



TETRA TECH

Living shorelines

Vamsi Krishna Sridharan, Ph.D., M.ASCE

June 1, 2024

Photo credits:

<https://shorebread.com/2017/03/23/then-now-the-beaches-of-crisfield/>

<https://ewn.erdc.dren.mil/atlas-series/volume/engineering-with-nature-an-atlas-volume-2/>

<https://hcr.ny.gov/living-bay-projects>

<https://www.erdc.usace.army.mil/Media/Publication-Notices/Article/3783545/engineering-with-nature-an-atlas-volume-3/>



- Introduction to living shorelines



- Living shoreline approaches



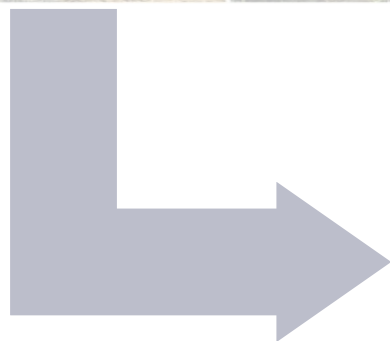
- Implementing living shorelines



- Introduction to living shorelines



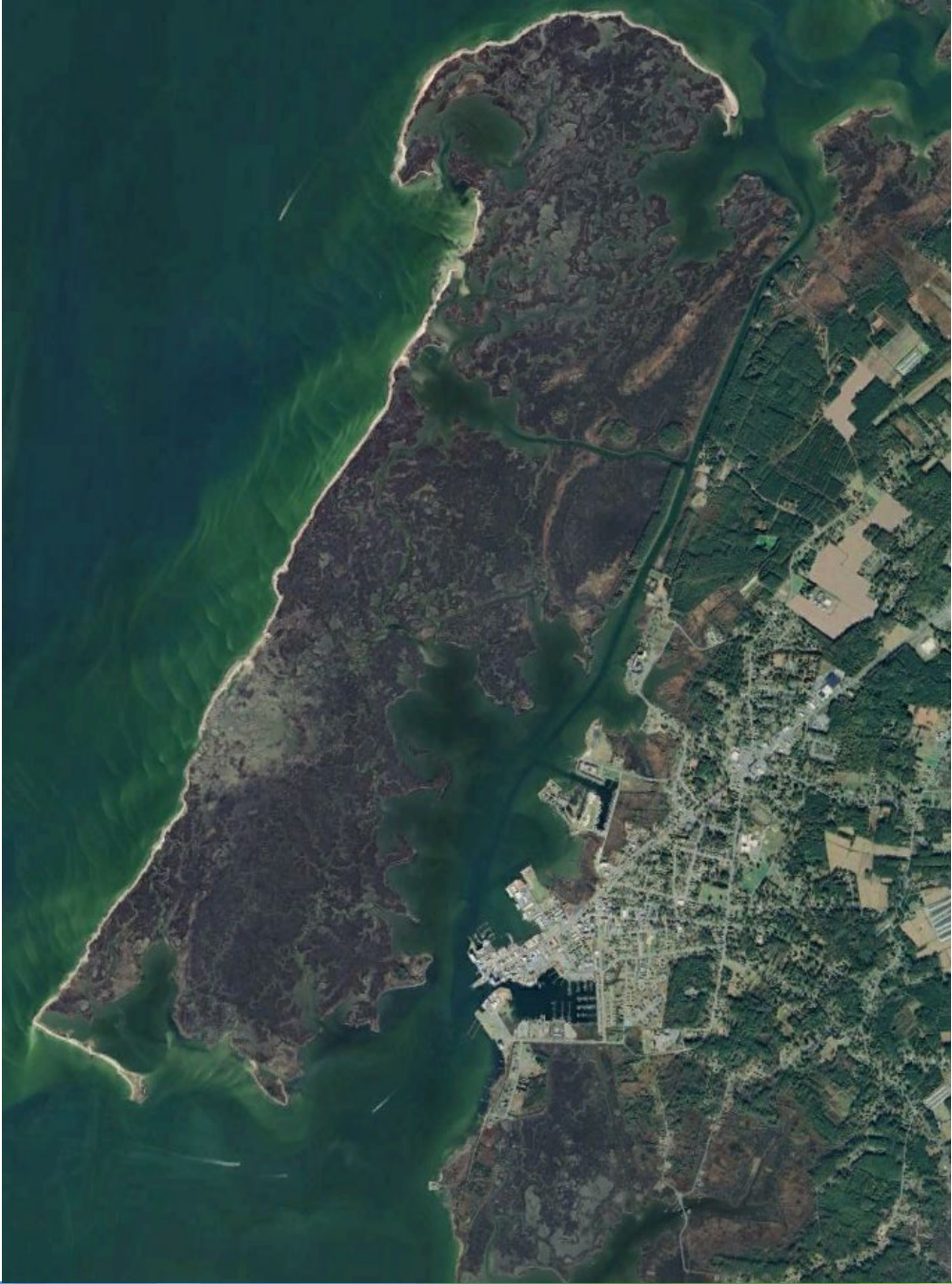
- Living shoreline approaches



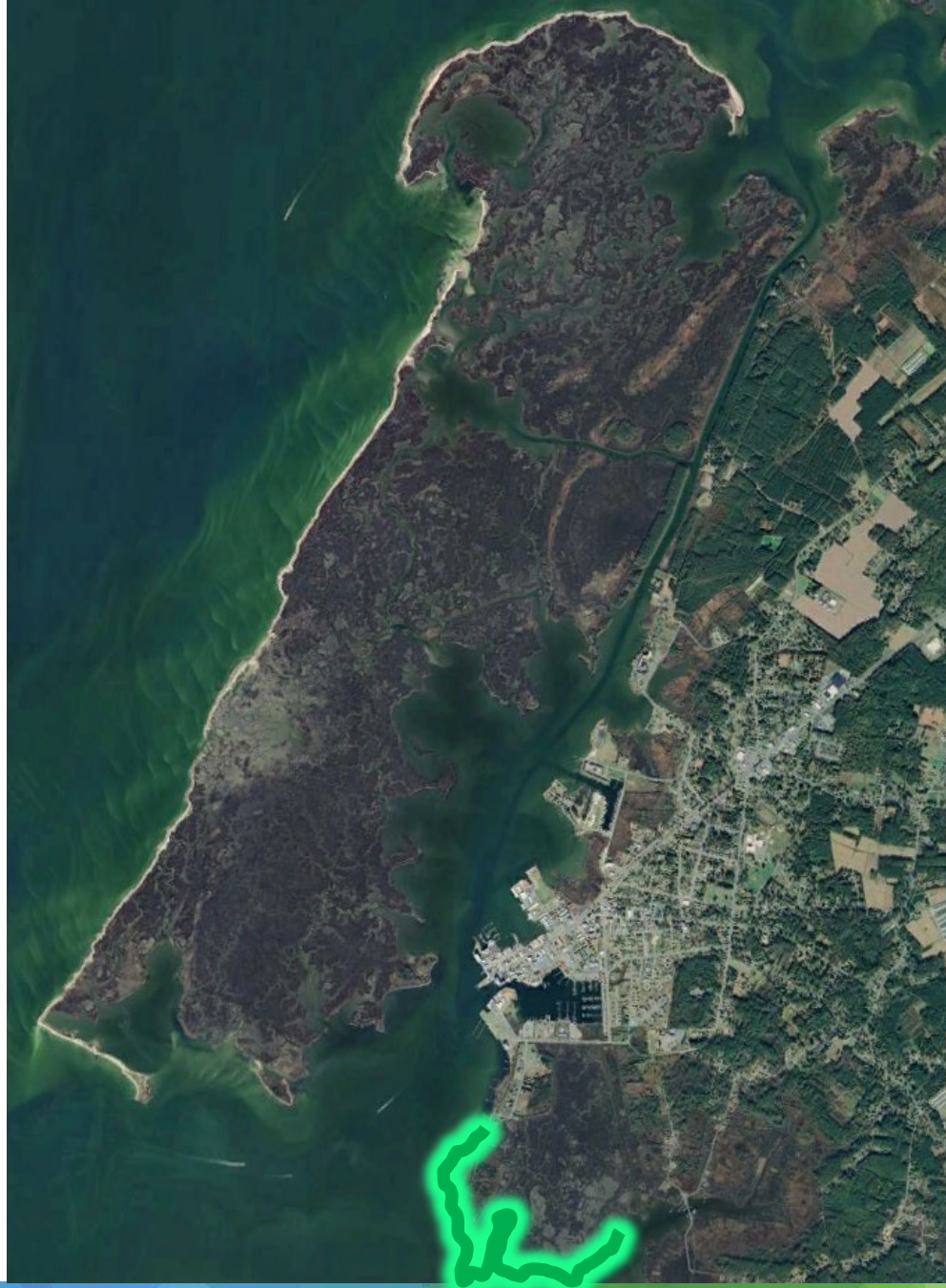
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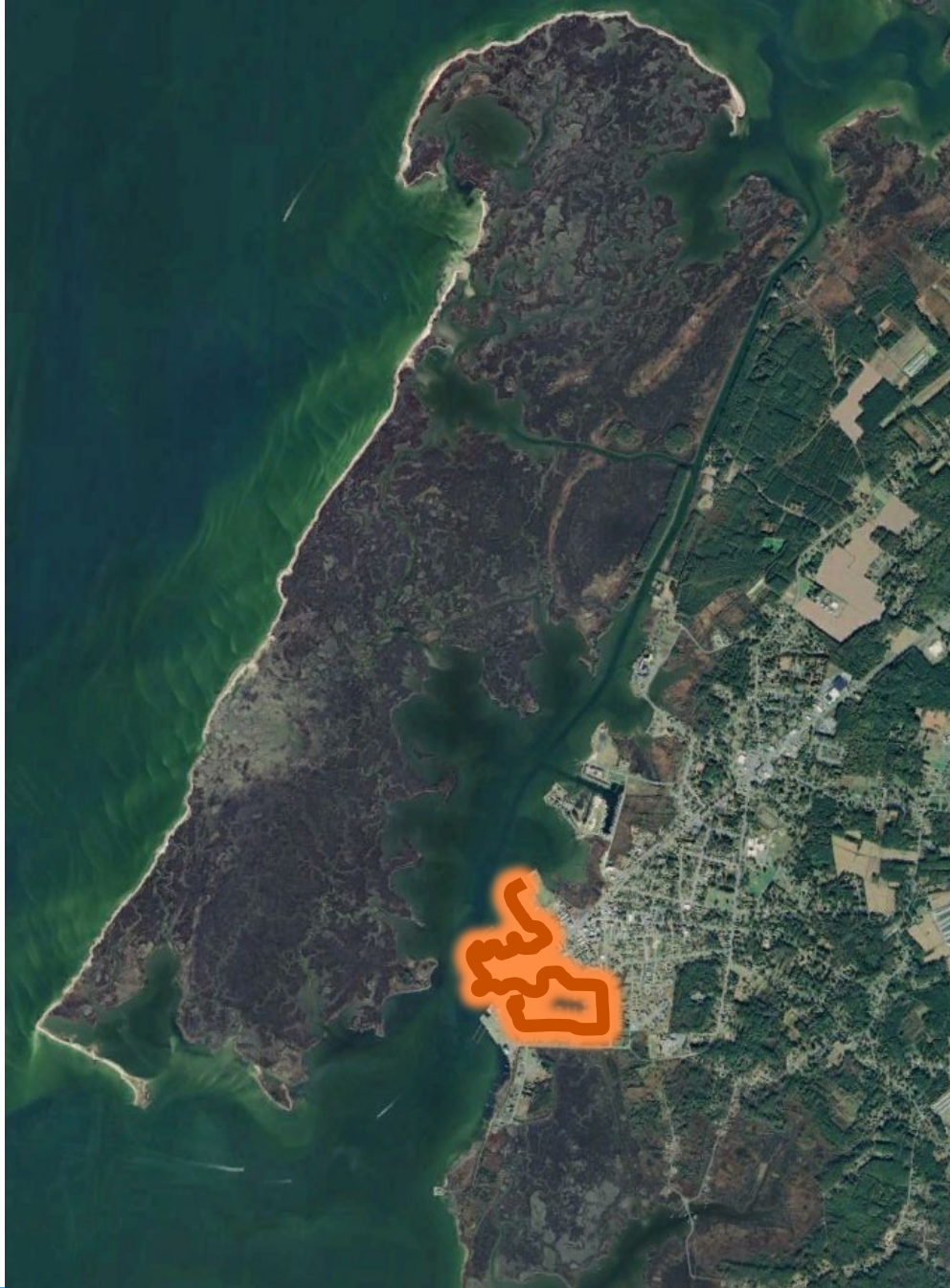
Coastal threats





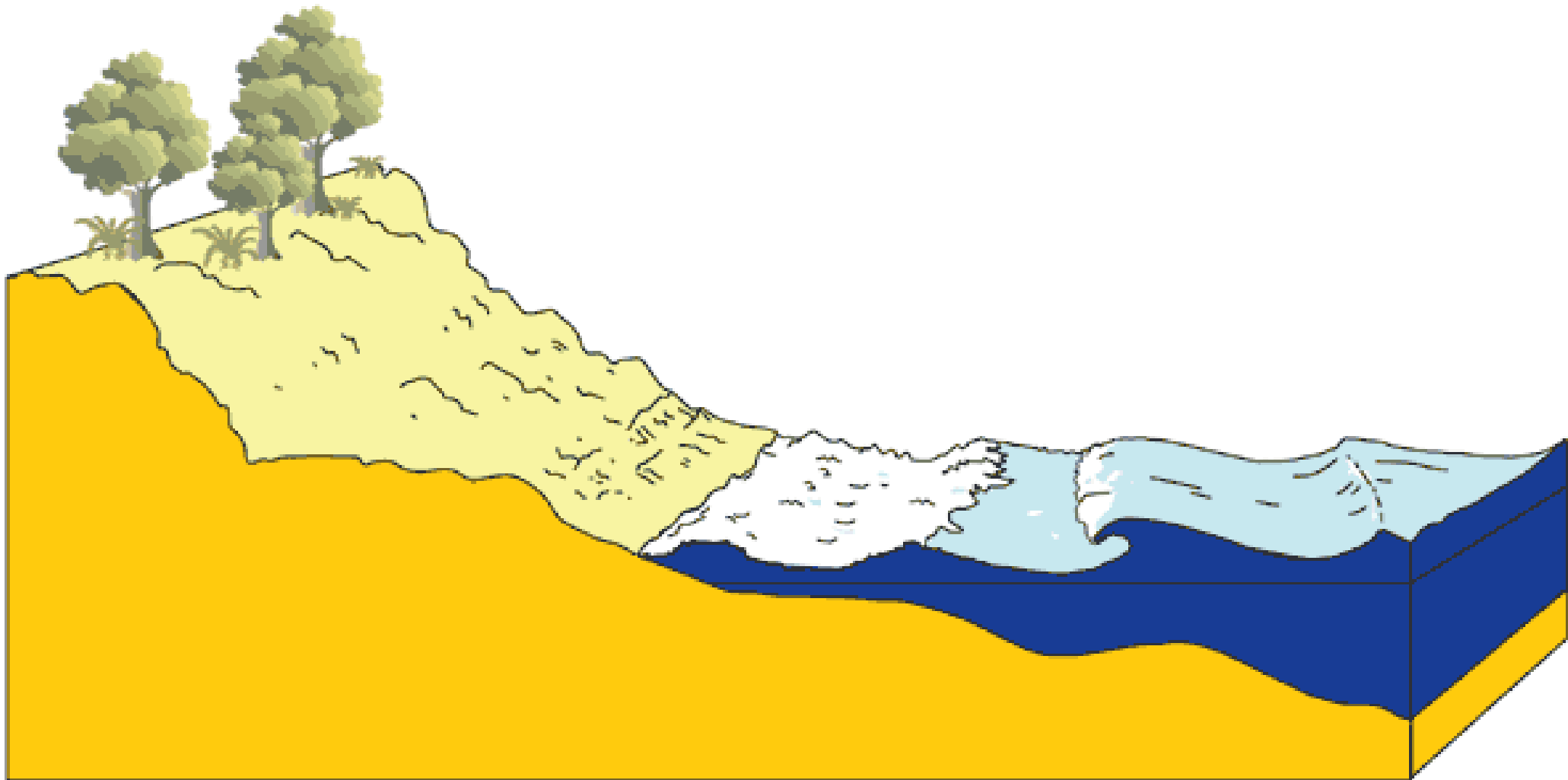






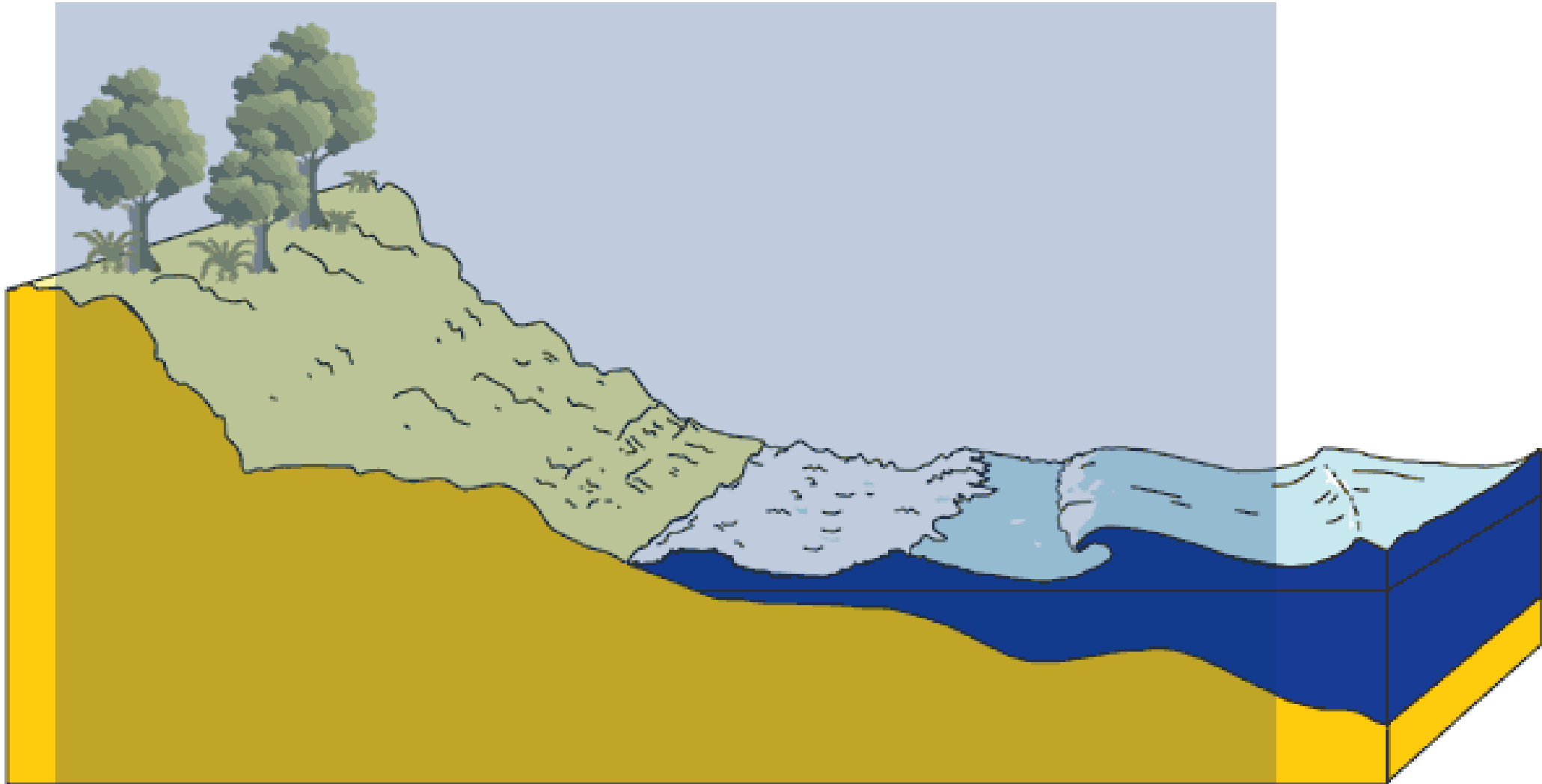


Beaches and dunes



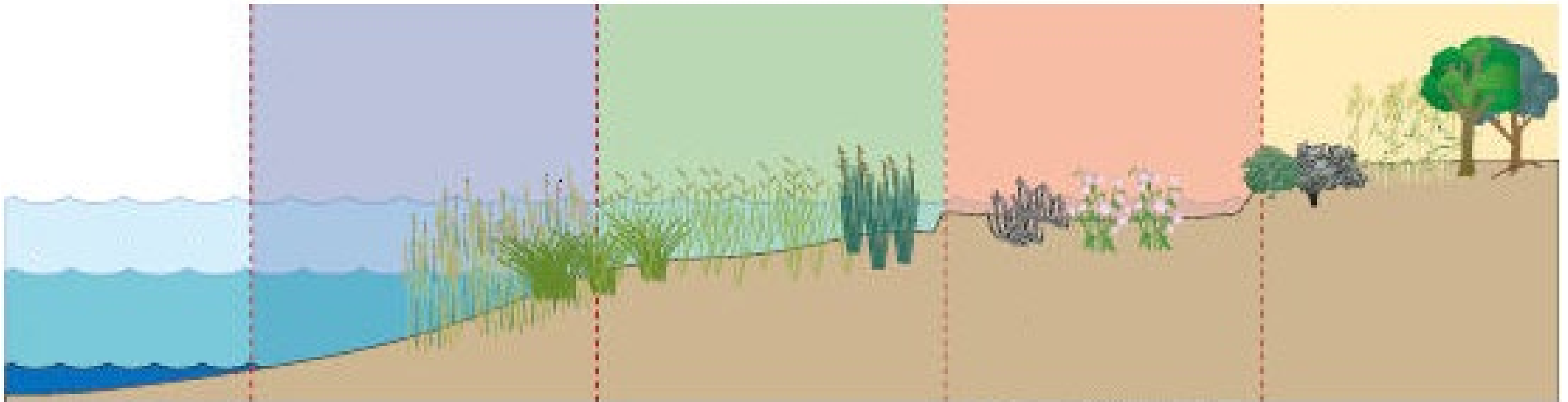
Source: https://ozcoasts.org.au/indicators/coastal-issues/beach_erosion/

Beaches and dunes



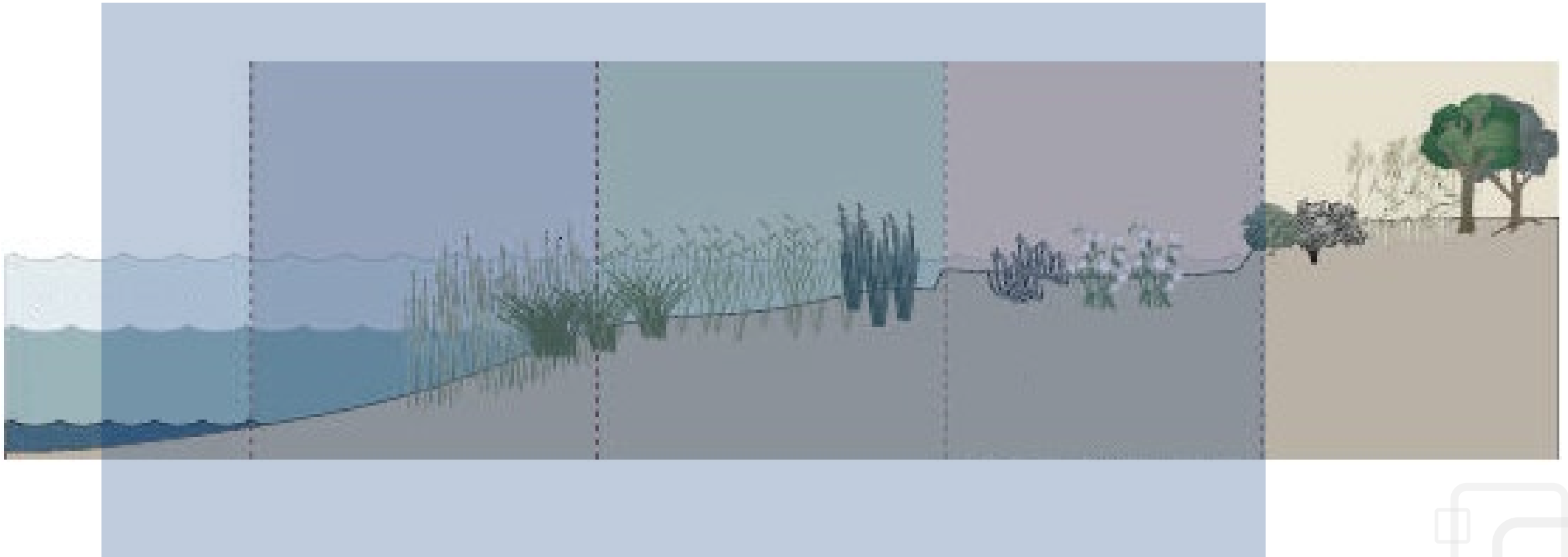
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Marshes and coastal wetlands



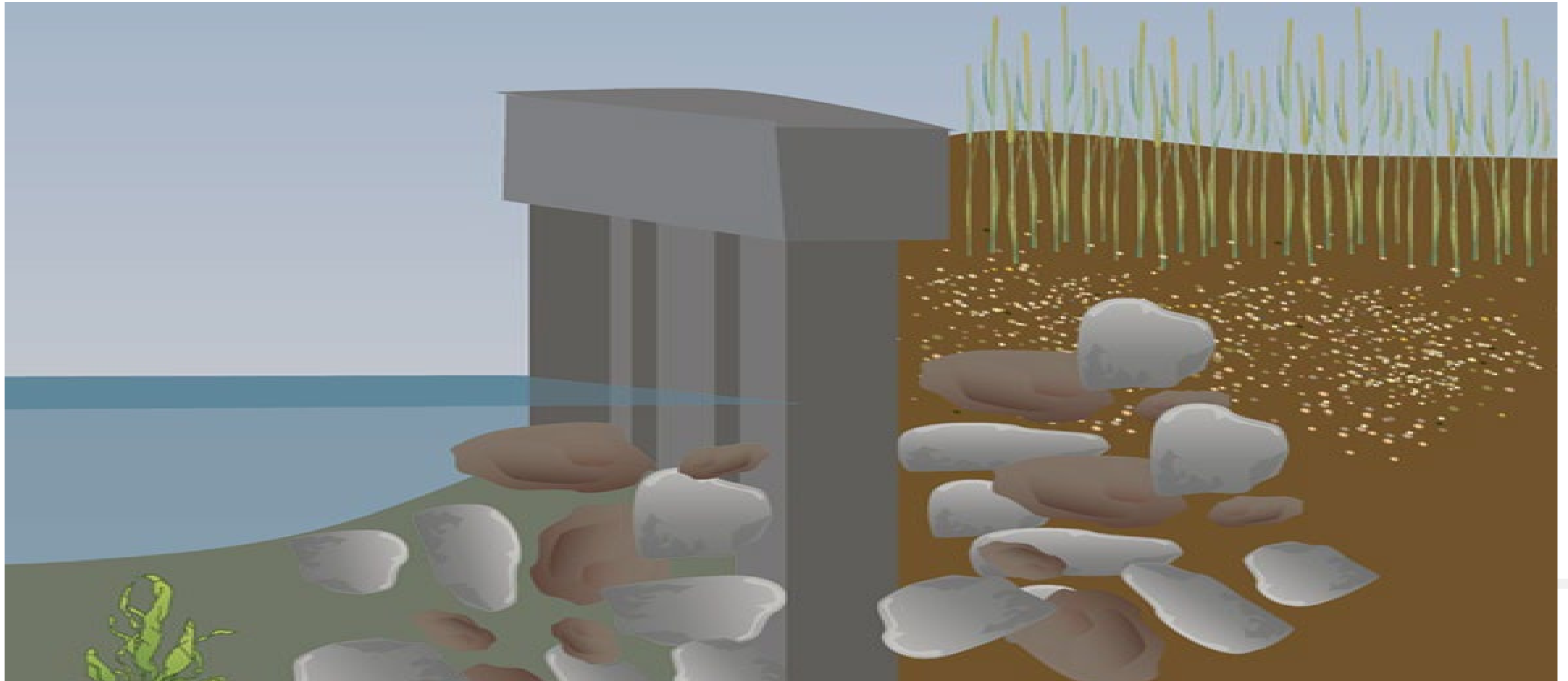
Source: https://ccrm.vims.edu/livingshorelines/ls_wetland_plants_zone.html

Marshes and coastal wetlands



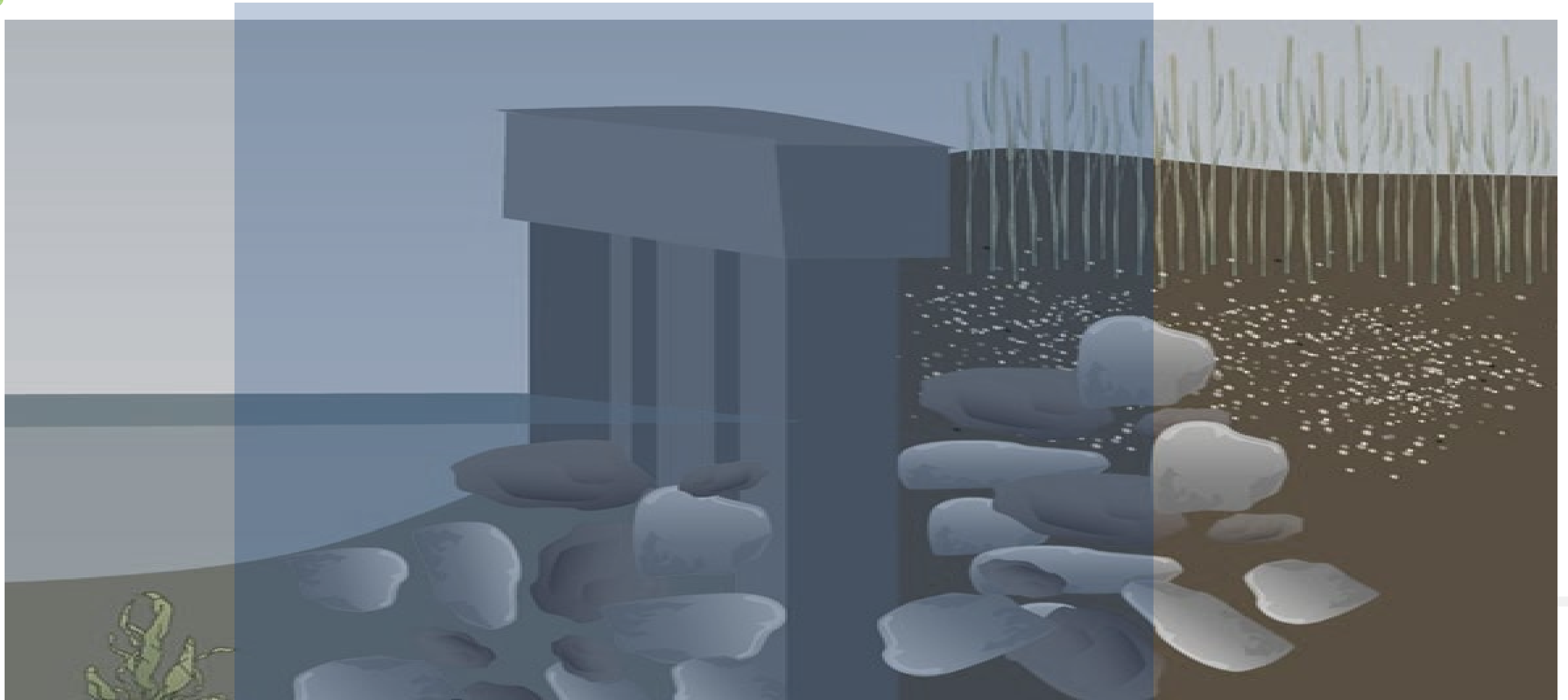
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Built environment



Source: <https://www.fisheries.noaa.gov/insight/understanding-living-shorelines>

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What are living shorelines?

“**Living shorelines**’ is a term used to define a number of shoreline protection options that allow for natural coastal processes to remain through the strategic placement of plants, stone, sand fill, and other structural and organic materials.” (Restore America’s Estuaries 2023)



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Habitat protection



Sources: <https://www.floatingislandinternational.com/wave-mitigation-shoreline-protection.html>;
https://www.researchgate.net/figure/Marsh-erosion-reportedly-induced-by-boat-generated-waves-on-Lynnhaven-River-Virginia_fig6_325111248;
https://dnr.maryland.gov/ccs/Documents/training/lsopt_dw.pdf

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Habitat protection



Erosion control and coastal process maintenance



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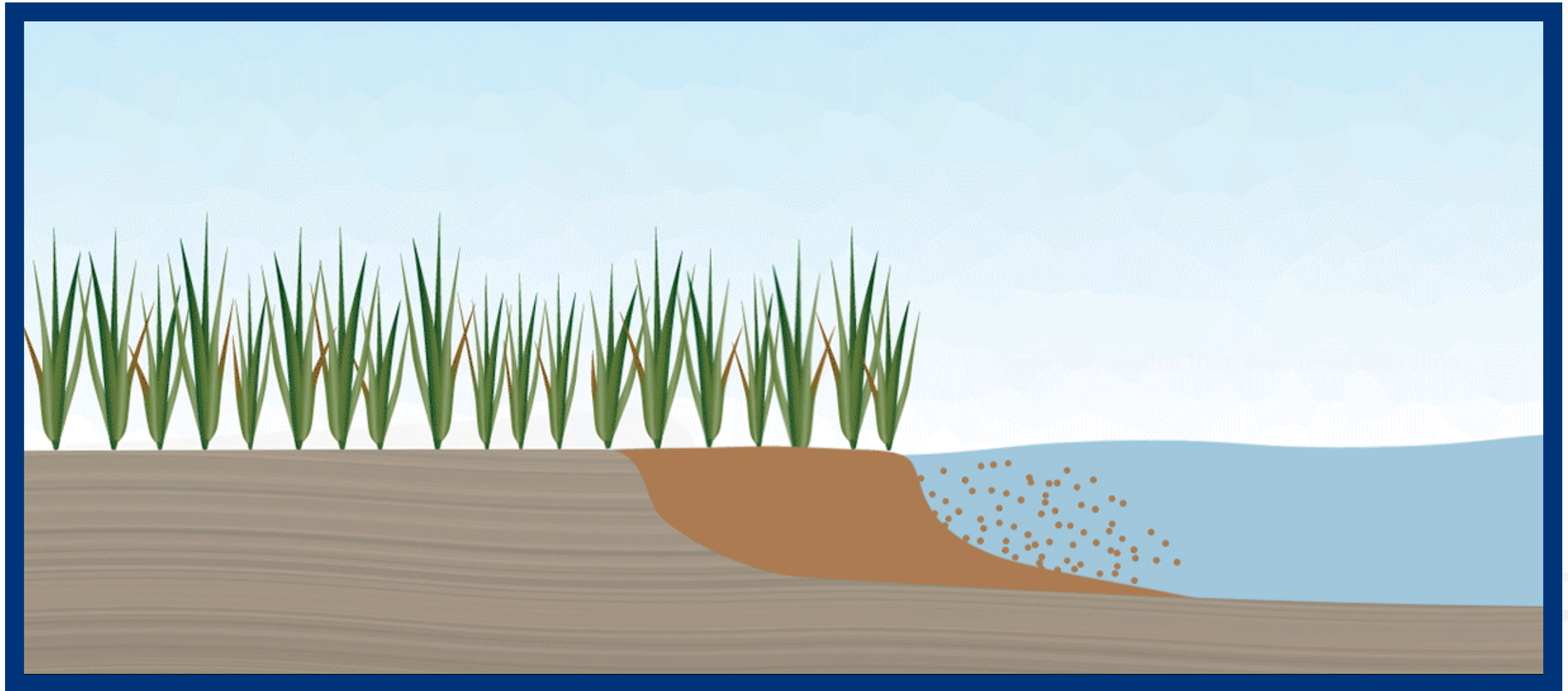


Wave action and flooding



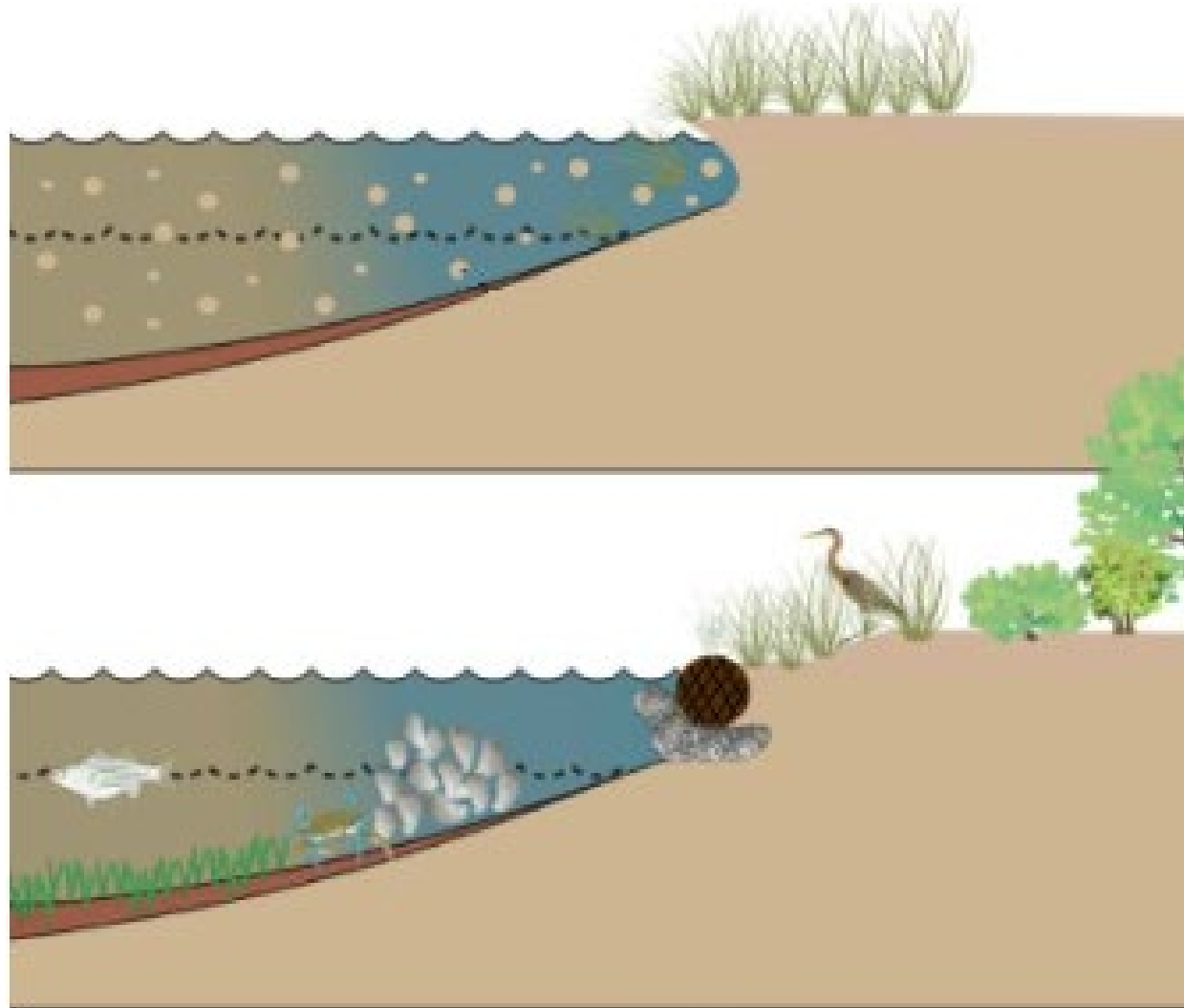
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https://dnr.maryland.gov/ccs/Documents/training/lstotp_dw.pdf

How do living shorelines work? Waves and coastal erosion



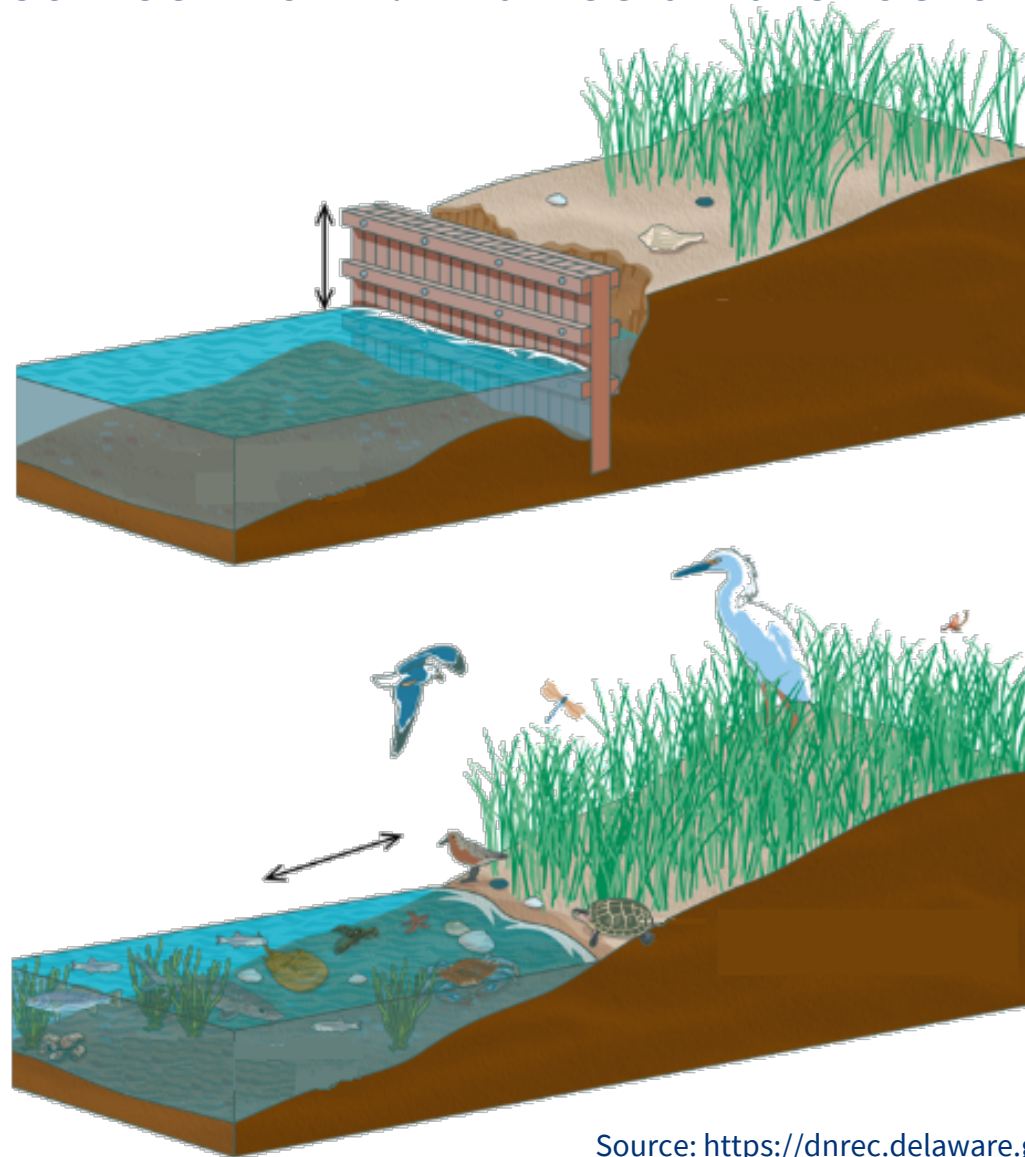
Source: longislandsoundstudy.net/our-vision-and-plan/thriving-habitats-and-abundant-wildlife/living-shoreline-projects/

How do living shorelines work? Waves and erosion



Source: <https://dnrec.delaware.gov/watershed-stewardship/wetlands/living-shorelines/>

How do living shorelines work? Waves and erosion



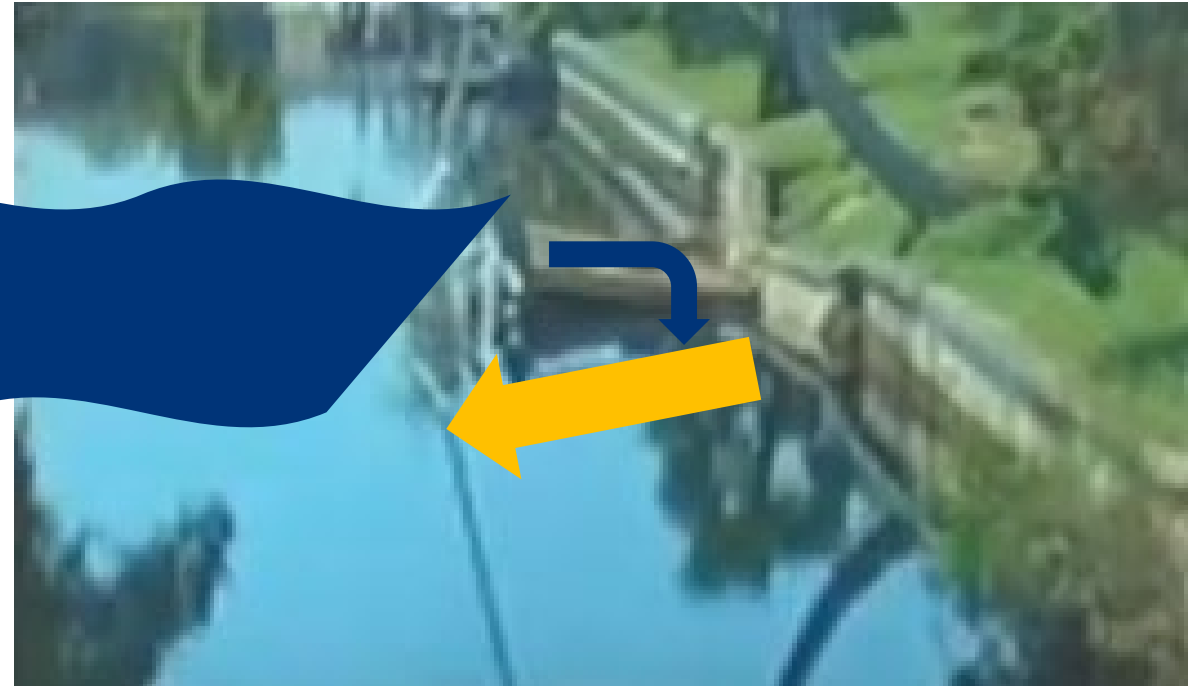
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How do living shorelines work? Protecting infrastructure



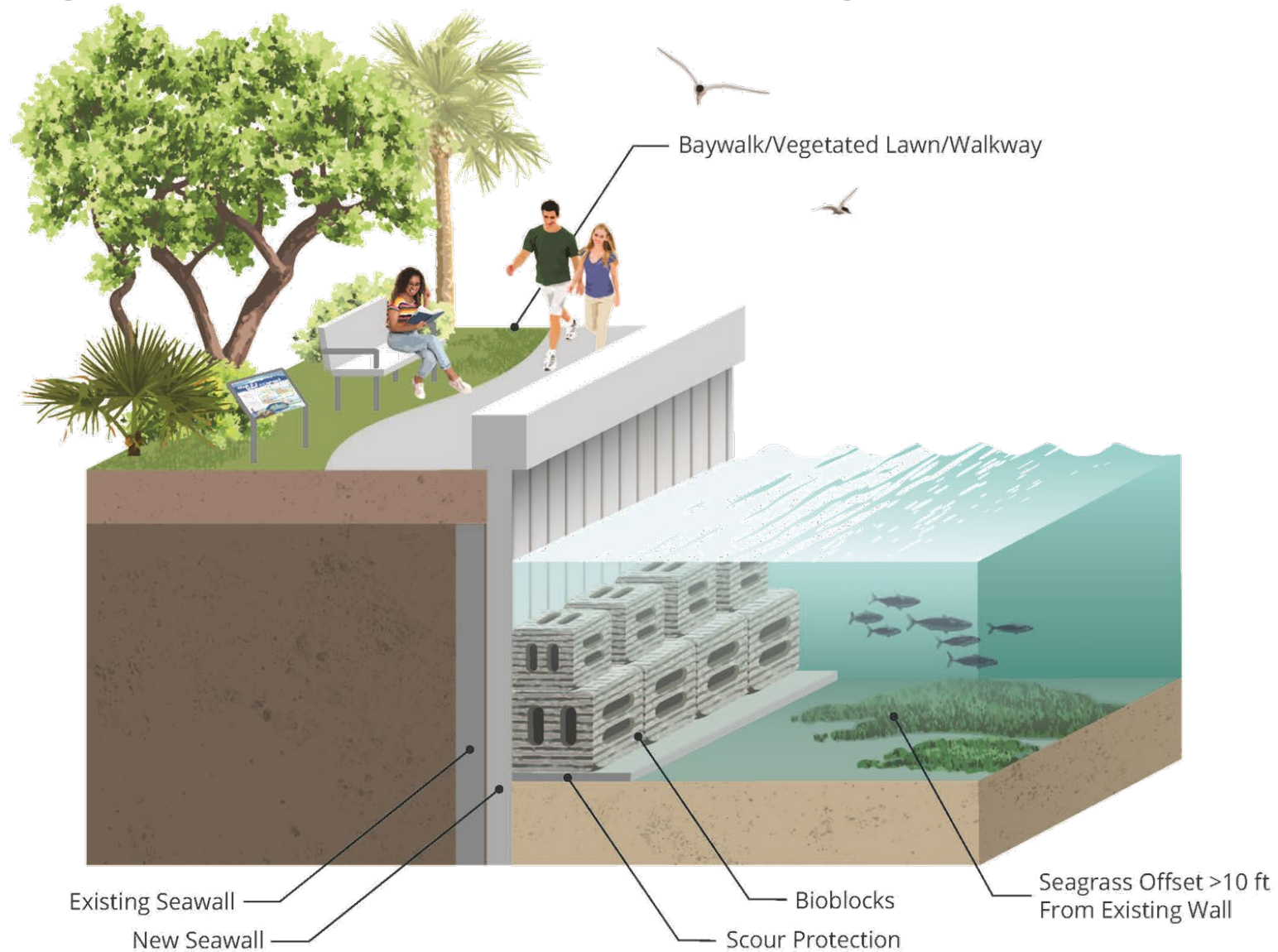
Sources: <https://truline.us/seawall-construction/why-do-seawalls-fail/>; <https://www.youtube.com/watch?v=sY25tGYKQGM>

How do living shorelines work? Protecting infrastructure



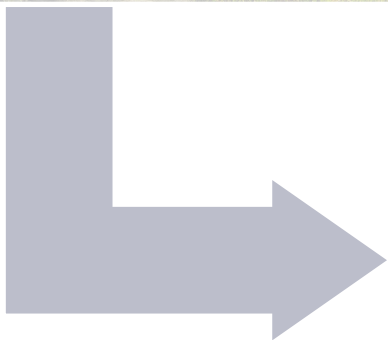
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How do living shorelines work? Protecting infrastructure





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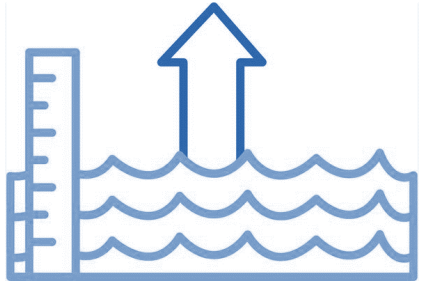


- Living shoreline approaches

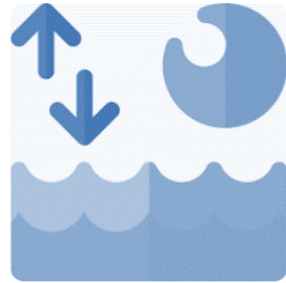


- Implementing living shorelines

Factors influencing living shorelines



Factors influencing living shorelines



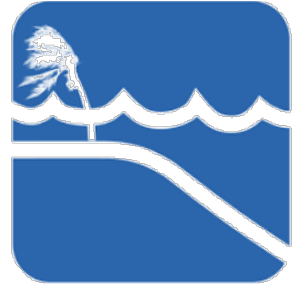
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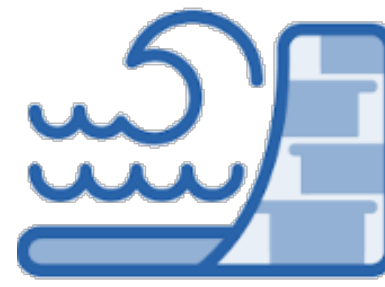
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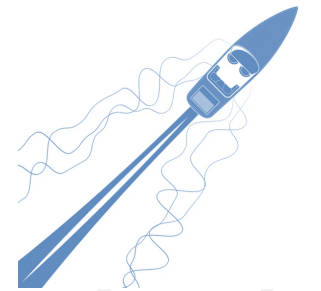
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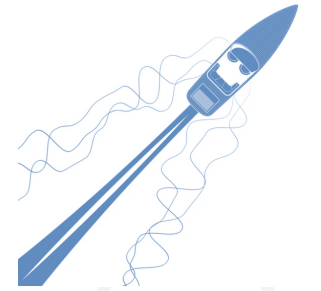
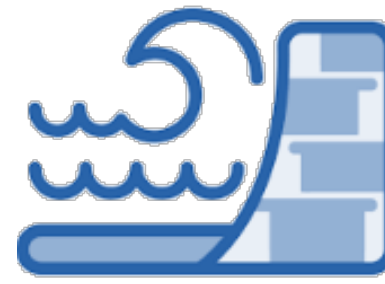
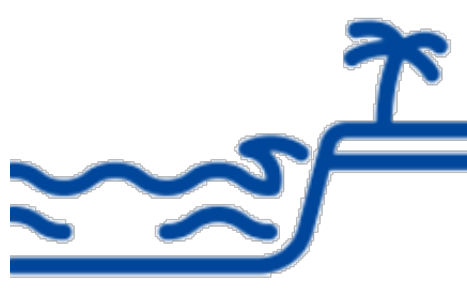
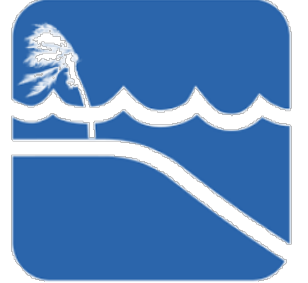
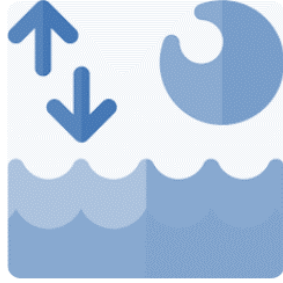
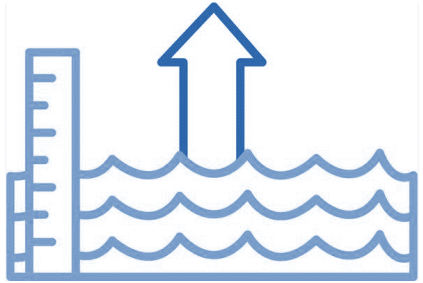
Factors influencing living shorelines



Factors influencing living shorelines



Factors influencing living shorelines



Types of living shorelines

Vegetated shores



Types of living shorelines

Edging and sills



Types of living shorelines

Retrofitted shoreline protection structures



Types of living shorelines

Shoreline stabilization and vegetated breakwaters



Types of living shorelines

Vegetated shores



**Retrofitted
shoreline protection structures**



Edging and sills



**Shoreline stabilization and
vegetated breakwaters**



Vegetated shores and slopes



Sources: <https://coast.noaa.gov/data/digitalcoast/pdf/living-shoreline.pdf>; Tensar;
<https://www.nature.org/en-us/about-us/where-we-work/united-states/maryland-dc/stories-in-maryland-dc/mddc-how-we-work-resilient-coasts/>

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Edging and sills



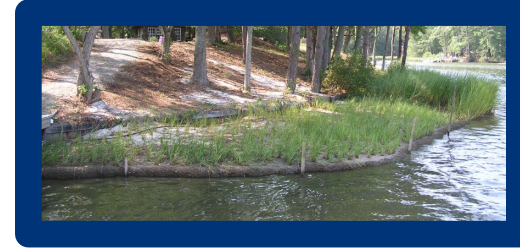
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Redeemed and retrofitted structures



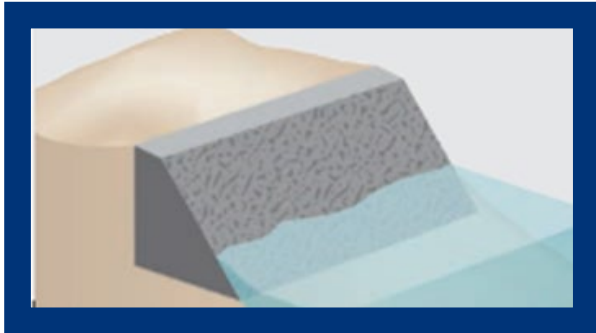
Sources: ReefWalls 2020; <https://haddad-drugan.com/seawall-strata>

Redeemed and retrofitted structures



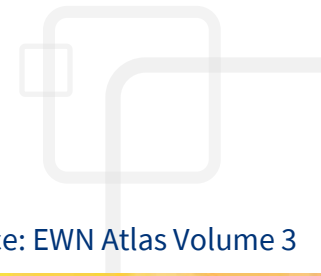
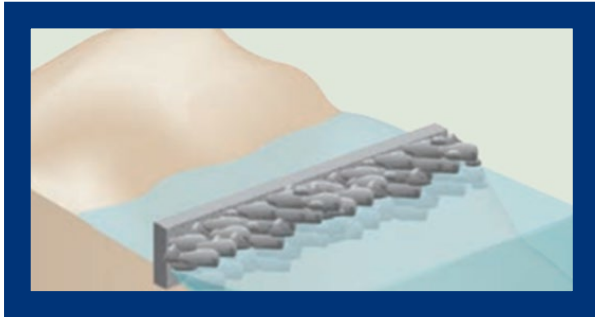
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Retrofitted structures



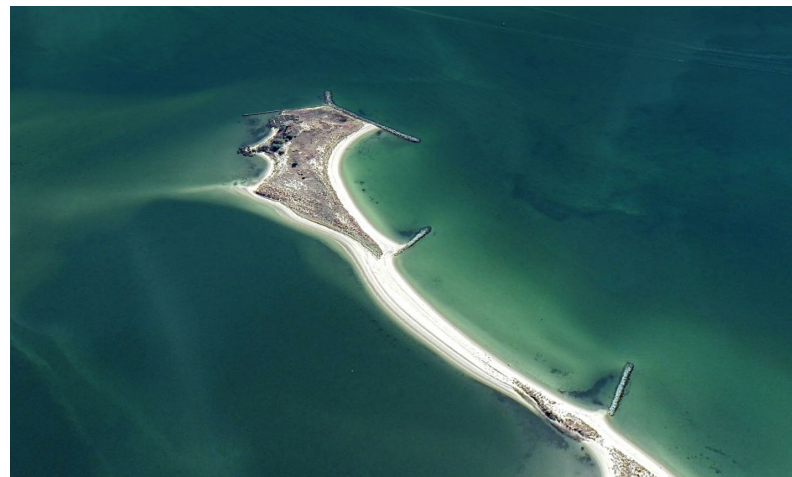
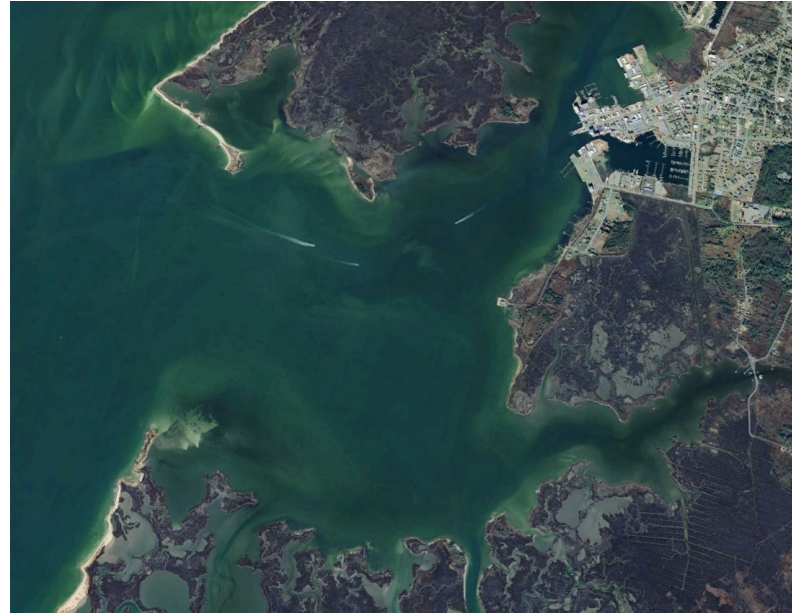
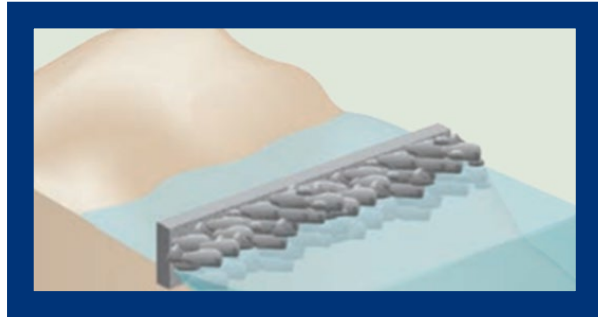
Sources: ReefWalls 2020; <https://haddad-drugan.com/seawall-strata>

Shoreline stabilization and vegetated breakwaters



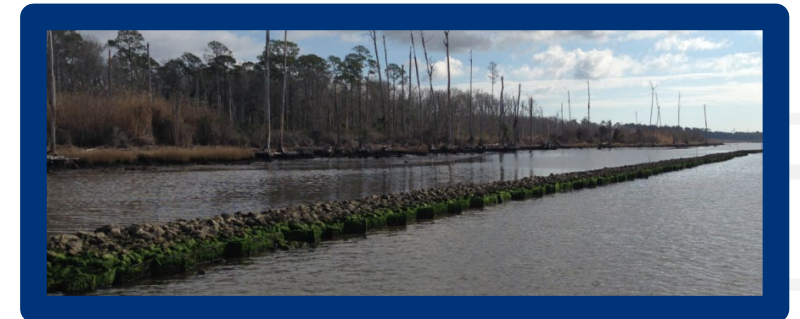
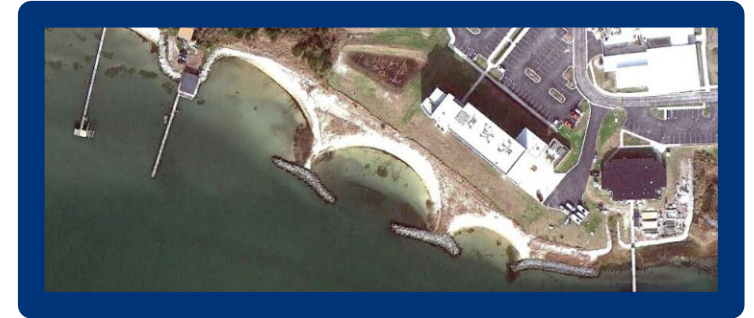
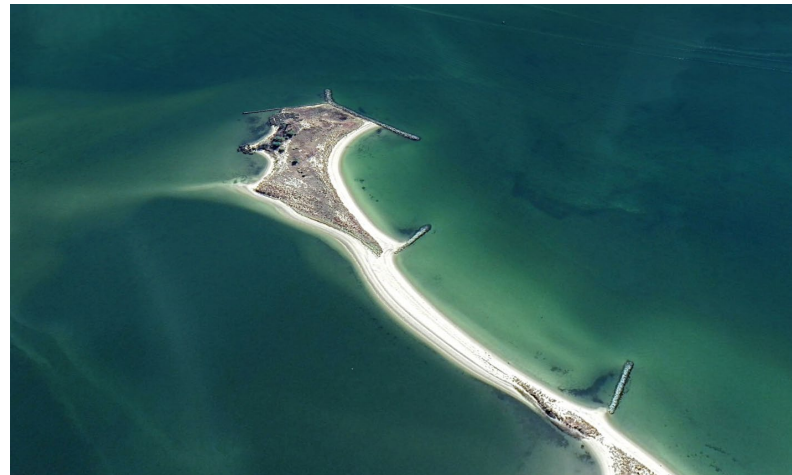
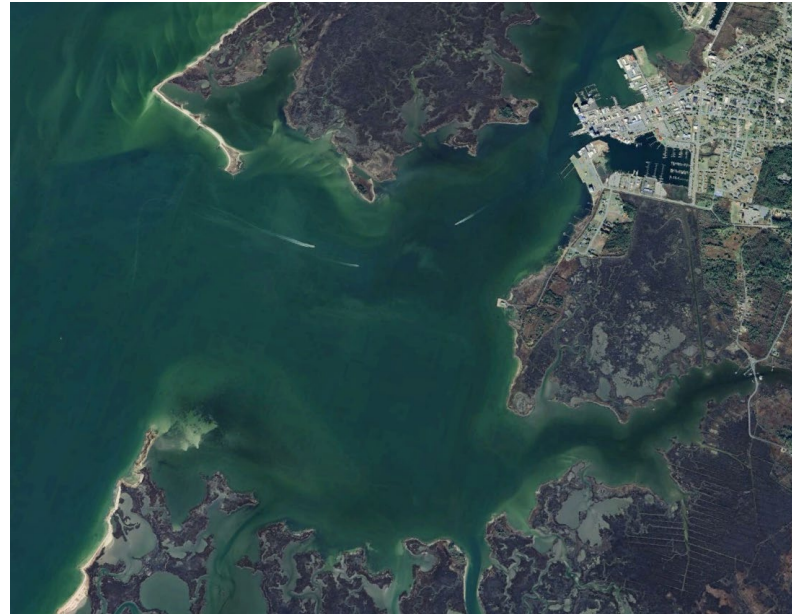
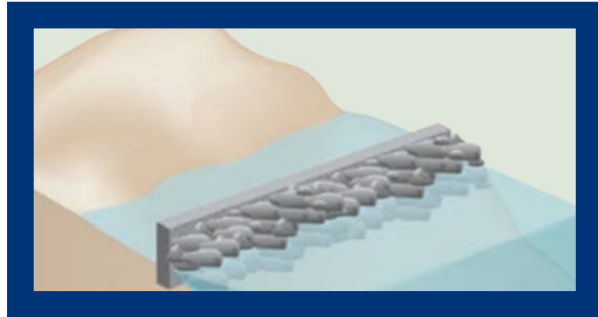
Source: EWN Atlas Volume 3

Shoreline stabilization and vegetated breakwaters



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Spectrum of living shorelines

Spectrum of living shorelines



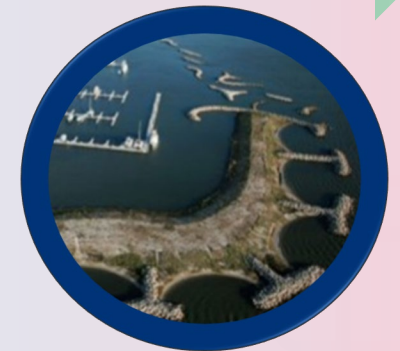
Spectrum of living shorelines



Vegetation and aquatic life

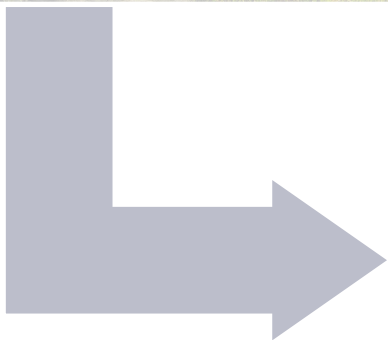
Natural materials

Natural and hard engineered materials

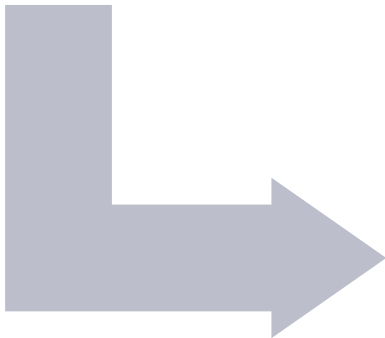




- Introduction to living shorelines



- Living shoreline approaches



- Implementing living shorelines

Mix and match



Mix and match



Mix and match



Mix and match



Implement, monitor, and adapt



Implement, monitor, and adapt

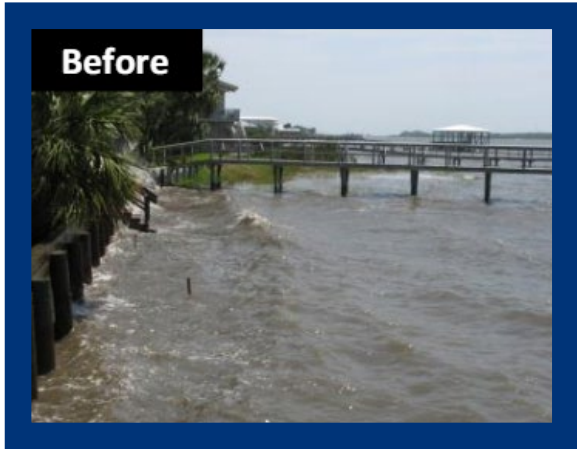
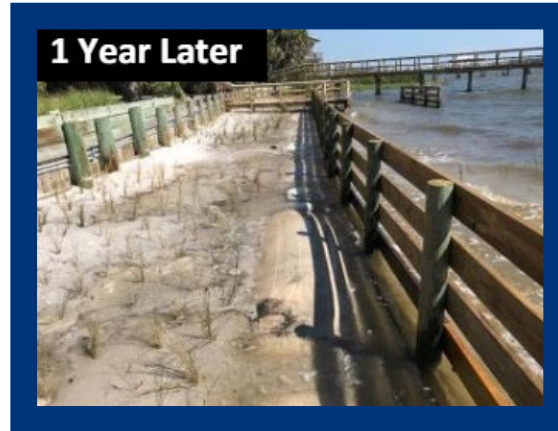


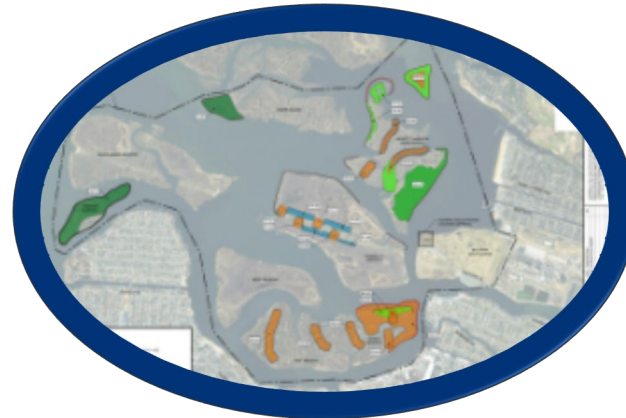
Photo credits: Florida Fish and Wildlife Conservation Commission living shoreline training for marine contractors

Implement, monitor, and adapt



- Monitor conditions
- Plan access and manage debris
- Trim plants, remove temporary materials, maintain connections to the water

Contact us



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Additional resources to get excited about living shorelines

- Simulation showing seawalls vs. living shorelines handling waves: <https://www.youtube.com/watch?v=xEX8-IAZl7k>
- Flume experiments showing different types of hard infrastructure and offshore breakwaters: <https://www.youtube.com/watch?v=3yNoy4H2Z-o>
- DIY demo of no restoration vs. seawalls vs. living shorelines: <https://www.facebook.com/TeamORCA/videos/living-shorelines-demonstration/222681002299648/>
- Field measurements of how living shorelines perform vs. Hardened shorelines during a storm event: <https://www.youtube.com/watch?v=-tp6AyryidY>
- Practical applications for erosion control in Chesapeake Bay: <https://www.youtube.com/watch?v=fbaTy4Xf4Xo>
- Homeowner's perspective on storm protection: https://www.youtube.com/watch?v=9OM_qBnUMxA
- Research perspectives on living shorelines, including a nice demo of how to design them optimally: <https://www.youtube.com/watch?v=DwSrTICsG2I&t=1s>

Six shoreline threats faced by coastal communities

Intertidal or high-tide flooding

- Inundation during high tide
- Daily problem
- Nuisance factor
- Can disrupt connectivity and access
- Salinity intrusion into water supplies and habitats
- Worsens during king tides
- Threat of rip-tides

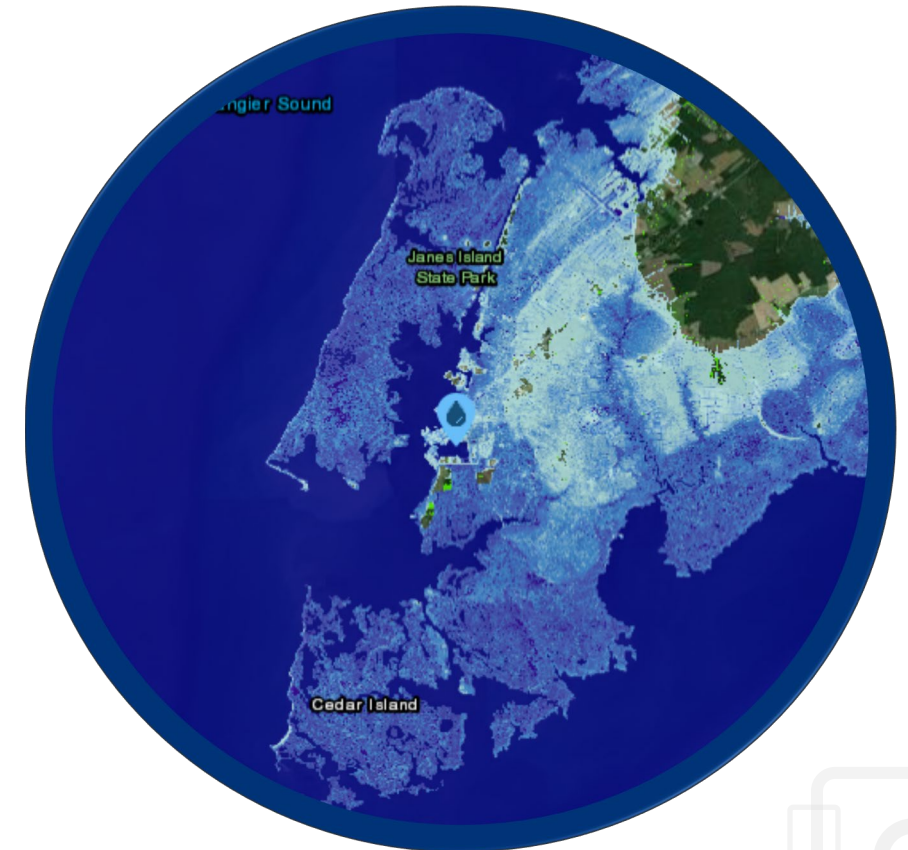


Source: <https://oceanservice.noaa.gov/facts/high-tide-flooding.html>

Six shoreline threats faced by coastal communities

Sea Level Rise

- Coastal squeezing of land by the ocean
- Salinity intrusion of water supply and habitats
- Regular, and continuous inundation of areas
- Transport and connectivity disruptions
- Property loss



Source: <https://coast.noaa.gov/slr/#/layer/slr/3/-8440504.288465895/4578682.894369816/12/satellite/109/0.8/2050/interHigh/midAccretion>

Six shoreline threats faced by coastal communities

Wind wave runup, breaking, and overtopping

- Rapid intrusion, piling, and spraying of water onto land
- Damage to the shoreline
- Damage to structures and infrastructure including road surfaces
- Can cause injury, and washaway of moveable property



Source: <https://www.imperial.ac.uk/events/166502/processes-that-influence-wave-overtopping/>

Six shoreline threats faced by coastal communities

Storm surge inundation

- Piling of water during storm events
- Slow moving tall mass of water inundating the coast
- Severe damage to coastal infrastructure, homes, roads, and coastal habitat
- Increases flood risk and raises insurance premiums



Sources: <https://mynews13.com/fl/orlando/weather/2023/09/07/bathymetry--a-lesser-known-factor-for-storm-surge>; <https://toolkit.climate.gov/topics/coastal/storm-surge>

Six shoreline threats faced by coastal communities

Inland flooding

- Flooding during heavy rainfall or snowmelt
- Flash flooding
- Disruption to lives and livelihoods
- Disruptions to connectivity
- Decreased water quality inland and in the Bay
- Increase in insects, disease vectors and vermin



Source: <https://wamu.org/story/20/09/17/sally-brings-widespread-flash-floods-to-inland-areas-after-causing-havoc-on-coast/>

Vegetated shores and slopes

Bank grading

- Creating gentle slopes where possible
- Alternations to the microtopography near the shoreline to reduce sudden elevation changes
- Creating stepped vegetated slopes using marine mattresses and planting seedlings
- May be infeasible in places with limited setback or with microtopographies associated with different habitats



Wave dissipation benefit

Vegetated shores and slopes

Marsh plantings

- Live staking of shoreline with short woody plants
- Contour wattling by laying bundles of plant branches between stakes and covering them with soil
- Brush matting by covering shoreline with branches to reduce wave energy
- Vegetated riprap by inserting short woody plants between rock riprap



Erosion control
Wave dissipation
Storm surge mitigation

Edging and sills

Seagrass beds

- Transplanting seagrasses using mechanical planters
- Seeding seagrasses
- Shallow waters with light penetration ideal
- Oxidic, bioturbated soils ideal



High tide slowdown
Wave attenuation

Edging and sills

Coir material

- Placement of organic materials such as fiber mats, biologs, and seeded coir logs
- Applying oyster shell bags on the shoreline to prevent erosion
- Limited to low tidal range
- Can create post-storm debris



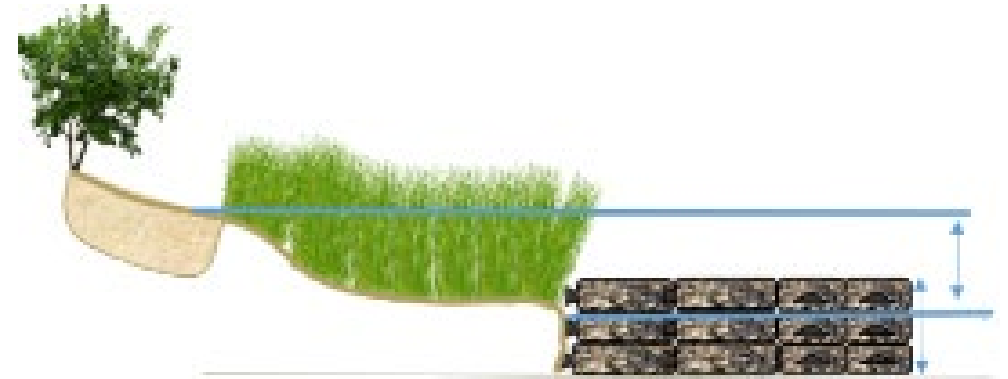
Erosion control
Wave dissipation
Storm surge mitigation

Edging and sills

Oyster beds

- Distributing high density of oyster shells with a high-pressure hose on the shoreline
- Distribution oyster shells along with stone, rocks, cobbles and other materials
- Limited to small tidal range
- Susceptible to very cold winter snaps and icing

Erosion control
Wave dissipation



Edging and sills

Interlocking bioblocks

- Oyster shells within marine mattress (reticulated concrete-, fabric-, or gabion-based mesh filled with oysters) to stabilize the shore
- Placing NatrX, EConcrete, or other such 3D-printed concrete blocks (with highly corrugated surfaces) in interlocking configuration along the shoreline
- May replace benthic ecosystems

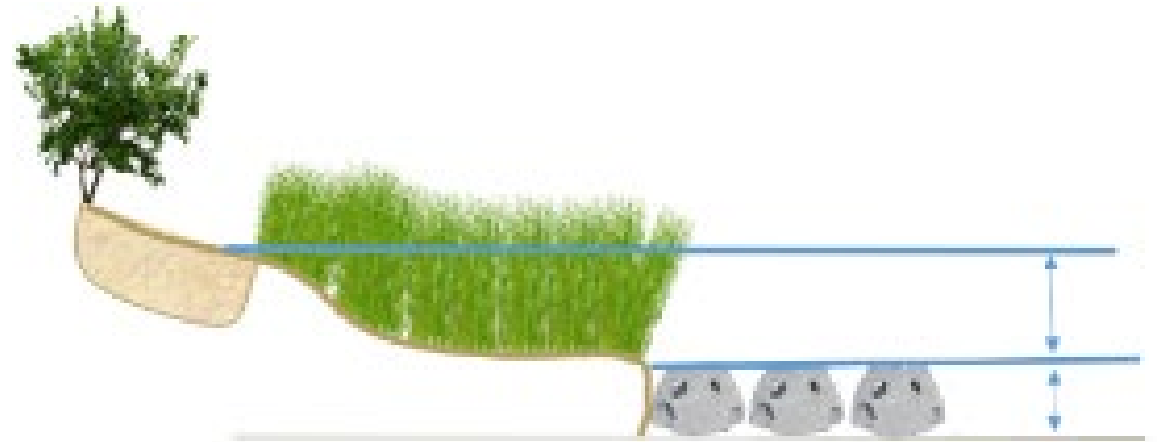
Erosion control
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Edging and sills

Oyster reef balls

- Placing oyster reef balls near the shoreline to dissipate waves
- Limited to small tidal range



Erosion control
Wave dissipation
Storm surge mitigation

Edging and sills

Rock

- Placement of rocks
- Placement of riprap
- Placement of rock-filled gabion boxes
- Sill construction can remove sand from the shoreline



Erosion control
Wave dissipation

Redeemed and retrofitted seawalls

Living seawalls

- Seawall panels providing wave dissipation due to their complex shape
- Biomimicking plates (small-scale relief features such as reef plates) attached to seawalls or bulkheads allowing accretion of biomass to help protect existing hard infrastructure further
- Planting vegetation near or atop seawalls
- Placing rocks/reef balls near seawall toe
- Can cause undesirable biofilm and invasive species buildup on surfaces

Wave attenuation

Protection to hard infrastructure that helps prevent storm surge flooding



Breakwaters and groins

- Placement of rock sills or oyster reef groins perpendicular to shoreline to prevent longshore sediment transport
- Placement of breakwaters parallel to shore along groins
- Ideally suited for medium-density housing areas, marinas, etc.
- May be expensive to install



Wave attenuation
Erosion control

Shoreline stabilization and vegetated breakwaters

Vegetated coastal breakwaters

- Sand berm and rock placement to accrete sand through longshore sediment transport
- Offshore living breakwater made of oyster shells, porous granite, ecofriendly concrete, or reef balls
- Native plants and edging at breakwater toes to prevent erosion
- Requires extensive scientific research and on-site investigations

Wave attenuation

Protection to hard infrastructure that helps prevent storm surge flooding

Storm surge mitigation

