Scientific and Technical Advisory Committee Workshop
Conowingo Infill Influence on Chesapeake Water Quality
January 13 – 14, 2015

How Does the Bay Respond to Large Freshwater Events?

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Spill gates open – photo by David Harp

Tropical Storm Lee in 2011

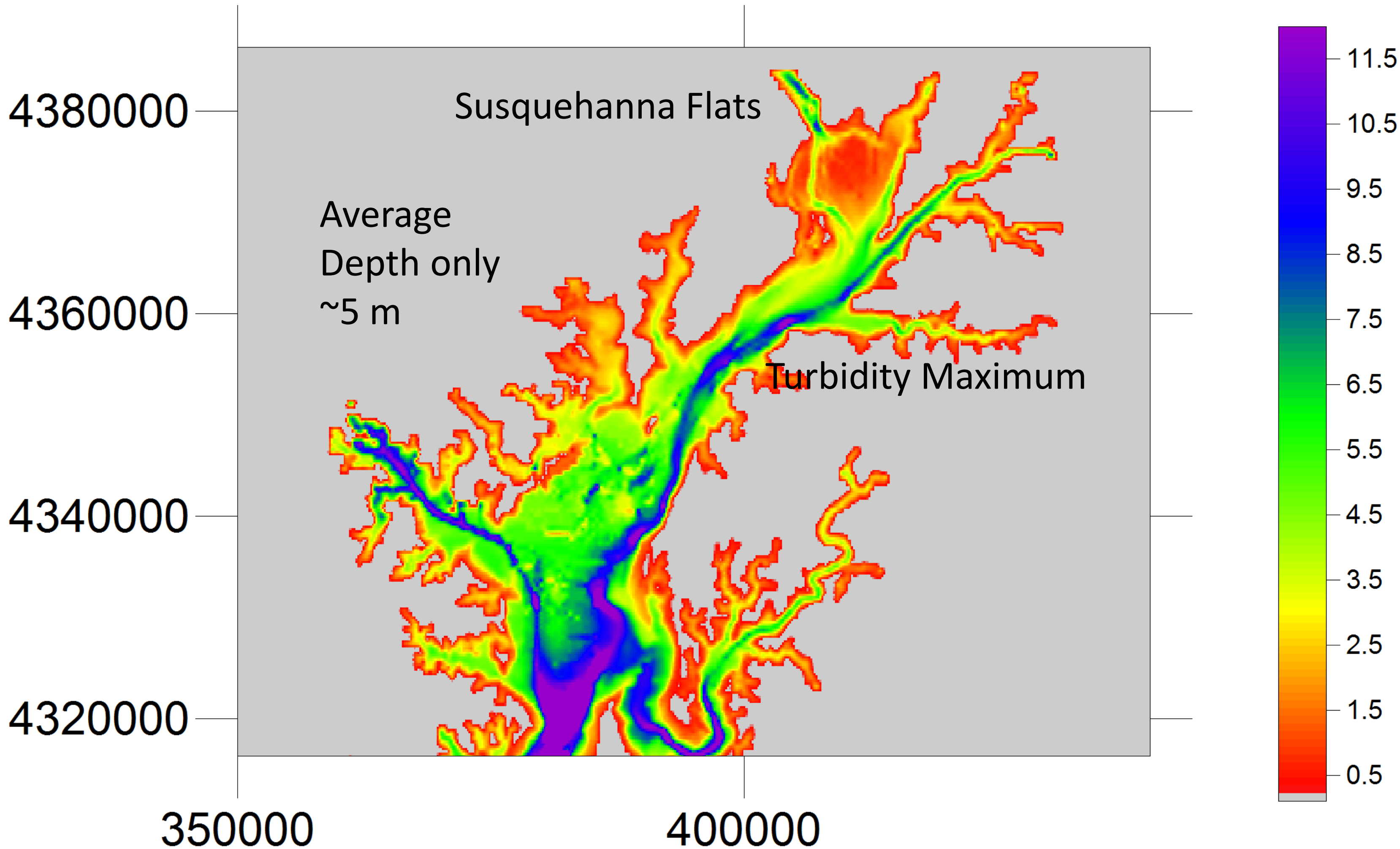
Focus on Chesapeake Bay circulation and sediment transport responses to large fresh water flow events from the Susquehanna River

- Assume that dissolved nutrient fluxes are not significantly enhanced by scour, because flows high enough to cause scour carry much larger riverine nutrient fluxes than are released by pore water erosion
- If this is the case then the additional sediment and nutrient impacts due to dam infilling are mostly due to increases in particle loads, particle transport processes, and the fate of particulate nutrients
- This talk considers only questions of particle transport and deposition, not resulting biogeochemical impacts. However, it is clear that particles that deposit in oxygenated upper Bay waters have much less biogeochemical impact than particles that deposit in the seasonally anoxic deep trough of the mid-Bay.

Sediment runoff during storms is common

- Sediment-related turbidity is widespread, generally highest near riverine sources
- Sediment loads after large rain events are large (~proportional to flow speed cubed)
- BUT:
  - Inputs come from all rivers, most of which are not dammed
  - Enhanced turbidity is relatively short-lived
  - Historical inputs were much larger, but the Bay was relatively healthy
- SO: How much difference does the infilling of Conowingo Dam make? Infilling is causing larger sediment loads than previously due to inhibited deposition/enhanced erosion

Upper Bay has three major features that can interrupt or modulate sediment and nutrient fluxes from the Susquehanna



From Jerry Schubel's summary of the geological effects of TS Agnes (June 21-23, 1972) on the Bay

Sedimentation rates were greatest in the upper reaches of the Bay and its tributaries, and decreased markedly in a downstream direction. In large areas of the upper Bay between Turkey Point and Tolchester 15-25 cm of new sediment was deposited by Agnes. In the shipping channel in this same region as much as one meter of new material was deposited. According to CBI observations, farther upstream on the Susquehanna Flats approximately ten acres of new islands and several hundred acres of new inter-tidal areas were formed. In addition, there was appreciable fill in several stretches of the shipping channel that extends from Havre de Grace to the head of the Bay.

Physical Characteristics of Susquehanna Flats

- Approximately 8 km across at widest point, ~7,600 m shallow flats and ~400 m channelized
- **Shallows < 1.5 m deep, shipping channel >6 m deep**
- Spring tidal range ~0.8 m, similar meteorological tides
- Susquehanna River flow averages ~1100 $m^3 s^{-1}$, lower in summer, instantaneous flow controlled at Conowingo Dam 10 km upstream from SF
- **Sandy bottom sediments, fining slightly towards south**
- **Dense submerged grass beds in late summer, absent in winter and early spring**

Preliminary ADH Model Flow Predictions (Steve Scott, ERDC)

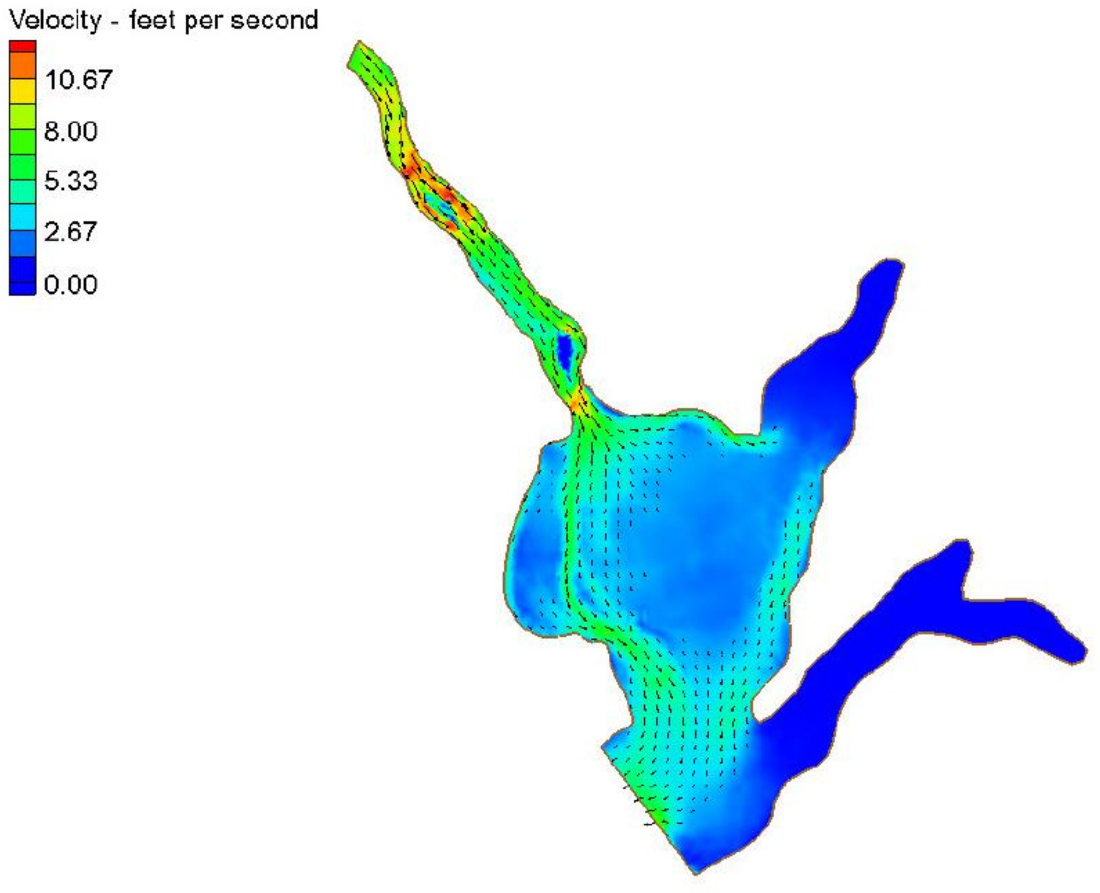
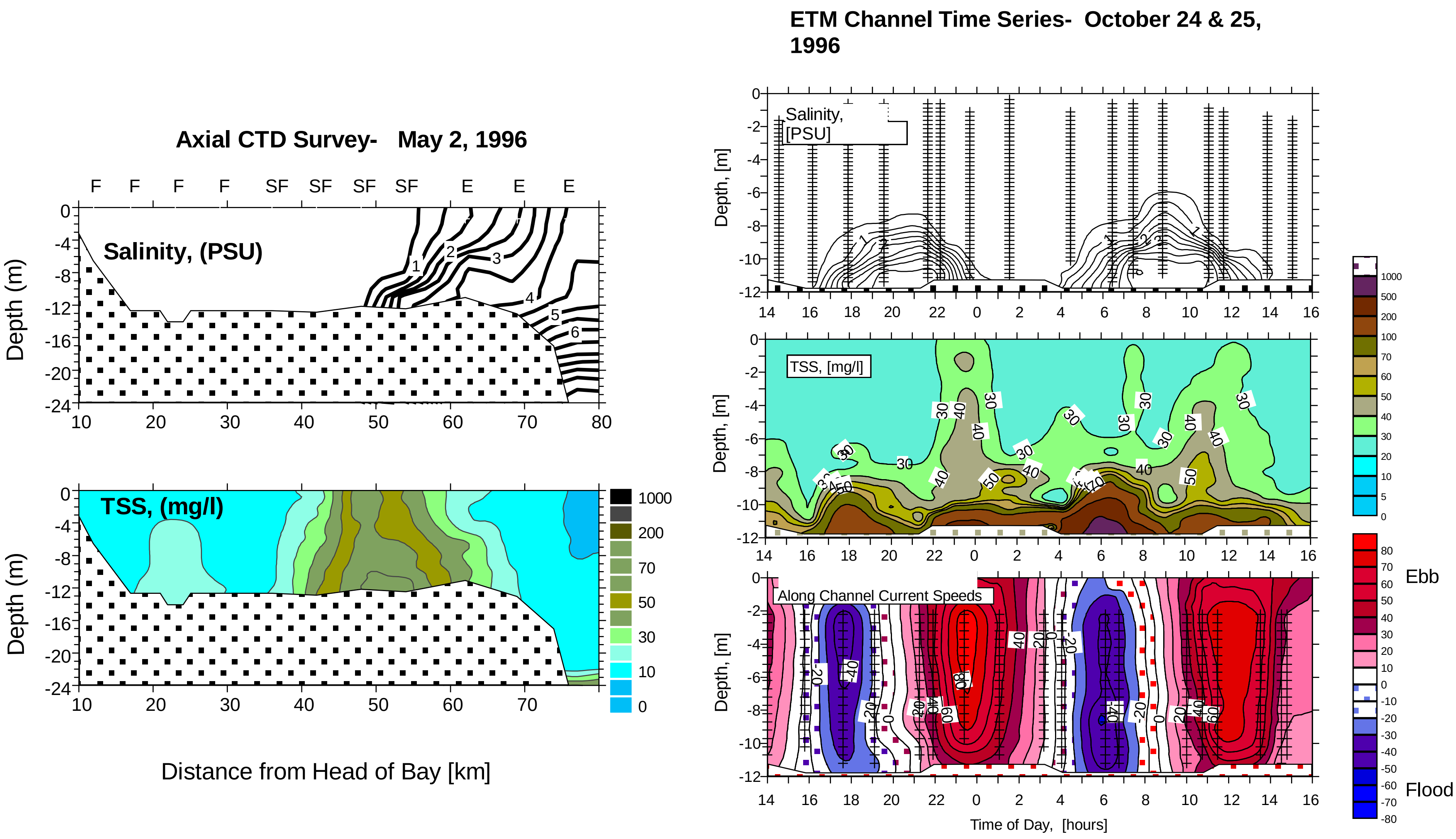


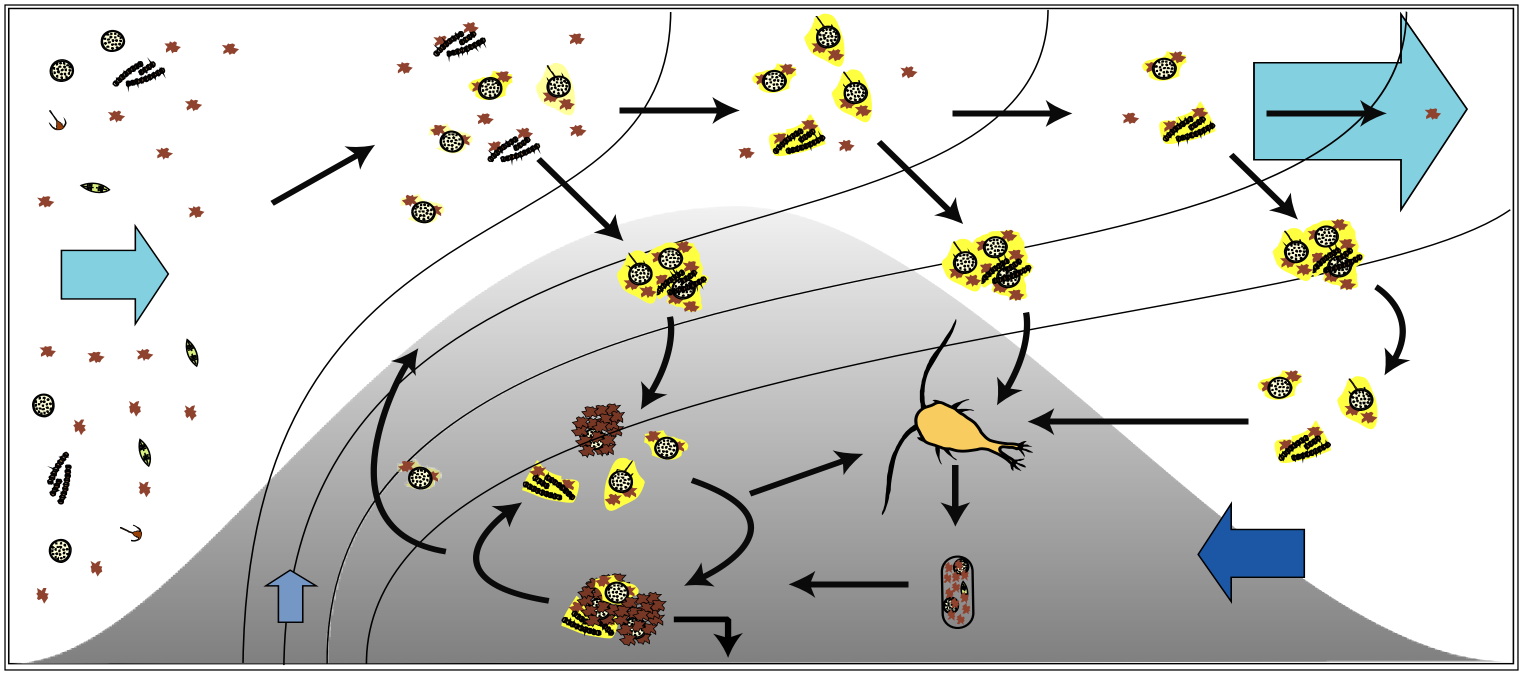
Figure 36 Velocity in Susquehanna Flats for a discharge of 600,000 cfs

Physical Features of the ETM

TSS= Total Suspended Solids



Conceptual Model of Particle Dynamics in Chesapeake Bay ETM:

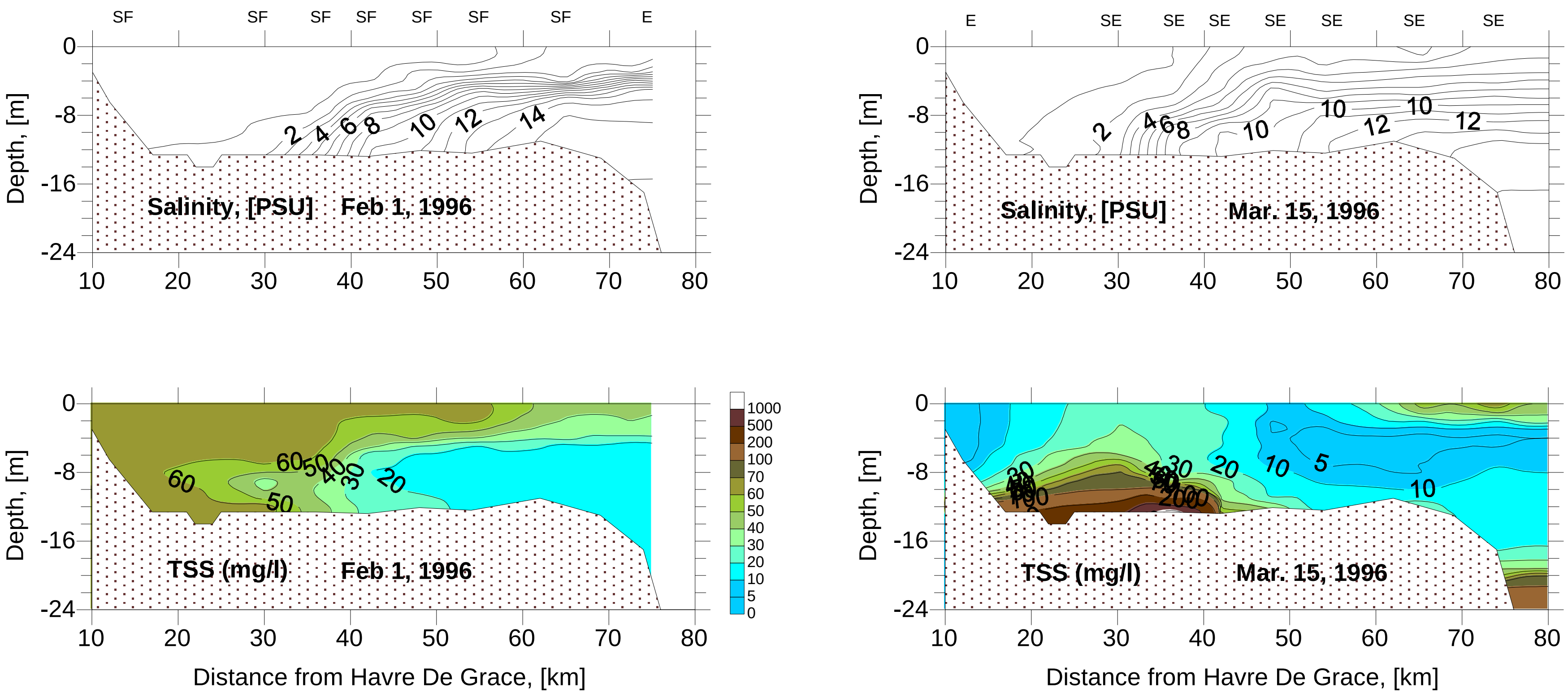


ETM are established and maintained through a combination of near-bottom transport convergence, particle settling, and tidal resuspension. The efficiency of particle trapping is enhanced by flocculation/aggregation, which is enhanced by biological activity.

ETM Salinity and Suspended Sediments

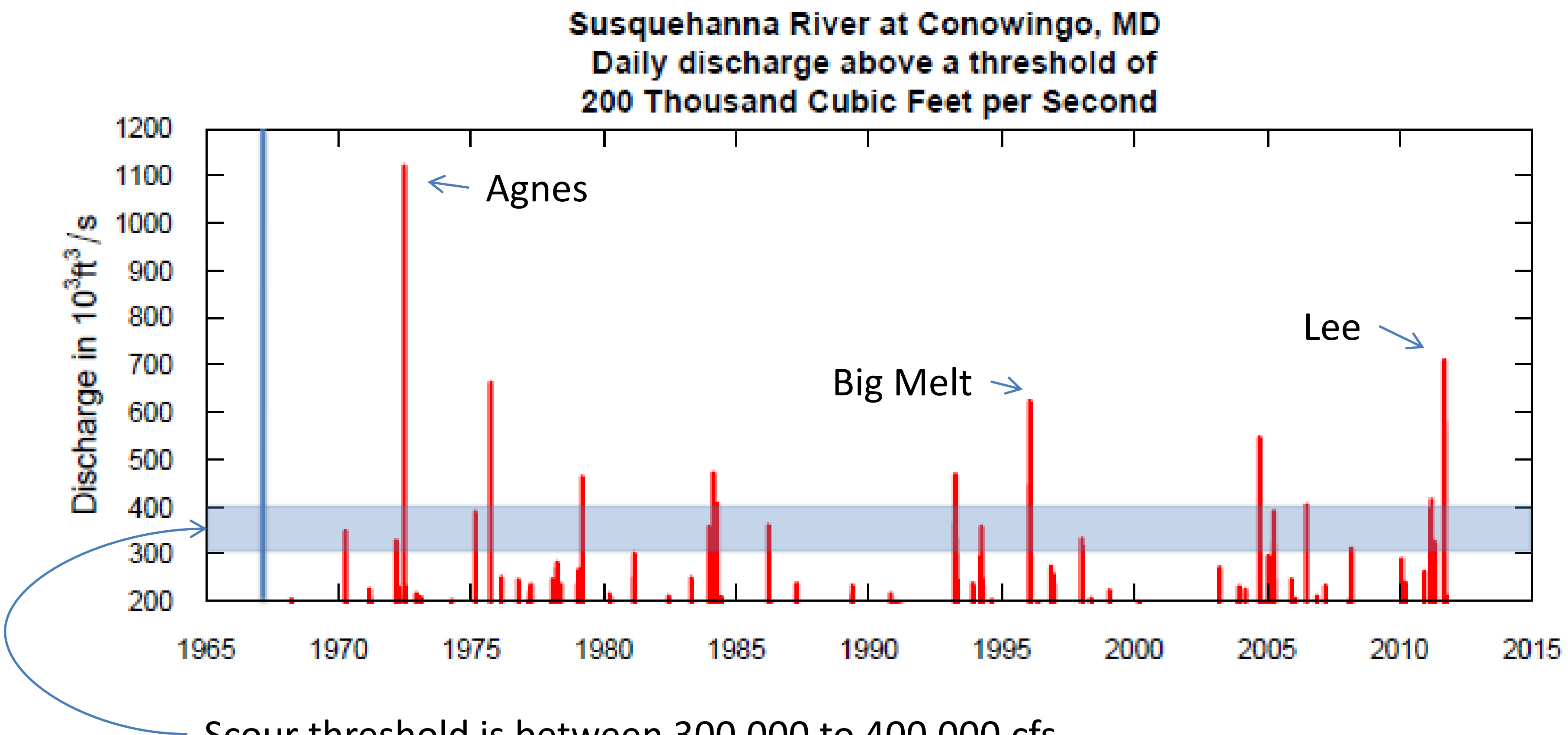
(Winter/Spring 1996)

There are circumstances associated with some high flow events that allow sediment to escape the ETM and move seaward beyond the upper Bay, but the efficiency of the ETM sediment trap is rapidly re-established afterwards.



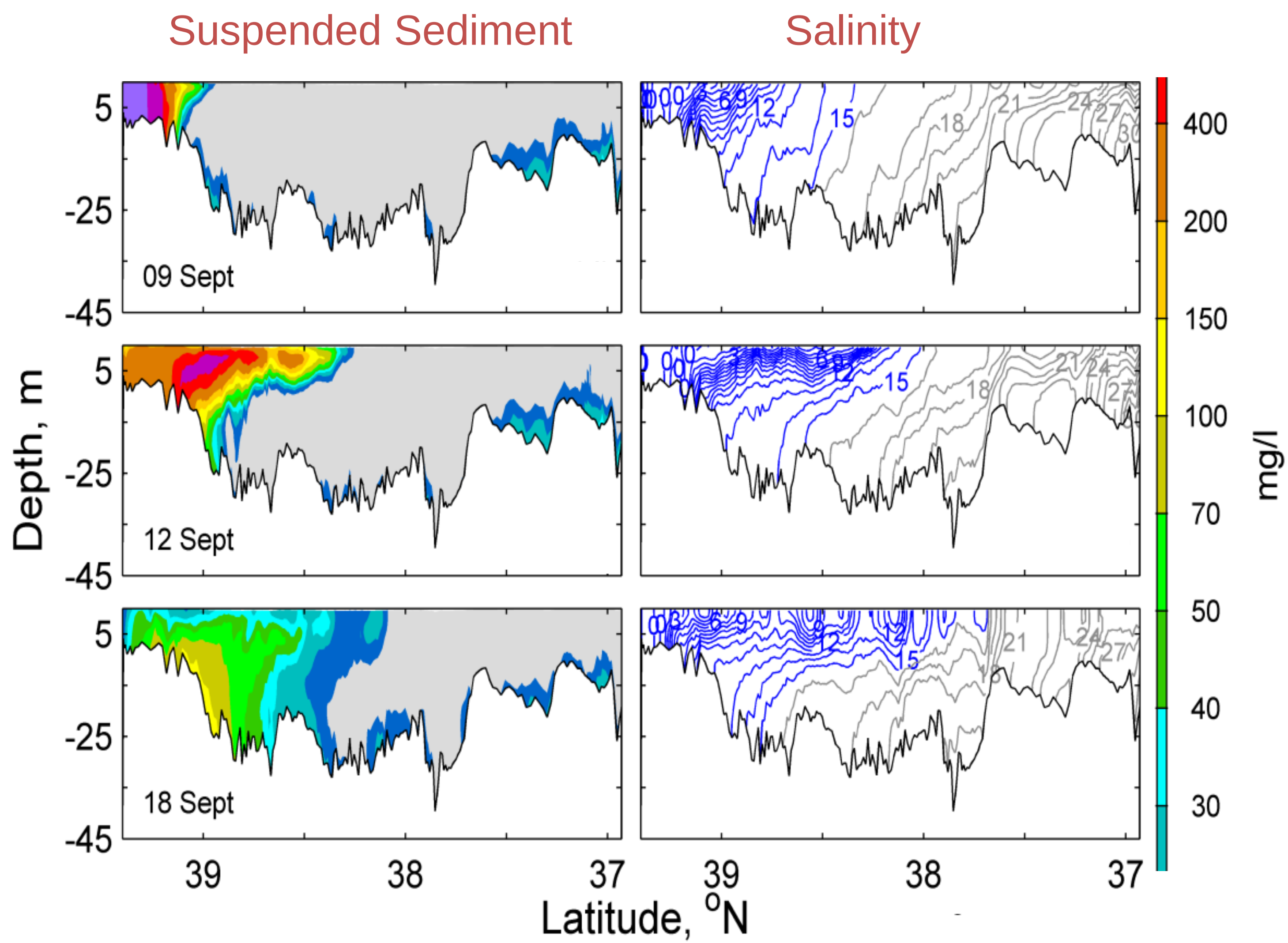
When, why, and how much?

Historical Flow – Peaks Indicate Scour Events (Pulses)



Scour threshold is between 300,000 to 400,000 cfs

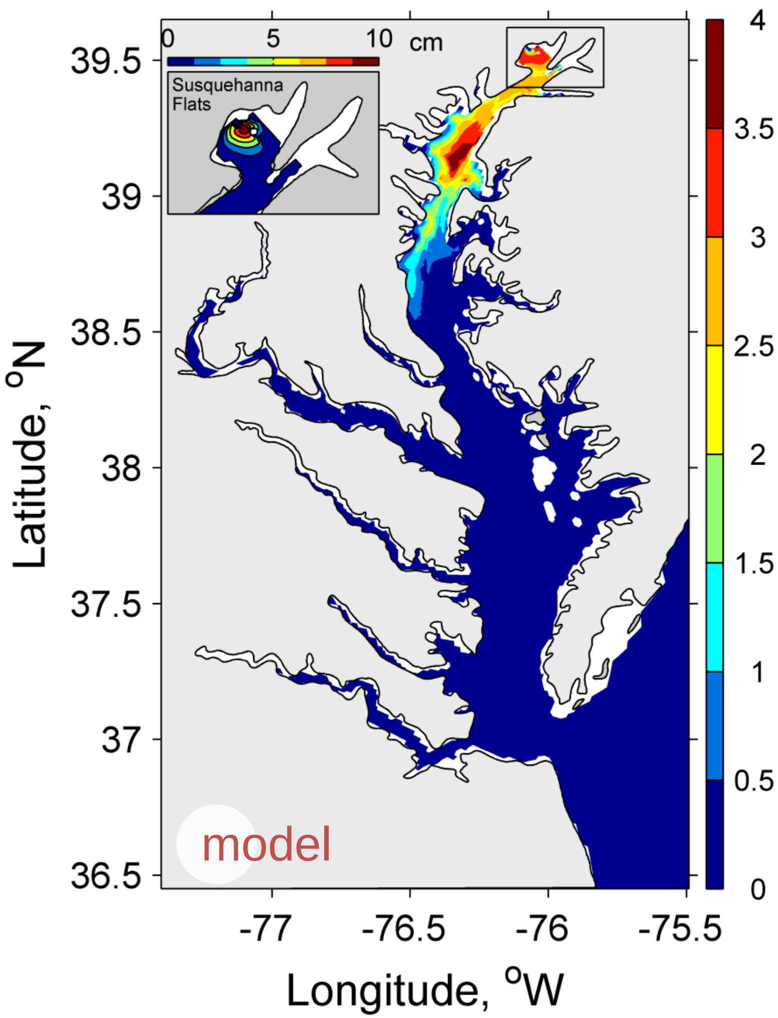
Computer Modeling of sediment plume and salinity – Ming Li's group
This example shows a model of TS Lee in 2011

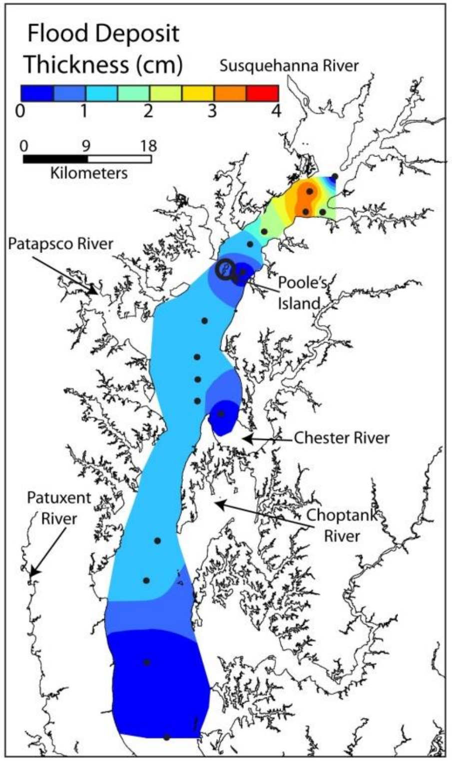


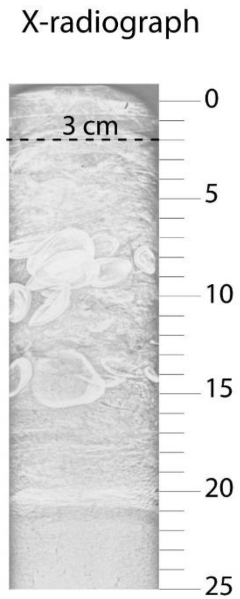
Sediment plume evolved in three stages: river forcing; gravitational adjustment and sediment setting (Cheng et al., 2013).

Sediment deposition

Comparing model predictions (left) to observations (right)







observations from sediment cores

10 cm of sands were deposited in Susquehanna Flats.
3-4 cm of silts and clays were deposited in upper Bay, in agreement with coring measurements (Palinkas et al., 2014).

But what about those enormous plumes of dirty water that are visible from space?

Tropical Storm Lee in 2011

- Large sediment plume is confined to relatively fresh upper layer (~ 5-7 m thick)
- In order to remain suspended, the particles must be very fine and settle very slowly
- The finer particles are, the better they reflect light (think fog vs. rain)
- The plumes visible from space are likely relatively thin and contain high, but *not huge* concentrations of fine particles – but we need more and better data
- There is some highly relevant work recently published or ongoing using satellite imagery to make quantitative estimates
- **50 mg/l in a 5 m thick layer amounts to 0.25 kg/m^2 of material, or about 1 mm of deposition**

- The other large influences of major storms on the Bay are fresh water and dissolved nutrient loads
- This figure from the TS Agnes book shows surface salinities approximately 10 days after the storm in the lower (VA) Bay ranging from 3 off the Potomac to 16 at the Bay mouth
- Infilling of the Conowingo Dam makes little (if any) difference for fresh water and dissolved nutrient loads
- The authors of that report noted that fresh water caused the most dire impacts to the oyster and soft clam populations

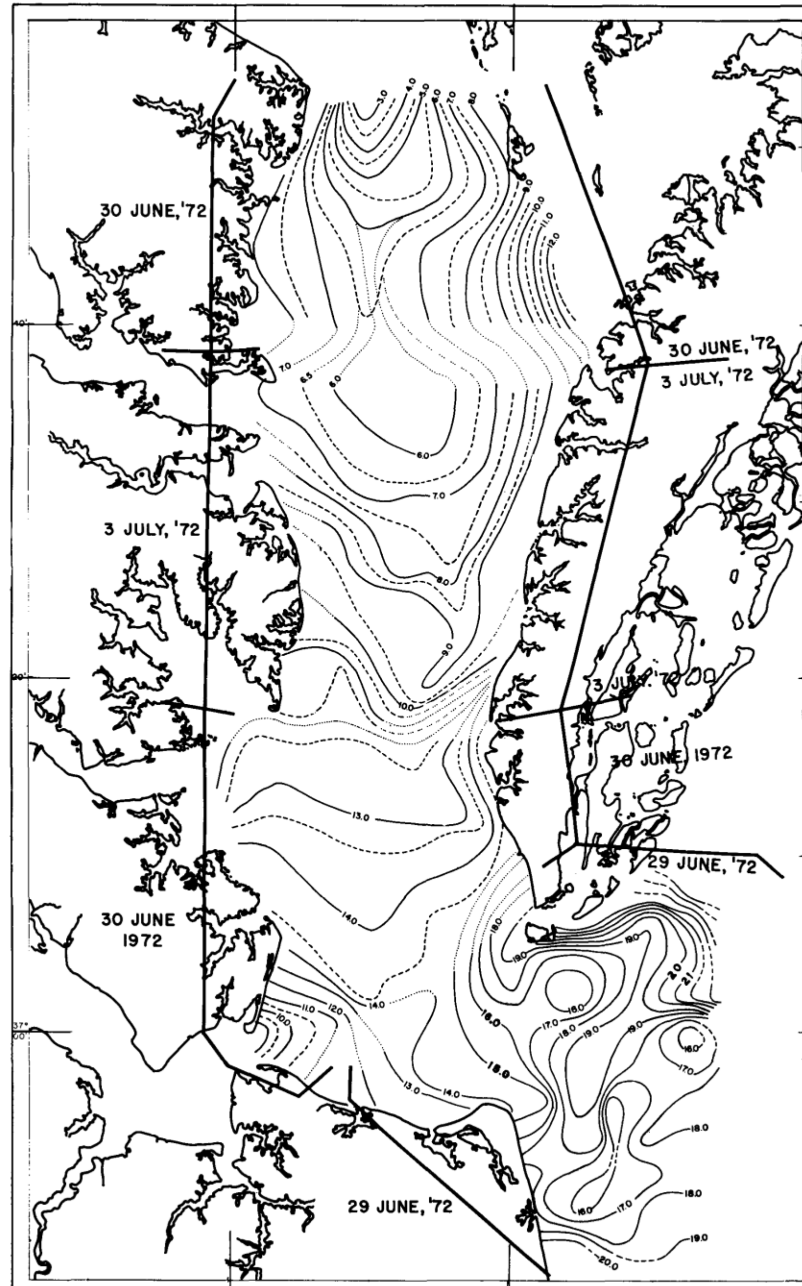


Figure 6. Surface salinities for lower Chesapeake Bay during the period 29 June - 3 July 1972.

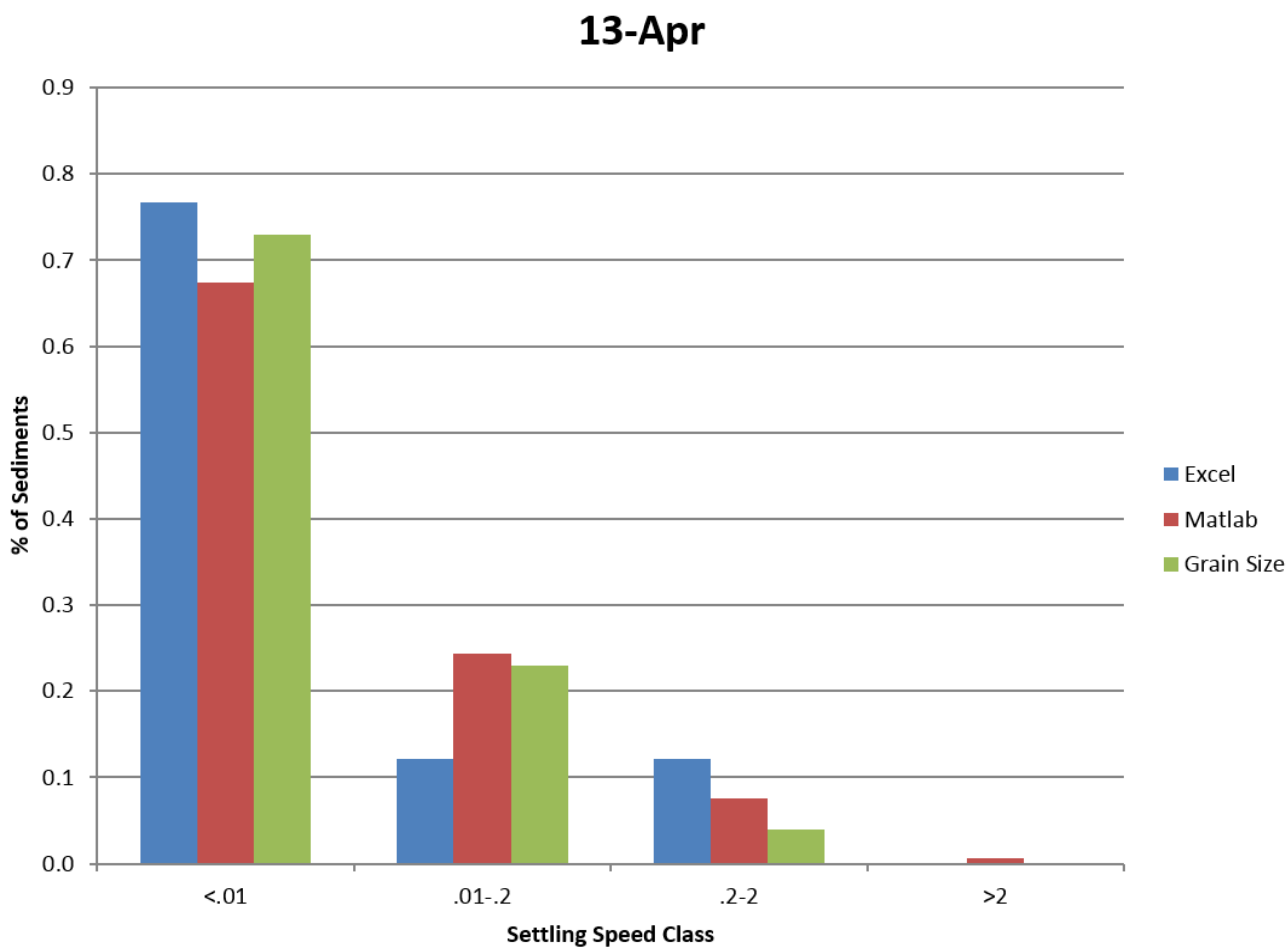
How to estimate and parameterize particle settling speeds?

- Particle inputs across Conowingo dam encompass a range of particle sizes and settling speeds
- Particle size distributions have been measured during selected events by USGS
- A number of previous studies have investigated particle sizes and settling speeds in the Bay
- My group's role in the current Conowingo project is to characterize suspended particle sizes and settling velocities, both at the dam and downstream during events

Settling tube measurements – Sanford group

USGS Sampling at the Catwalk

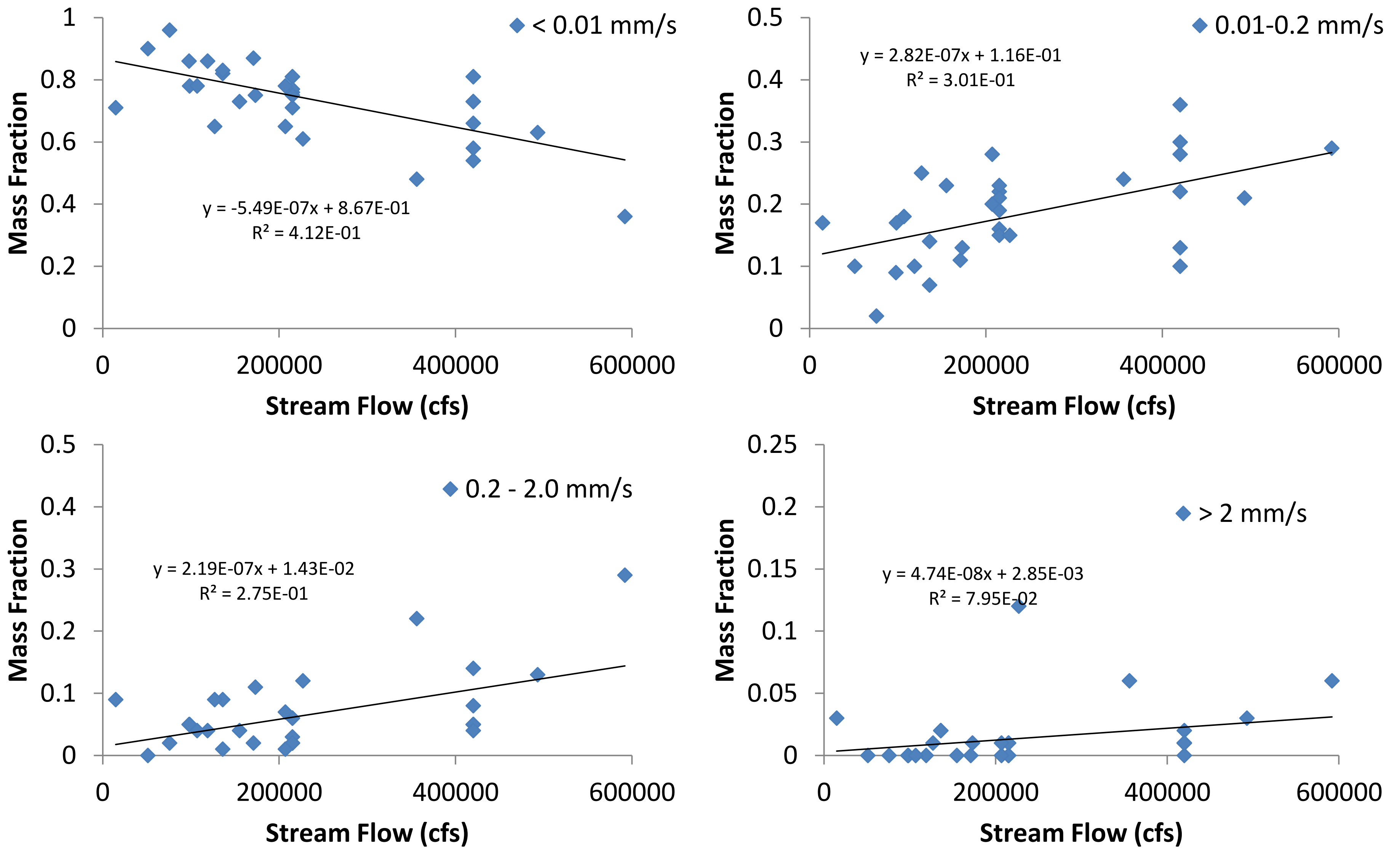
Settling tube experiment



Grain size based settling velocities calculated using Stokes settling velocity formula, assuming solids density is 2,650 kg m^{-3}

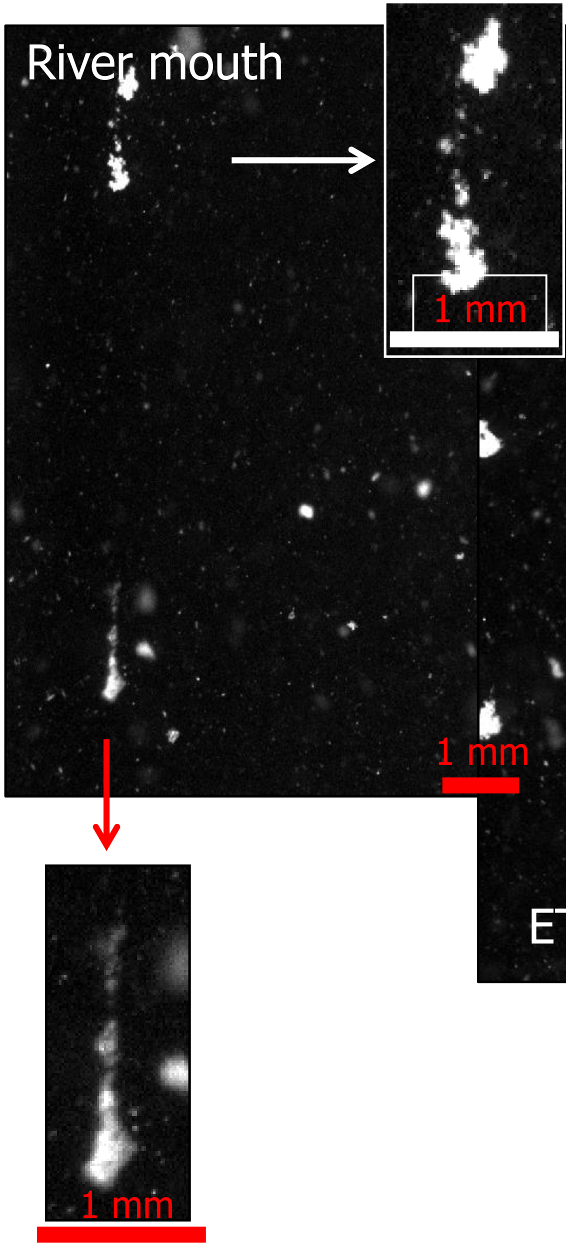
Plot comparing % of total sediments for each of the four settling classes found using the UMCES settling tube analyses and the USGS grain size analysis for the event on April 13th, 2015. The data agrees nicely, as the percentages are similar for each class across the three methods. This means that using the more readily available grain size data for events such as this one is sufficiently accurate.

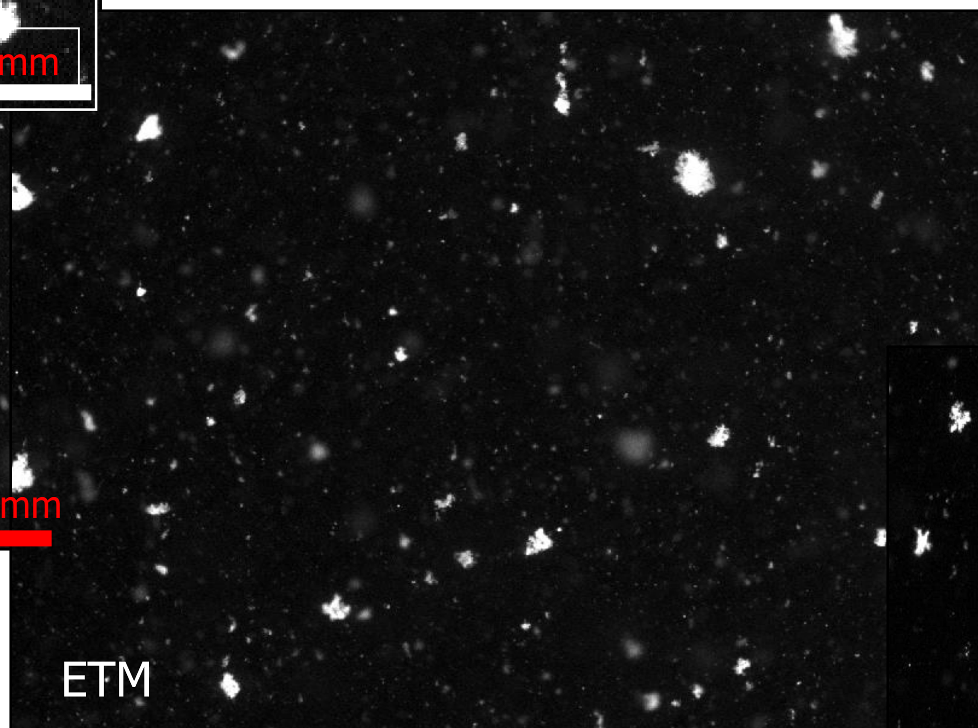
Mass Fractions in Different Settling Velocity Classes as a Function of Flow Speed from USGS Particle Size Observations. Different fractions sum to 1 at all settling speeds.

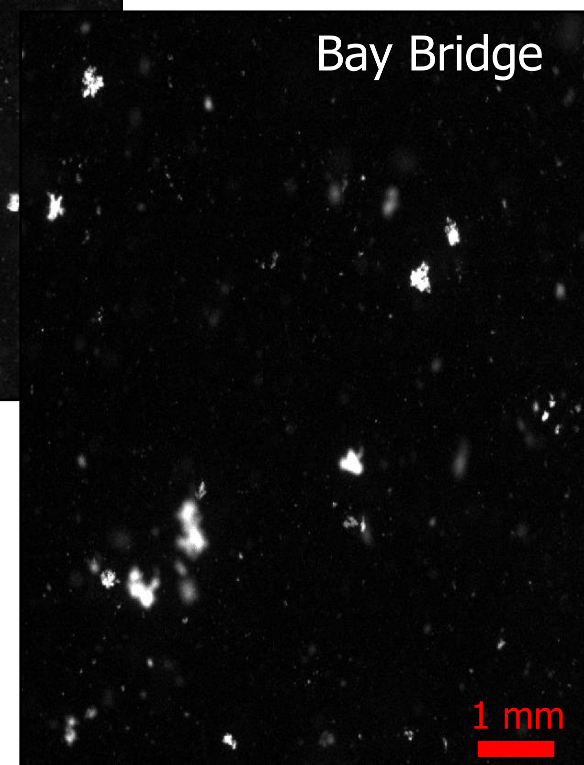


Flocculation becomes important as particles enter estuary

Settling velocities of large flocs typically 1 mm/s, even though component particles are almost entirely clay sizes







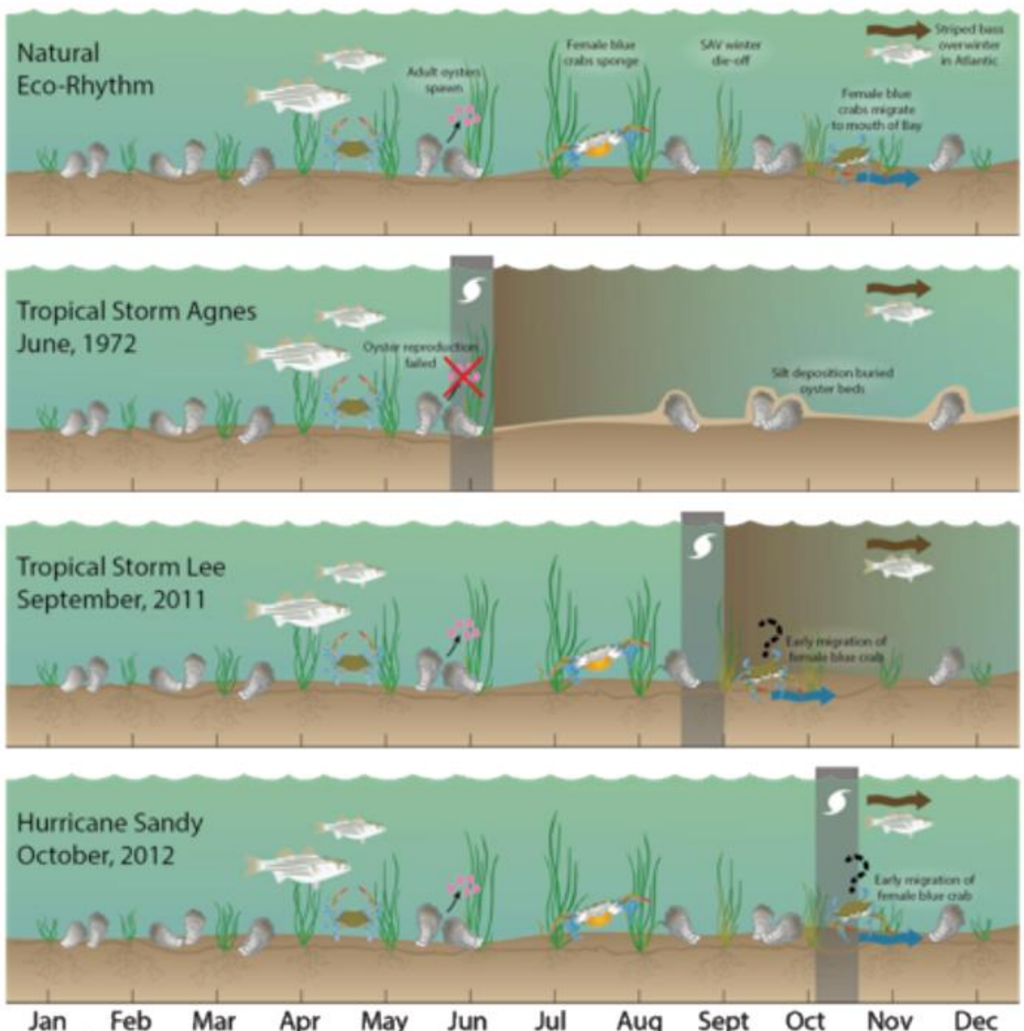
Still to come – Upper Chesapeake Bay Plume response cruises on the RV Rachel Carson

Nature has not been cooperating, but we are working in the meantime to analyze existing data, and we are planning an early spring cruise whether or not there is an identifiable event.

Preliminary Conclusions

- Susquehanna Flats may not be a significant long term trap for particulate nutrients, though seasonal modulation of nutrient loading may be more important
- Under low to moderately high flow conditions, it is likely that the ETM does trap (and bury) most of the sediment loading from the Susquehanna.
- There is significant bypassing of the ETM under very high flow conditions, but when and how much remains to be determined.
- Characterizing and parameterizing particle settling speed distributions, and possible changes in these distributions with flow and location, is critically important!
- Significant redistribution of recent deposits occurs post-deposition before “final” incorporation into the surface sediments

The Timing of the Event Affects the magnitude of the Water Quality Impact on the Bay



Spring/summer event has the most impact

Fall event has the least impact

ian.umces.edu

From Dennison, 2013

Time Frame

- Program start – Feb 2015
- Spring/Summer 2015 – long core program
- Spring 2015: sediment-water exchange program
- Spring freshet/events – Settling behavior, biogeochemistry, possible flood response cruises
- Summer 2015 – estuarine core experiments, possible flood response cruises
- Modeling –throughout
- Most data – by summer 2016
- Draft Final Report – Oct/Nov 2016
- <u>Final Report – Dec 2016</u>