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Coastal Engineering Principles and Practices for Puerto Rico

Coastal Risk Management Symposium

Natural, Structural and Hybrid Interventions

PROGRAMA DE MANEJO ZONA COSTANERA

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November 22, 2019

What Does Coastal Resiliency Mean?

- The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or man-made, under all circumstances of use. This definition also applies to engineering, ecological, and community resilience.
- The ability of a community to bounce back after hazardous event
  - To a more productive and functional stage
  - Design and build back with more resiliency

Key Threats

- Waves
- Flooding
  - Coastal Flooding (set up, storm surge, extreme tides)
  - Rainfall
- Hurricanes
  - Winds
  - Tides
  - Storm Surge
- Sea Level Rise

Vulnerability

- Aged, obsolete and outdated infrastructure
- Population profile
  - Elderly
  - Children
  - Poverty
- Inadequate planning, project site selection and preparedness
- Lack of education and public awareness
- Poor communication

How has Coastal Erosion been traditionally addressed in PR?

- Informal construction and lack of design
- Concrete debris deposits and land reclamation
- Use of Gabions for coastal protection – DO NOT USE!
  - Corrosion and undersized rocks
- Vertical seawalls exposed to wave action – AVOID!
  - Magnification of wave action
  - End effects
- Set back and maintain adequate distances between assets and threats (wave attack, shoreline erosion)
- Understand that the shoreline is dynamic and changes
  - Where it was 20 years ago is not where it is today
  - Where it is today is not necessarily going to be where it will be tomorrow

Inadequate Design - Informal Construction

Marbella Club, Palmas del Mar

Gabions

- Steel cages filed with small rocks
- Good for fresh water – BAD for salt water

Gabions in Corcega, Rincon

Gabions in Rincon

Vertical Seawalls

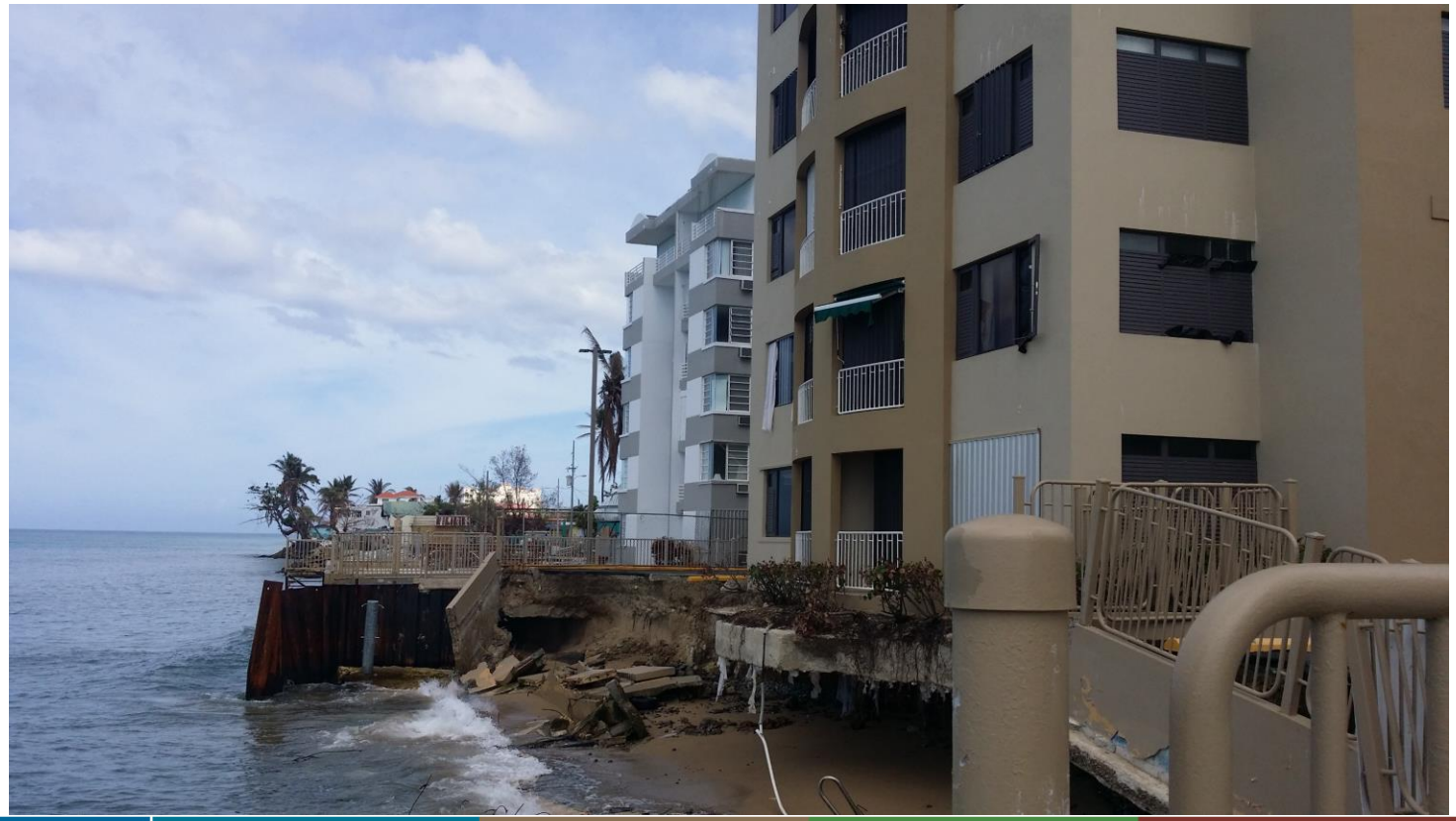
- Good as retaining structures
- Bad as energy dissipators

Vertical Seawalls

Vertical Seawalls

Vertical Seawalls

- Design considerations – not just static
- Wave impacts, reflection effects, scouring



Vertical Seawalls

- Catastrophic failure

Consequences?

- Further Impacts
  - Downstream Erosion
  - End Effects
- Increased Vulnerability
  - Worse than before
- Regulatory Agency Review Reluctance
  - Permit analysts lack technical support
  - Afraid to make bad decisions
  - Lengthy permitting processes

What can we do?

- Understand the root of the problem, raise awareness and educate
  - Public – cannot do whatever
  - Regulatory Agencies – need to learn what is acceptable and what is not acceptable
  - Scientific and Engineering Professionals – need to understand the regulatory framework, available resources and design procedures of coastal engineering

What are we doing now in PR?

- Central Recovery, Reconstruction and Resiliency Office
  - Post-Hurricane Maria
  - FEMA Recovery Funds
  - Private Property Debris Removal Program
- DNER's Vulnerability Assessments and Adaptation Plans
  - Community Based Pilot Studies in Five Municipalities (Rincon, Dorado, Culebra, Salinas & Loiza)
- DNER's Coastal Resiliency Funding Guide
  - Educate stakeholders about federal funding programs
- DNER's Coastal Engineering Guidelines
  - Educate and raise awareness – Planners and Permit Analysts on what's OK and what's not OK
  - Educate and provide tools and technical resources – Engineers and Contractors on how to address coastal erosion

What is Coastal Engineering?

- Coastal engineering is a branch of civil engineering concerned with the specific demands posed by constructing at or near the coast, as well as the development and transformation of the coast itself. The hydrodynamic impact of waves, currents, wind, tides, storm surges, hurricanes and tsunamis and the harsh environment of salt seawater are typical challenges for the coastal engineer.

What is the basic approach?

- Understand the coastal environment – Gather Information
- Public Education and Community Engagement
  - What is acceptable and unacceptable
  - Where to build, where not to build
- Adaptation Tools – Planning, Regulatory, Land Use, Structural, Non-Structural, Hybrid
- Conduct the necessary Studies and Engineering Analyses
- Monitoring and Evaluation – Lessons learned

Adaptation Tools

- Planning Tools
- Regulatory Tools
- Land Use Tools
- Structural Tools
- Non-Structural Tools
- Hybrid Techniques

Structural Tools

- Scour and Erosion Protection
  - Revetments
  - Nearshore reefs
- Structural Elevation
- Breakwaters & Artificial Reefs (submerged and emerged)
- Seawalls and bulkheads
  - In marinas and sheltered waters
  - Set back with toe protection
- Jetties and T-groins

Plaza del Mar Revetment, Palmas del Mar



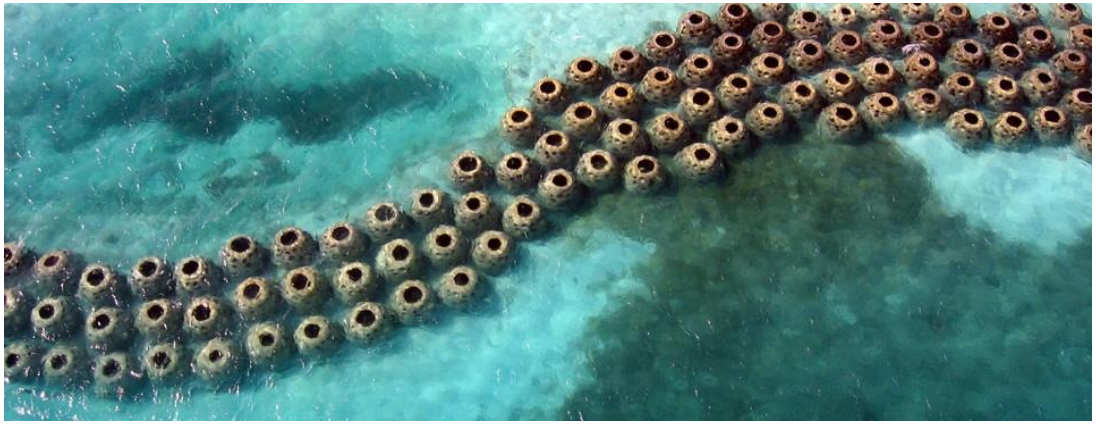



Before Maria – After Maria

Nearshore Artificial Reefs

Artificial Reef off Maiden Island, Antigua. Note turbulent water and erosion ridges on beach before reef (left), and clear calm water after reef (right). COG, Dr. Alfredo Torruella

Artificial Reefs



Nearshore artificial reefs constructed of Reef Balls®

Adopt an artificial reef Arrecife Condado

Escambrón Underwater Trail for restoration and recreation by Taíno Reefs

Condado Lagoon Underwater Trail - coral reef restoration by Taíno Reefs

Artificial Reefs

Narrowneck, Gold Coast of Australia. Note salient formation in front of beach (top) and fishing boats near reef (bottom).

Breakwaters

Tetra Pods

Dolos

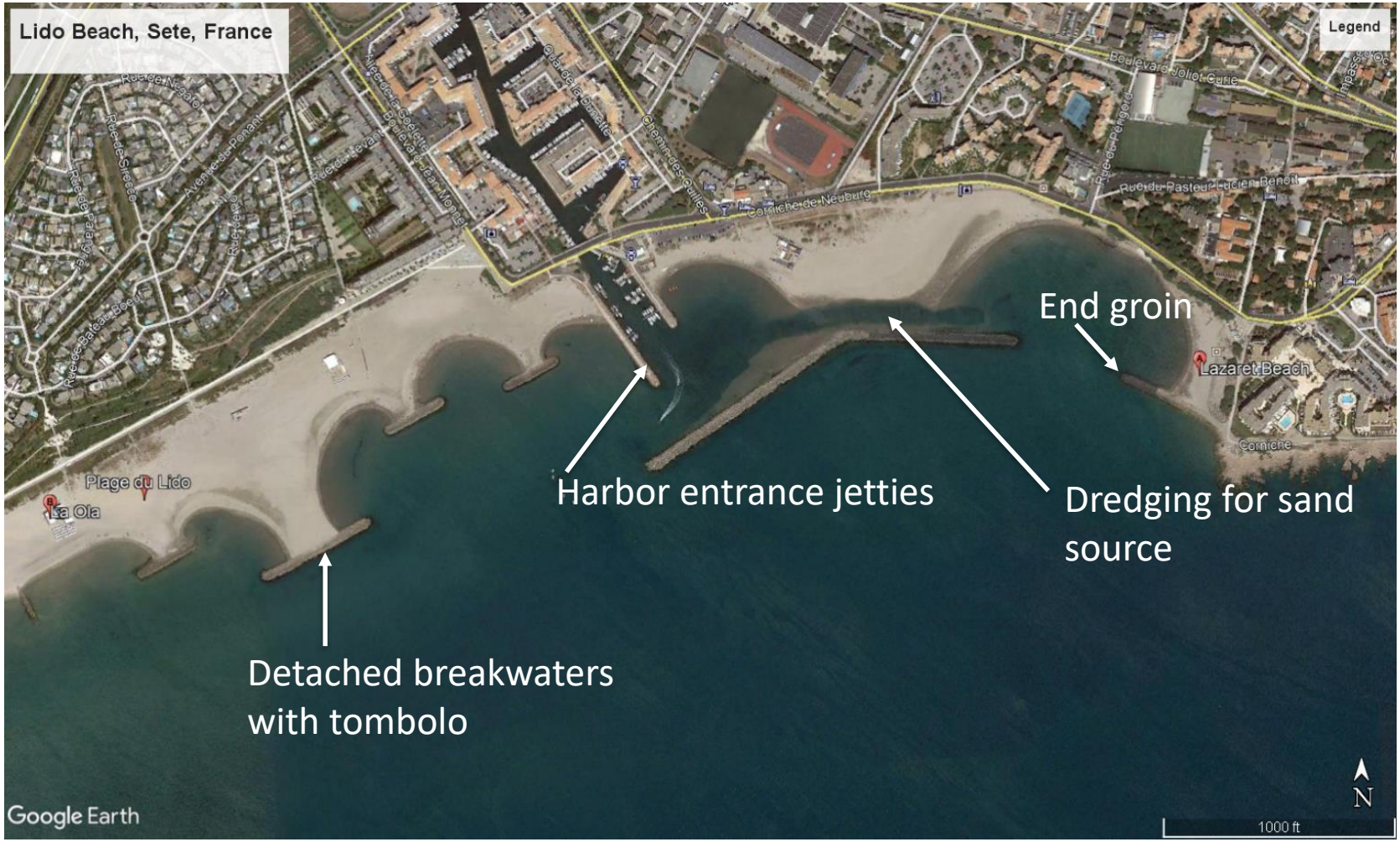
Tri-Pods

Cubes

Jetties and Groins

Okinawa, Japan

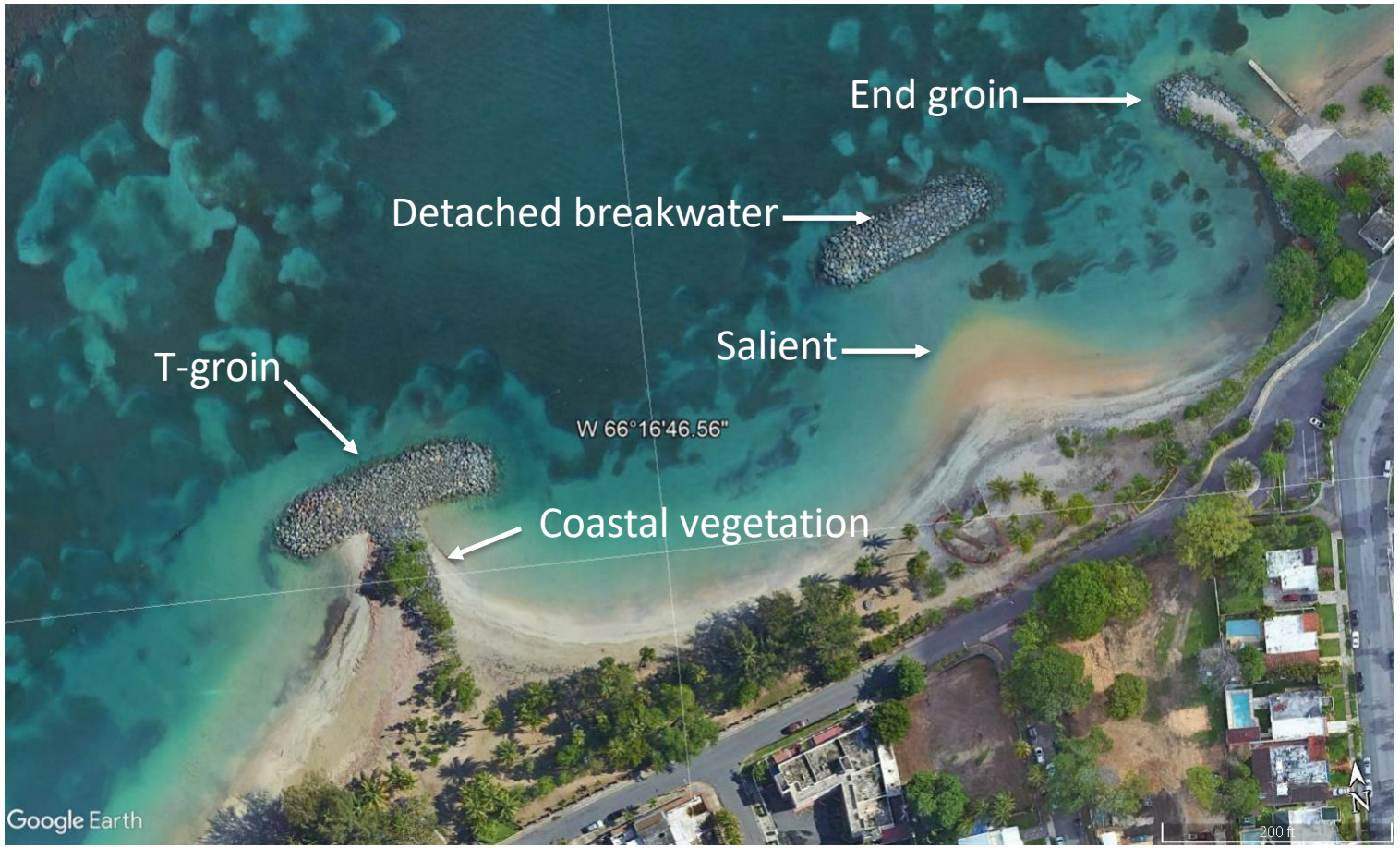
Jetties, Breakwaters, Beach Nourisment and Inland Marina, Lido Beach, FR



Jetties, Breakwaters, Beach Nourisment and Inland Marina, Lido Beach, FR

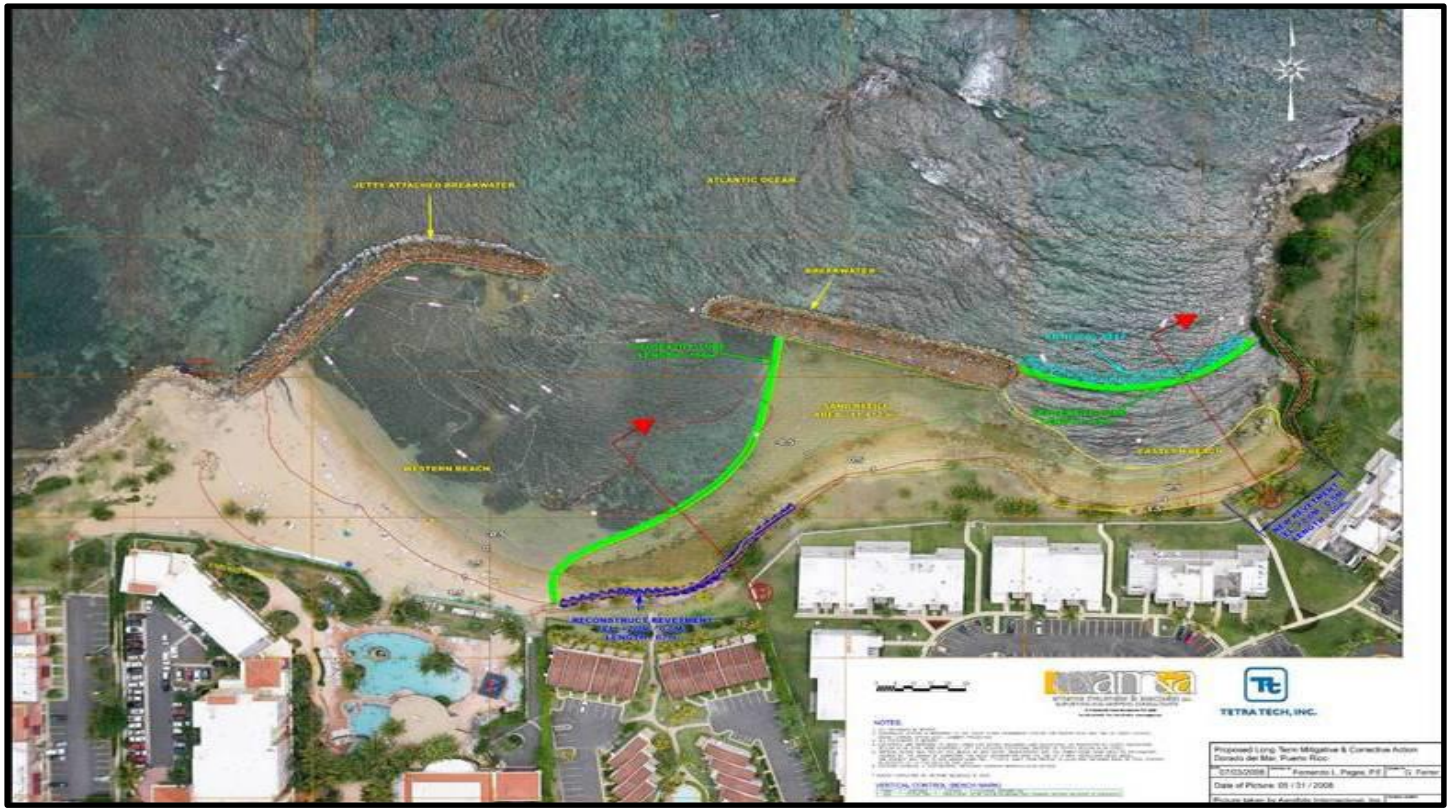
Detached Breakwater, T-Groin, End Jetty

Dorado, Puerto Rico



Breakwater System

Dorado del Mar Breakwater Improvements, Puerto Rico

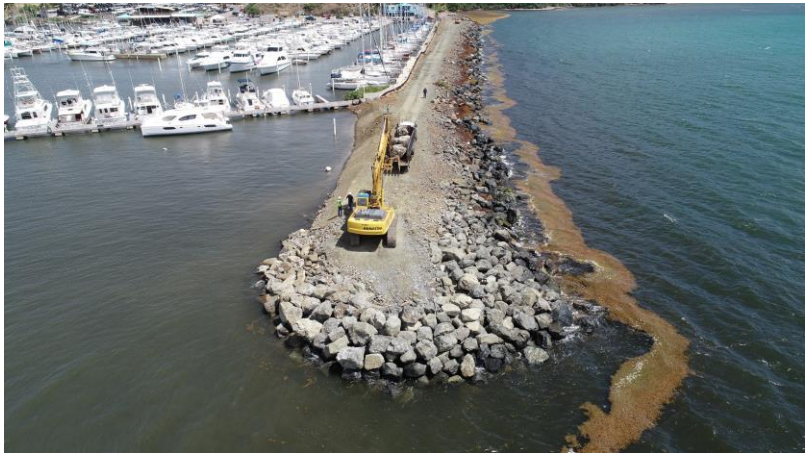


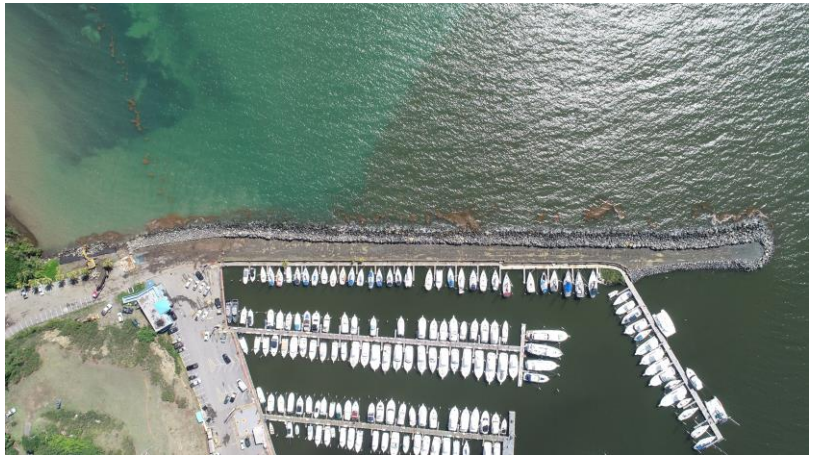
Detached Breakwater

El Morro, Puerto Rico

Attached Breakwater

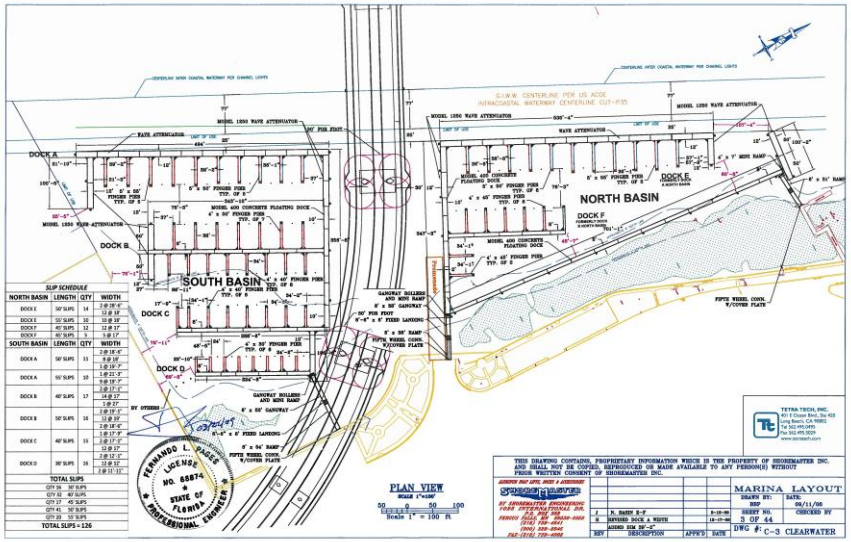
Puerto Chico, Fajardo, Puerto Rico





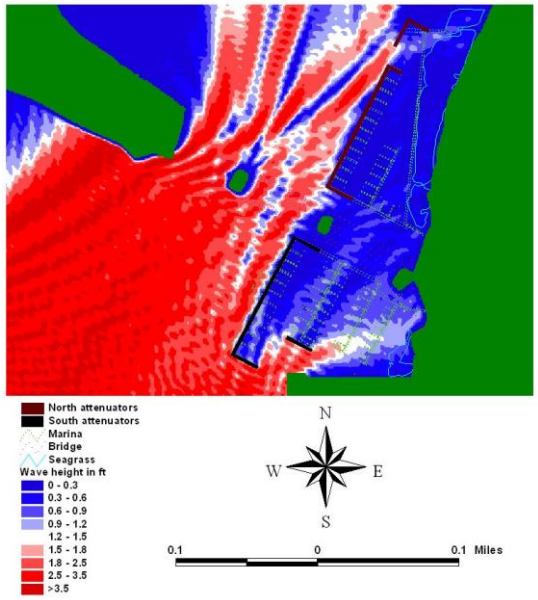
Floating Breakwaters – Marina Papagayo, Costa Rica

Floating Breakwaters – Clearwater Marina, FL

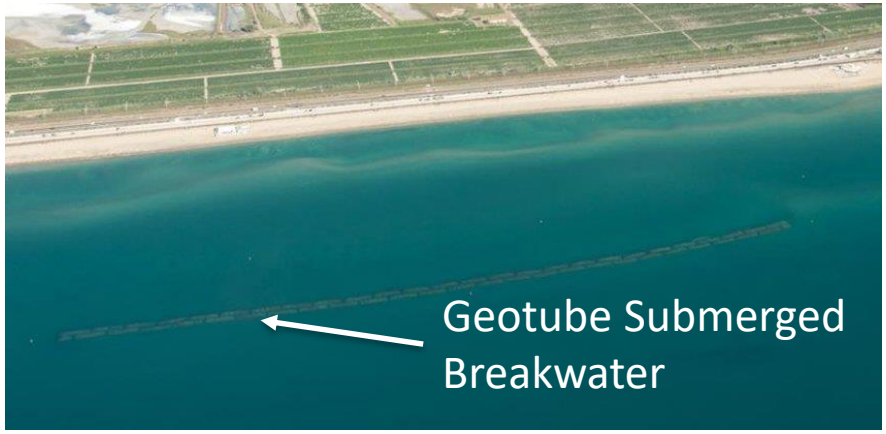


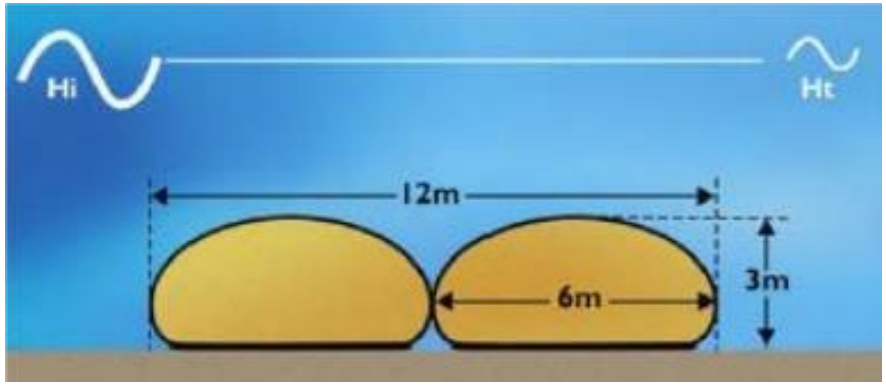
Incident Wave:
H = 4.2 ft; T = 3.5 s; Dir: SW (225 deg)

Marina Layout 2



Submerged Breakwater/Perched Beach



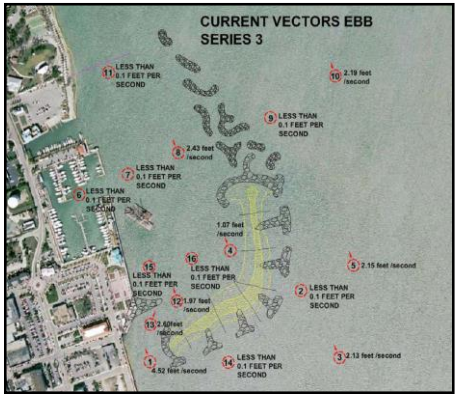


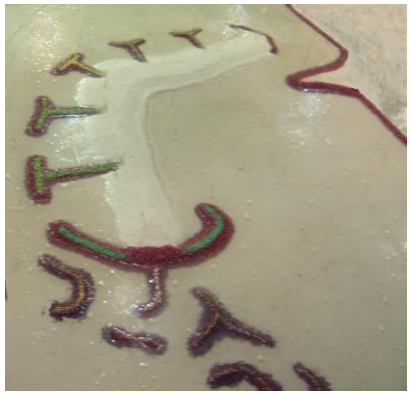
Use of sand filled geotubes to create submerged breakwater. Location: Lido Beach, Sete, France. (Ref.: Zengerink, 2017)

Beach Nourishment

Beach Nourishment

Waterfront Restoration and Protection Project – An Effective Multifunctional Approach





Non-Structural Tools

- Artificial reefs
- Coastal wetland creation
- Dune building
- Beach nourishment
- Living shorelines

Hybrid Techniques

- Combinations of Structural and Non-Structural
  - Breakwaters + Beach Nourishment
  - Revetments + Vegetated Dunes

Tiered Bulkhead

Oyster Reefballs

What are the typical baseline studies

- Bathymetric and Topographic Surveys
- Biological and Habitat Characterization Studies
- Meteorological and Oceanographic Studies
  - Wind, Waves, Currents, Storm Surge, Tides
- Geotechnical and Sand Characterization Studies
  - Sand compatibility analyses
- Hydrodynamic Modeling
  - Waves, Currents, Sediment Transport, Water Quality
- Environmental Assessment or Impact Studies

What are the typical design criteria

- Engineering Analysis & Design
  - Revetments, Seawalls and Bulkheads
  - Breakwaters, Artificial Reefs
  - Beach Nourishment, Sand Dunes
- Design Significant Wave Height
- Design Wave Period
- Location, Water Depths
- Layout, Extent, and Elevations
- Armor Stone Size, Weight & Gradation
- Sand Grain Size Distribution
- Foreslopes, Backslopes, Runup

Coastal Engineering Technical References

- US Army Corps of Engineers, Coastal Engineering Manual, URL: http://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/?udt_43544_param_page=4
- US Army Corps of Engineers, 2013. Coastal Risk Reduction and Resilience: Using the Full Array of Measures, Report Number CWTS 2013-3, Directorate of Civil Works, US Army Corps of Engineers, Washington, DC, September 2013.
- Federal Emergency Management Agency, (FEMA). Hazus Flood Model, URL: https://www.fema.gov/hazus-mh-flood-model
- Appelquist, L. R., T. Balstrom, K. Halsnaes, 2016. Managing Climate Change Hazards in Coastal Areas - The Coastal Hazard Wheel Decision-Support System, United Nations Environmental Programs. URL: http://coastalhazardwheel.org/.
- PRDNER, Coastal Engineering Guidelines, 2019.
- Many other resources available for each application – UNDERSTAND THE PROBLEM AND APPLY SCIENCE AND ENGINEERING!

Regulatory Framework

Federal – USACE

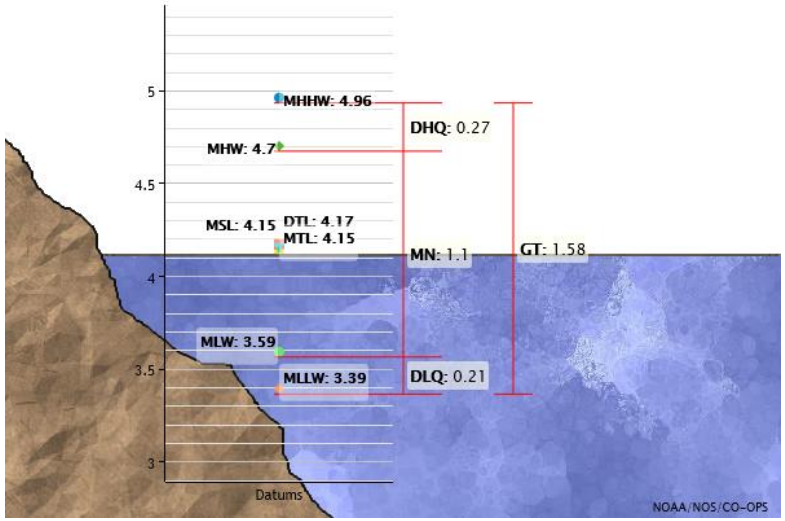
- Section 10 of Rivers and Harbors Act of 1899
  - Works within navigable waters of the US
- Section 404 of the Clean Water Act
  - Fills of submerged land within waters of the US

Local – Puerto Rico Department of Natural and Environmental Resources

- DNER 4860 Regulation
  - Submerged Lands Concessions

Federal Jurisdiction

- Federal Agency USACE
  - USACE Regulates Navigable Waters of the US
  - Below Mean High Tide – NOAA Tidal Info
    - Datums for 9755371, San Juan, La Puntilla, San Juan Bay PR



Local PR Jurisdiction

- PR DNER
  - Coastal Maritime Zone
    - *Space between low tide line and the limit where winter and major temporal waves reach the shore*
  - 9 nautical miles offshore
  - Regulation 4860 - Regulation for the Use, Surveillance, Conservation and Administration of the Territorial Waters, the Areas Submerged Under These and the Maritime Terrestrial Zone

Main Hurdles to Solving Coastal Erosion and Restoration in PR

- Past history and bad planning
- Lack of understanding of the coastal environment
  - Planners and engineers – one size does not fit all
  - Regulatory agencies technical resources – under funded
  - Public perception – anything done in the coast is BAD
- Lack of appreciation for our coastal resources as an economic resource
  - Invest in protection and eco-restoration
  - Advance Private Property Debris Removal program
- Governmental Bureaucracy

Opportunities for Solving Coastal Erosion and Strengthening Coastal Resiliency in PR

- Long history of lessons learned
- First hand experience documenting EXTREME events in the Caribbean
- Coastal Engineering Guidelines – DNER
- Best in Class – Physical Oceanographic and Coastal Resources – UPRM – CARICOOS
- Regional pioneers of Climate Change Advisory and Policy – PRCCC
- Think beyond traditional engineering – think and engineer with NATURE and LIVE the SHORELINE!