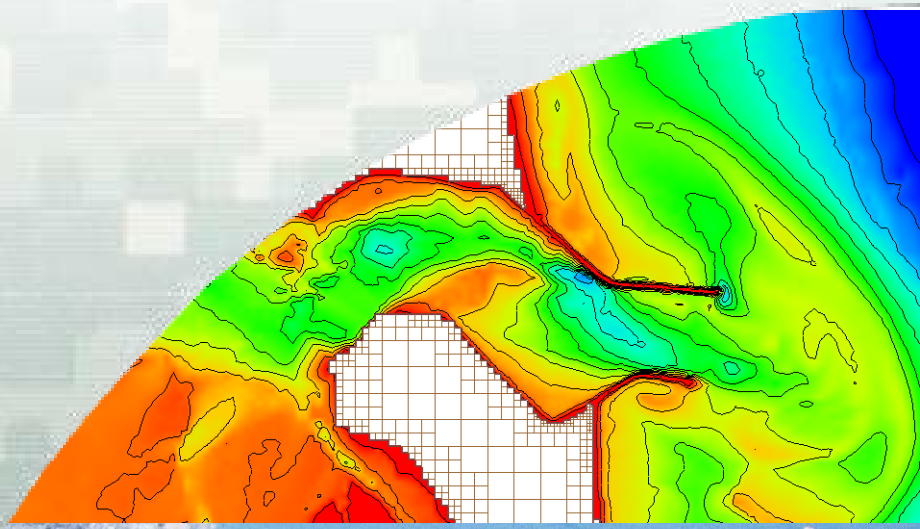
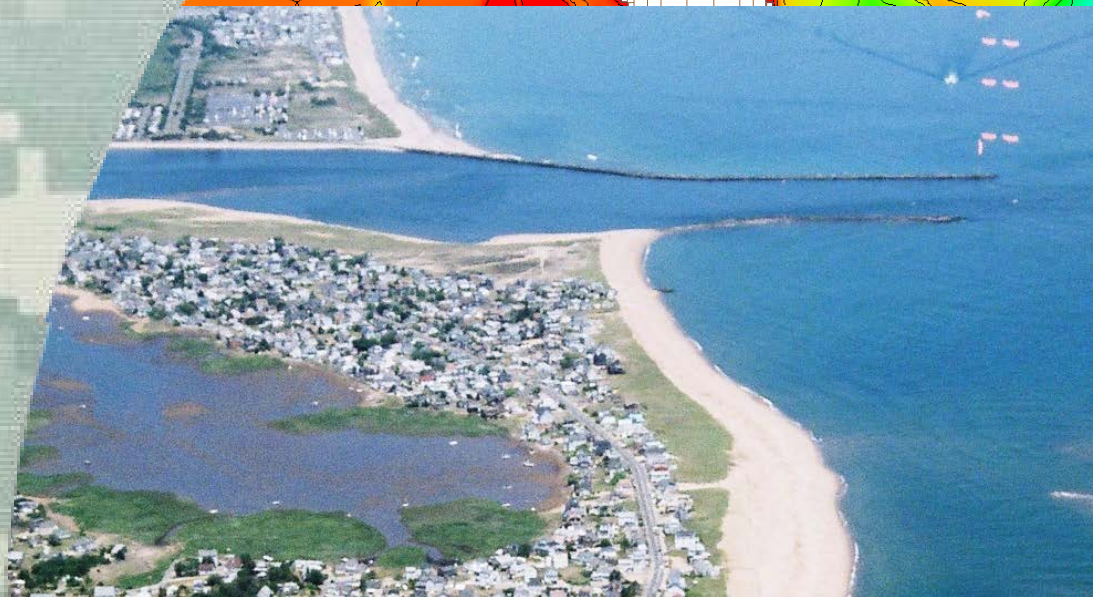
MERRIMACK ESTUARY AND NEWBURYPORT INLET, MASSACHUSETTS

Coastal Inlets Research Program

March 26, 2015





US Army Corps of Engineers

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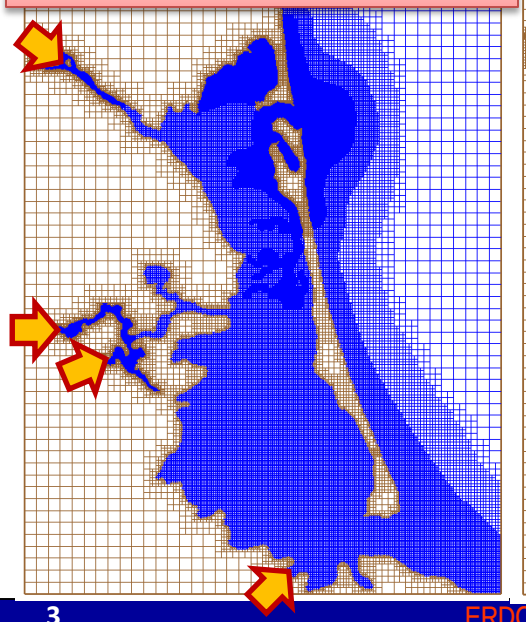
Outline

- Background
- Method
- Model calibration/validation
- Initial Alternatives for 1-mos simulations
- Selected additional Alternatives for 6-mos simulations
- Summary

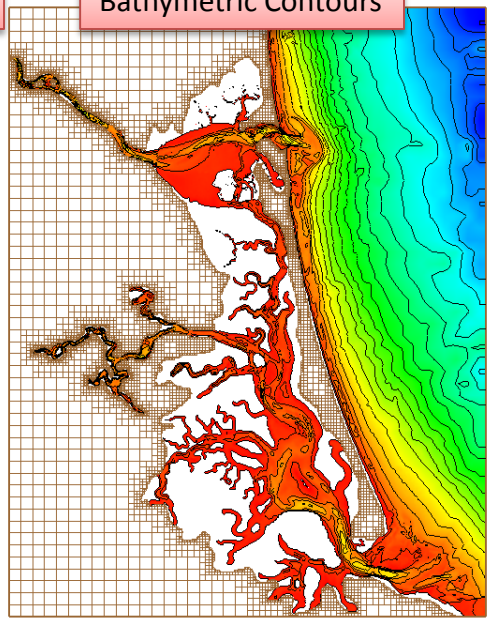
Background

- Merrimack Estuary (inlet system)
- Merrimack Inlet: adjacent to Salisbury Beach and Plum Island
- Newburyport Harbor: 5.6 km (3.5 miles) from the mouth of Merrimack River
- Merrimack Embayment: mixed-energy and tide-dominated inlet
- Mean tide range: 2.6 m (8.5 ft)
- Significant wave height: 1.0 m (3.3 ft) Dominant wave direction: northeast
- Sediment: coarse to very coarse

Grid with River Flow Input Locations



Bathymetric Contours



Problem and Objectives

Problem Statement:

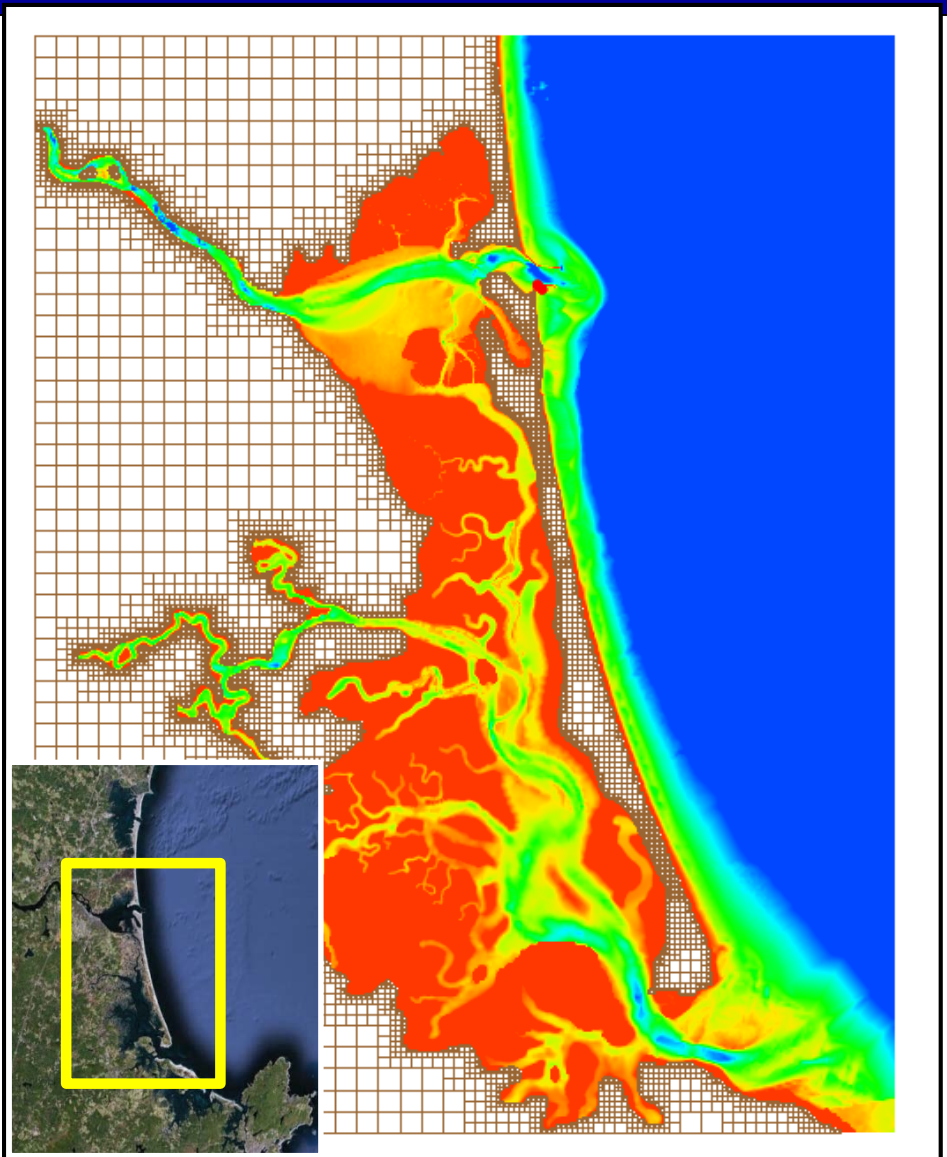
- Many of the beaches on Plum Island have experienced critical erosion – an average of 4 m (13 ft) of erosion between 2000 and 2009
- Erosion is threat to coastal properties and infrastructure
- Salisbury Beach has also experienced chronic erosion and the trend of erosion will continue into the future

Study Objectives:

- Reduce erosion of adjacent beaches
- Decrease shoaling and increase the navigability of Merrimack Inlet and Newburyport Harbor
- Increase performance of the jetties and develop a sand management strategy

Study Domain

- Plum Island Sound
- Merrimack River and Inlet
- Domain size: 15 x 20 km
- No of cells: ~ 73,000
- Cell size: 12 ~ 400 m
- Water depth: -4 ~ 40 m
- D_{50} : 0.2 ~ 1.1 mm

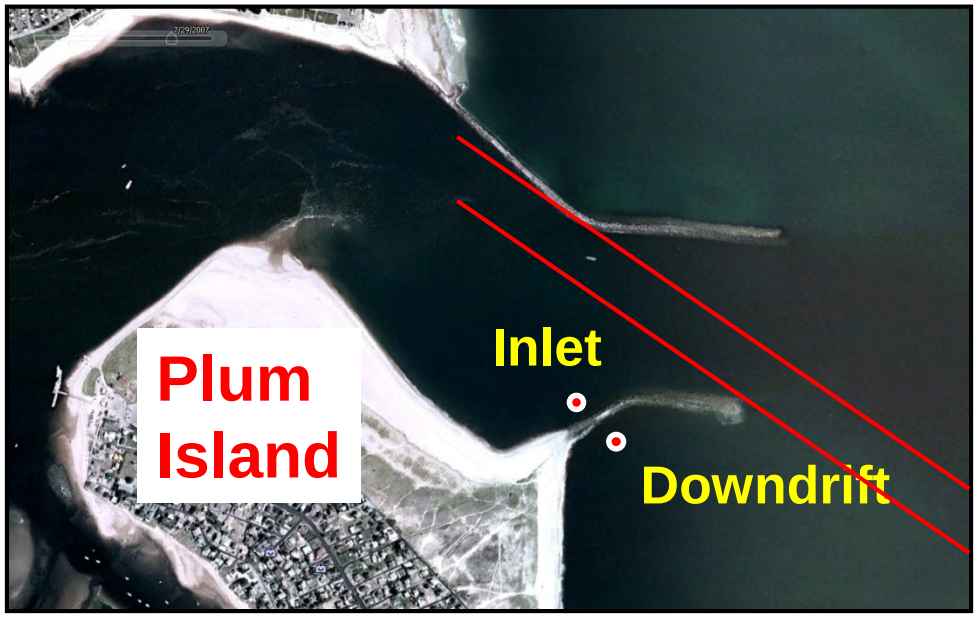


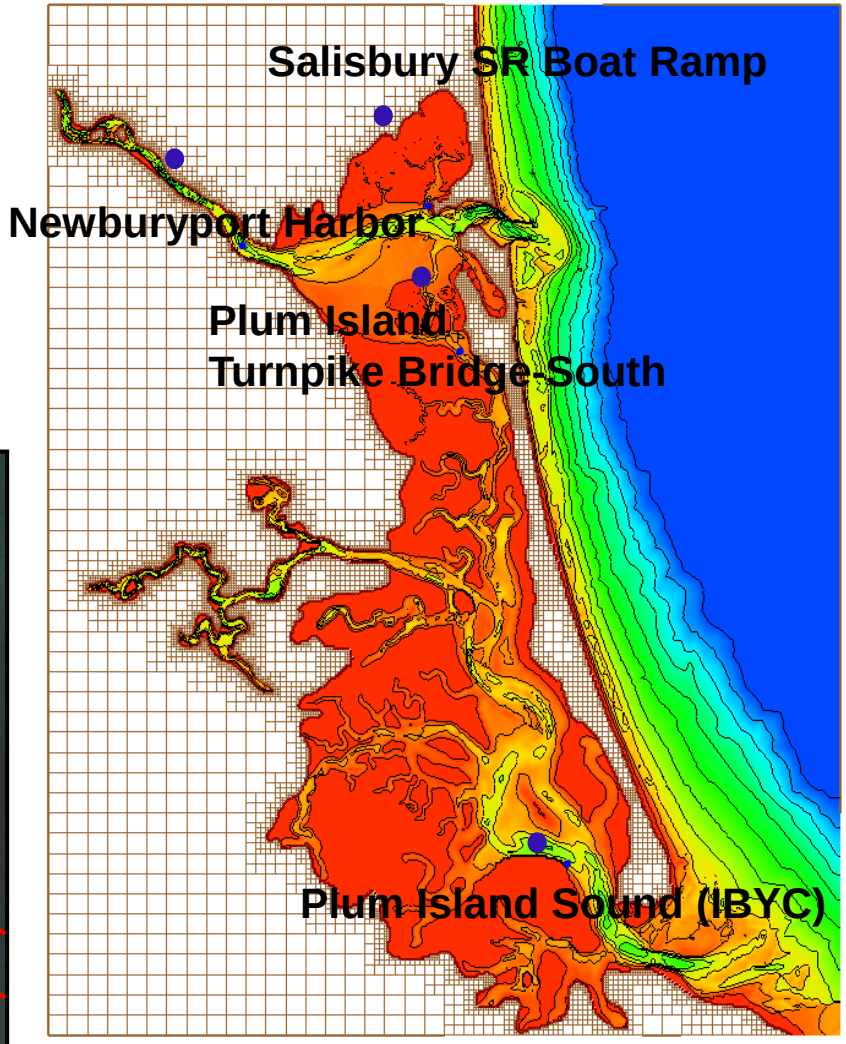
Hydrodynamic and Wave Forcing

- Tide (Fort Pt, NH)
- Wind (IOSN5)
- Waves (44098)
- Rivers (Merrimack, Mill, Parker, Ipswich)
- Low energy month (September 2012)
- High energy month (January 2011)
- Sediment grab sampling

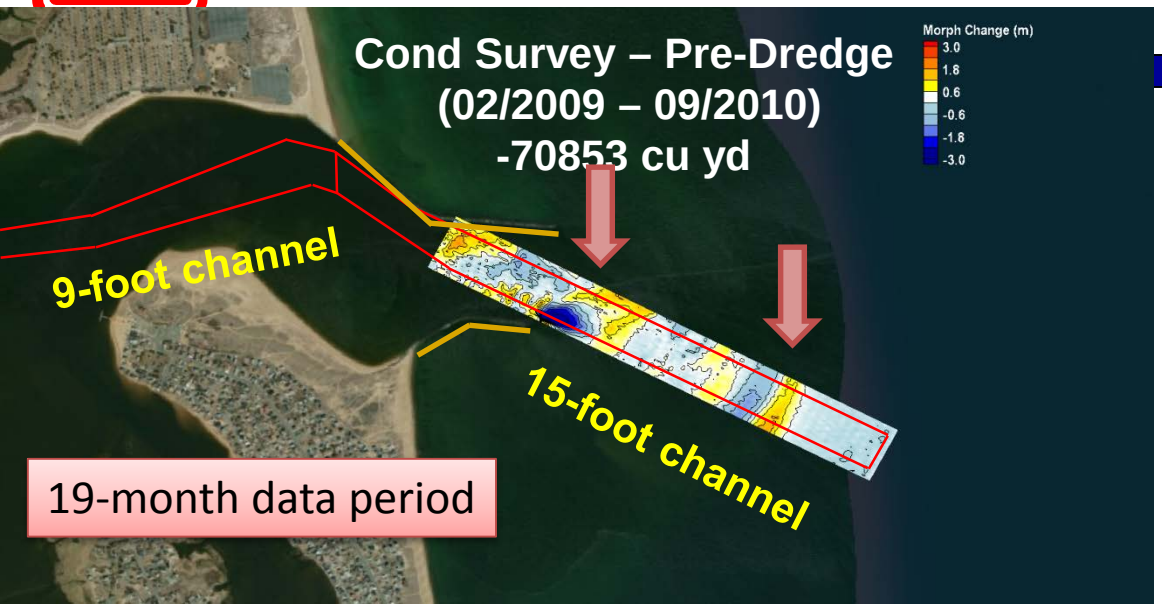
Model Calibration/Validation

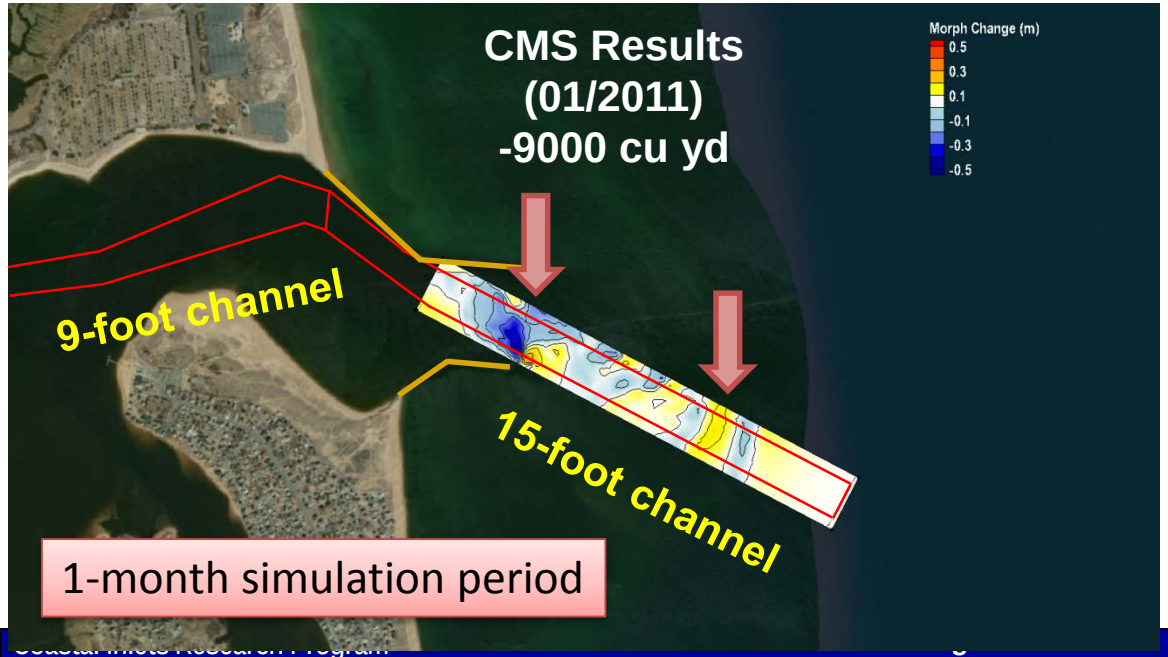
- 2 Acoustic Doppler Current Profile (ADCP) data sets
- 4 water level gauges
- Calibration – September 2012
- Validation - October 2012





Morphology Change





15-foot Channel Agreement:

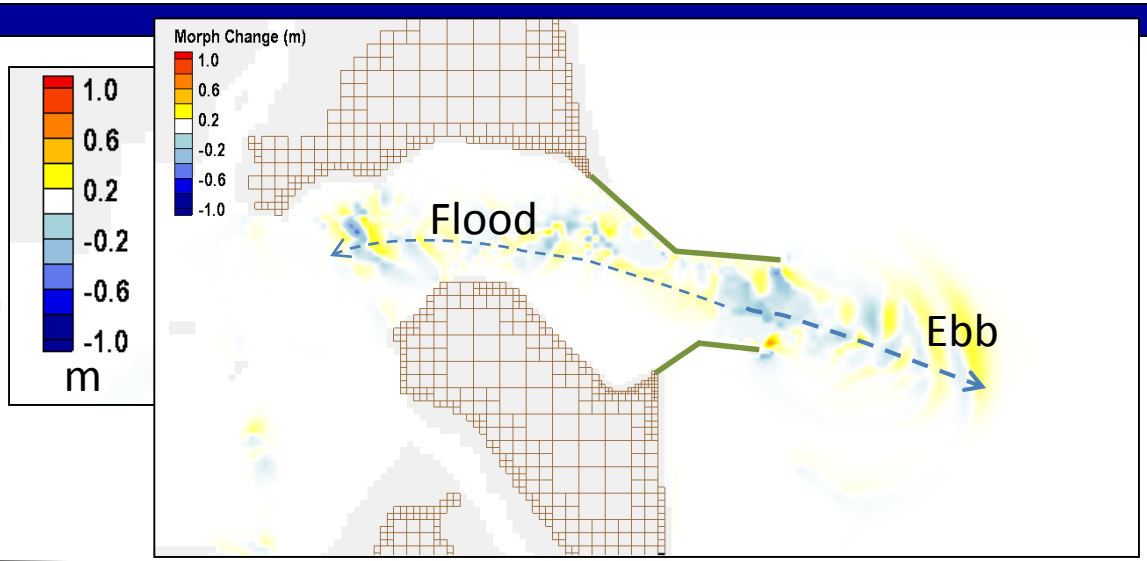
- Erosion in the channel
- Erosion hotspot at the tip of south jetty
- Erosion/accretion pattern at ebb shoal
- Similar Patterns

Morphology Change

September 2012

(Low Energy Month)

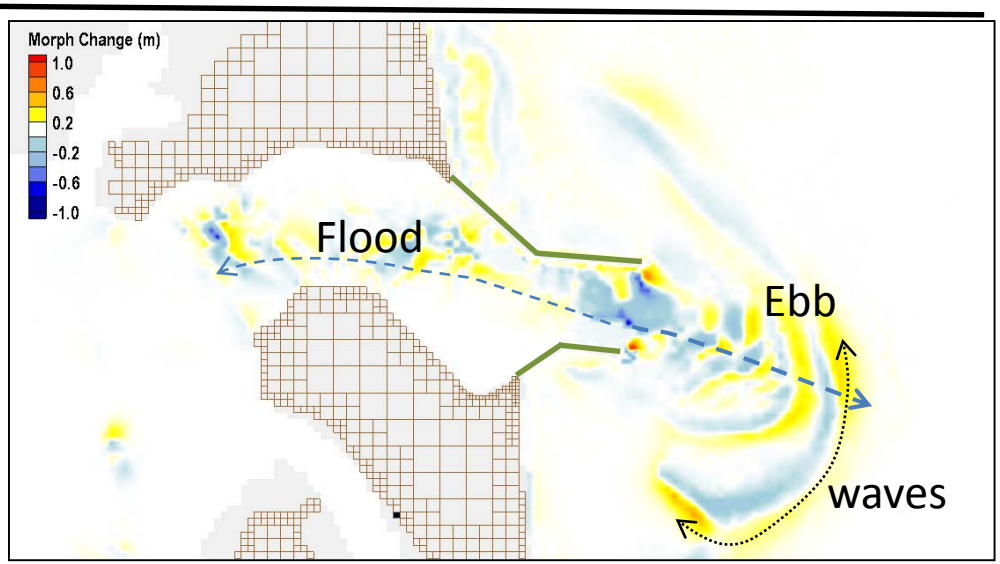
- Accretion on outer lobe of ebb shoal
- Some scour in channel
- Deposition near jetty tips



January 2011

(High Energy Month)

- Bar formation and bypassing from north around ebb tidal shoal
- Deposition on southeast lobe of ebb shoal
- Scour of inlet throat and deposition near jetty tips

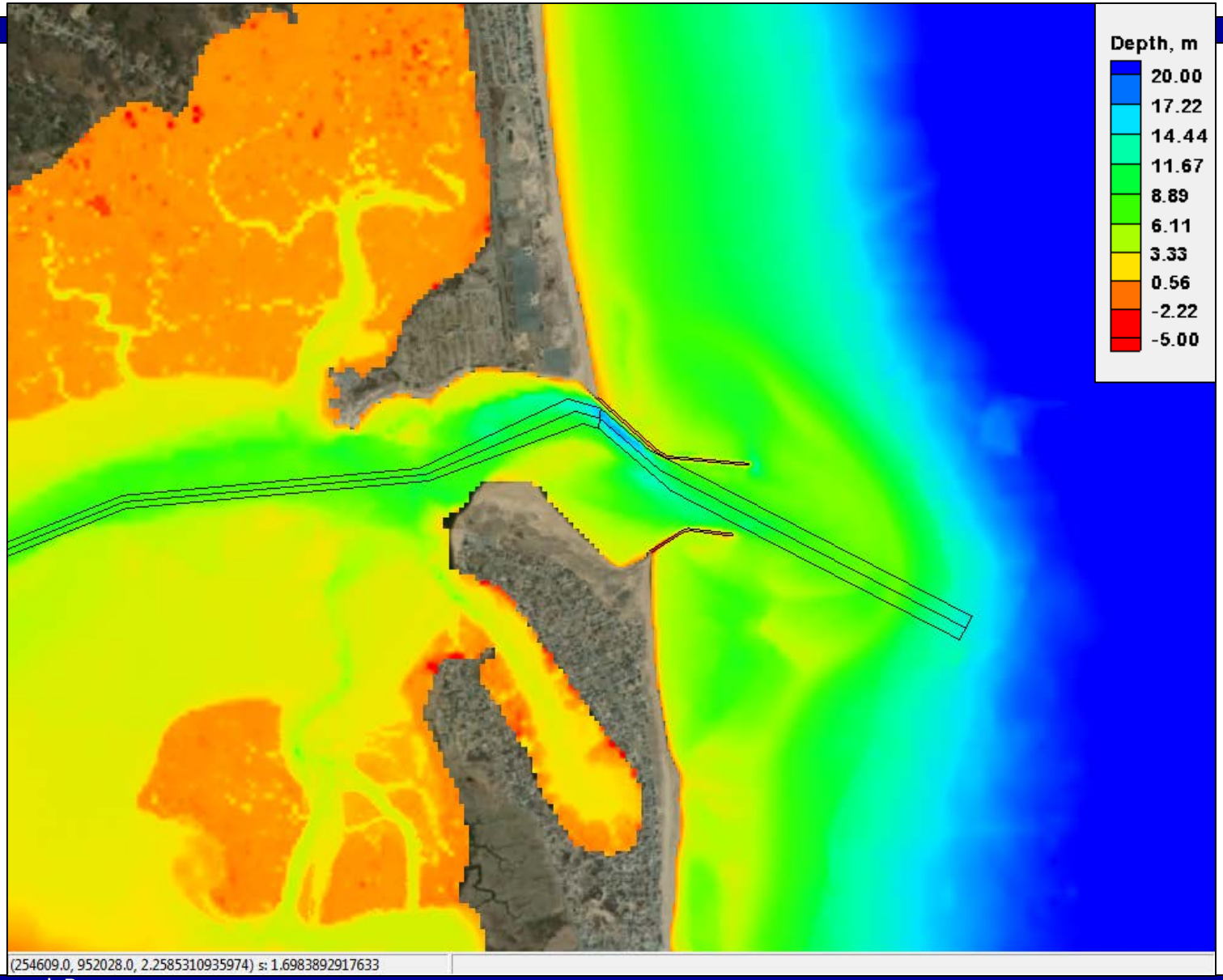


Alternatives for Initial Screening

- Simulations of High-Energy Month
- 19 Alternative configurations provided by New England district
  - Alternatives 1-3 – Calibration, Validation, Existing
  - Alternatives 4-19 – Structural and Sand Management Strategies

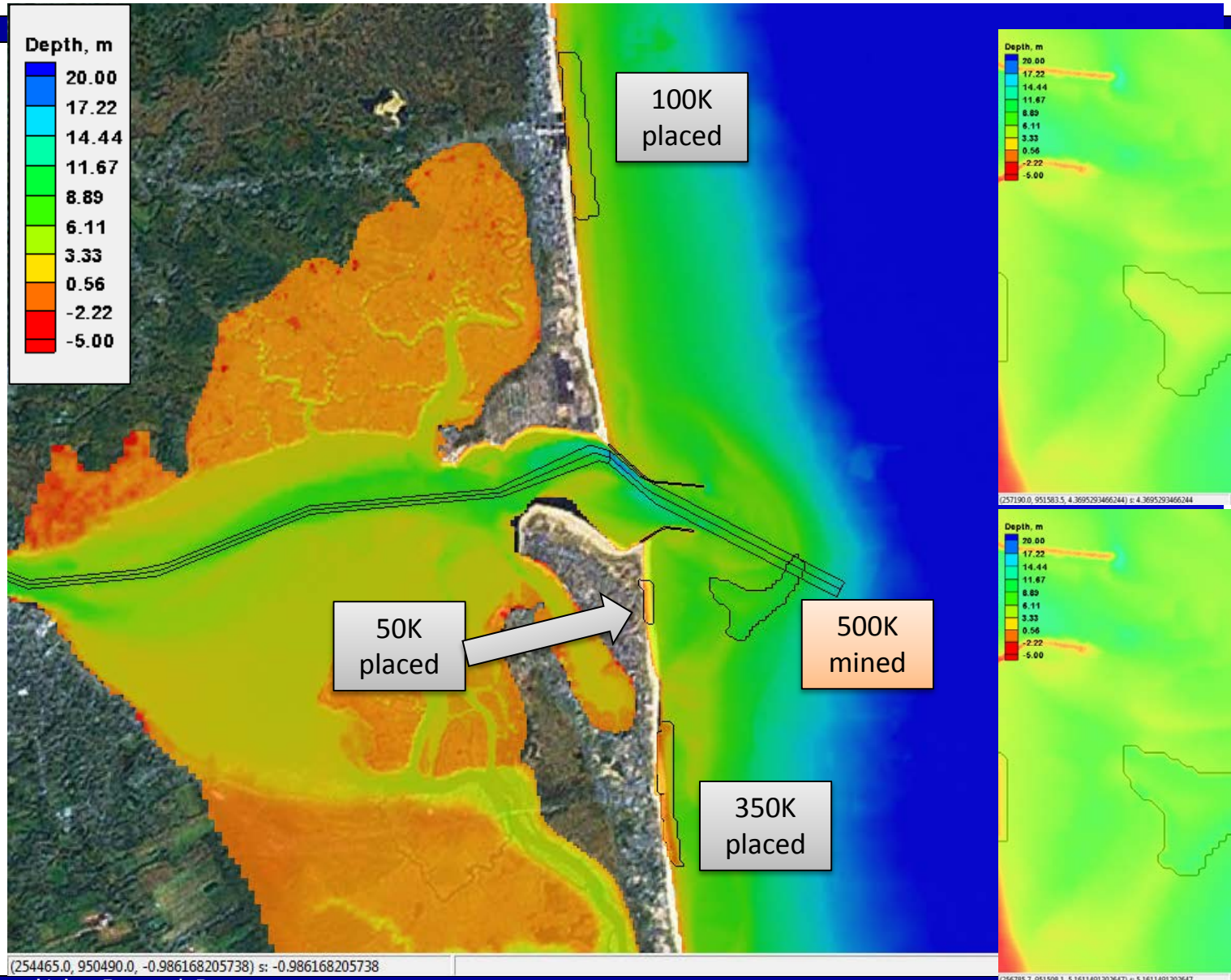
Alternative 4 (Base Condition)

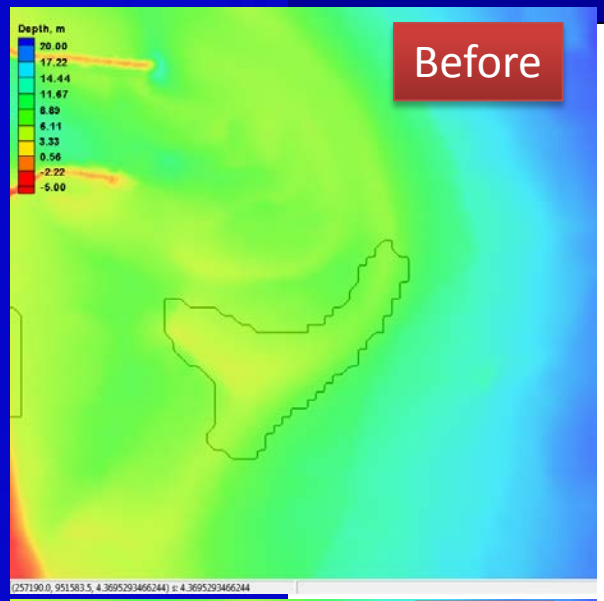
Partially Rehabilitated South Jetty

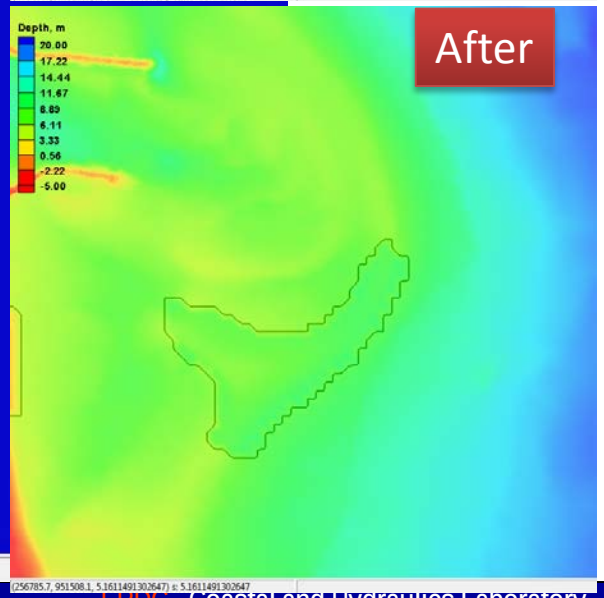


Alternative 5

Mine ebb delta 500K CY & Place 100K, 50K, 350K

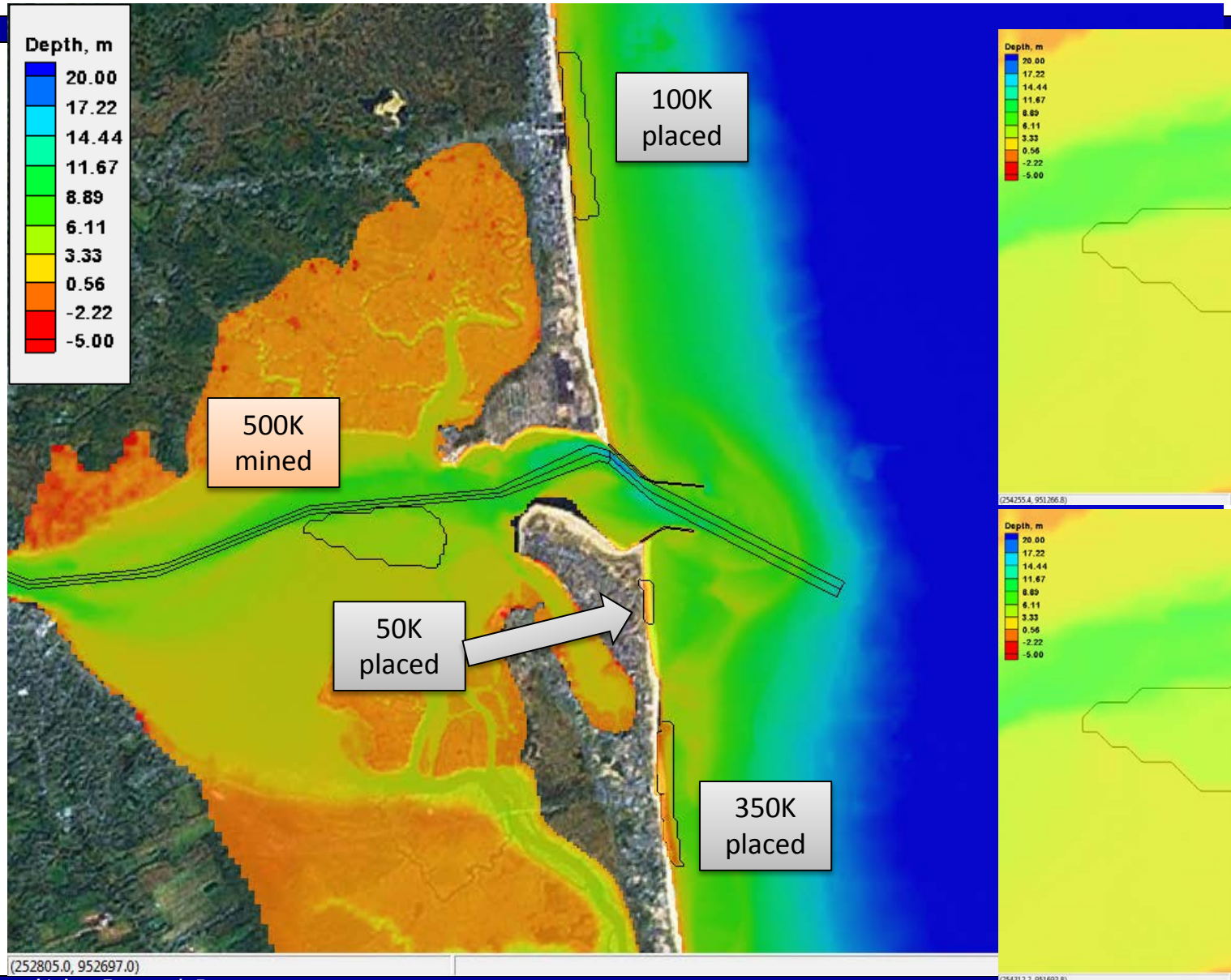


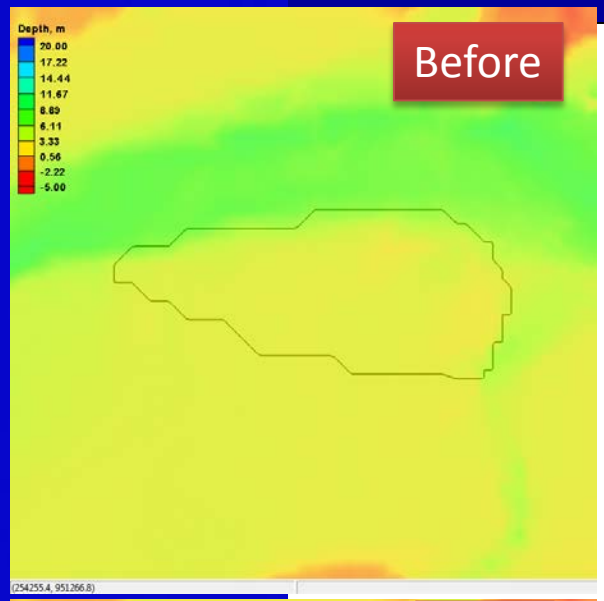


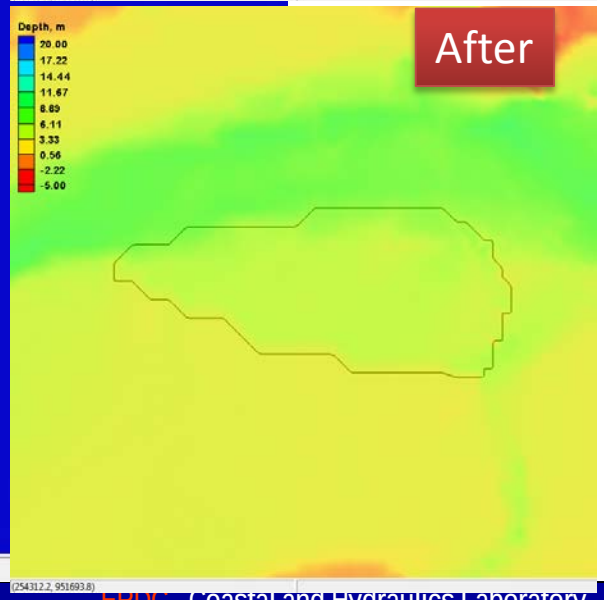


Alternative 6

Mine flood delta 500K CY & Place 100K, 50K, 350K

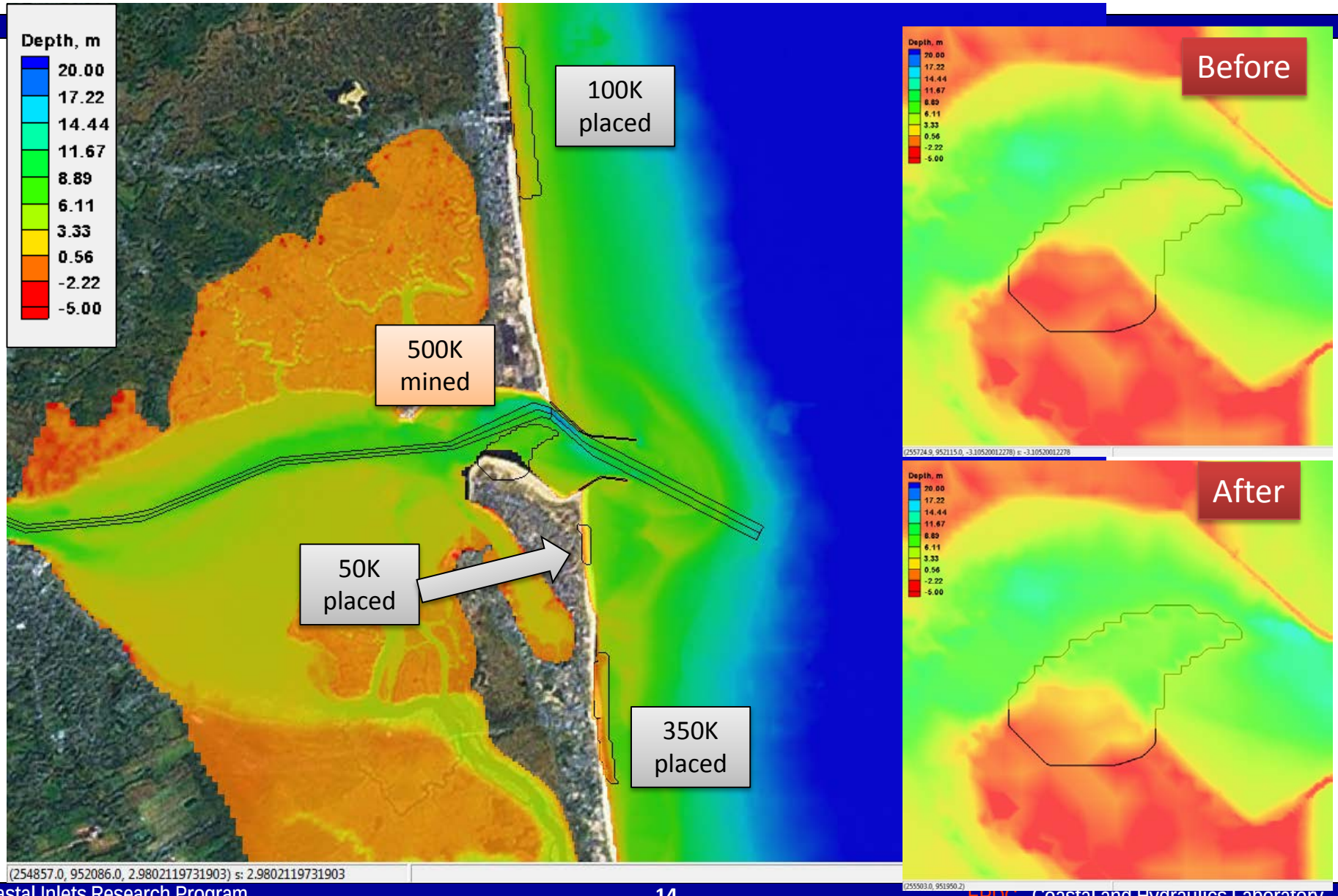






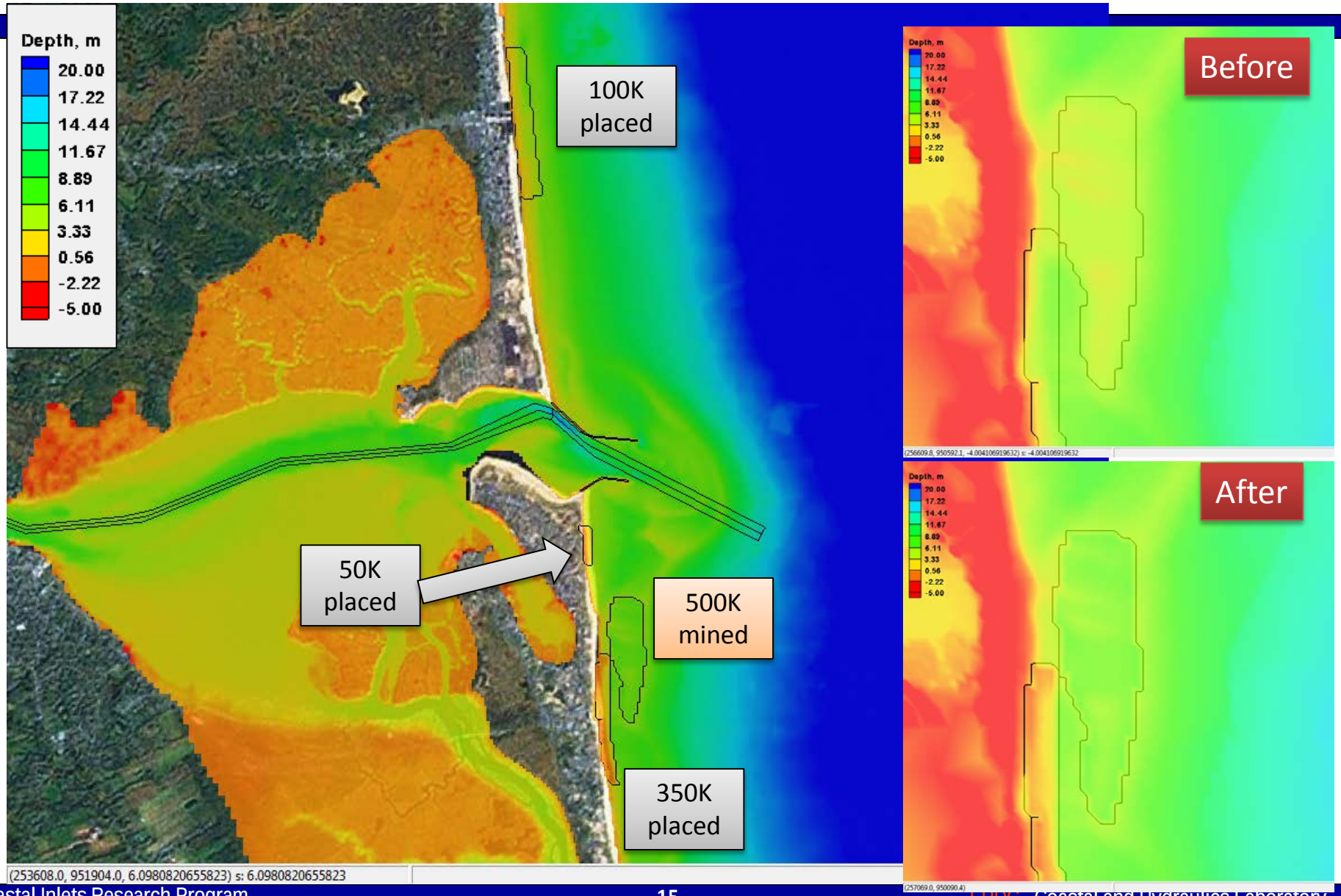
Alternative 7

Mine North Point 500K CY & Place 100K, 50K, 350K



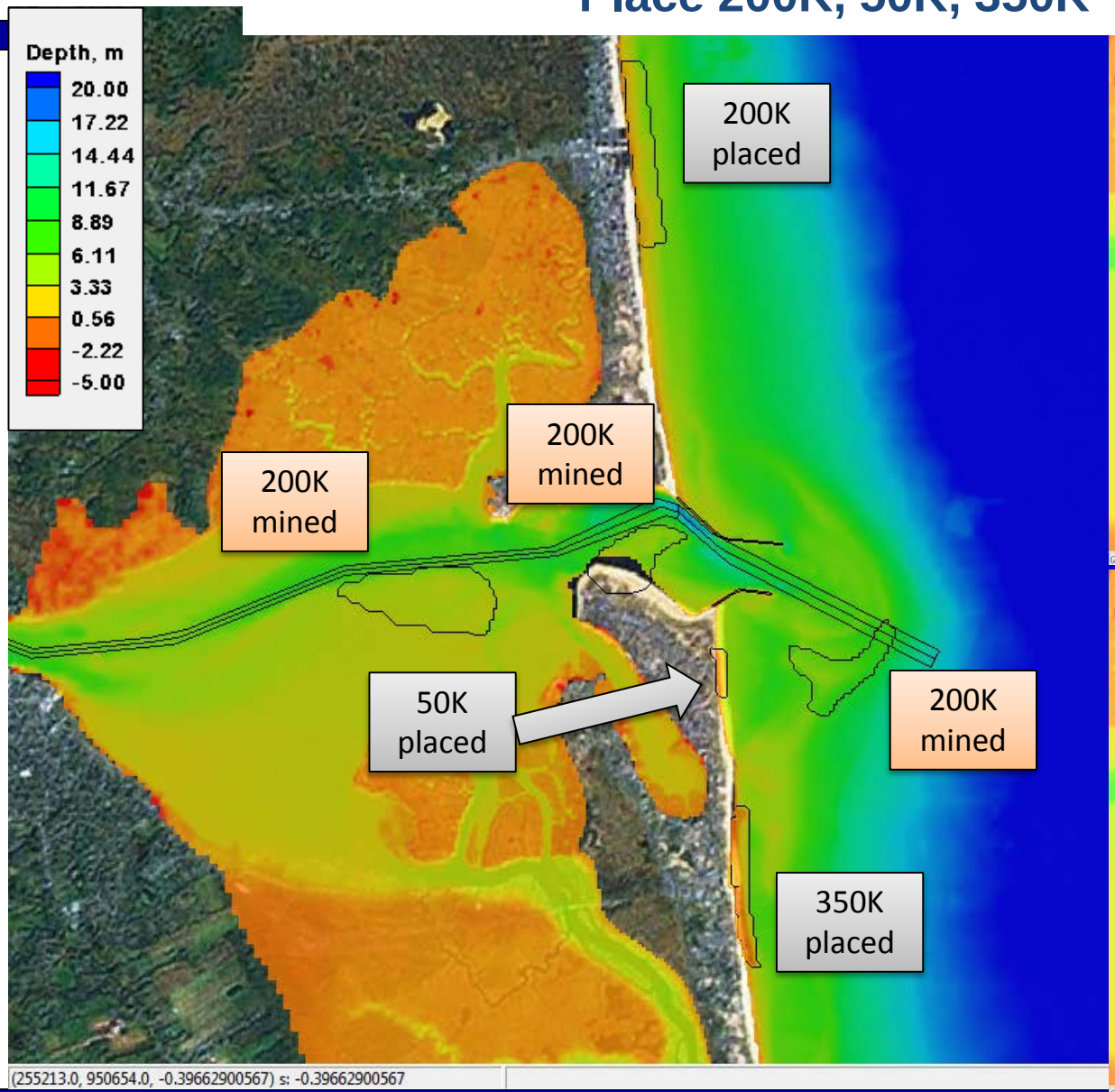
Alternative 8

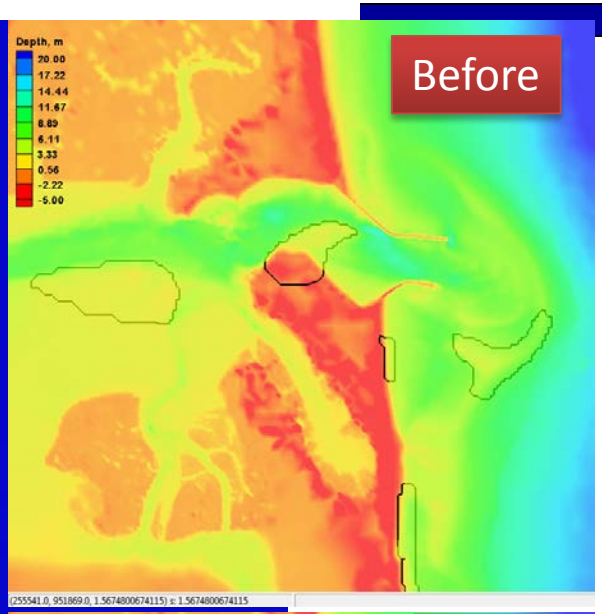
Mine nearshore bars 500K CY & Place 100K, 50K, 350K

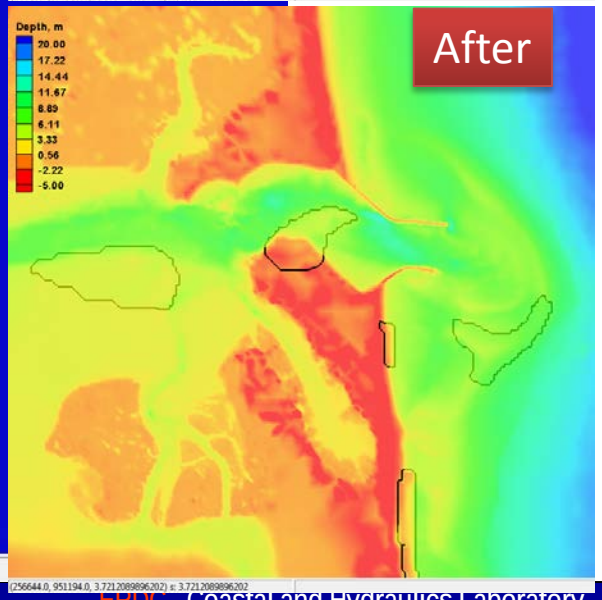


Alternative 9

Mine 200K CY each from ebb, flood, north point. Place 200K, 50K, 350K



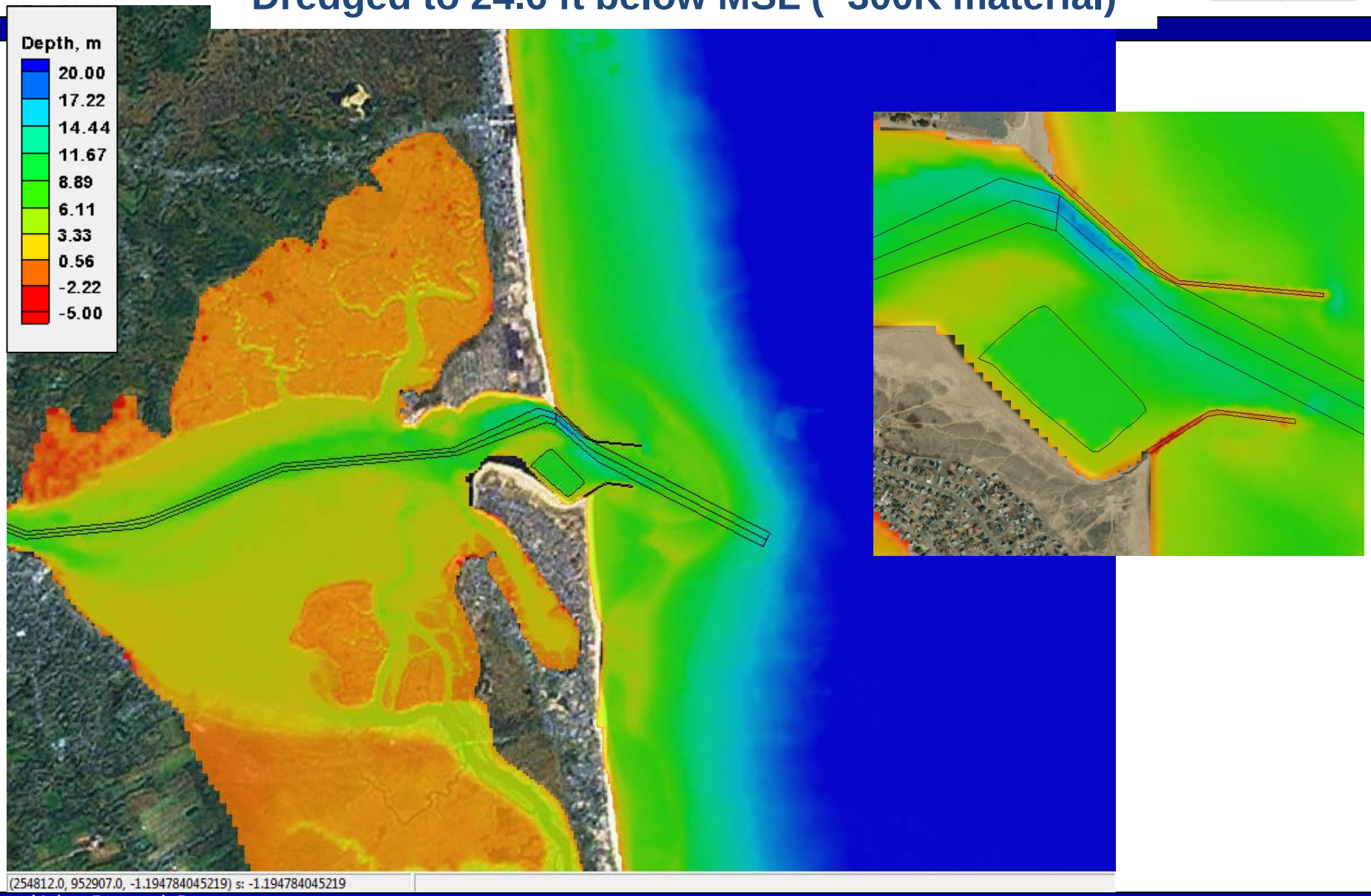




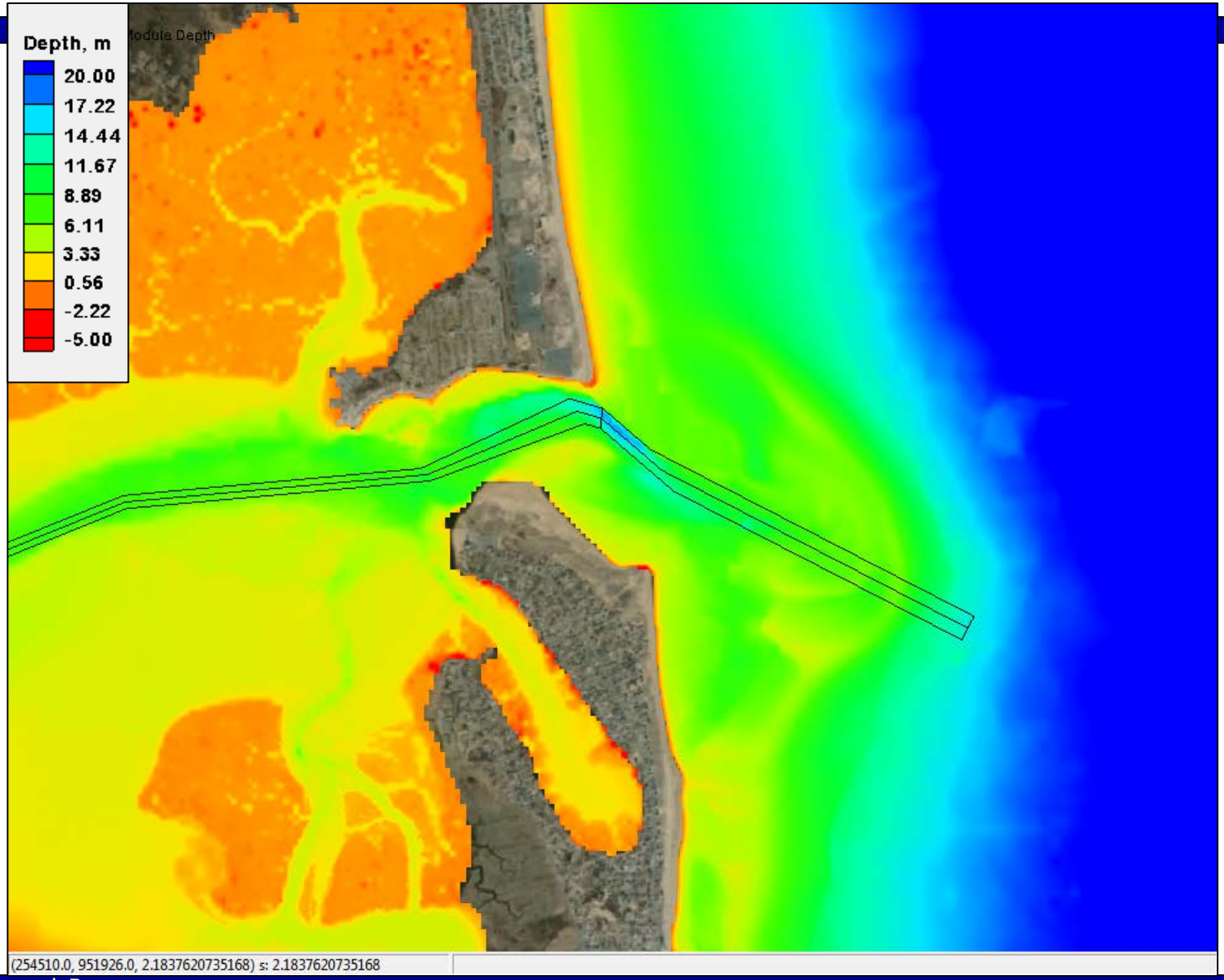
Alternative 10

Sedimentation Basin

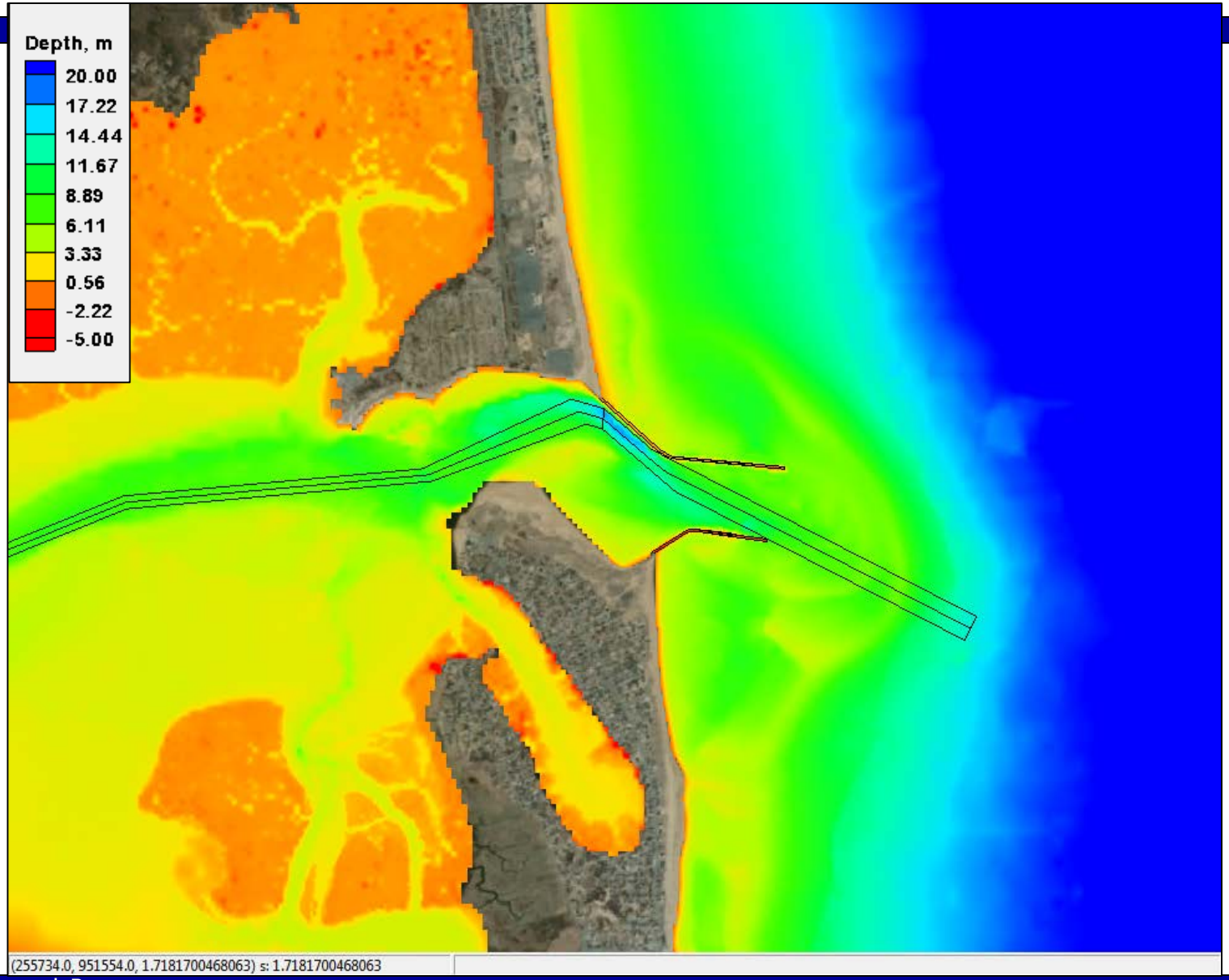
Dredged to 24.6 ft below MSL (~300K material)



Alternative 11
Removal of Both Jetties

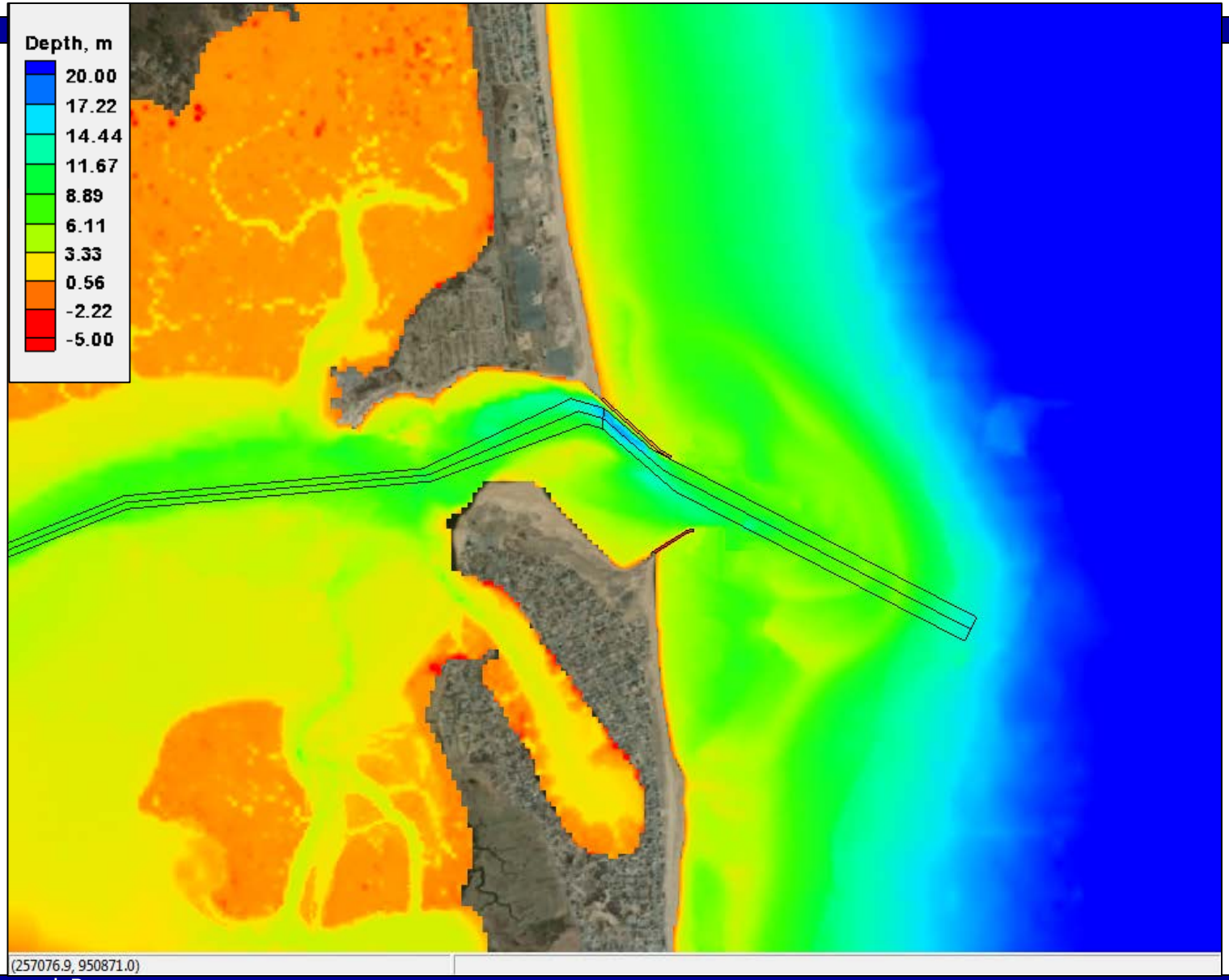


Alternative 12
Extend Jetties by 500 ft



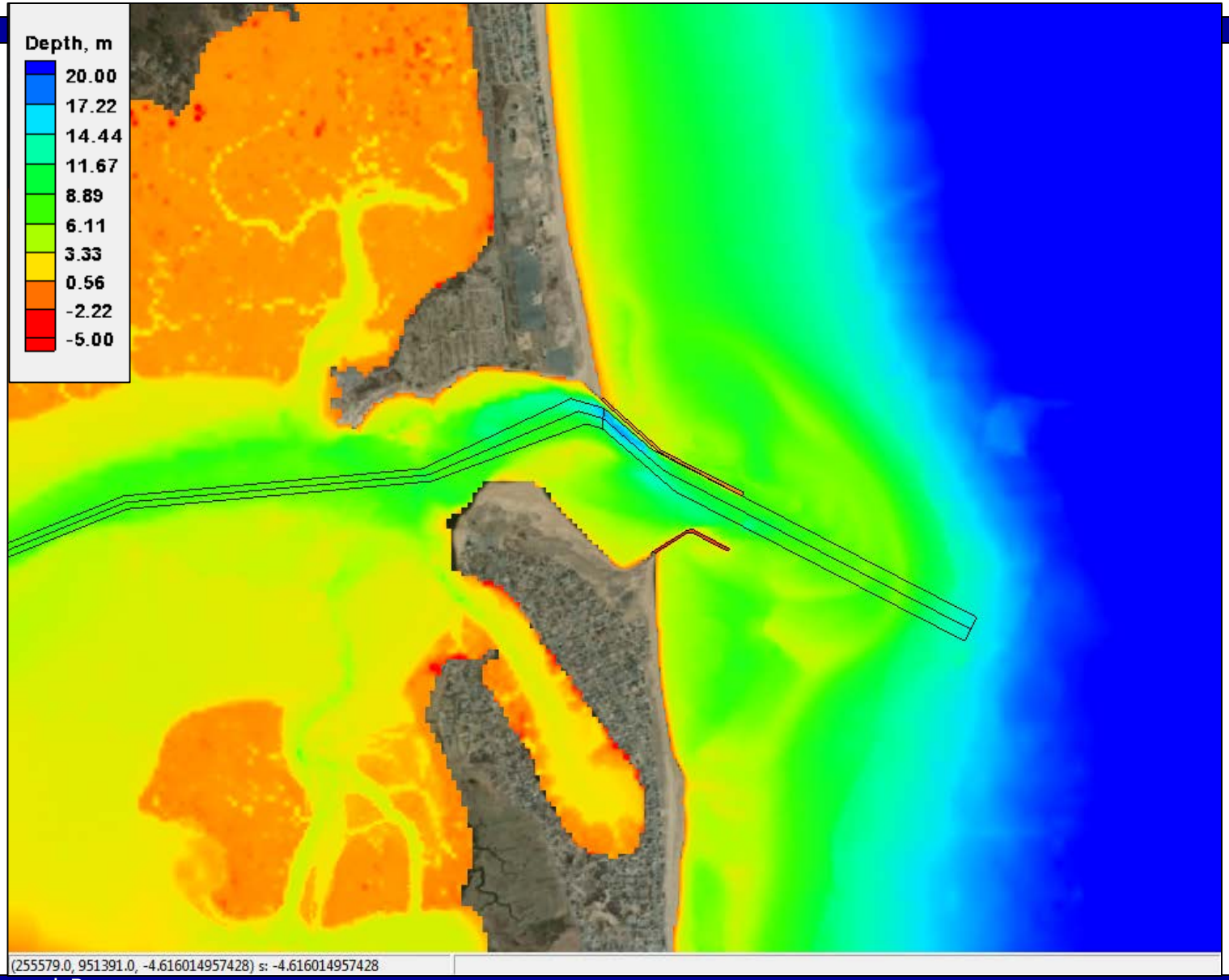
Alternative 13

Remove outer portion of both jetties

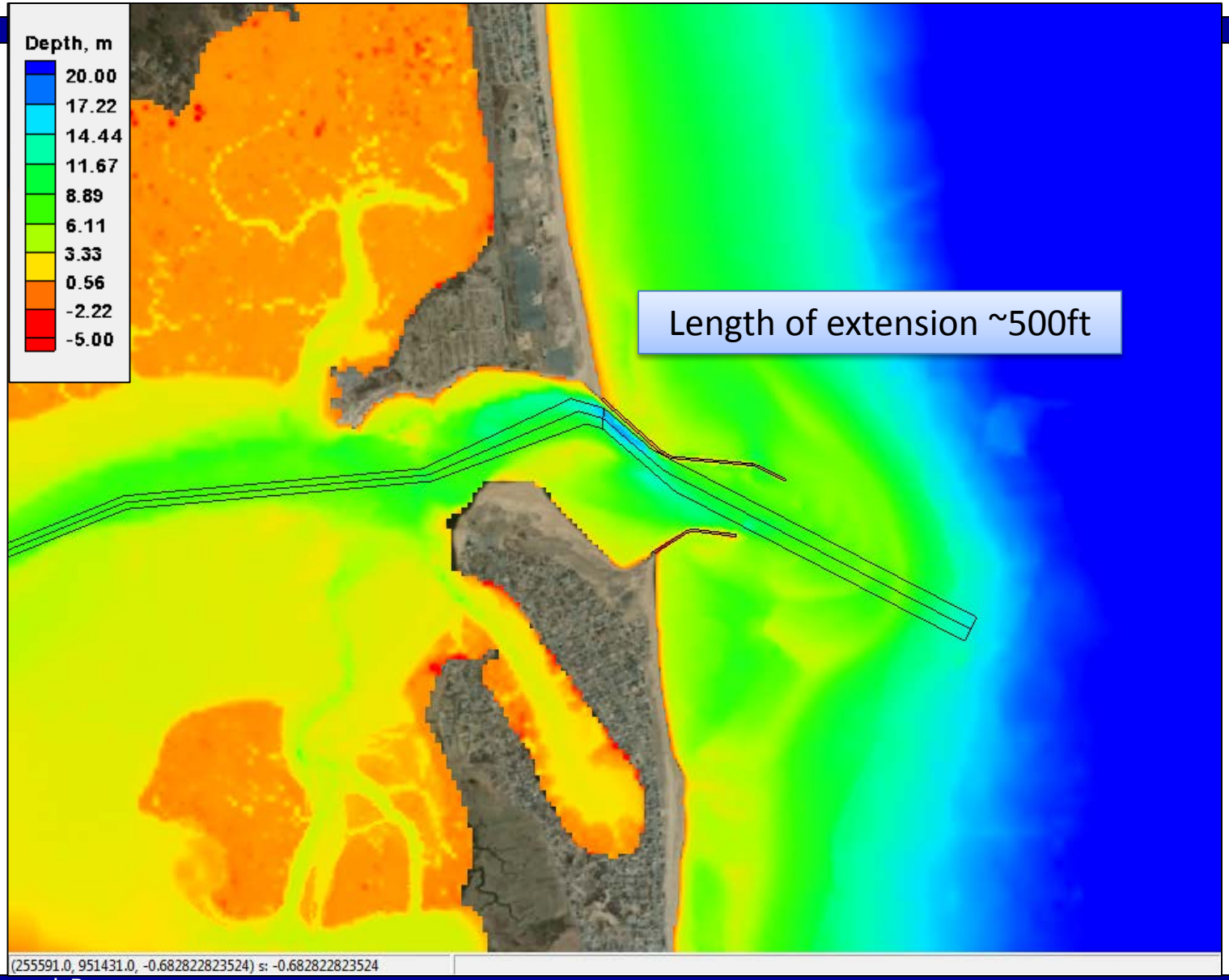


Alternative 14

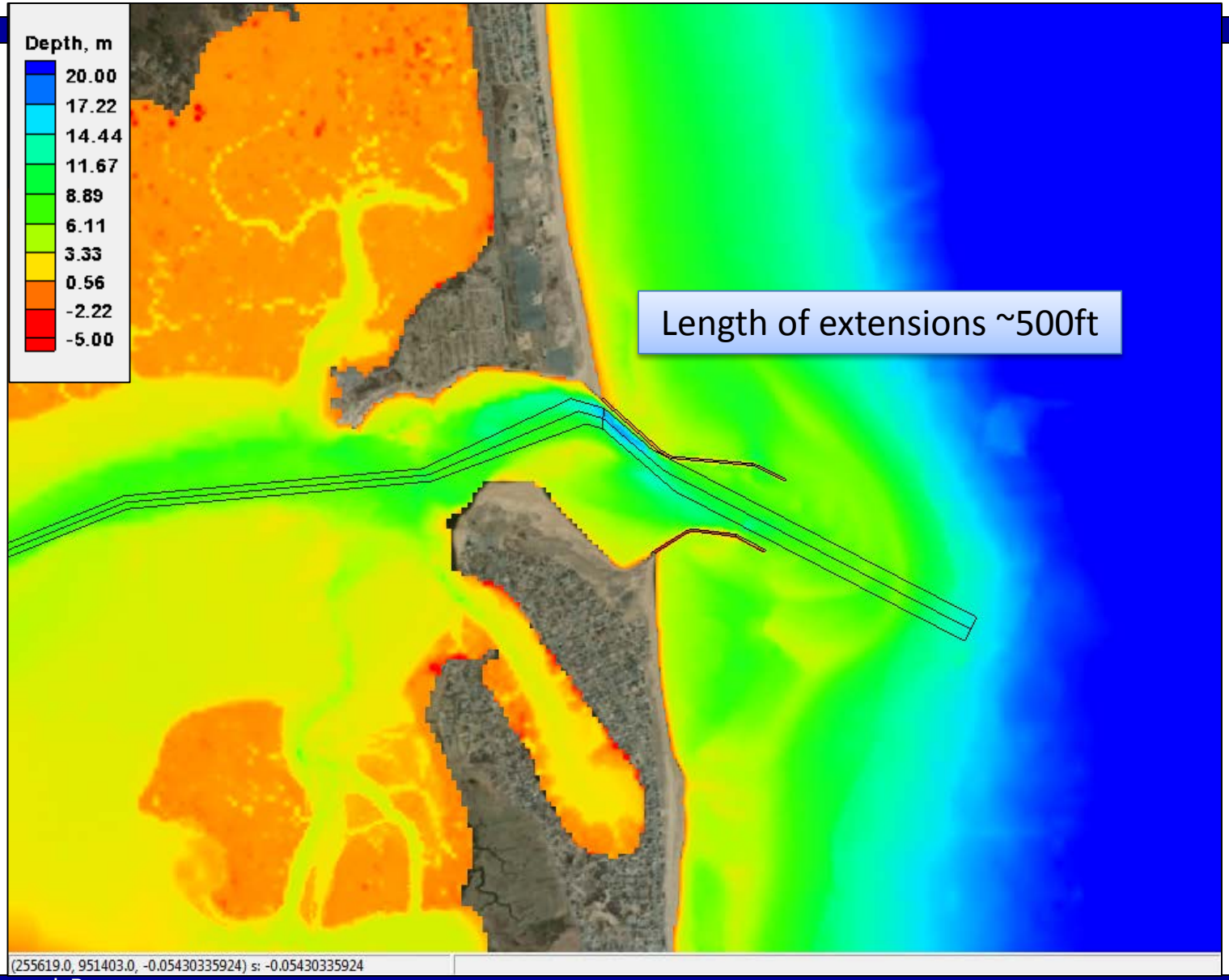
Reorient Jetties with alignment of navigation channel



Alternative 15
Add dogleg on north jetty

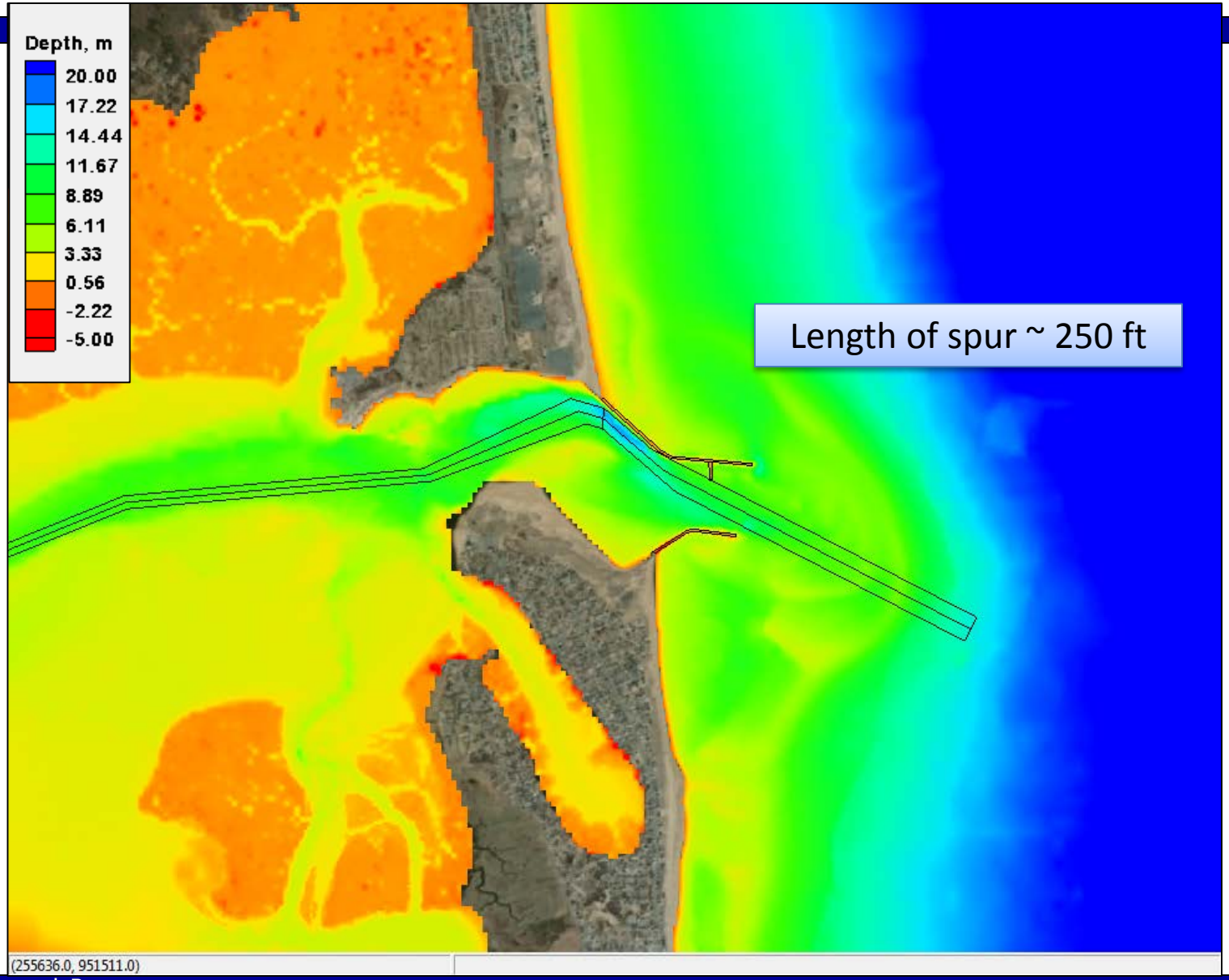


Alternative 16
Add dogleg to both jetties



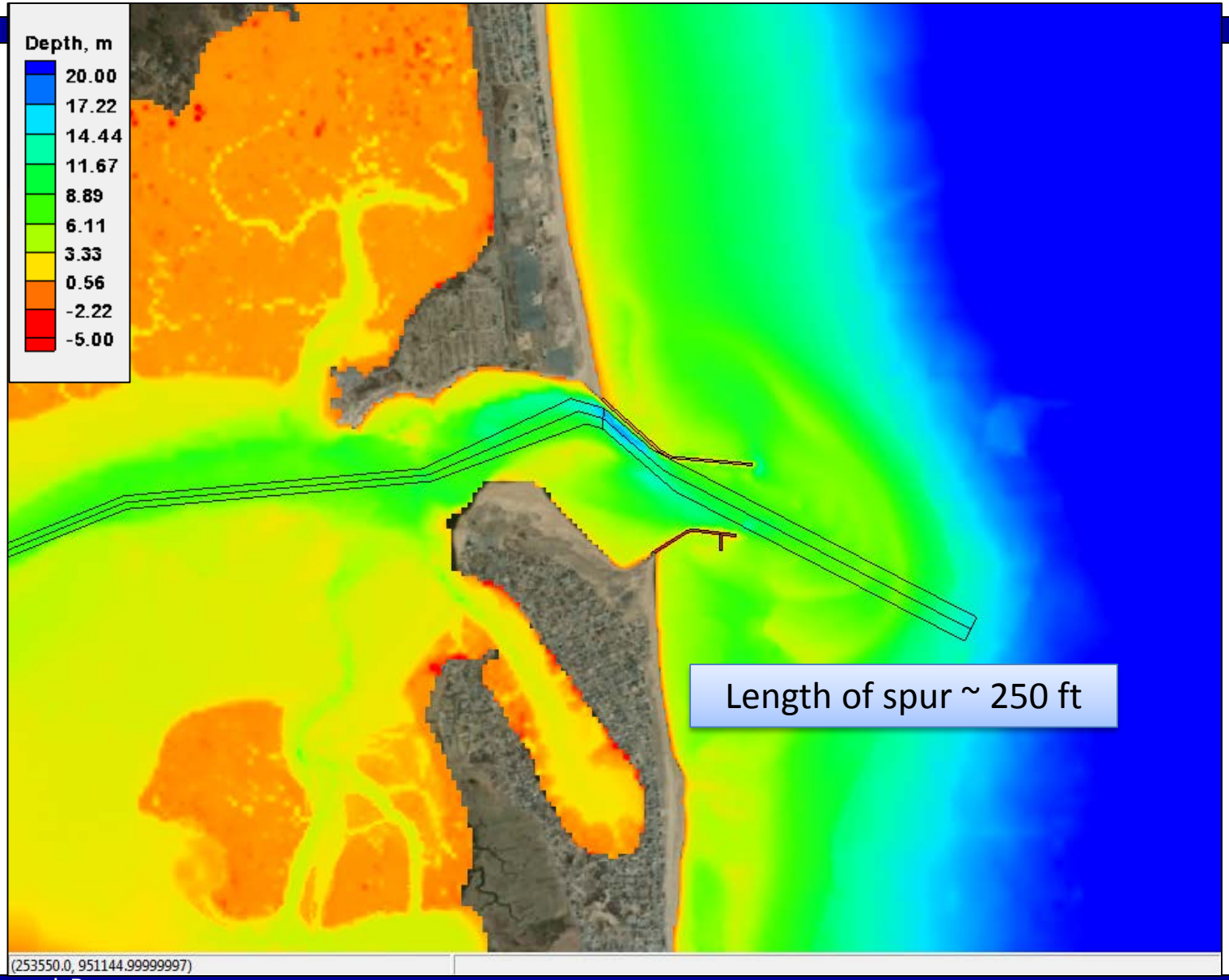
Alternative 17 north

Add spur inside north jetty



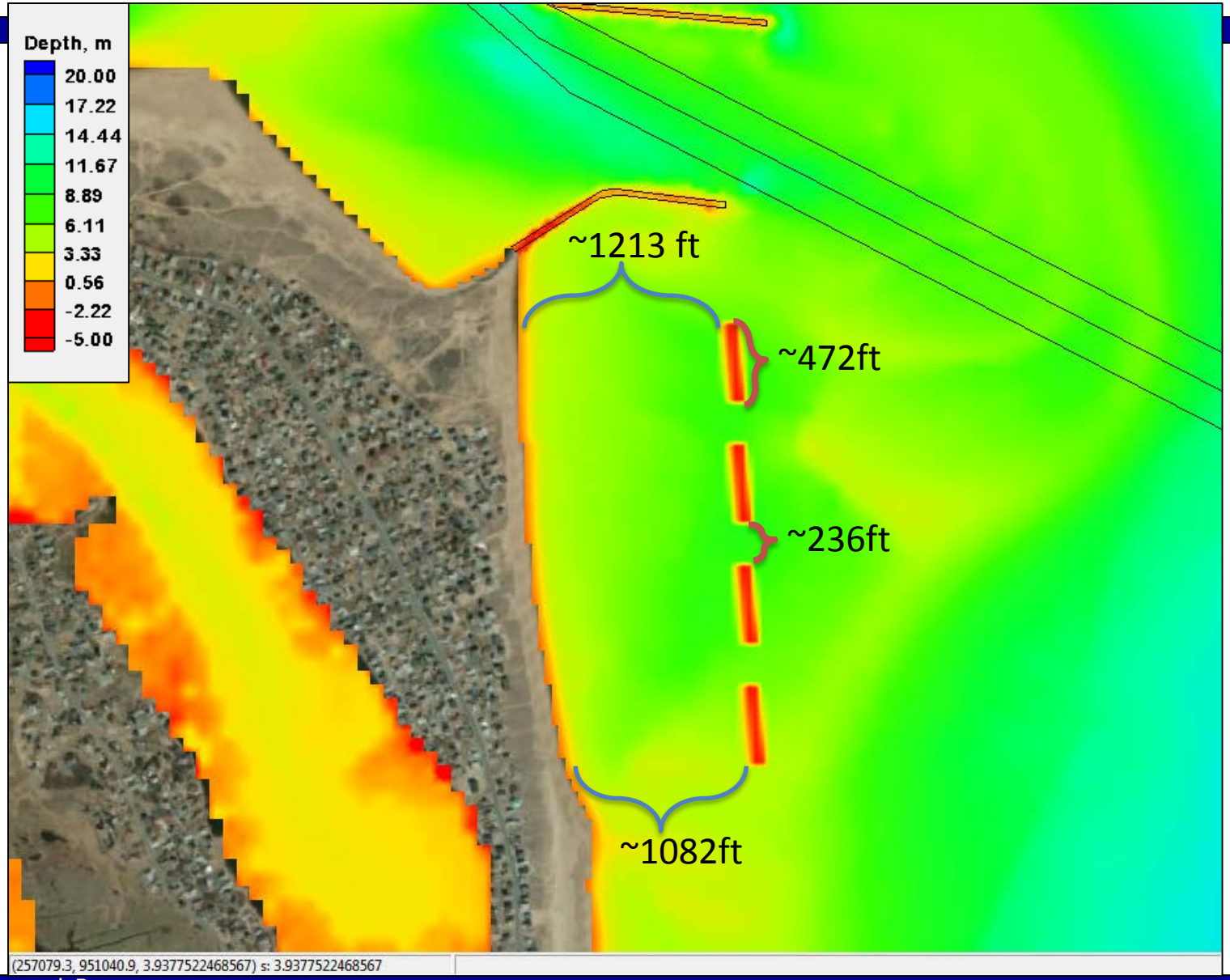
Alternative 17 south

Add spur outside south jetty



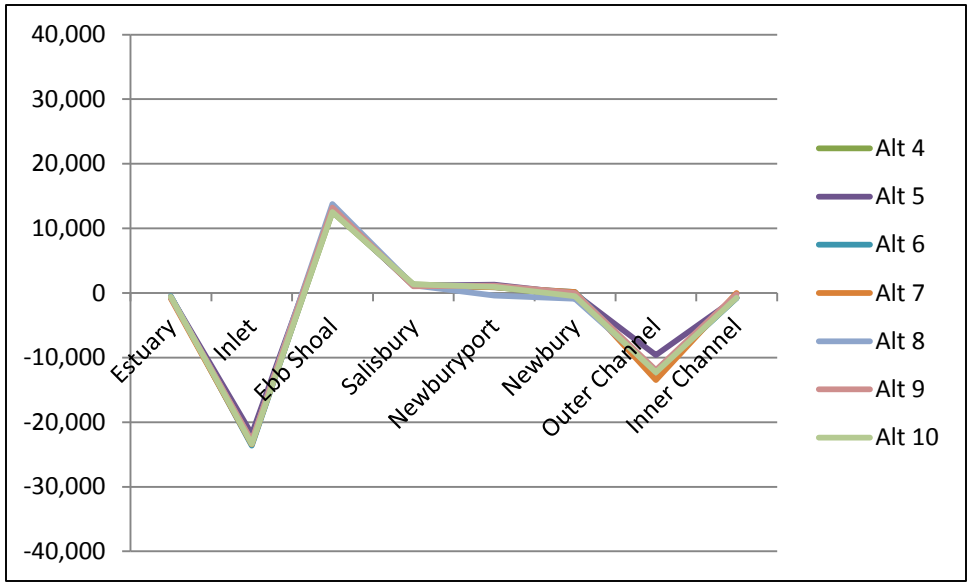
Alternative 19

Add detached breakwaters offshore of Plum Island

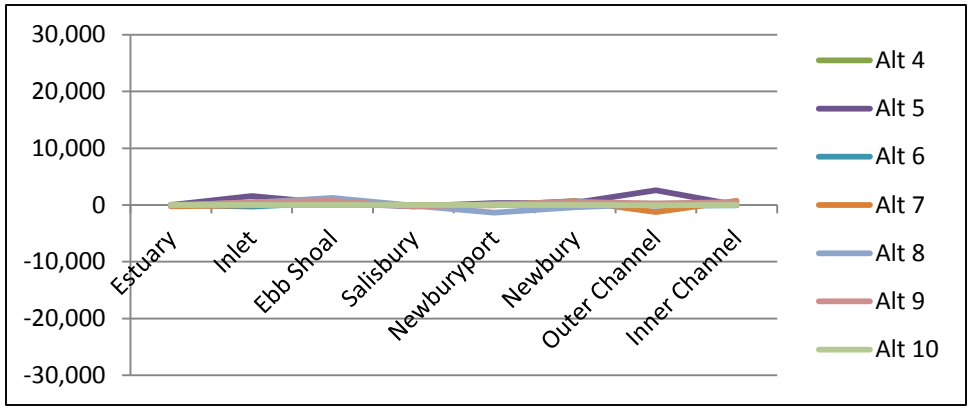


Volume comparison for each region for Alts 4-10

Morphology Change, cu yd



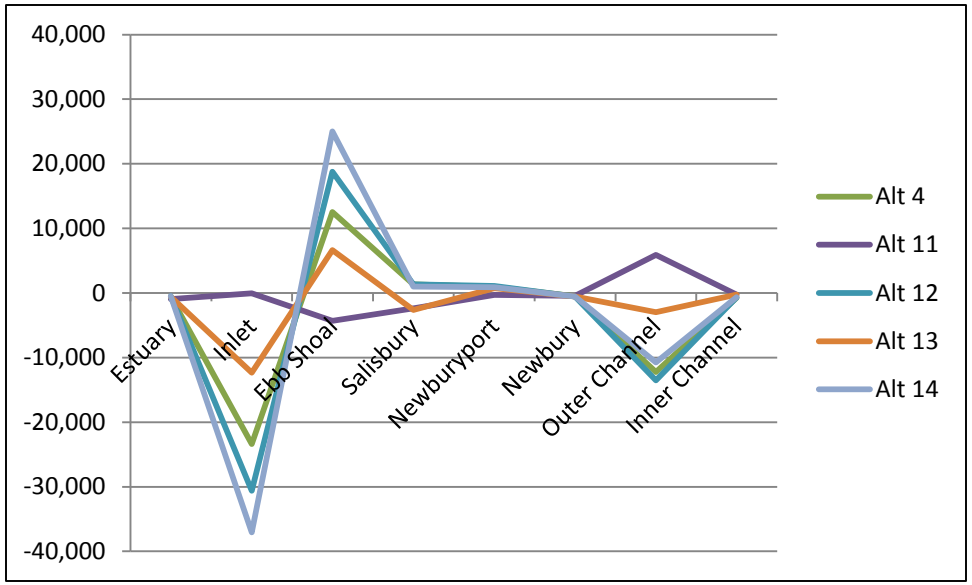
Morph Change minus Base Condition, cu yd



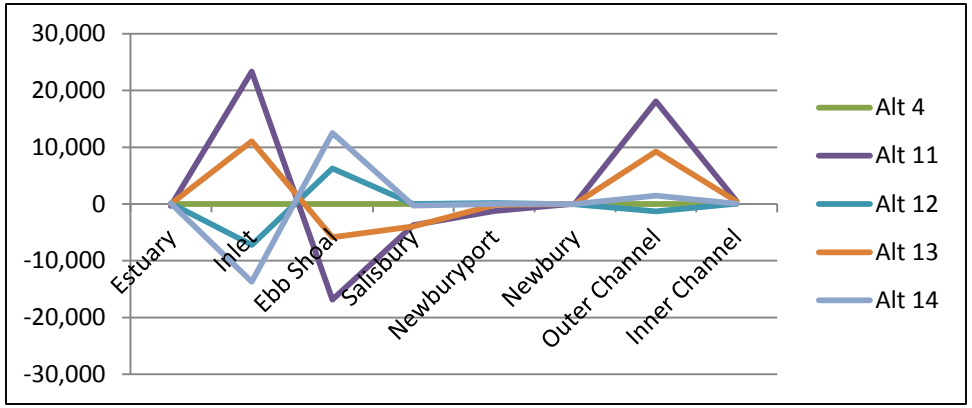
Alt	Description
4	Base (rehabbed S. Jetty)
5	Mine Ebb Delta 500K
6	Mine Flood Delta 500K
7	Mine North Point 500K
8	Mine Nearshore Bars 500K
9	Mine 200K ebb/flood/N. Pt.
10	Sedimentation Basin
11	Remove Both Jetties
12	Extend Jetties 500-ft
13	Remove outer Jetties
14	Align jetties with Nav channel
15	Dogleg north Jetty
16	Dogleg both Jetties
17n	Spur inside North Jetty
17s	Spur outside South Jetty
19	Detached BWs Plum Is.

Volume comparison for each region for Alts 11-14

Morphology Change, cu yd



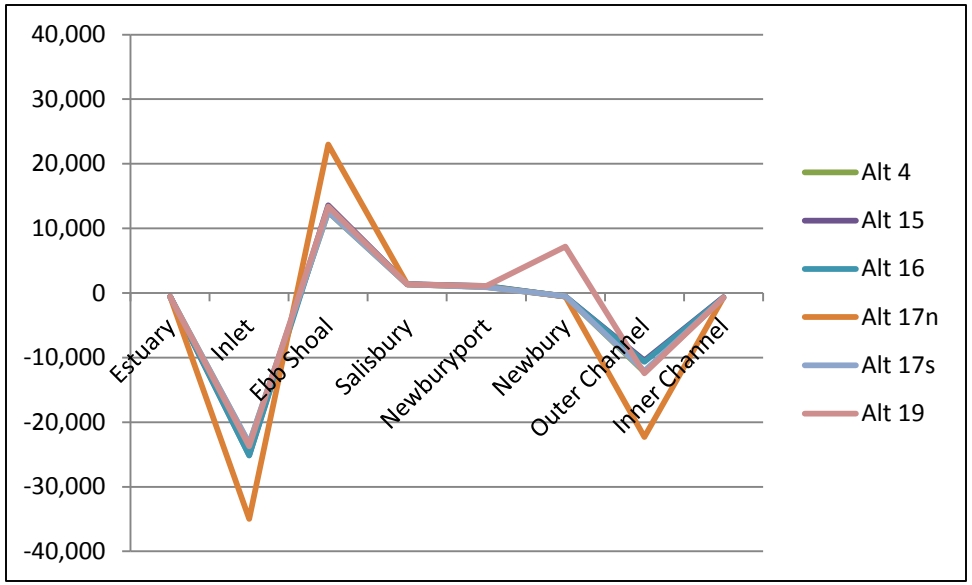
Morph Change minus Base Condition, cu yd



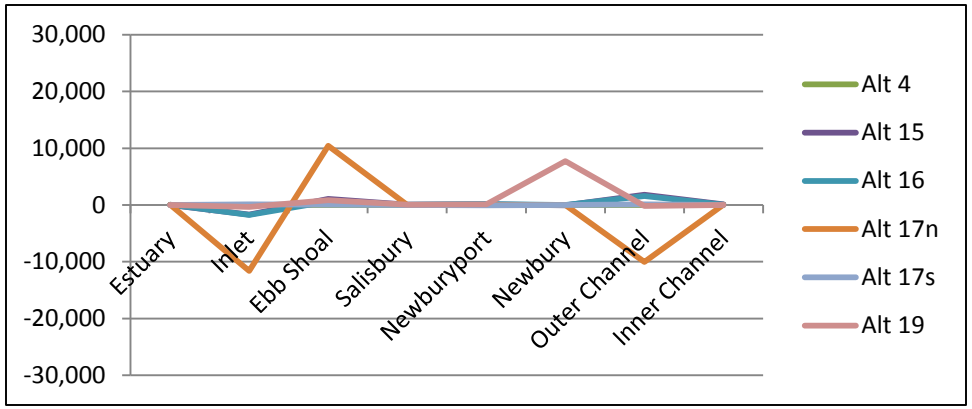
Alt	Description
4	Base (rehabbed S. Jetty)
5	Mine Ebb Delta 500K
6	Mine Flood Delta 500K
7	Mine North Point 500K
8	Mine Nearshore Bars 500K
9	Mine 200K ebb/flood/N. Pt.
10	Sedimentation Basin
11	Remove Both Jetties
12	Extend Jetties 500-ft
13	Remove outer Jetties
14	Align jetties with Nav channel
15	Dogleg north Jetty
16	Dogleg both Jetties
17n	Spur inside North Jetty
17s	Spur outside South Jetty
19	Detached BWs Plum Is.

Volume comparison for each region for Alts 15-19

Morphology Change, cu yd



Morph Change minus Base Condition, cu yd



Alt	Description
4	Base (rehabbed S. Jetty)
5	Mine Ebb Delta 500K
6	Mine Flood Delta 500K
7	Mine North Point 500K
8	Mine Nearshore Bars 500K
9	Mine 200K ebb/flood/N. Pt.
10	Sedimentation Basin
11	Remove Both Jetties
12	Extend Jetties 500-ft
13	Remove outer Jetties
14	Align jetties with Nav channel
15	Dogleg north Jetty
16	Dogleg both Jetties
17n	Spur inside North Jetty
17s	Spur outside South Jetty
19	Detached BWs Plum Is.

Criteria for Selecting Alts for 6-mos Simulations

Select Alts to:

1. Minimize adverse impacts on Newburyport and Newbury beaches
   - Preference given to adding sand to these sites
2. Minimize adverse navigation impacts
3. Include at least one jetty alternative
4. Include an Alt with detached breakwaters (likely costly, but better protection of downdrift beaches)
   - Extend detached breakwaters further downdrift to provide more protection
   - Include an option to place sand at the time of detached breakwater construction

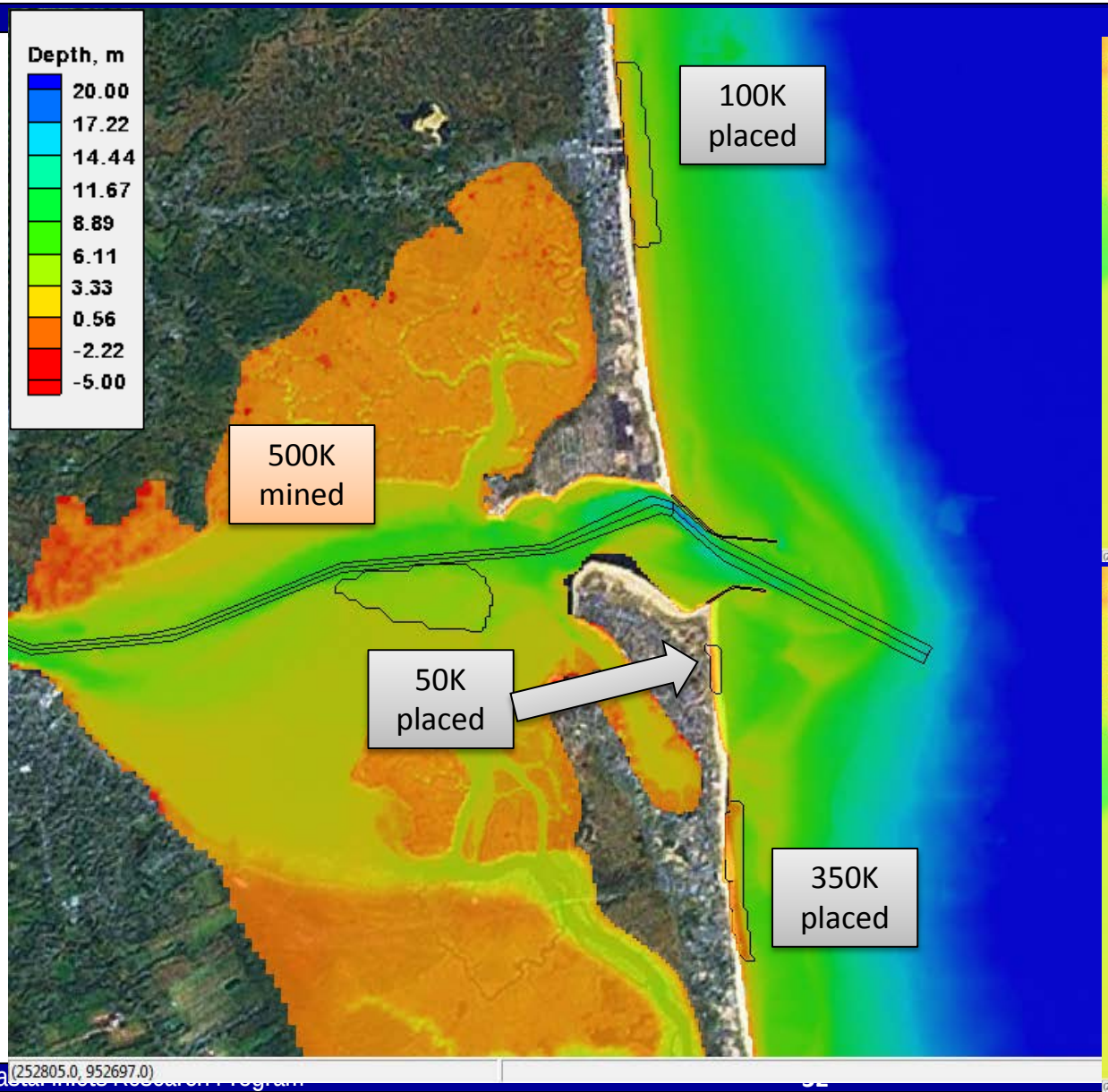
Alternatives for Mid-Term (6 mos) Simulations

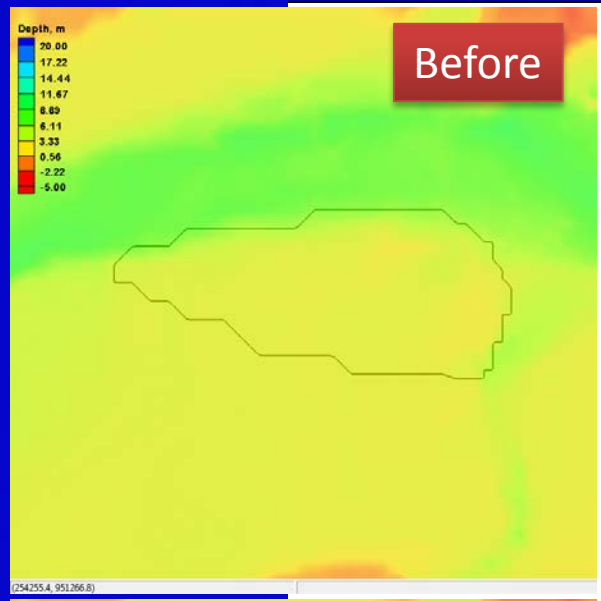
"b, c" indicate Alternatives modified from original 1-mos simulations.

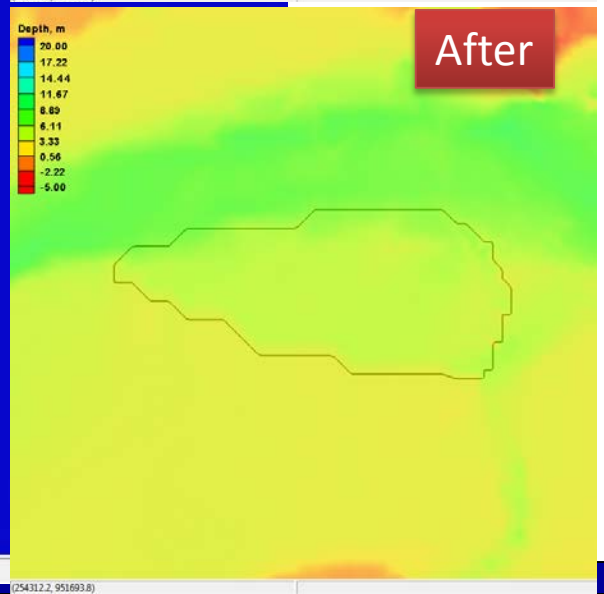
- Alt 6 – mine flood shoal and place on beaches
- Alt 7b (modified) – only subaerial mining of north spit
- Alt 10b (modified) – sedimentation basin moved slightly further north to minimize adverse south jetty impacts
- Alt 13 – remove outer portion of jetties (structural alternative minimizing adverse impacts)
- Alt 19b (modified) – extending detached breakwater system further to south to provide more protection
- Alt 19c (modified) – Alt 19b plus sand placed from deposition basin

Alternative 6 (no modification)

Mine flood delta 500K CY & Place 100K, 50K, 350K

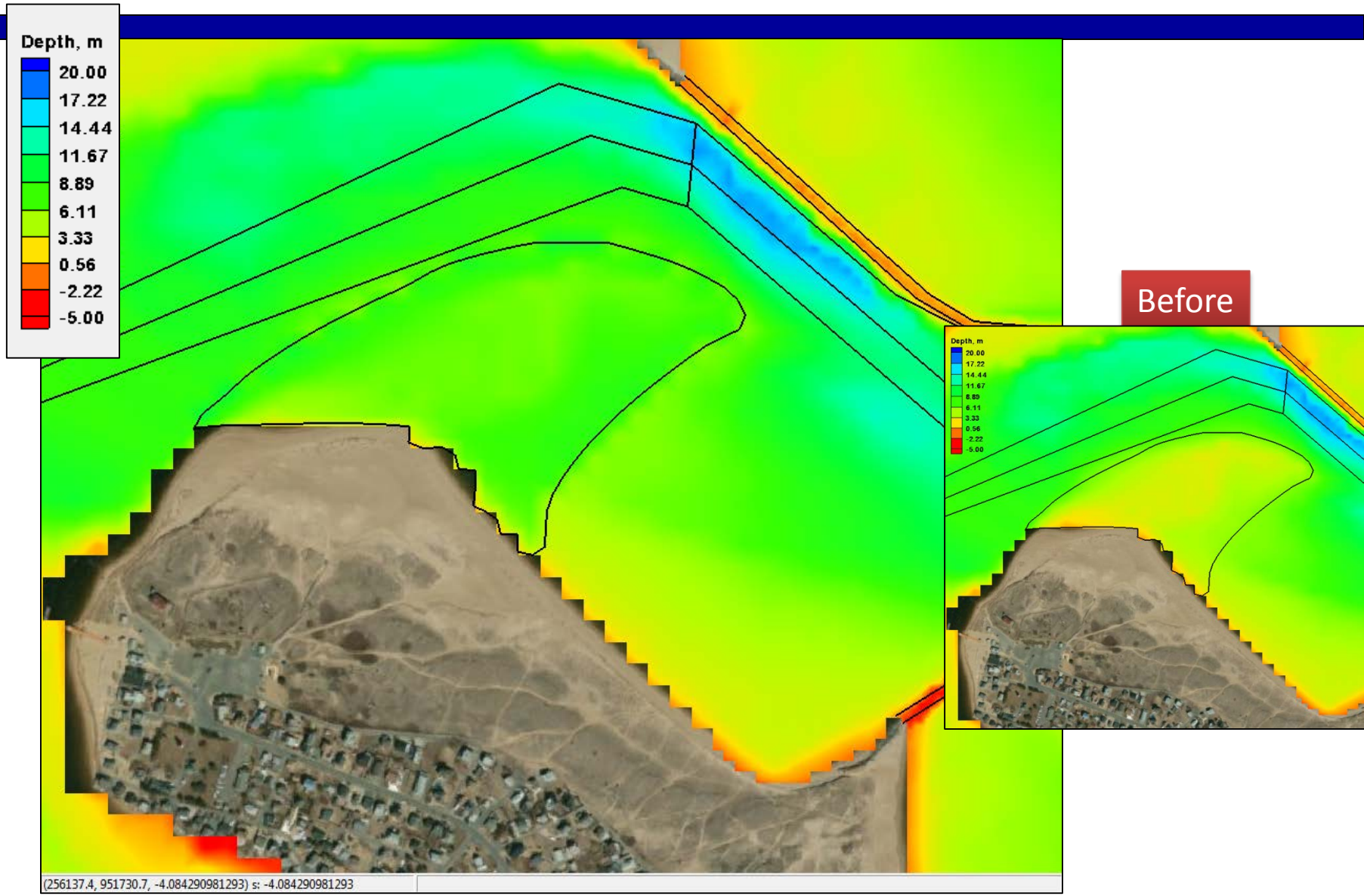






Alternative 7b

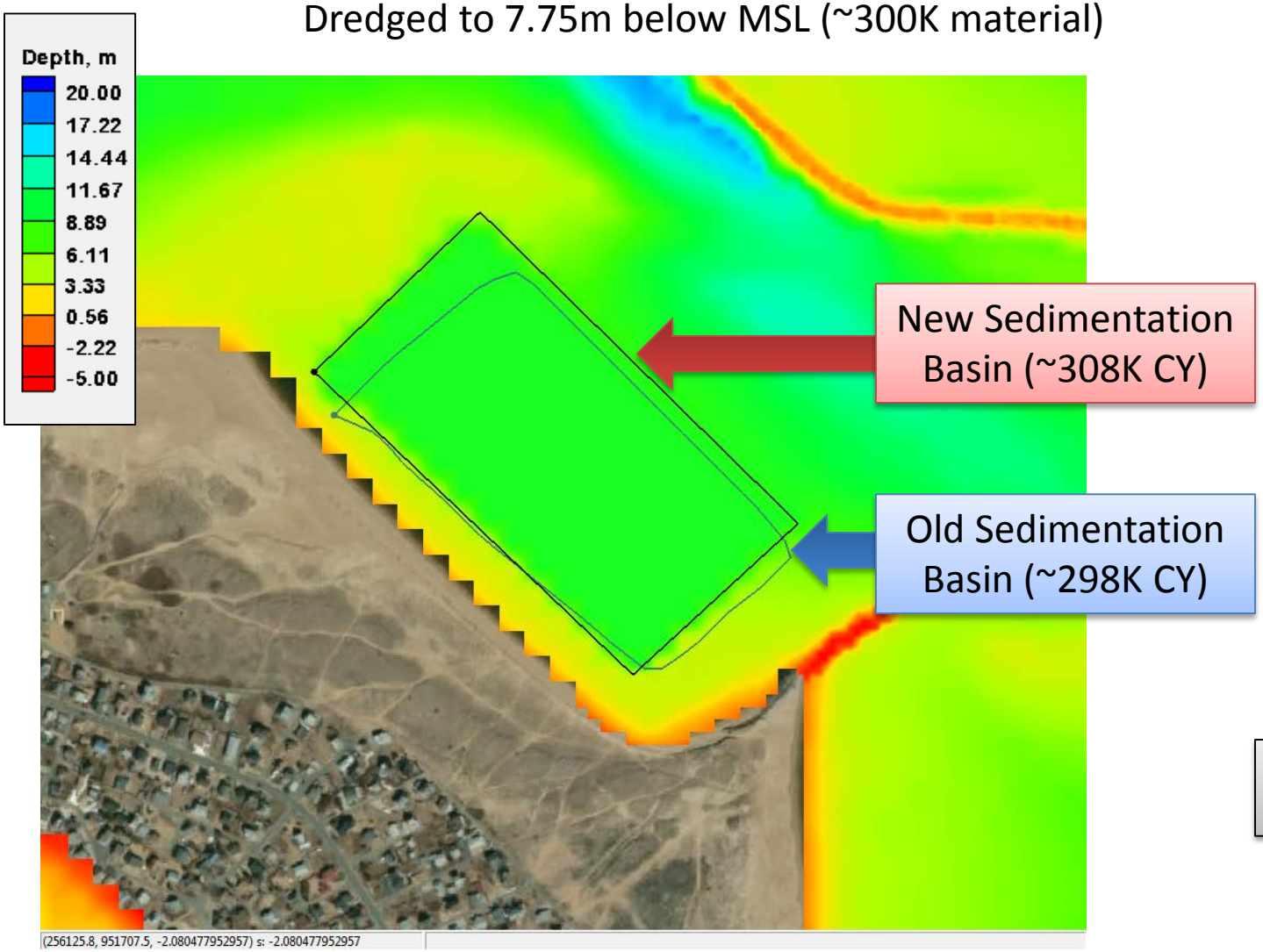
Mine North Point 375K CY & Place 100K, 50K, 225K

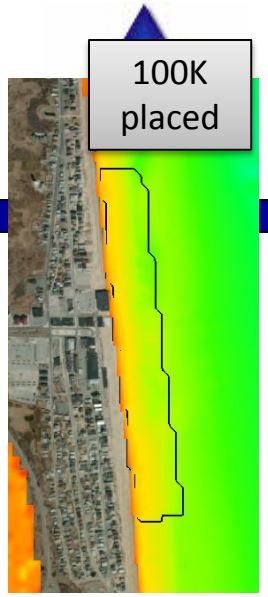


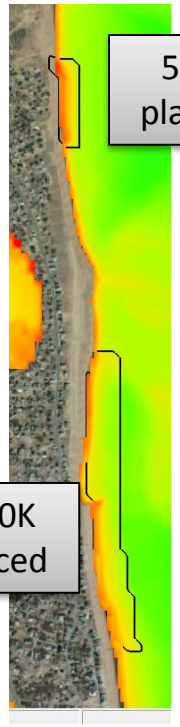
Alternative 10b

Sedimentation Basin & Place 100K, 50K, 150K

Dredged to 7.75m below MSL (~300K material)

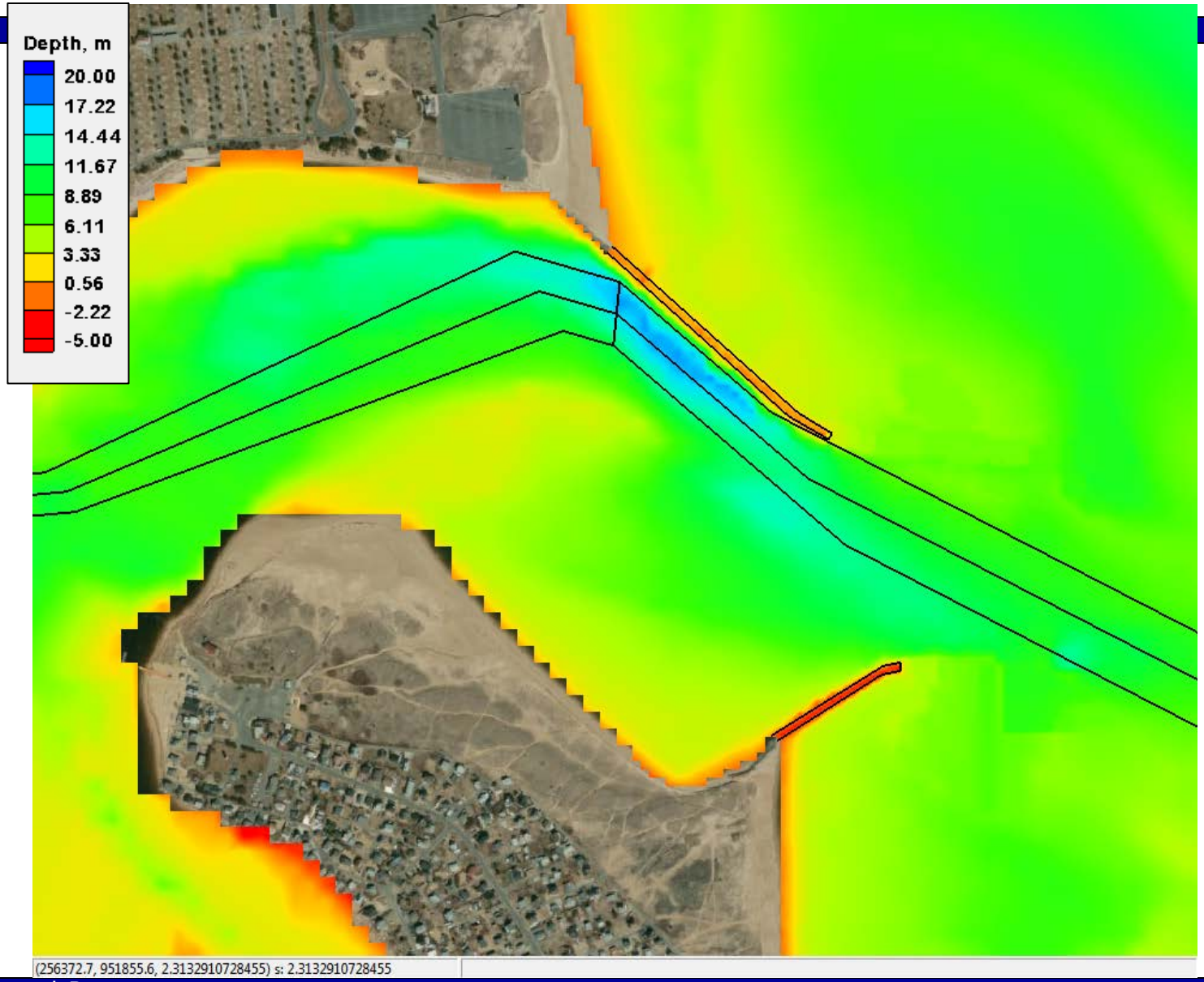






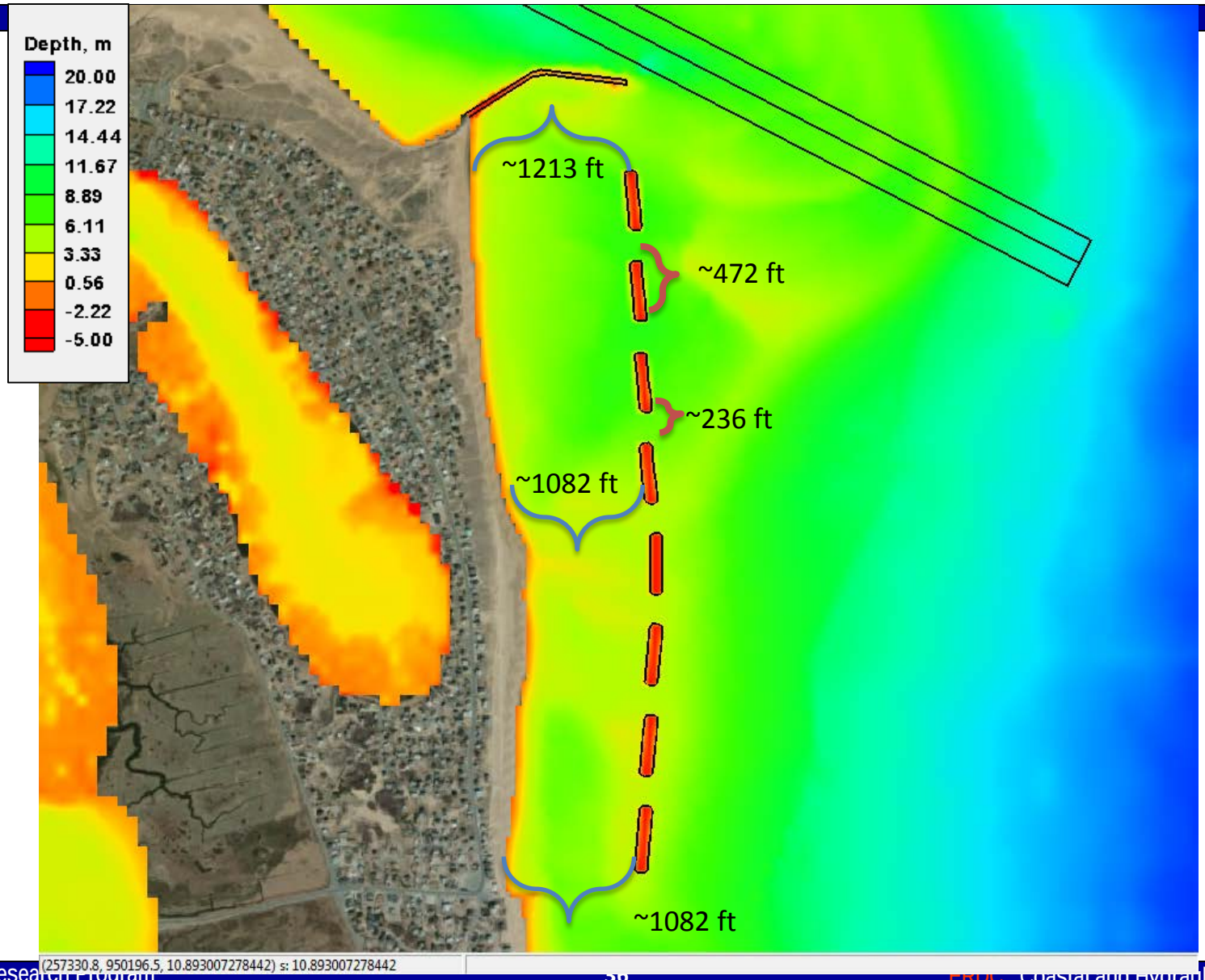
Alternative 13 (no modification)

Remove outer portion of both jetties



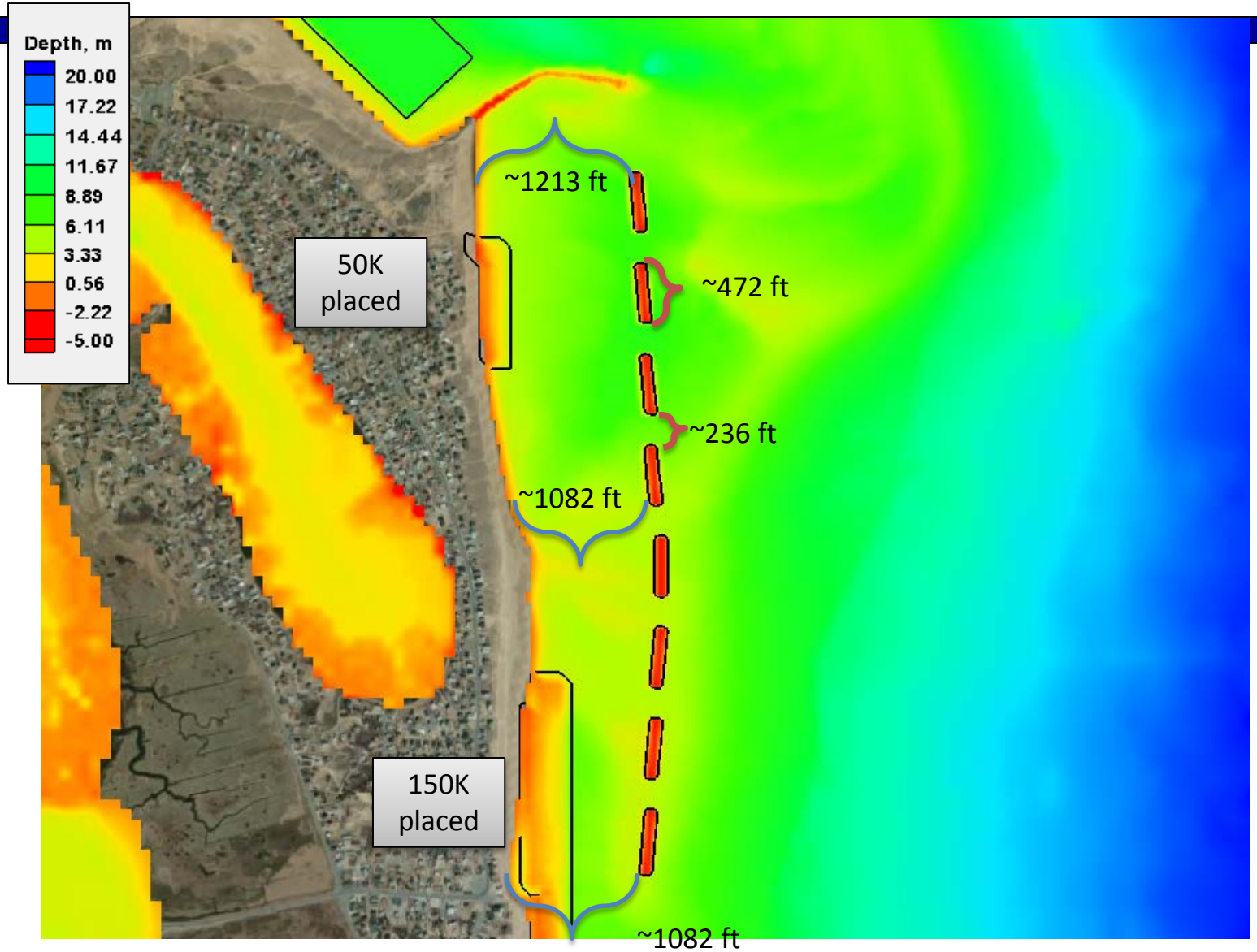
Alternative 19b

Expanded detached breakwaters offshore of Plum Island



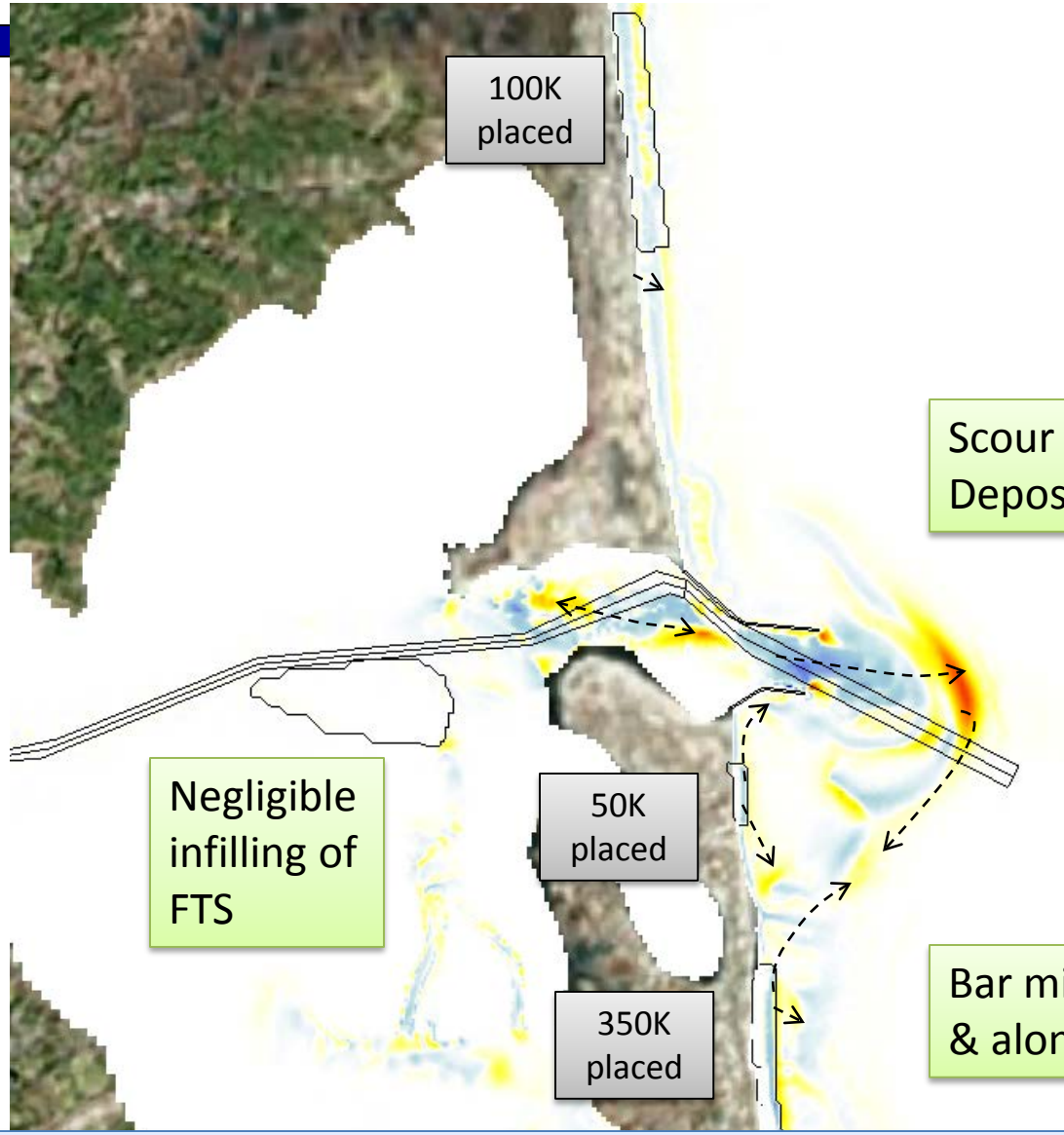
Alternative 19c

Detached breakwaters + Sedimentation Basin + Sand on Beaches



Alternative 6

Mine flood delta 500K CY & Place 100K, 50K, 350K



Scour inlet throat
Deposition outer ETS

Negligible infilling of FTS

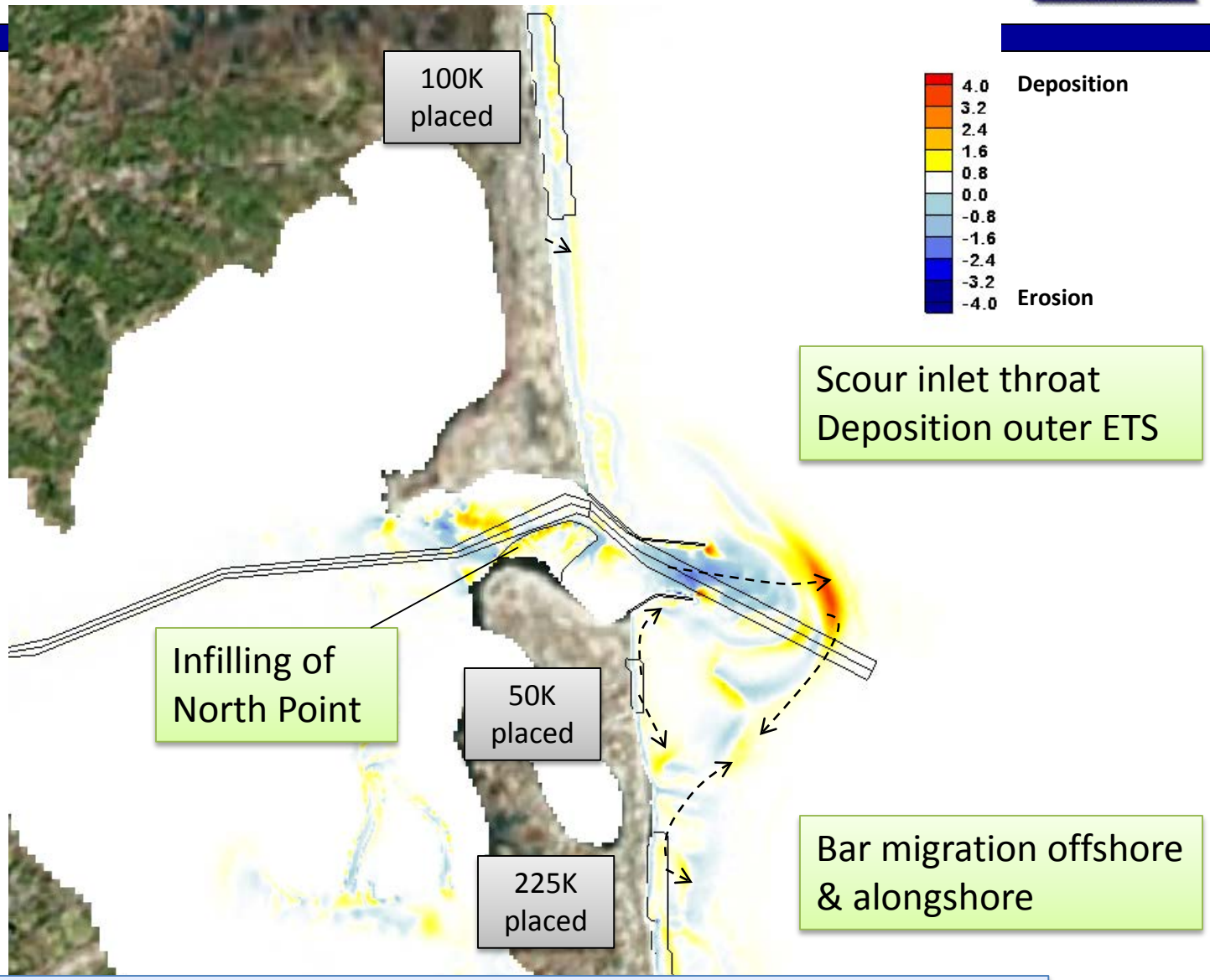
Bar migration offshore & alongshore

Morphology Change – 6 months beginning January 2011

Alternative 7b

Mine North Point 375K CY & Place 100K, 50K, 225K

- Similar ocean-side responses as with Alt 6
- Difference is in infilling of North Point mining region

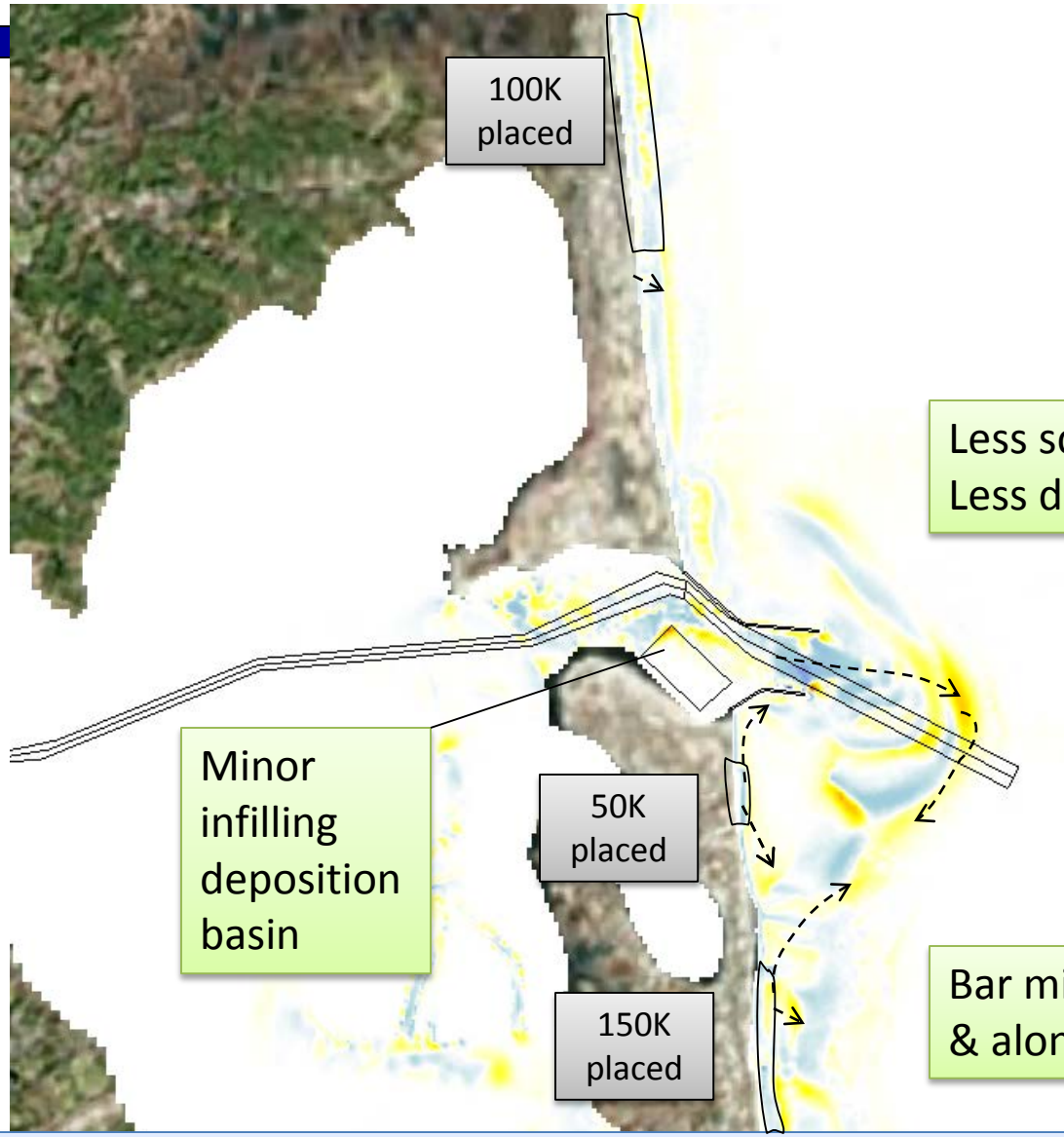


Morphology Change – 6 months beginning January 2011

Alternative 10b

Sedimentation Basin & Place 100K, 50K, 150K

- Similar to Alts 6 & 7b except as noted
- Deposition basin is outside of active flow area; mining has minor effect on processes, as compared to Alts 6 & 7b



Less scour inlet throat
Less deposition ETS

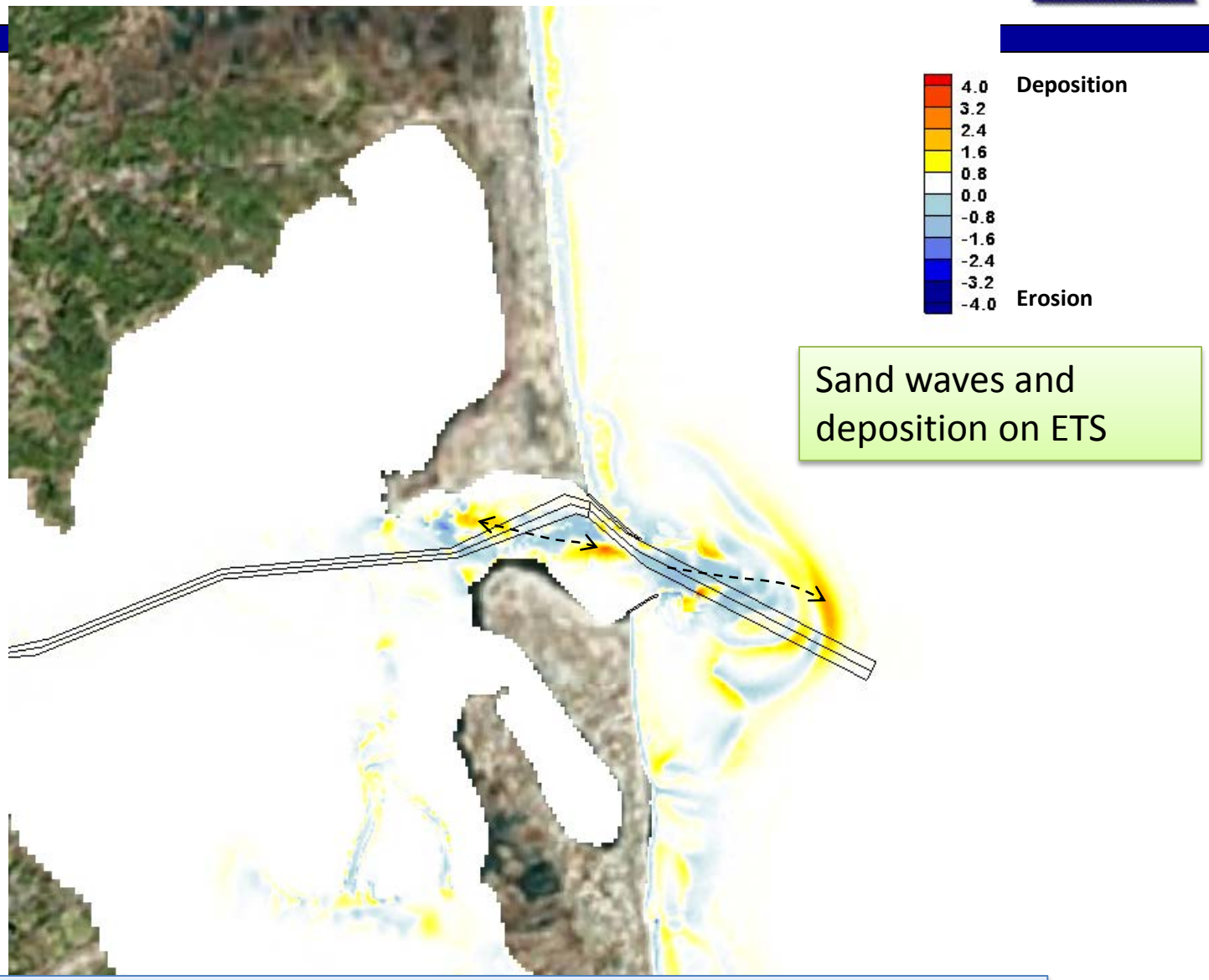
Bar migration offshore & alongshore

Morphology Change – 6 months beginning January 2011

Alternative 13

Remove outer portion of both jetties

- Erosion of North Point
- Reorientation of Navigation Channel
- More sand waves in Navigation Channel



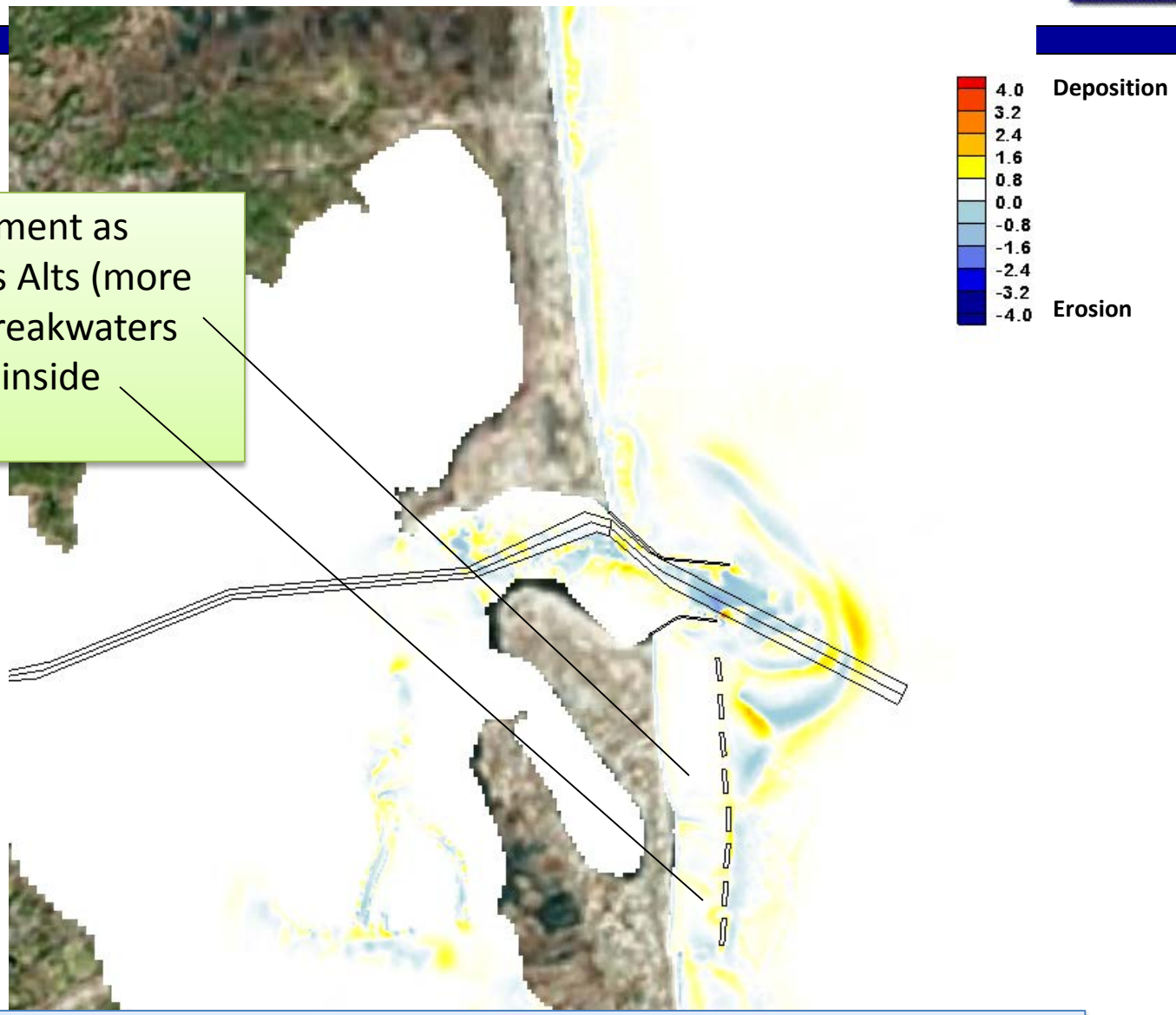
Sand waves and deposition on ETS

Morphology Change – 6 months beginning January 2011

Alternative 19b

Expanded detached breakwaters offshore of Plum Island

- Less sediment movement as compared to previous Alts (more quiescent) in lee of breakwaters
- Slight accretion just inside breakwaters

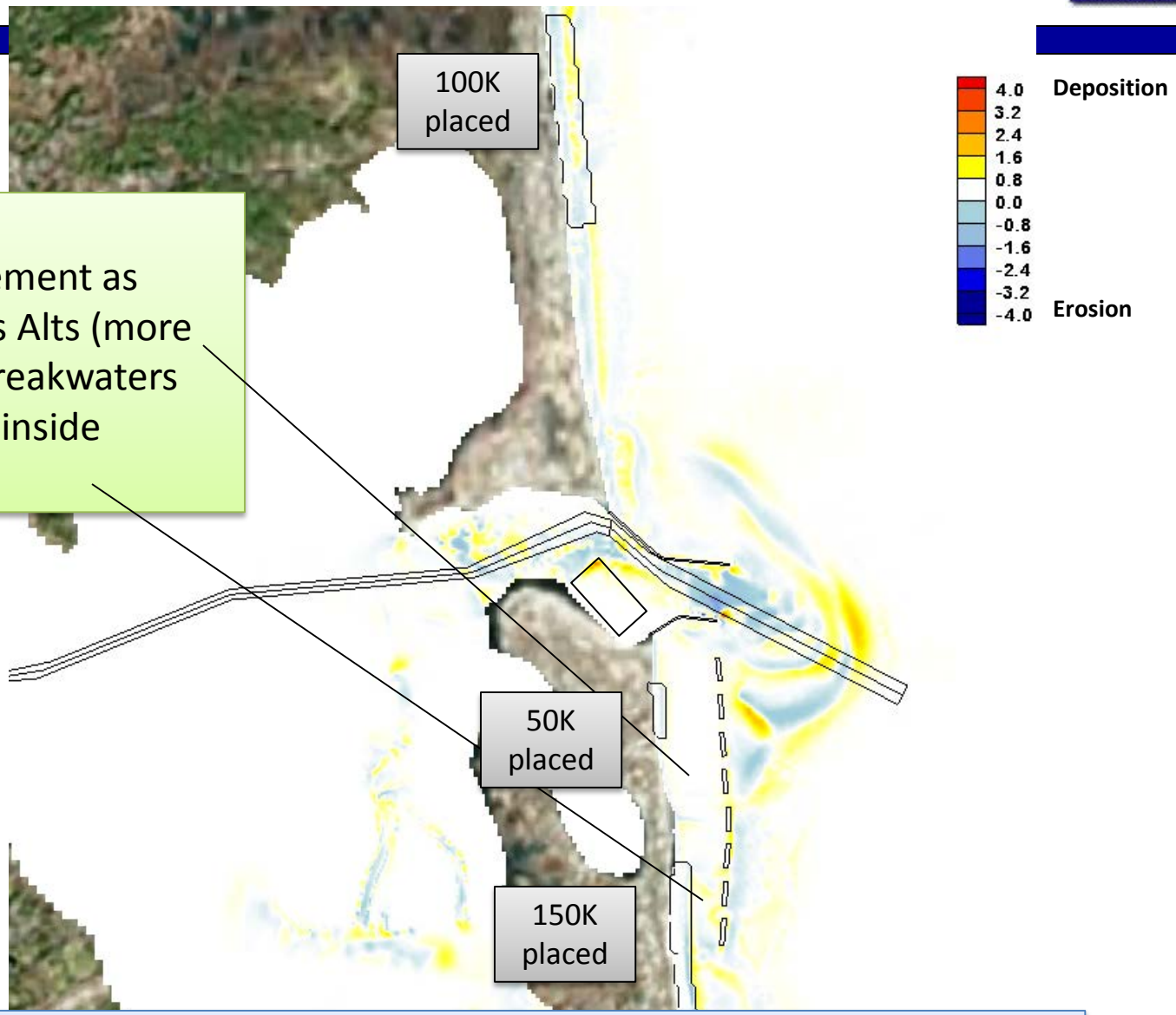


Morphology Change – 6 months beginning January 2011

Alternative 19c

Detached breakwaters + Sedimentation Basin + Sand on Beaches

- Similar to 19b
- Less sediment movement as compared to previous Alts (more quiescent) in lee of breakwaters
- Slight accretion just inside breakwaters



Morphology Change – 6 months beginning January 2011

Summary & Recommendations

Structural Alternatives

- Do not recommend removing jetties
  - Removal of structures hinders navigation safety
  - Sediment is more likely deposited into channel, increasing shoaling and bar formation within channel
- Detached breakwaters offshore Newburyport decrease energy in lee of structures, protecting nearshore
  - Slight deposition to lee of structures observed in 6 mos
  - Placement of sand with structures provides longer-term solution for beach stability
  - Further design would need evaluation with short-term (storm) and long-term beach response models

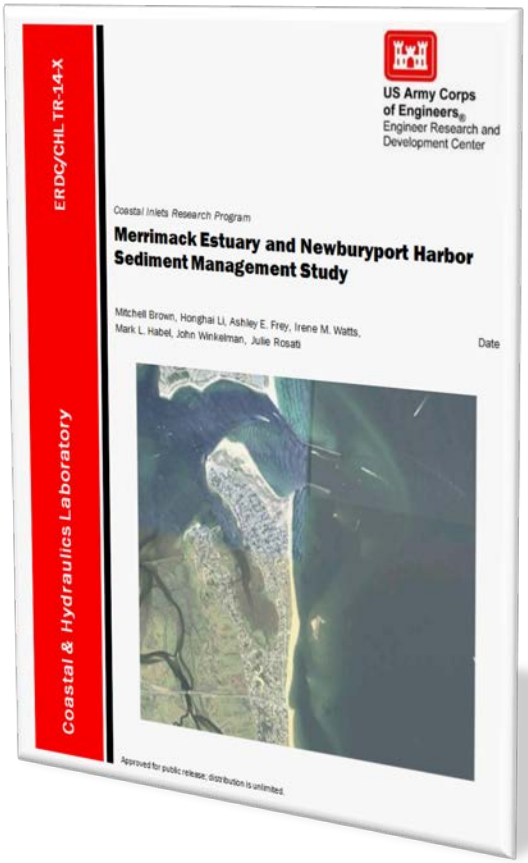
Summary & Recommendations

Sand Management Alternatives

- North Point Mining
  - Potential for long-term source; refills faster than other mining sites
  - Improves navigability of inlet
- Deposition Basin
  - Not as much morphologic change as other mining options
  - Does not refill as rapidly as North Point
- Flood Tidal Shoal Mining
  - Similar morphologic change as North Point Mining
  - Does not refill as rapidly as North Point
- Could consider combination of mining sources

Next Steps

- Complete analysis and documentation
- For feasibility assessment of beach alternatives, short-term and long-term beach response assessments are required
  - Short-term storm response assessment, e.g., SBEACH, BEACH-fx
  - Long-term shoreline change assessment, e.g., GenCade, GENESIS



Thank You!

Mitchell Brown	Mitchell.E.Brown@usace.army.mil	601-634-4036
Honghai Li	Honghai.Li@usace.army.mil	601-634-2840