CSAT-derived insights into the relationship between navigation channel deepening and future maintenance requirements

Rachel Bain, Michael Hartman, Anna Godfrey, and Kaite McPherran

CIRP Technical Discussion   •   May 14, 2024

Open questions
(A non-exhaustive list)

- What sites have you worked on where shoaling rates have increased after deepening?

- Have you worked on any sites where the shoaling rate has **NOT** increased after deepening?

- Have you noticed any patterns related to where shoaling increases after deepening, versus where it doesn't?

    - *Dominant processes? (e.g., tide dominated versus river dominated, high wave energy versus low wave energy, …)*

    - *Location within system? (e.g., entrance channel versus inner harbor, spur channels versus main channel, …)*

    - *Location within reach? (e.g., center of channel versus side slopes)*

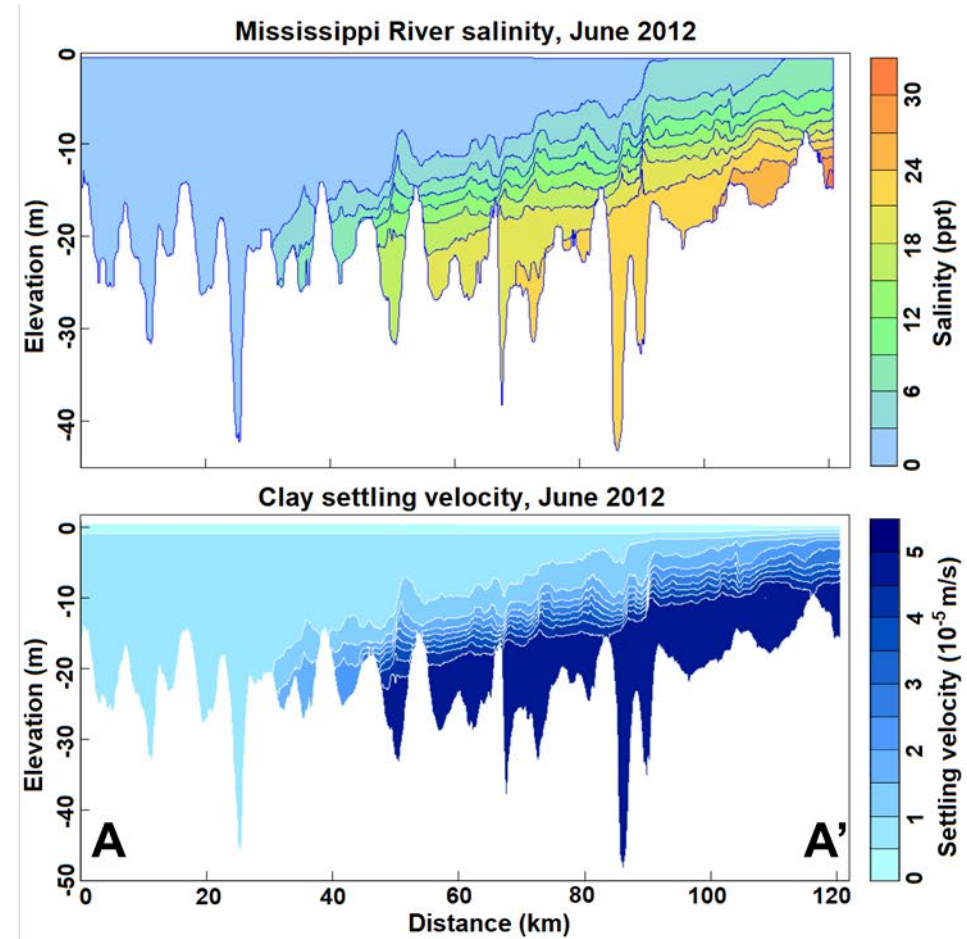- Do you have records of dredging volume that we can use for validation?

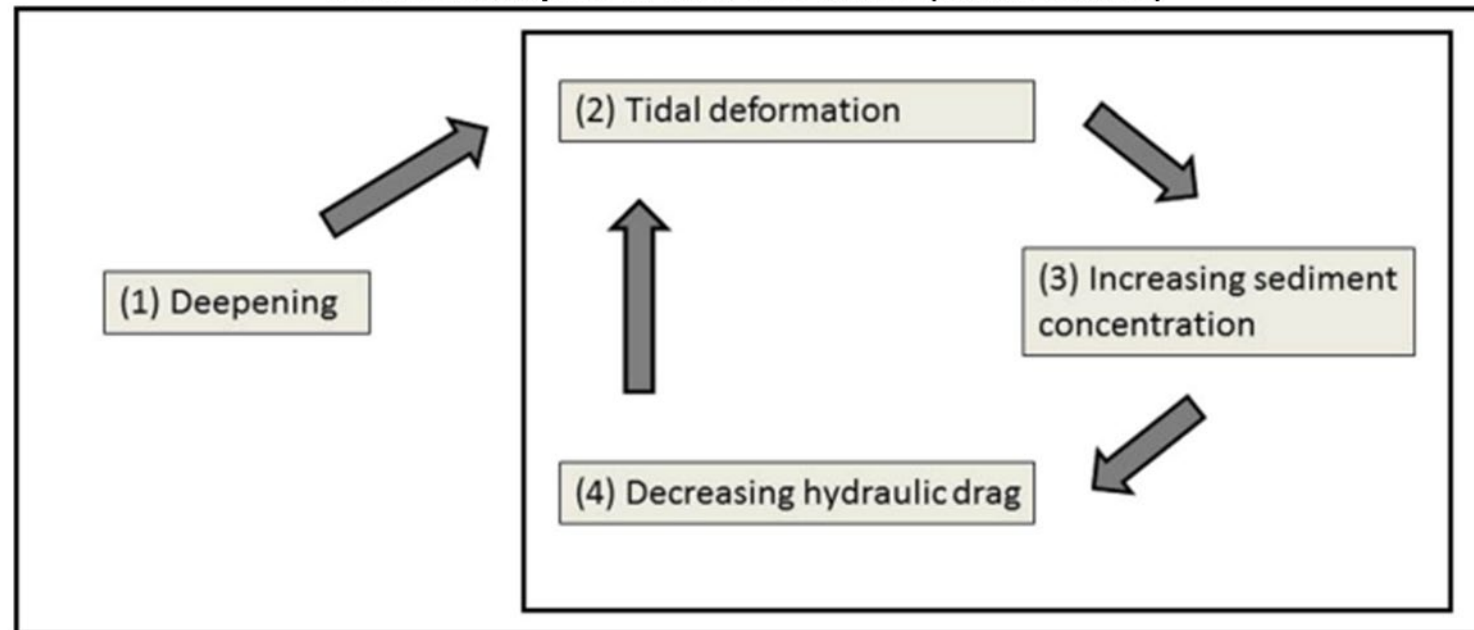# Why is shoaling higher in enlarged channels?
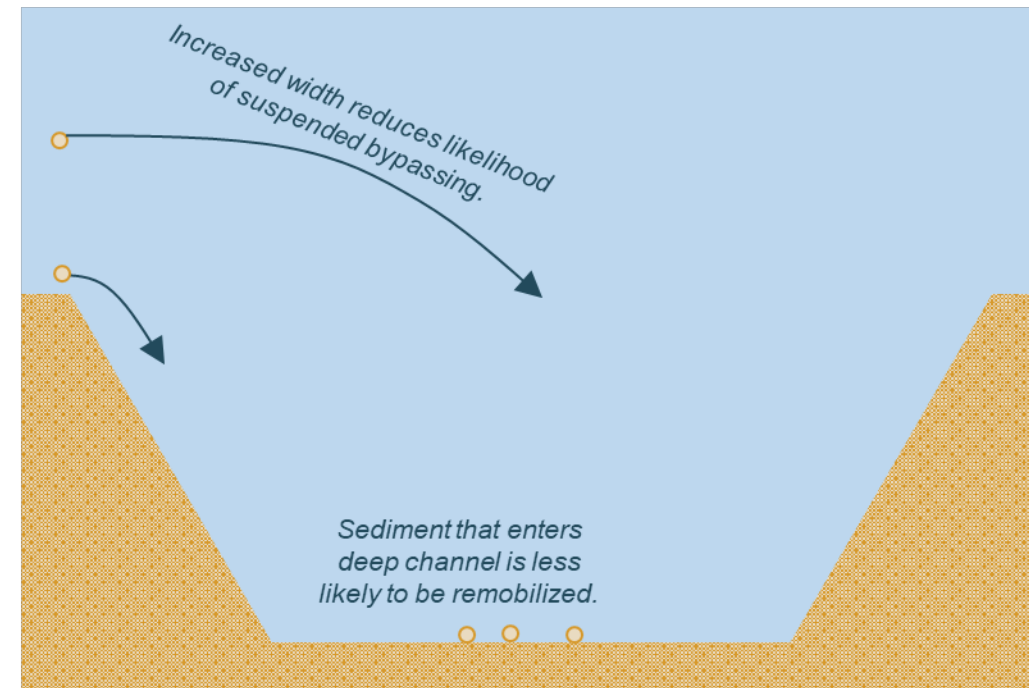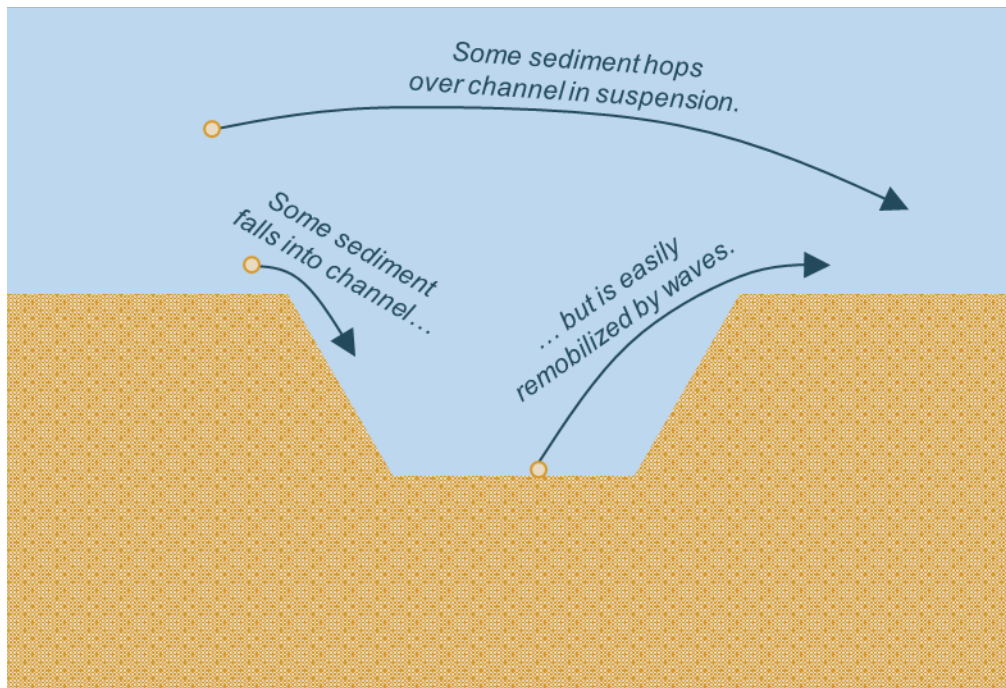
- Reduced bypassing rate

After Kraus and Larson (2001)

Why is shoaling higher in enlarged channels?

- Reduced bypassing rate

- Enhanced salinity intrusion

Edited from Ayres (2015)

Why is shoaling higher in enlarged channels?

- Reduced bypassing rate

- Enhanced salinity intrusion

- Tidal deformation

Deepening-initiated feedback cycle between tidal amplification and sediment import in the Ems River (Netherlands)

van Maren et al. (2015)

Why is shoaling higher in enlarged channels?

- Reduced bypassing rate

- Enhanced salinity intrusion

- Altered tidal dynamics

- Larger vessels → larger wakes

Image: USACE NAO (2015)

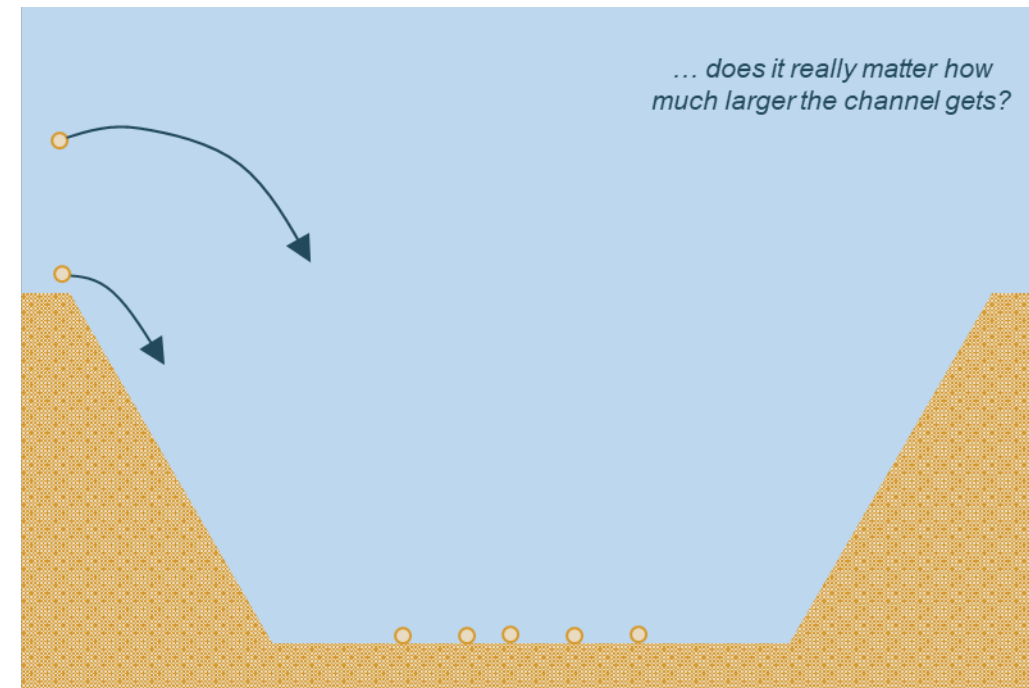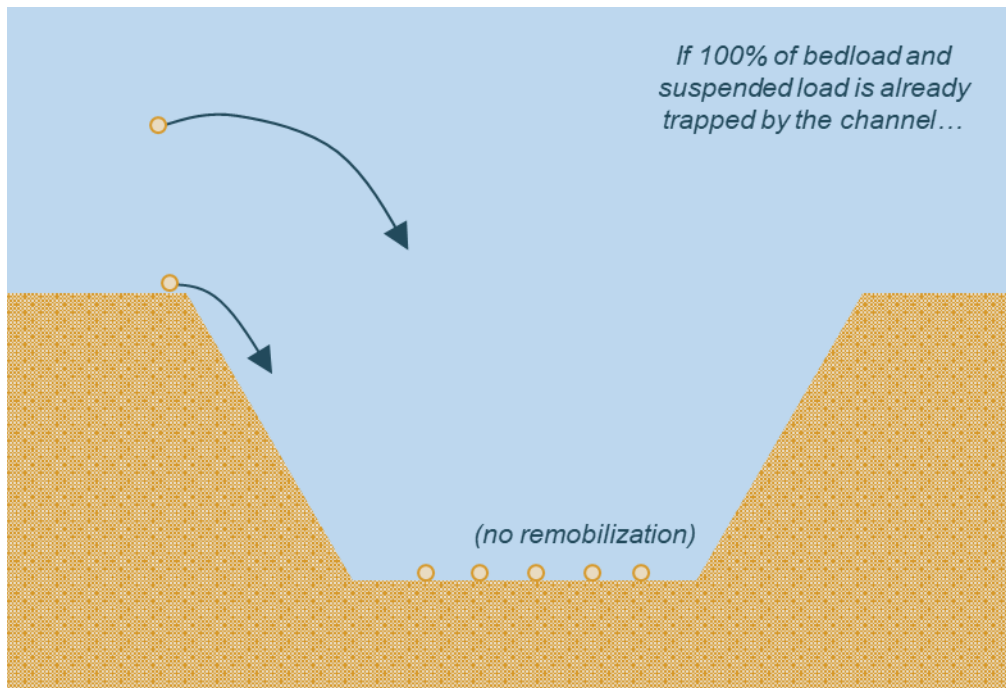# Why might shoaling NOT be higher in enlarged channels?

- Cross-sectional area enlarged due to dredging → Larger tidal prism → Higher velocities
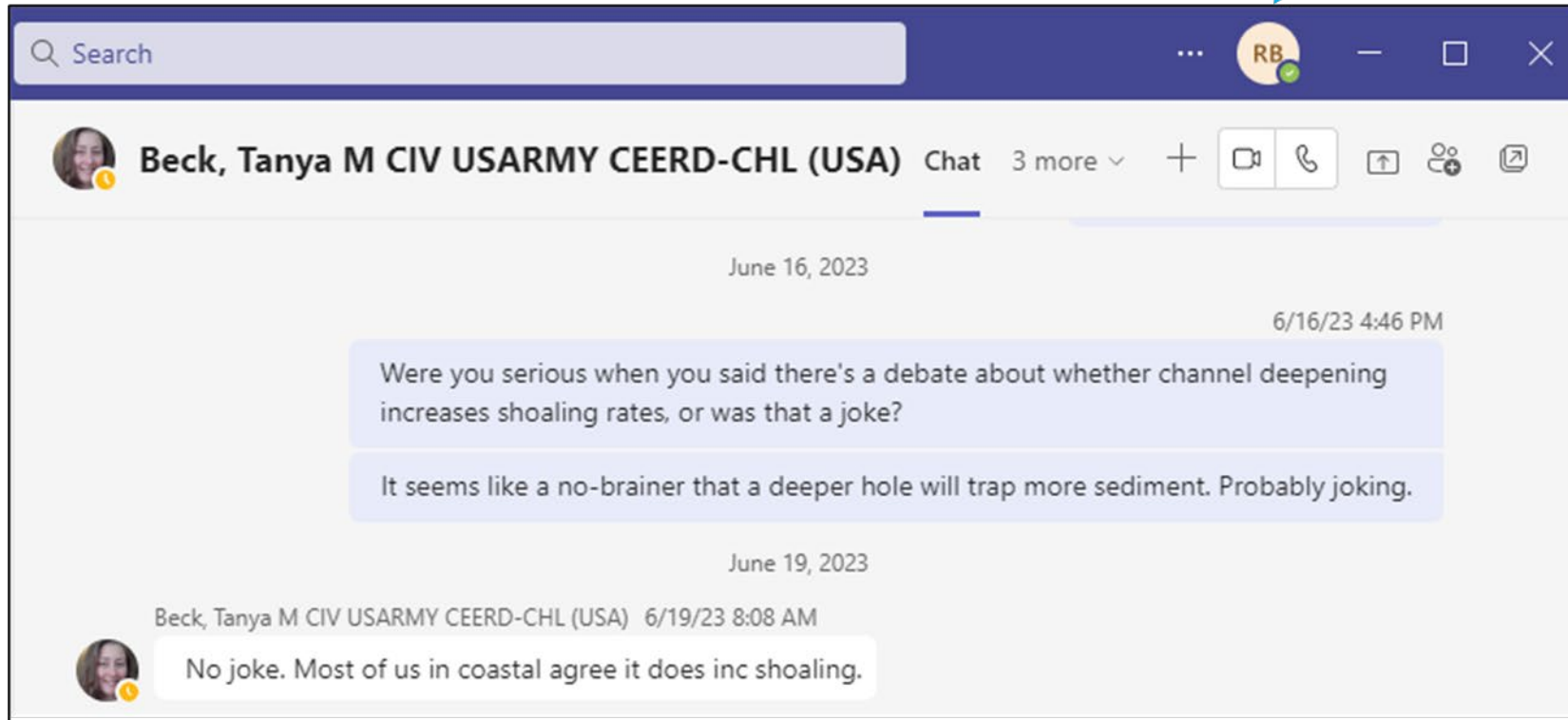
All else equal … really simplifying things here!

Why might shoaling NOT be higher in enlarged channels?

- Cross-sectional area enlarged due to dredging → Larger tidal prism → Higher velocities
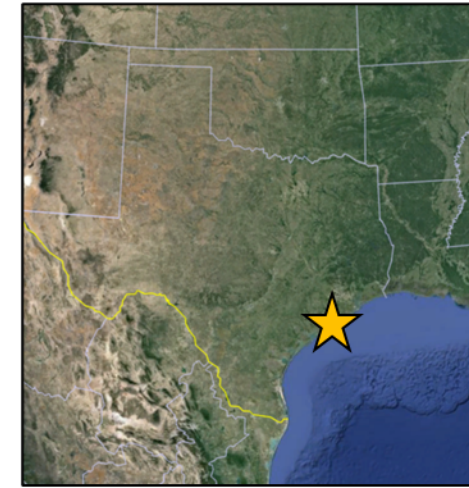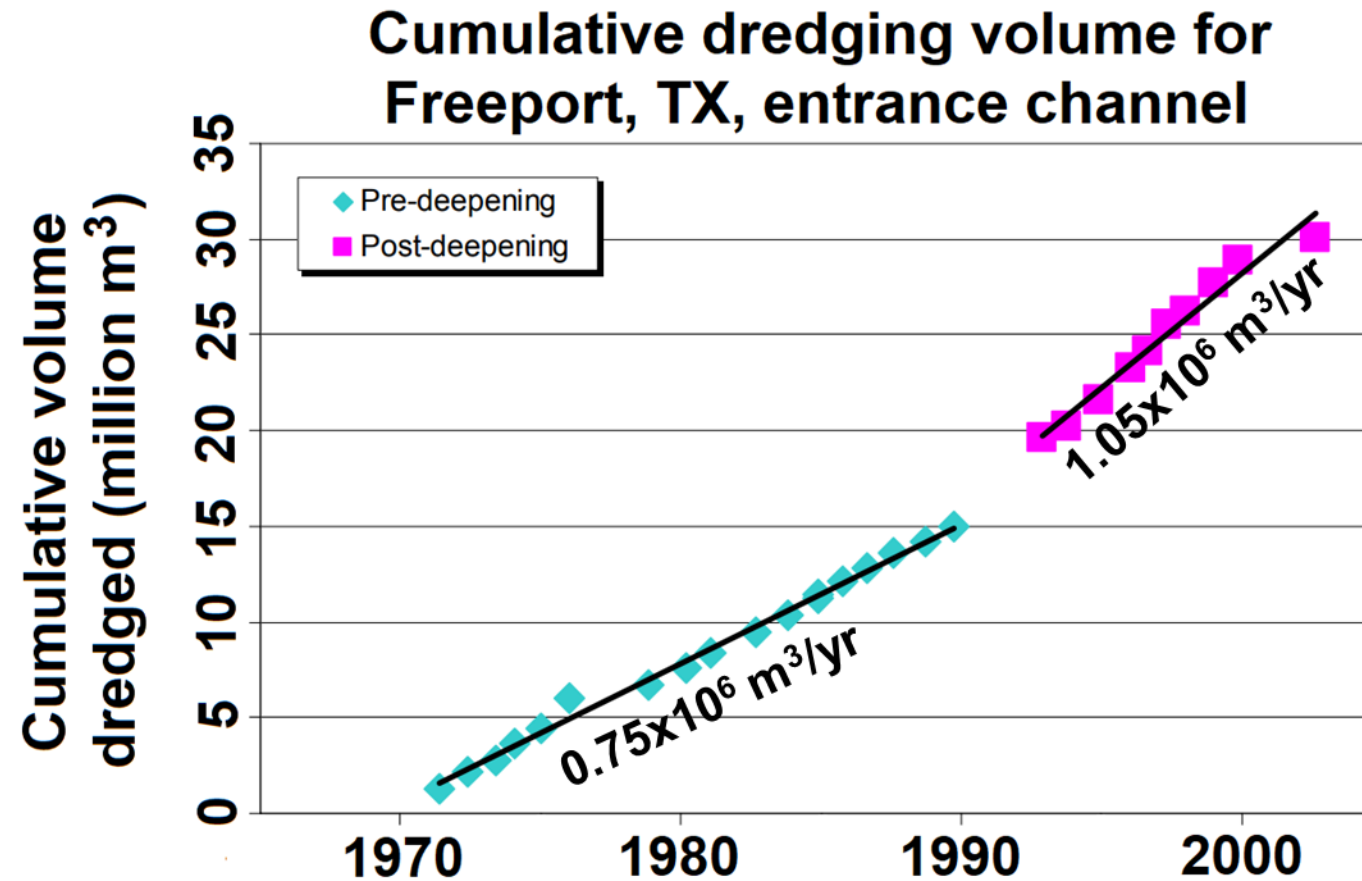
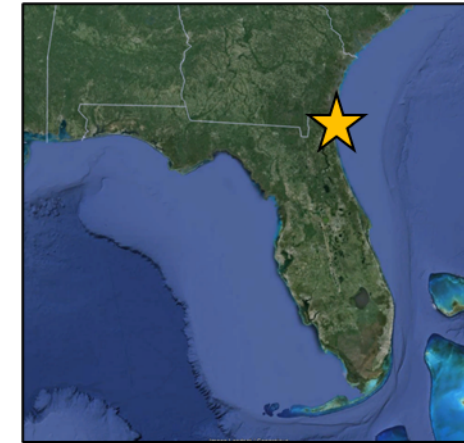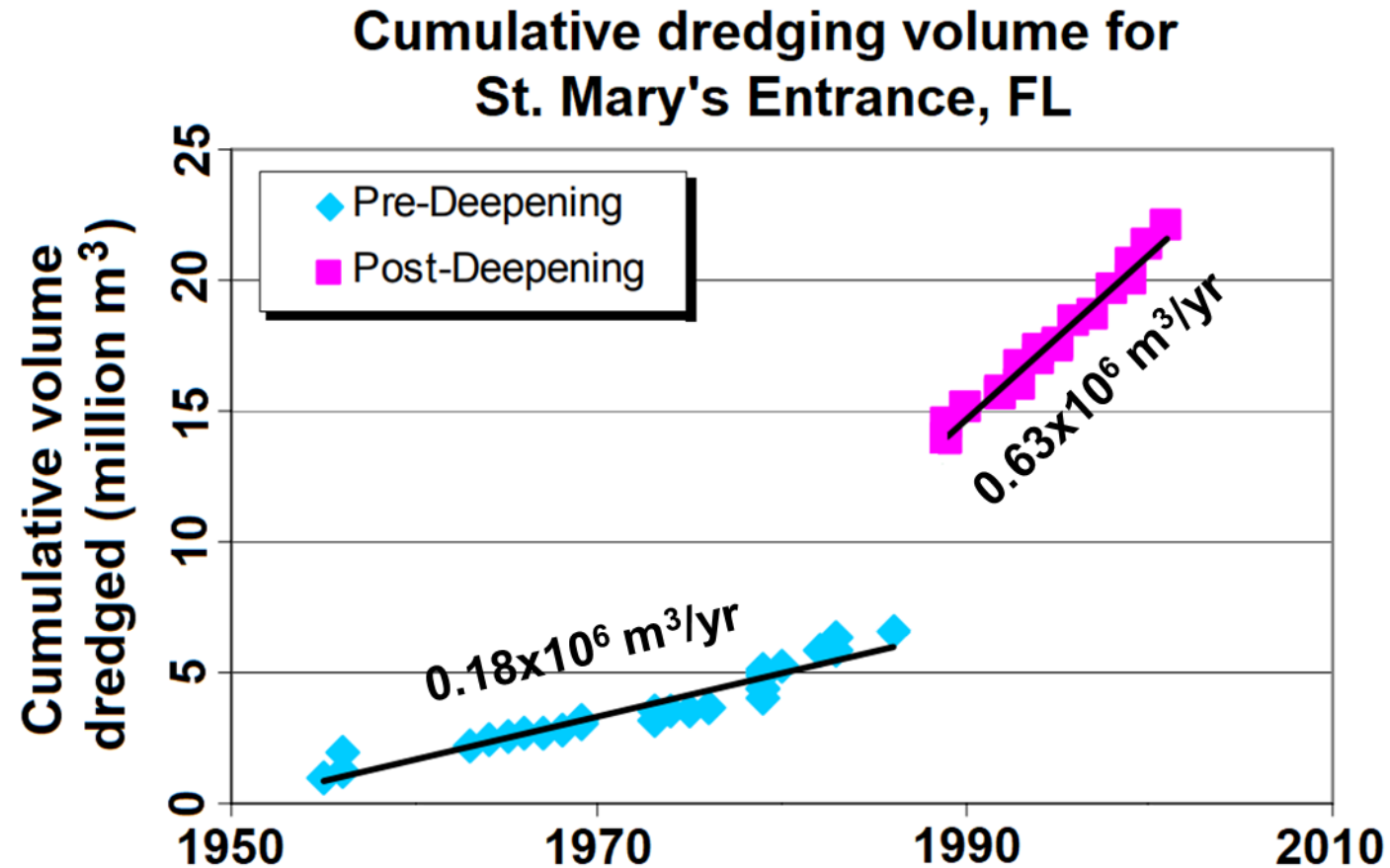- Finite sediment availability

But our mental model generally says…

Rachel

Does reality match our mental model? Ex.1

Edited from Rosati (2005)

Does reality match our mental model? Ex.2

Cumulative dredging volume for St. Mary's Entrance, FL

Edited from Rosati (2005)

Does reality match our mental model? Ex.3

Tate et al. (2014)
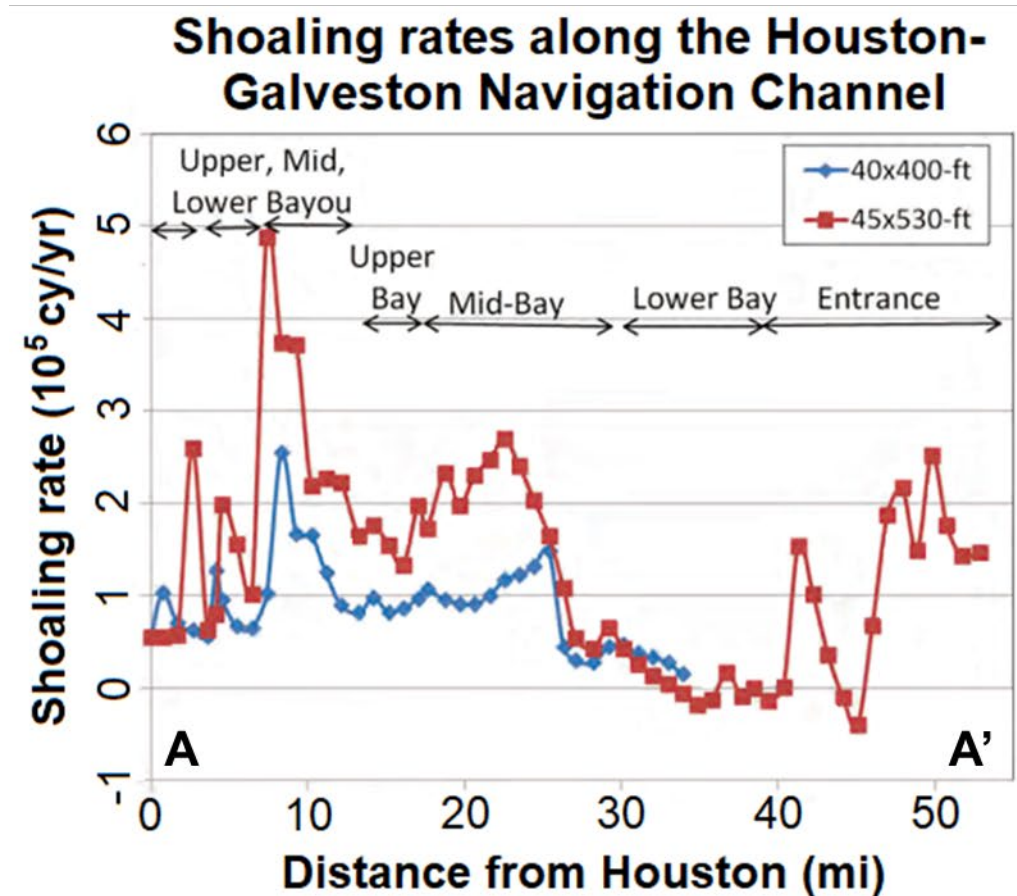
Does reality match our mental model? Ex.4

- San Francisco raised some questions ...

Cumulative maintenance dredging volume for San Francisco (CA) Main Ship Channel

Legend:
- Partly 45 ft, partly 50 ft maint. depth
- Whole channel 50 ft maint. depth
- Whole channel 55 ft maint. depth*

6.36×10^6 cy/yr
5.85×10^6 cy/yr
6.99×10^6 cy/yr
3.63×10^6 cy/yr
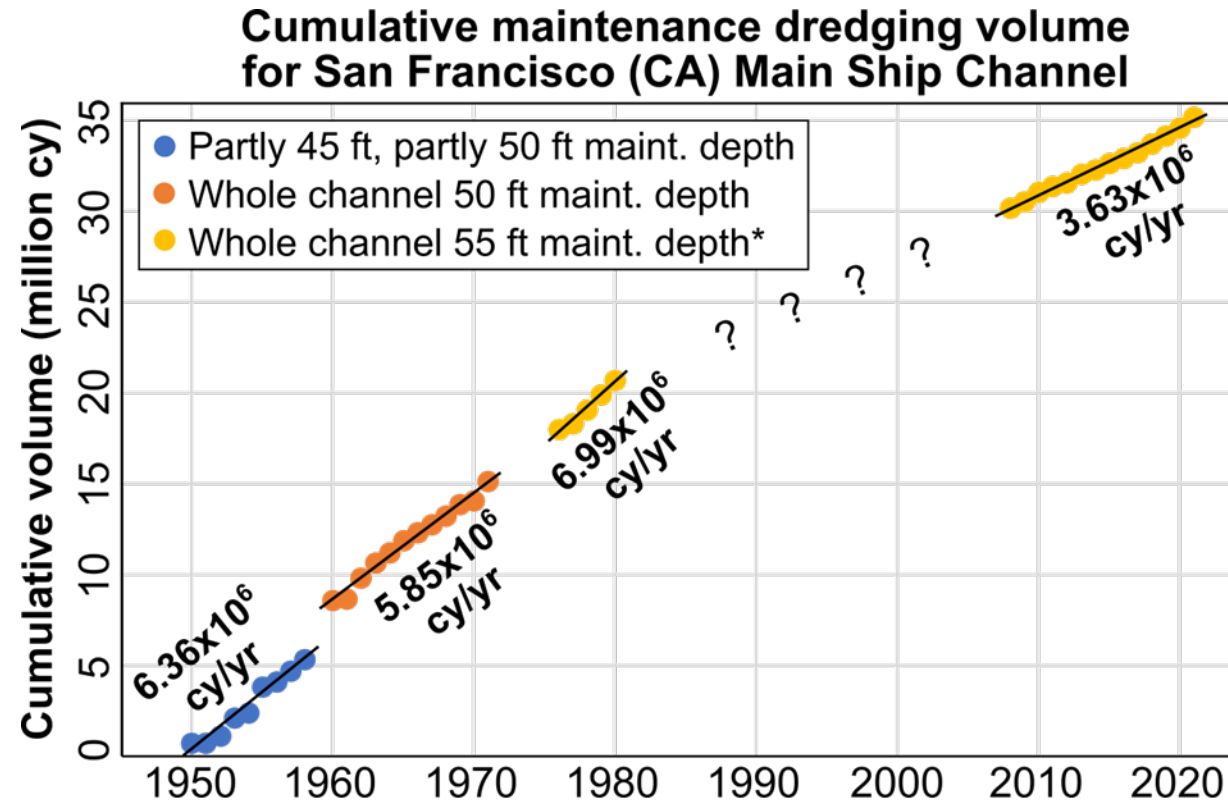
… but then SPN told us that **they haven't been maintaining the Main Ship Channel to the full 55 ft in recent years** due to budgetary constraints.
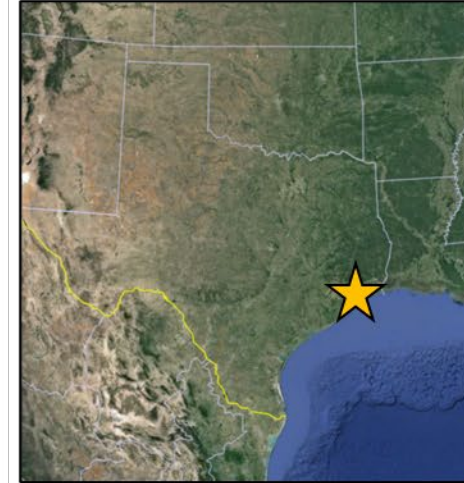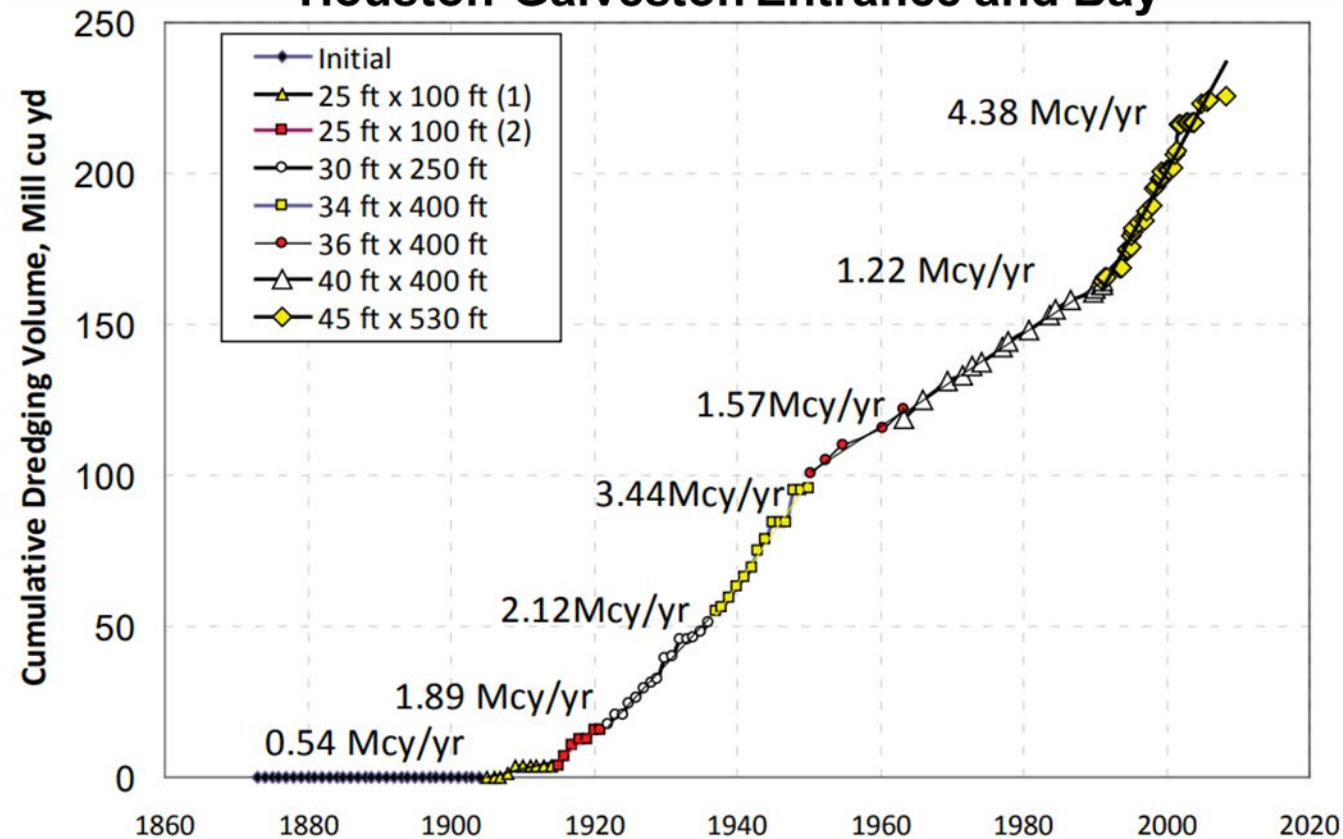
Does reality match our mental model? Ex.5

- If (as our paradigm suggests) deepened channels always have a higher shoaling rate, does a lower shoaling rate always imply that the maintained depth has been reduced? **Not at Calcasieu!**
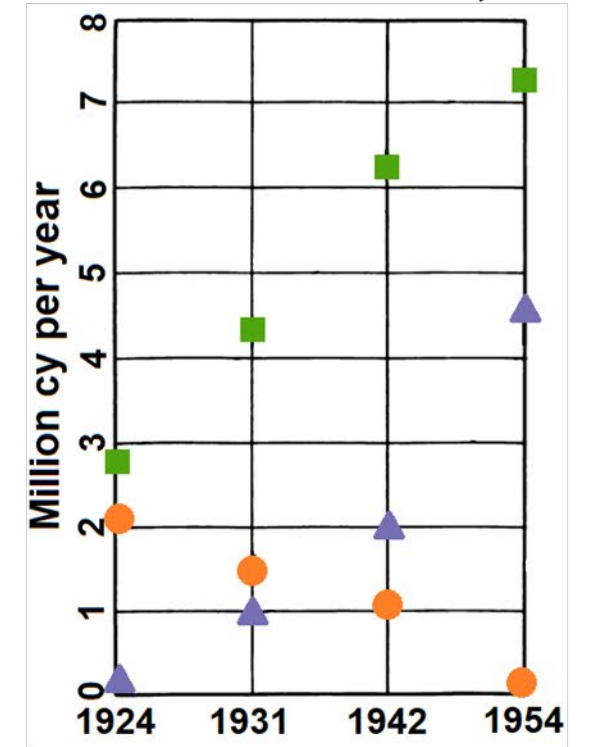

Cumulative maintenance dredging volume for Calcasieu (LA) Pass, Lake, and River

Pre-published data from Cadigan et al. (in revision) and Holzenthal et al. (in review)
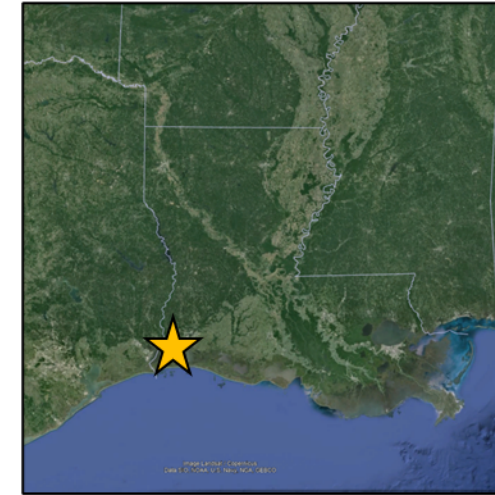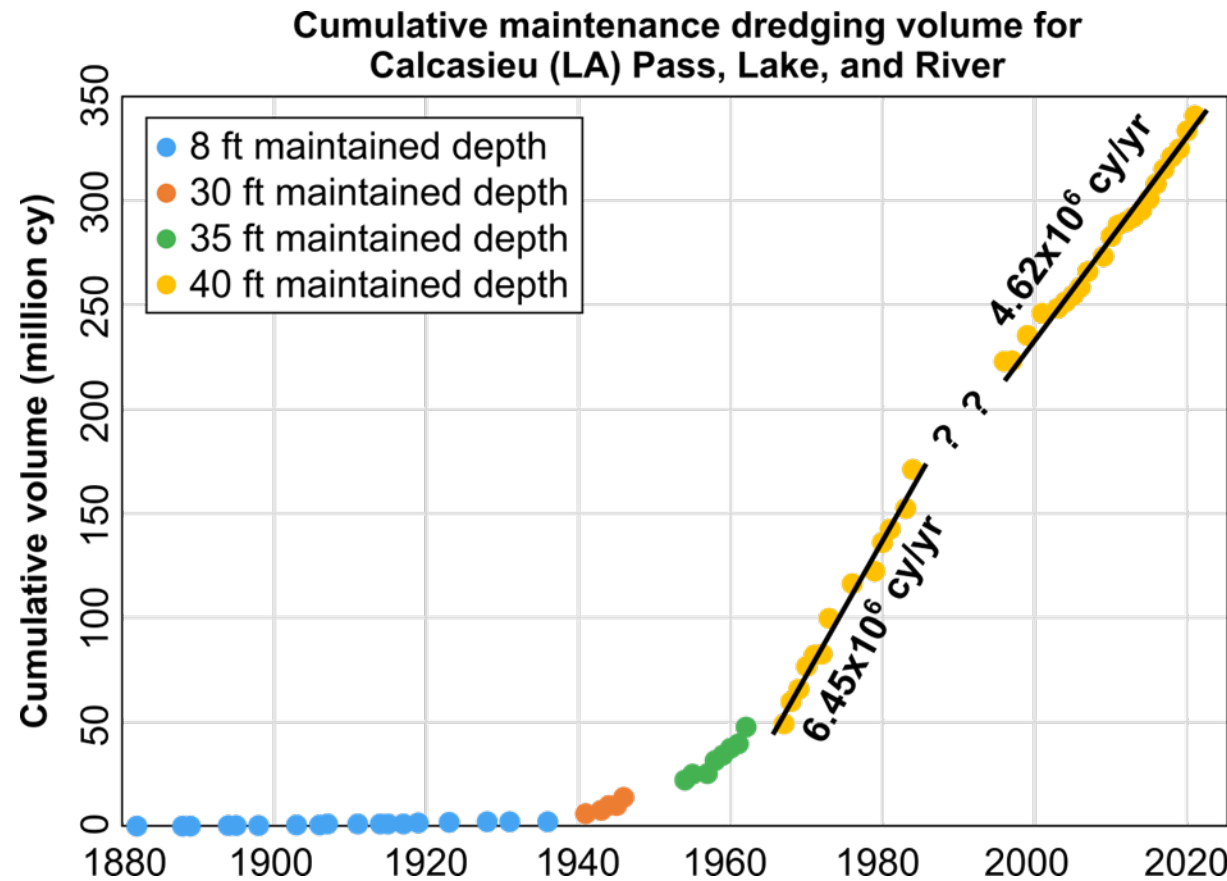
Does reality match our mental model? Ex.6

Cumulative O&M dredging volumes for Houston-Galveston Entrance and Bay

Tate et al. (2014)

Does reality match our mental model? Ex.7

Edited from Simmons (1965)

Does reality match our mental model? Conclusions

- Although some studies confirm that shoaling accelerates in enlarged channels, other studies (and unpublished datasets) indicate that we may have oversimplified the relationship.
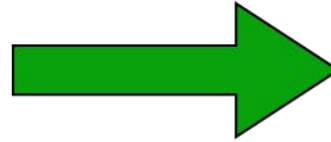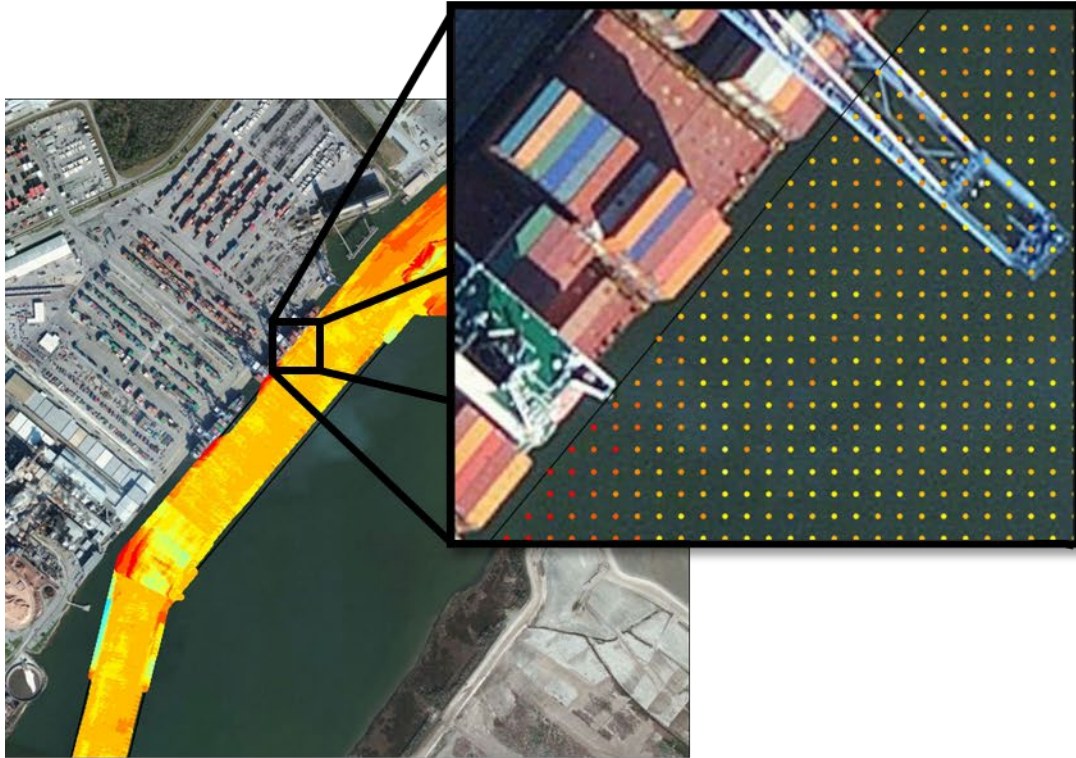
- How can we address this issue more comprehensively?

Corps Shoaling Analysis Tool (CSAT) overview

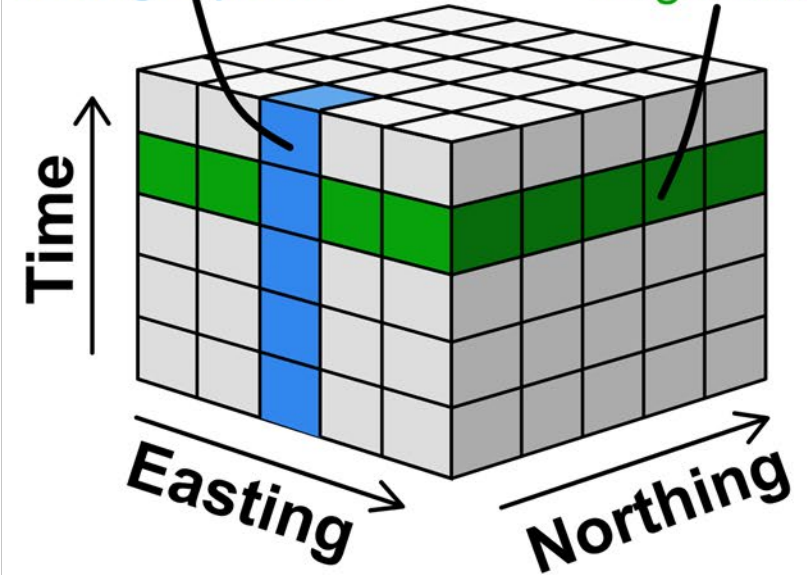1) USACE Districts upload hydrographic survey data to the **eHydro database** in a standardized format.

*POC: **Dr. Michael Hartman**, Michael.A.Hartman@usace.army.mil*
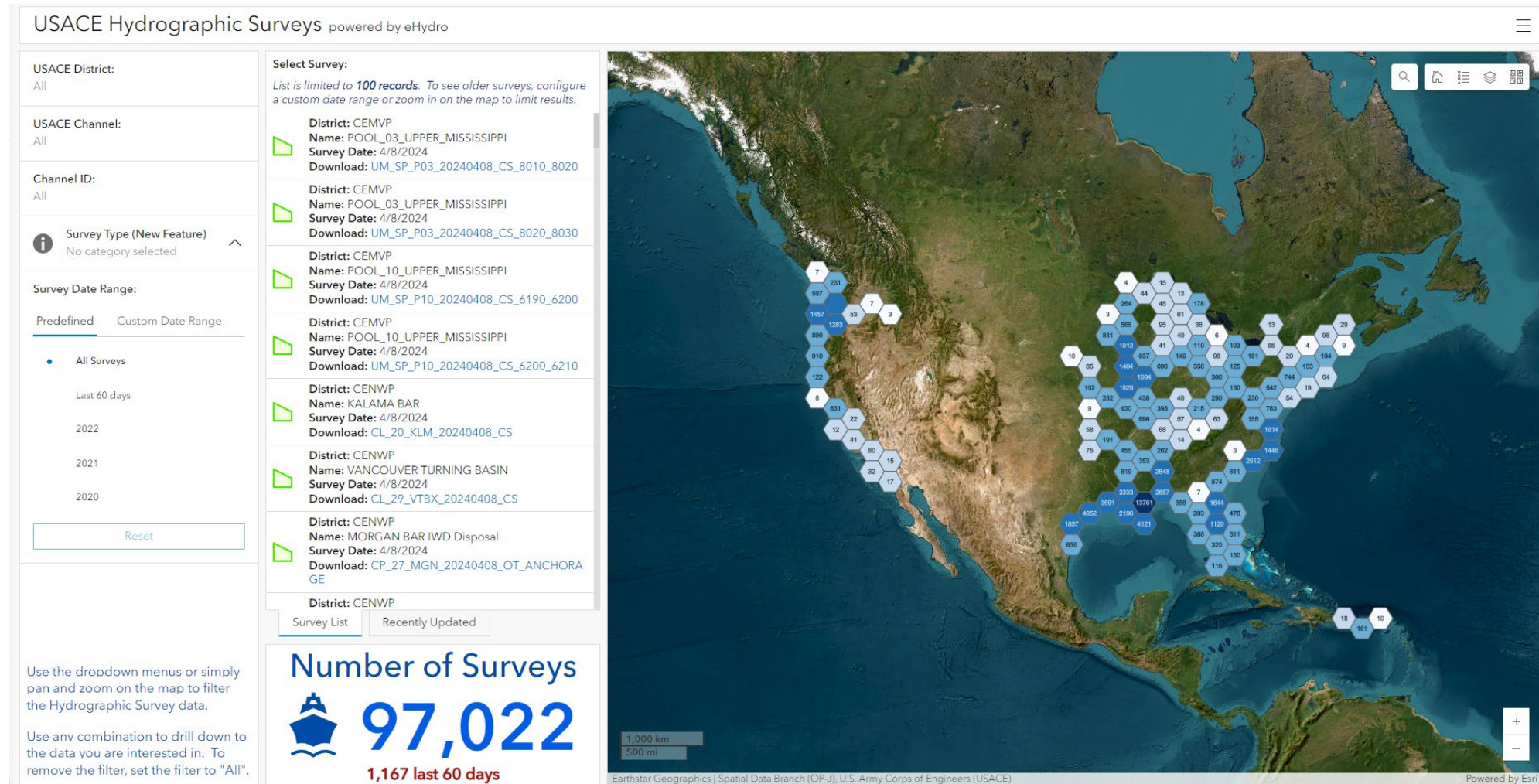
Corps Shoaling Analysis Tool (CSAT) overview

2) The bed elevations are gridded to create a space-time cube.

Corps Shoaling Analysis Tool (CSAT) overview
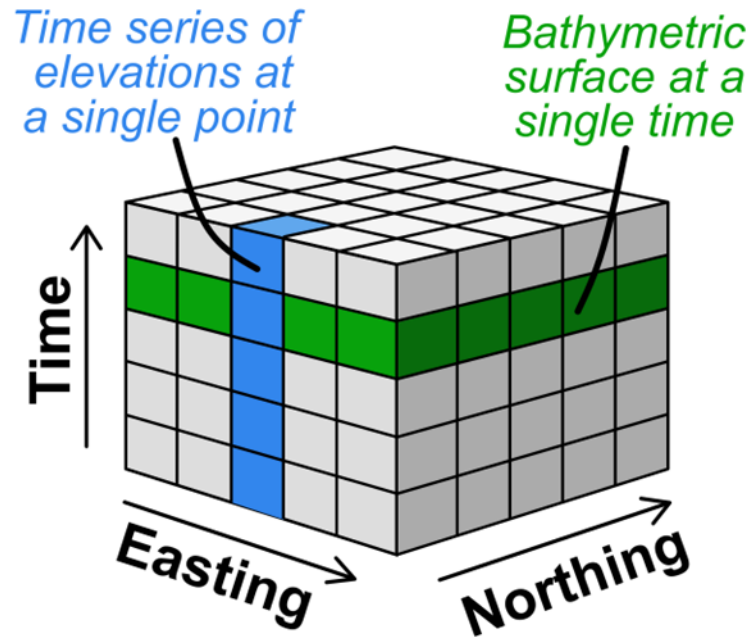
3) At **each pixel**, the time series of observed bed elevations is used to forecast future bed elevations.

4) Summing the pixelwise predictions generates a shoaling volume forecast for the entire reach.
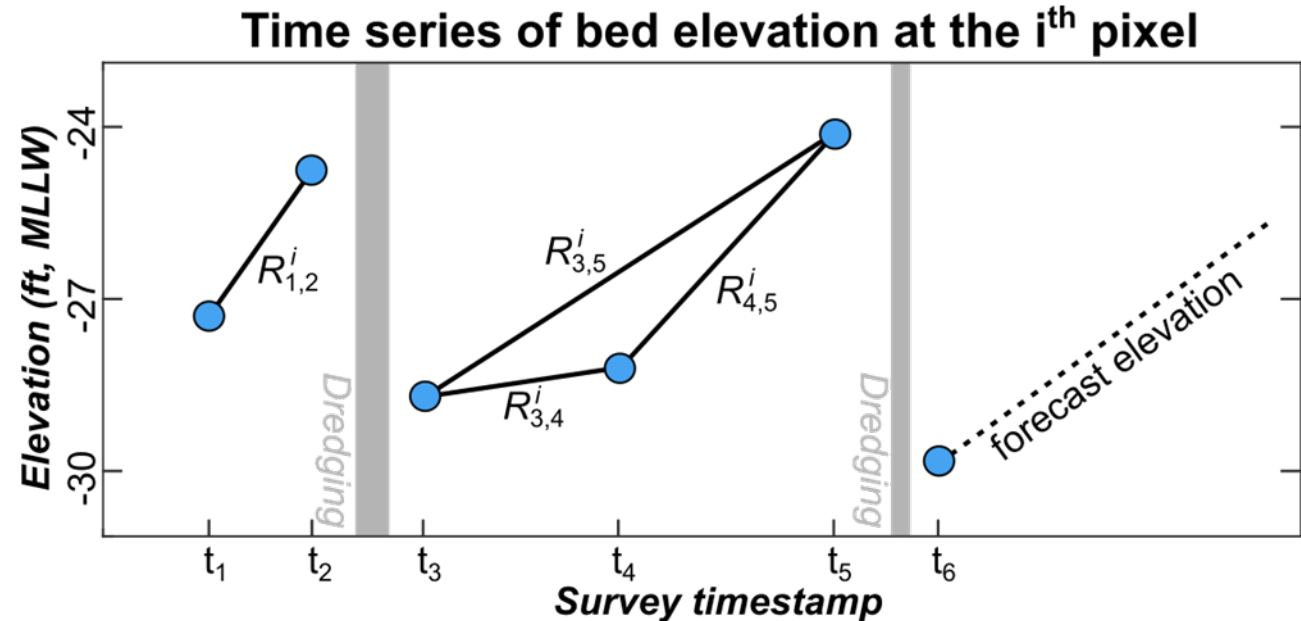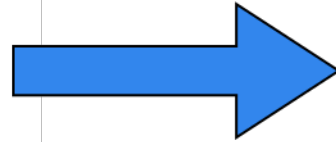
POC: *Dr. Michael Hartman*, *Michael.A.Hartman@usace.army.mil*

What new insights can CSAT give us?

Case study: Savannah Harbor, Georgia

- Entrance channel deepened from 42 ft to 47 ft MLLW between 2015 and 2018.

- Inner harbor deepened from 42 ft to 47 ft MLLW between 2019 and 2022.

- How much has the shoaling rate increased?

Images from USACE SAS

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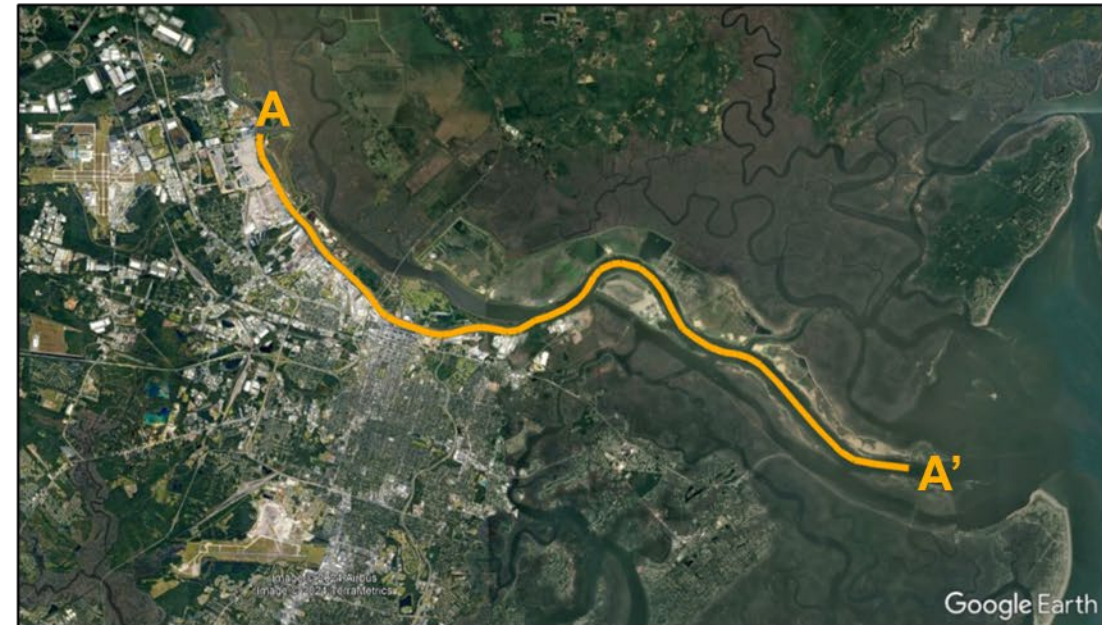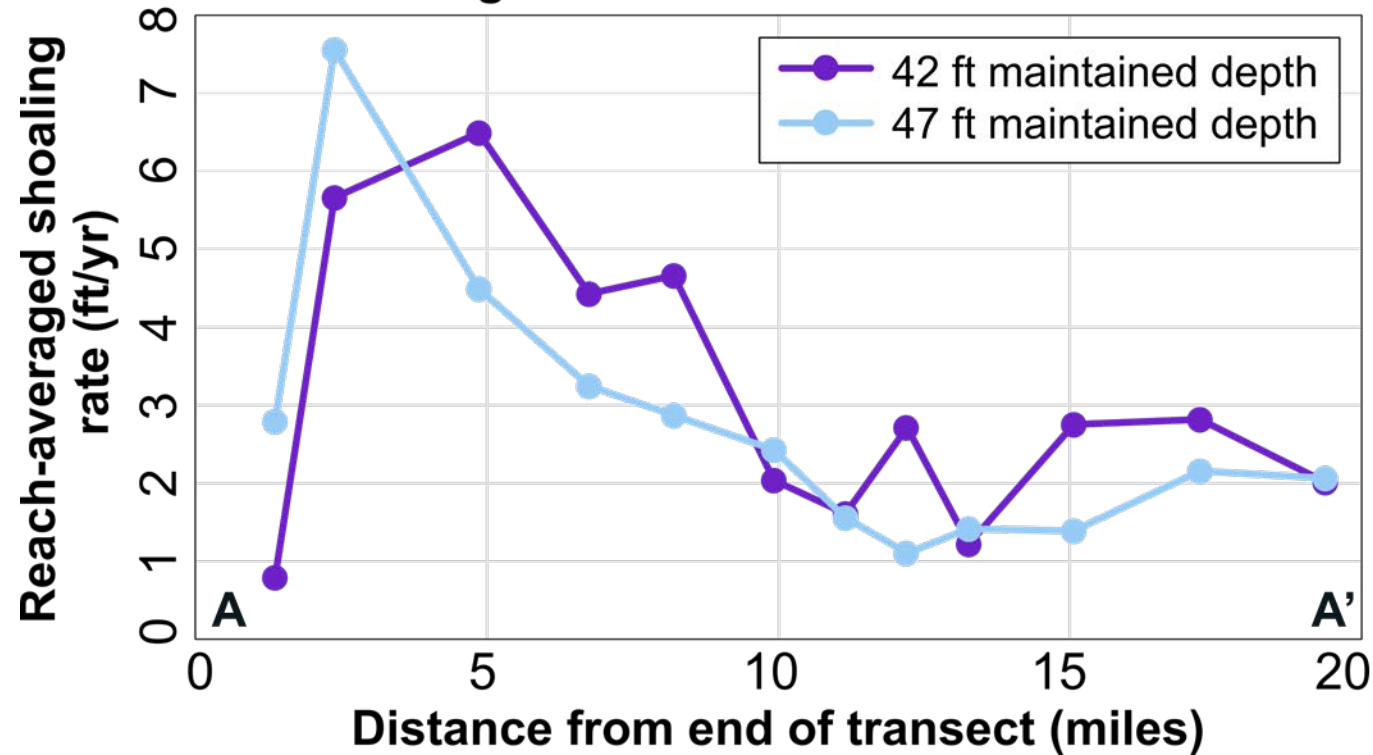
Has the shoaling rate increased?

If so, how much?
If not, why?

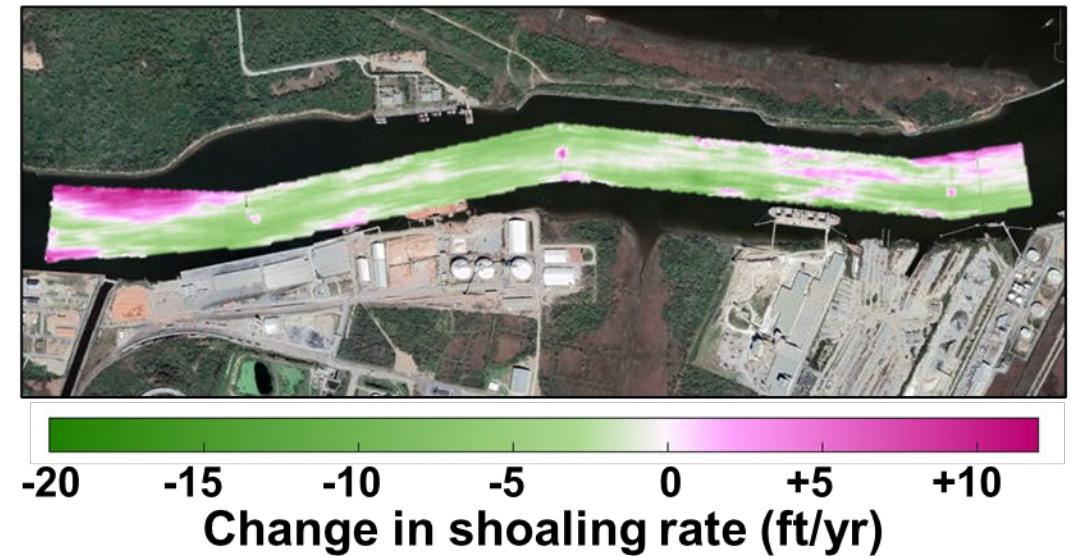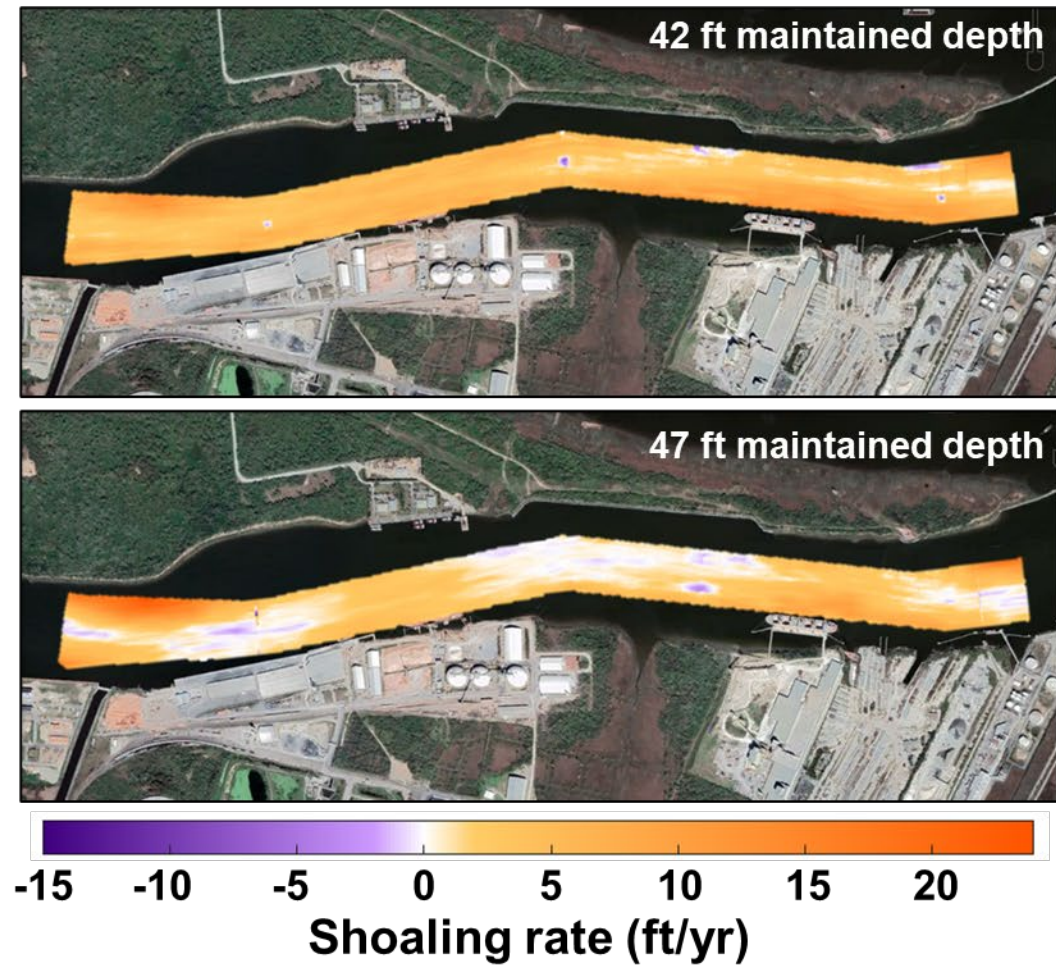What physical processes are driving this behavior?

Time-averaged, reach-scale variability

- CSAT indicates that reach-averaged shoaling rates have actually **decreased** in many Savannah Harbor reaches since the channel was enlarged.
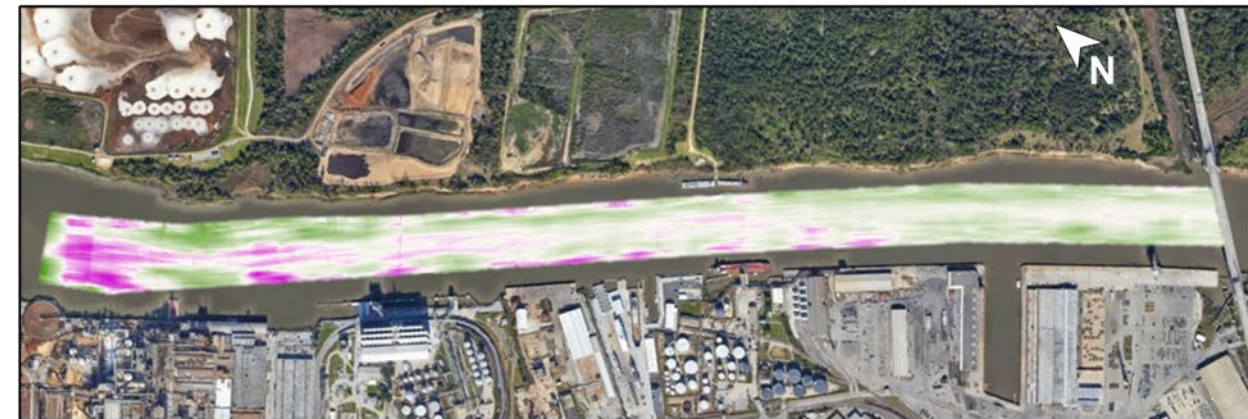
*POC: **Anna Godfrey**, Anna.D.Godfrey@usace.army.mil*

Time-averaged, pixel-scale variability. Ex.1

*POC: **Anna Godfrey**, Anna.D.Godfrey@usace.army.mil*

Time-averaged, pixel-scale variability. Ex.2

42 ft maintained depth

47 ft maintained depth

Shoaling rate (ft/yr)

Change in shoaling rate (ft/yr)

POC: **Anna Godfrey**, Anna.D.Godfrey@usace.army.mil

"Instantaneous", pixel-scale behavior

Distribution of shoaling rates with depth
(Marsh Island Channel, Savannah, GA)

Is this an accuracy issue?
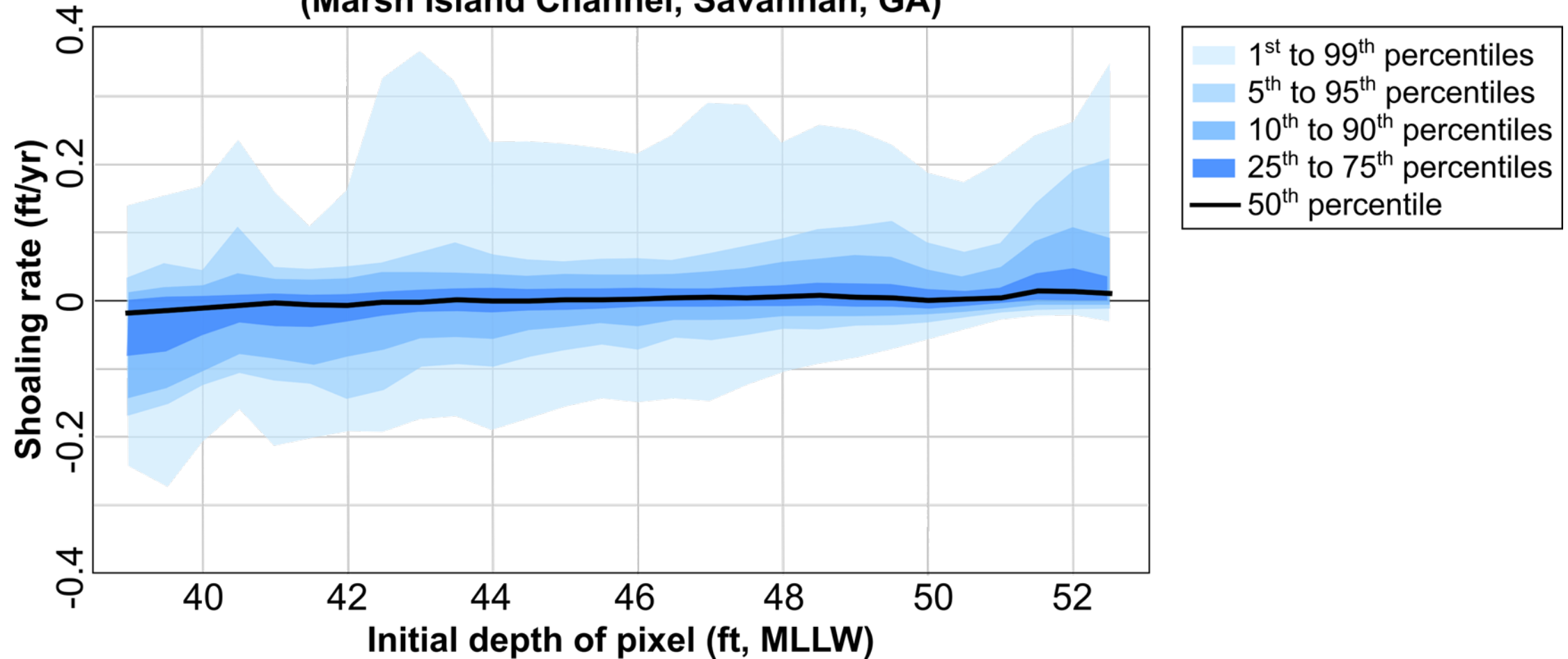
In the world of sedimentology, this is good!
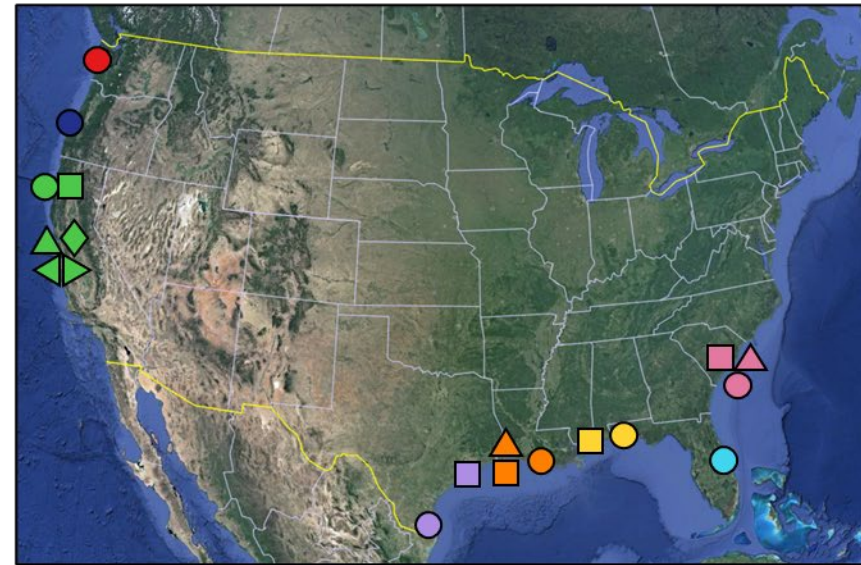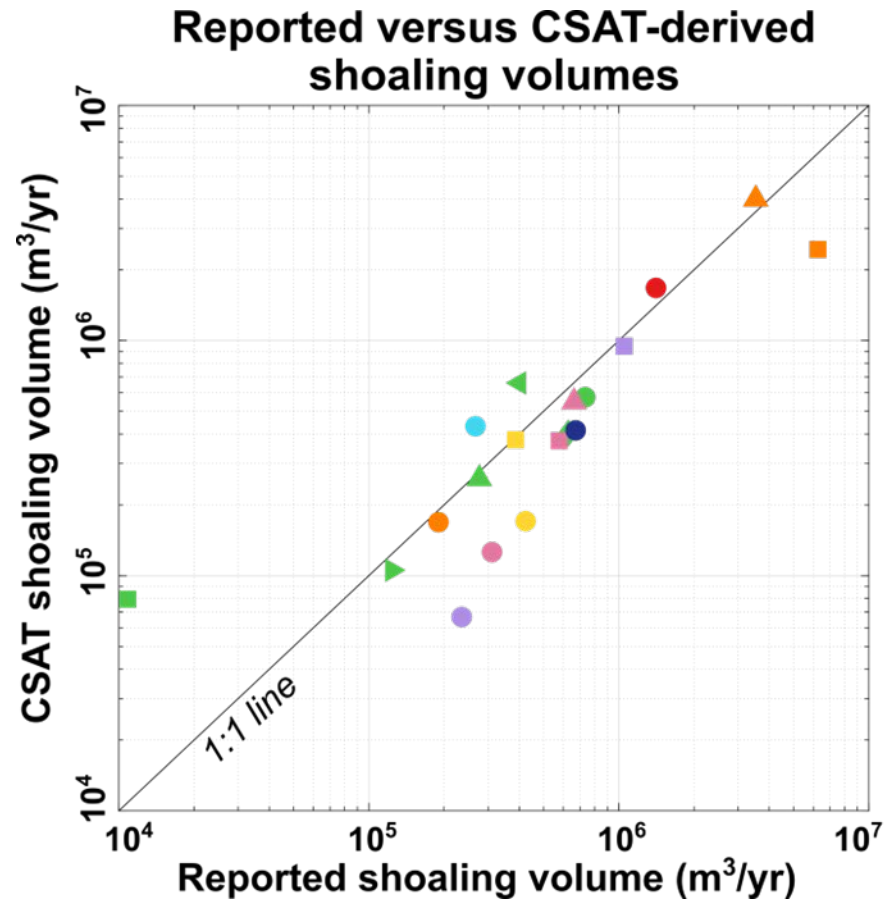
- CSAT predicts shoaling volumes with an accuracy that is typically better than order-of-magnitude!

Figure from Bain et al. (in prep)

Is this an accuracy issue?
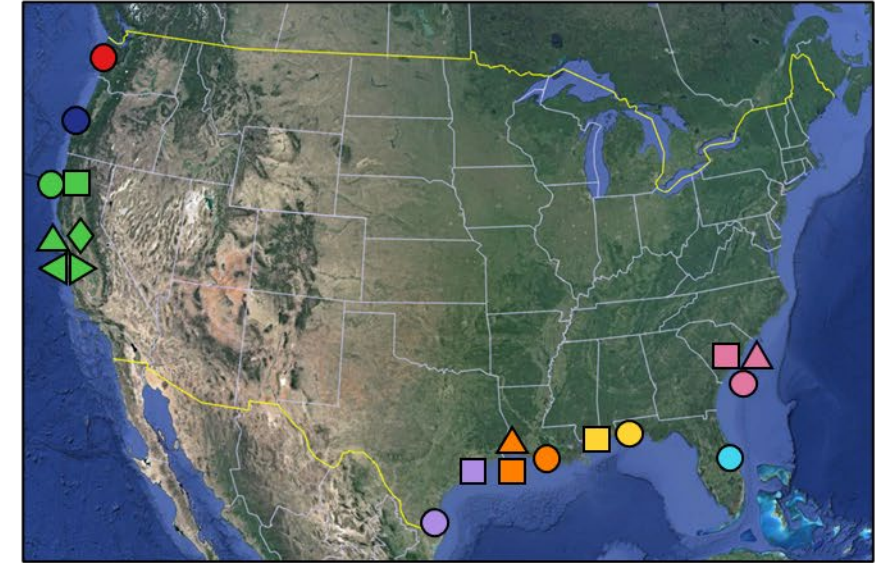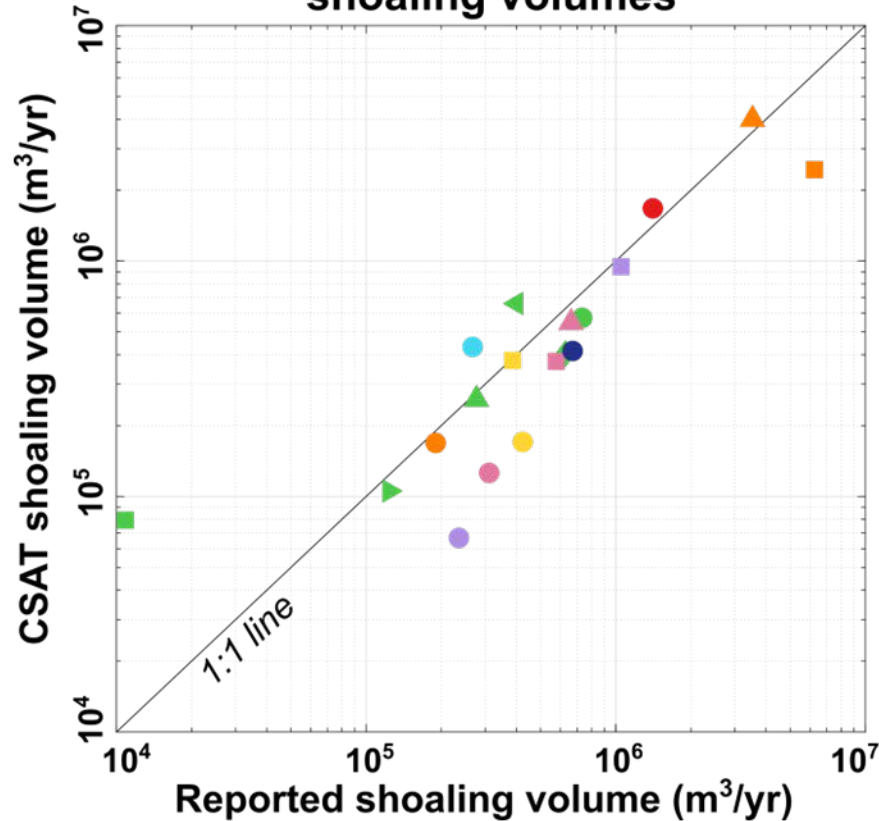
Do you have records of shoaling volume that can help us validate CSAT? If so, we would love to hear from you!

Contact: Rachel.L.Bain@usace.army.mil

Channel management implications

Shoaling rate as a function of depth
(Wrecks Channel, Savannah Harbor, GA)
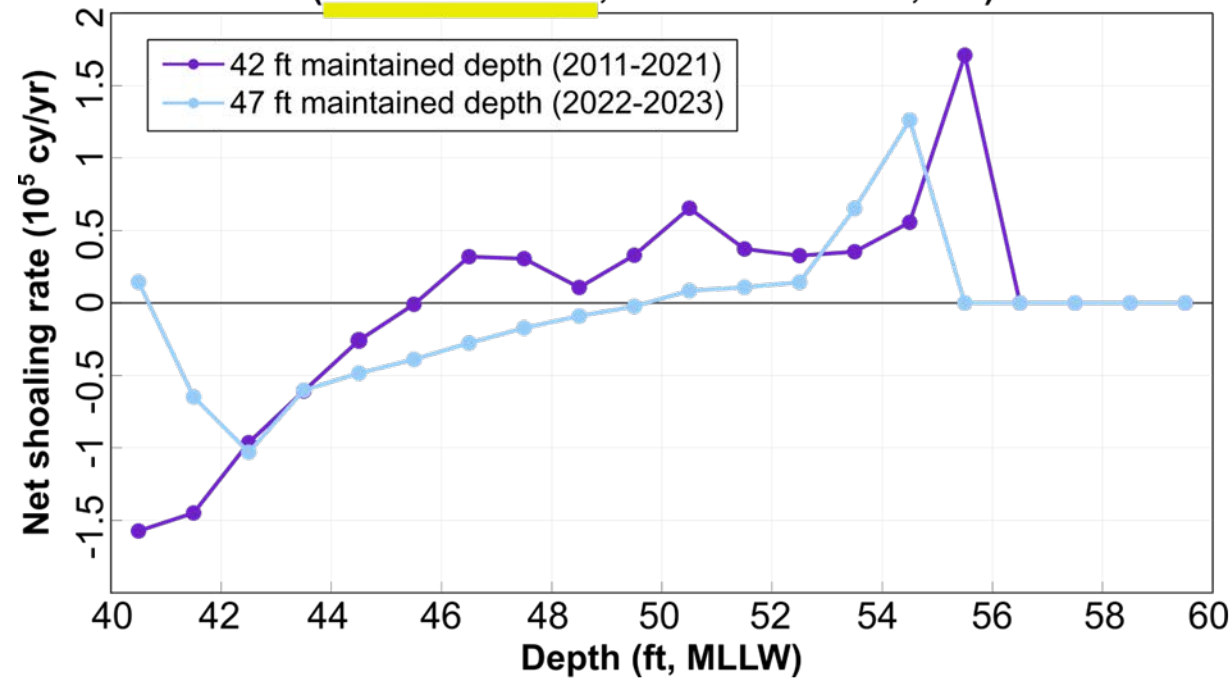
Shoaling rate as a function of depth
(Jones Island Range, Savannah, GA)

*POC: **Dr. Kaite McPherran**, Kaitlyn.A.McPherran@usace.army.mil*
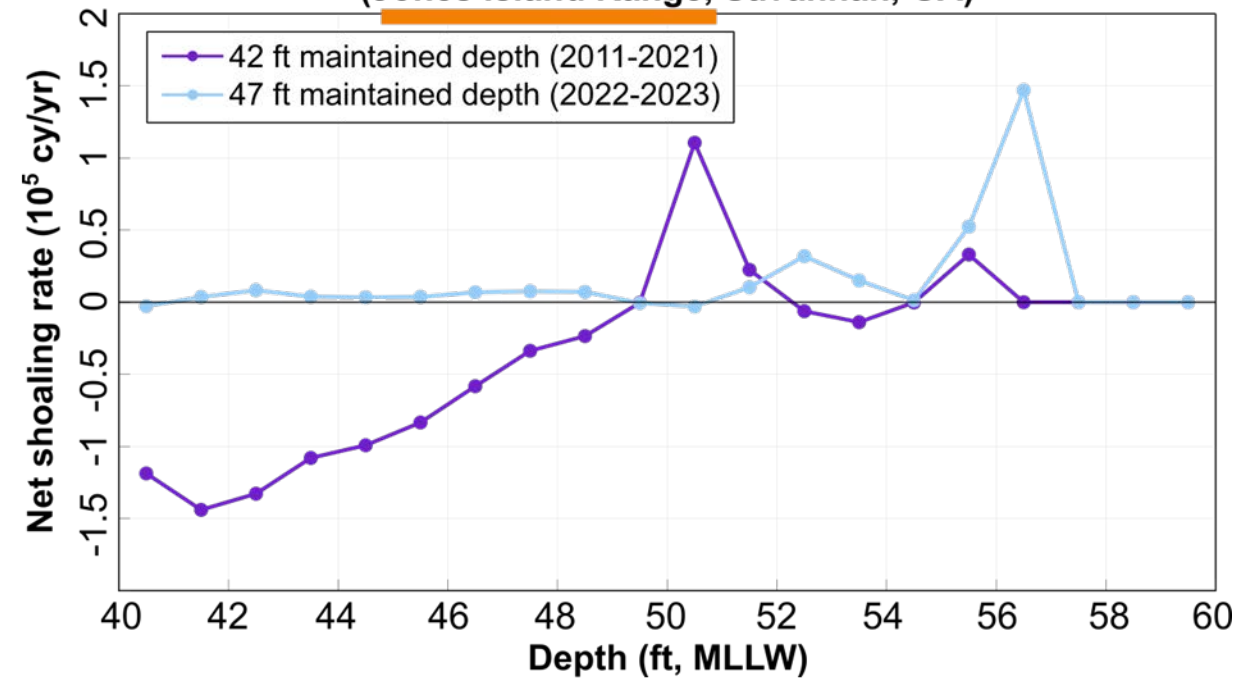
Conclusion

- Our community's paradigmatic understanding of the deepening-shoaling relationship is that enlarging a channel increases the infilling rate.

- Although there are examples where this is true, researchers have known since (at least) the 1960s that sometimes enlarging a channel *decreases* the infilling rate.

  - *This occurs at spatial scales ranging from tens of feet up to entire projects, and at temporal scales ranging from days to decades.*

- Exciting opportunity to identify and revisit knowledge gaps!

We like questions!

Points of Contact:

CSAT installation and usage………. Michael Hartman (Michael.A.Hartman@usace.army.mil)

Savannah District project………….. Anna Godfrey (Anna.D.Godfrey@usace.army.mil)

Kaite McPherran (Kaitlyn.A.McPherran@usace.army.mil)

Questions about this presentation… Rachel Bain (Rachel.L.Bain@usace.army.mil)

General CSAT questions…………… dll-ceerd-csat@usace.army.mil

Or visit the CSAT website
for more information: