Phase 1 Report: Pamet Harbor Inlet Jetty & Sediment Study, Town of Truro, MA

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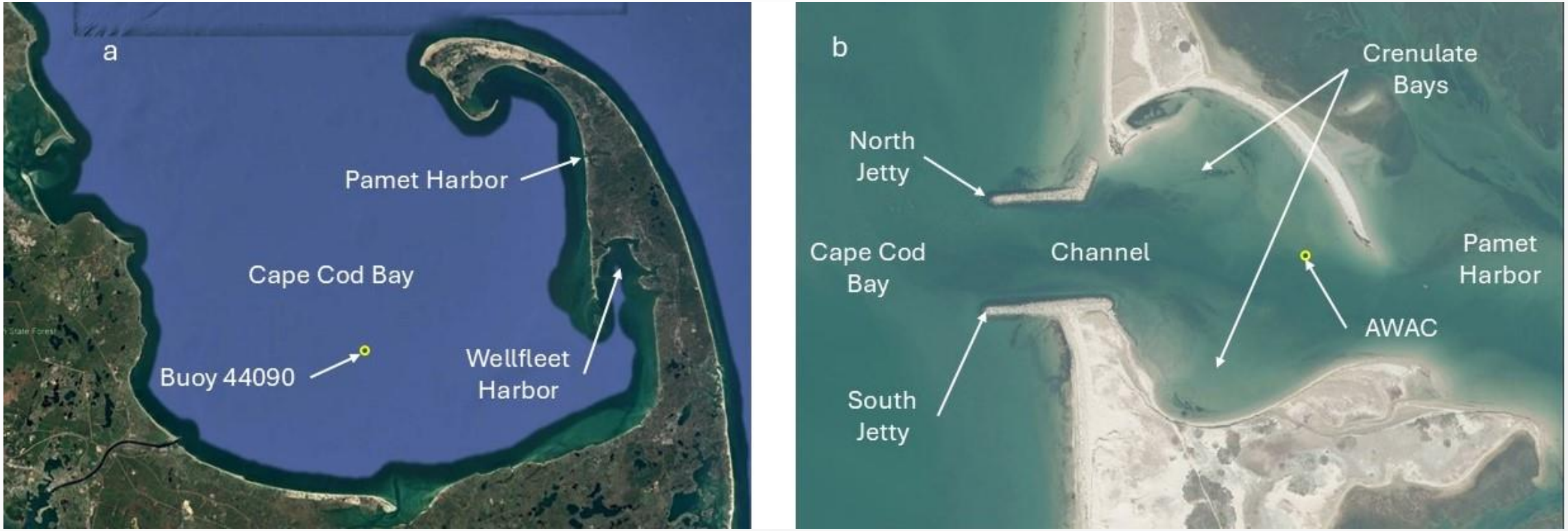
Southward view along Pamet Harbor North Jetty showing breakthrough of recently renourished area. Photo source: Environmental Partners report, 1 May 2025.

Agenda

1. Setting
2. Scope
3. Technical approach
4. Results
5. Conclusions
6. Recommendations for Phase 2

Northward view from Pamet Harbor North Jetty showing recently renourished area. Figure source: Environmental Partners report, 1 May 2025.

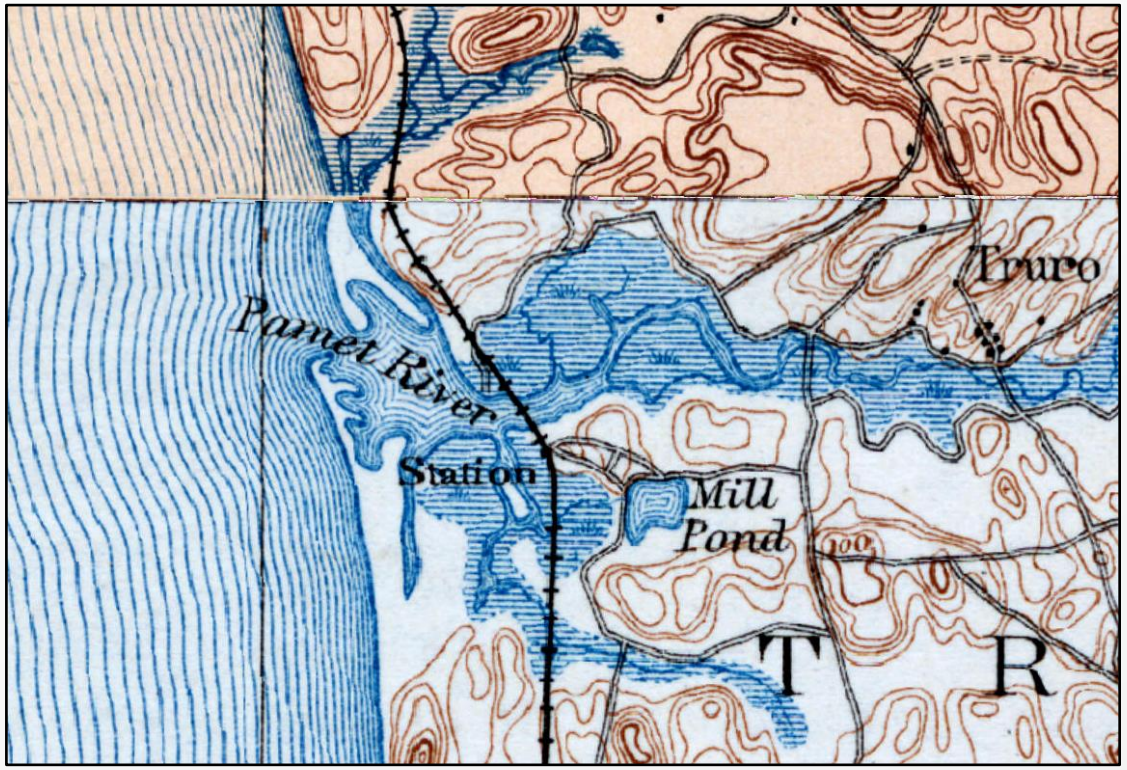
Setting



(a) Regional scale including NOAA Buoy 44090 and (b) local scale including Woods Hole Group AWAC measurements site. Figure source: Google Earth.

Phase 1 Scope

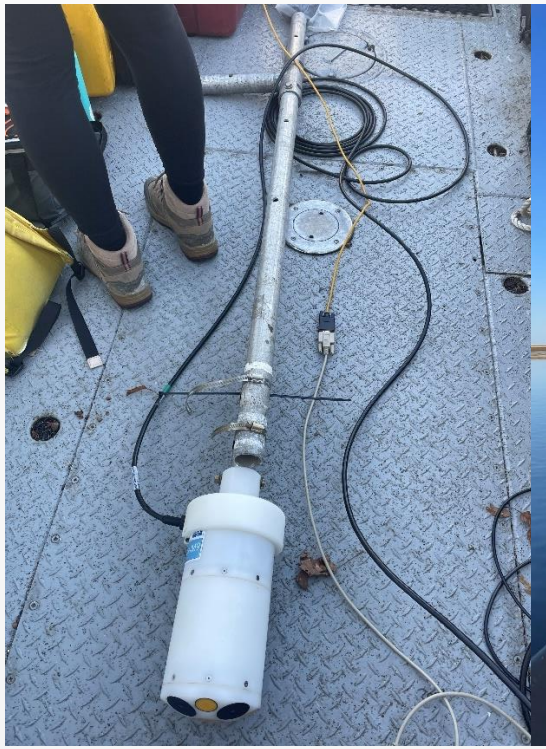
1. Bathymetric and topographic surveys
2. Tide, wave, and current data collection
3. Inlet current profile measurements
4. Shoreline change and history of inlet geomorphology
5. Analysis of historical dredging and placement
6. First level sediment budget and inlet stability analysis
7. Crenulate bay / inlet literature review
8. Technical report
9. Project management and meetings



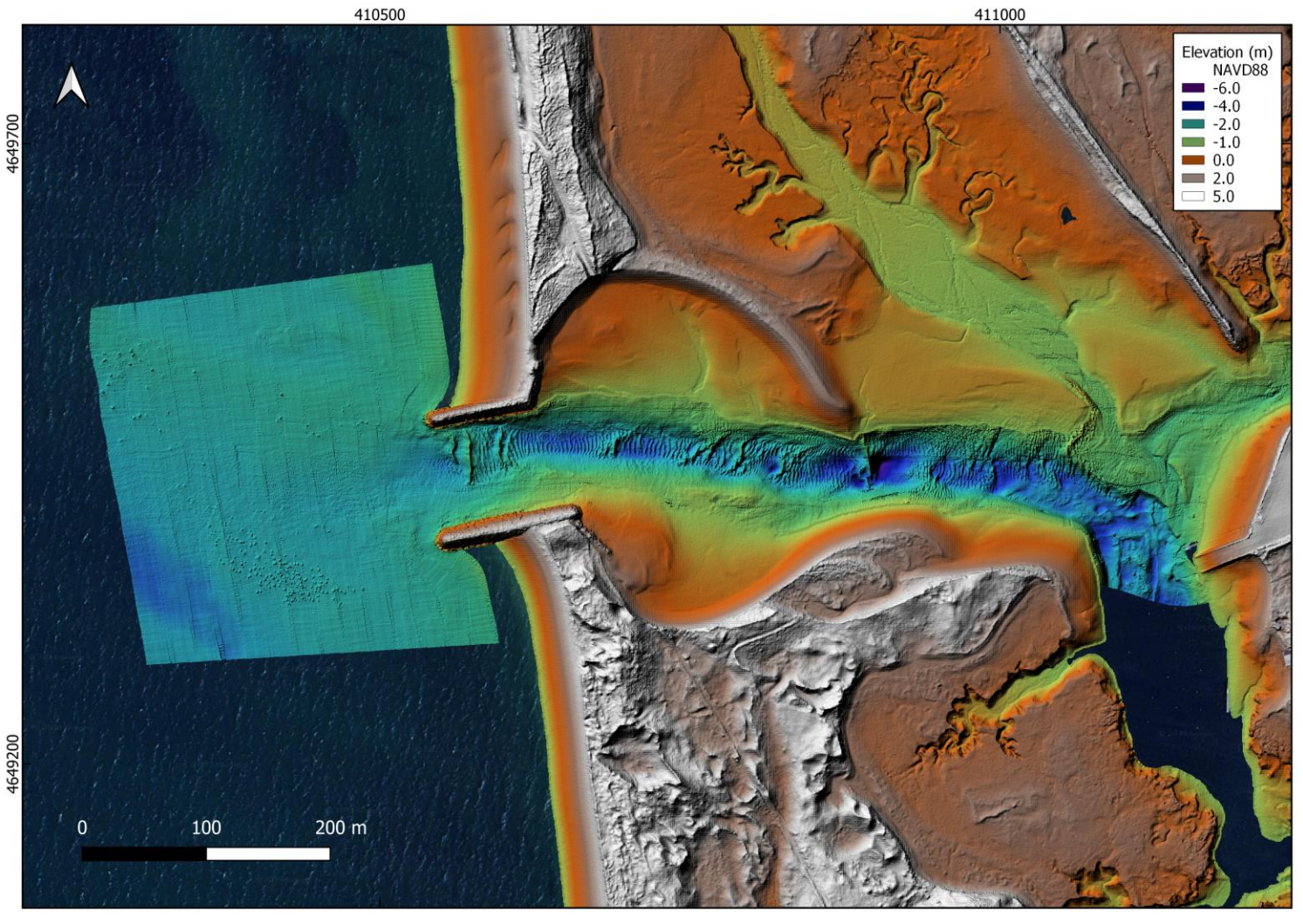
USGS Topographic Chart circa 1900

Technical Approach

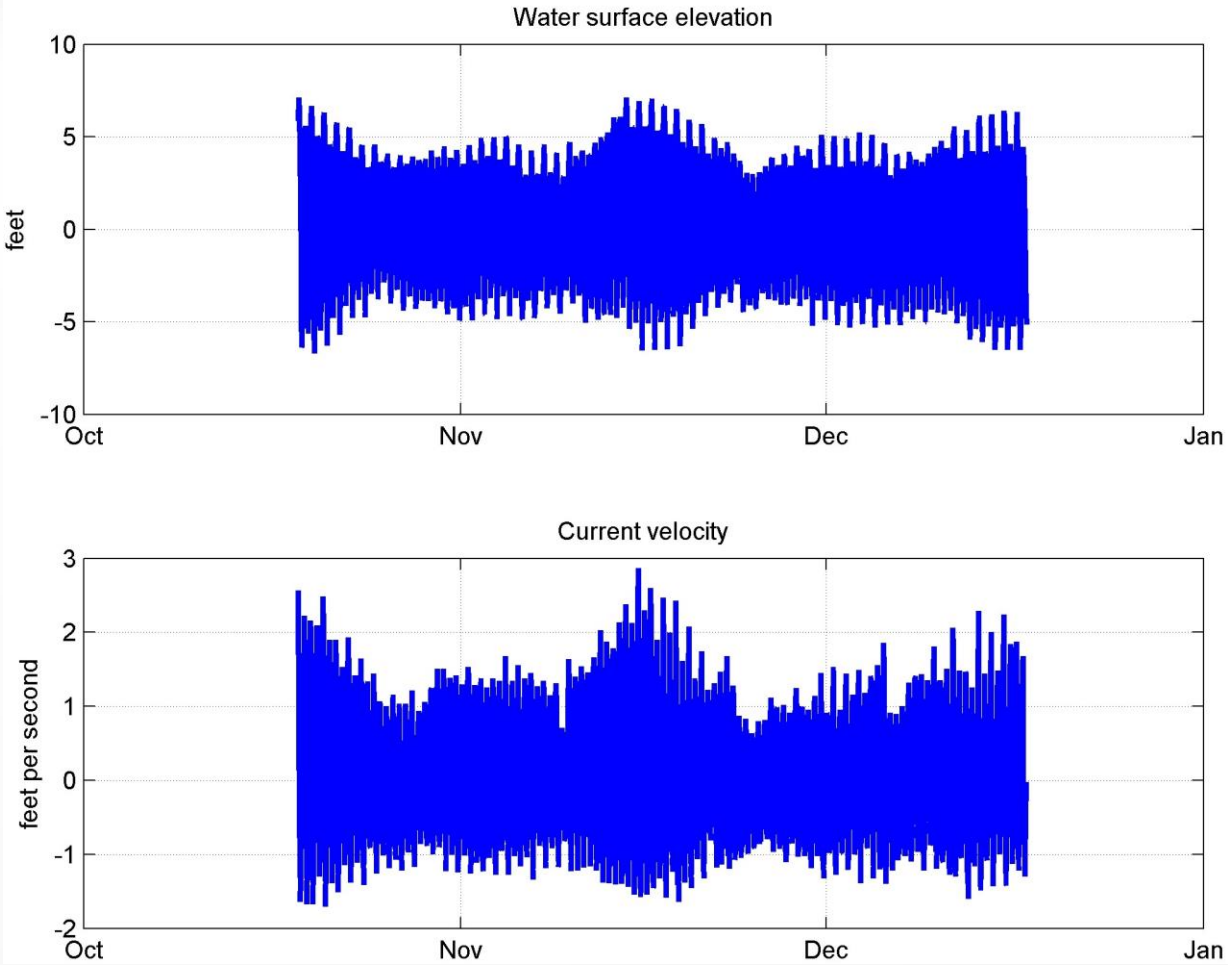
- Data sets
  - NOAA wave measurements from Buoy 44090 in Cape Cod Bay
  - Historical aerial photos
  - Town of Truro dredge records
  - Woods Hole Group and Center for Coastal Studies topographic & bathymetric surveys
  - Woods Hole Group shipboard current survey (ADCP)
  - Woods Hole Group tide, current, and wave measurement (AWAC)
- Analyses and models
  - Tidal constituent analysis
  - Digital Shoreline Analysis System (DSAS)
  - Hydrodynamic box model of inlet and estuary
  - Wave-driven longshore sand transport model
  - Crenulate bay model



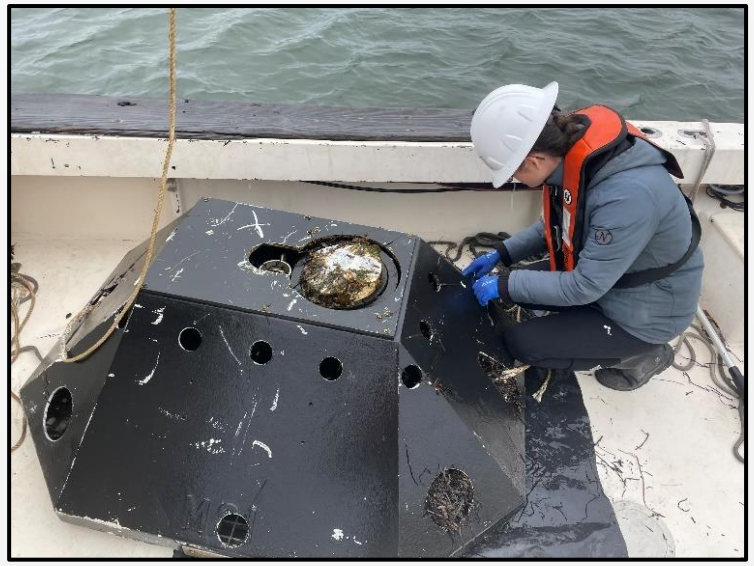
Bathymetric & Topographic Surveys



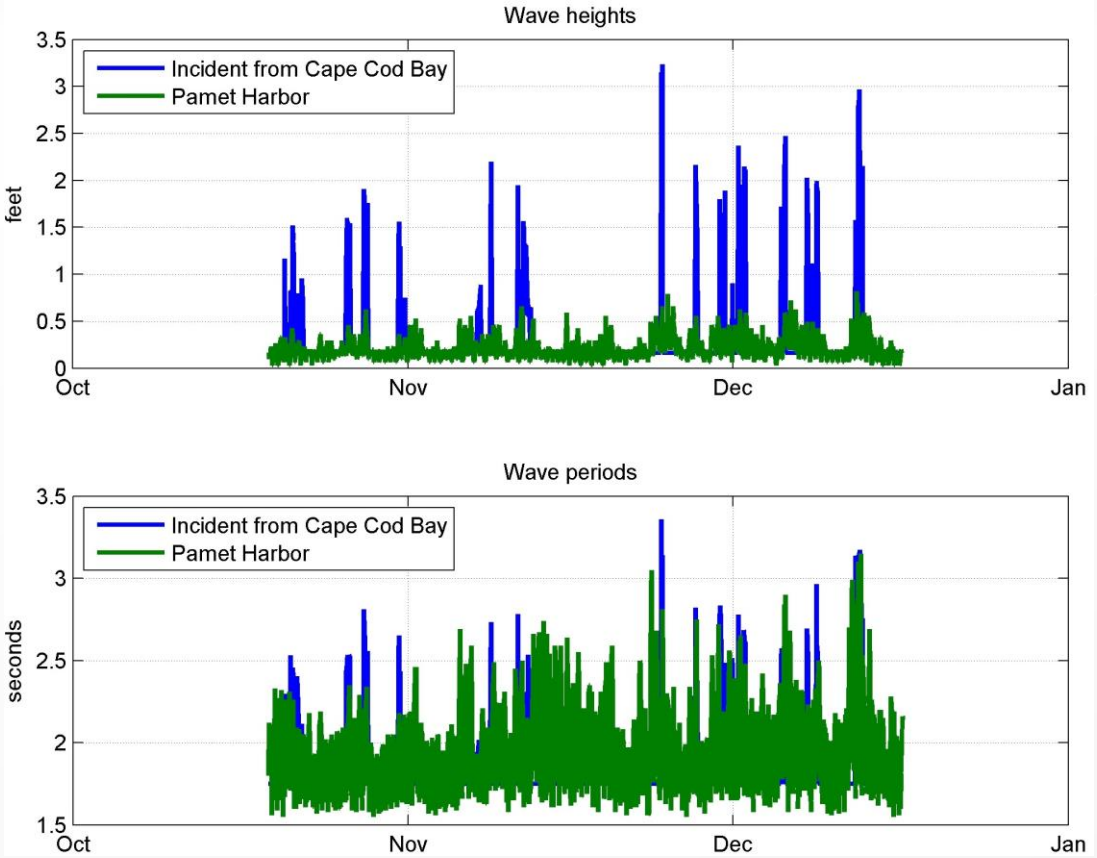
Tide and Current Data Collection



- Tides and currents are predominantly semidiurnal with strong fortnightly variability
- Fit to conventional model explains 98% of tidal variance and 90% of current variance
- Currents are flood dominant, i.e., flood currents are stronger than ebb currents, implying net transport of sediment into Pamet Harbor from Cape Cod Bay



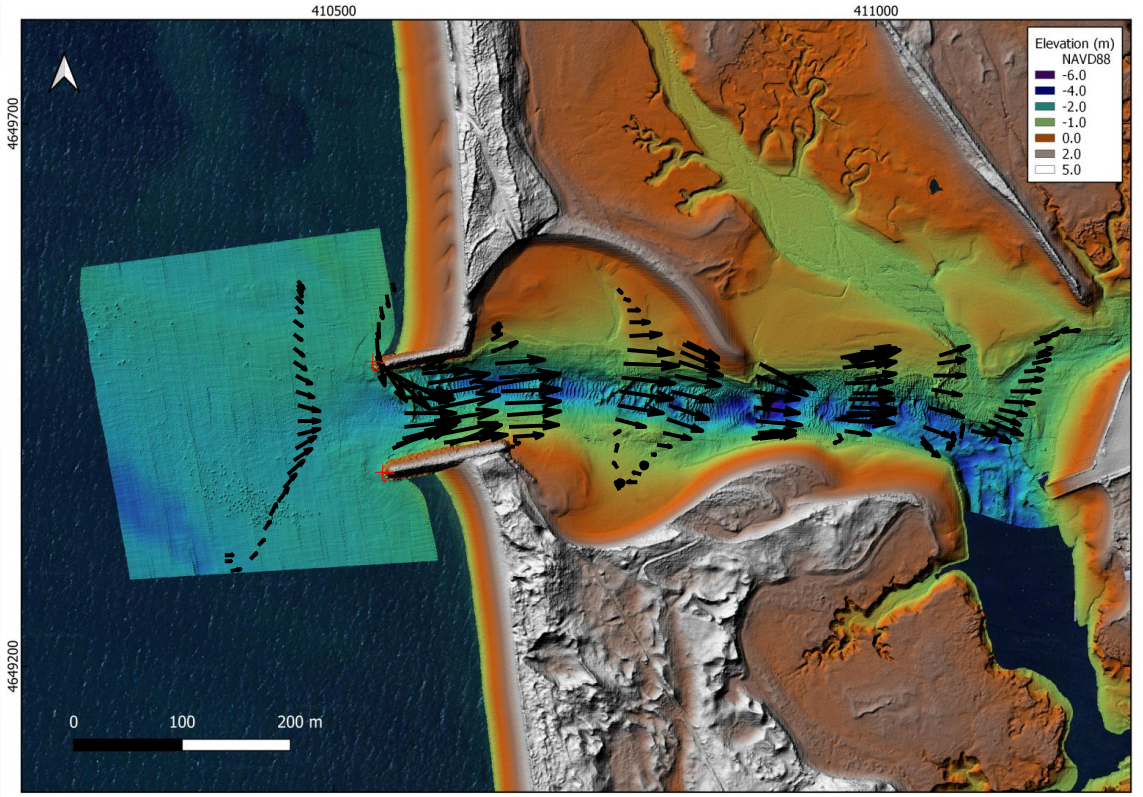
Wave Data Collection



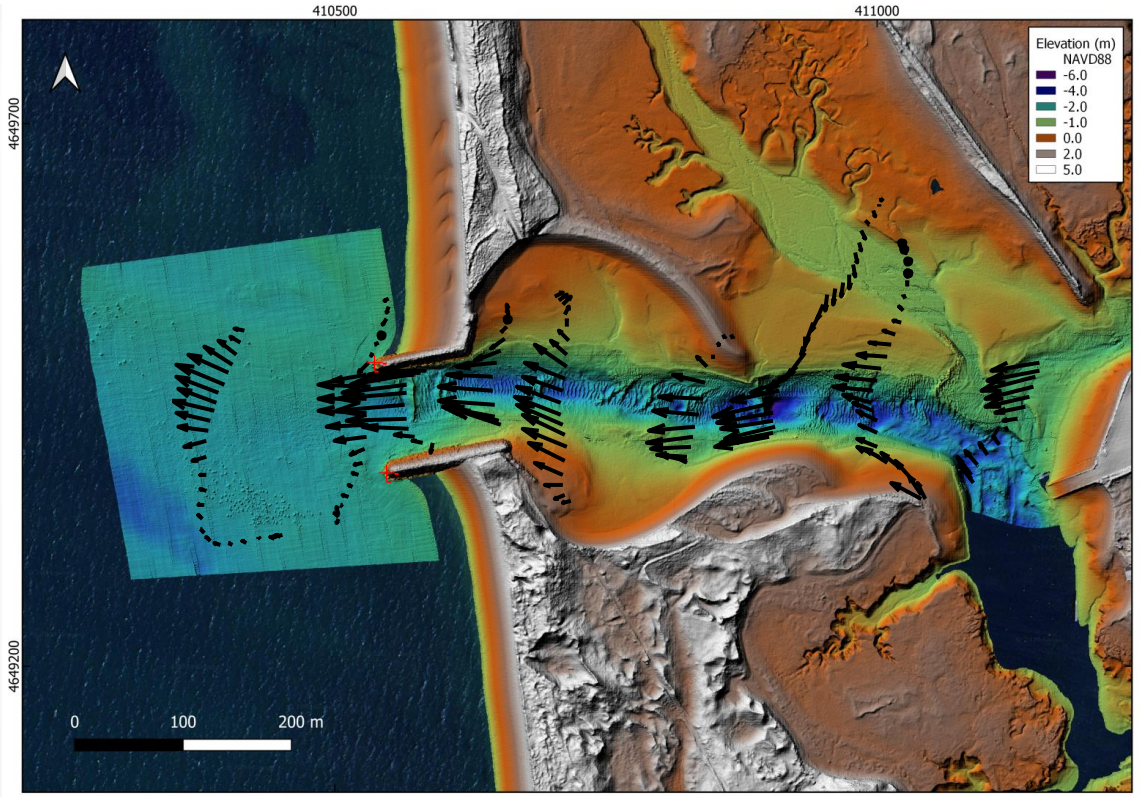
- Largest waves coincide with large incident waves outside inlet in Cape Cod Bay
- Reduction of wave height from Cape Cod Bay to Pamet Harbor is attributed to:
  - Energy loss in channel between jetties
  - Wave refraction and diffraction from channel into crenulate bays

Shipboard Current Velocity Measurements

Maximum Flood Current



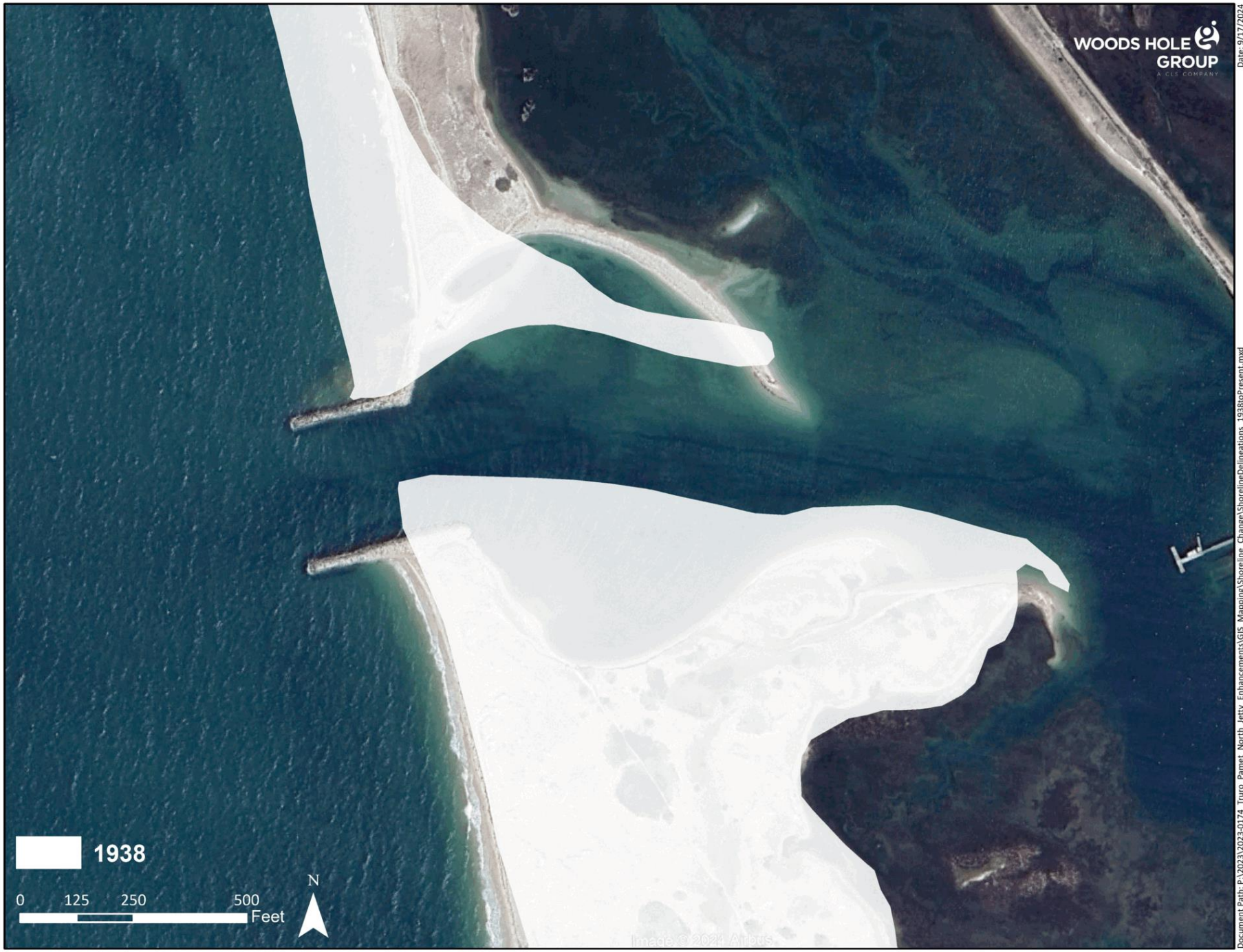
Maximum Ebb Current



- Maximum flood and ebb flow speeds ≈ 2.5 ft/s
- Strong velocities are confined primarily to main channels
- Velocities are weak over flats in crenulate bays

Inlet Geomorphology 1938–2023

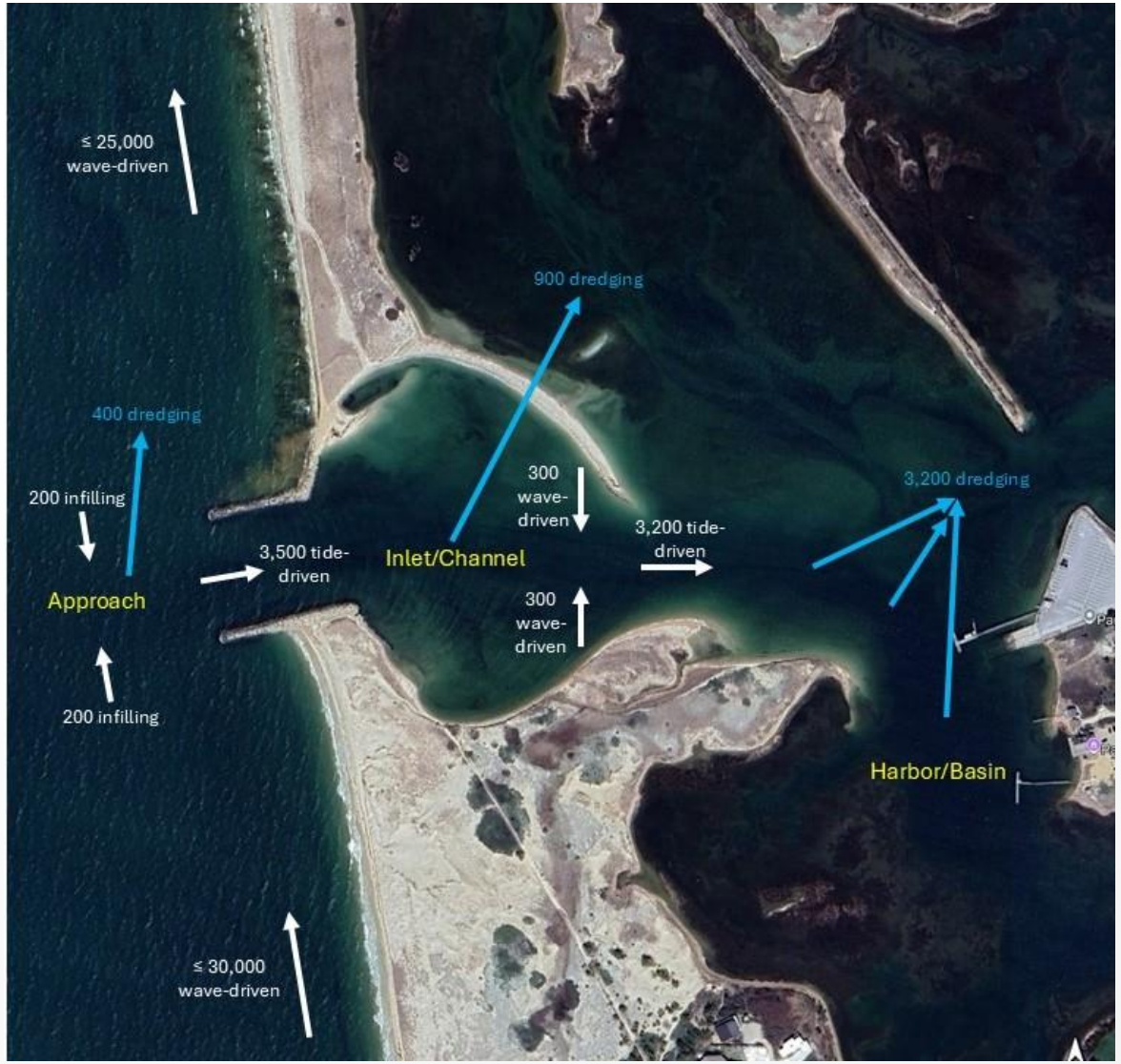
- Jetty installation
  - Southern pre-1951
  - Northern 1951
- Photos since 2011 show:
  - A northern crenulate bay, with a constant shape and growing dimensions, bordered by a landward-moving spit
  - A southern crenulate bay, with an evolving shape and growing dimensions



Shoreline Change Analysis 2009–2023

- Beach on Cape Cod Bay is erosional south and north of the inlet and intensified adjacent to inlet.
- Southern crenulate bay is erosional seaward and depositional landward, reflecting ongoing evolution.
- Spit east of northern crenulate bay has migrated eastward and seems to have established quasi-steady shape.

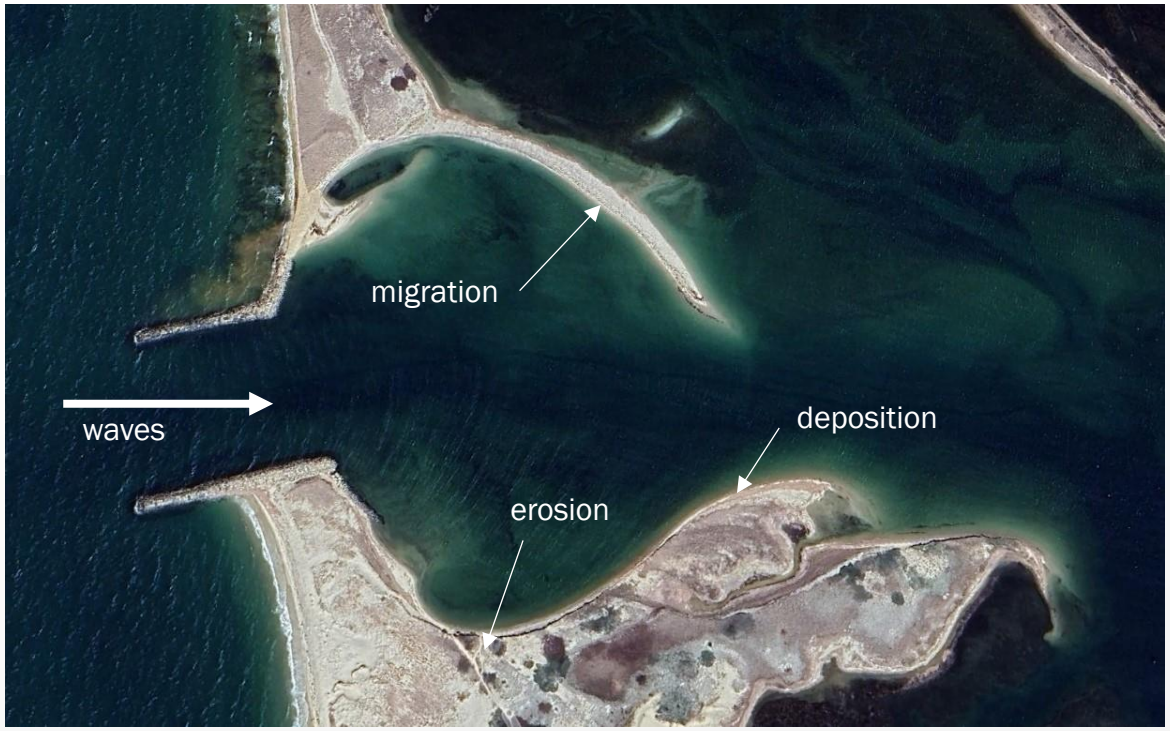
First-level Sediment Budget & Inlet Stability Analysis



- A sediment budget is a tool that allows an estimate of the sediment transport rates within a pre-defined area of the coastal zone accounting for all sediment sources, sinks, and transport pathways.
- Symbols:
  - Yellow text indicates names of features
  - Blue arrows and text indicate dredge operations
  - White arrows and text indicate wave- and current-driven sediment transport
  - All figures represent transport rates in cubic yards per year
- Estimated transport rates based on:
  - Hydrodynamic box model of currents
  - Current measurements
  - Wave measurements
  - CERC formula for wave-driven transport
  - Dredge records
  - Shoreline change rates
- Inlet imports sediment, indicating long-term infilling in absence of dredging
- Broadening the inlet would lessen the sediment import rate

Crenulate Bay/Inlet Literature Review

- Extensive literature
- Primarily a wave-driven process
- Nearly shore-parallel wave propagation favors crenulate bay formation
- North crenulate bay:
  - Shape is close to equilibrium predicted by classic models
  - Narrow spit likely formed by over-wash from Cape Cod Bay and is migrating slowly landward, probably because of overtopping and wave-driven transport during storm surge.
  - Further evolution is likely limited by sediment supply.
- South crenulate bay:
  - Active erosion up-wave and deposition down-wave indicate ongoing bay formation, far from equilibrium.
  - Differs from north crenulate bay because of plentiful supply of erodible sediment.



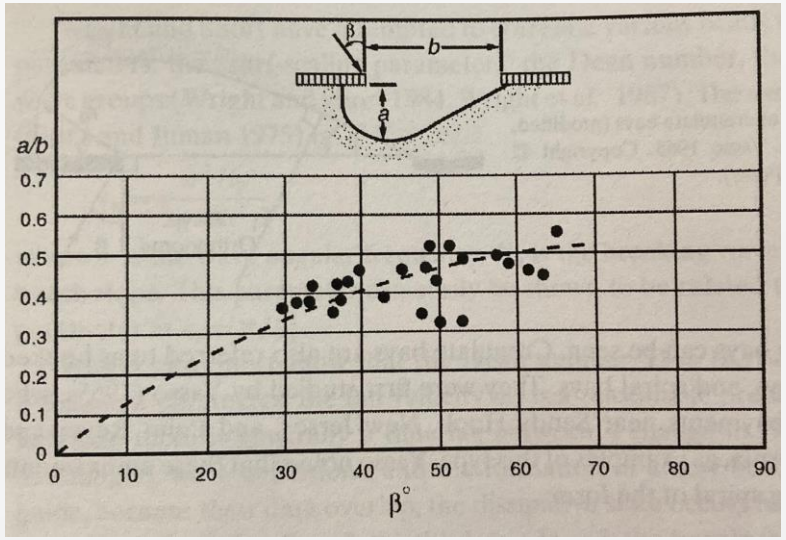


Figure 9.5 in Dean & Dalrymple, from Silvester (1970).

Phase 1 Conclusions

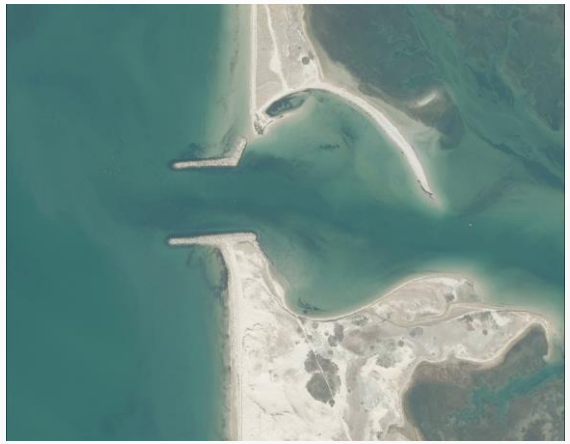
1. Pamet Harbor is in a predominantly erosional beach environment in eastern Cape Cod Bay.
2. Tidal currents produce a net landward transport of sand through the inlet into Pamet Harbor.
3. The net landward transport of sand into the Pamet Harbor through the inlet likely increases erosion on the Cape Cod Bay beaches just north and south of the inlet.
4. Sand transport forced by waves entering Pamet Harbor from Cape Cod Bay causes ongoing growth of the crenulate bays.

Recommendations for Phase 2

Approach:

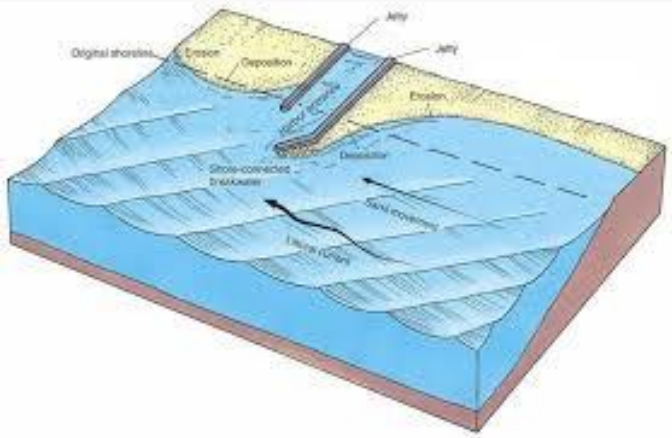
- Focus on analysis and design of feasible alternatives
- Analytical tools include targeted model simulations of:
  - Wave transformation, currents, and sand transport in inlet and channel
  - Longshore and cross-shore sand transport on Cape Cod Bay beaches

Examples of alternatives:



No action

Continued/expanded use of coir envelopes



Angled jetty at entrance

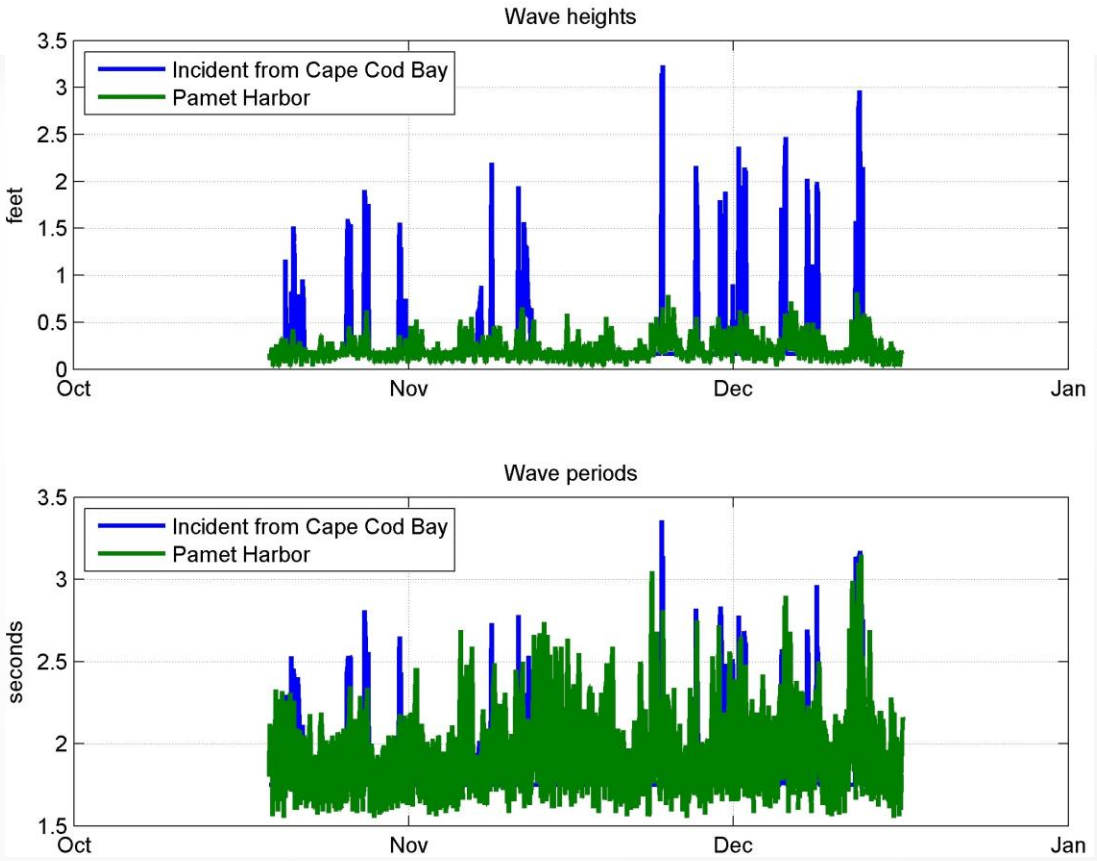
Diamond at landward jetty end

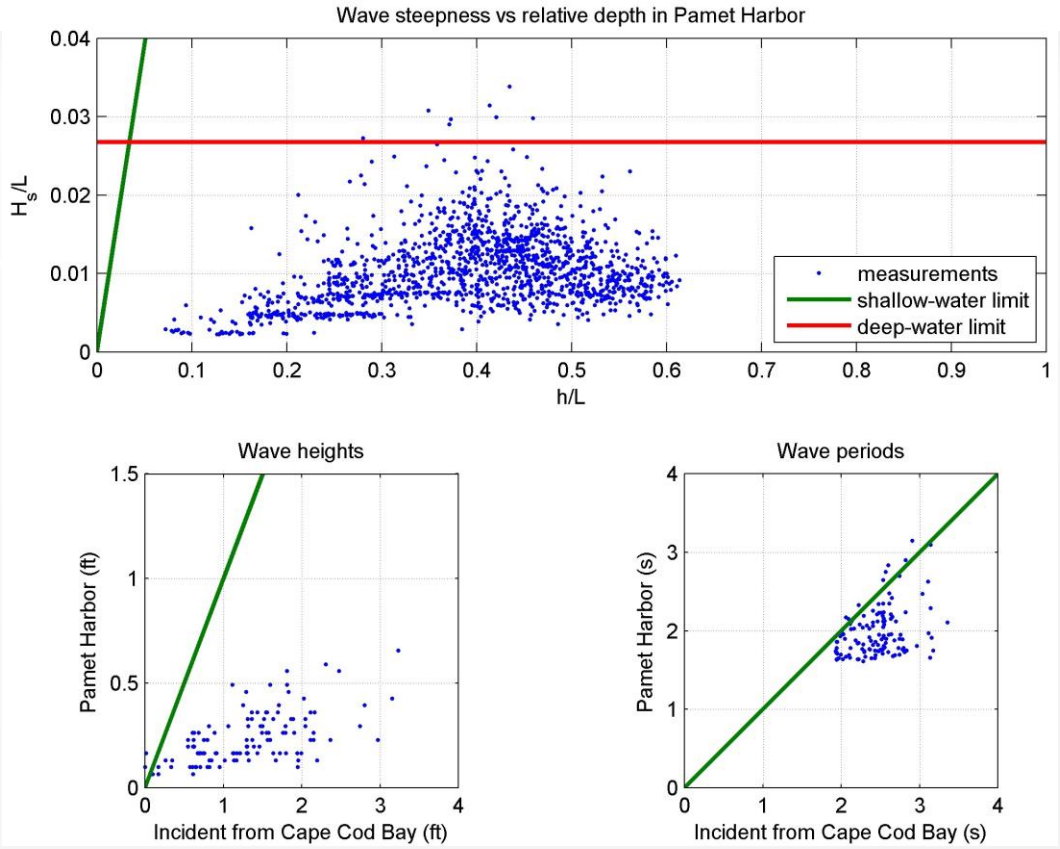
Recommendations for Phase 2 (continued)

Alternative		Goal		Anticipated maintenance requirements
Number	Name	Mitigate erosion on beaches outside inlet	Mitigate erosion in crenulate bays	
1	No action			Major
2	Continued/expanded use of coir envelopes	✓ .	✓ .	Moderate
3	Nourishment	✓ .	✓ .	Moderate
4	Dune restoration	✓ .		Moderate
5	Jetty modification: angled entrance	.	✓ .	Low
6	Jetty modification: landward extension/diamond terminus		✓ .	Low

Backup

Task 2 results: wave data collection





- Largest waves coincide with large incident waves outside inlet in Cape Cod Bay
- Wave heights at measurement location are limited by steepness rather than water depth
- Reduction of wave height from Cape Cod Bay to measurement location is attributed to energy loss in inlet channel between jetties and refraction/diffraction from channel into crenulate bays

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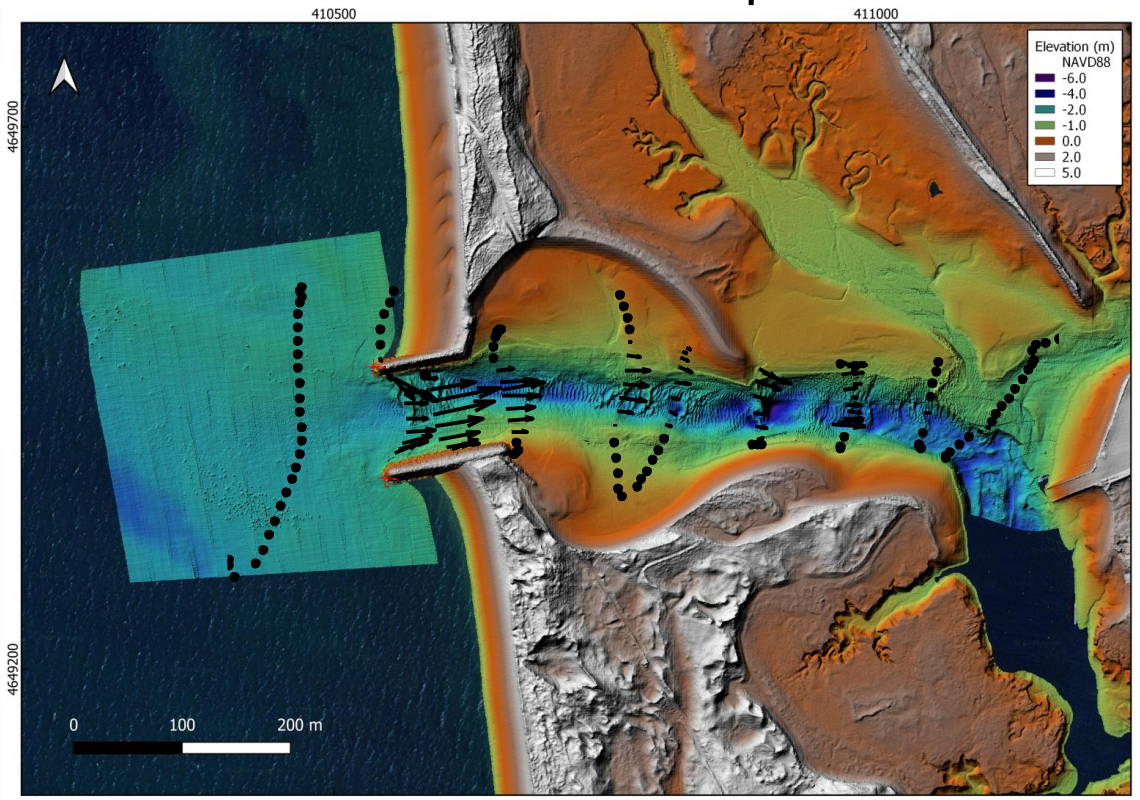
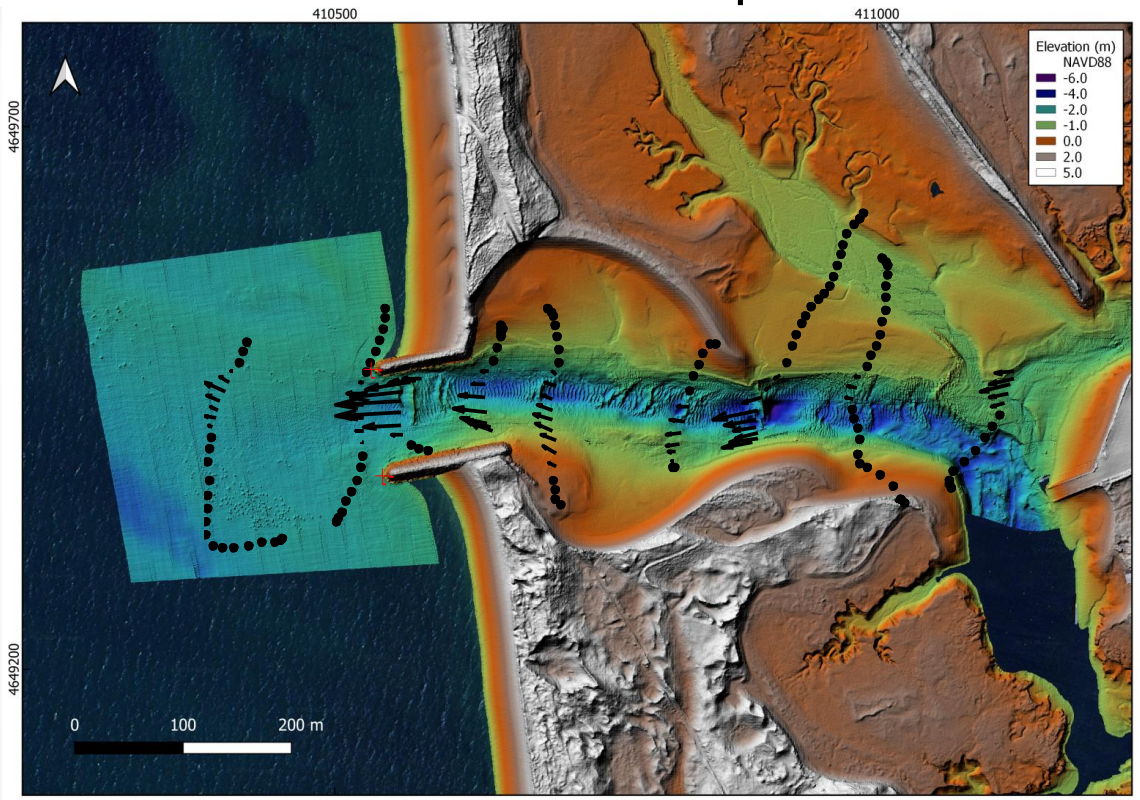
Task 3 results: sediment transport from shipboard velocities

Maximum Flood Transport



Maximum Ebb Transport



- All values are potential, representing transport that would occur given sufficient supply of erodible sediment
- Maximum flood and ebb values ≈ 1.5 ft^3 per ft per hr
- Strong transport is confined to main channels
- Current-driven transport is negligible over sand flats in crenulate bays

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Task 5 results: analysis of historical dredging & placement

Data as Received

Fiscal Year	Source Location	Cubic Yards
2000	Harbor	13,187
2012	Harbor Channel	12,857
2014	Harbor	2,908
2015	Harbor	22,857
2016	Harbor	10,778
2017	Inner Harbor	8,111
2018	Inner Harbor Basin	5,879
2019	Harbor/Basin	10,000
2020	Approach & Inner Channel/Mooring Basin	14,653
2021	Harbor Approach and Inlet	1,572
2022	Harbor Inlet, Approach, and Basin	3,299
2024	Harbor Inlet, Approach, and Basin	6,570
25-year total		112,671

Approximate Annualized Allocations

Source Location	Cubic Yards
Approach	400
Inlet/Channel	900
Harbor/Basin	3,200
Total	4,500

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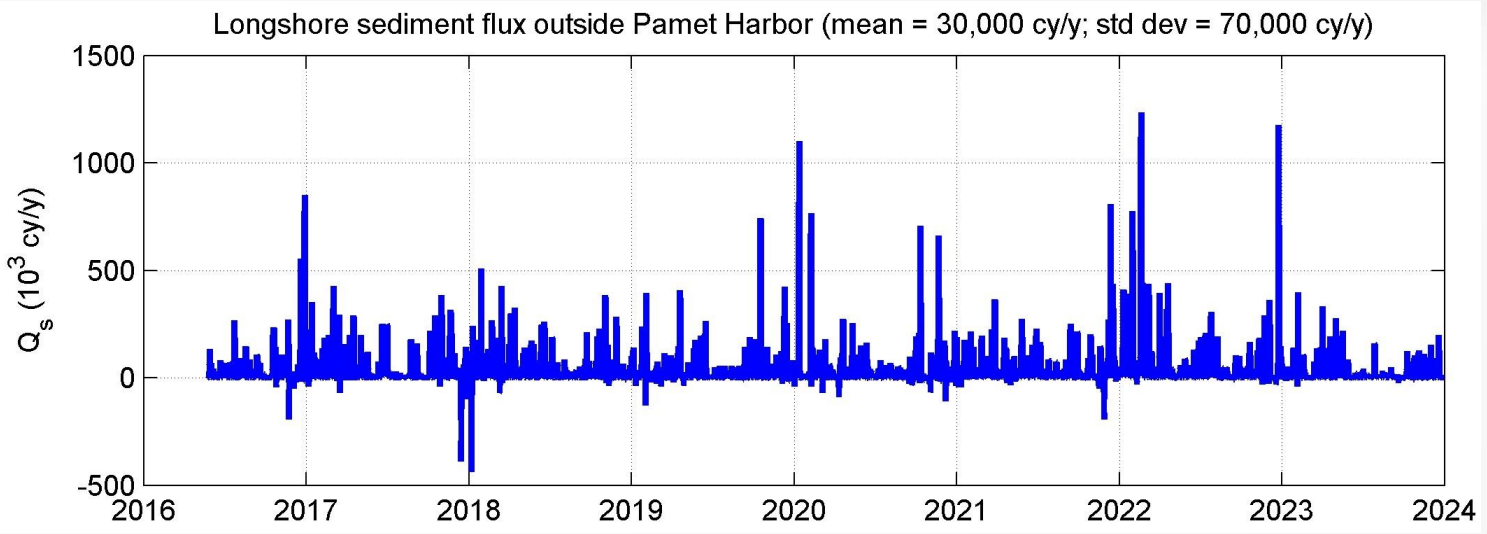
Task 6 results: longshore sand transport on Cape Cod Bay beaches



- Rates are potential, meaning they are estimates of the transport that would occur in the presence of sufficient erodible beach sand
- Beach is erosional both south and north of inlet; less so southward because of jetties