EXAMPLES OF TIDAL EMBAYMENT MODIFICATIONS AND SHOALING: POSSIBLE IMPLICATIONS FOR LARGE SCALE WETLAND NOURISHMENT

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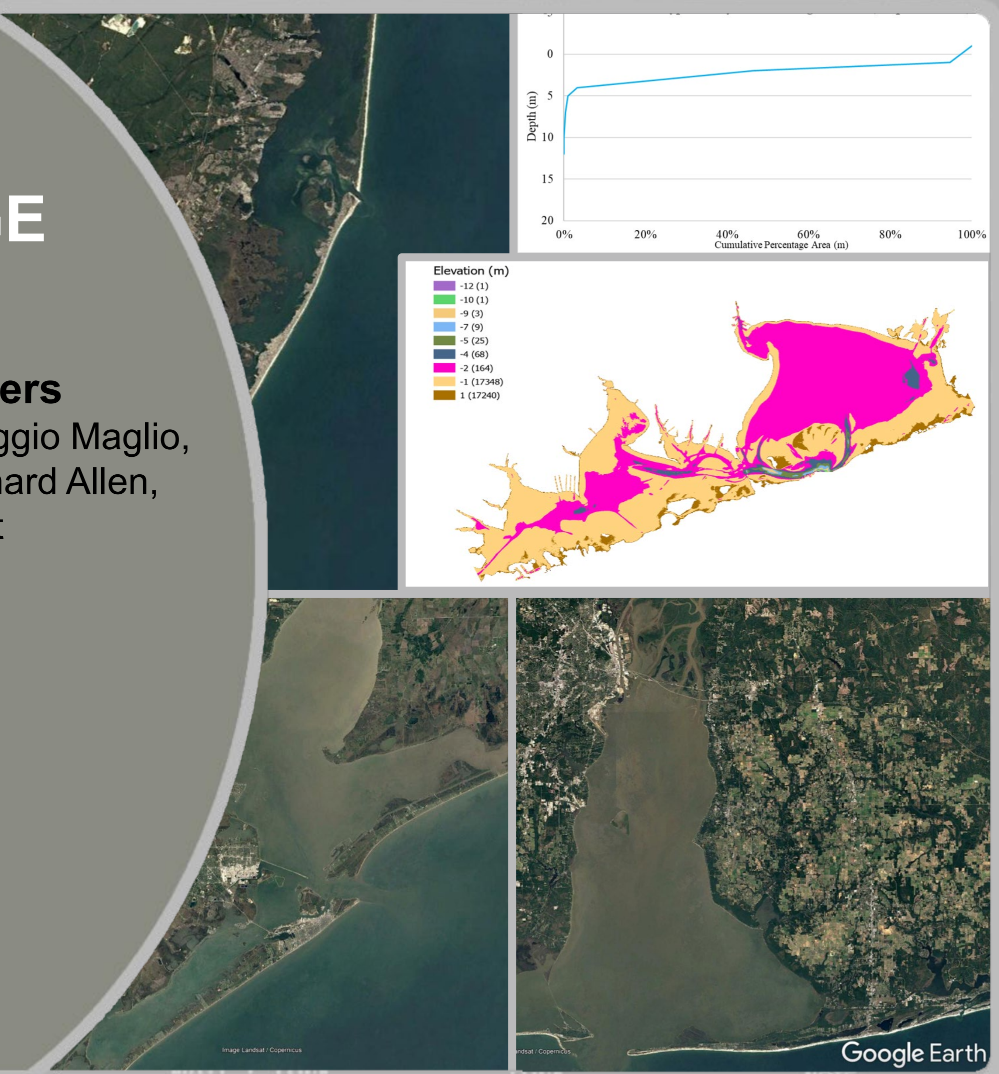

COASTAL INLETS RESEARCH PROGRAM

FY21 TECHNICAL DISCUSSION

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ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

Goals

- Develop generalized guidance concerning the medium- to long-term impacts of strategic sediment placement in tidally-influenced bays and rivers, with an emphasis on:
  - Impacts on sediment transport
  - Impacts on tidal inlet morphodynamics
  - Impacts to navigation

Literature Review Findings

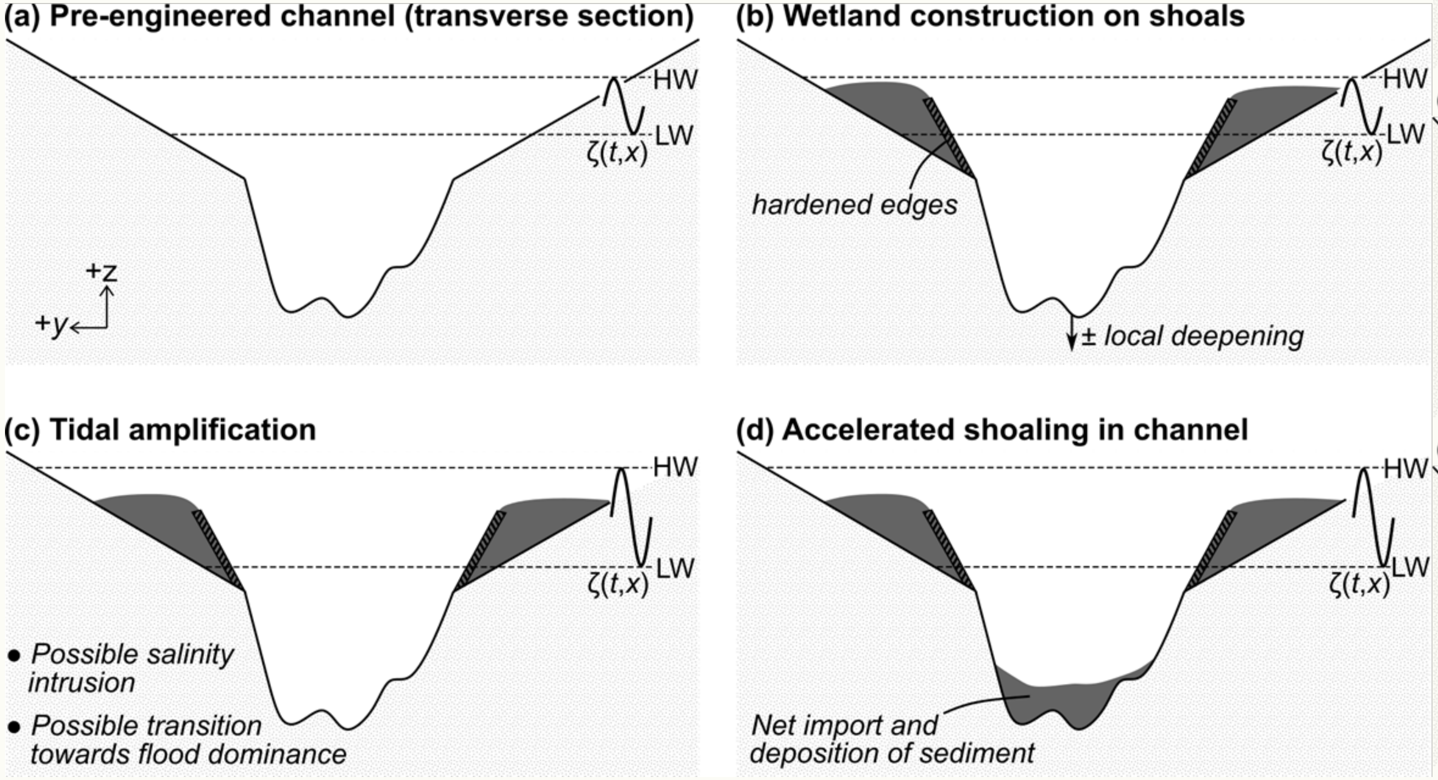
- Navigation impacts of large-scale wetland nourishment is a knowledge gap
- Other large-scale embayment modifications have been suggested to have hydrodynamic impacts on the system
- Effects of anthropogenic modification are largely site-specific, but extrapolating previous conclusions may have some utility
- The lack of literature on this topic limits the scope of the conclusions.

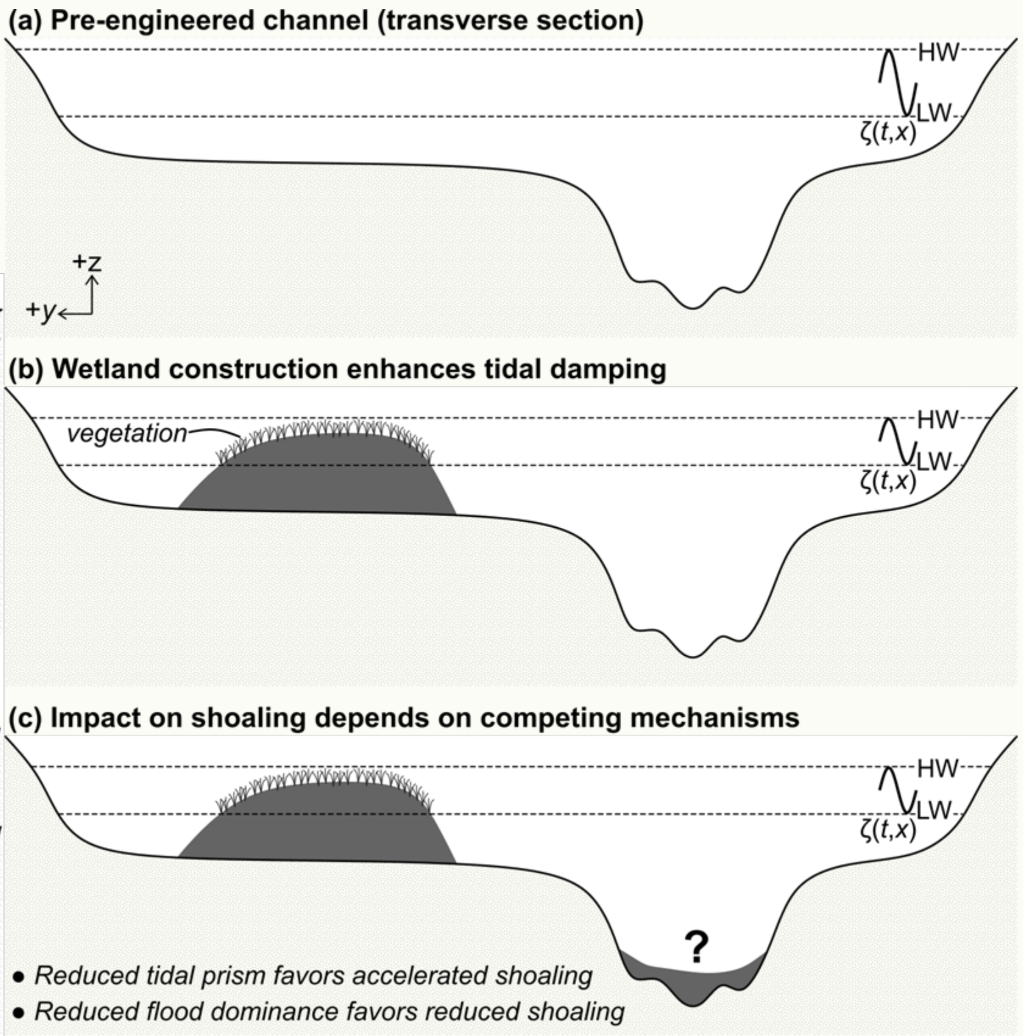
Altered Embayment Hydrodynamics & Morphodynamics

- **Tidal amplification and damping**
- **Tidal asymmetry**
- **Tidal prism reduction and capture**
- **Sediment trapping**
- **Geotechnical failure**

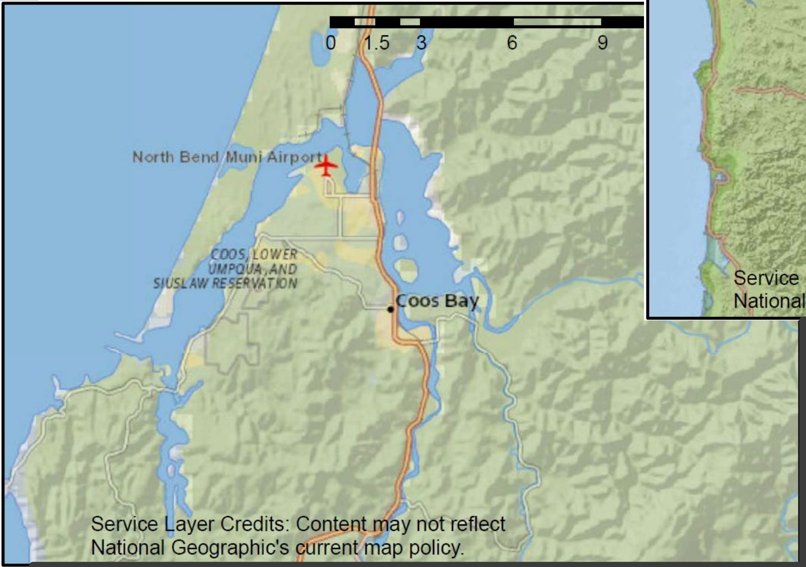
Tidal Amplification & Damping

- Intertidal area contributes to tidal damping
- Land reclamation, shoreline hardening, and flow path straightening contribute to tidal amplification





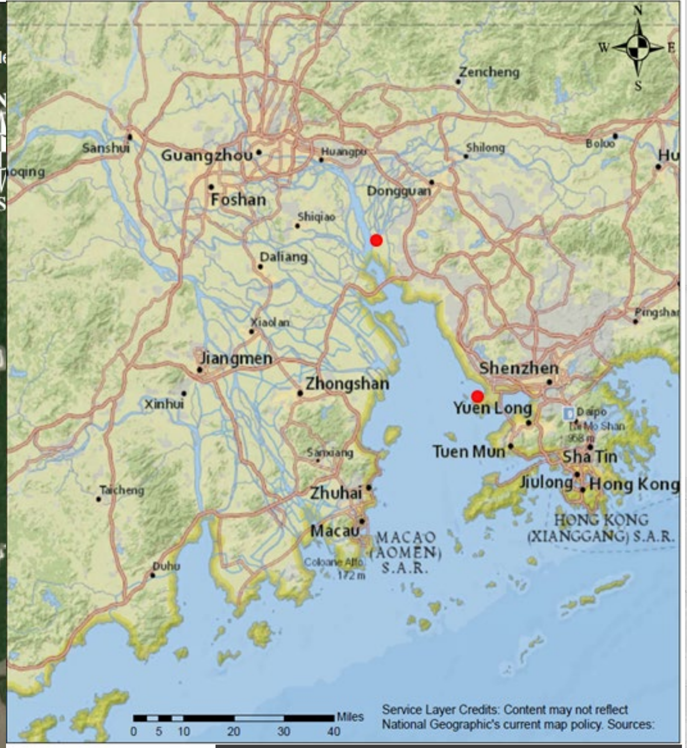
Tidal Amplification Examples



Channel deepening and land reclamation in **Coos Bay, OR**, may have amplified the tides, increased salinity intrusion and contributed to major channel shoaling (Eidam et al. 2020)

Channel deepening and drag reduction (straightening, narrowing, bedform removal) in **the Columbia River, OR/WA** may have lowered water levels and amplified the tide **near Vancouver/Portland** (Jay et al. 2011)

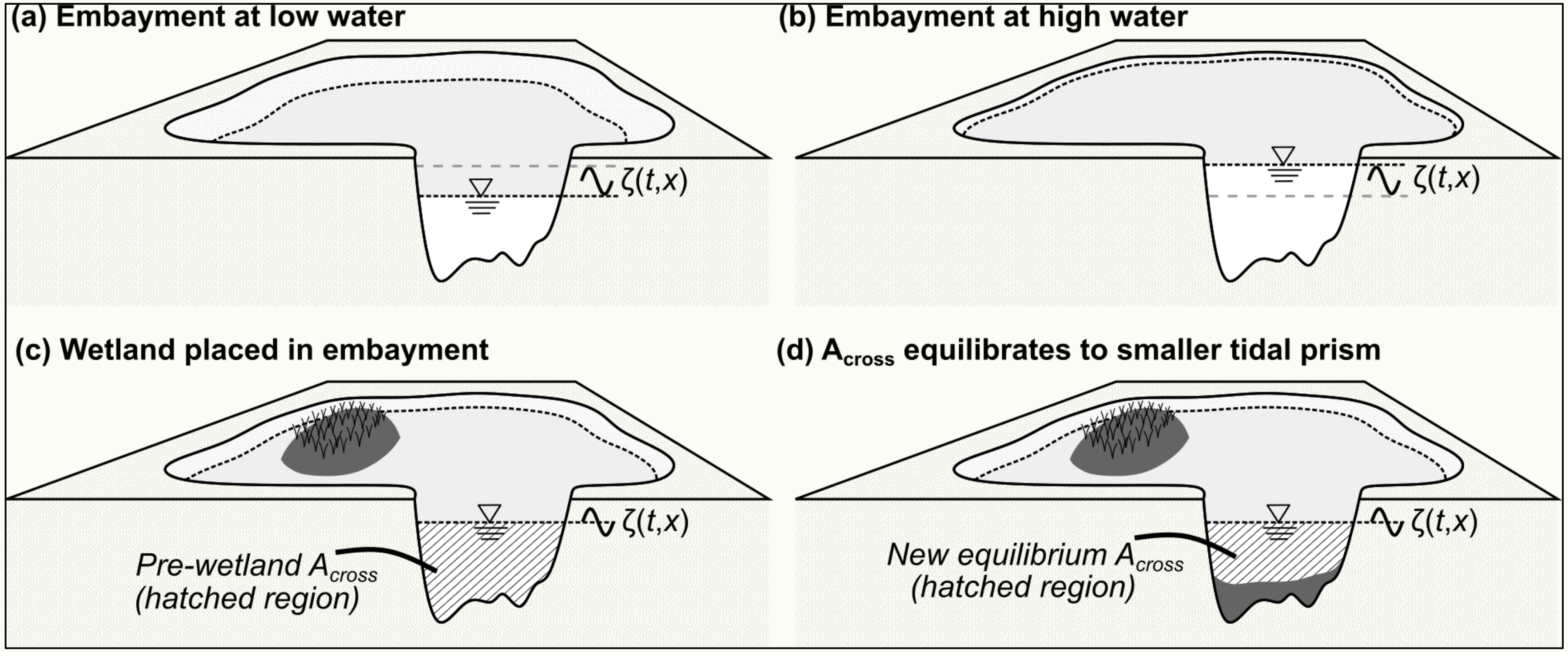
Spring tidal range in **the Pussur Estuary, Bangladesh**, has increased by up to 100 % following the removal of 1000 km^2 of intertidal area and 2000 km of secondary creeks and channels (Pethick and Orford, 2013)



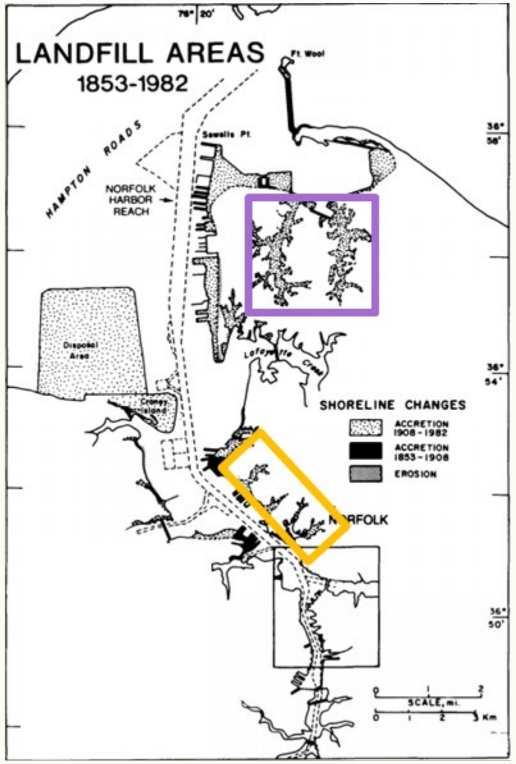
Land reclamation, shoreline hardening, and a reduction in shoreline complexity in **Lingdingyang Bay, China**, may have contributed to tidal amplification (Zhang et al. 2021).

Tidal Prism Reduction

- Adding sediment within the tidal frame may reduce tidal prism



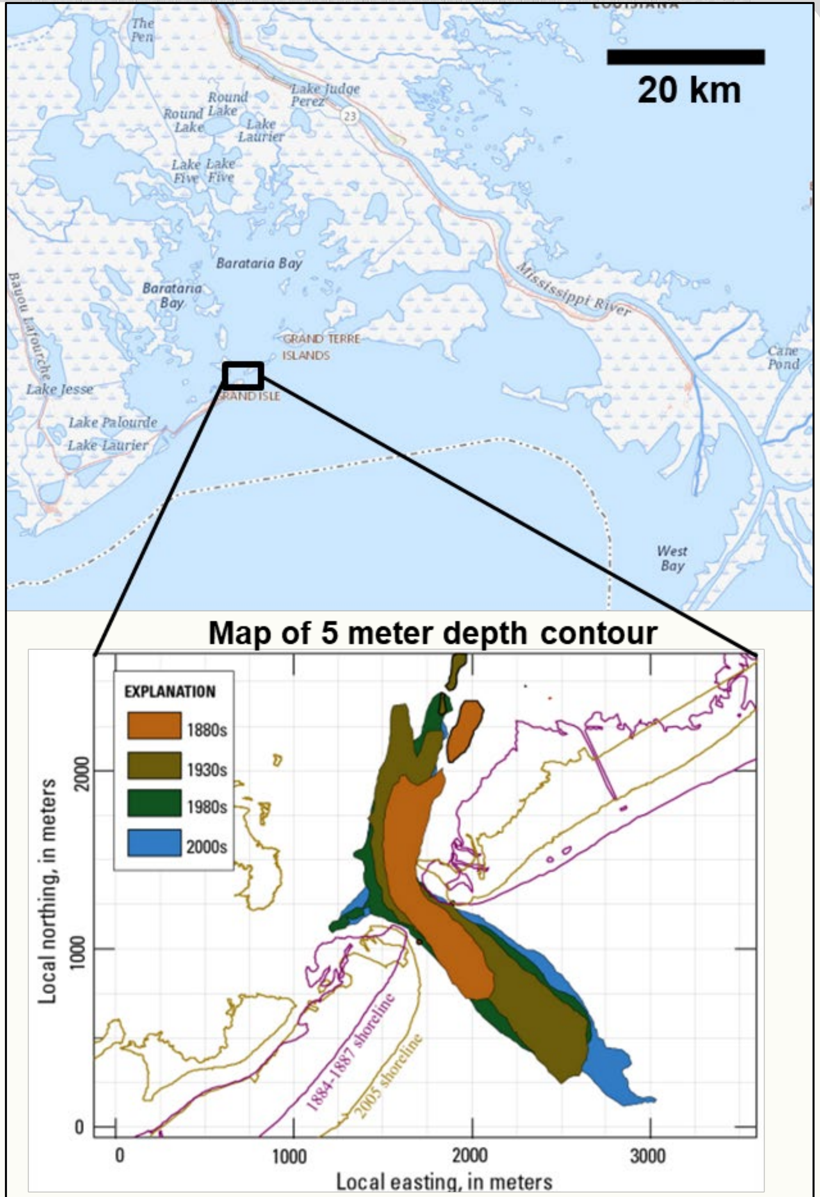
Tidal Prism Reduction Examples



Satellite image from Google Earth, ©2021 TerraMetrics; shoreline change map from Nichols and Howard-Strobel (1991).

Land-filling in **Norfolk Harbor, VA**, has reduced the tidal prism and contributed to accelerated shoaling in the navigation channels (Nichols and Howard-Strobel, 1991).

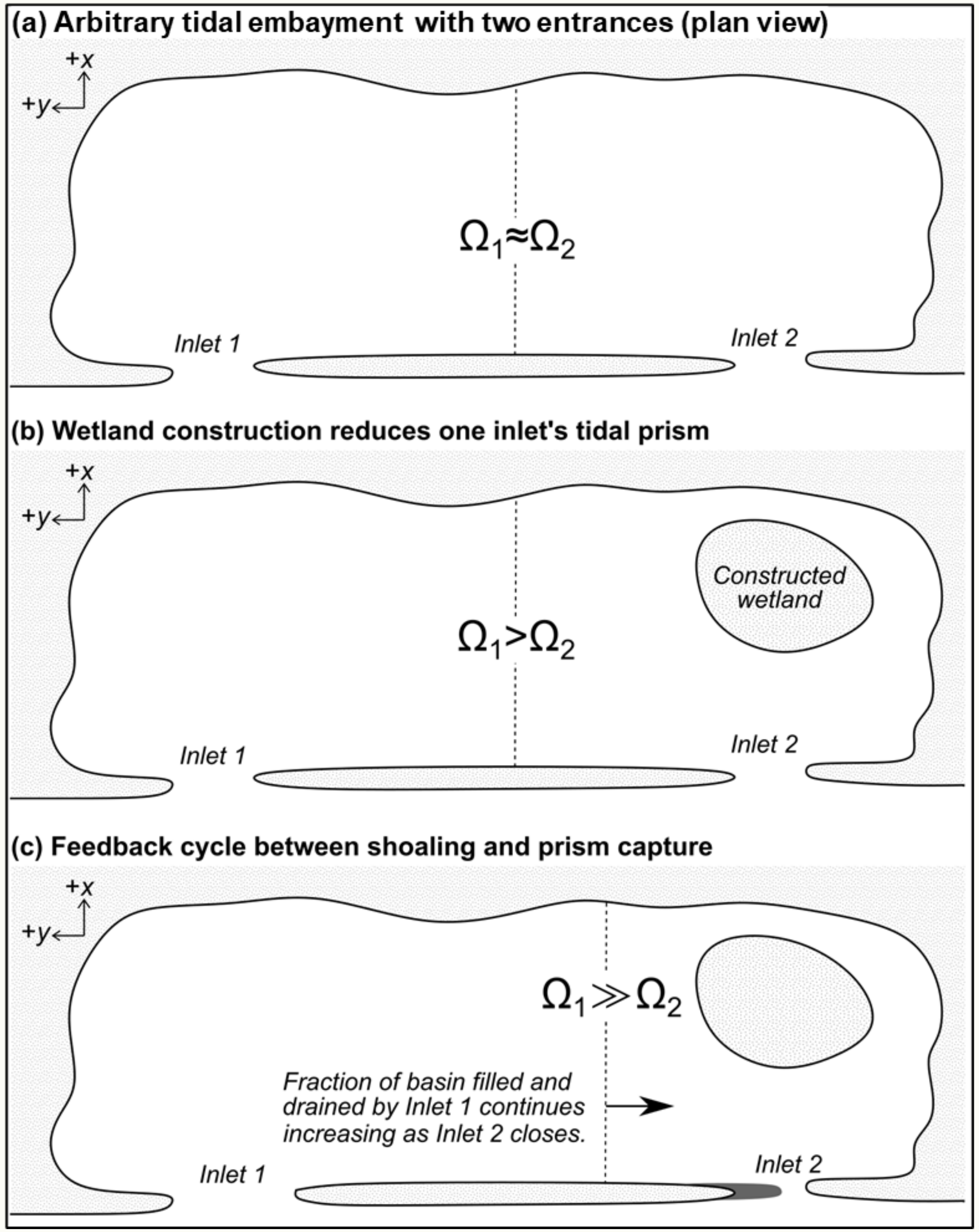
>700 km^2 of wetland loss in **Barataria Bay, LA**, has increased the tidal prism and generated a 44% increase in inlet cross-sectional area since 1880. In-bay wetland construction has been proposed as a method for reducing inlet scour (FitzGerald et al., 2003)



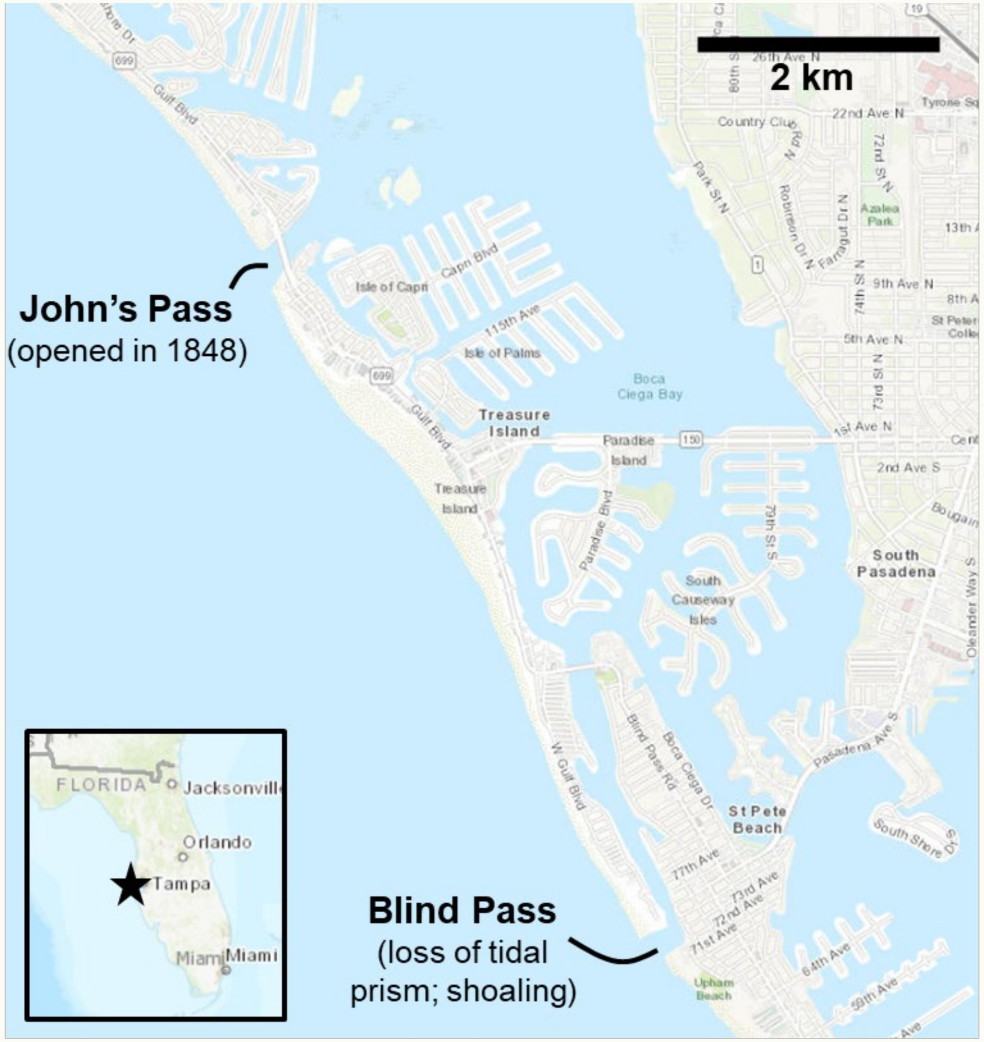
Upper: the National Map (USGS, 2020). Lower: bathymetry from Howes et al. (2013)

Tidal Prism Capture

- In multichannel systems: obstructing flow, adding material within the tidal frame, or decreasing hydraulic drag can redirect tidal flow and contribute to tidal prism capture



Tidal Prism Capture Example



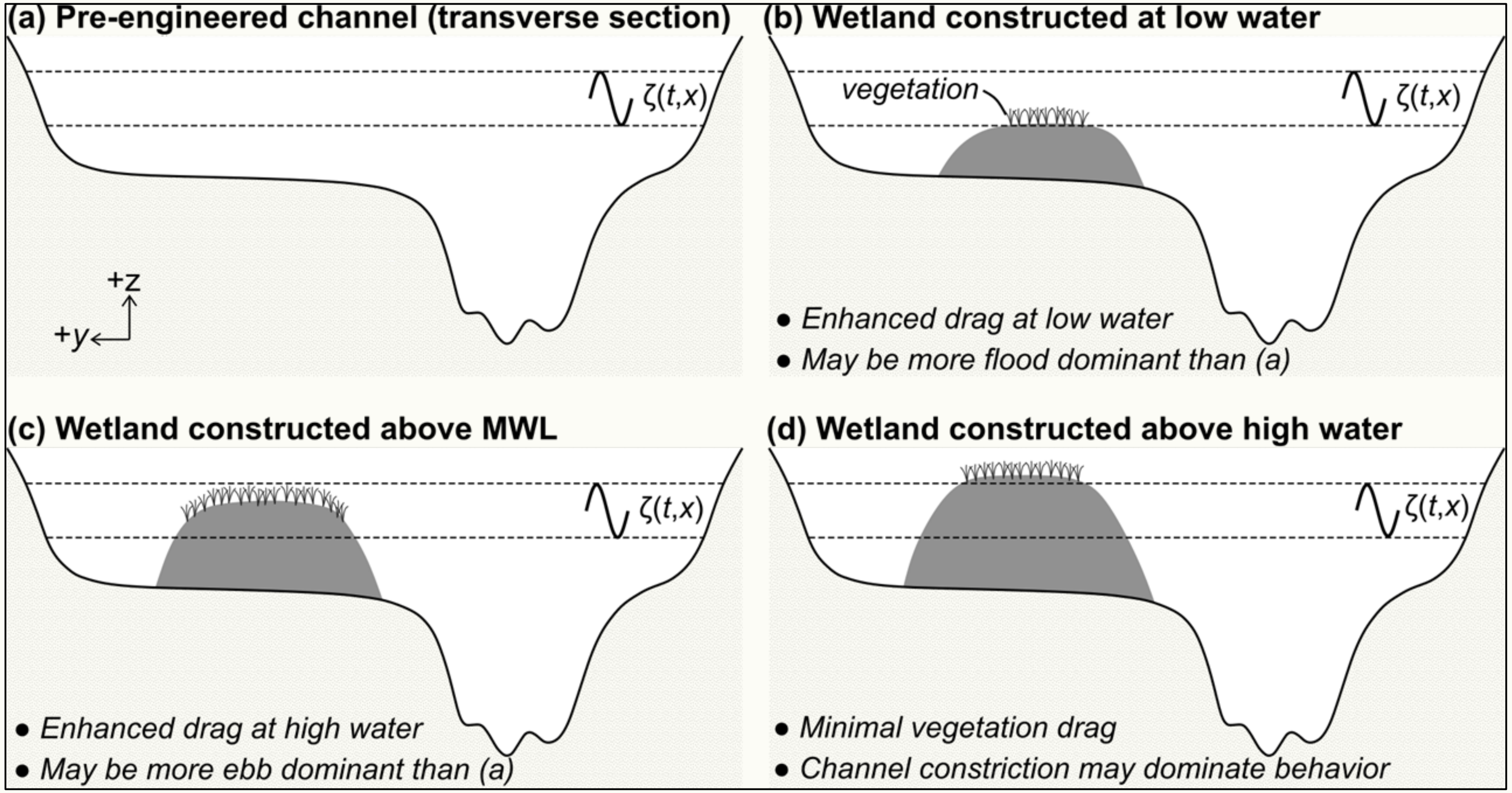
World Topographic Map provided by Esri, HERE, Garmin; ©OpenStreetMap contributors and the GIS User Community.

Above: Imagery of John's Pass from 1926 through 2010 (Wang and Beck, 2012); note island construction within the bay beginning in 1957.

Artificial opening of **John's Pass, FL**, in 1848 captured a large fraction of the tidal prism from Blind Pass. Tidal prism loss at Blind Pass was further enhanced by island construction in the bay (Wang and Beck, 2012).

Tidal Asymmetry

- Friedrichs and Aubrey (1988), among others, predict tidal asymmetry will be related to the ratio of tidal amplitude to depth and the ratio of intertidal volume to channel volume
- More intertidal area often makes systems more ebb dominant, but the ratio of depth to tidal amplitude is also important
- Fortunato and Oliveira (2005) allow intertidal areas to transmit some tidal energy and replace relative intertidal storage with relative intertidal width, and the relative depth of the intertidal areas
- Intertidal areas slightly higher than MWL are predicted to be most ebb dominant
- Intertidal areas near low water are more flood dominant than intertidal areas higher in the tidal frame



Tidal Asymmetry & Wetland Nourishment

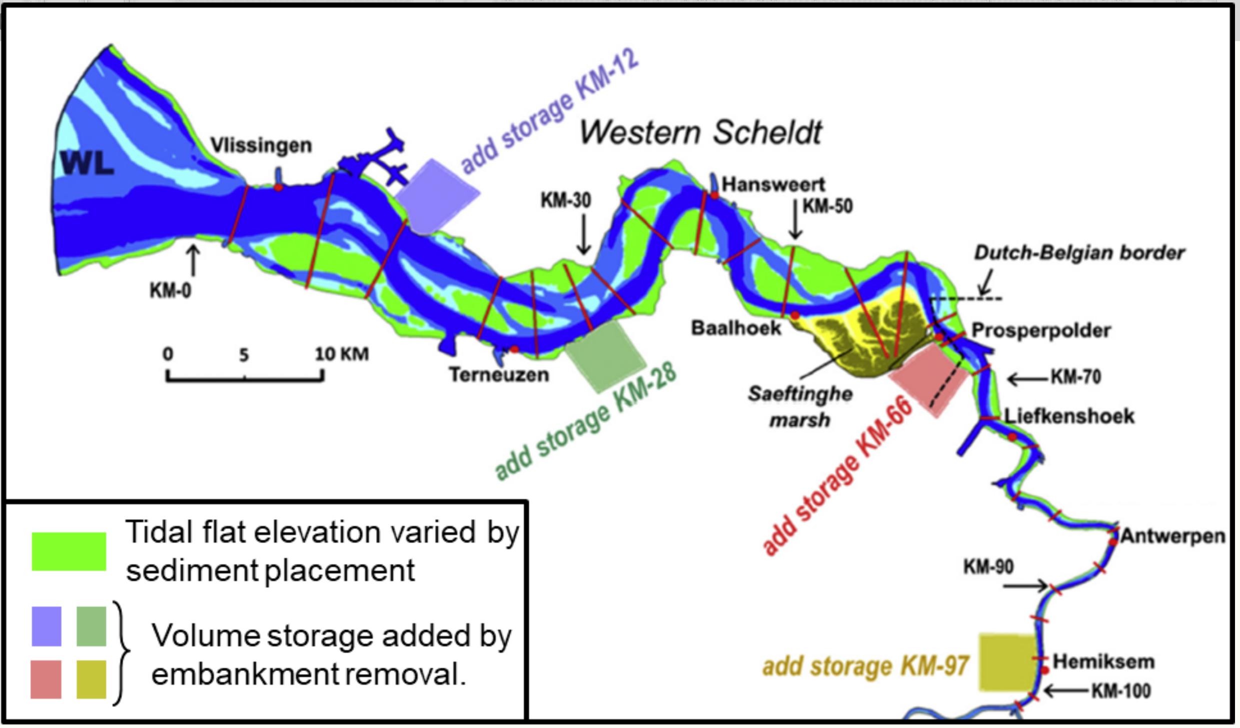
Stark et al. (2017) systematically evaluated the effect of wetland construction at varying elevations and positions along the **Western Scheldt** estuary.

Wetlands were created by either:

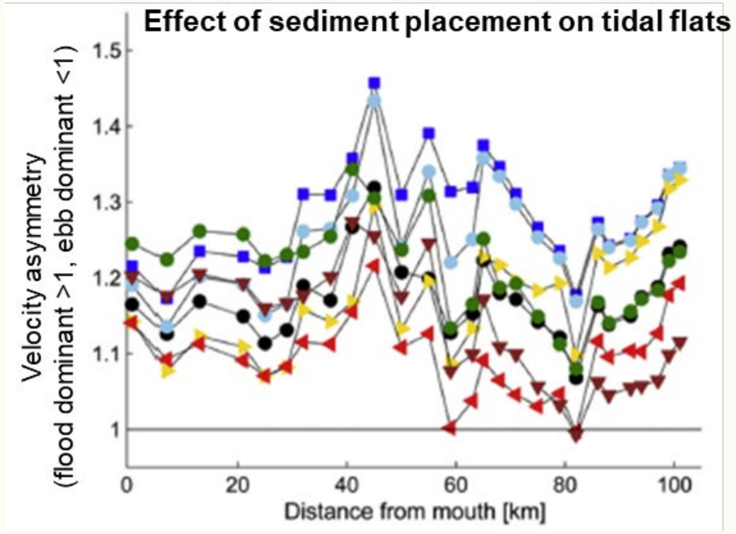
- *Embankment removal at the channel margin.*
- ***Placement on tidal flats within the flow-carrying cross section.***

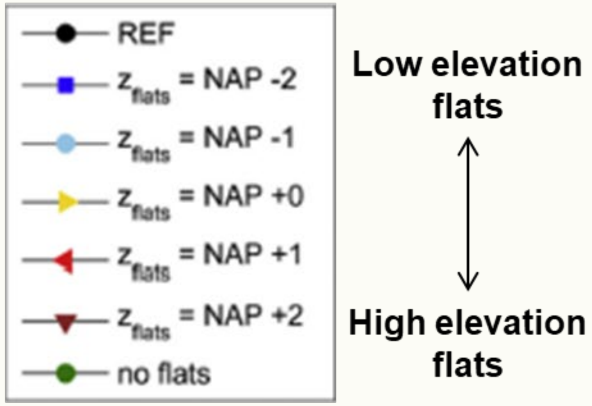
For placement on tidal flats:

- *Elevations below mean water level tended to enhance flood dominant velocities (relative to a simulation with no flats; diagram at right).*
- *Elevations above mean water level tended to reduce flood-dominant velocities.*



Map of Western Scheldt estuary with simulation scenarios (Stark et al., 2017).

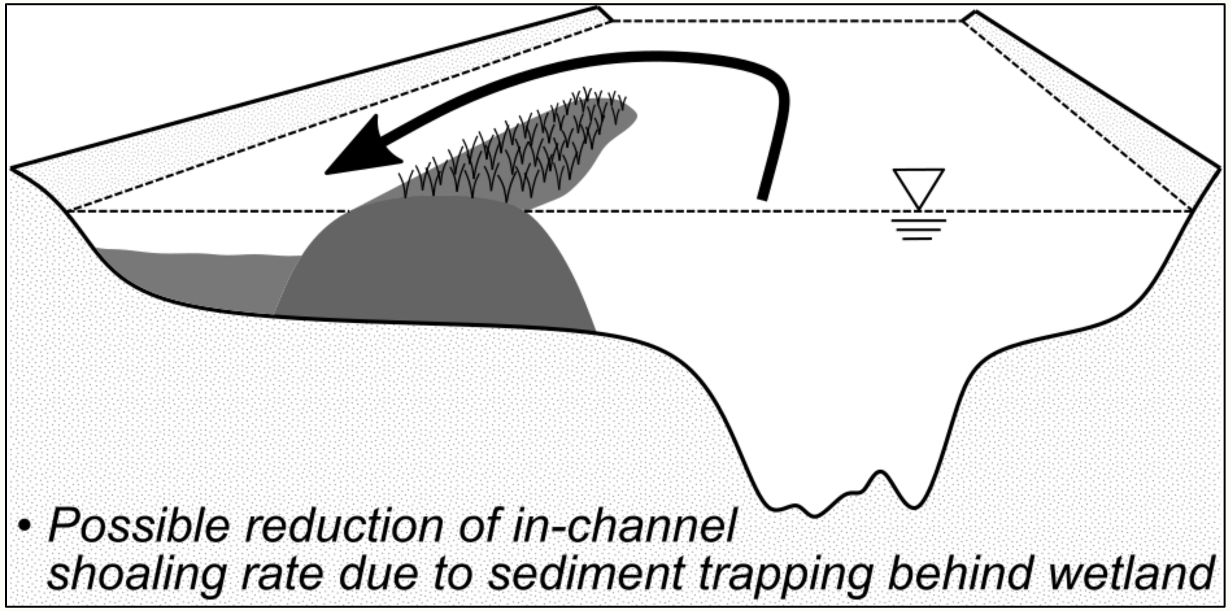




Model results from Stark et al. (2017)

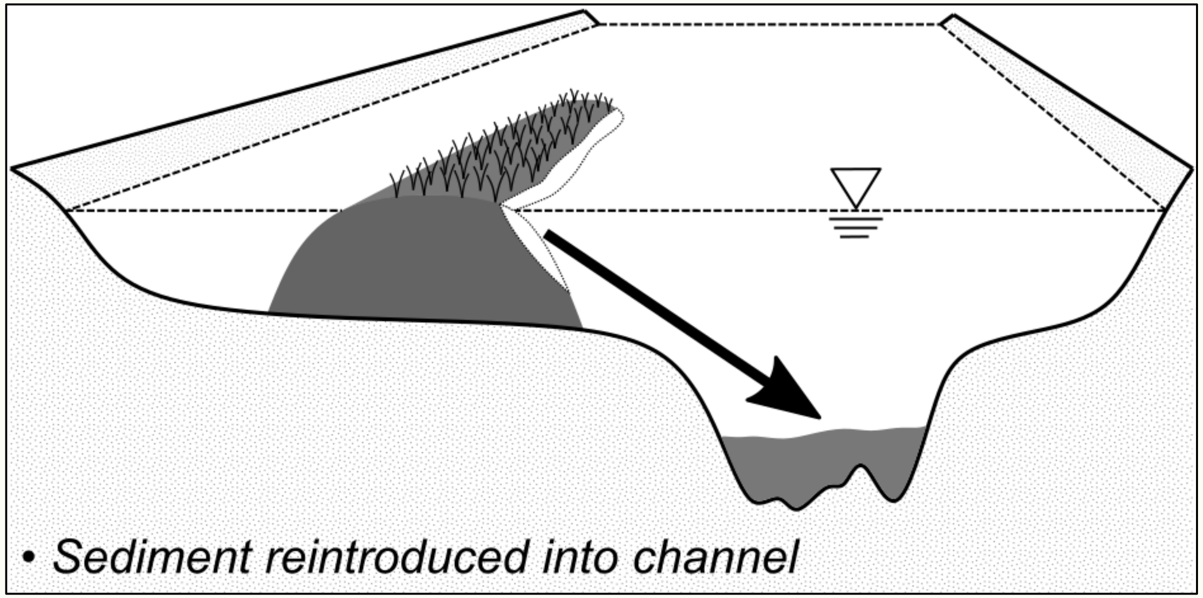
Sediment Trapping

- “Morphodynamic pathways” can transfer sediment from high- to low-energy areas (e.g., flow expansion, sheltering, tidal flats)
- Wetland nourishment could alter circulation patterns or shelter nearby areas
- This could lead to increased sediment deposition outside of the navigation channel
- Increased deposition outside of the navigation channel can, but does not always, reduce channel shoaling rates
- Model results indicate that expanding **Atkinson Island in Galveston Bay** may have reduced flow velocities behind the island and accelerated shoaling, but overall circulation pattern change also accelerated navigation channel shoaling (Tate et al. 2014)



Geotechnical Failure

- Channel edge steepening, cyclical pore-water pressure induced strain-softening, elevated pore pressure, and wetland vegetation weakening from advancing salinity gradients can all contribute to geotechnical failures
- Bank collapse could be possible at sites without hardened edges
- Additional placements atop previous placed unconsolidated sediment may enhance the likelihood of bank collapse
- Recurring placement and containment levee construction on unconsolidated sediment from previous placements at **Spilmans Island in Galveston Bay** led to two slope failures in the 1990's (Kayyal and Hasen, 1998).



Literature Review Conclusions

- **The hydrodynamic response to embayment engineering is a complex topic, and it has been under-studied in a wetland placement context.**
- **Certain site-specific responses to large-scale embayment modification may be relevant to wetland nourishment in some systems.**
  - ***Tidal amplitude:*** narrowing & reducing friction amplifies tides; adding intertidal area may damp tides.
  - ***Tidal prism reduction:*** adding sediment within the tidal frame can reduce tidal prism.
  - ***Tidal prism capture:*** altering one side of a multichannel system can redirect more flow through one of the channels.
  - ***Tidal asymmetry:*** intertidal area makes systems more ebb dominant, particularly at elevations slightly above MWL. Elevations near MLW may contribute to flood dominance.
- **Complicating factors**
  - Individual modifications are often not in isolation, and responses may occur gradually over years
  - The relationship between modification scope and embayment response is not clear
  - Applicability across the full spectrum of embayments is unclear.
- ***Collaboration opportunities welcome!***

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