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The assessment of sediment bed properties within the York River estuary as a function of spring and neap tidal cycle

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Virginia Institute of Marine Science

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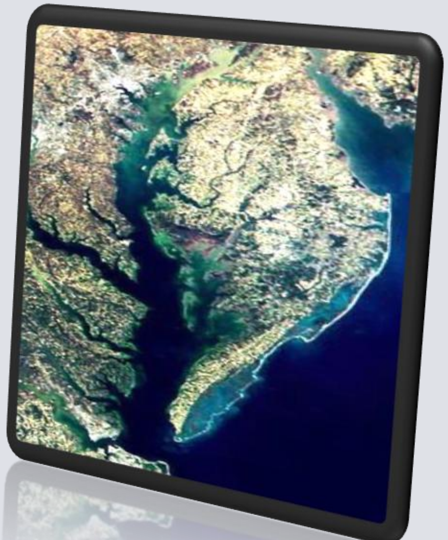
The assessment of sediment bed properties within the York River estuary as a function of spring and neap tidal cycles

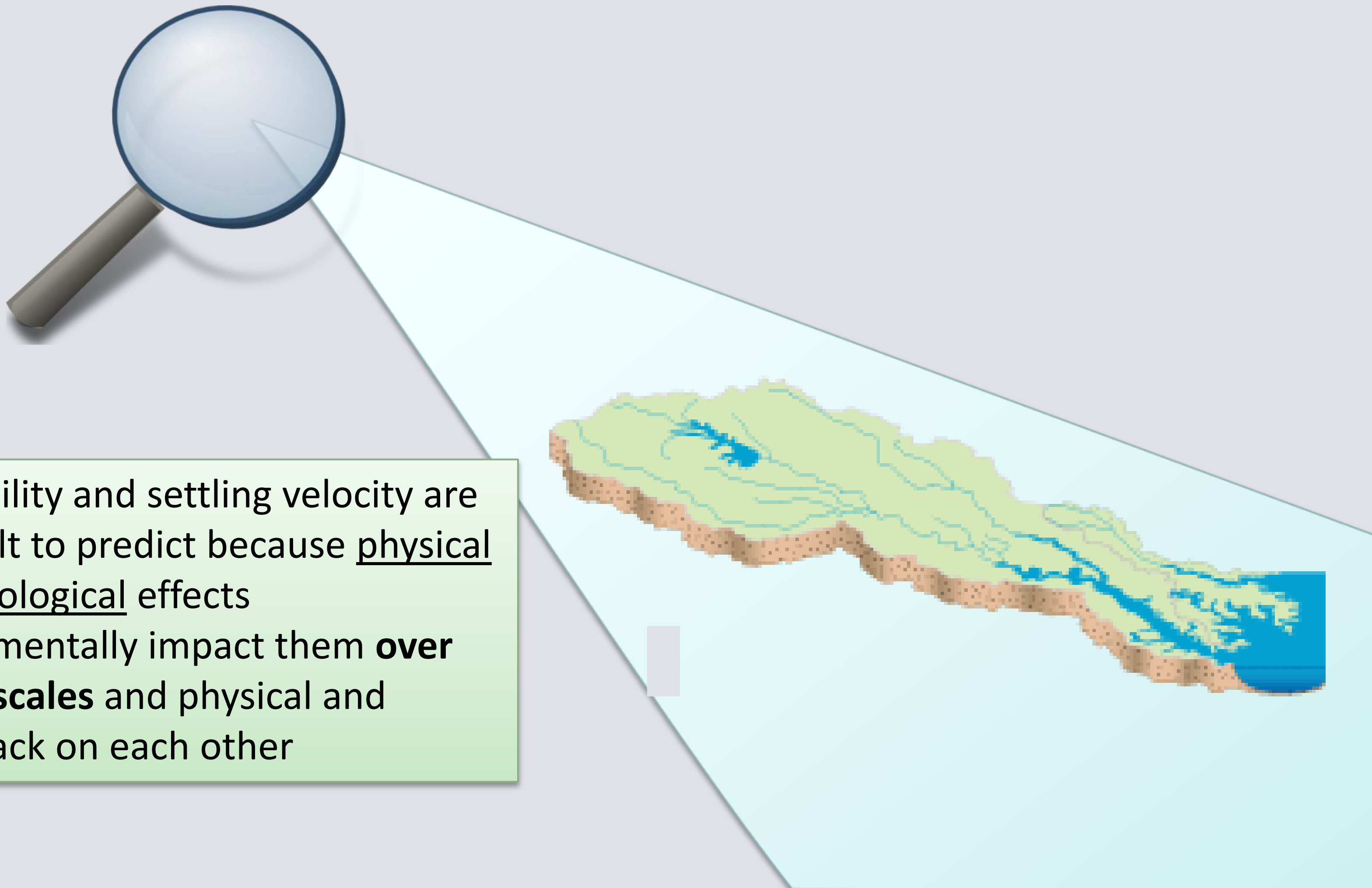


Lindsey Kraatz and Carl Friedrichs
York River Research Symposium
April 20, 2011

Motivation

NSF MUDBED Project (Multi-disciplinary Benthic Exchange Dynamics)

Understanding fine sediment transport is critical to managing coastal water quality and ecological health, and to understanding coastal ecology, chemical fluxes and the geological record.



Erodibility and settling velocity are difficult to predict because physical and biological effects fundamentally impact them **over short scales** and physical and feedback on each other

Background

- Erodibility
  - Stress to initiate movement of particles
  - Mass eroded at a given stress
- Erodibility of sediment beds is a function of:
  - Grain size
  - Water content
  - Mineralogical composition
  - Biological activity
  - Salinity
  - Temperature
  - Etc
- Fine sediment erosion difficult to predict
  - Number of techniques have been developed
    - Laboratory flume tests (Parchure and Mehta, 1985)
    - In situ measurements using submersible flumes (Maa, 1998)
    - Cores (McNeil et al, 1996)

Background

Motivation
Background
Study Area
Sample Collection
Water Content
Mud:Sand Ratio
Erodibility
Summary
Management Implications

- Erodibility
  - Stress to initiate movement of particles
  - Mass eroded at a given stress

- Erodibility of sediment beds is a function of:
  - ***Grain size***
  - ***Water content***
  - ~~Mineralogical composition~~
  - ***Biological activity***
  - ~~Salinity~~
  - ~~Temperature~~
  - Etc

- Fine sediment erosion difficult to predict
  - Number of techniques have been developed
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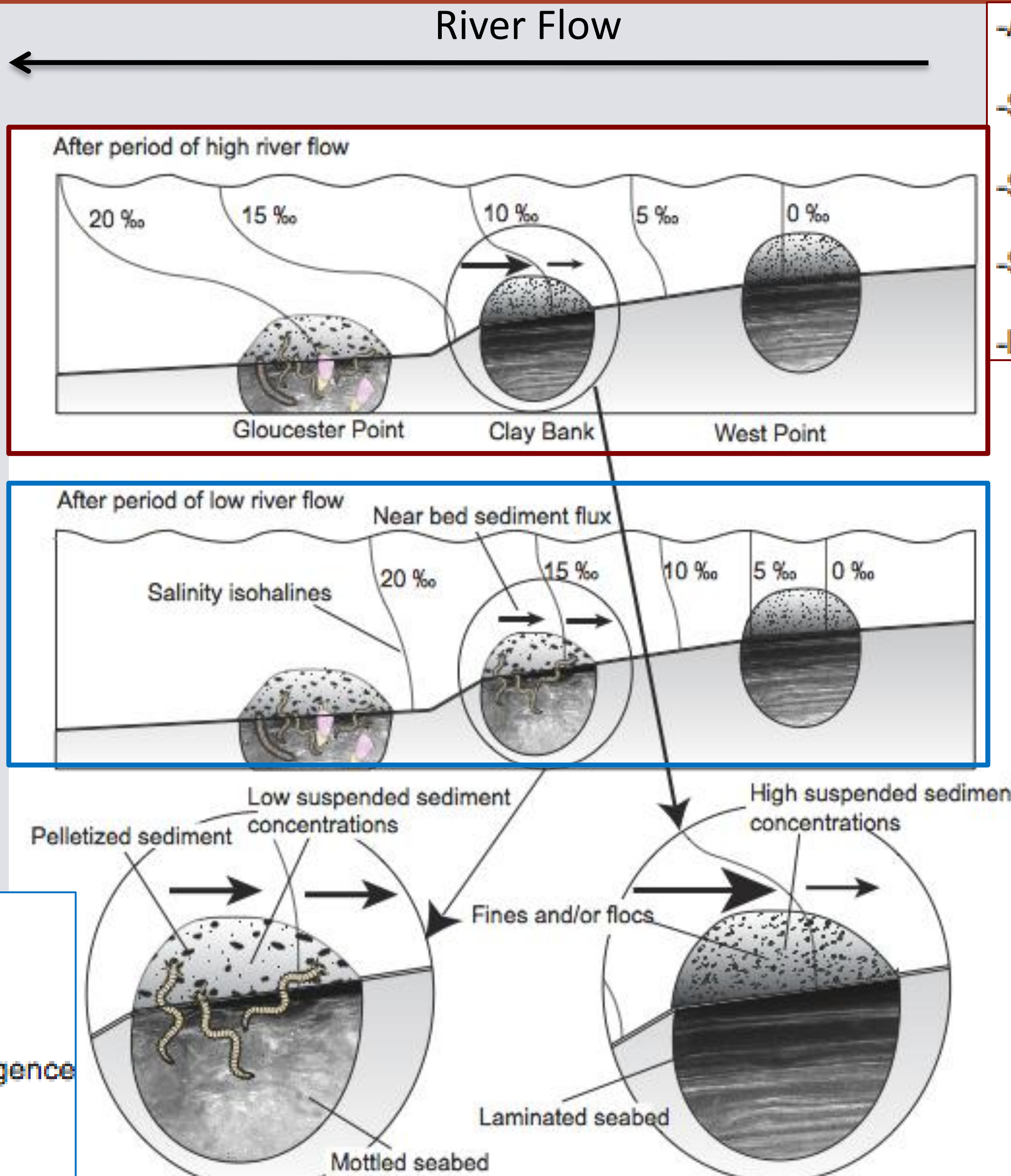
    - In situ measurements using submersible flumes (Maa, 1998)
    - Cores (McNeil et al, 1996)

York River



-After high river flow

-Stratified

-Sediment flux convergence

-STM

-High erodibility

-After low river flow

-Little or no stratification

-No sediment flux convergence

-No STM

-Low erodibility

(Lin and Kuo, 2001), (Schaffner et al., 2001) (Lin and Kuo, 2003), (Scully and Friedrichs, 2003), (Dickhudt et al. 2008), , (Cartwright et al., 2009), and (Friedrichs, 2009)

York River

Motivation
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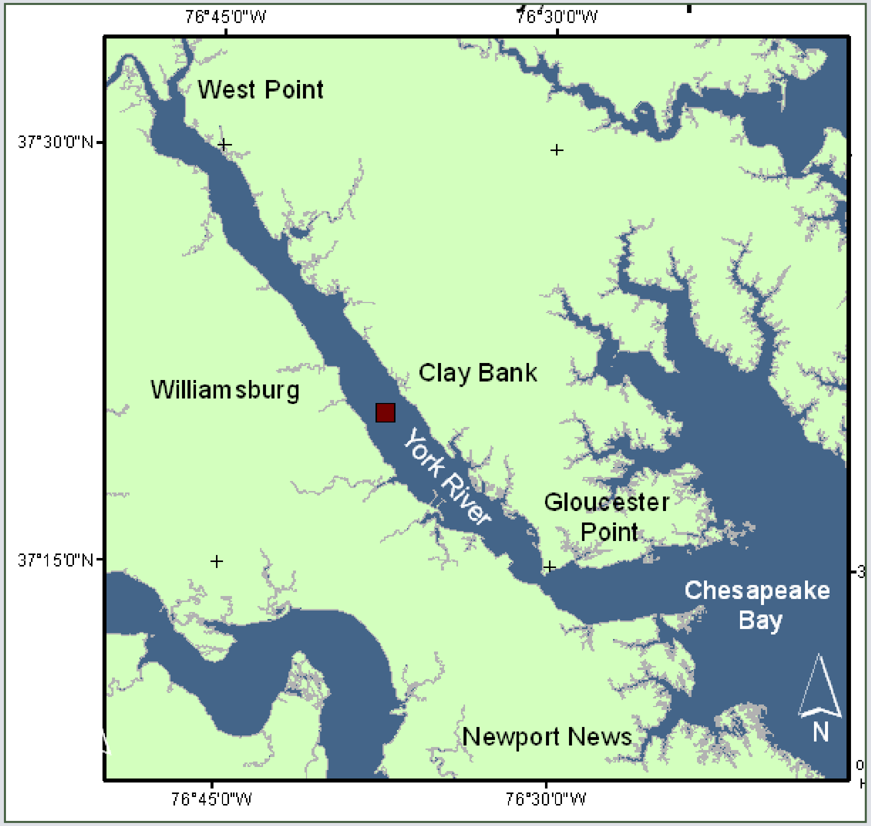
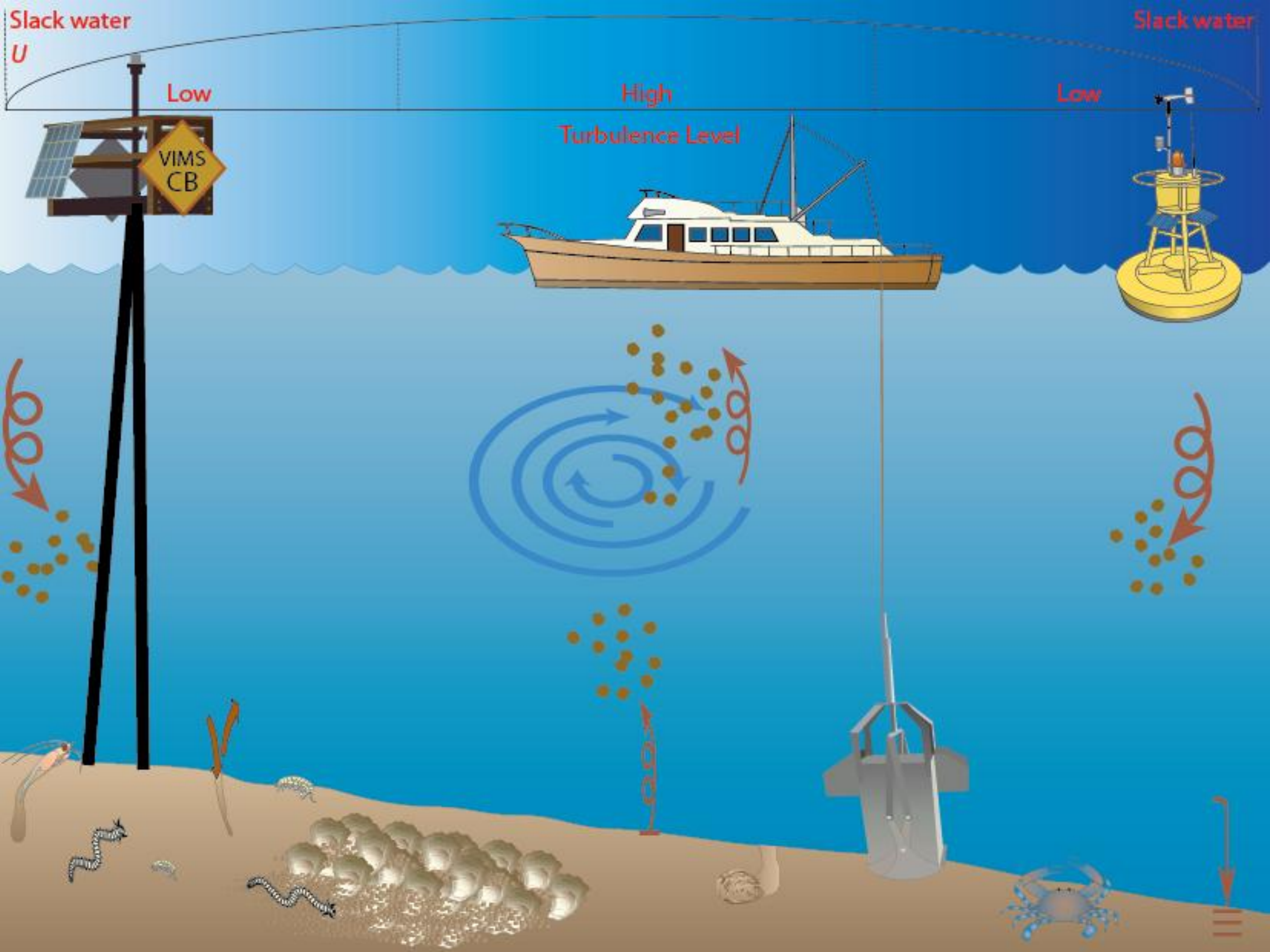
- Microtidal system ~ 0.8m range
- Studies show deep physical mixing of the seabed up to 100 cm on spring-neap and longer time cycles
- Mixing can occur by:
  - Physical processes
  - Bioturbation
- Strong tidal currents
- - ~1 m s^{-1} near surface
- Severely fetch limited
- - Weak local wind waves
- ETM located at West Point
- STM found seasonally at Clay Bank





Slack water
U
Low
High
Low
Slack water
Turbulence Level
VIMS
CB

Sample Collection

- Sediments were collected with a Gomex box core during the spring of 2010
- Collection occurred:
  - weekly
  - during slack tides
  - analyzed differences of spring and neap sediment properties and erodibility
- Each week, cores were sub-sampled for:
  - Water content
  - Grain size
  - Organic content
  - Digital X-radiography
  - Erodibility
  - Be^7 Isotope ~ Sediment dating

P. Dickhudt

Sample Collection

Motivation
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Erodibility
Summary
Management Implications

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  - ***Grain size***
  - Organic content
  - Digital X-radiography
  - ***Erodibility***
  - Be^7 Isotope ~ Sediment dating

P. Dickhudt

Water Content

Motivation
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Study Area
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Mud:Sand Ratio
Erodibility
Summary
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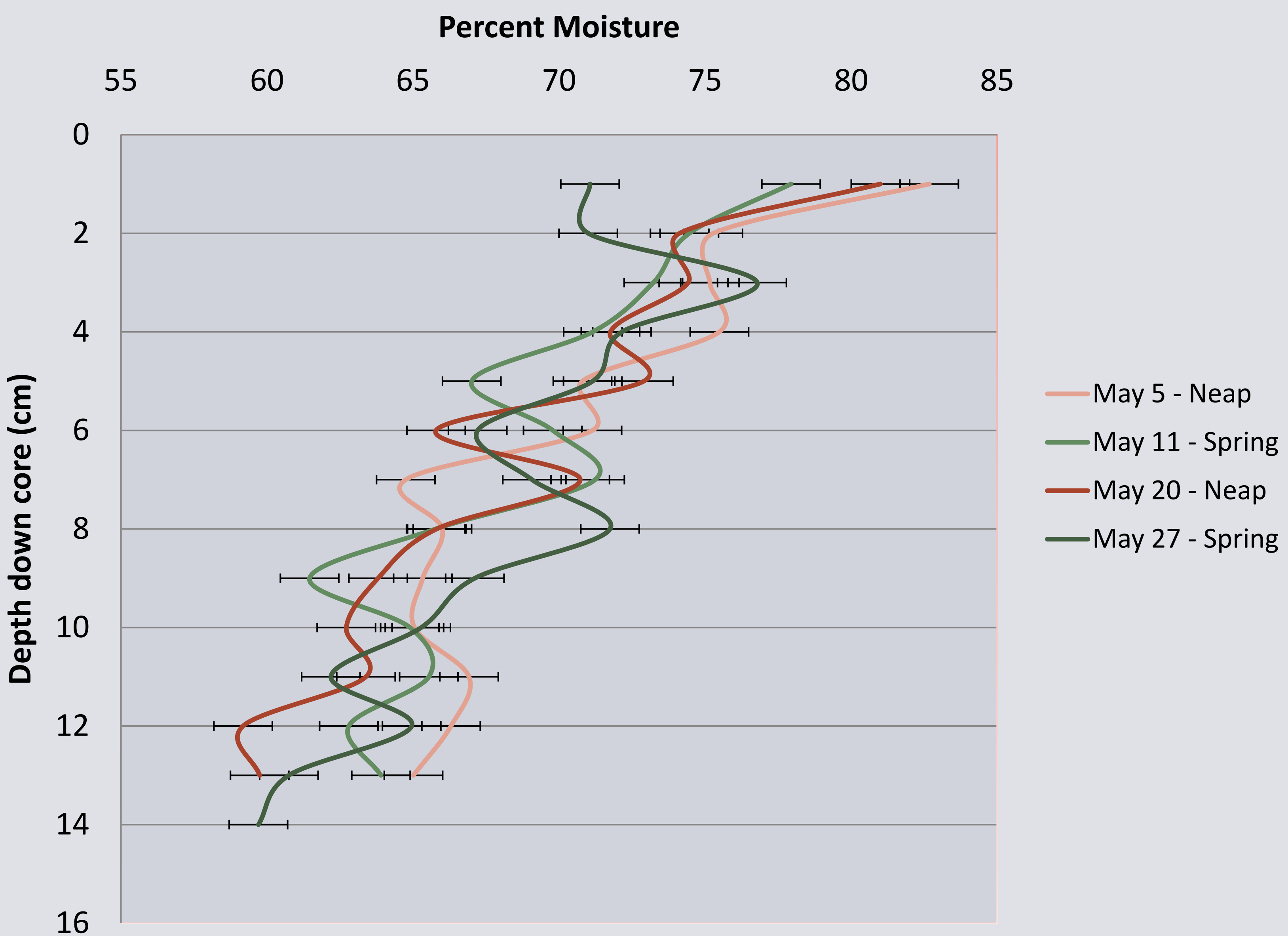
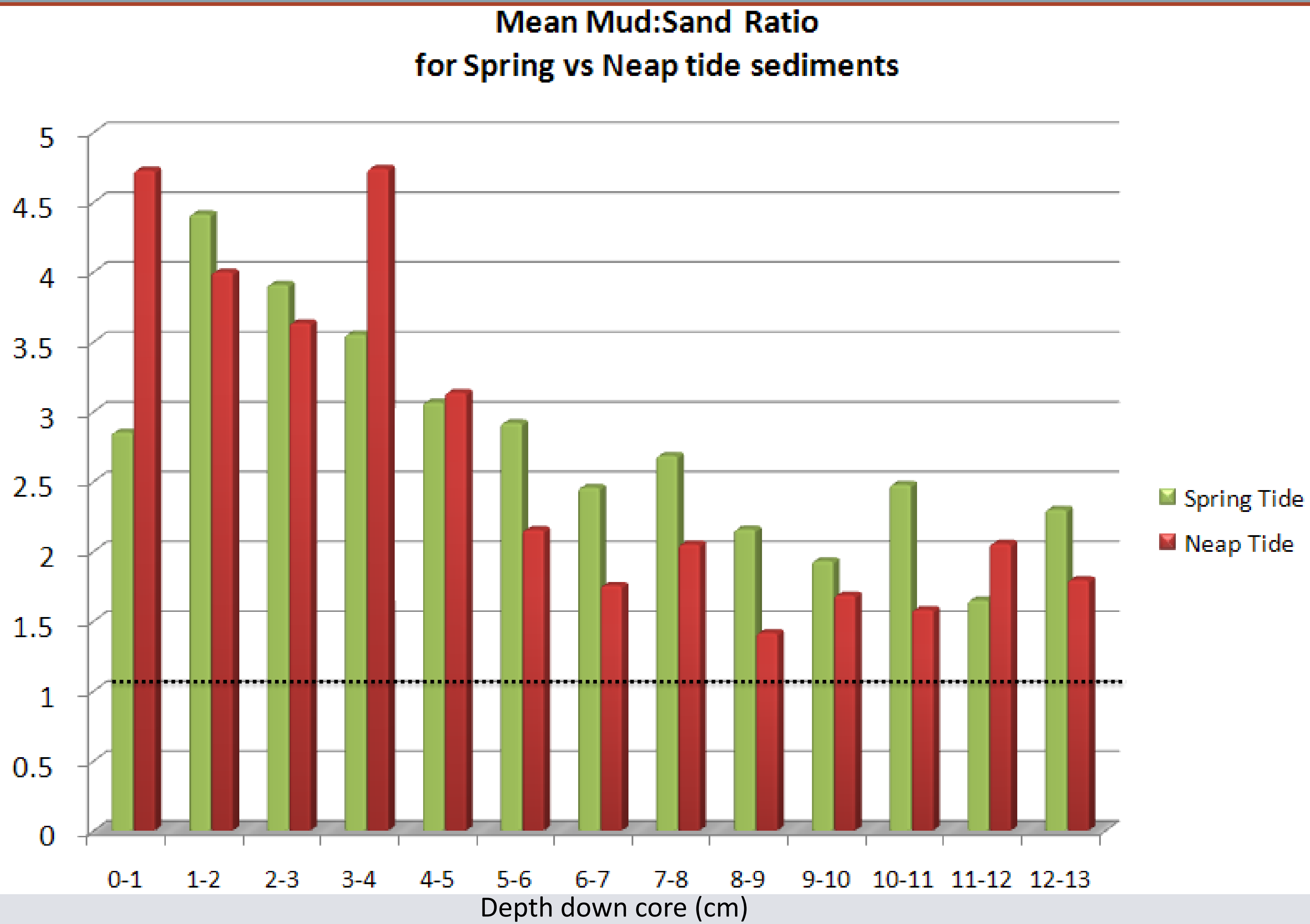
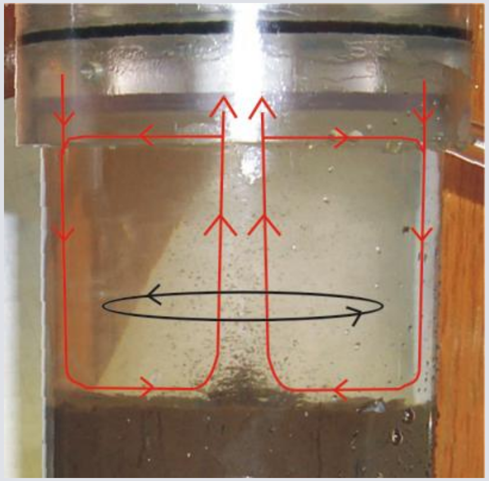


Mud:Sand Ratio

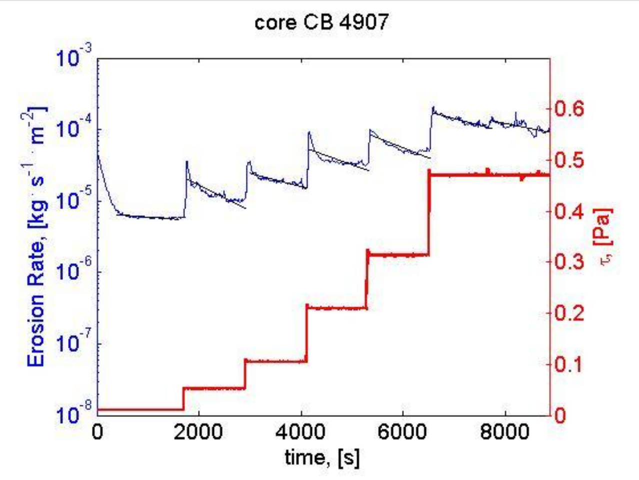


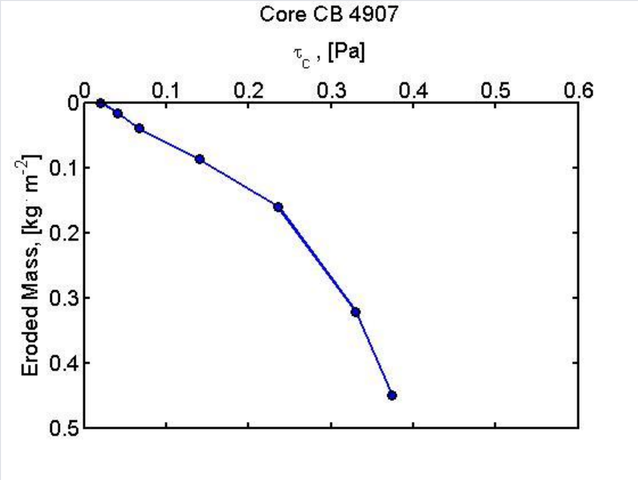
Erodibility

- Dual core Gust Microcosm
- 2 cores collected *in situ*
- Simulates tidal resuspension
- Profiles of critical shear stress and erosion rate constant

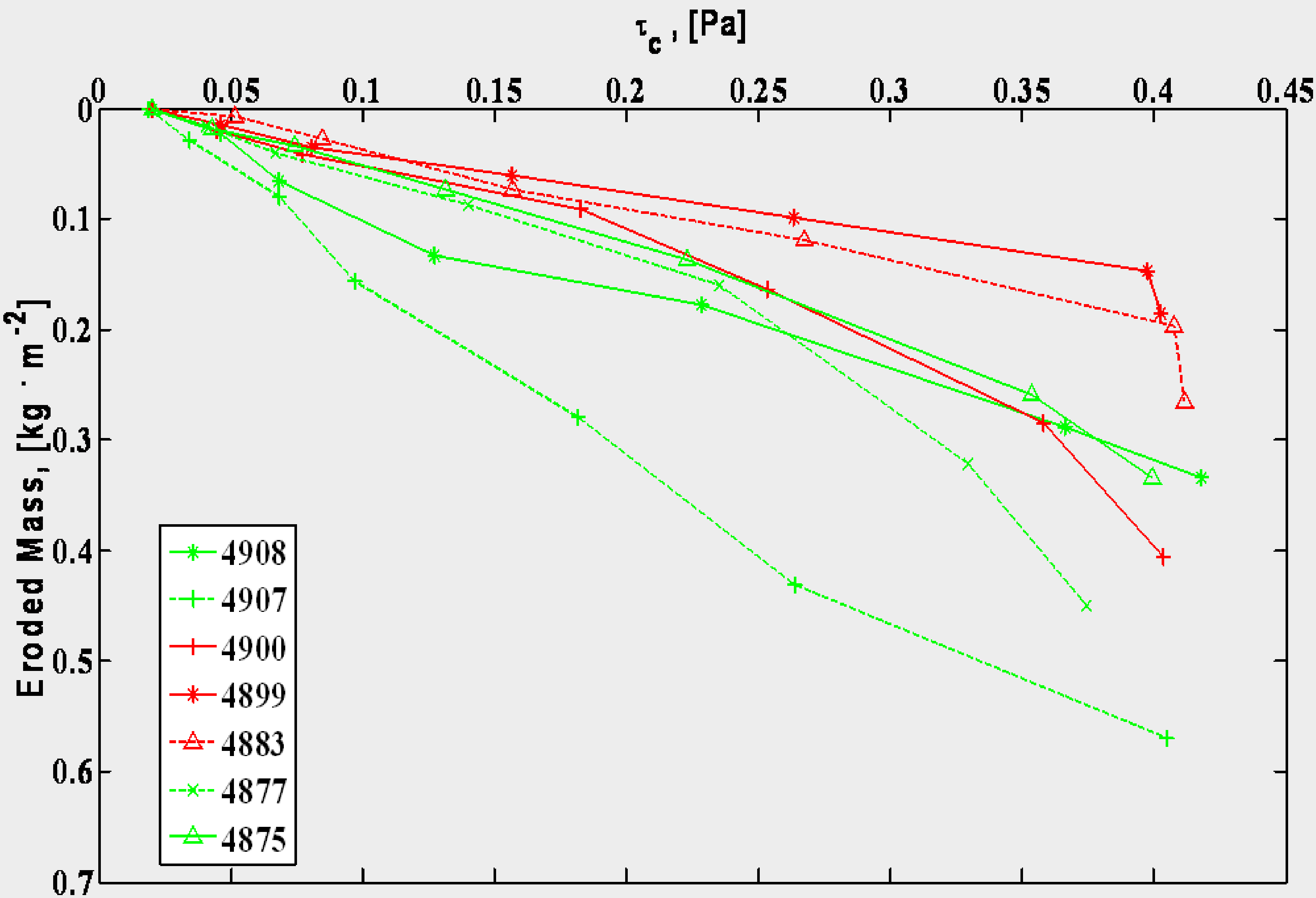


(Dickhudt et al., 2009)



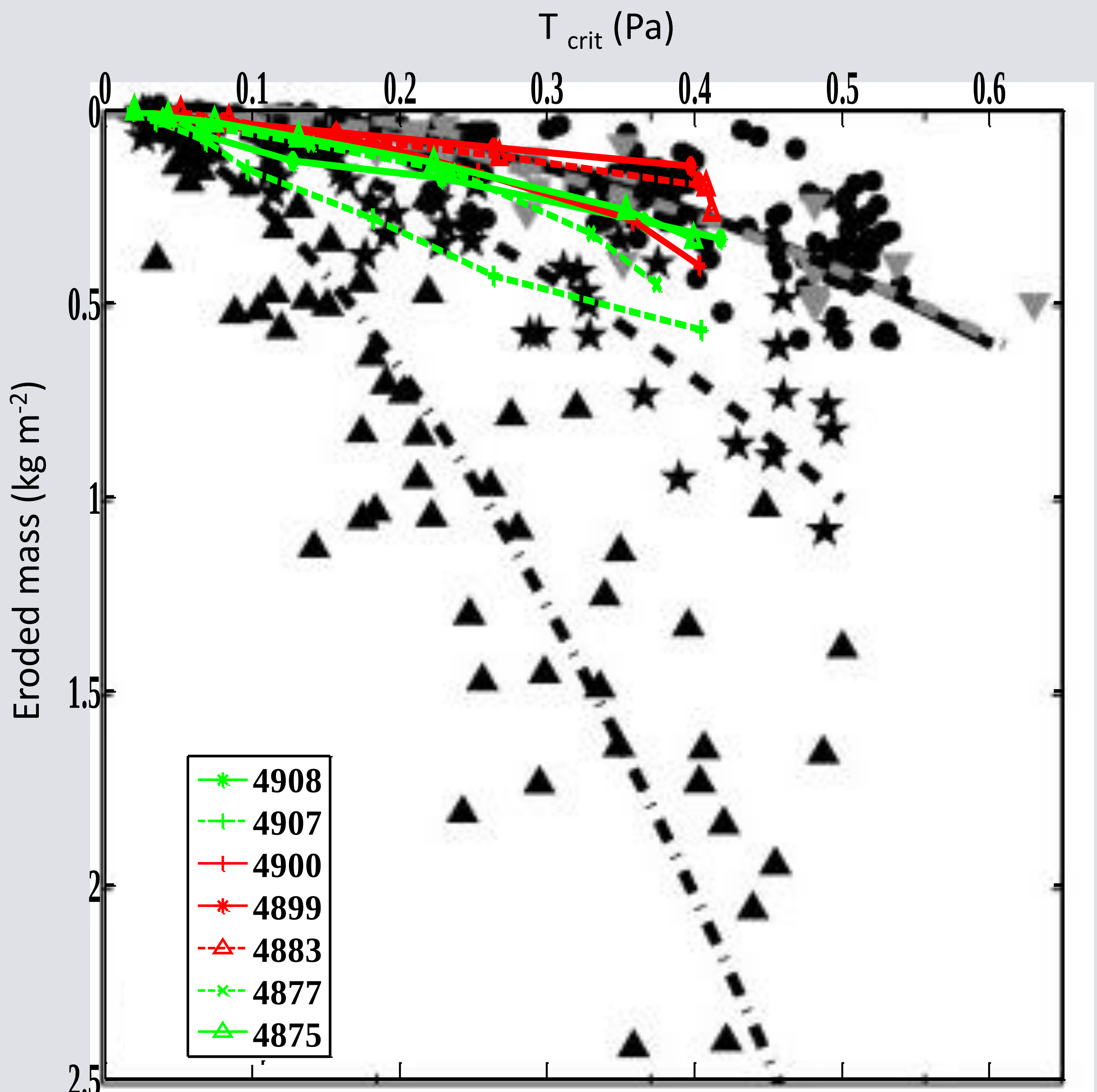


Erodibility



Erodibility vs. Dickhudt et al., 2009

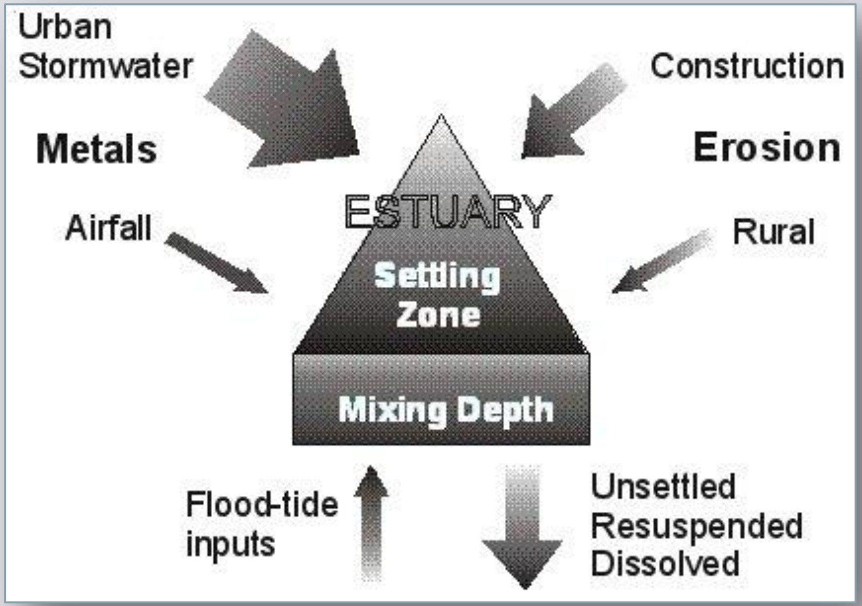
- Motivation
- Background
- Study Area
- Sample Collection
- Water Content
- Mud:Sand Ratio
- Erodibility
- Summary
- Management Implications



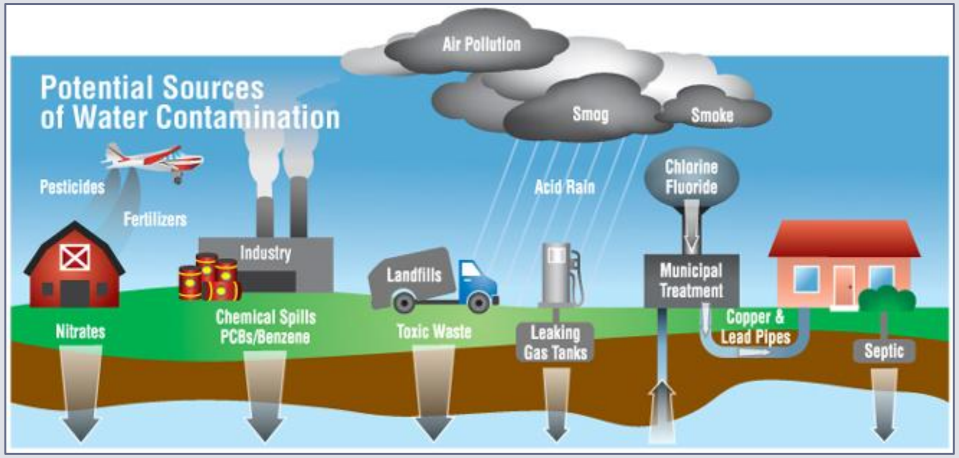
Management Implications

Motivation
Background
Study Area
Sample Collection
Water Content
Mud:Sand Ratio
Erodibility
Management Implications
Summary

- Sediment dynamics is one of the most important factors affecting coastal, estuarine, and riverine systems
- Little is known about the transport and dynamics of fine-grained sediment, despite the importance of particle dispersal
- High quantities of suspended sediment can result in negative impacts within the estuary, including:
  - *enhanced light attenuation*
  - *dis*ruption and change of benthic community structure and distribution
  - modified transport of organic carbon
  - changes in the location and duration of eutrophication and hypoxia
  - pollutant contamination



http://diffusesources.com/files/estuarydiagram.jpg



http://www.waterwise.com/images/waterwisdom/thinkbeforeyoudrinkpict.jpg

Summary

Motivation
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Study Area
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Water Content
Mud:Sand Ratio
Erodibility
Management Implications
Summary

- Seafloor sediments exhibited a higher erodibility during ***spring tides*** than neap tides
- More muds were present and a higher water content was found during ***neap tides***.
- This is thought to be due to a higher abundance of ***flocculated sediments present*** during ***neap tides*** than spring tides.
- Sediment transport greatly affects all aspects of estuarine ecosystem health, ranging from light limitation to pollutant contamination.

Acknowledgements

Committee

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Tim Gass

Sam Lake

Rachel Corrigan

Cielomar Rodriguez

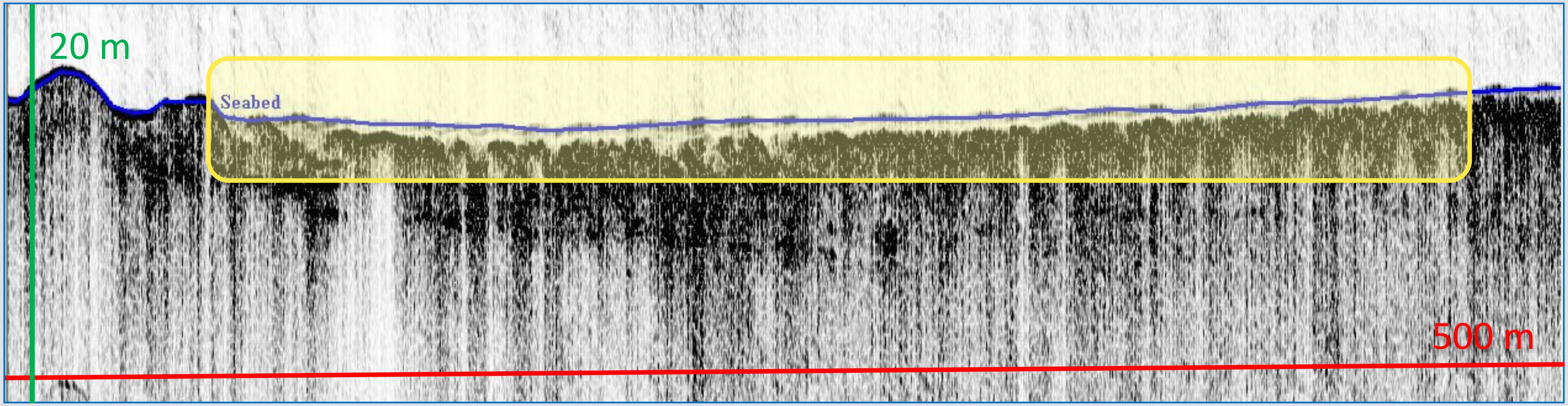
Julia Moriarty

Funding Sources

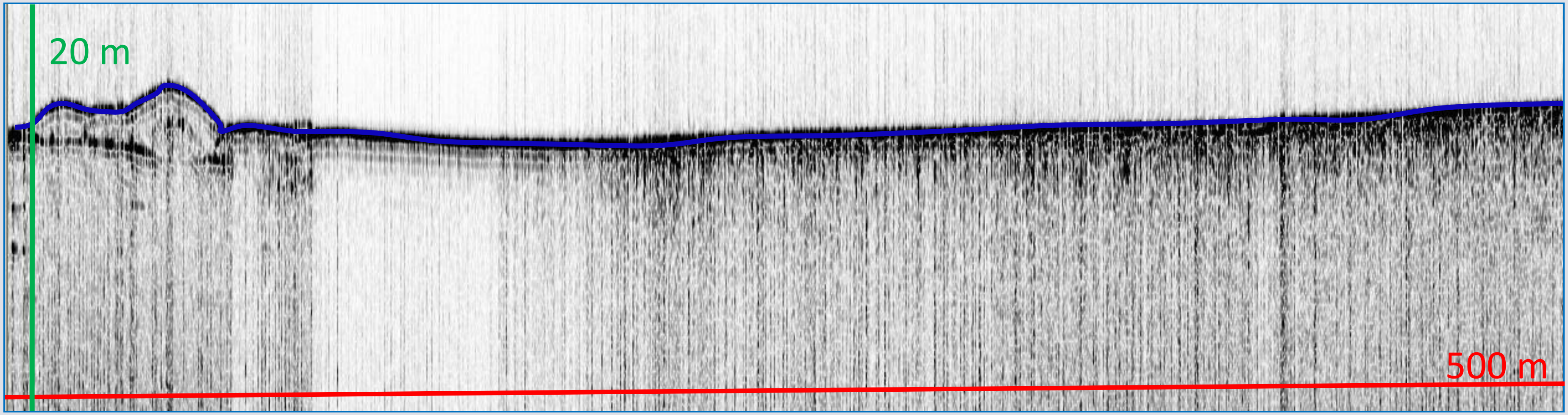
NSF Co-Op ~ OCE-0536572

NSK GK-12 ~ DGE-0840804

Chirp Records

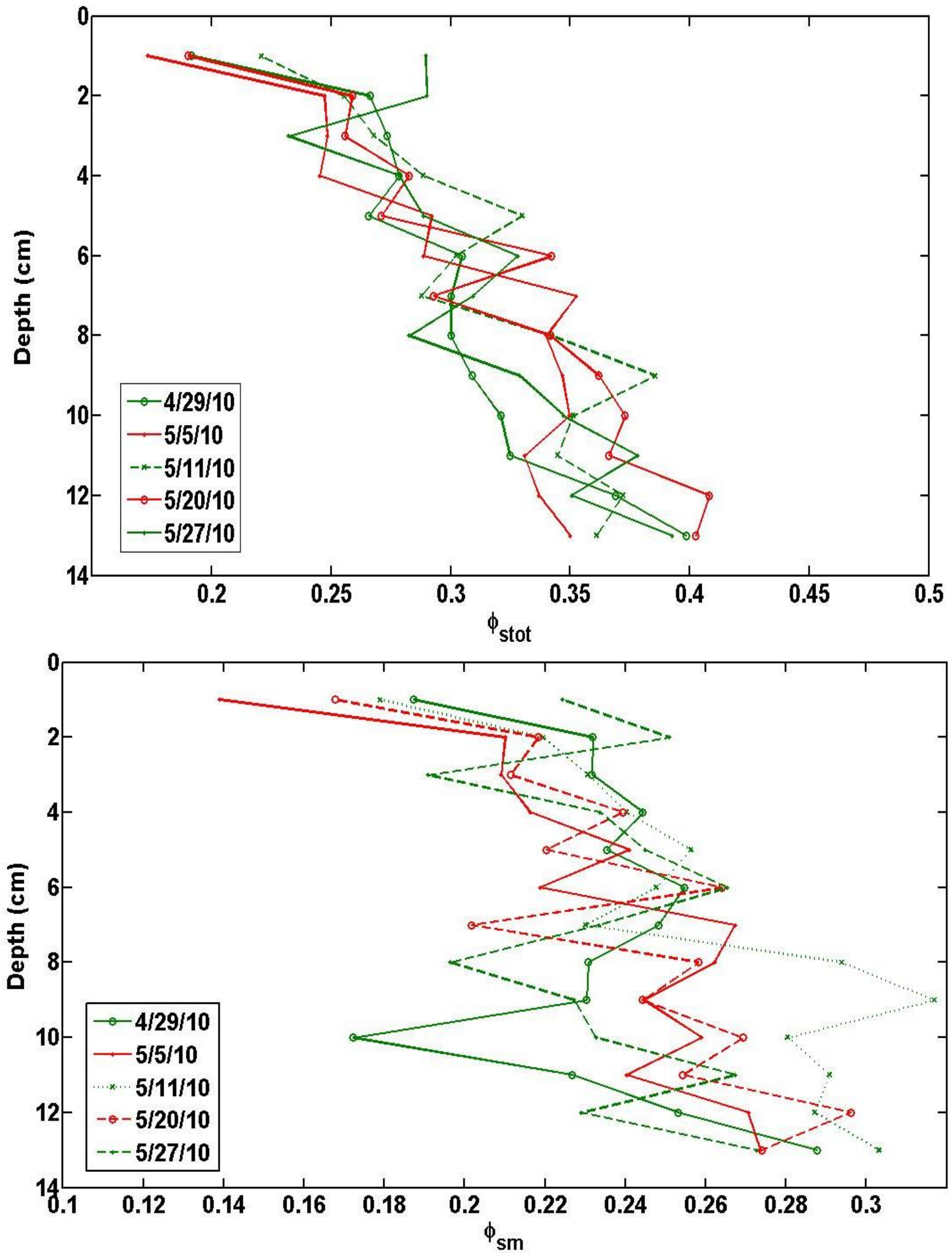


April 07



October 07

Erodibility vs. Dickhudt, 2009



Motivation
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Mud:Sand Ratio
Erodibility
X-rays
Summary
Management Implications

X-Rays

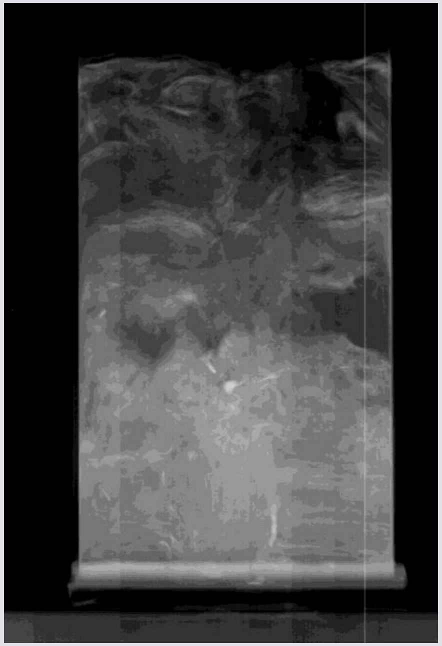
12 cm wide x 2.5 cm thick x 10-20cm in length

Grayscale indicative of relative density

X-ray negatives

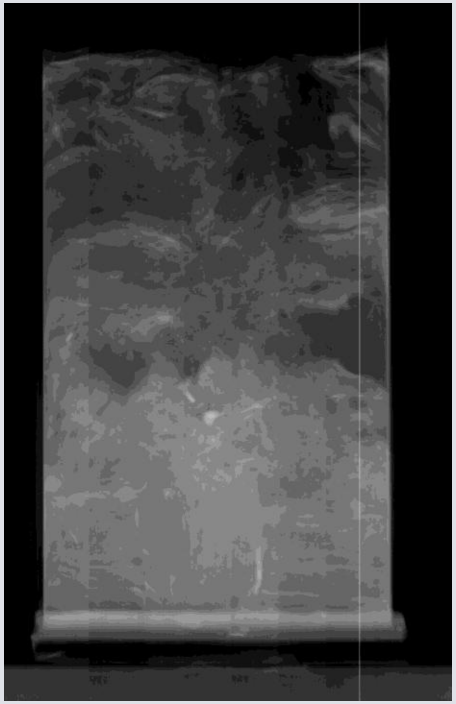
- Light shade = high density
- Dark shade = lower density

April 29, 2010 ~ Clay Bank



4878

4878_perpendi



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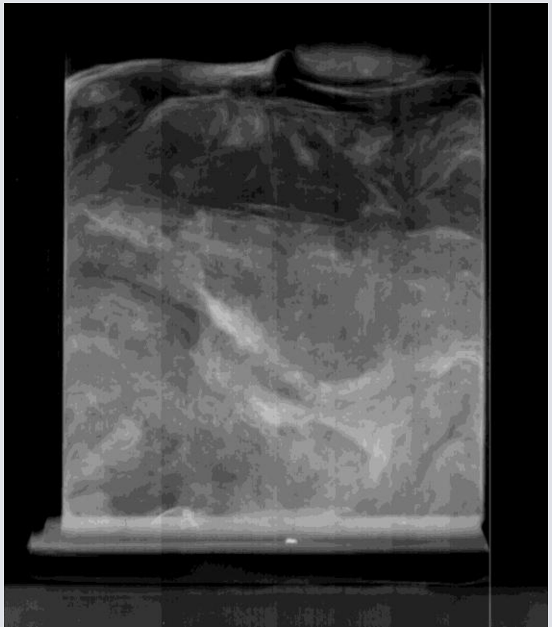
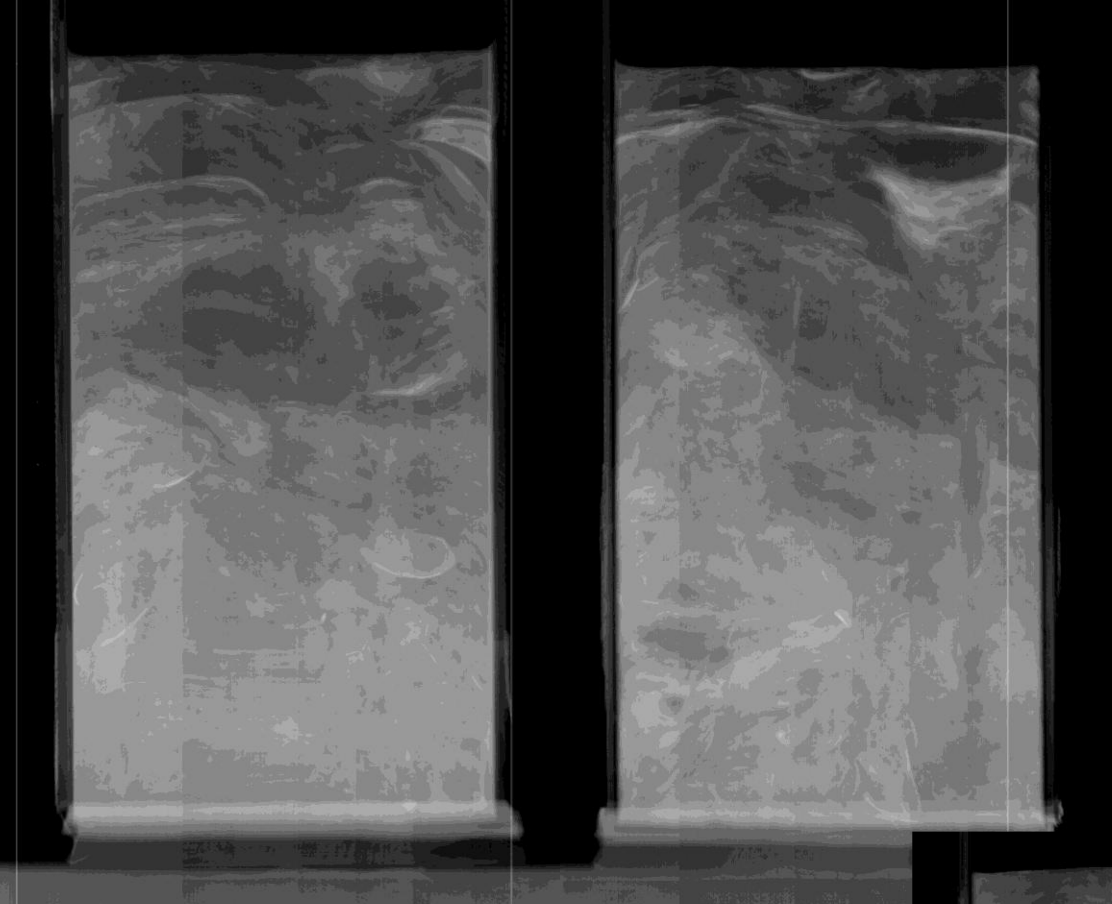


4876

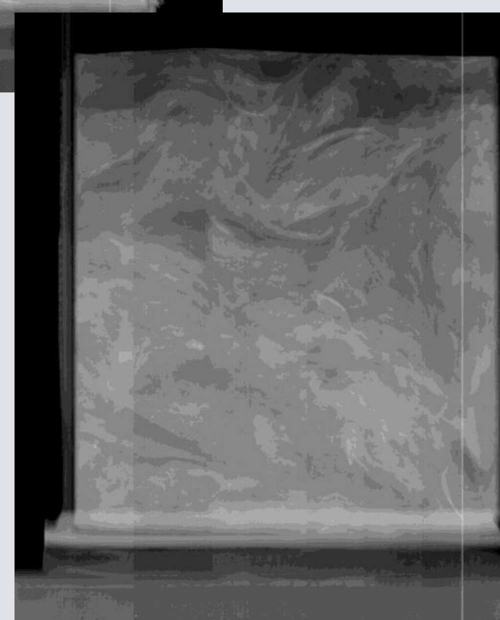
May 5, 2010 ~ Clay Bank



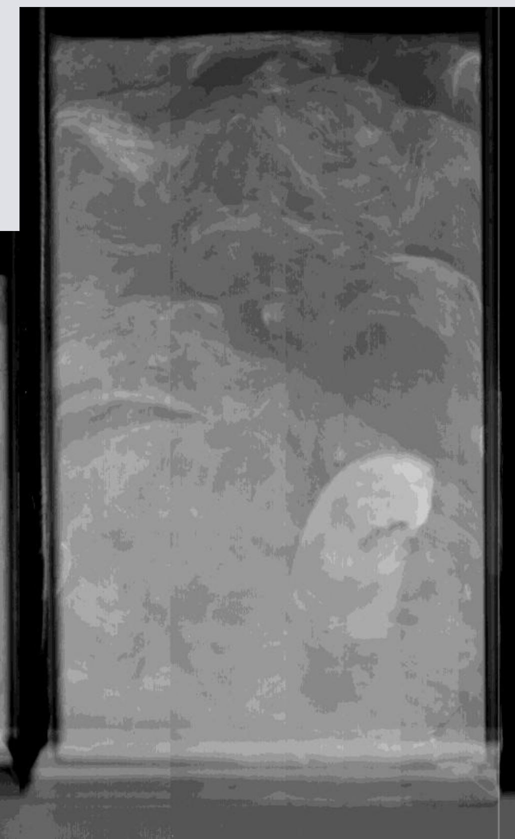
4884 A

4884 B

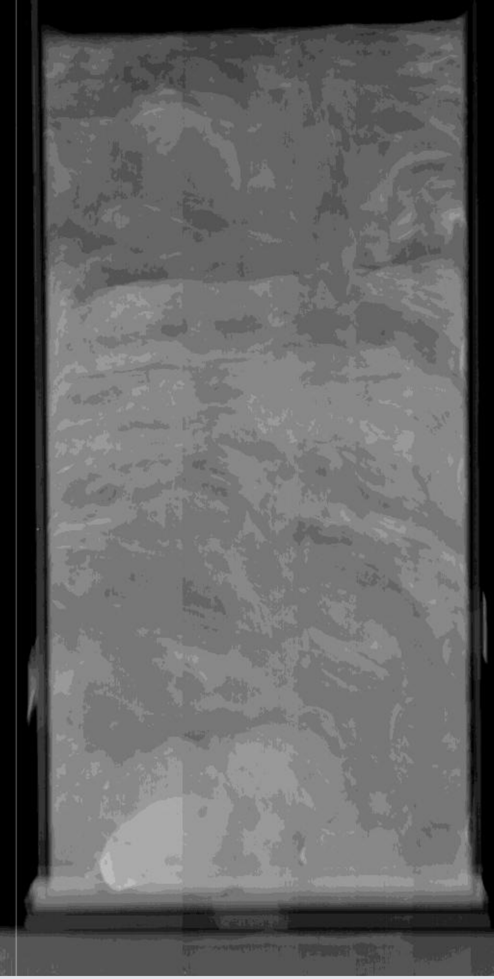
4885 A



4885 B



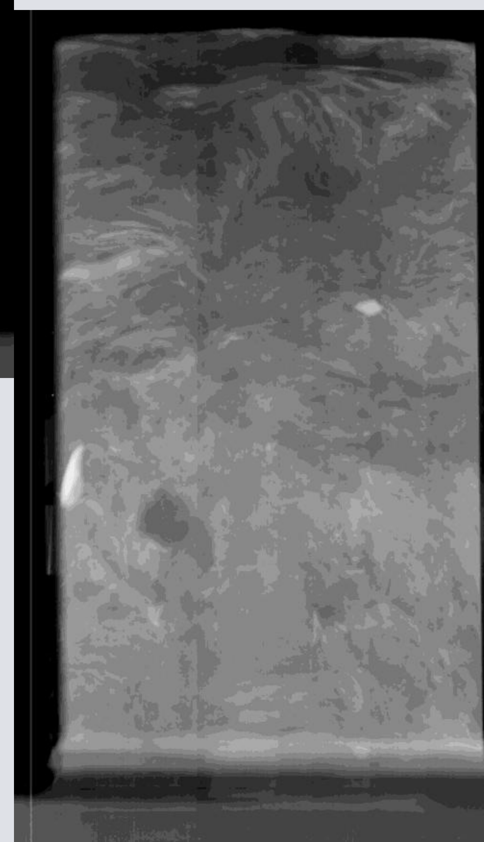
May 11, 2010 ~ Clay Bank



4891 A

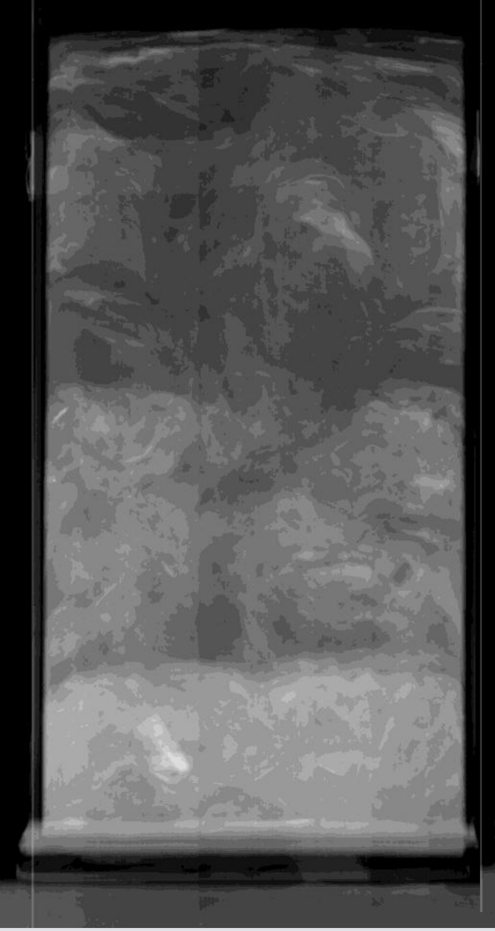
4891 B

4892 A

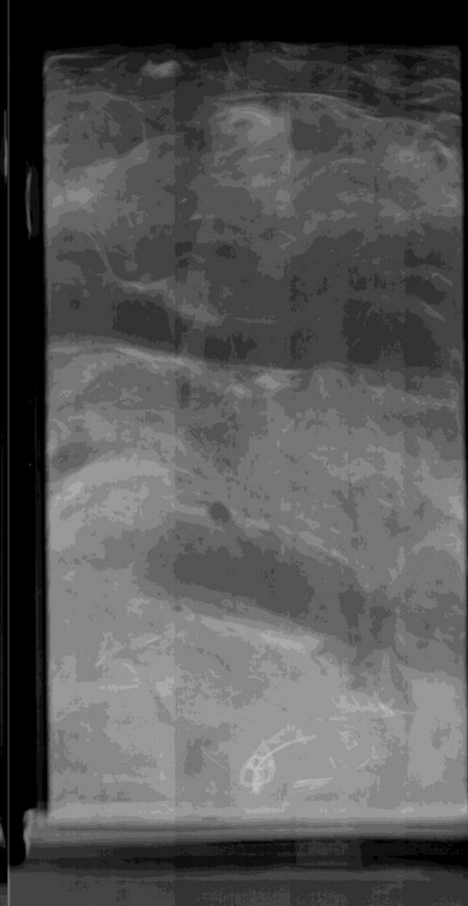


4892 B

May 20, 2010 ~ Clay Bank



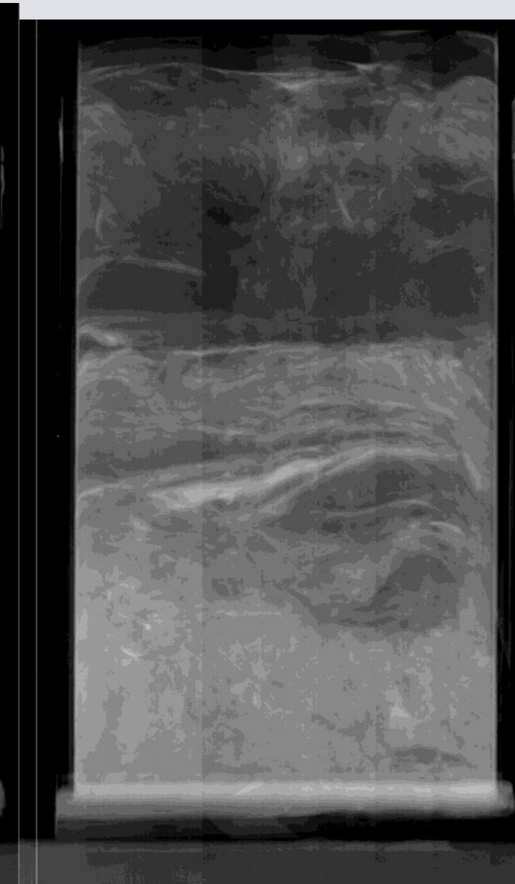
4898 A



4898 B

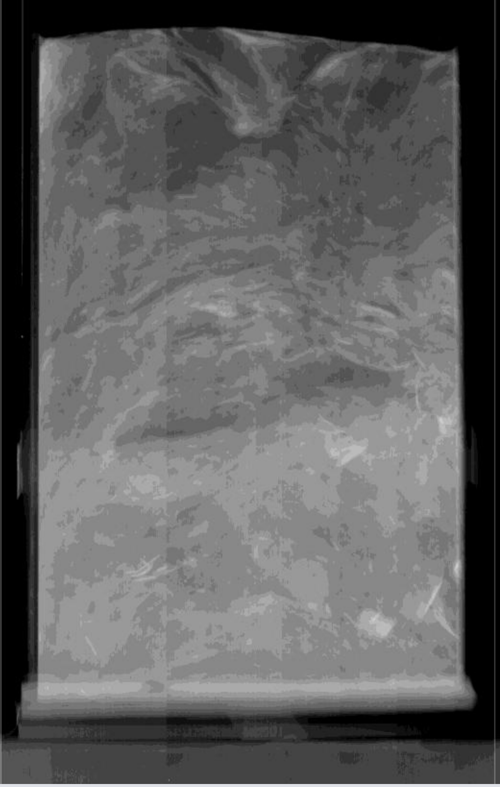
4901 A

4901 B



4897

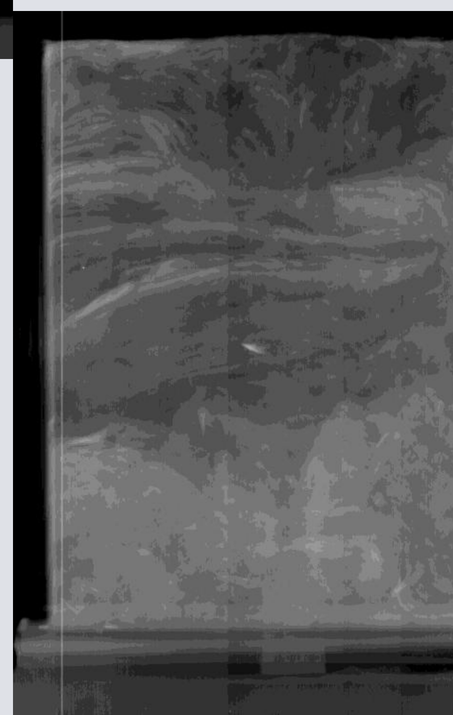
May 27, 2010 ~ Clay Bank



4905 A

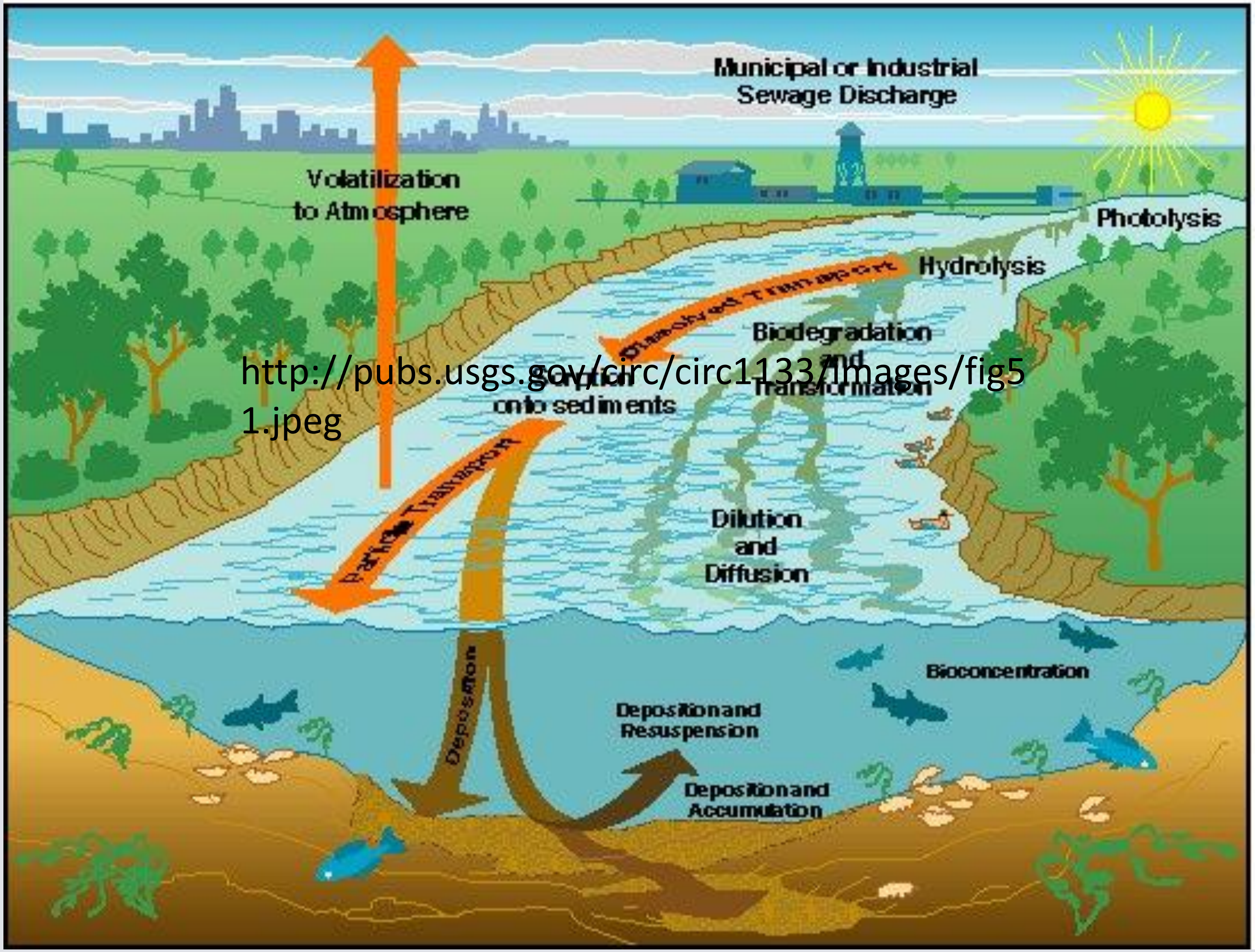
4905 B

4906 A



4906 B

Figure 51--*Fate of Contaminants in the River*



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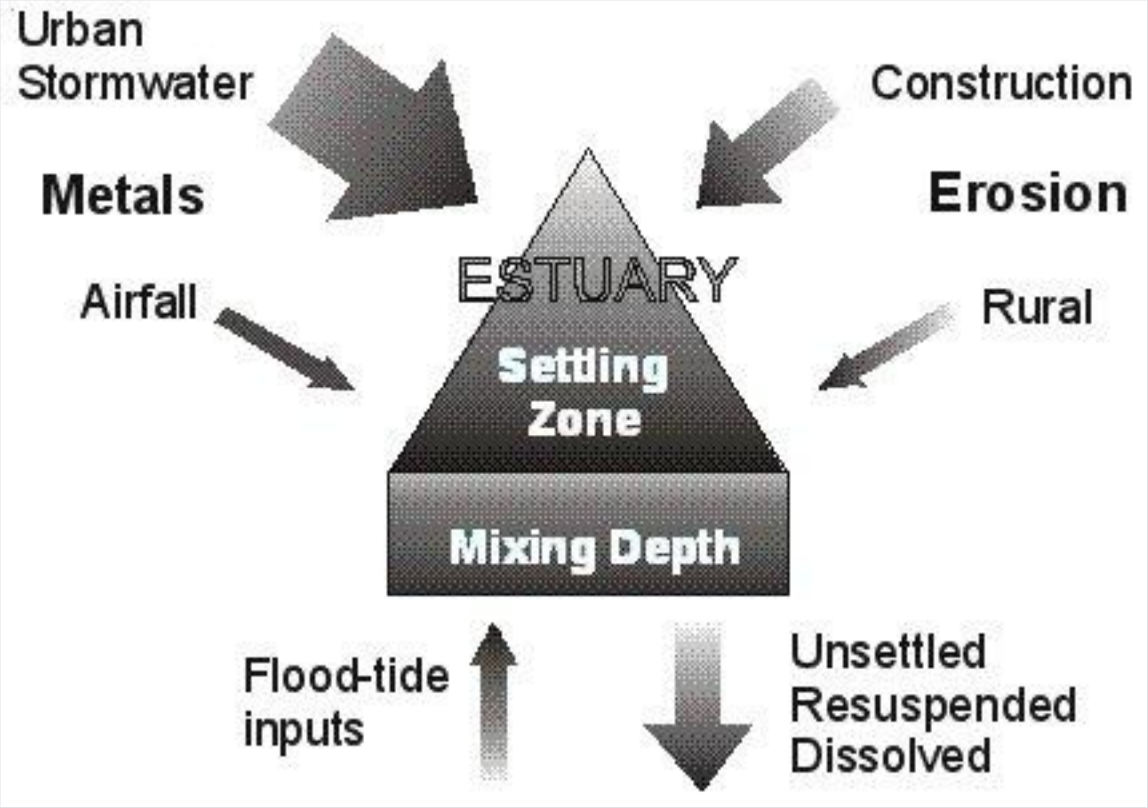
http://diffusesources.com/files/estuarydiagram.jpg



Fresh water and sediment transport

Lin and Kuo (2001)

- Persistent ETM - West Point

  - near limit of salt

- Ephemeral STM - Clay Bank

  -first stratification downstream of ETM

  -elevated river flow

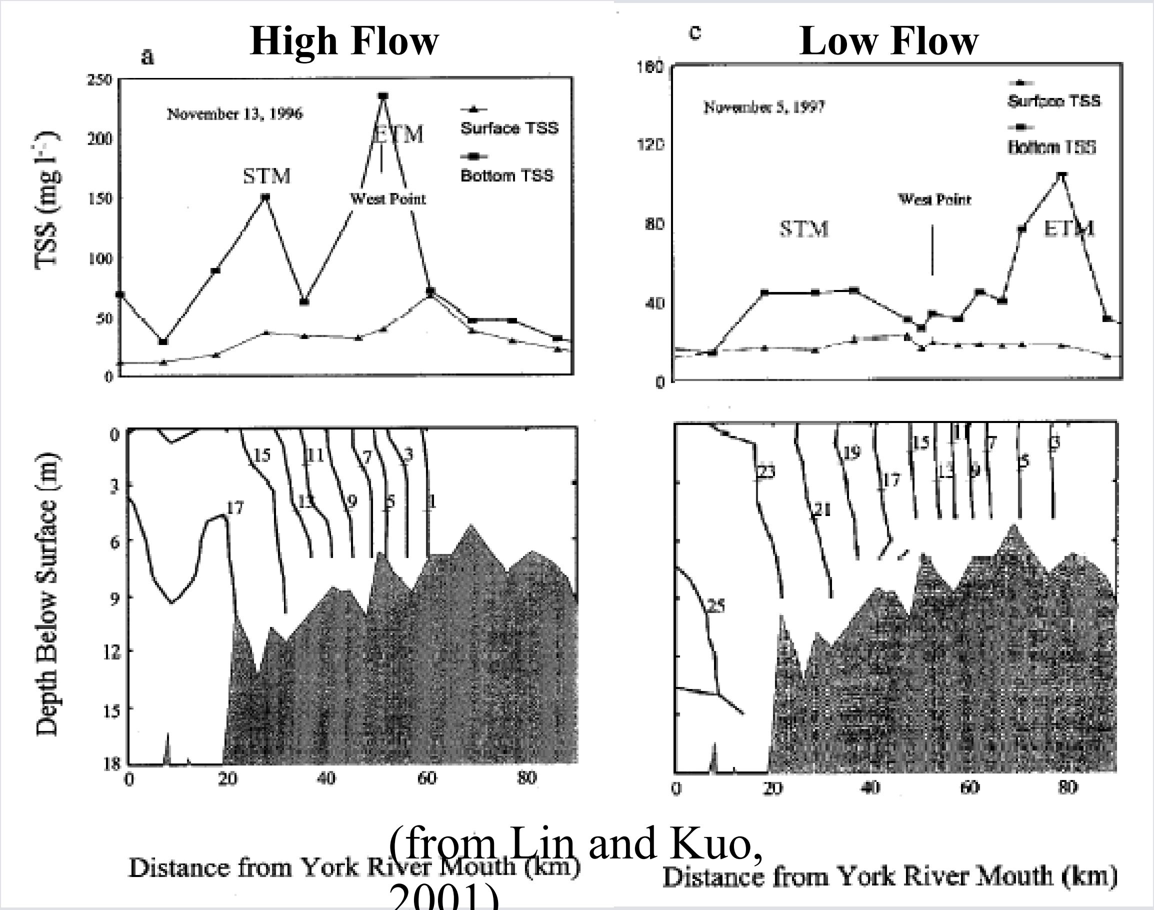
  - sediment trapping

  - high TSS

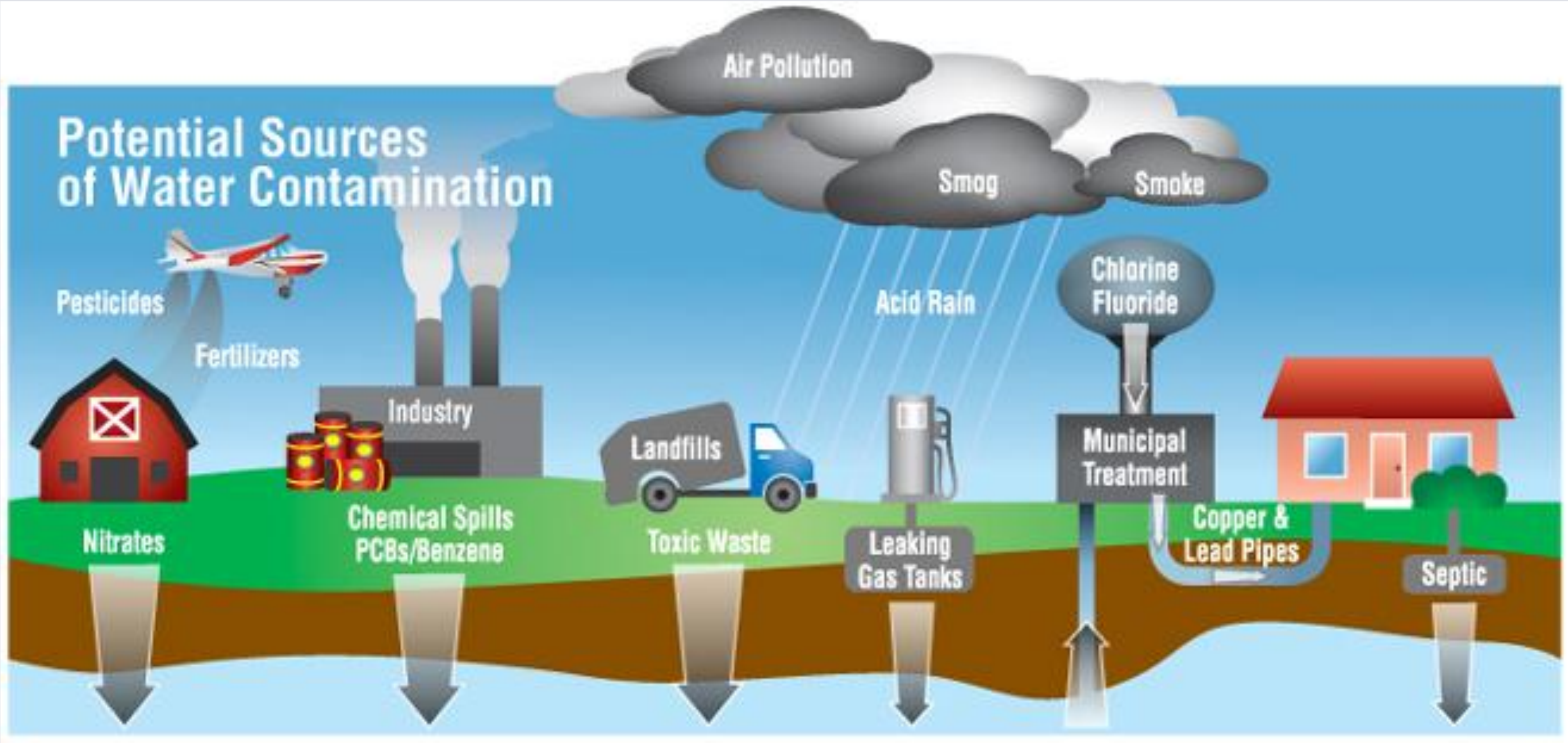
  - low river flow

  - no trapping

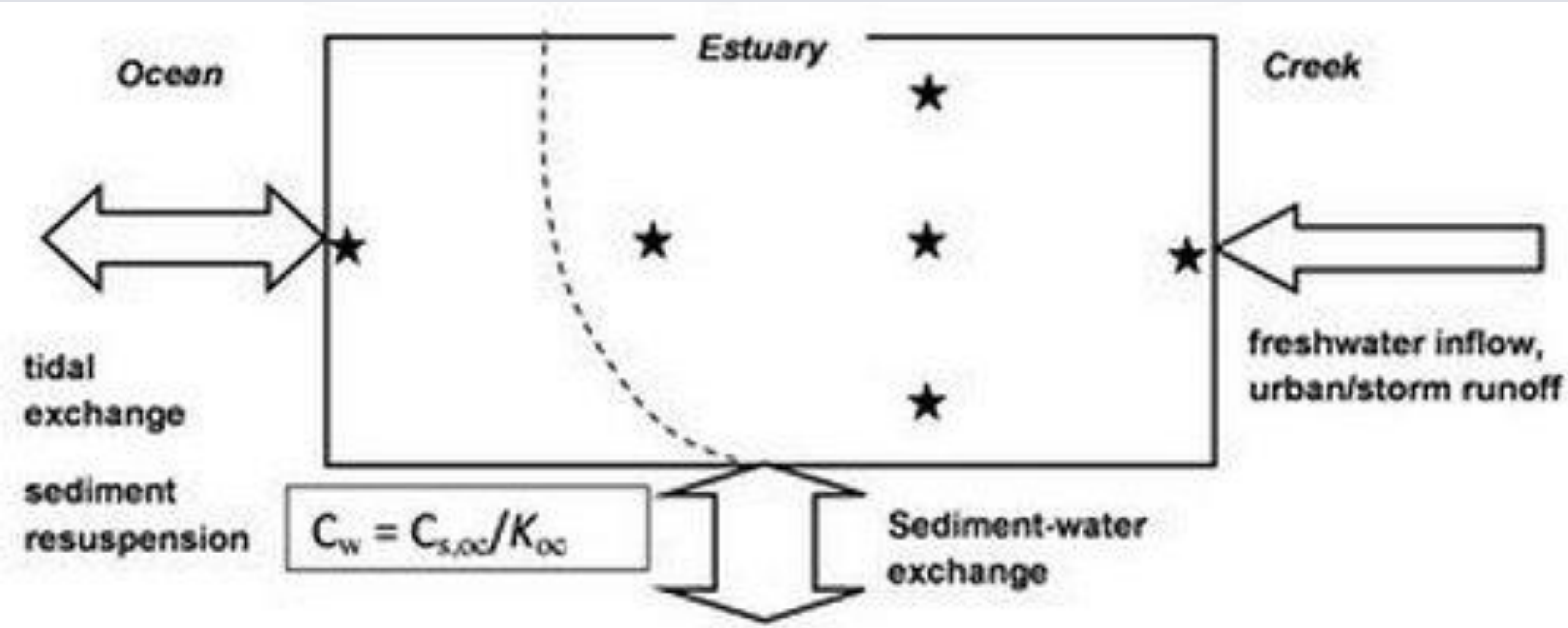
  - low TSS



(from Lin and Kuo, 2001)



http://www.waterwise.com/images/waterwisdom/thinkbeforeyoudrinkpict.jpg



http://www.sccwrp.org/images/ResearchAreas/Contaminants/MeasurementFateAndBioavailability/PassiveSamplingApplications/EstimatingLoadingsAndFluxes/EstimatingLoadingsAndFluxes_Figure1.jpg

Erodibility

-Stress to initiate movement of particles

- Mass eroded at a given stress

Influences on cohesion and erodibility

Physical

- ~~Salinity~~
- ~~Temperature~~
- ~~Mineralogy~~
- Grain size
- Consolidation (water content, solids fraction, bulk density, etc.)

Biological

Biostabilization

- Organic content
- Colloidal carbohydrates
- Extracellular polymeric substances (EPS)
- Pelletization (?)

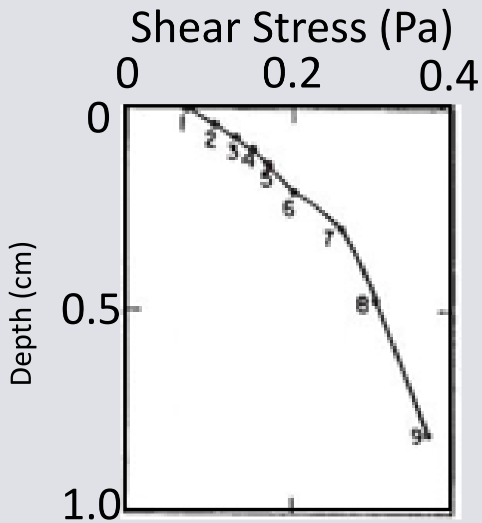
Biodestabilization

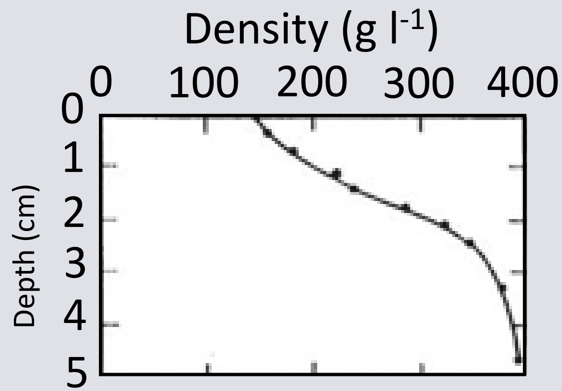
- Bioturbation
- Pelletization (?)

Consolidation and Erodibility

- Bulk density
  w/depth into sediment

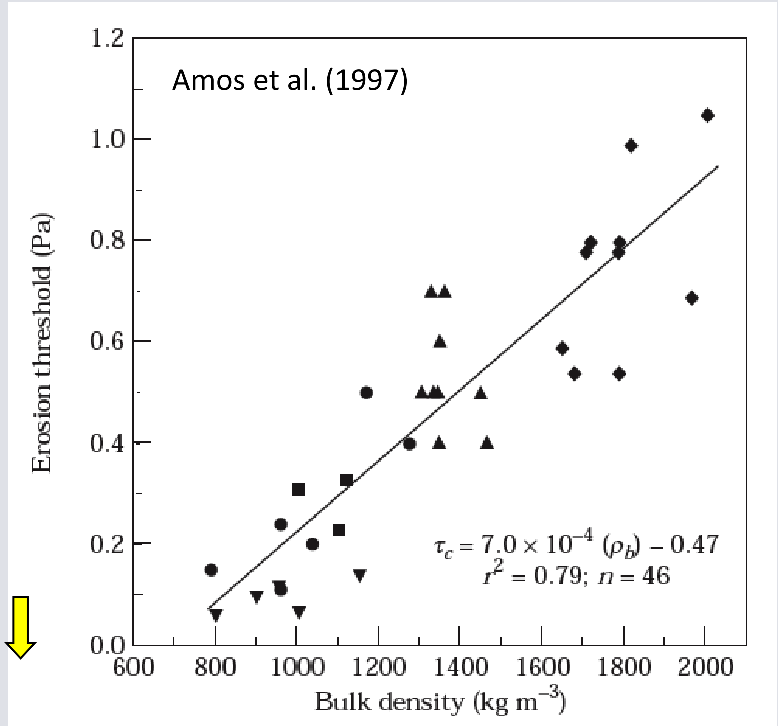
- As bulk density
  - critical stress (τ_c)
    and
  - erodibility





Parchure and Mehta (1985)

Erodibilit
y

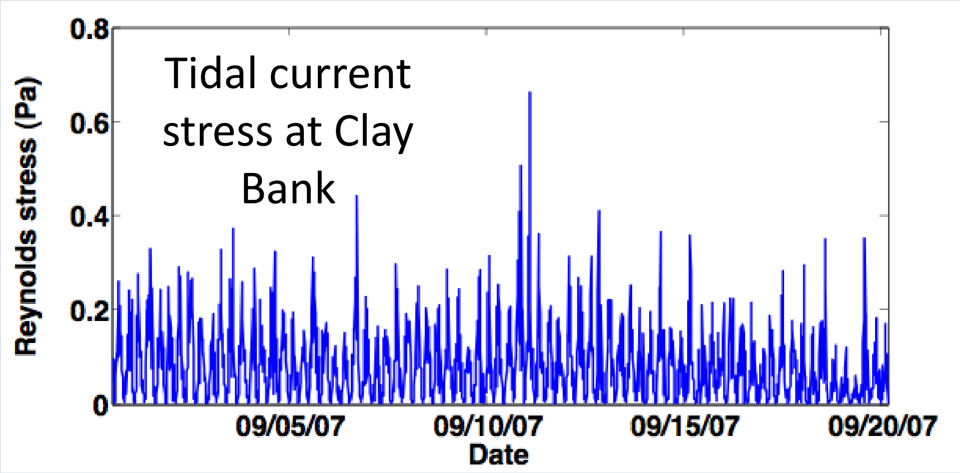


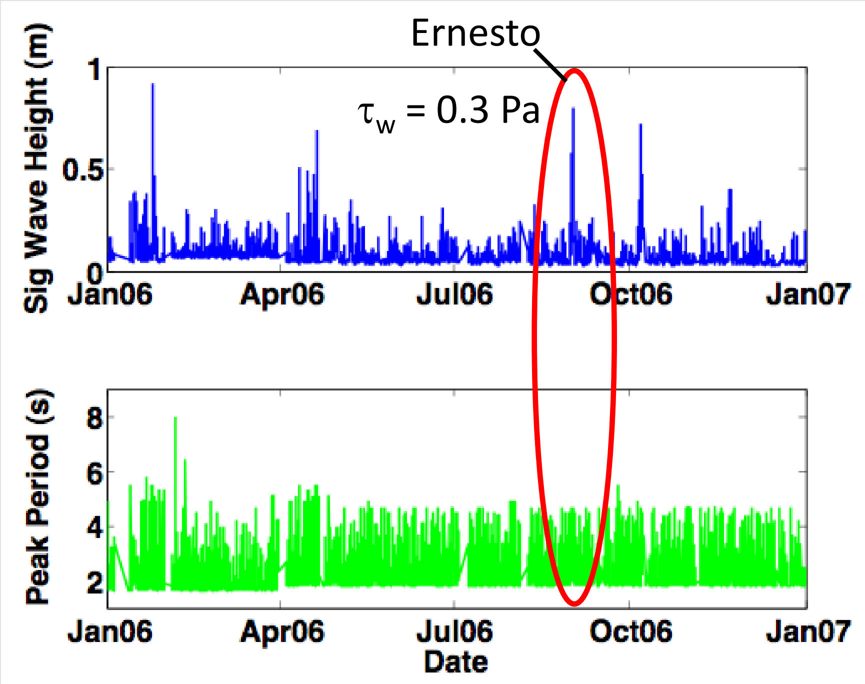
Influence of Tides vs Waves

- Microtidal
  - 0.8 m range
- Strong tidal currents
  - ~1 m s^{-1} near surface
- Severely fetch limited
  - Weak local wind waves
  - Period < 5 sec
  - Height < 0.5 m

-largest wave stresses ≈ average tidal stresses

- Suspended sed. stratification limits resuspension (Friedrichs et al (2000)





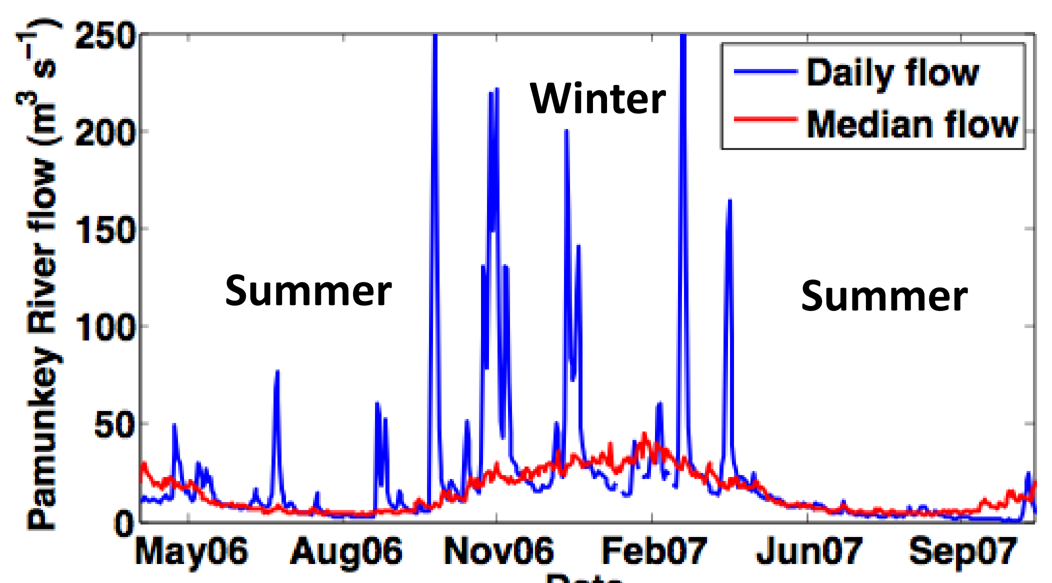
Fresh Water and Sediment Supply

Fresh Water Supply

- High in winter
- Low in summer
- Episodic

Sediment Sources

- Riverine
  ~ 55%
- Shoreline erosion
  ~ 12%
- Chesapeake main stem
  ~ 33%
  (Nichols (1991))



http://waterdata.usgs.gov/nwis

Residence Time

- 70 - 200 years
  -Dellapenna et al. (1998; 2003)
- Supply small relative to active in system