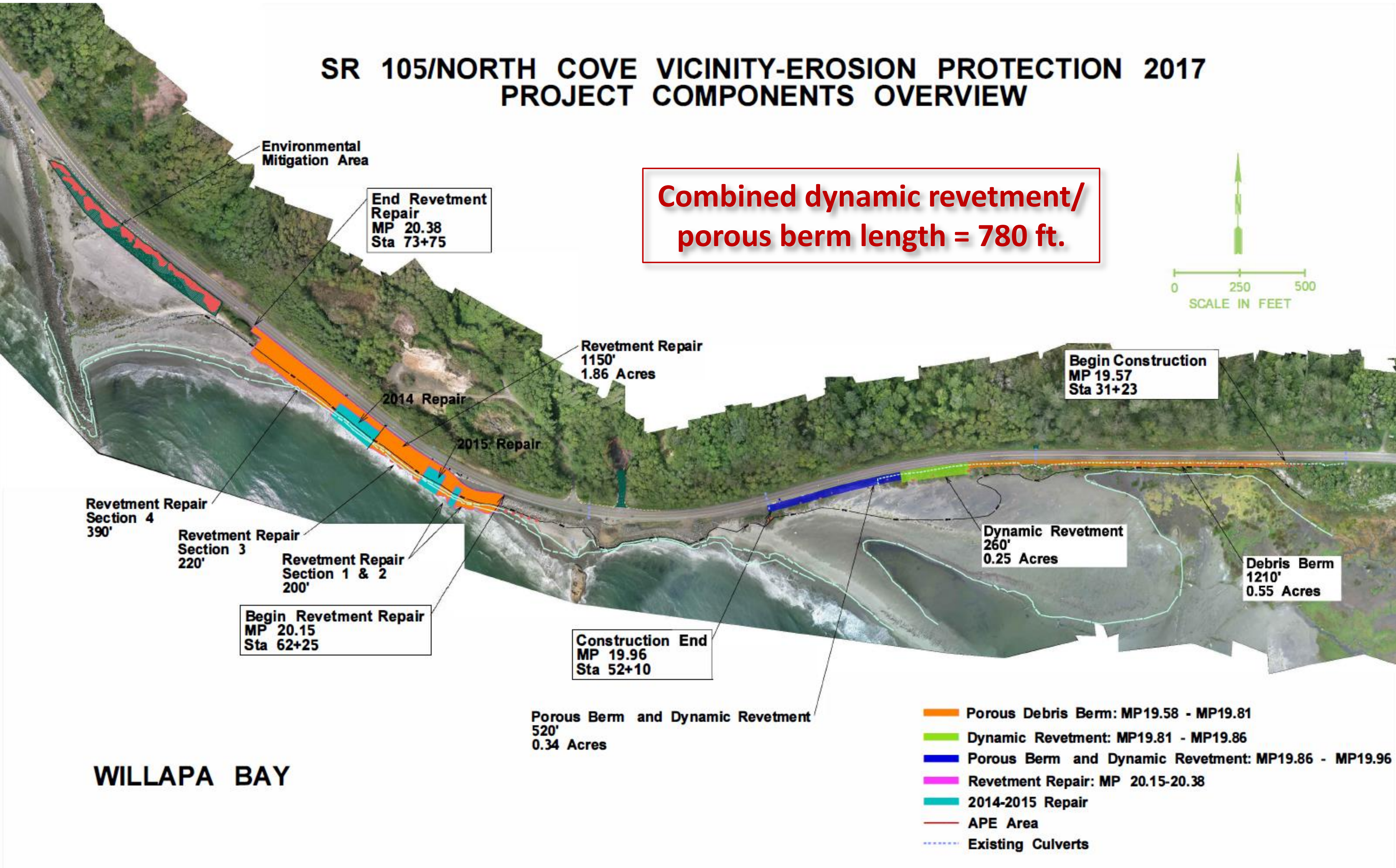

Shoreline Predictions
Shoreline Predictions
2015
2020
2030
2040
2050
2060
0 1,000 2,000 Feet
0 0.25 0.5 Miles
Washington State Plane South meters, NAD-83
224000
225000
226000
227000
228000
229000
168000
167000
166000
165000
164000
163000
162000
161000

Natural cobble berm vs. built dynamic revetment

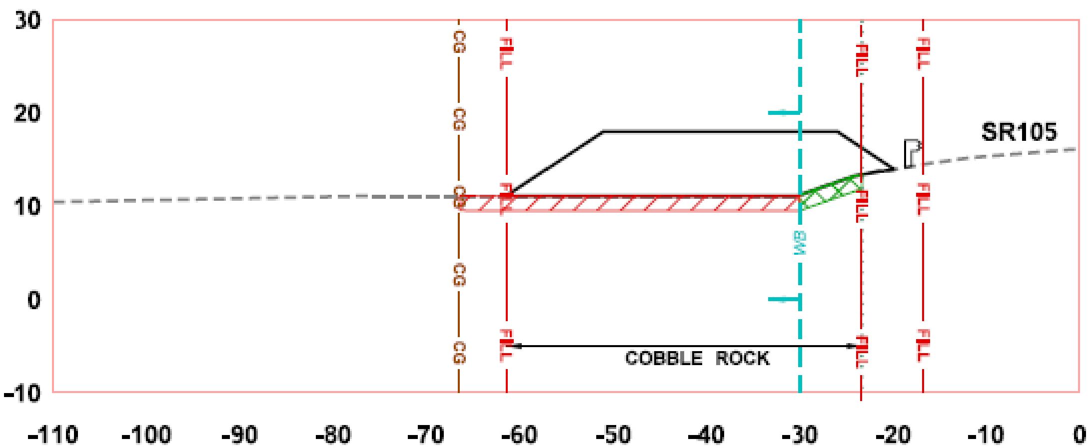
Kalaloch Beach 1

North Cove

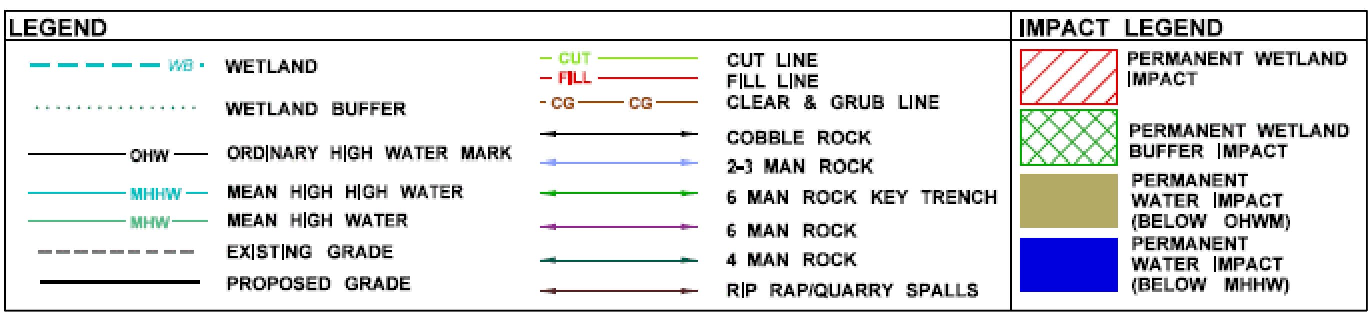
WSDOT North Cove Erosion Protection Project



WSDOT North Cove Erosion Protection Project



DYNAMIC REVETMENT - SECTION F - STA 45+50



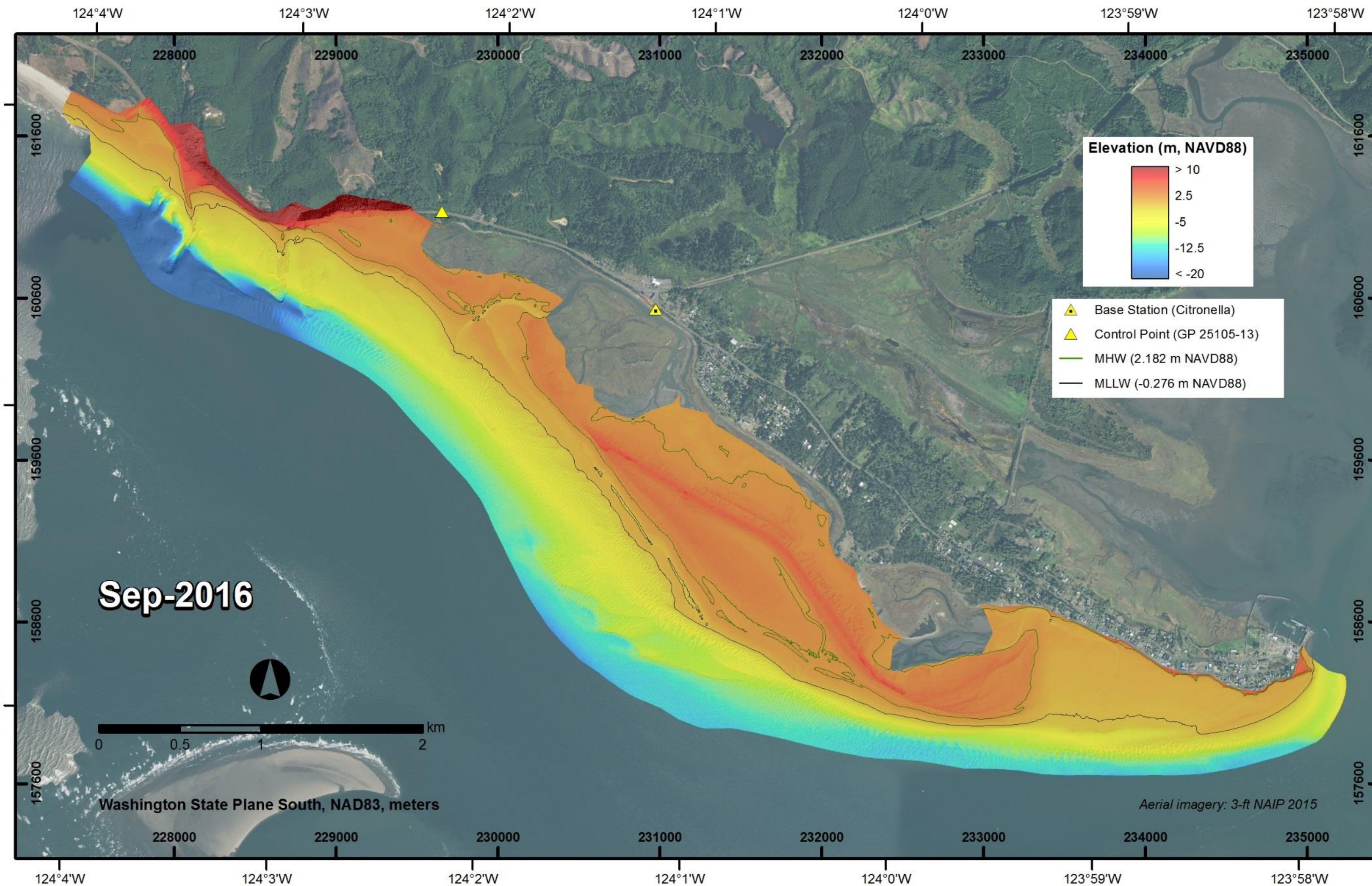
Dynamic revetment = 260 ft. long x 40 ft. wide (top width), composed of more than 2,000 cubic yards of cobble and gravel

Shoalwater Bay Project

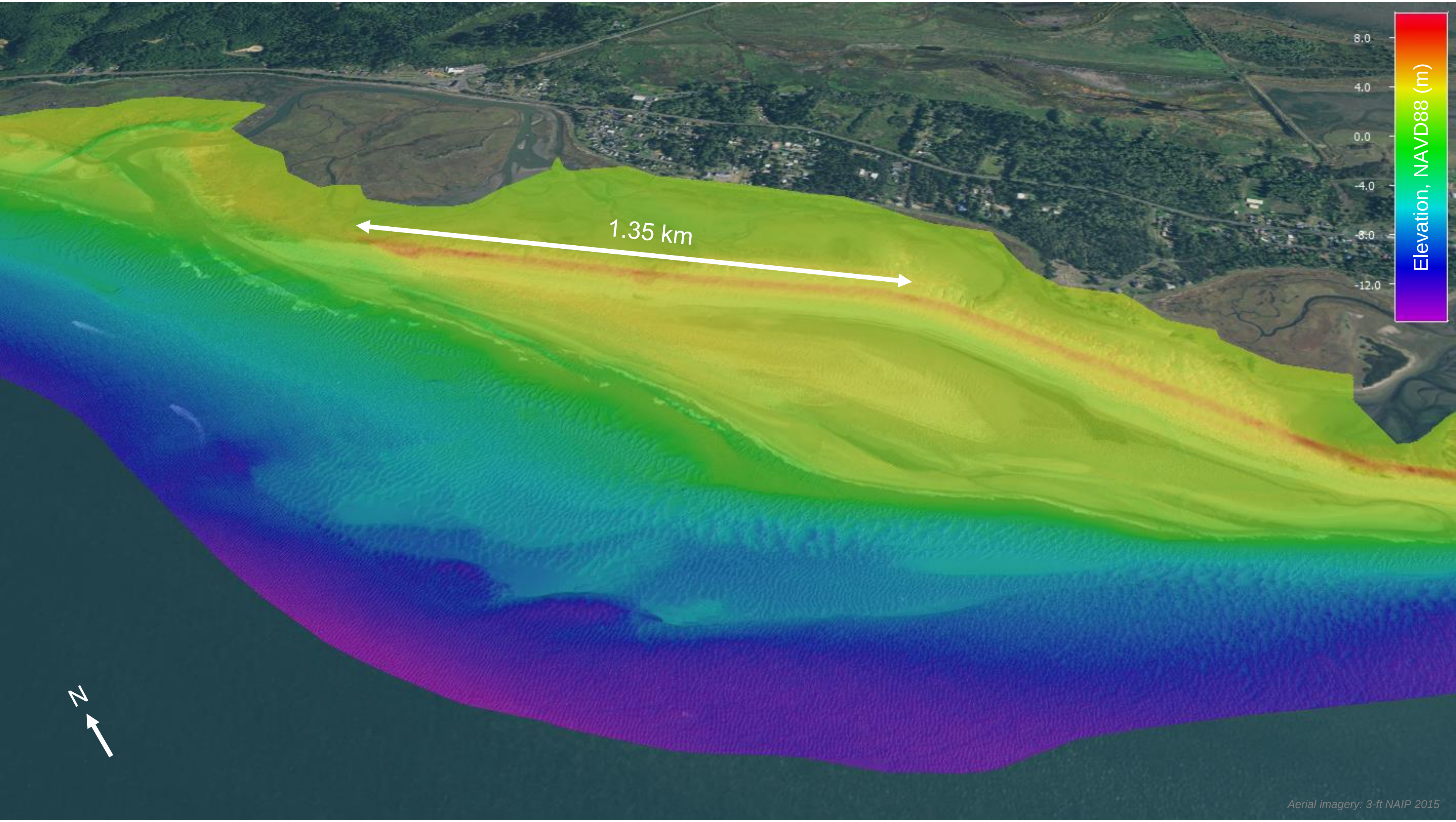
Graveyard Spit, Willapa Bay

- 600,000 cy sand to restore barrier dune to 25 ft MLLW top elevation in 2008
- 844,088 cy sand renourishment in summer 2018

Shoalwater Bay Project Monitoring

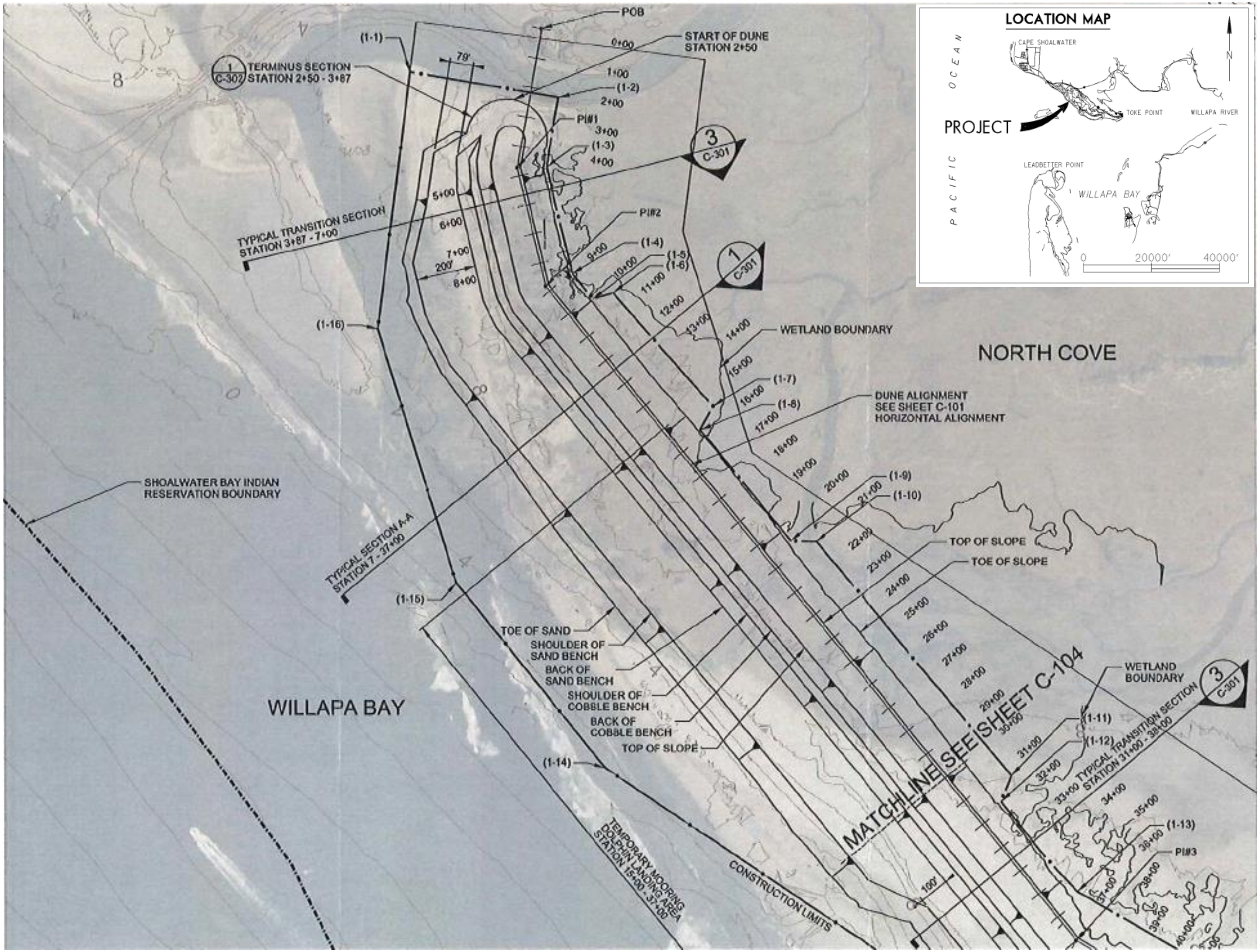


Shoalwater Bay Project Monitoring

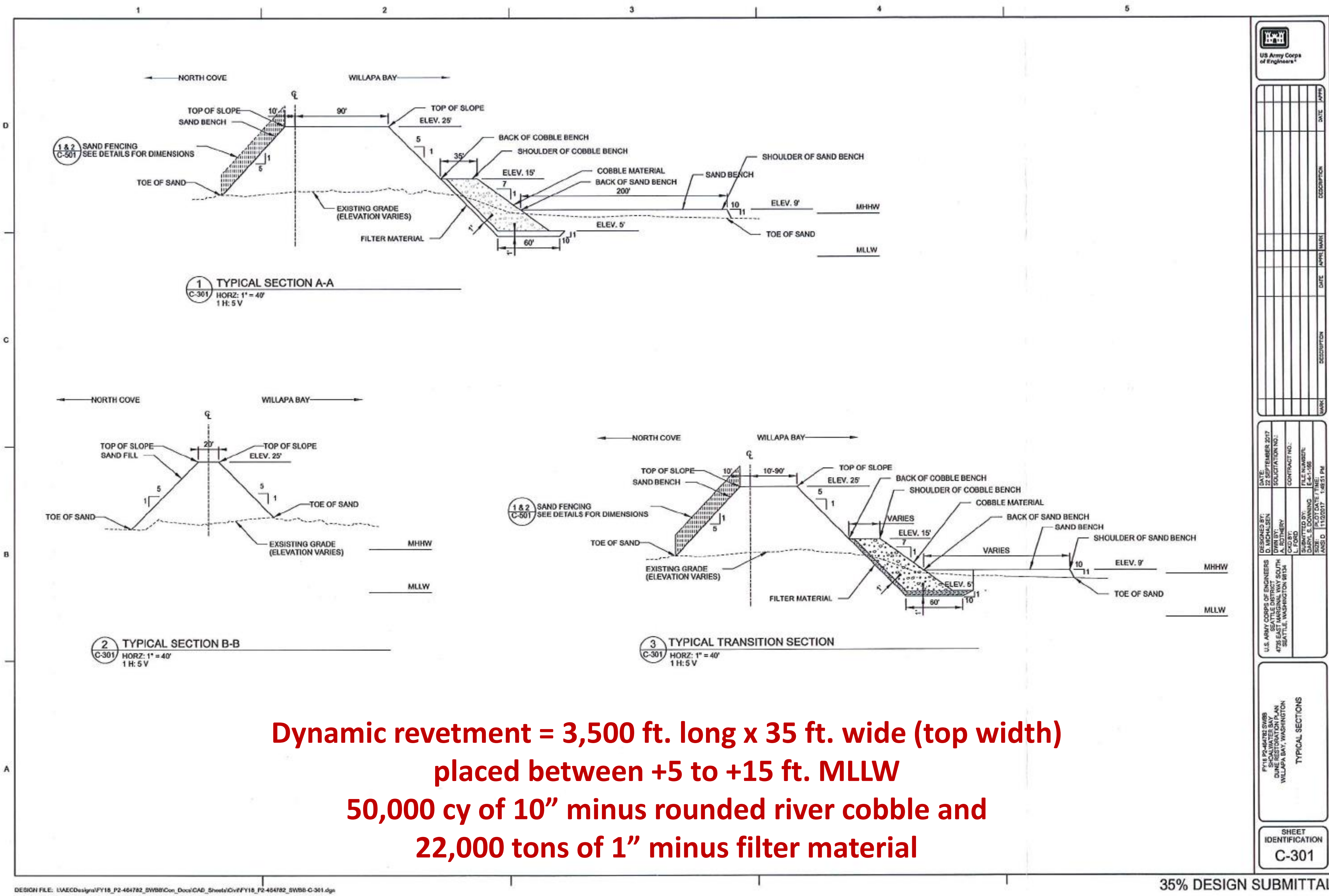


Multibeam, Lidar, & Topo-merged DEM

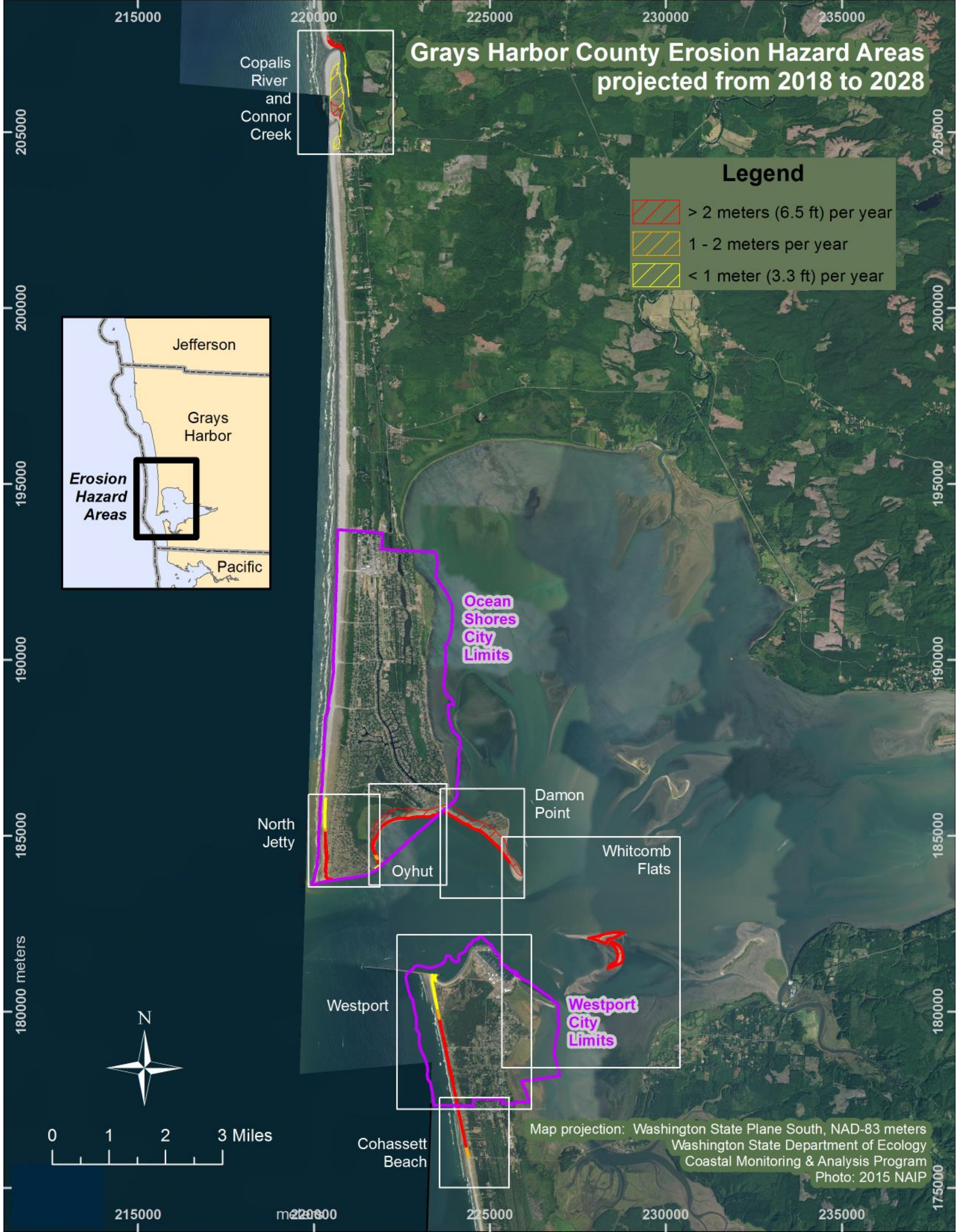
USACE Shoalwater Bay Dune Restoration Plan – Summer 2018



USACE Shoalwater Bay Dune Restoration Plan Summer 2018



Dynamic revetment = 3,500 ft. long x 35 ft. wide (top width)
placed between +5 to +15 ft. MLLW
50,000 cy of 10" minus rounded river cobble and
22,000 tons of 1" minus filter material



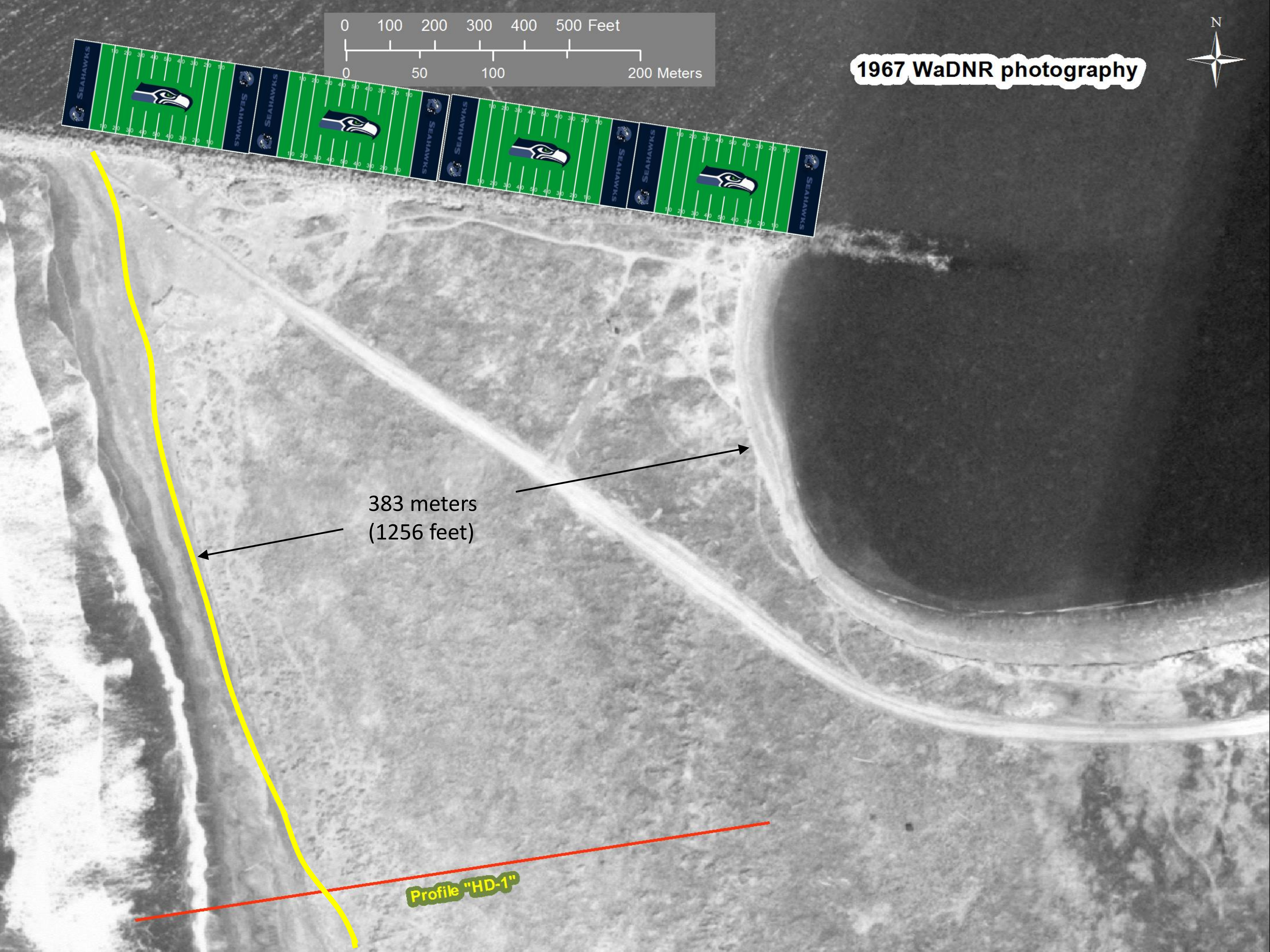
Grays Harbor County Erosion Hazard Areas projected from 2018 to 2028
Legend
> 2 meters (6.5 ft) per year
1 - 2 meters per year
< 1 meter (3.3 ft) per year
Copalis River and Connor Creek
Jefferson
Grays Harbor
Erosion Hazard Areas
Pacific
Ocean Shores City Limits
North Jetty
Oyhut
Damon Point
Whitcomb Flats
Westport
Westport City Limits
Cohassett Beach
N
0 1 2 3 Miles
215000
220000
225000
230000
235000
205000
200000
195000
190000
185000
180000 meters
175000
Map projection: Washington State Plane South, NAD-83 meters
Washington State Department of Ecology
Coastal Monitoring & Analysis Program
Photo: 2015 NAIP

Half Moon Bay, Westport

History of Beach and Nearshore Nourishment in Grays Harbor County

Year	Nearshore Sites		Beach Sites				Description of Beach Nourishment
	South Beach (cy)	Half Moon Bay (cy)	Breach Fill (cy)	Half Moon Bay (cy)	Westport (cy)	Ocean Shores (cy)	
1992		200,000					
1993	373,000						
1994	265,000	146,000	600,000				600,000 cy sand to fill the breach
1995				300,295	82,000		300,295 cy sand south of revetment; 82,000 cy sand at City outfall
1996		274,780					
1997		308,604		5,000			5,000 cy sand at HMB shoreline berm south of revetment
1998		421,468					
1999	76,187	228,470		228,963			228,963 cy sand at revetment extension beach fill
2000			11,600				11, 600 cy of 12" minus cobble and gravel along HMB Breach Fill
2001			16,100				16,100 cy of 12" minus cobble and gravel along HMB Breach Fill
2002	75,219	378,441	135,000				135,000 cy sand at HMB
2003	125,388	329,106			1,700		1,700 cy sand at HMB beach along dune trail
2004	262,176	289,652	29,553				29,553 cy sand at HMB Breach Fill
2005	217,909	102,184	22,779				22,779 cy sand at SB at Breach Fill
2006	55,170	126,892					
2007		140,406					
2008		171,353					
2009	214,502	144,975					
2010	118,182	91,720	30,000				10,000 cy sand at HMB Breach Fill; 20,000 cy sand at SB Breach Fill
2011	298,251	177,150					
2012	142,313	111,205	30,000				30,000 cy sand from upland source to Breach Fill
2013	477,637	86,147					
2014	498,440						
2015	506,330					3,350	1,600 cy of sand + 1,750 cy of sand placed in front of geotubes
2016	544,980						
2017	499,001	101,019					
Sum	**4,749,685**	**3,829,572**	**875,032**	**534,258**	**83,700**	**3,350**	
	Total Nearshore		**Total Beach**				**Total Nourishment**
	8,579,257		**1,496,340**				**10,075,597**

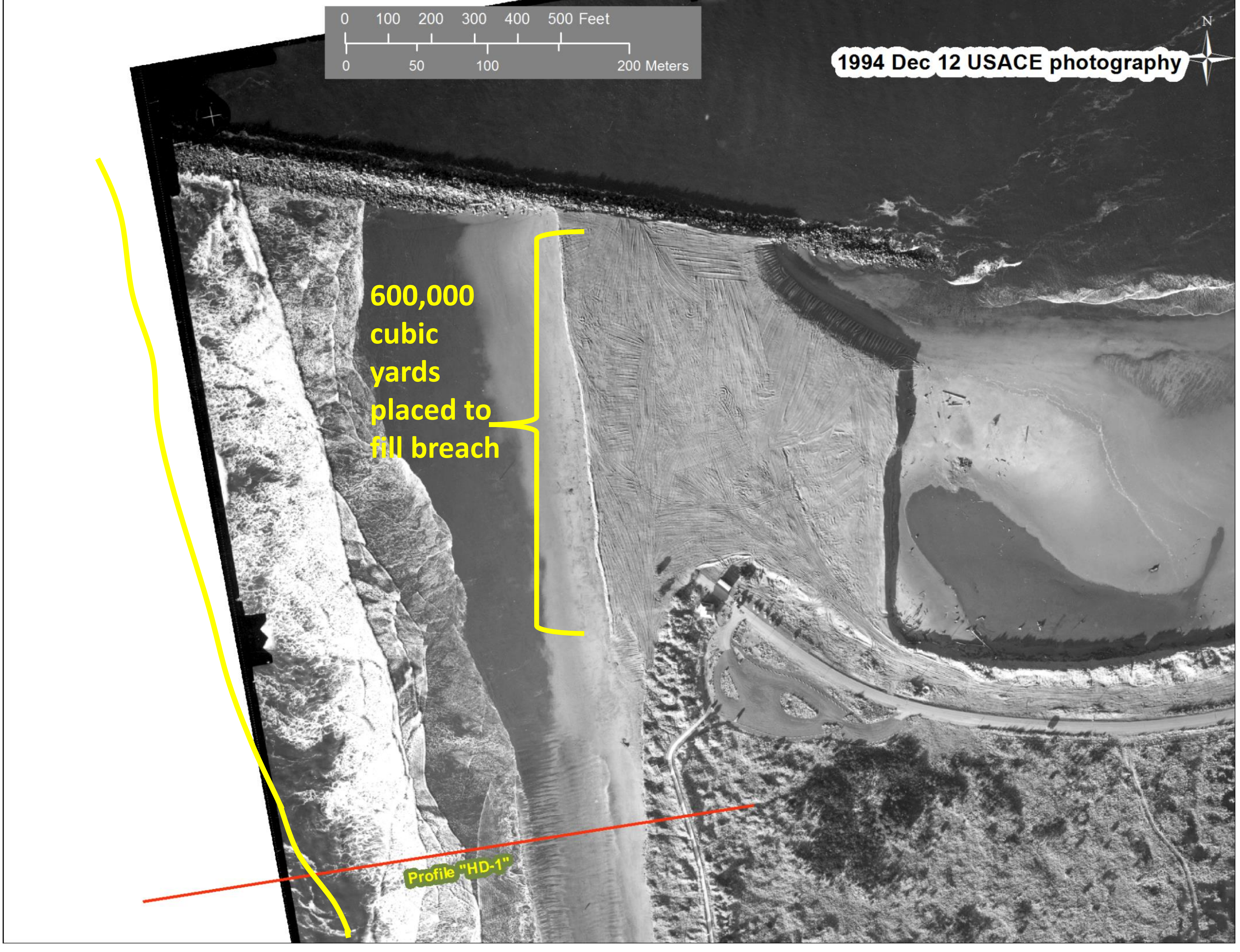

0 100 200 300 400 500 Feet
0 50 100 200 Meters
1967 WaDNR photography
N
383 meters
(1256 feet)
Profile "HD-1"

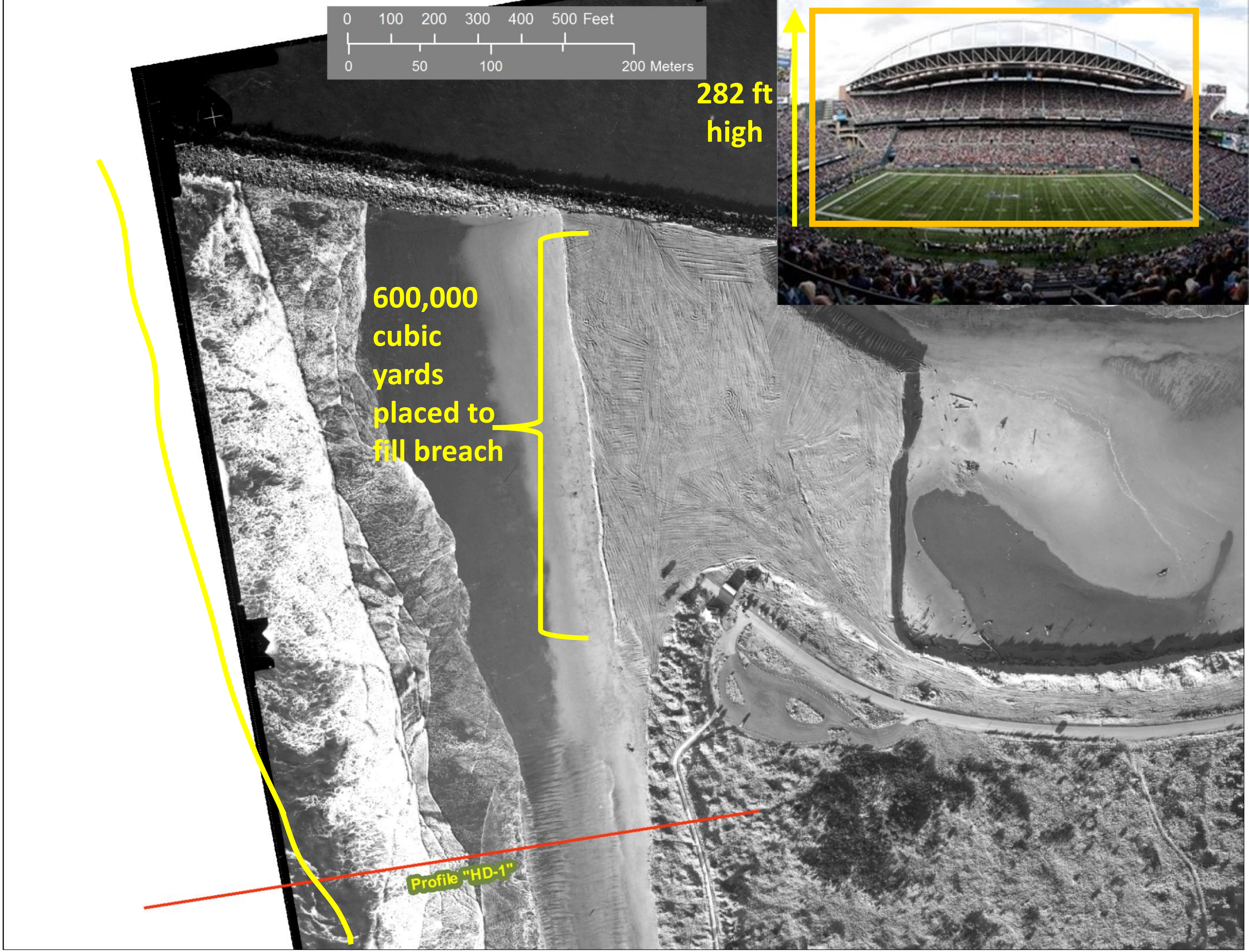


0 100 200 300 400 500 Feet
0 50 100 200 Meters
1967 WaDNR photography
N
383 meters
(1256 feet)
Profile "HD-1"

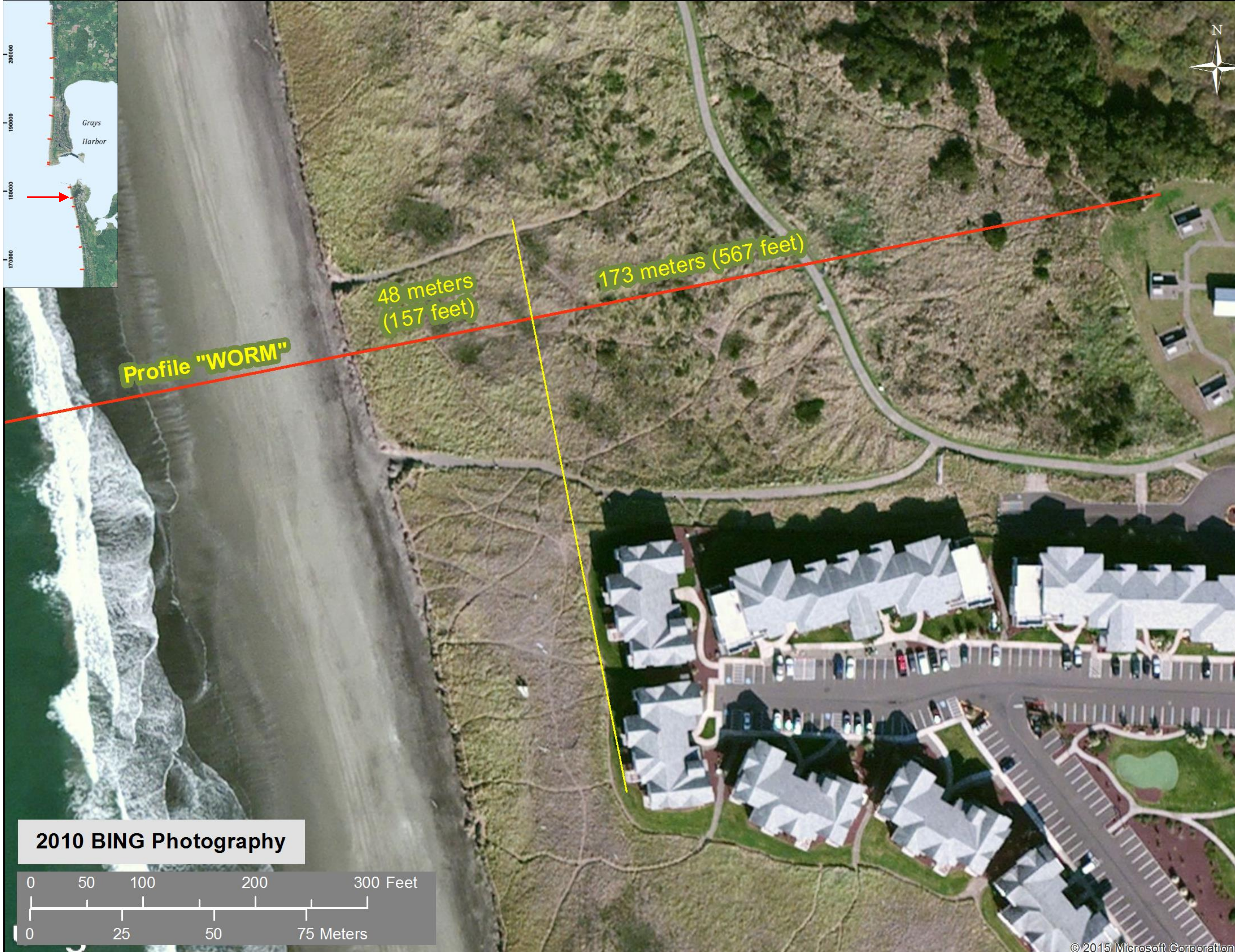
0 100 200 300 400 500 Feet
0 50 100 200 Meters
1994 Mar 6 USACE photography
N
Profile "HD-1"

0 100 200 300 400 500 Feet
0 50 100 200 Meters
1994 Mar 6 USACE photography
N
SEAHAWKS
Profile "HD-1"

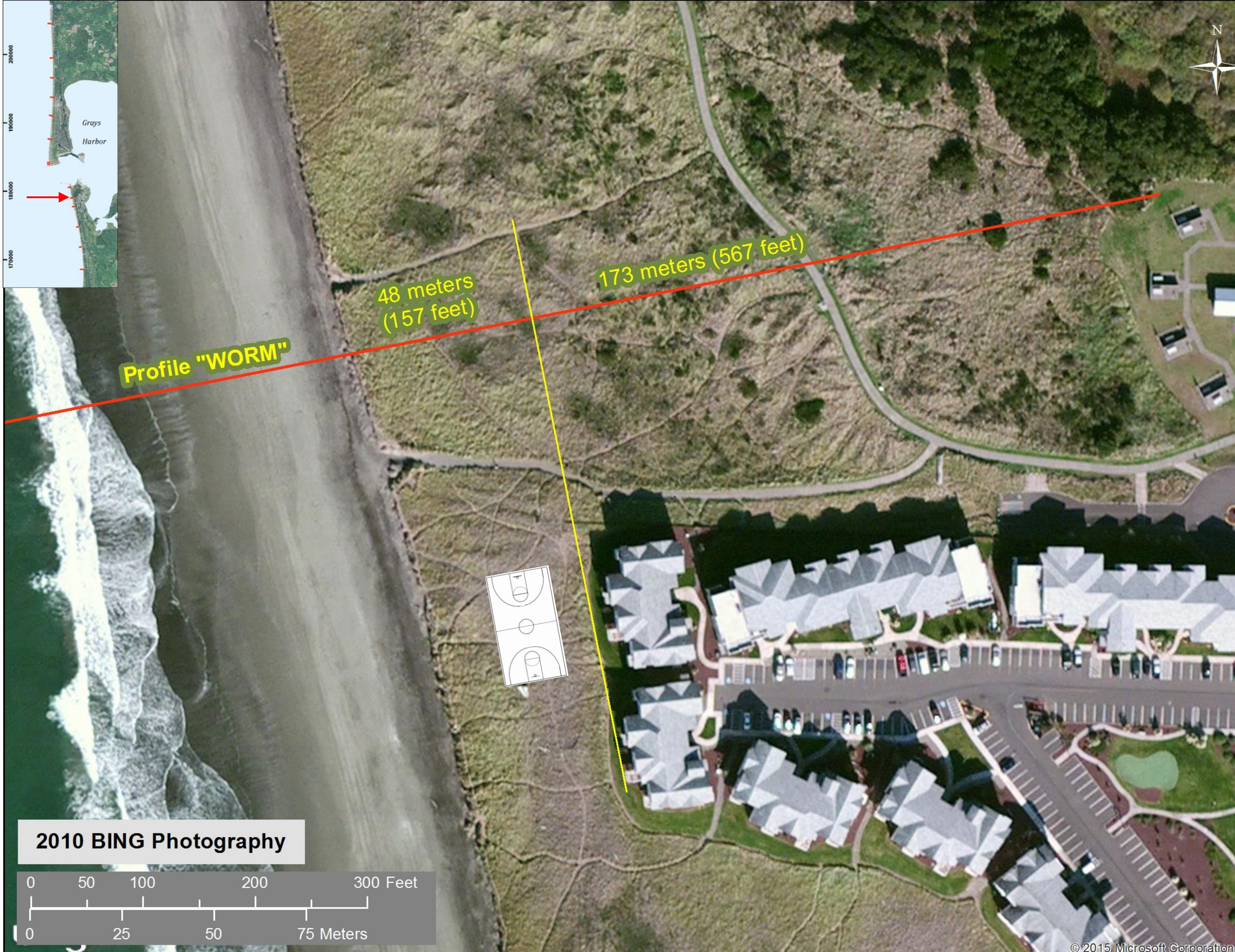

0 100 200 300 400 500 Feet
0 50 100 200 Meters
1994 Dec 12 USACE photography
N
600,000 cubic yards placed to fill breach
Profile "HD-1"


0 100 200 300 400 500 Feet
0 50 100 200 Meters
282 ft high
600,000 cubic yards placed to fill breach
Profile "HD-1"

0 100 200 300 400 500 Feet
0 50 100 200 Meters
2010 BING Photography
N
200 m of retreat at 4.6 m/yr over 43 years
Profile "HD-1"
(656 ft @ 15.3 ft/yr)
bing
Image courtesy of USGS Earthstar Geographics SIO © 2015 Microsoft Corporation

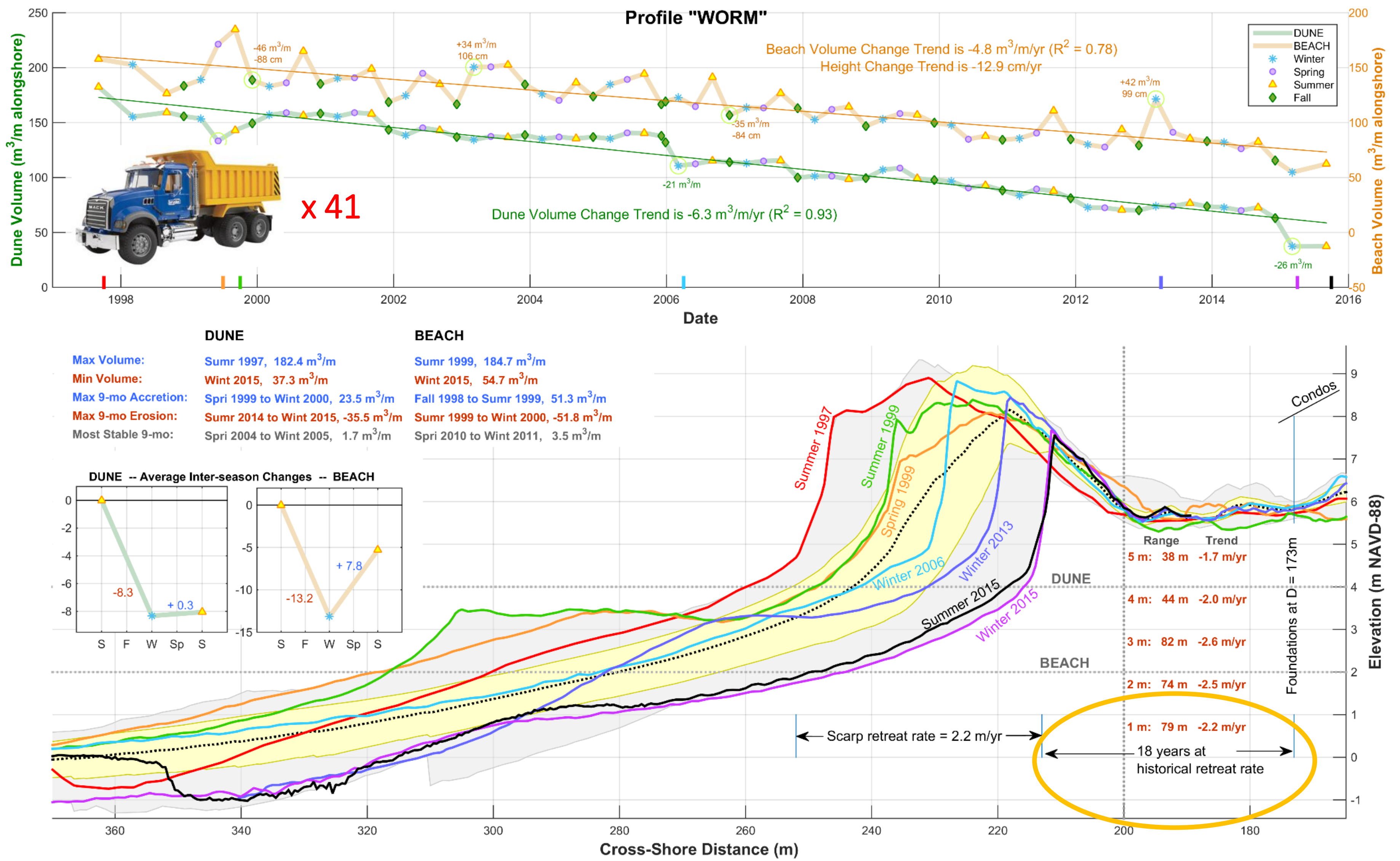


Grays
Harbor
Profile "WORM"
48 meters
(157 feet)
173 meters (567 feet)
N
2010 BING Photography
0 50 100 200 300 Feet
0 25 50 75 Meters
© 2015 Microsoft Corporation



Grays
Harbor
200000
190000
180000
170000
N
48 meters
(157 feet)
173 meters (567 feet)
Profile "WORM"
2010 BING Photography
0 50 100 200 300 Feet
0 25 50 75 Meters
© 2015 Microsoft Corporation

N
173 meters (567 feet)
65 meters
(213 feet)
Profile "WORM"
1999 SWC Photography
0 50 100 200 300 Feet
0 25 50 75 Meters

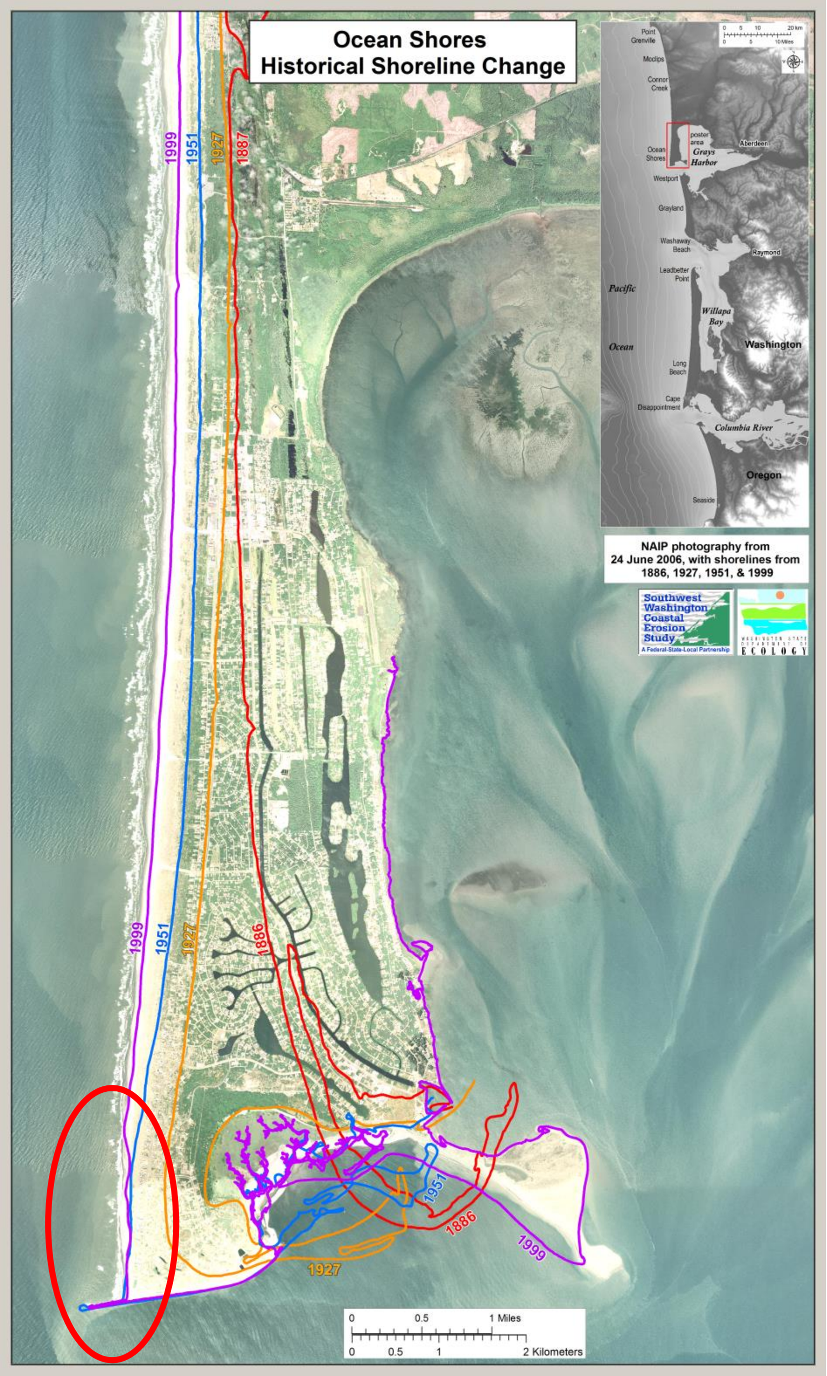


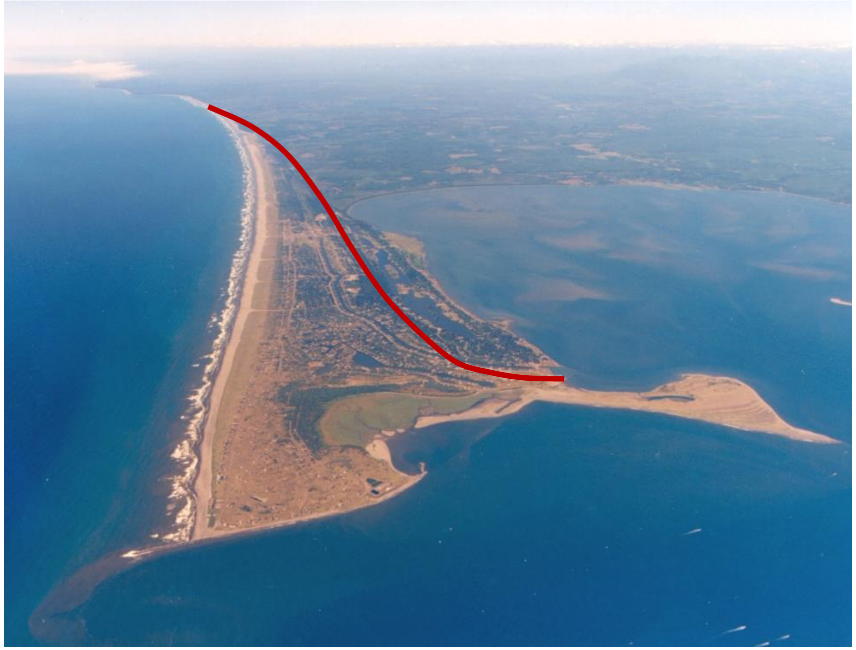
Profile "WORM"
Beach Volume Change Trend is -4.8 m³/m/yr (R² = 0.78)
Height Change Trend is -12.9 cm/yr
Dune Volume Change Trend is -6.3 m³/m/yr (R² = 0.93)
x 41
DUNE
BEACH
Winter
Spring
Summer
Fall
Dune Volume (m³/m alongshore)
Beach Volume (m³/m alongshore)
Date
DUNE
BEACH
Max Volume: Sumr 1997, 182.4 m³/m Sumr 1999, 184.7 m³/m
Min Volume: Wint 2015, 37.3 m³/m Wint 2015, 54.7 m³/m
Max 9-mo Accretion: Spri 1999 to Wint 2000, 23.5 m³/m Fall 1998 to Sumr 1999, 51.3 m³/m
Max 9-mo Erosion: Sumr 2014 to Wint 2015, -35.5 m³/m Sumr 1999 to Wint 2000, -51.8 m³/m
Most Stable 9-mo: Spri 2004 to Wint 2005, 1.7 m³/m Spri 2010 to Wint 2011, 3.5 m³/m
DUNE -- Average Inter-season Changes -- BEACH
Summer 1997
Summer 1999
Spring 1999
Winter 2006
Winter 2013
Summer 2015
Winter 2015
Condos
Range Trend
5 m: 38 m -1.7 m/yr
4 m: 44 m -2.0 m/yr
3 m: 82 m -2.6 m/yr
2 m: 74 m -2.5 m/yr
1 m: 79 m -2.2 m/yr
Foundations at D= 173m
Scarp retreat rate = 2.2 m/yr
18 years at historical retreat rate
Elevation (m NAVD-88)
Cross-Shore Distance (m)

March 3, 2015

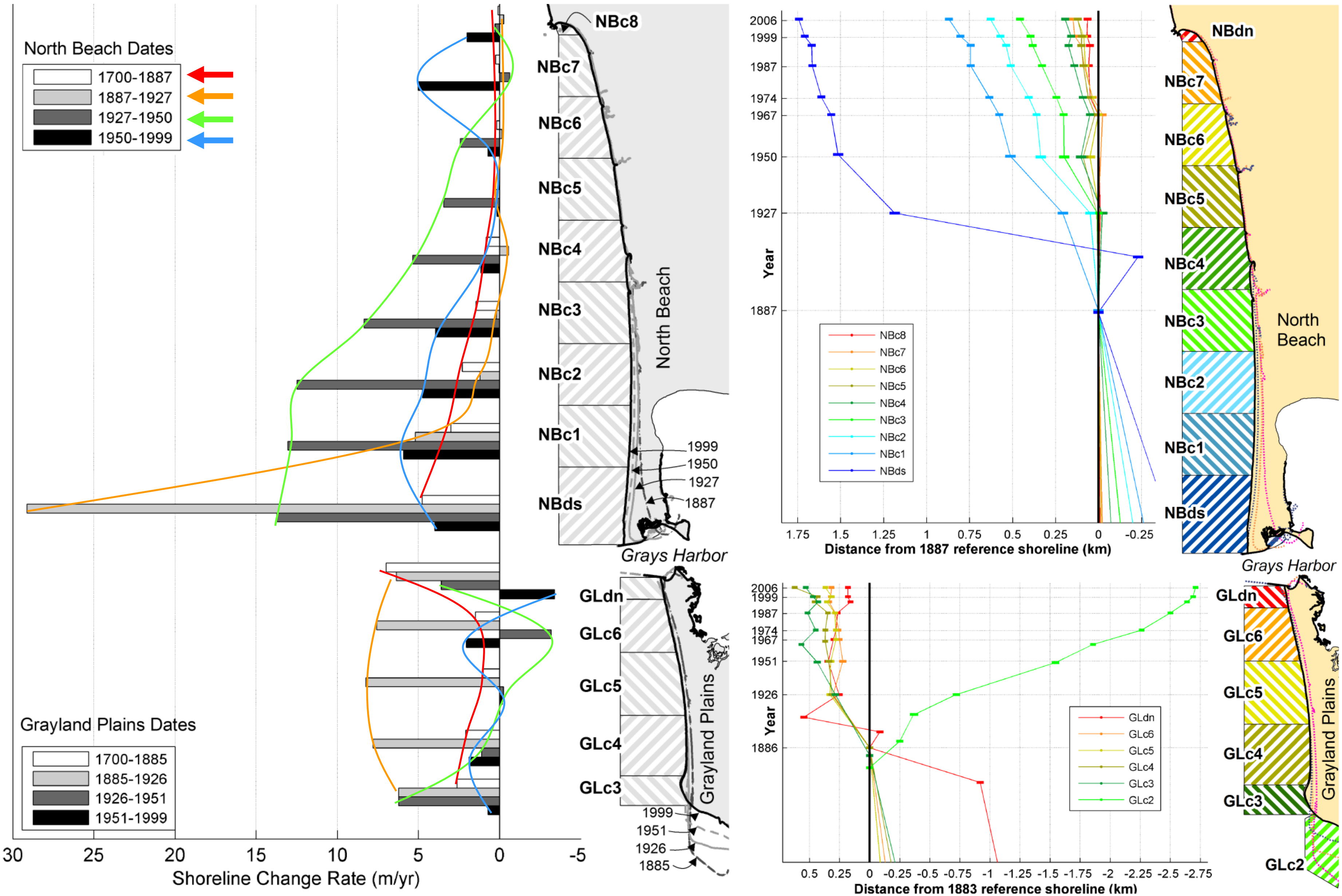
					Volume Change Trends (m^3/yr/m)			Total Volume (cubic yards per year)				
	Description		**Approx Northing**	Length of shoreline represented (m)	**DUNE**	**BEACH**	**DUNE + BEACH**	**DUNE**	**BEACH**	**DUNE + BEACH**	**Erosion only**	**Net loss or gain**
North Beach		**Diana**	199545	**3900**	9.8	10.2	20.0	**49,700**	**52,100**	**101,900**	**-25,800**	**487,300**
	the casino	**Casino**	196555	**2902**	3.5	14.4	17.9	**13,100**	**54,800**	**68,000**		
		Damons	193740	**2778**	10.5	21.2	31.7	**38,100**	**77,000**	**115,100**		
		ET	191000	**3068**	12.9	17.8	30.6	**51,600**	**71,400**	**123,000**		
		Butter	187605	**1800**	15.0	13.7	28.7	**35,300**	**32,200**	**67,400**		
		NB #19	187400	**604**	8.7	10.9	19.6	**6,800**	**8,600**	**15,500**		
		NB #14	186397	**909**	8.3	5.2	14.1	**9,900**	**6,200**	**16,700**		
	scarp ends	**NB #10**	185582	**499**	6.2	-2.8	4.1	**4,000**	**-1,800**	**2,700**		
		NB #9	185398	**195**	1.8	-2.4	-0.6	**500**	**-600**	**-100**		
		NB #8	185192	**203**	6.1	-5.2	-2.6	**1,600**	**-1,400**	**-700**		
		NB #7	184992	**196**	0.7	-6.6	-6.3	**200**	**-1,700**	**-1,600**		
		NB #6	184799	**196**	2.7	-9.8	-12.0	**700**	**-2,500**	**-3,100**		
		NB #5	184601	**198**	-2.0	-15.4	-16.1	**-500**	**-4,000**	**-4,200**		
		NB #4	184404	**183**	-5.7	-15.4	-21.5	**-1,400**	**-3,700**	**-5,200**		
	geobags	**X1-North**	184235	**100**	-0.4	-8.3	-8.8	**-100**	**-1,100**	**-1,200**		
		NB #3	184204	**115**	-3.8	-11.6	-17.5	**-600**	**-1,700**	**-2,600**		
	wave	**NB #2**	184005	**128**	-4.3	-12.8	-22.9	**-700**	**-2,100**	**-3,800**		
	bumpers	**X1-South**	183948	**102**	0.0	-7.1	-7.6	**0**	**-1,000**	**-1,000**		
	North Jetty	**NB #1**	183801	**146**	7.0	-4.5	2.7	**1,300**	**-900**	**500**		
					Grays Harbor							
Grayland Plains	*South Jetty*	**HD-1**	180642	**1120**	1.3	-2.8	-1.4	**2,000**	**-4,100**	**-2,100**	**-63,100**	**-26,900**
	Westport By	**Worm**	179078	**877**	-7.2	-7.8	-15.0	**-8,300**	**-8,900**	**-17,200**		
	the Sea	**GP #85**	178887	**195**	-2.8	-7.0	-11.5	**-700**	**-1,800**	**-2,900**		
		GP #84	178687	**188**	0.2	-7.4	-9.5	**0**	**-1,800**	**-2,300**		
		GP #83	178512	**149**	-0.7	-6.3	-4.5	**-100**	**-1,200**	**-900**		
		GP #82	178389	**362**	NaN	-6.7	NaN	NaN	**-3,200**	NaN		
		Spice	177787	**1776**	-4.9	-7.1	-12.0	**-11,400**	**-16,400**	**-27,800**		
	scarp ends	**Rdan**	174837	**2900**	8.3	-1.4	6.9	**31,500**	**-5,200**	**26,300**		

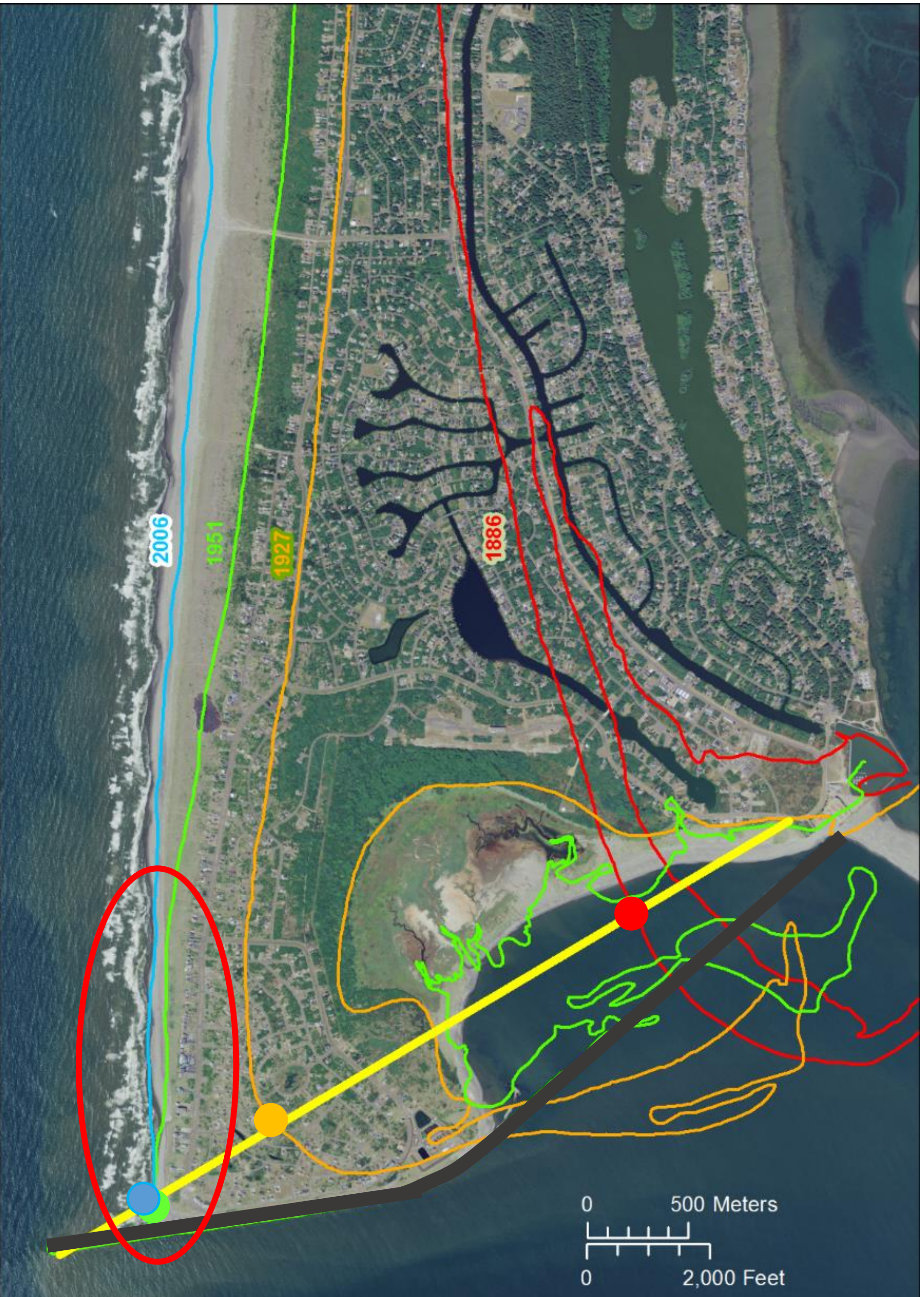
Historical Shoreline Change



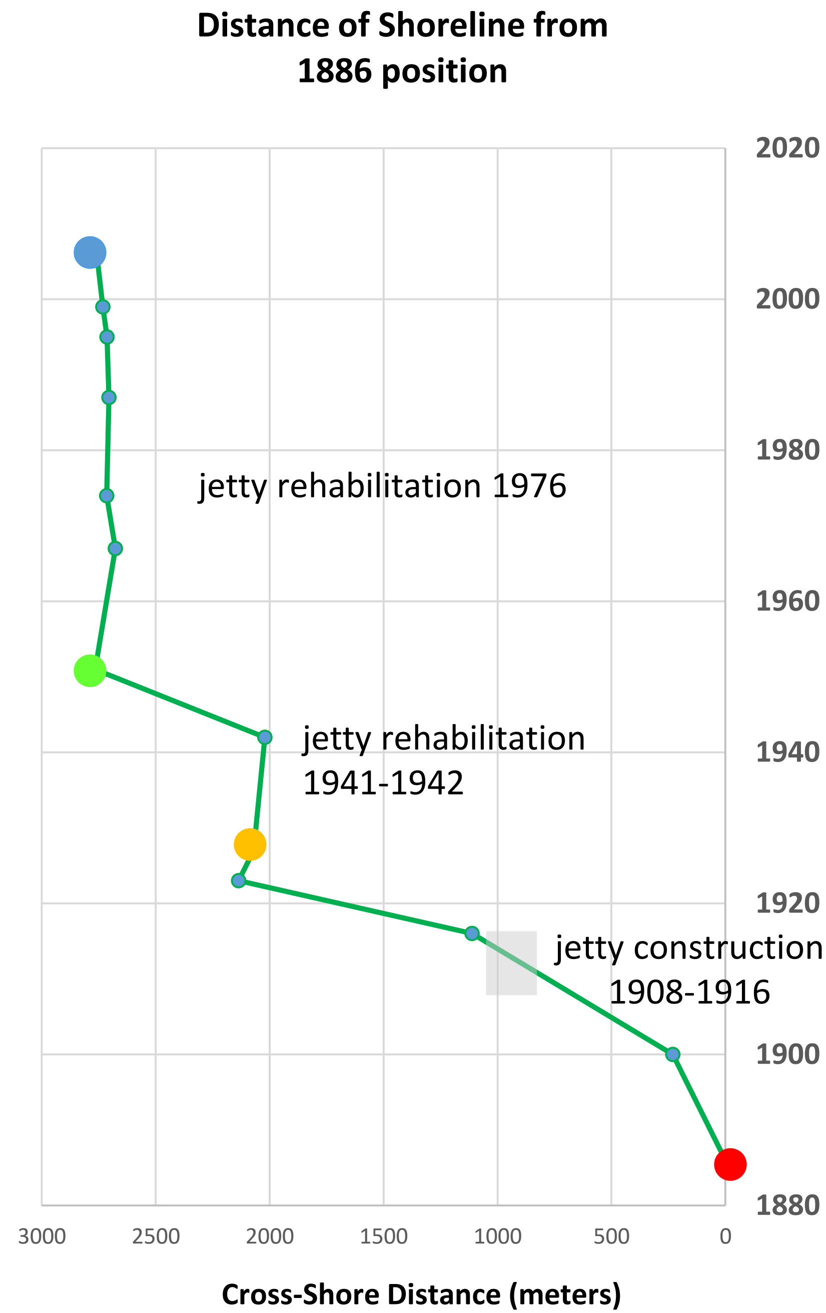


Historical Shoreline Change





2006
1951
1927
1886
0 500 Meters
0 2,000 Feet



Distance of Shoreline from 1886 position
jetty rehabilitation 1976
jetty rehabilitation 1941-1942
jetty construction 1908-1916
2020
2000
1980
1960
1940
1920
1900
1880
3000
2500
2000
1500
1000
500
0
Cross-Shore Distance (meters)

Photo courtesy of Nick Bird, City of Ocean Shores

Photo courtesy of Nick Bird, City of Ocean Shores

November 2, 2015


November 9, 2015
Nourishment


March 8, 2016
Rock revetment

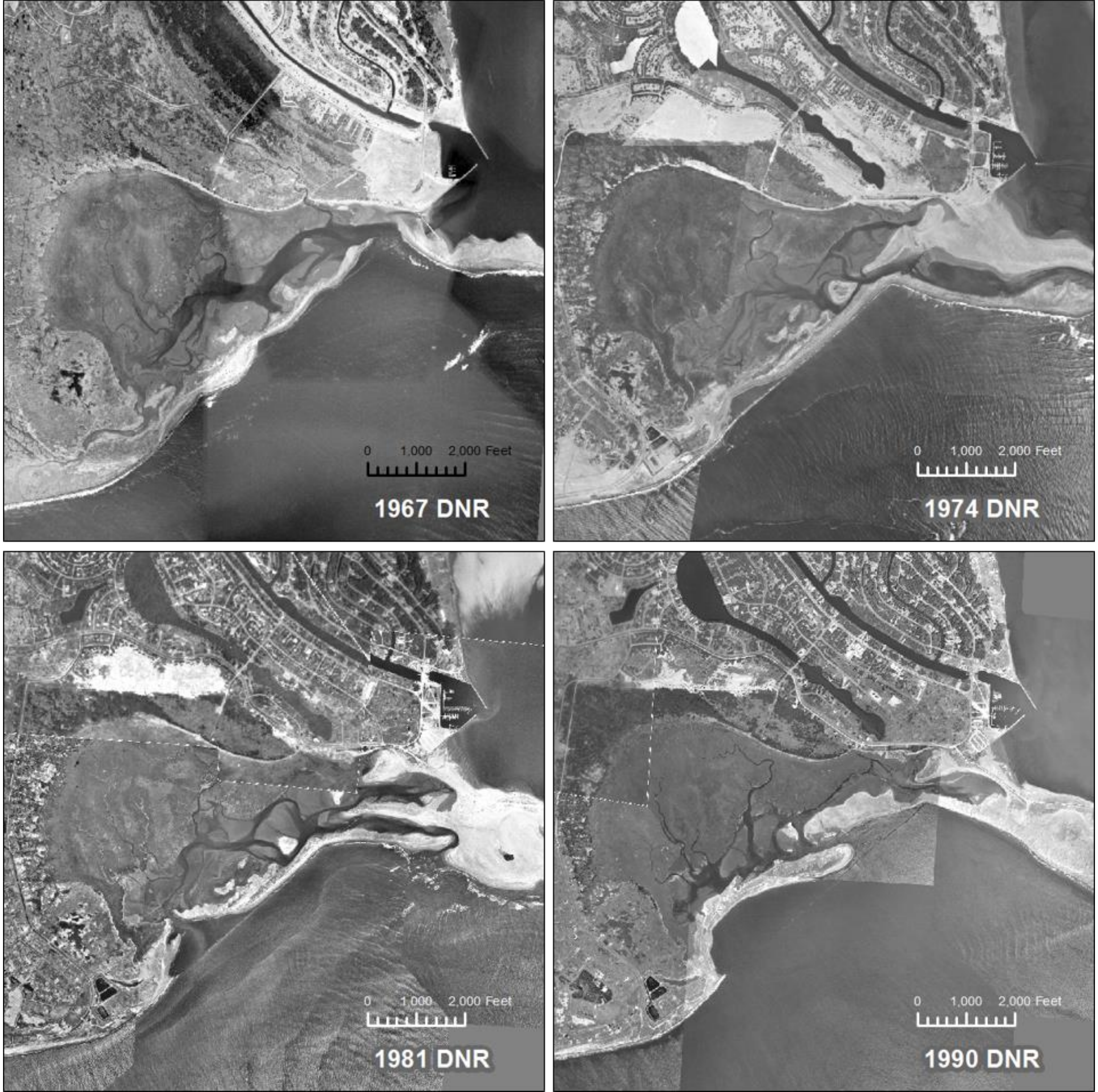

June 4, 2016
End scour

N
100 m
Google Earth imagery (8/17/2016)

Ocean Shores North Jetty Summary

- North Jetty is deteriorating and affects shoreline stability
- Aggravated erosion occurring at end of rock structures
- Lack of suitable transitions between rock and dune sand
- Dune erosion scarp extends from jetty to 1.9 km north along shoreline
- Average erosion of 25,800 cubic yards/year of sediment from beaches and dunes
- A dune breach represents the highest risk to upland infrastructure
- Sand fences during Spring to Fall may help to increase resilience during the subsequent winter
- Beach and dune nourishment offers only a temporary solution
- Rehabilitation of Grays Harbor North Jetty is critical to preventing a chronic erosion problem


Oyhut Erosion Hazard Area
projected from 2018 to 2028
with 2006-2016
changerates in ft/yr
222000
222500
223000
223500
186000
185500
185000
184500
184000
meters
-82.5
-58.4
-32.5
-65.5
-65.5
-68.9
-77.8
-62.6
-20.3
-16.8
-14.3
-11.9
-6.9
-6.2
-5.2
-6.6
-10
-2.1
Ocean Shores City Limits
Legend
> 2 meters (6.5 ft) per year
1 - 2 meters per year
< 1 meter (3.3 ft) per year
N
0
500
1,000
1,500 Feet
Map Projection: Washington State Plane South, NAD-83, meters
Washington State Department of Ecology
Coastal Monitoring & Analysis Program
Photo: 2015 NAIP
222000 meters
222500
223000
223500


0 1,000 2,000 Feet
1967 DNR
0 1,000 2,000 Feet
1974 DNR
0 1,000 2,000 Feet
1981 DNR
0 1,000 2,000 Feet
1990 DNR


0 1,000 2,000 Feet
1999 DNR
0 1,000 2,000 Feet
2006 NAIP
0 1,000 2,000 Feet
2011 NAIP
0 1,000 2,000 Feet
2015 NAIP

Southwest Washington Coastal Erosion Study Results

- The coast between Tillamook Head, OR and Point Grenville, WA (~ 100 miles) relies on sand supplied by the Columbia River
- Compared to geologic-scale change (~ 4-6,000 years), beach accretion and erosion have accelerated since the onset of jetty construction (~ 100 years)
- Jetty construction modified the ebb deltas, changing local sediment supply to shoreline for tens of kilometers and decades
- Sand was redistributed from deltas to adjacent beaches
- Dredging volumes are significant relative to the sediment budget
- Sand volumes necessary to maintain current shoreline positions have been estimated by historical change analyses, beach monitoring, and shoreline modeling
- Recent beach erosion is result of decrease local supply of sand from ebb deltas and the jetty condition at Ocean Shores
- Knowledge of coastal change across a range of space and time scales has informed management and mitigation approaches.

Take Home Points

- Coastal erosion is influenced by jetties and other coastal structures (long term, short term, maintenance)
- Sand nourishment reduces coastal erosion
- Cobble berms/dynamic revetments tend to reduce erosion with minimal impact
- Coastal erosion intensity varies based on sediment budget, wave climate, and sea-level
- Elements of successful projects have included:
  - Assessment and monitoring
  - Regional scientific context
  - Regional strategy and alternative approaches
  - Collaborative project development
  - Examples: Benson Beach, North Cove, Shoalwater Bay, Westport, Ocean Shores North Jetty, Taholah