Living Shoreline Case Study

Delaware City Refinery, Delaware City

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Project Details

Goals:
- Shoreline Position
- Habitat

Energy Environment:
- High (1-6 mile fetch)
  Wind-driven waves especially storms
  Wakes from commercial boat traffic

Construction Dates:
- September 2015 (5 working days)

Partners:
- Delaware City Refining Company LLC
- Living Shorelines Solutions Inc. (LSS)
- Cardno, Inc.

See the Site Before and After

Pre-installation September 2015

Post-installation October 2020

Baseline Conditions

June 2014
Severely eroding shoreline along

Baseline Conditions

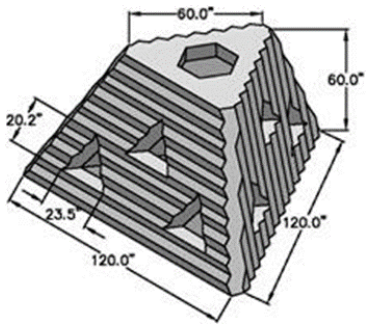
Issues:
- Ongoing shoreline erosion threatened critical infrastructure servicing the refinery's dock area including roads, pipelines, and fire-fighting stations
- Shoreline retreat averaged ~2.3ft. per year (2007 -2013) with higher annual loss rates in years with hurricanes and nor'easters

Site Characteristics/Important Features to Consider:
- Design must be resilient; capable of accommodating sea level rise (+50 years)
- Compatible with port operations including maintenance dredging of nearby ship berths and permanent booming for oil spill response
- Aesthetics not a driving consideration
- Construction access required heavy-lift cranes to move machinery and materials over active pipelines

Living Shoreline Installation

Design Elements:

- Wave Attenuation Devices (WADs®)

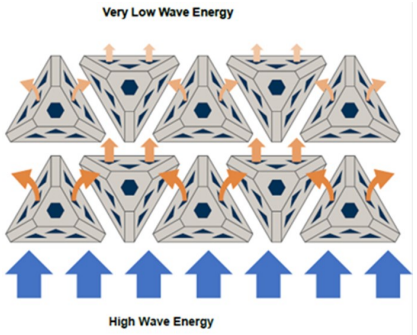


Permitting:

- State—Delaware Individual Subaqueous Lands Permit
- Federal—Army Corps of Engineers Section 404 Individual Permit

Materials and Placement:

- WADs® are proprietary 3-sided, pyramid-shaped, pre-cast concrete structures with openings (baffles) on each facet to dissipate wave energy
- WADs® for this project were manufactured at local concrete plant using molds leased from product developer (LSS) and hauled to site on flatbed trailer
- Hydrodynamic modeling used to refine WAD® dimensions and deployment configuration
- ~500 WADs® arranged along 1,450 linear feet of eroding shoreline in overlapping double-row parallel to shore just above MLW
- WADs® placed offshore using crane or amphibious excavator



Monitoring Efforts

Metric	Method
Shoreline position	Cross Sections (RTK)
Sediment accretion	Coring/Grain Size
Habitat	Vegetated edge (GPS)
Habitat	Wildlife (Visual/Photo)
WAD® Stability	Visual/Photo/GPS
Major Weather	Event Log

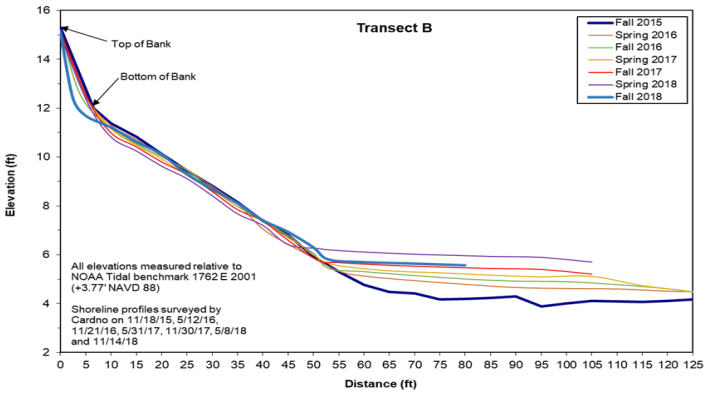
Measured Environmental Results

- Passive accretion/retention of fine-grained silt and clay sediments along protected shoreline
- 1.9ft. average increase in bottom elevation landward of WADs® within 3 years
- Marsh vegetation expanding to colonize new sediment deposits
- No settling or shifting of WADs® observed to date
- WADs® did not deter wildlife use
- First project to use WAD® technology in Delaware River Basin (demonstration project)

Adaptive Management/Lessons Learned

Design Elements

- Need to lift equipment/materials over pipelines during construction added complexity/cost
- Accretion monitoring hampered by low bearing capacity of newly deposited sediments
- Value of hydrodynamic modeling during design to avoid costly post-construction reconfiguration
- Shoreline energy reduction and passive accretion from WADs eliminated need for shoreline augmentation using dredge material



Project Photos

September 2015
Placement of WADs® with amphibious excavator

September 2015
Wave energy reduction landward of WAD® array