Hyperpycnal Flow Within Low Gradient River Deltas and Implications for Both Sand and Mud Transport Onto the Shelf: Brazos River, Northern Gulf of Mexico*

By

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Search and Discovery Article #50091 (2008)
Posted October 24, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008.

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Abstract

Sediment transport from river mouths via hyperpycnal flow is a well documented process for high gradient rivers worldwide. However, many important hydrocarbon-bearing deltaic systems were derived from lower gradient systems where hyperpycnal flow is not normally attributed. The Brazos River provides a modern example of such a low-gradient river. We had the unique opportunity to sample the mouth and proximal shelf of the Brazos River during the flooding of July 2007. Using a CTD equipped with a turbidity sensor, water column profiles were taken on an along-shelf transect from the river mouth 10 km northeast in the direction of the plume transport and an across shelf transect from the river mouth 8 km offshore to the seaward edge of the plume. In addition, bottom-water samples and shallow gravity cores were collected to determine the thickness of the flood deposit, suspended sediment concentration, pore-water salinity, and grain-size distribution. We found both a high turbidity hypopycnal plume as well as a high turbidity bottom layer, with low turbidity in the middle of the water column. Brazos River mud is characteristically red, while marine sediment is olive-grey. Preliminary result reveal a distinctively red, porous storm layer, composed of up to 30% sand that extended 5 km from the river mouth. The presence of sand within the storm layer and the high turbidity bottom layer suggest hyperpycnal flow existed during the flood. If this is the case, hyperpycnal flow may be a regular occurrence on the Brazos River and may be more common within low-gradient river systems than previously believed, providing an additional mechanism for transporting both sand and mud across the inner shelf.

Evidence suggesting hyperpycnal flow within a low gradient river delta and implications for both sand and mud transport onto the shelf: Brazos River

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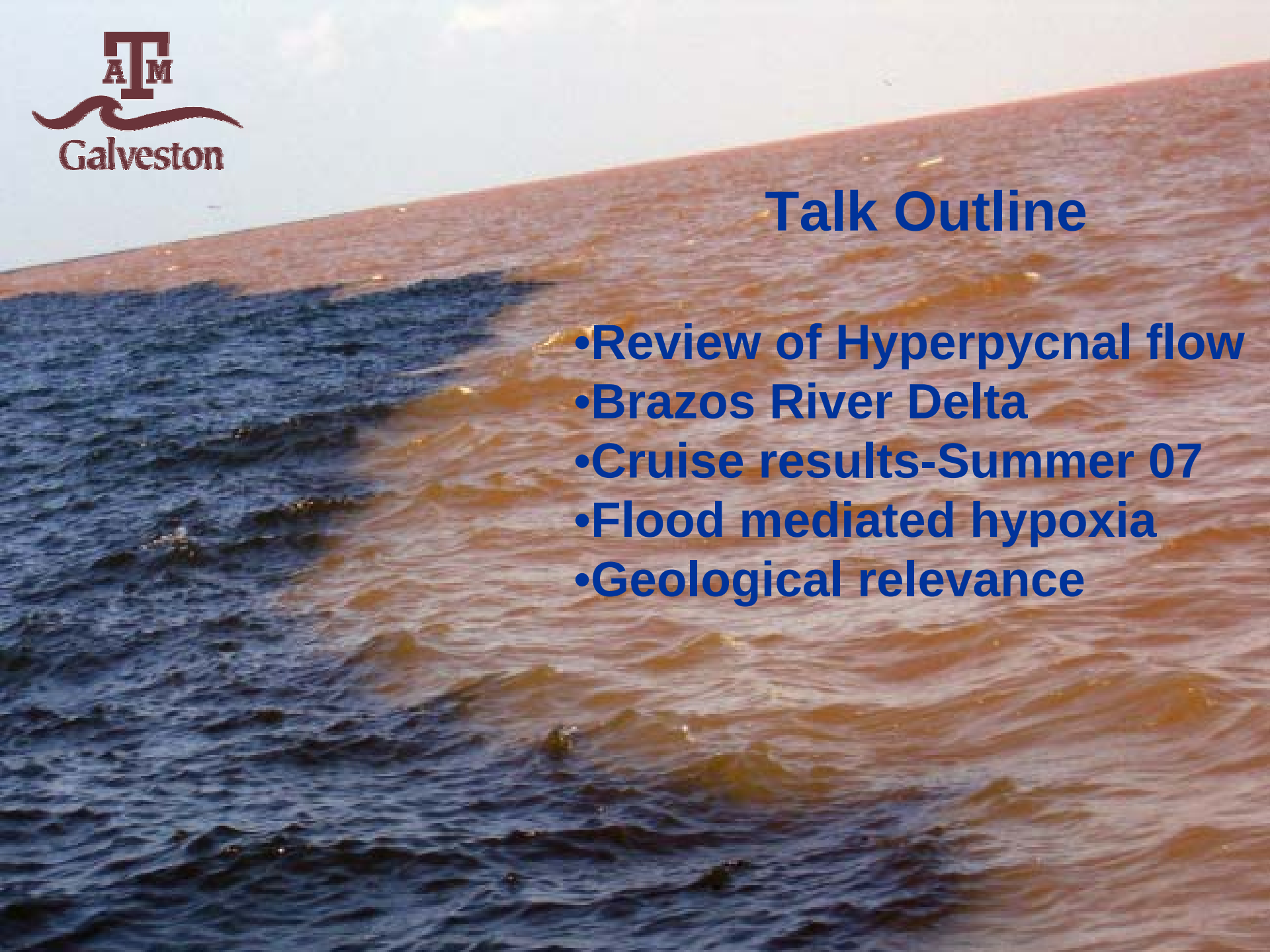
Acknowledgements

Carmen Fraticelli
Damian O'Grady
ExxonMobil Upstream Research Company



Talk Outline

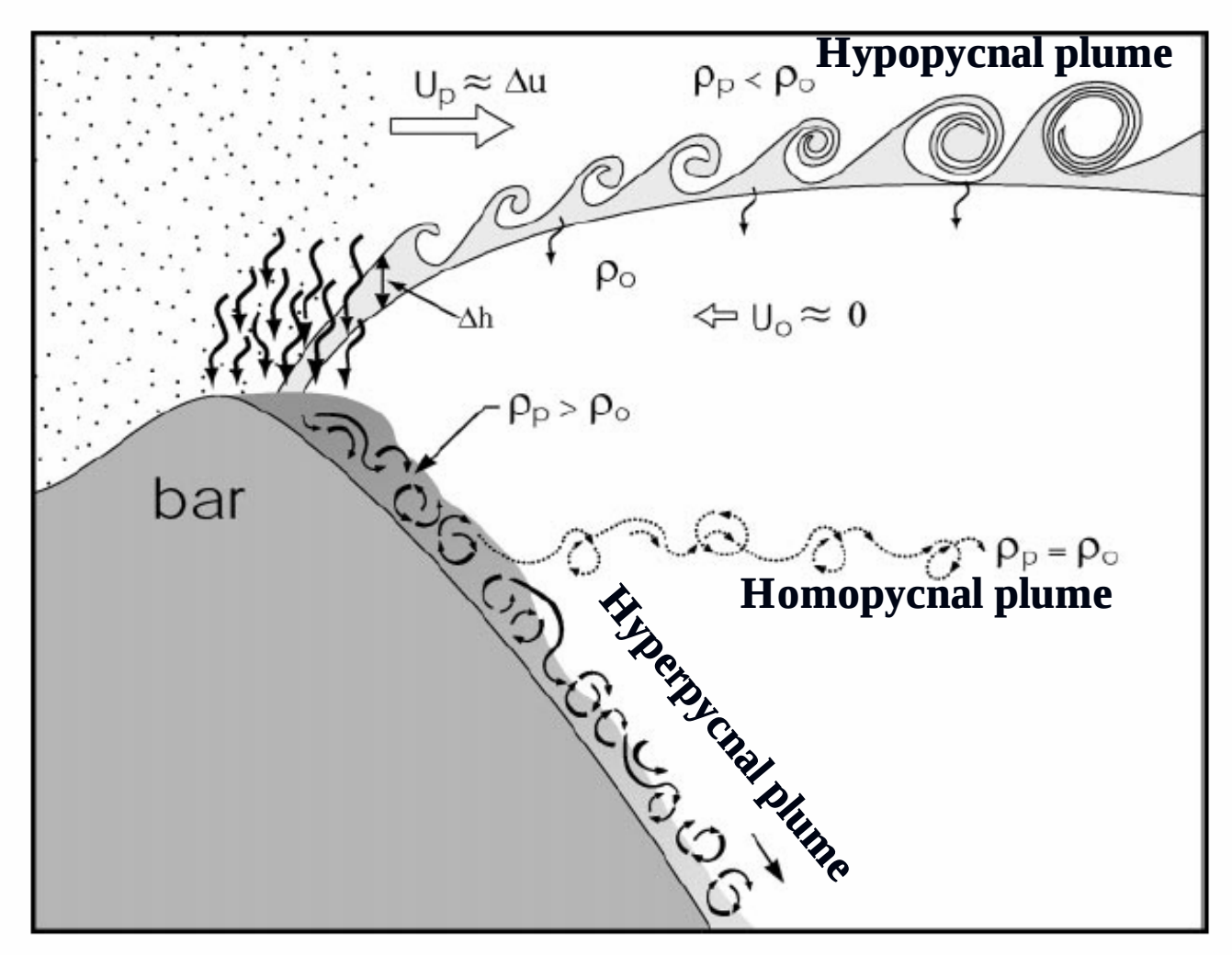
- Review of Hyperpycnal flow
- Brazos River Delta
- Cruise results-Summer 07
- Flood mediated hypoxia
- Geological relevance

Different types of plumes

Sepik River, Papua New Guinea

ρ_o = density of ambient water

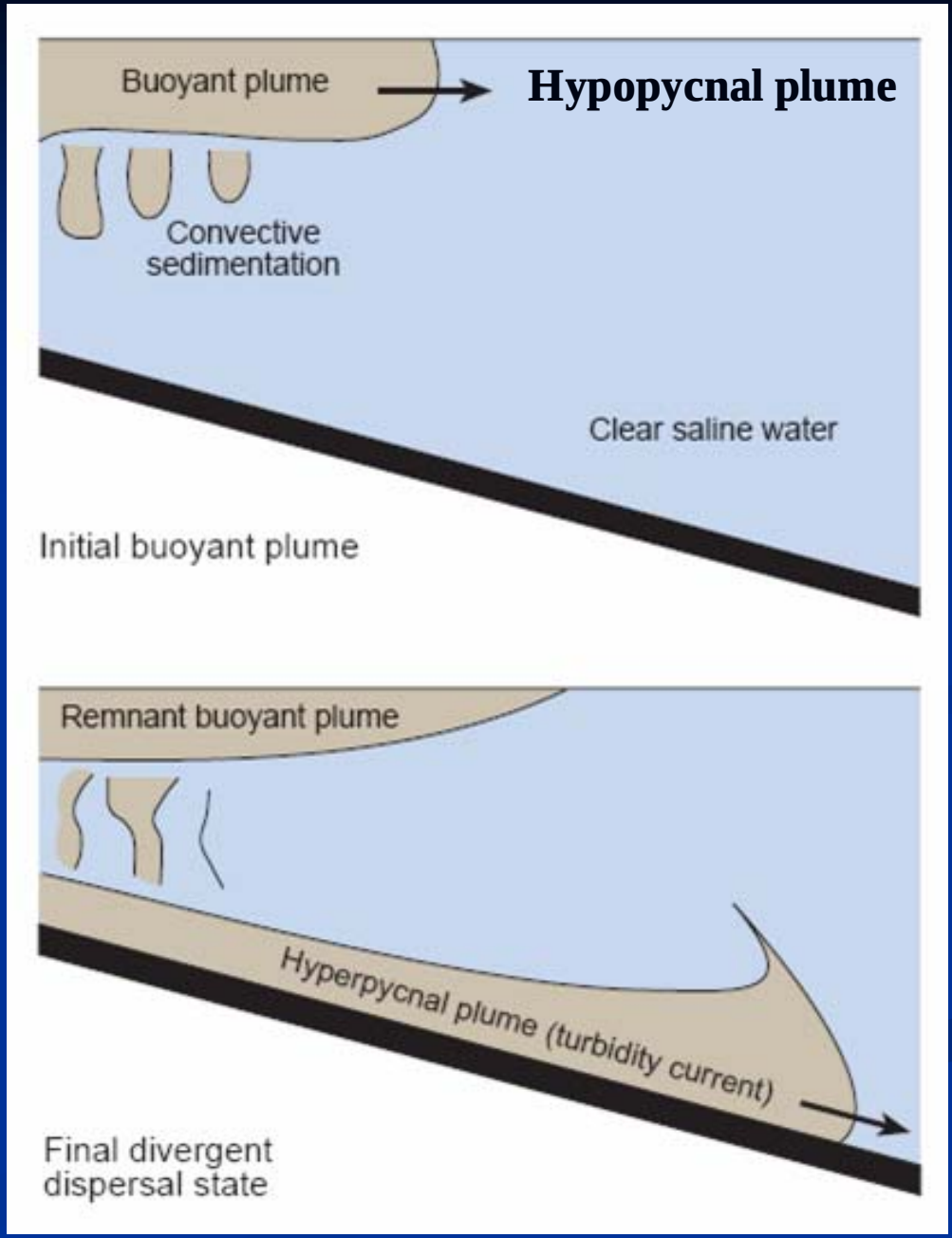
ρ_p = density of sediment plume



(Kineke et al., 2000)

What is a hyperpycnal flow?

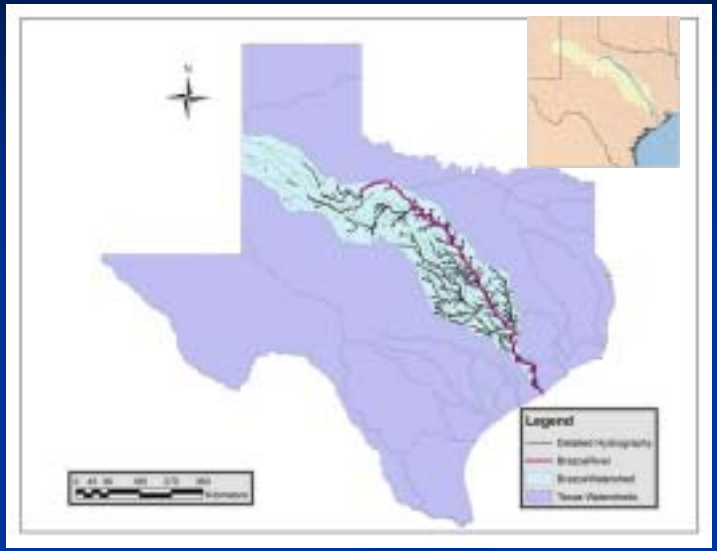
- **River derived effluent of suspended sediment that has a higher density than the ambient water of receiving basin (ocean or lake)**
- **Flow will move along the bottom, below the basin water, as a gravity driven turbidity flow**
- **Mixing of plume and basin water can increase density of plume, further strengthening under flows**



(From Parsons et al., 2007)

Hyperpycnal River Plumes normally associated with:

- Muddy, small to medium size rivers
- High gradient rivers
- Moderate to highly dipping and narrow shelves
- Proximity to submarine canyon

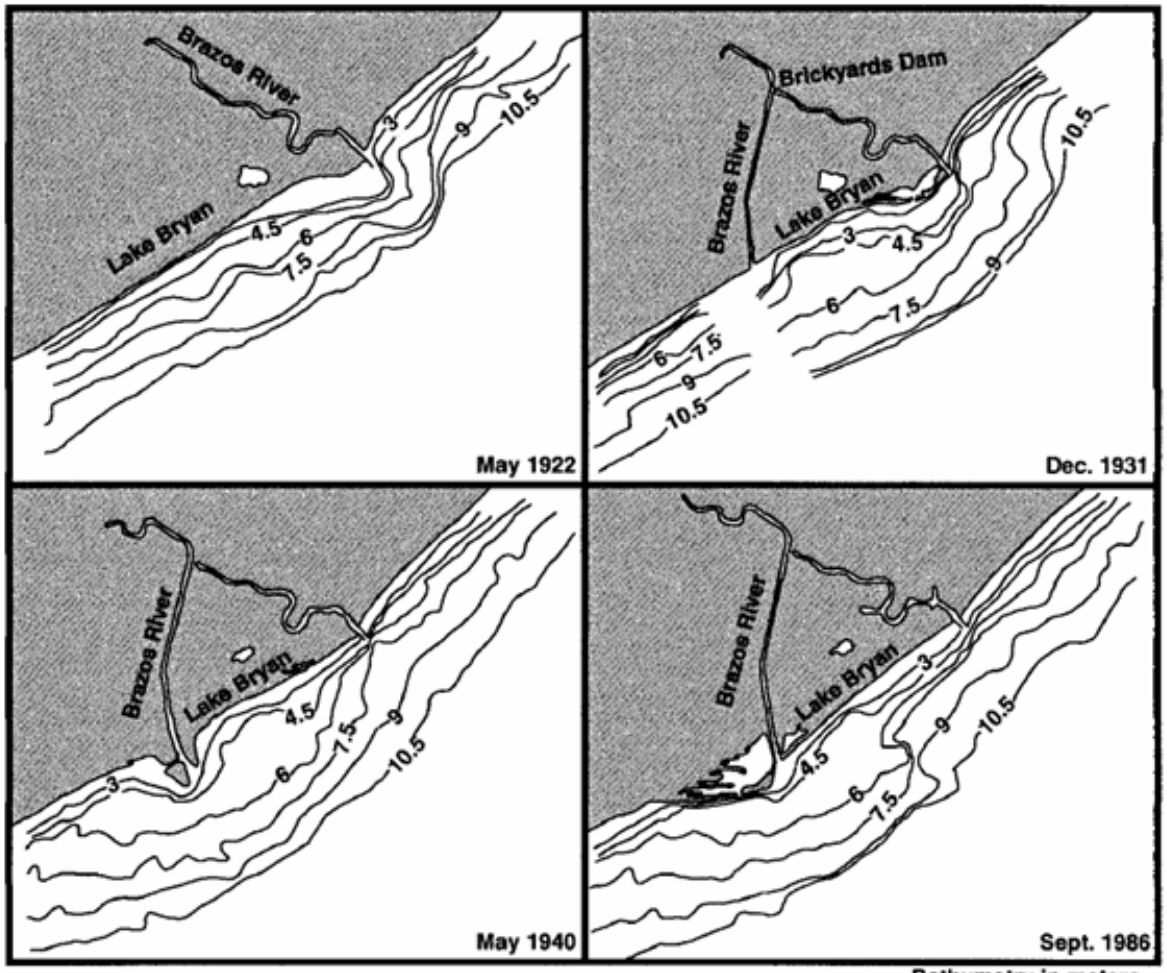


Brazos River is:

- Low gradient-mainly flows along coastal plain
- Coastal plain contains easily eroded muddy sediments
- Wide (125 km), gently dipping shelf
- No proximal submarine canyon
- Ranked as a moderately dirty river capable of hyperpycnal flow every 100 y or less (Mulder and Syvitski, 1995)-based on ave. suspended sediment concentration at peak discharge

Brazos River:

- 118,000 km^2
- 39 metric tons per square kilometer sediment yield
- 11th longest river in the US
- Only river on the Texas Coast that consistently drains into the Gulf of Mexico

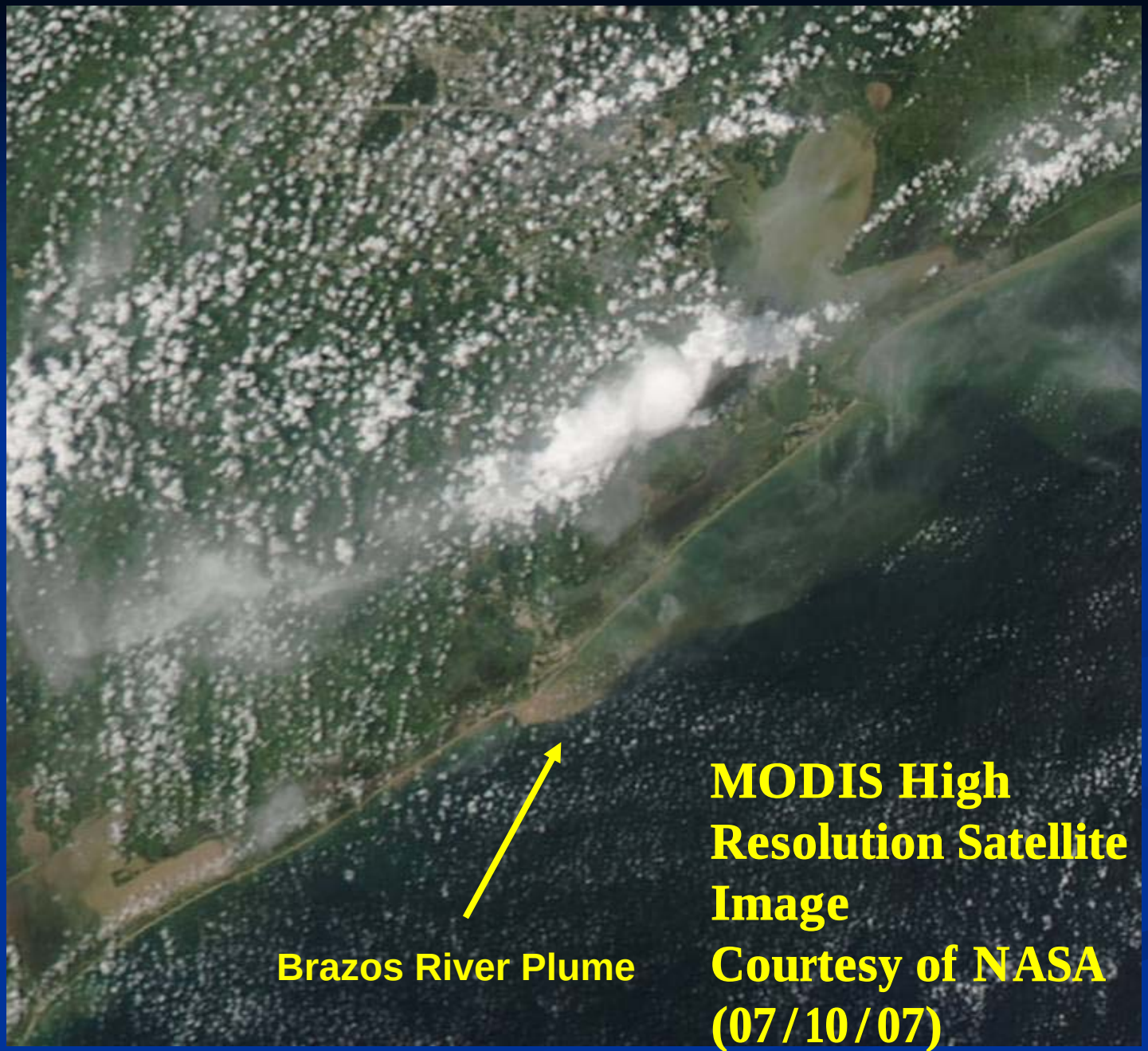


(Rodriguez et al., 2000)


Bryan Lake
Bryan Cut
Mud Pit
Bryan Beach
Redfish Bayou
Pelican Lake
Jones Lake
Old Intracoastal Waterway
© 2007 Europa Technologies
Image Houston-Galveston Area Council
©2007 Google™
Pointer 28°53'08.83" N 95°23'54.43" W elev 1 ft
Streaming 100%
Eye alt 39685 ft

Hwy 36 Bridge- 8 km from mouth of the river- July 7, 2007

Lower river banks have high levees to keep the river in the bank during flooding



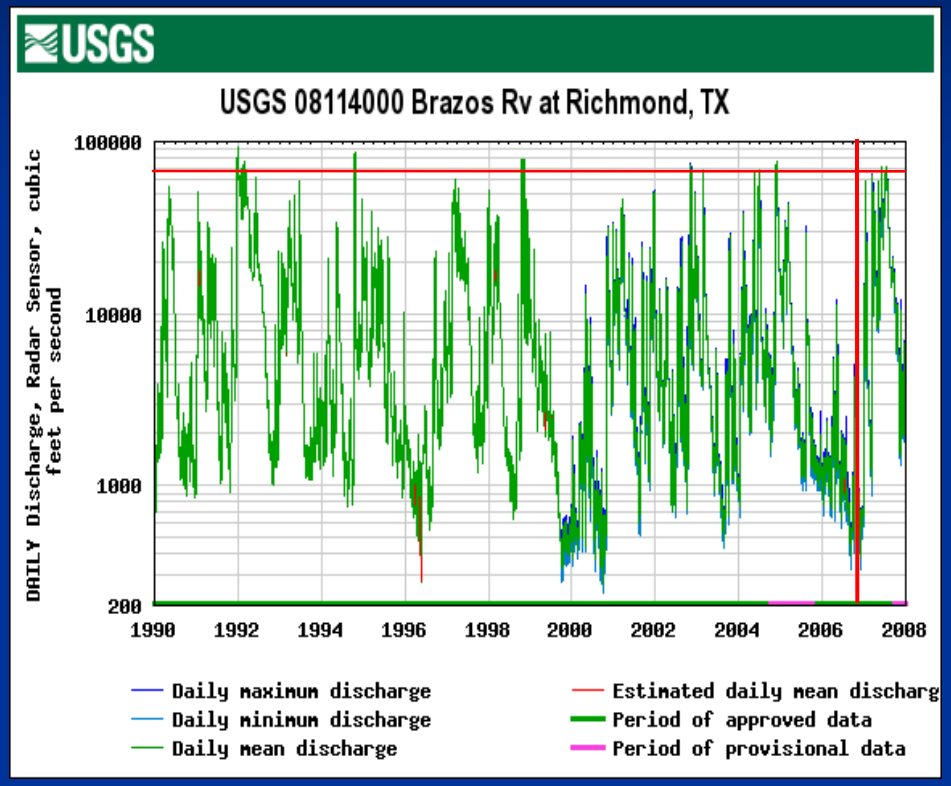
http://rapidfire.sci.gsfc.nasa.gov/subsets/?USA7/2007190/USA7.2007190.aqua.250m.jpg

River plume offshore of the Brazos River

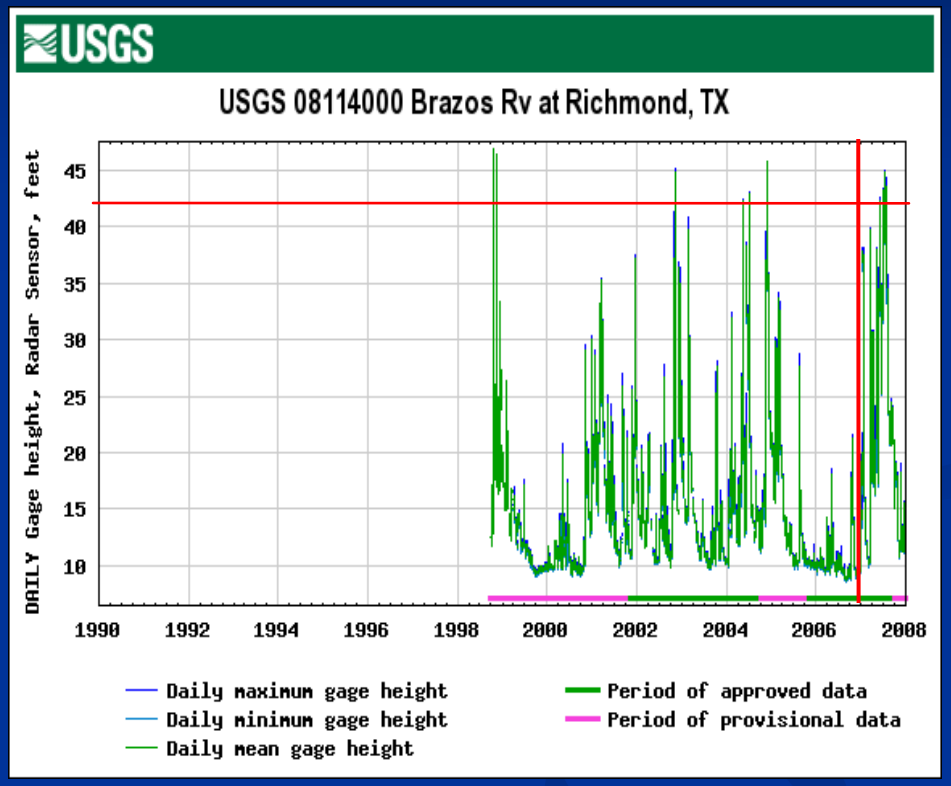
Brazos River Plume 7-12-07

Brazos River Plume 08-08-07

Brazos River-Richmond Station
Daily Discharge 1990-2007 (ft^3/sec)

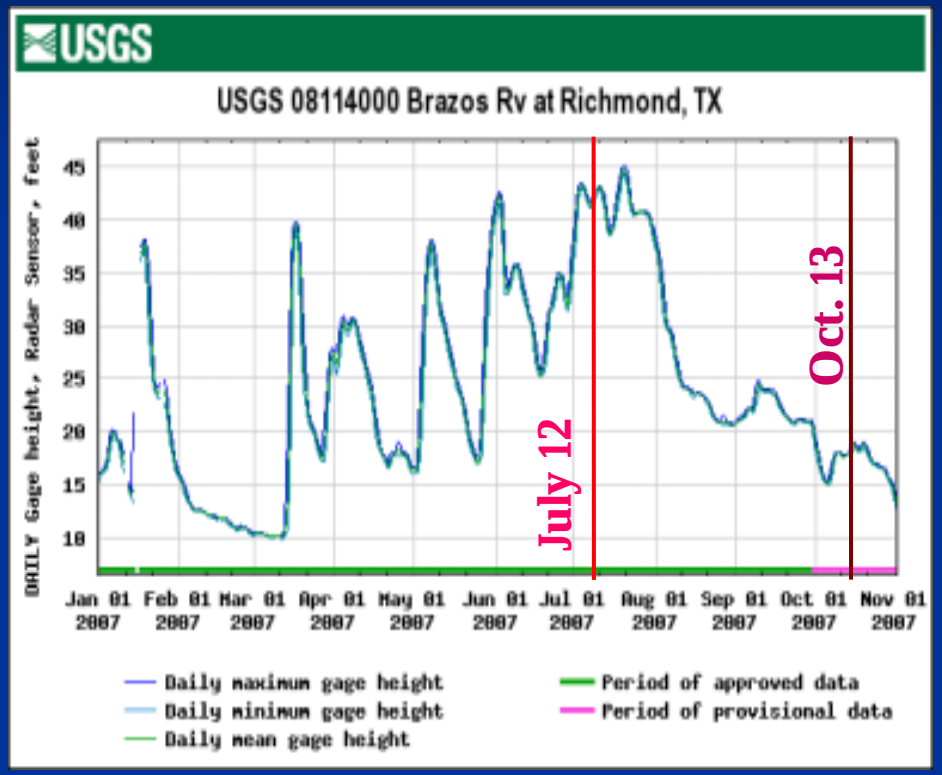


Brazos River-Richmond Station
Daily Gage Height 1999-2007 (ft)

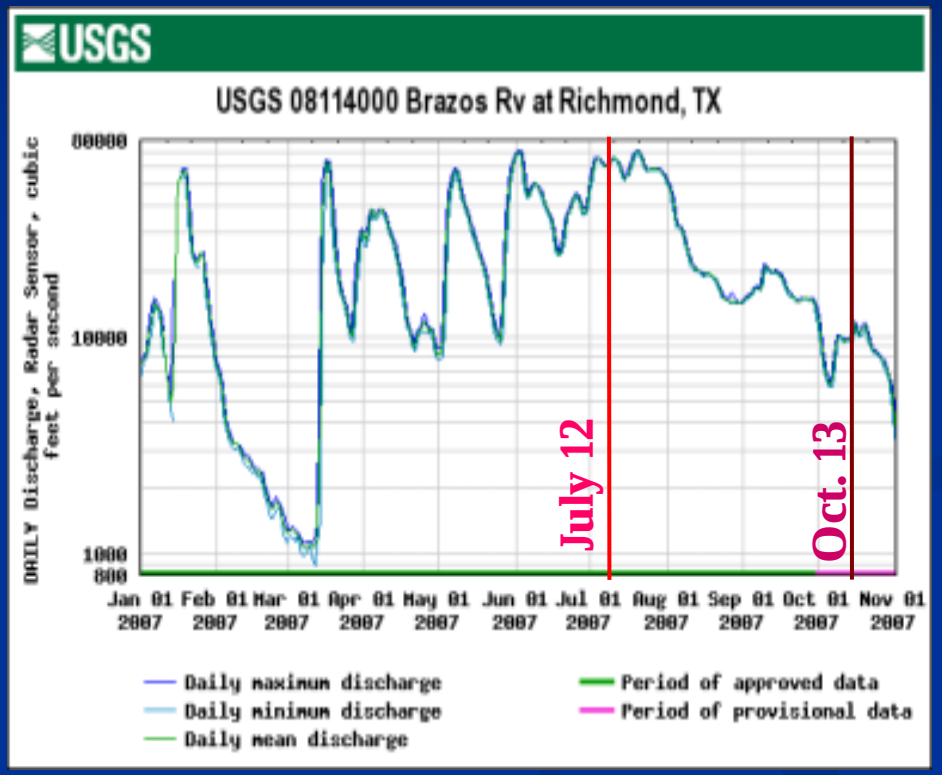


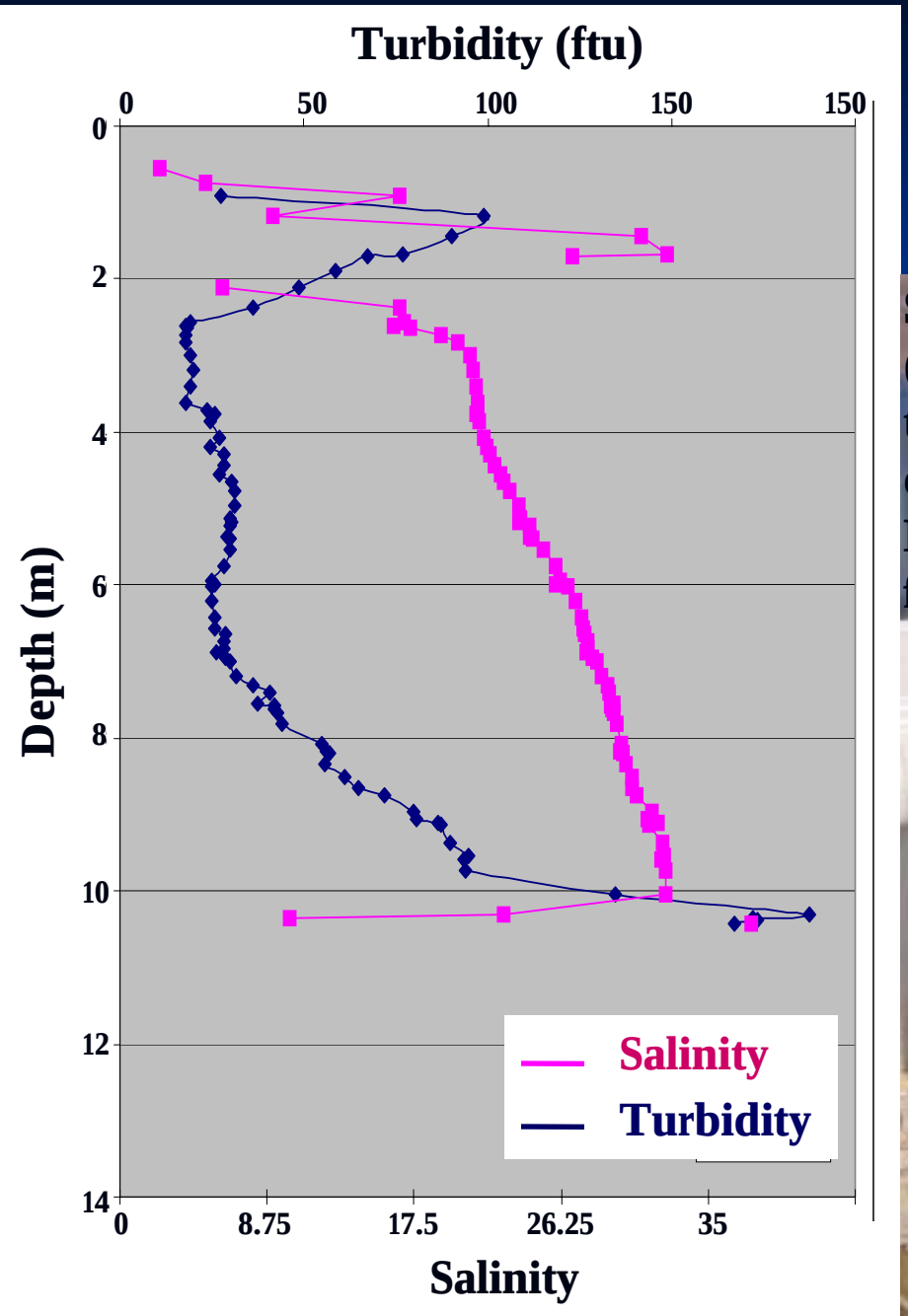
Summer 2007 Flood although longer in duration, was comparable in height and discharge to floods which happen on an annual to one in four year frequency

Brazos River-Richmond Station
Daily Discharge (ft3/sec): Jan. 1- Nov. 1, 2007

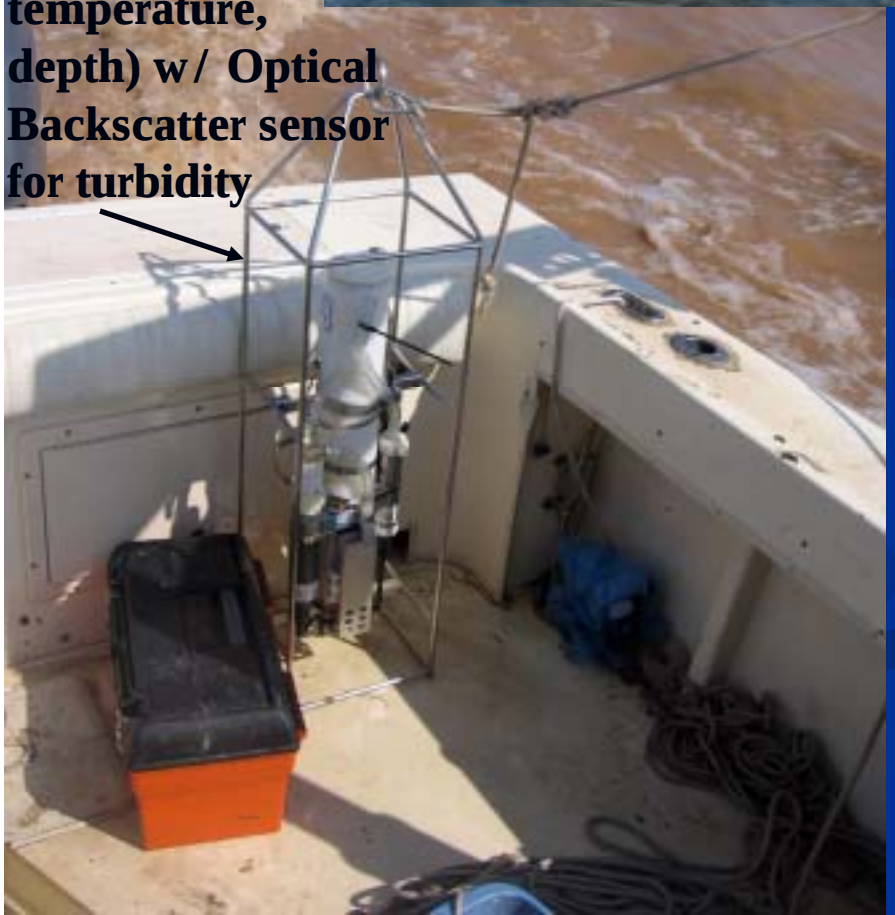


Brazos River-Richmond Station
Daily Gage Height (ft): Jan. 1- Nov. 1, 2007





Sea Bird CTD (conductivity, temperature, depth) w/ Optical Backscatter sensor for turbidity

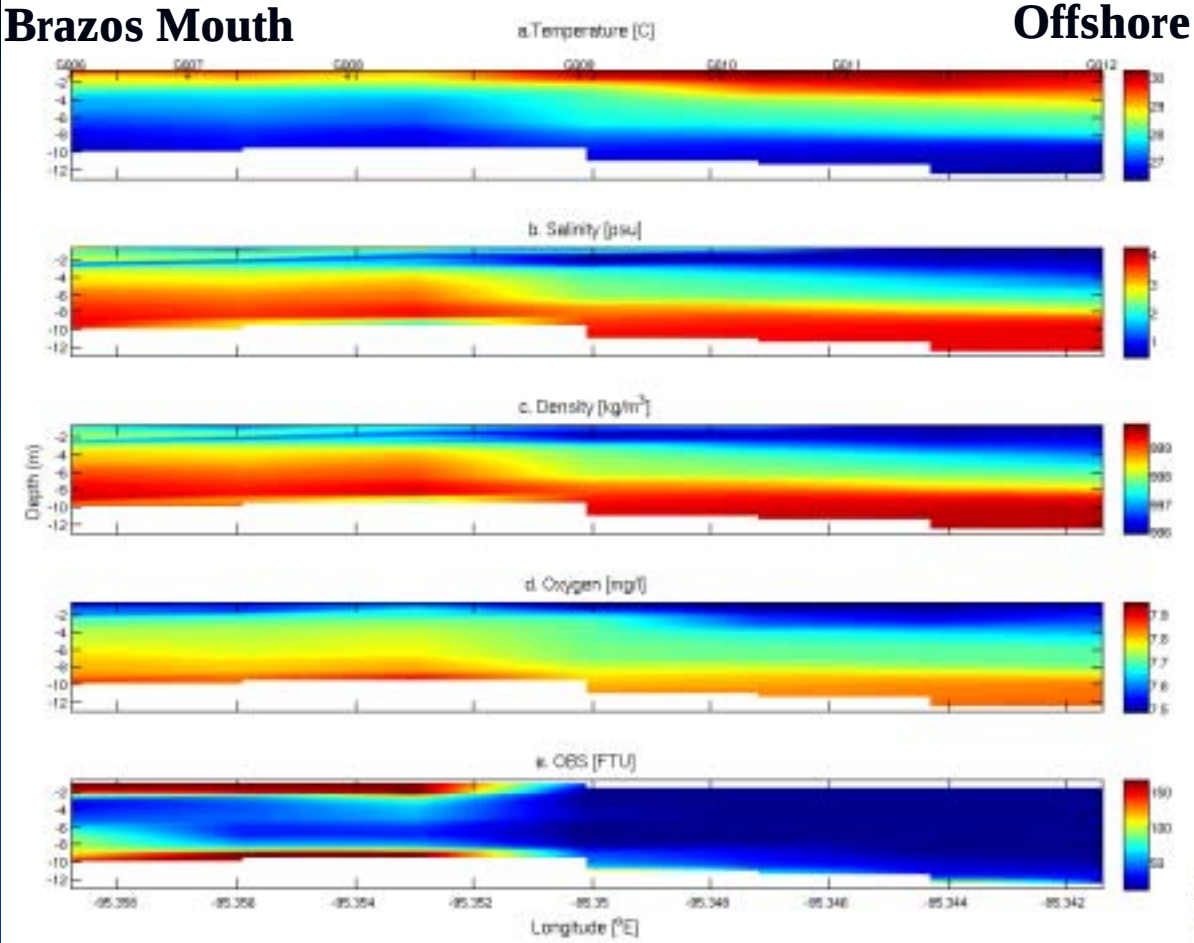


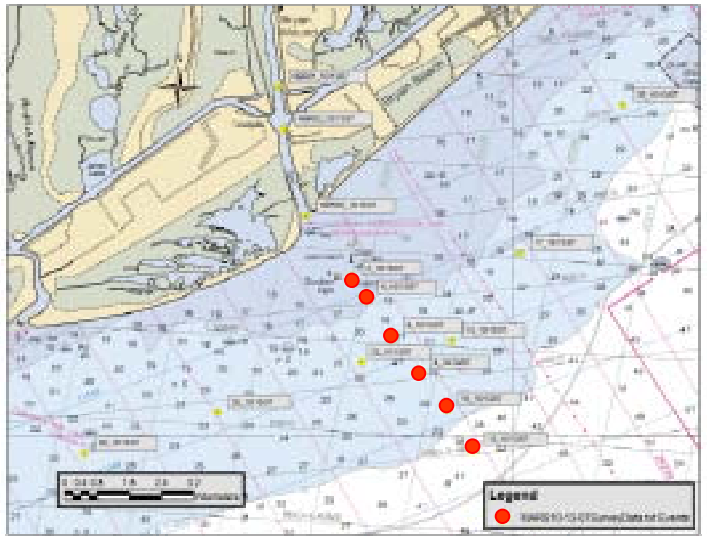
Aggie Rocket Corer

Light weight gravity corer

Removable core barrel

Brazos Mouth **Offshore**

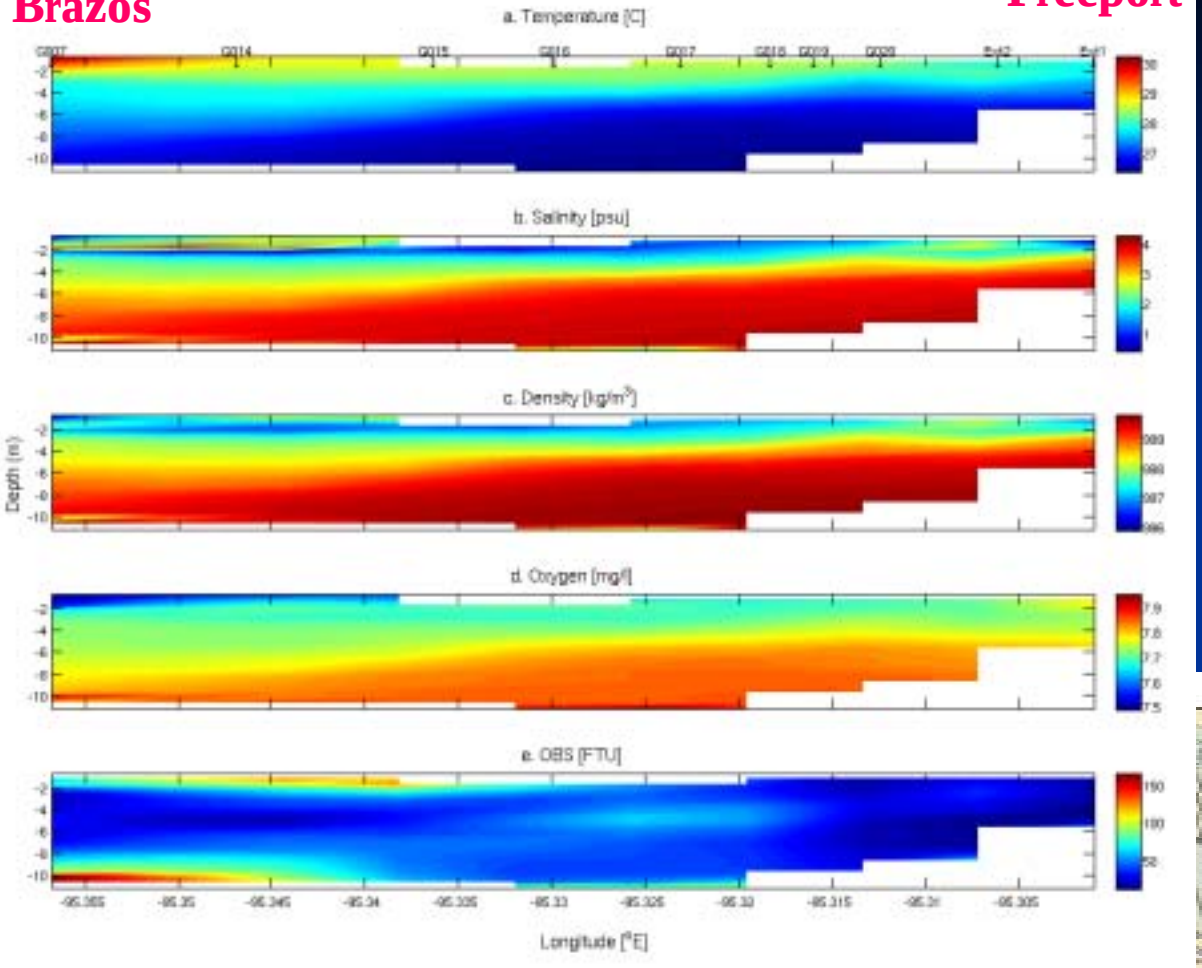


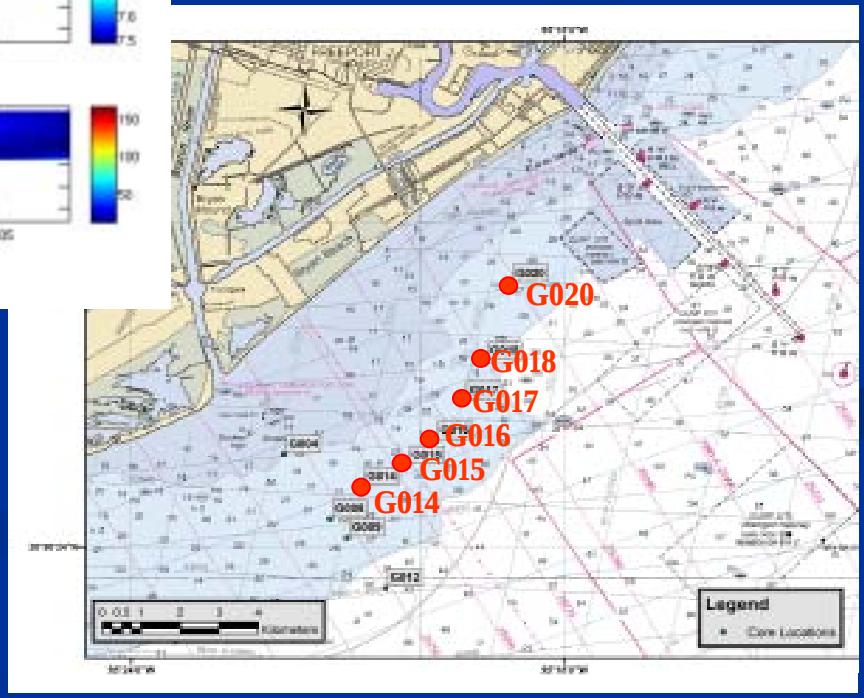


Shore Normal

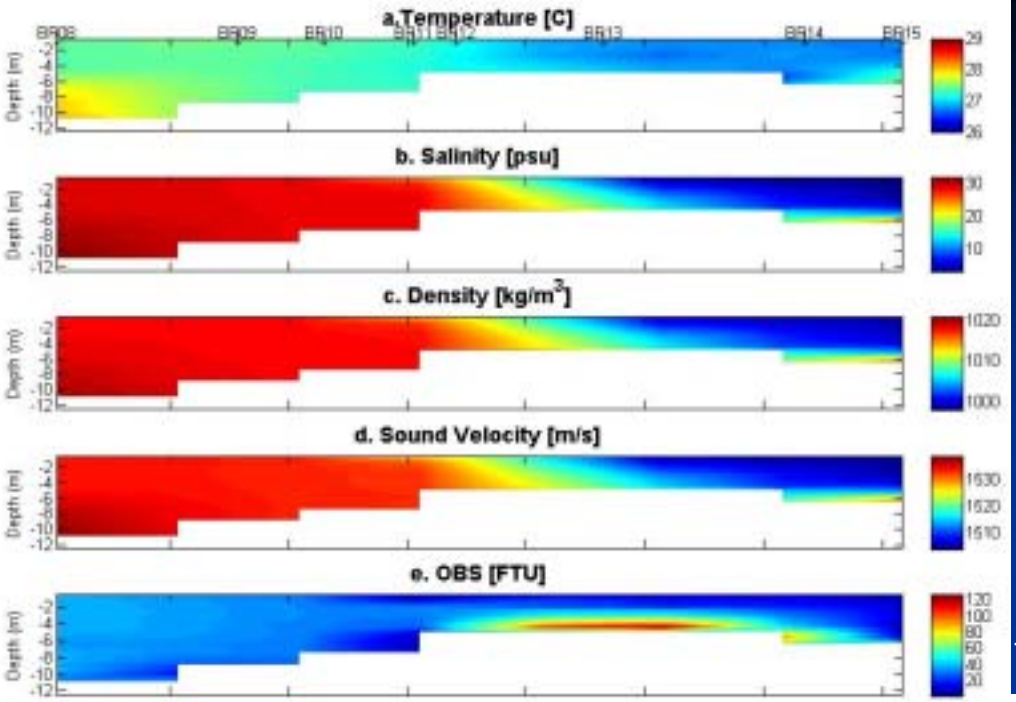
Brazos

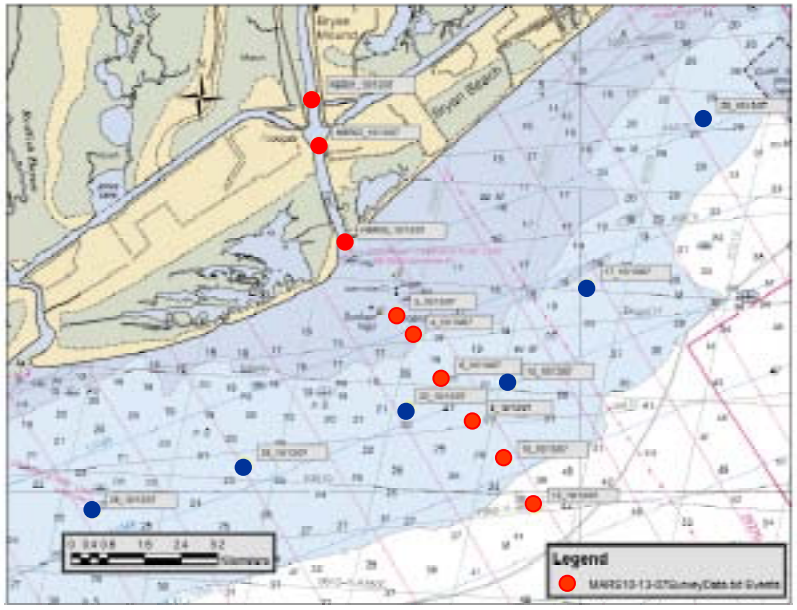
Freeport





Along Shore

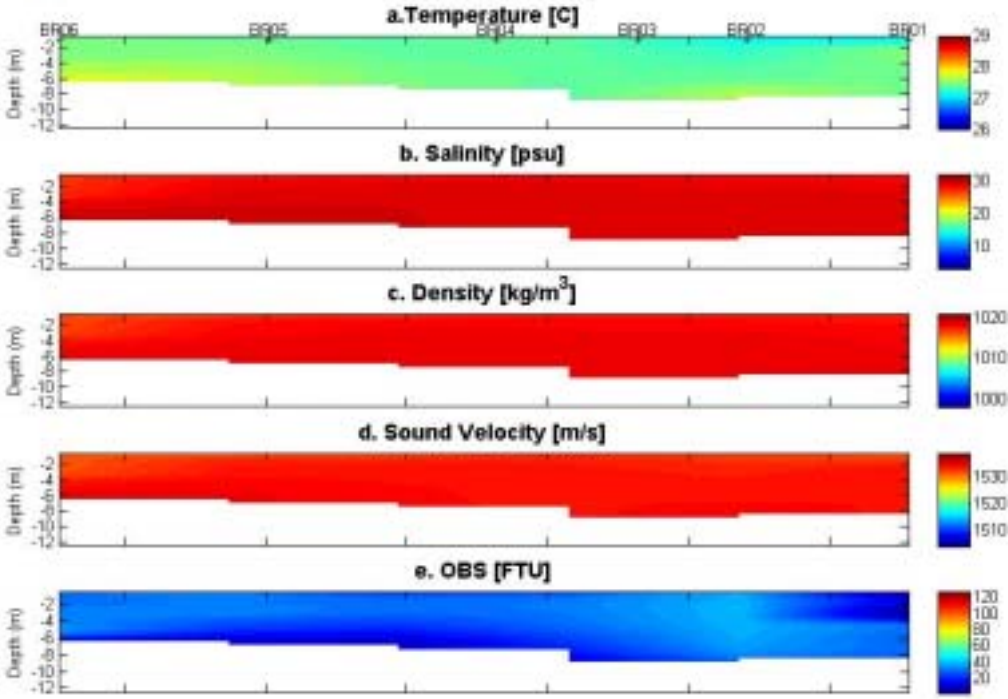


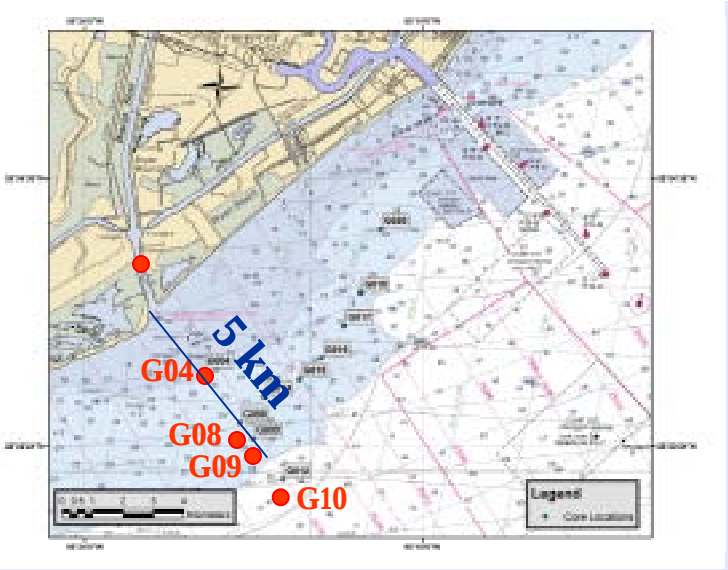


West 10-13-07 –Alongshore Transect East

← Offshore River Mouth River

10-13-07 –River to Offshore Transect





Seafloor

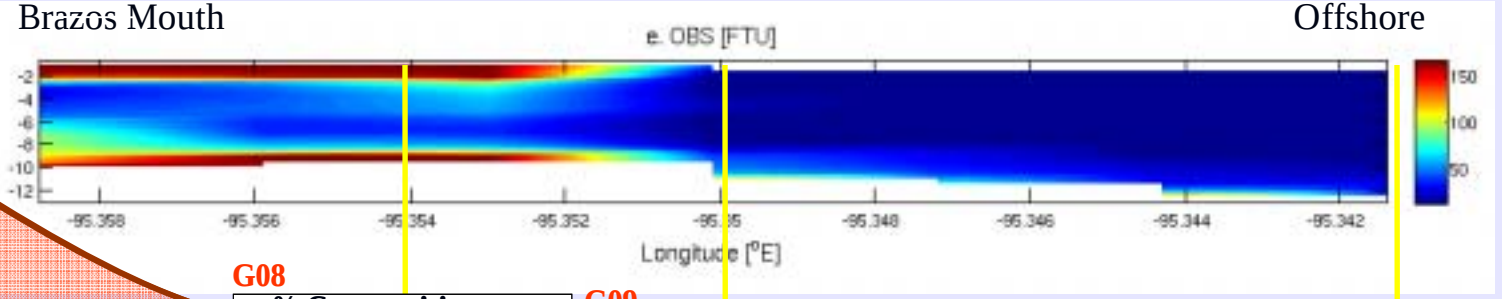
G04

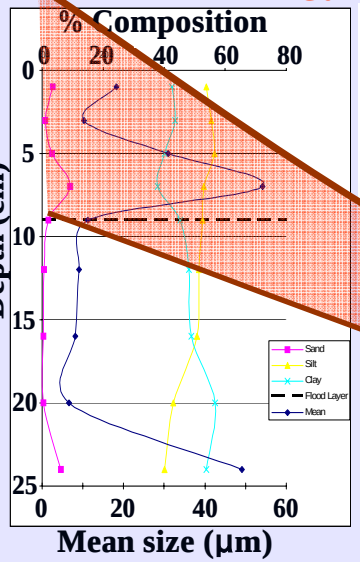
0 km

Brazos Mouth

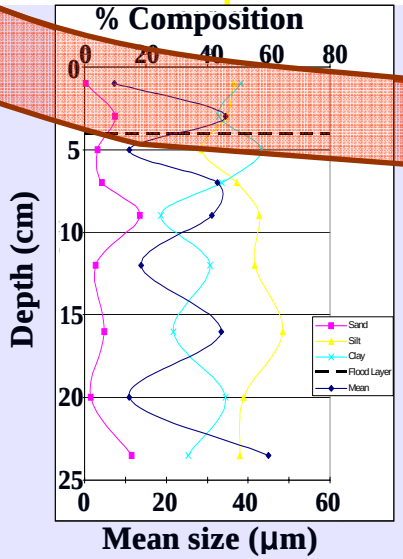
6.2 km

Offshore

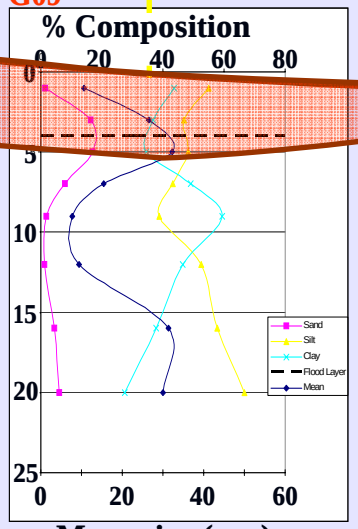




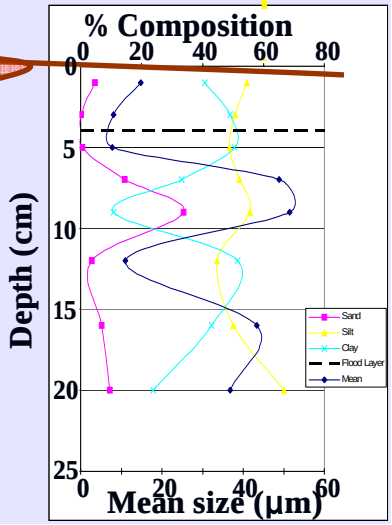
G08



G09



G10



Sand

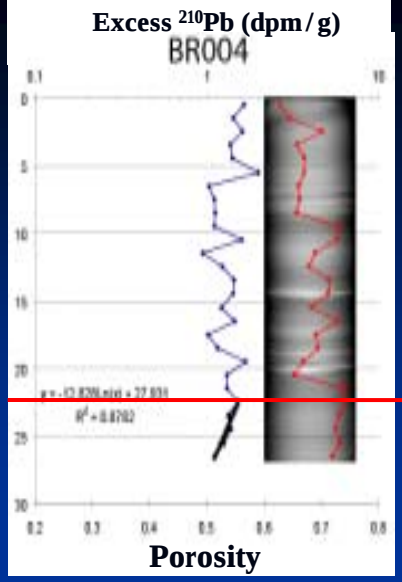
Silt

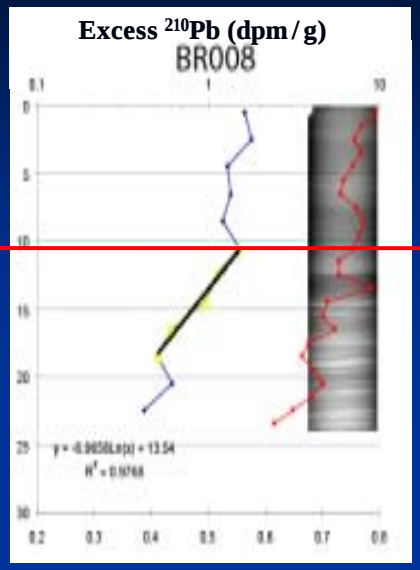
Clay

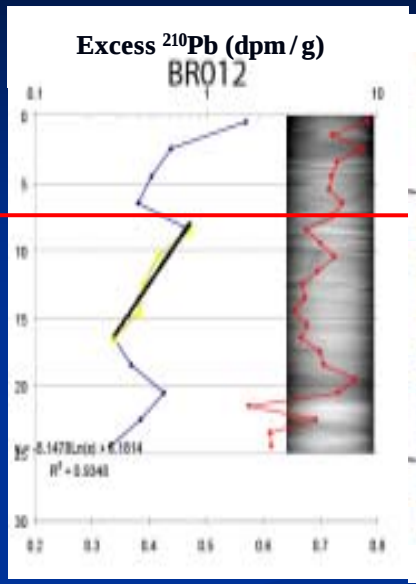
Mean

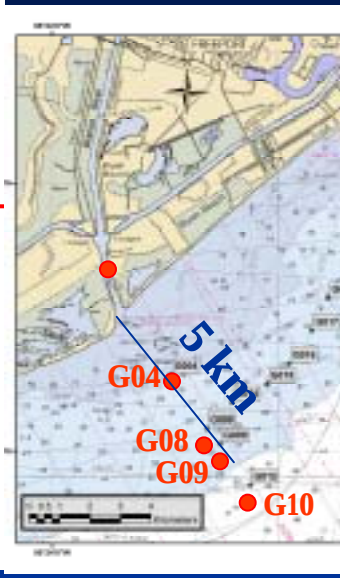
Flood Layer

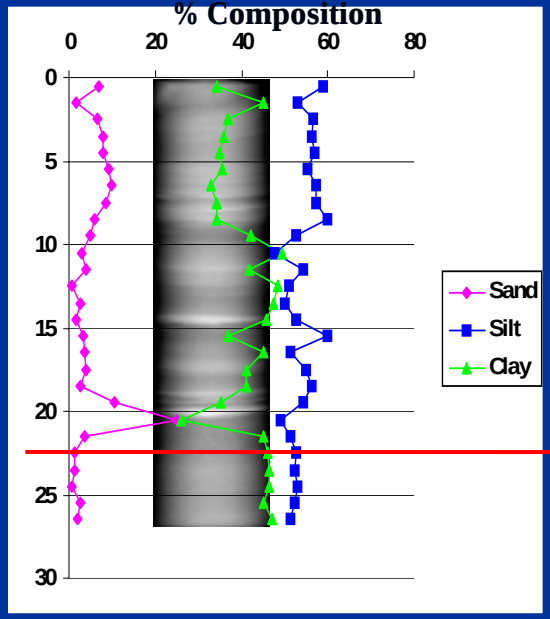
X-radiographs and ^{210}Pb and grain size distribution profiles of 10/13/07 Cores



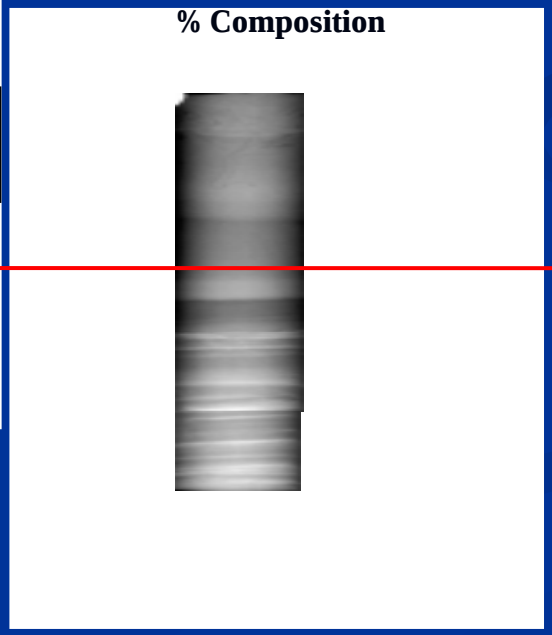


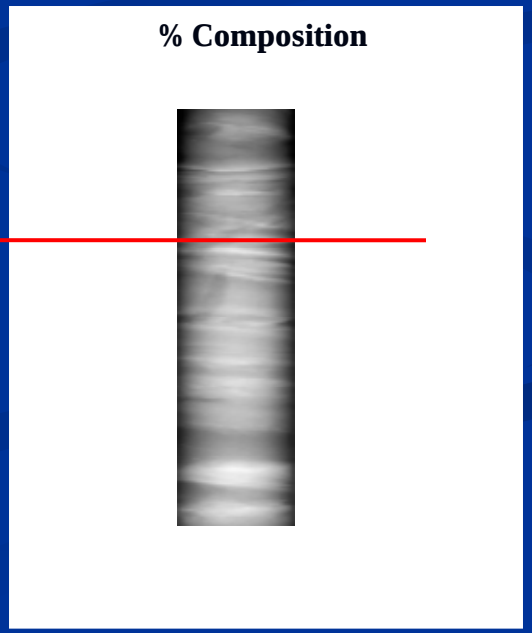




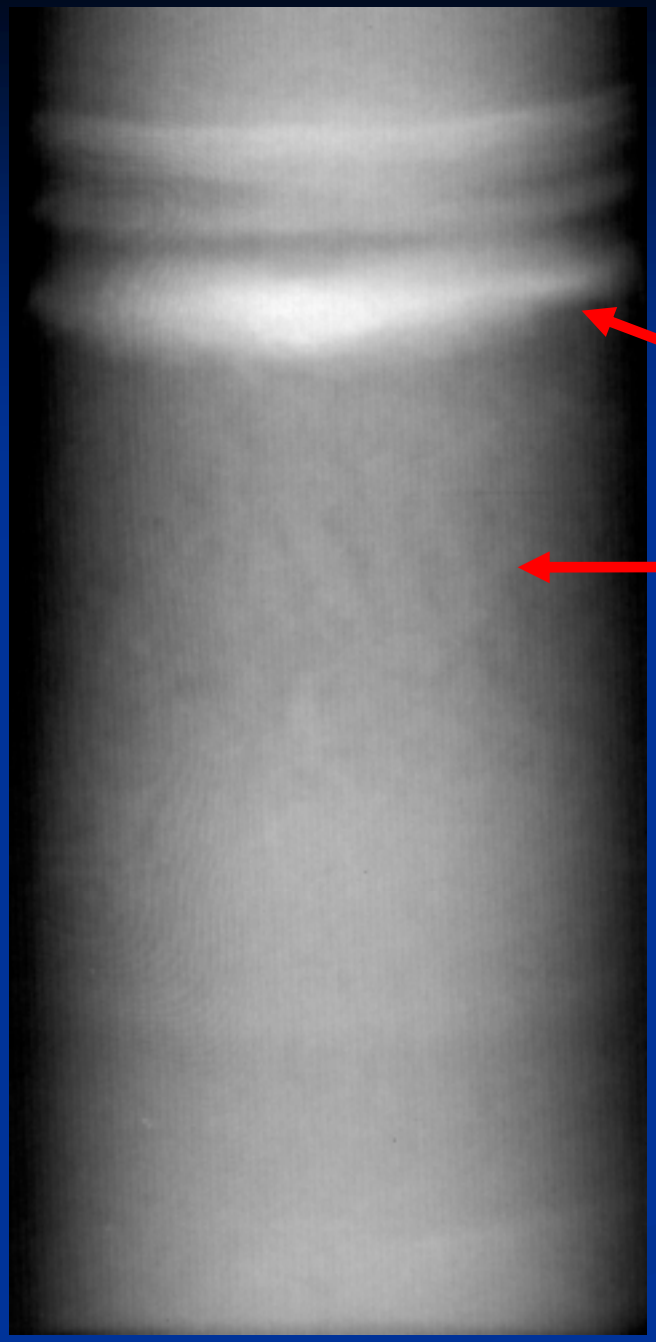


Sand
Silt
Clay





BR004 X-radiograph

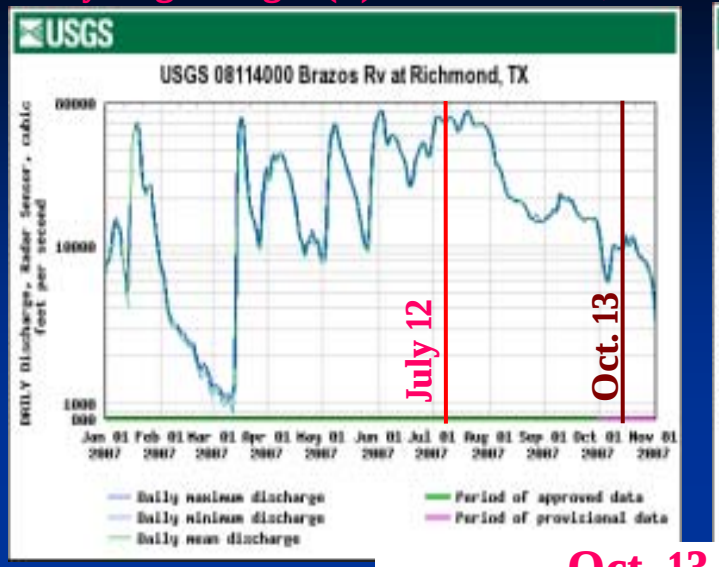


Coarser sediment shows up as lighter tones

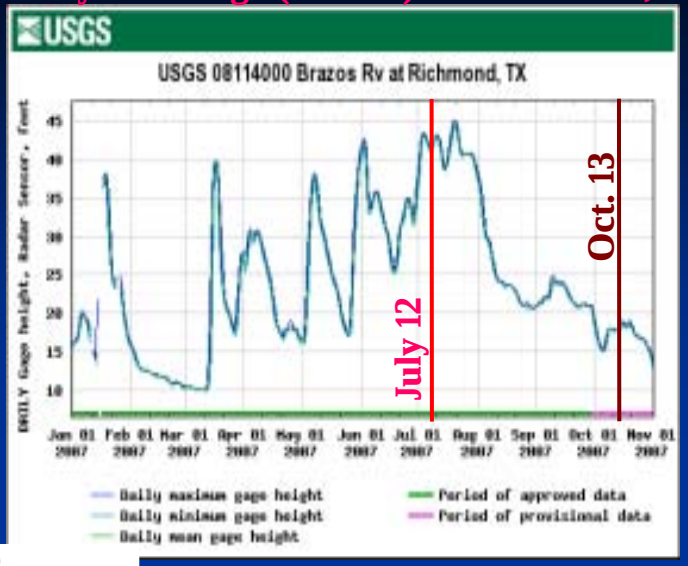
Base of storm layer

Bioturbation- extensive vertical worm burrows

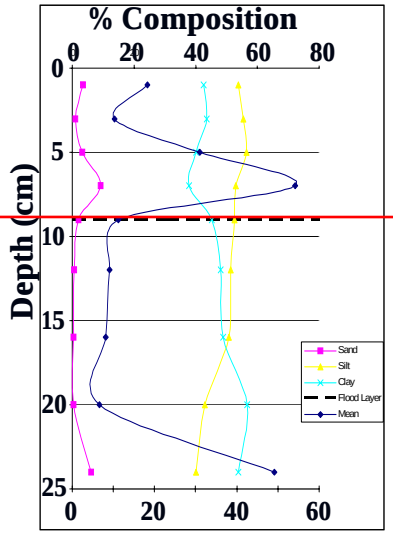
Brazos River-Richmond Station
Daily Gage Height (ft): Jan. 1- Nov. 1, 2007



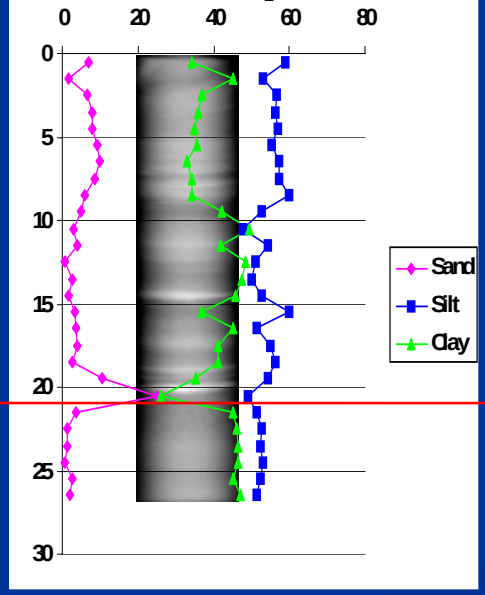
Brazos River-Richmond Station
Daily Discharge (ft3/sec): Jan. 1- Nov. 1, 2007



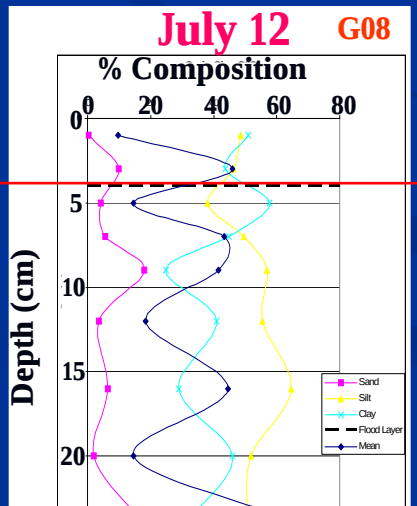
July 12 G04



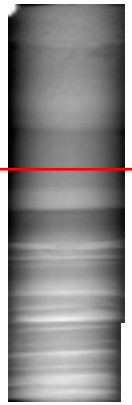
Oct. 13

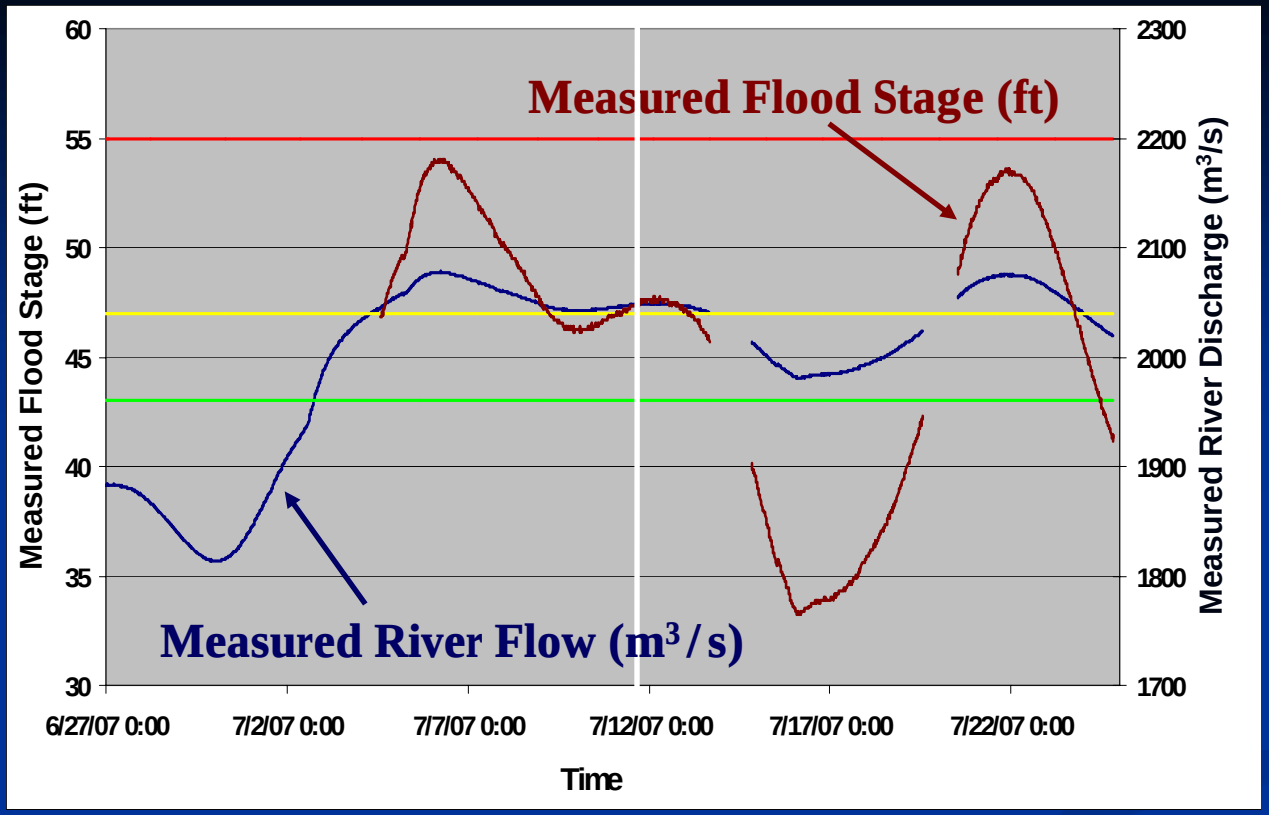


July 12 G08

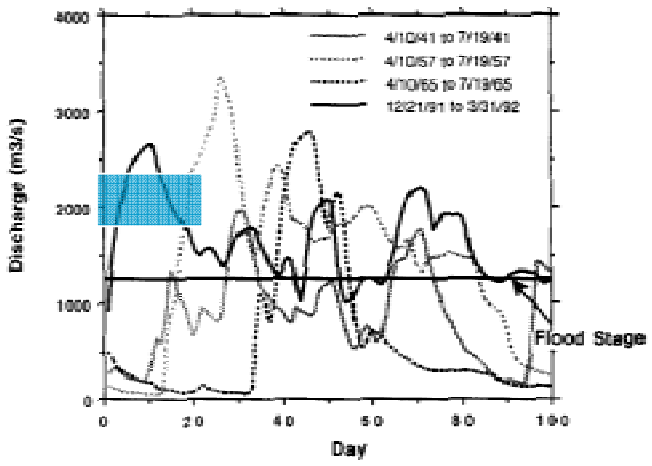


Oct. 13 G08





Brazos River
June 27- July 22, 2007



Time versus discharge for the Brazos River. Data acquired during the largest floods of this century are plotted. Discharge data were obtained from the U.S Geological Survey gauging station, Richmond, TX number 08114000 (Rodriguez et al.., 2000)

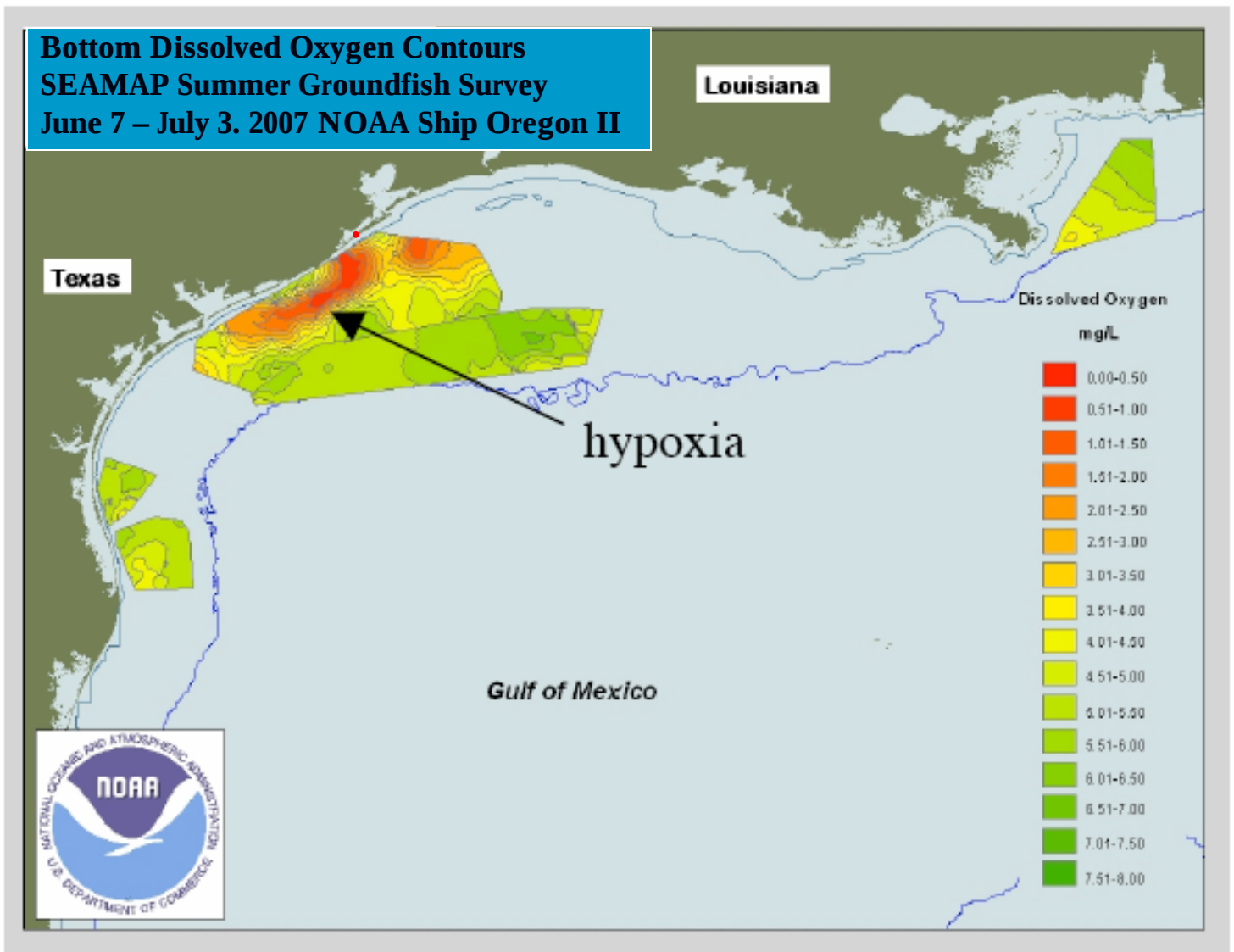
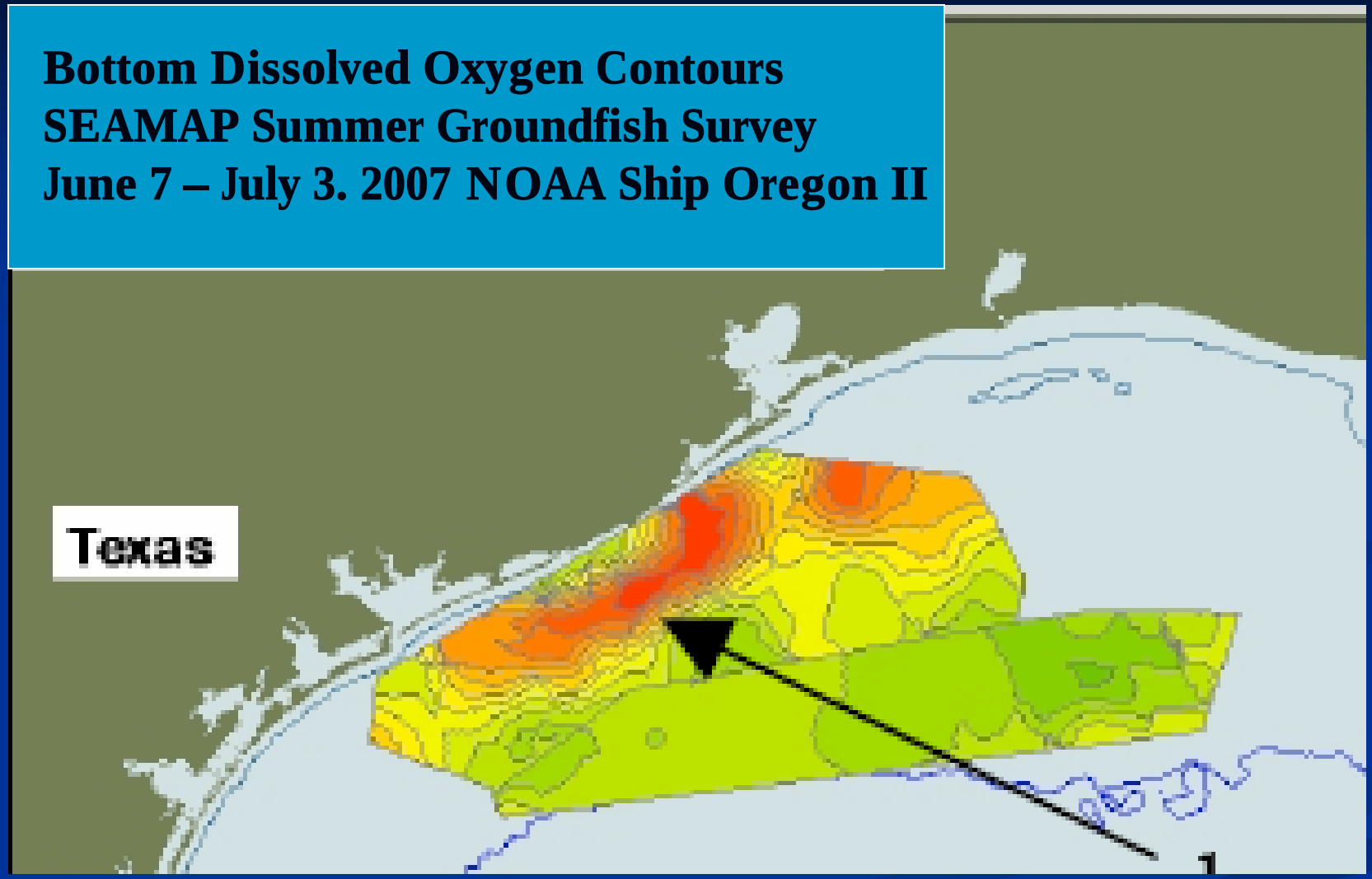


Figure 2. Bottom dissolved oxygen concentrations from various legs of NOAA SEAMP cruise, 7 June – 3 July, 2007. Hypoxic plume emanating from vicinity of Brazos River mouth is indicated (Figure courtesy of Gulf of Mexico Hypoxia Watch- NOAA:NCDDC.)

Bottom Dissolved Oxygen Contours
SEAMAP Summer Groundfish Survey
June 7 – July 3. 2007 NOAA Ship Oregon II



Conclusions

- **On July 12, 2007, during the peak discharge of Brazos River, we observed both a buoyant surface (hypopycnal) plume of suspended sediment**
- **and a highly turbid bottom layer (potentially even fluid mud), derived from the effluent of the Brazos River and extending over 5 km from the mouth of the river onto the shelf**
- **Was this a hyperpycnal plume or a wave supported boundary layer?**
  - **it was probably a combination of both, there were 1.5-2 m waves in 8-15 m of water,**
  - **the shore parallel transect revealed that the only place where a bottom turbid layer was observed was within 2 km of the axis of the plume**
  - **Bottom water salinities were low, further demonstrating the linkage with the river effluent.**
- **Very low angle dip of the shelf likely limited the distance offshore the flow extended**
- **River discharge data show comparable floods occur every 1-5 years**
  - **suggesting hyperpycnal flow is a very common occurrence (Mulder and Syvitski, 1995 suggested <100y)**

Conclusions-continued

- **^{210}Pb and grainsize profiles suggest multiple pulses of sediment discharge**
- **7-12-07 cruise sampled the first big pulse**
- **10-13-07 cruise sampled the preserved evidence of subsequent pulses**
- **Cores reveal sand was transported 5 km offshore**
- **Preserved layers in the cores suggest that previous, larger floods transported much thicker sand layers at core locations and likely transported the sand offshore of our study site**

Hypoxia on Brazos shelf appears to be the result from water column stratification due to high river discharge

- **When hyperpycnal flow occurs, nutrient and organic rich plume is injected into bottom waters and maintained by water column stratification-enhancing hypoxia if occurring in summer.**
- **These linkages need to be further investigated**

Why should a room full of petroleum geologist care?

- **Brazos River provides an ideal natural laboratory to investigate:**
  - **Role of hyperpycnal flow and shelf processes on sediment dispersal of both sand as well as mud on a low gradient, wide, passive margin shelf comparable to many depositional system relevant to petroleum geology systems**
  - **Relationship between hyperpycnal flow and the formation of hypoxia- broad implications in terms of formation of source rocks proximal to reservoir systems on shelf settings**