TVA Kingston Fly Ash Transport and Fate Study

Post-Spill Site Overview

Photo taken 01/08/09 by TVA.

Steve Scott ERDCWES – Principal Investigator

Craig Zeller – EPA Region 4 Remediation Project Manager

TVA Kingston Fly Ash Transport and Fate Study

The Emory River Impacted by Fly Ash Deposits

TVA Kingston Fly Ash Transport and Fate Study

Immediate Impacts to the Emory River

- **Reduced Channel Capacity / Increased Flood Risk (+ 8.0 feet for a 100 year return flood)**
- **Increased River Sediment Transport Capacity / Fly Ash Transport Risk**

TVA Kingston Fly Ash Transport and Fate Study

Goals of the Study

2009 - 2010

- Simulate Changes in River Hydrodynamics
- Evaluate Fly Ash Erosion and Transport Properties in Laboratory
- Simulate Fly Ash Transport and Fate for May 2009 Flood Event
- Evaluate The Impact of Dredging on Fly Ash Transport Potential

2010 – 2011

- Simulate Monitored Natural Recovery for Watts Bar Reservoir

TVA Kingston Fly Ash Transport and Fate Study

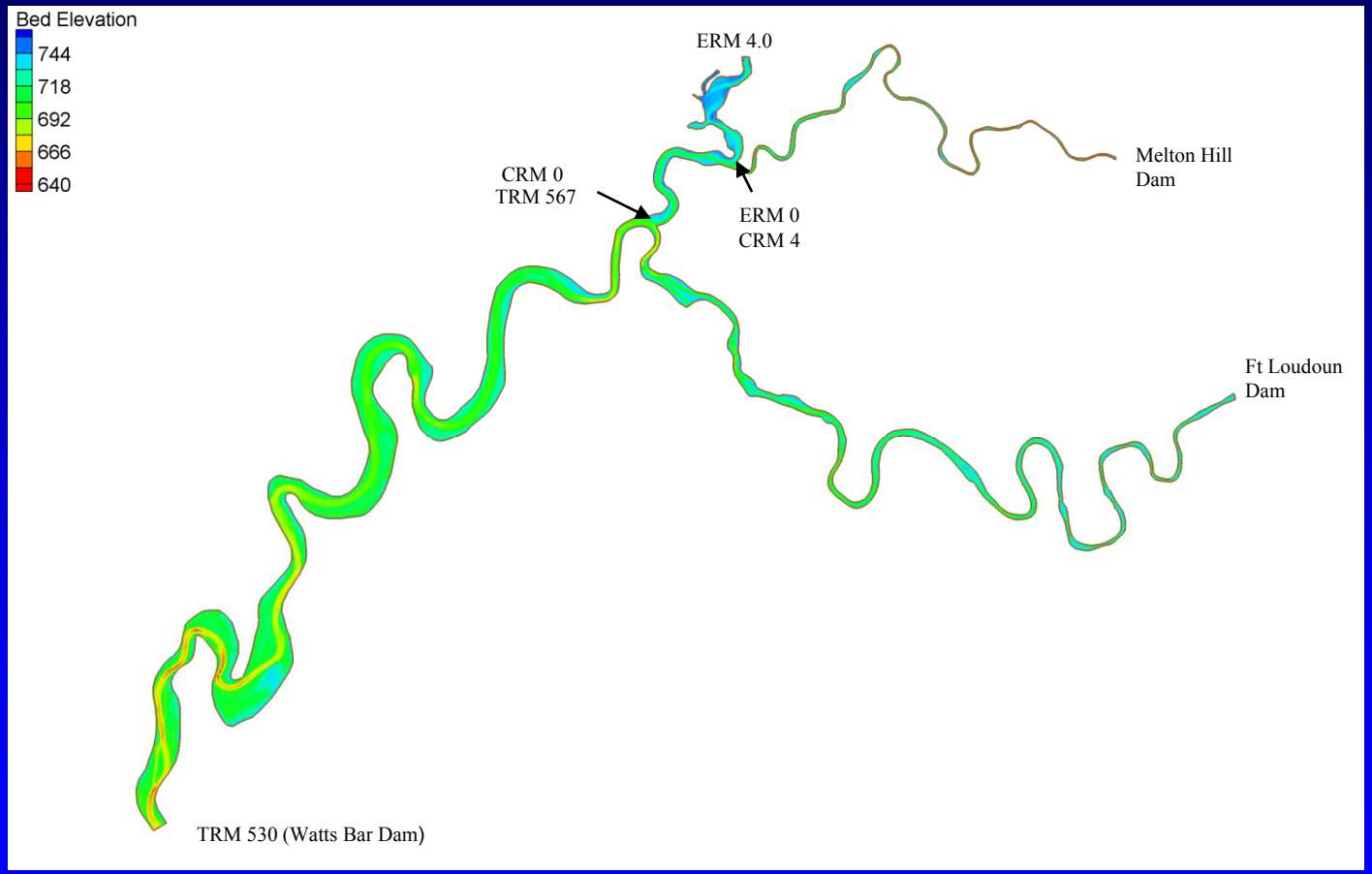
Methods

Modeling

- **Construct a 2D hydrodynamic / Sediment Transport Model (Watts Bar Reservoir Including the Emory, Clinch, and Tennessee Rivers)**
- **Utilize the Adaptive Hydraulics (AdH) Model Developed at ERDCWES**

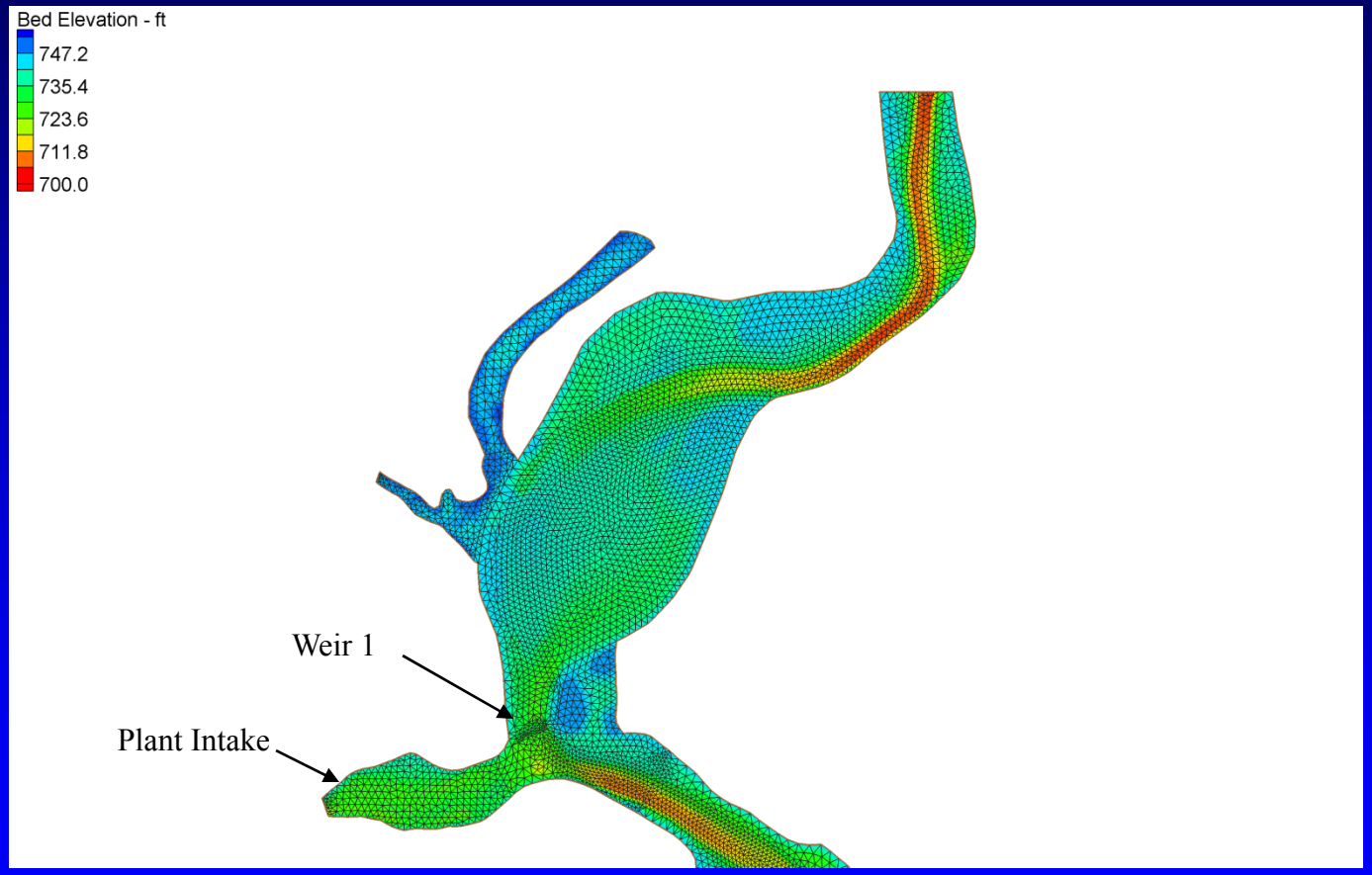
TVA Kingston Fly Ash Transport and Fate Study

Model Domain



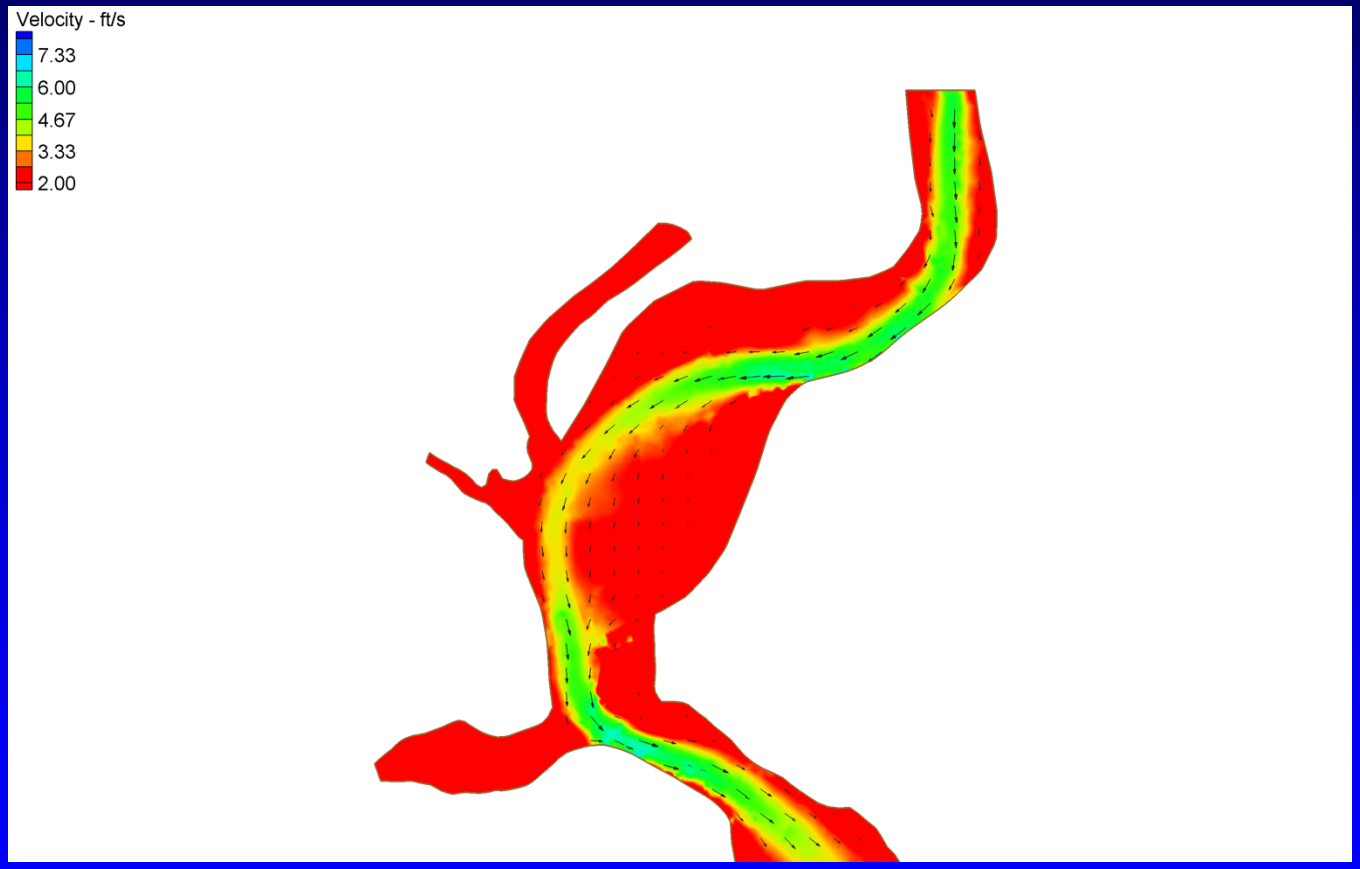
TVA Kingston Fly Ash Transport and Fate Study

Model Domain – Kingston Site



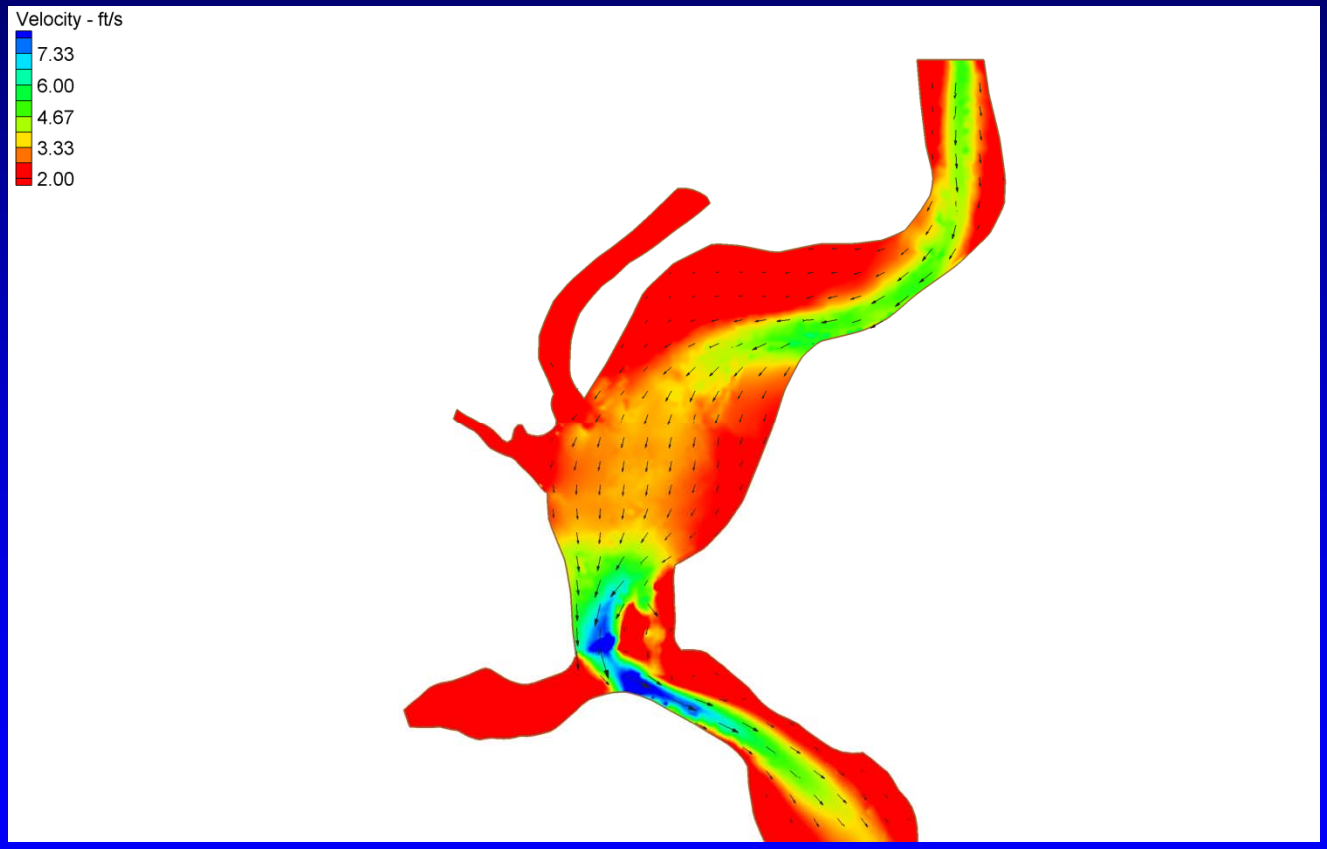
TVA Kingston Fly Ash Transport and Fate Study

Hydrodynamic Impacts: Pre-Spill Velocity – 70,000 cfs



TVA Kingston Fly Ash Transport and Fate Study

Hydrodynamic Impacts: Post-Spill Velocity – 70,000 cfs



TVA Kingston Fly Ash Transport and Fate Study

Comparison of pre and post spill hydrodynamics

- Fly ash spill increased flooding and transport risk
- A comparison of pre and post spill hydrodynamics indicates that channel transport capacity increased post spill
- Dredging restores channel capacity and bed slope to pre spill conditions

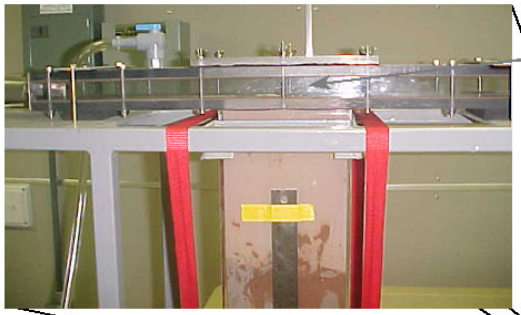
TVA Kingston Fly Ash Transport and Fate Study

Fly Ash Erosion / Transport Characterization

- **Laboratory scale SEDflume at ERDCWES**
- **Measures erosion rate of sediment cores**
- **Measures critical shear stress for erosion**

TVA Kingston Fly Ash Transport and Fate Study

SEDflume Description and Operation



ShearStress	Flow Rate
Pa	gpm
0.1	6.1
0.2	9.8
0.4	13.5
0.6	16.8
0.8	20.1
1.2	25.0
1.6	29.8
2.4	36.9
3.2	44.0
4.0	49.3
5.0	55.8
6.4	65.0
8.0	72.9
10.0	82.7

SEDflume Procedures

- Formed fly ash cores from TVA samples
- Cores were tested after 3, 15, and 35 days of consolidation
- Critical bed shear stress as well as erosion rate evaluated

TVA Kingston Fly Ash Transport and Fate Study

SEDflume Results

For maximum consolidation (>35 days)

- Critical bed shear stress ~ 0.5 Pascal (n/m^2)
- Erosion rate constant: 0.00384
- Erosion rate exponent: 1.759
- Final form of erosion rate equation: $$E = 0.00384\left(\frac{\tau_b}{\tau_c} - 1\right)^{1.759}$$
- Consolidated fly ash bulk density: 1950 kg/m^3
- Fly ash dry density: 1680 kg/m^3

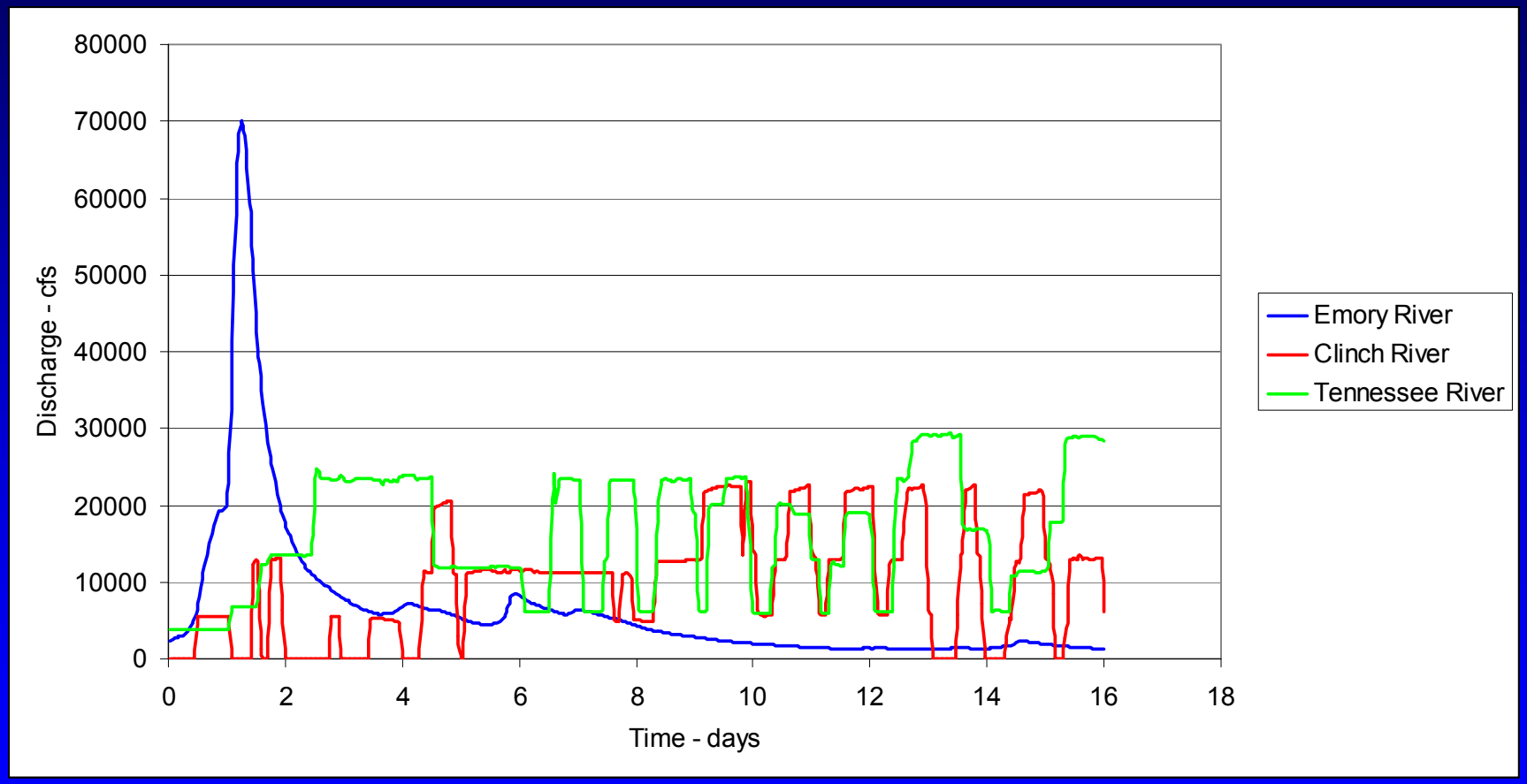
TVA Kingston Fly Ash Transport and Fate Study

Sediment Transport Modeling

- Model domain from the Kingston site to Watts Bar dam
- The ERDC Adaptive Hydraulics model (AdH) was used for the simulations Utilizing the SEDflume Results
- Six Fly Ash Grain Sizes were Simulated

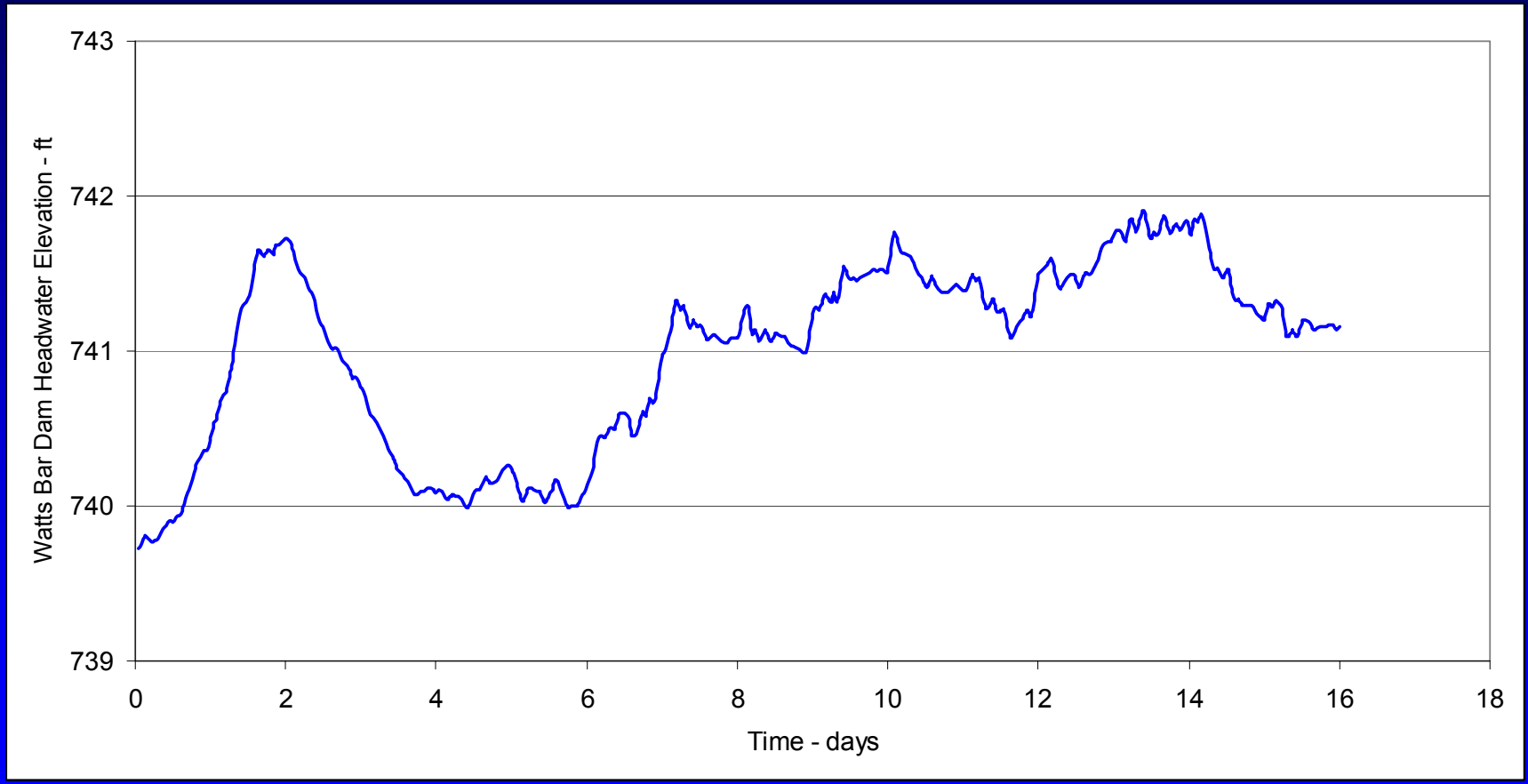
TVA Kingston Fly Ash Transport and Fate Study

Inflowing Hydrographs May 3 – May 18 2009



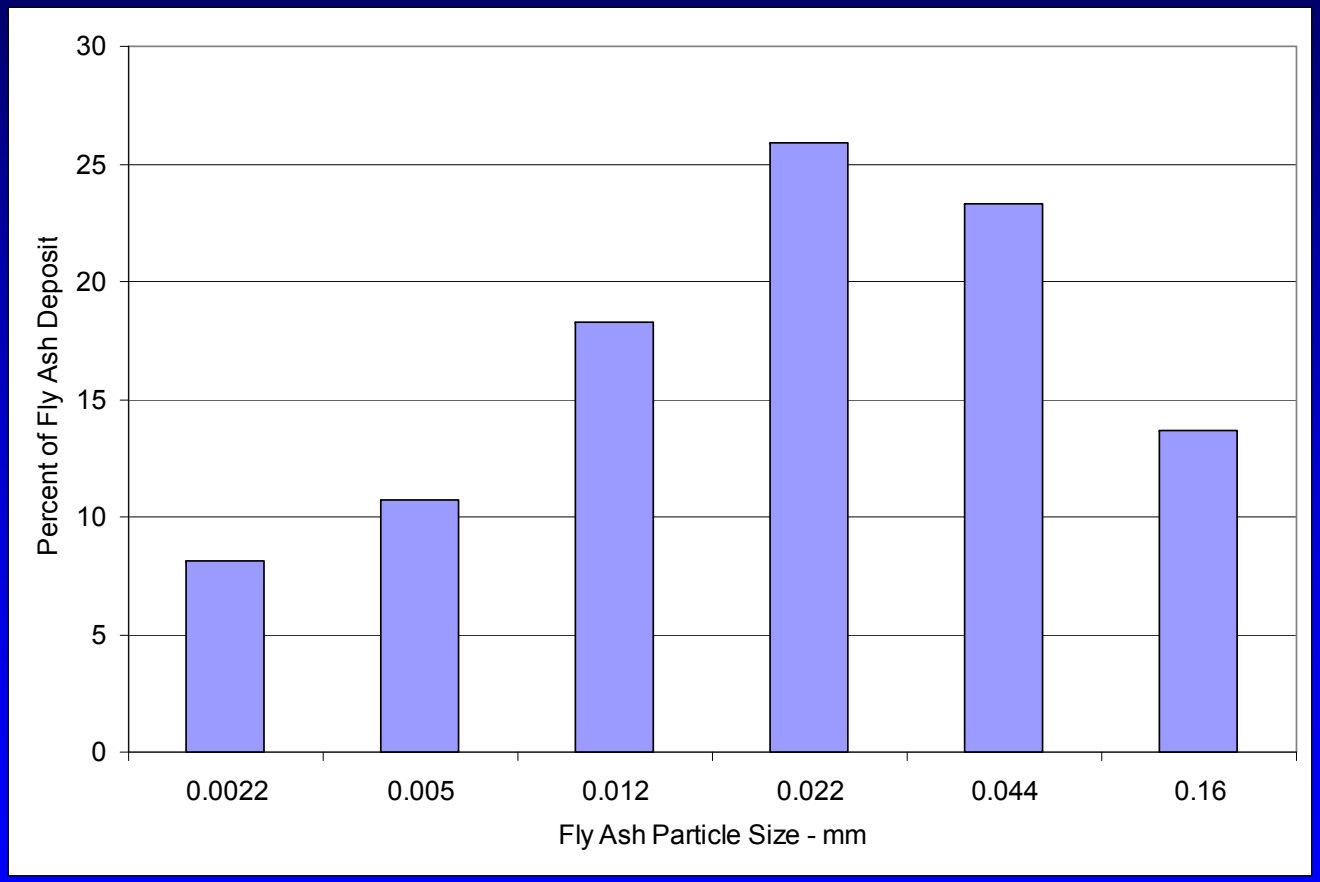
TVA Kingston Fly Ash Transport and Fate Study

Watts Bar Dam Headwater May 3 – May 18 2009



TVA Kingston Fly Ash Transport and Fate Study

Fly ash particle size fractions in the bed



TVA Kingston Fly Ash Transport and Fate Study

Fly Ash Transport and Fate Modeling

- Simulated the May 2009 flood event utilizing SEDflume results
- Fly ash deposition by reach by grain size was computed as well as fly ash concentrations along the domain
- Total bed change was computed for the May 2009 simulation

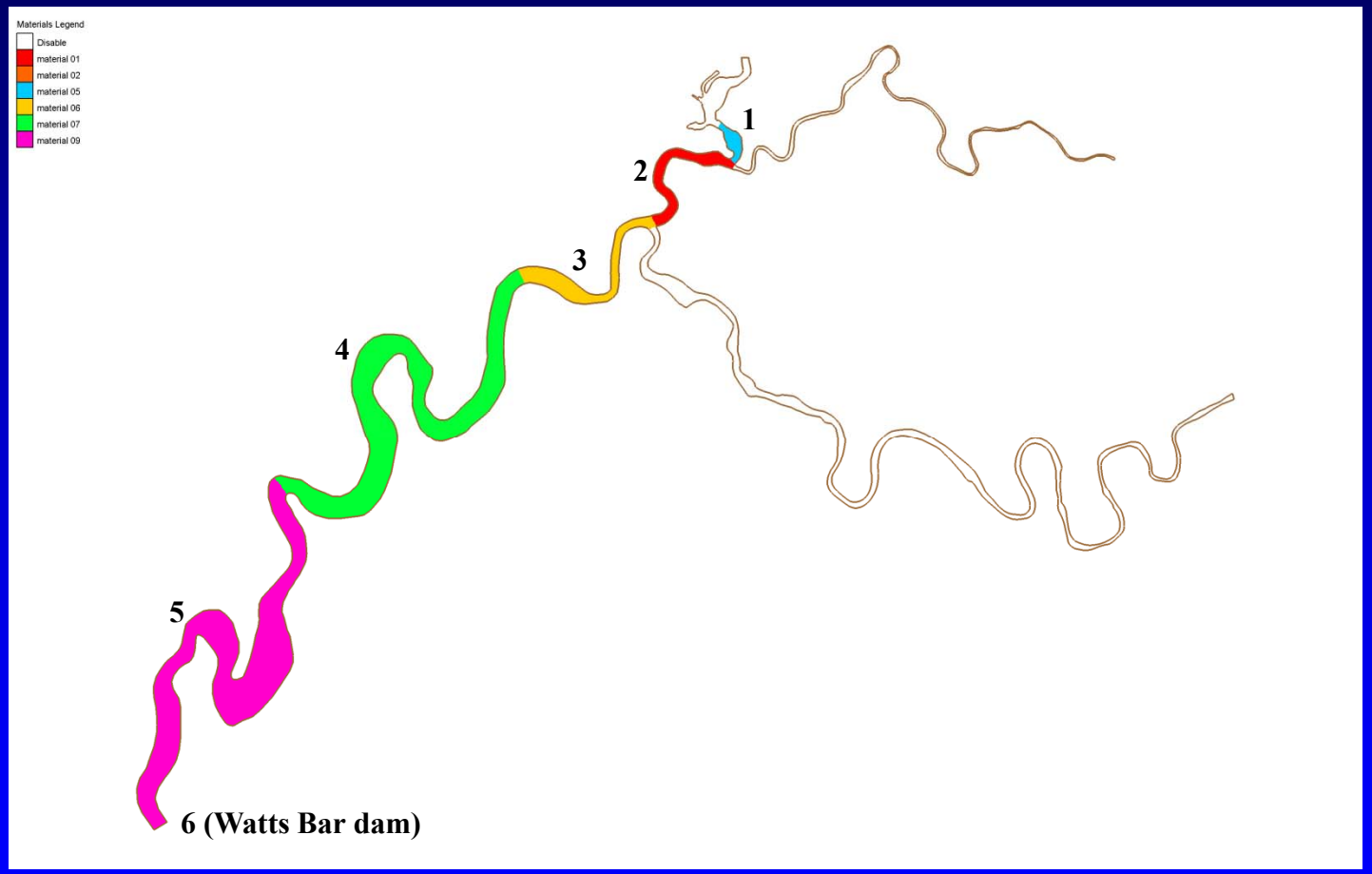
TVA Kingston Fly Ash Transport and Fate Study

Results

- Between 90,000 and 119,000 cubic yards of fly ash mobilized and passed below the site
- Up to 5-6 feet of scour occurred in some areas
- A maximum of approximately 3-4 inches of ash deposited just below the site in Analysis Reach 1.
- Ash deposition ranged from about 0.35 – 0.0003 inches for Analysis Reaches 2 - 6.

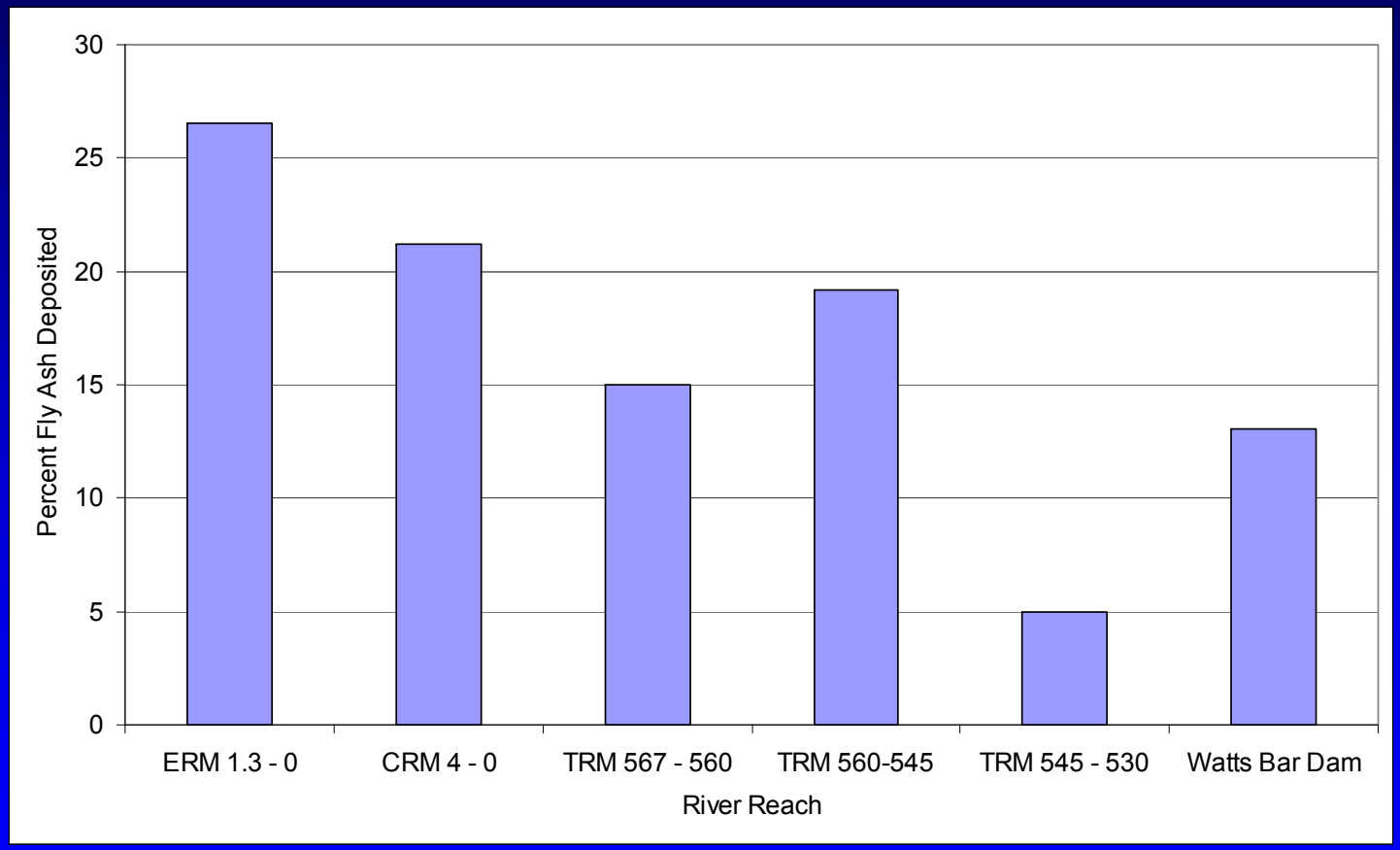
TVA Kingston Fly Ash Transport and Fate Study

Analysis Reaches



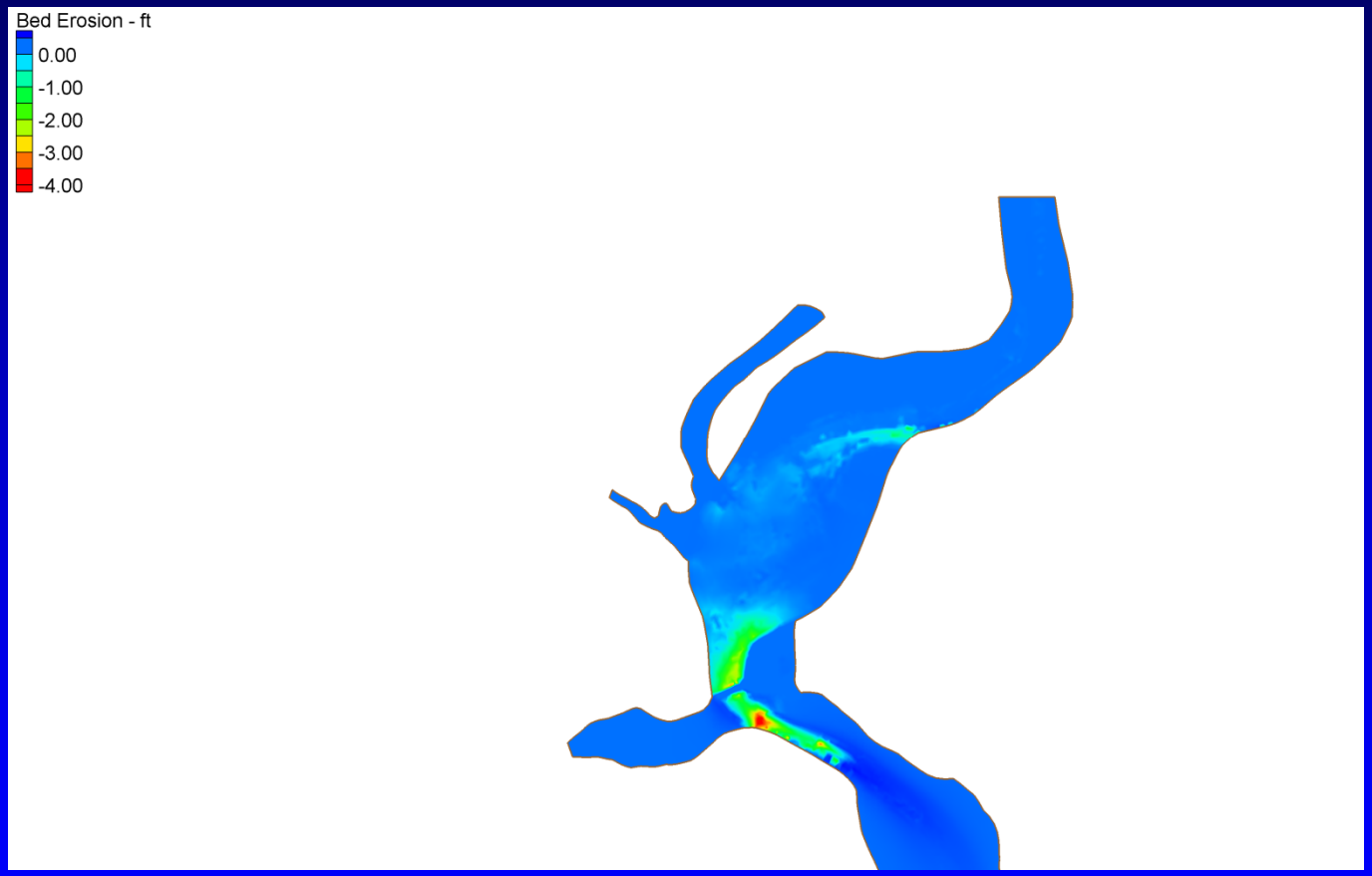
TVA Kingston Fly Ash Transport and Fate Study

Fate of Fly Ash by Analysis Reach



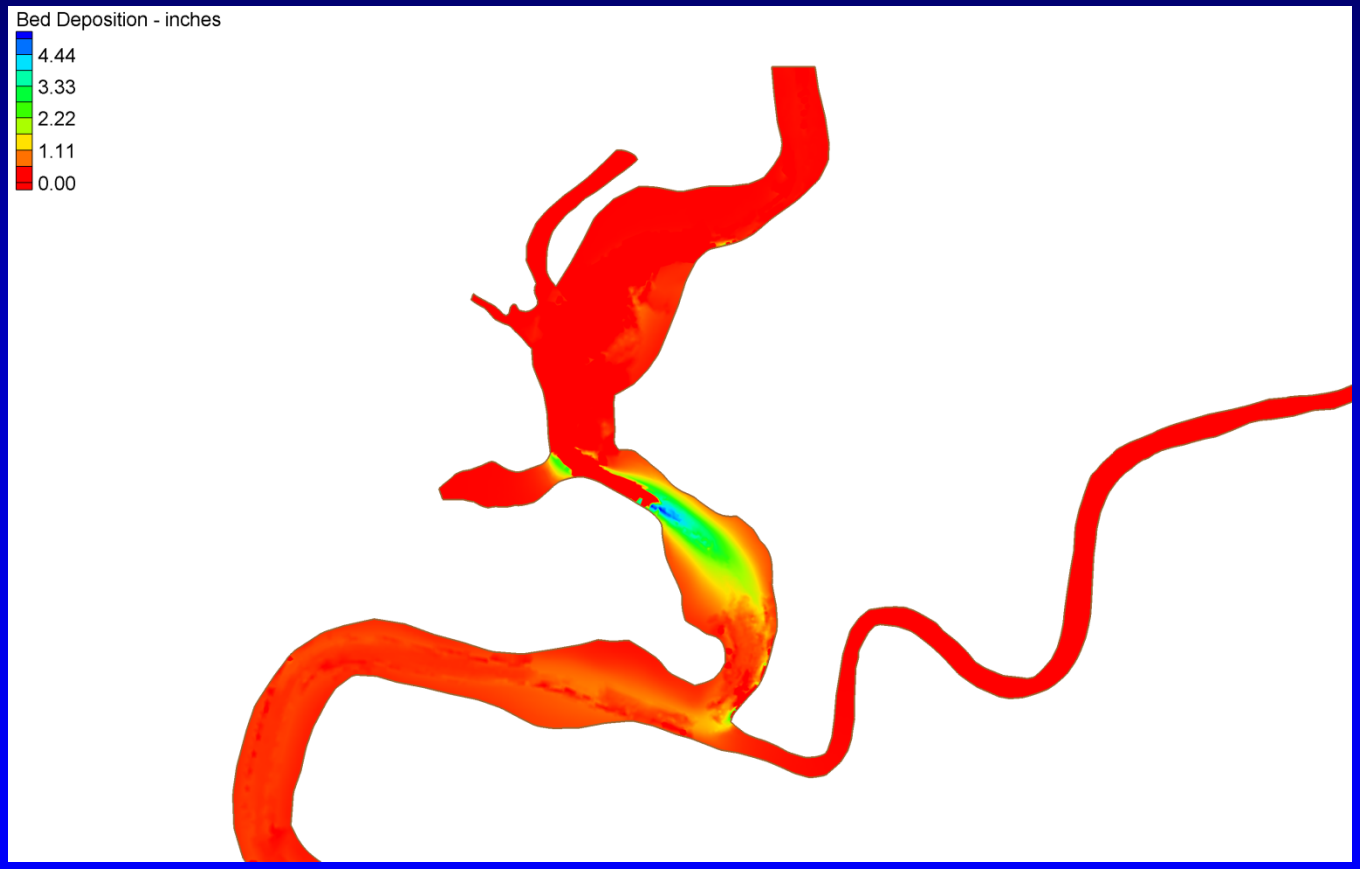
TVA Kingston Fly Ash Transport and Fate Study

Bed Change (Erosion) in the Emory River for the May Event



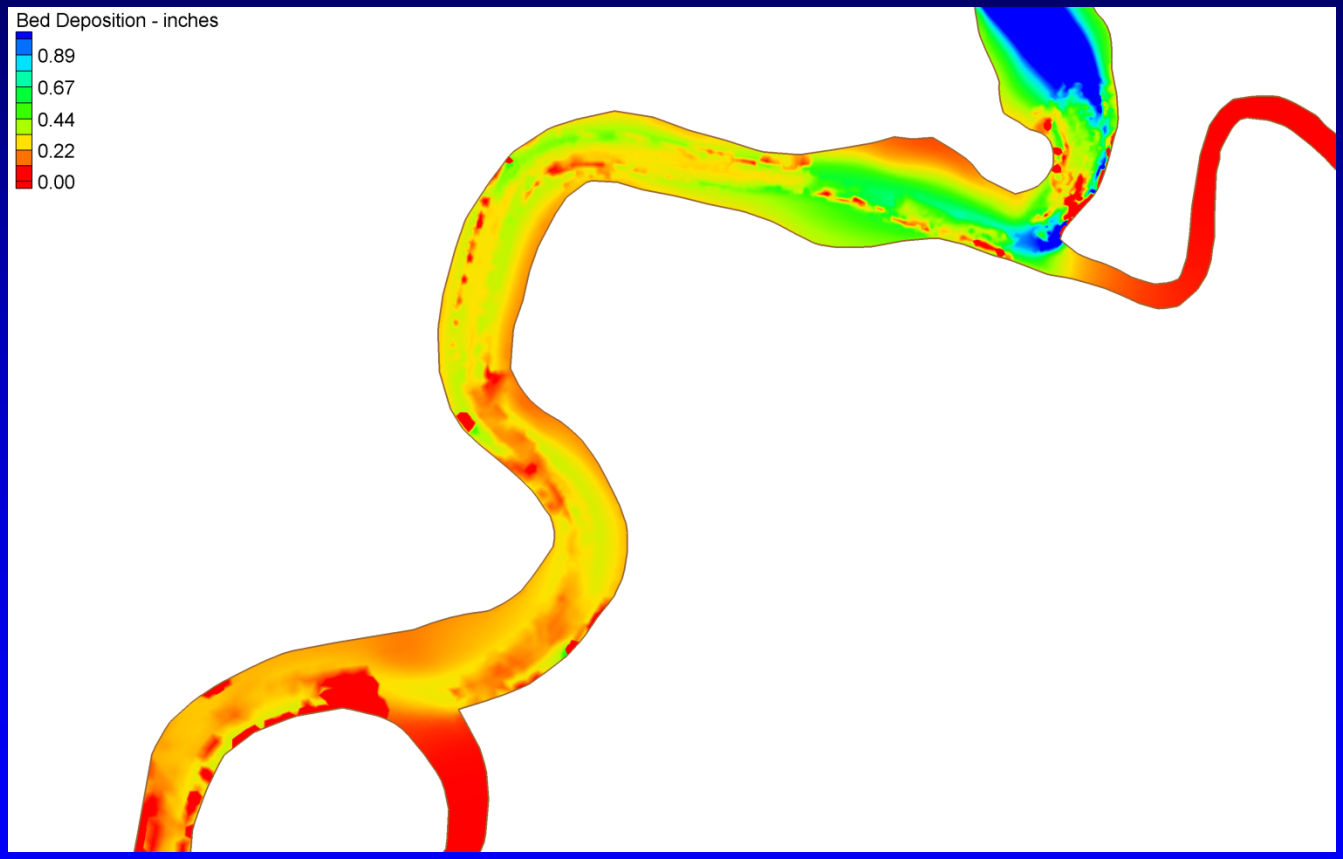
TVA Kingston Fly Ash Transport and Fate Study

Bed Change (Deposition) in Analysis Reach 1



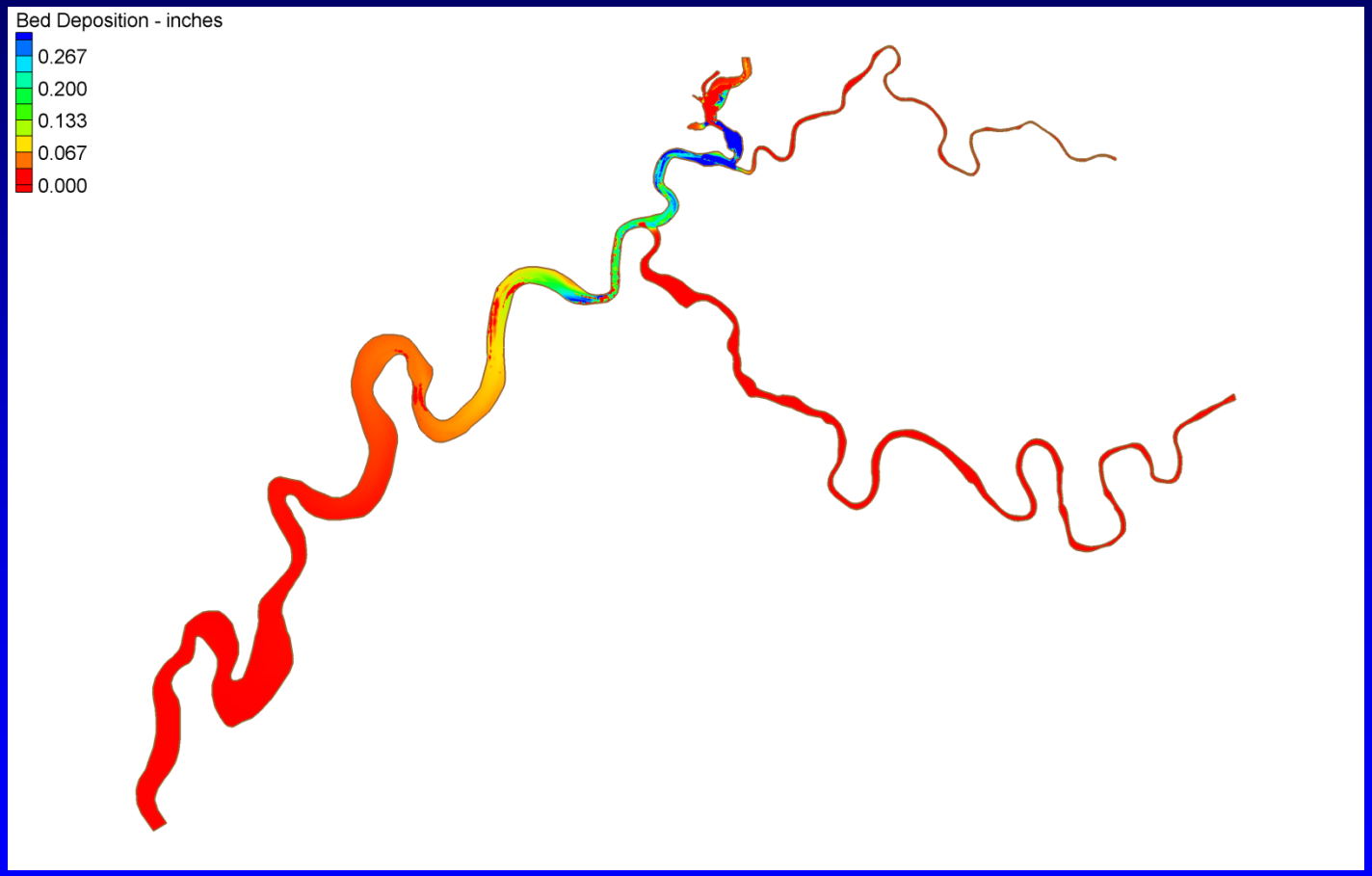
TVA Kingston Fly Ash Transport and Fate Study

Bed Change (Deposition) in Analysis Reach 2



TVA Kingston Fly Ash Transport and Fate Study

Bed Change (Deposition) in Analysis Reach 3-6



TVA Kingston Fly Ash Transport and Fate Study

Sediment Transport Conclusions

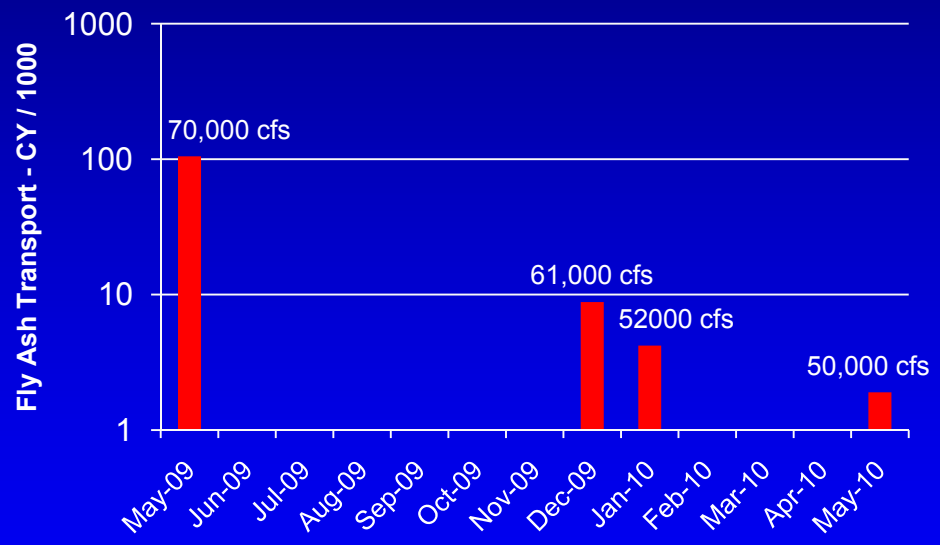
- Model results indicate between 90,000 and 119,000 cubic yards of fly ash transported below the Kingston site during the May 2009 flow event
- Depth of fly ash deposits ranged from 3 inches in the lower Emory River, 0.3 inches in the lower Clinch River, and less than 0.1 inches in lower Watts Bar reservoir

Model Simulations to Support Dredging

- AdH model was used to evaluate dredging impact on channel transport capacity
- Model simulations computed a reduction of fly ash transport for flood events as channel capacity was restored from May 2009 – May 2010
- Fly ash transport ranged from a peak of 100,000 cubic yards for the May 2009 flood event to 1870 cubic yards for the May 2010 flood event

TVA Kingston Fly Ash Transport and Fate Study

Reduction of Channel Transport Capacity Through Dredging



TVA Kingston Fly Ash Transport and Fate Study

Future Effort – Monitored Natural Recovery in Watts Bar

- Long term mixing and dilution of fly ash deposits with incoming native sediment load – Simulate burial rates and dilution to background concentrations
- The risk associated with fly ash deposits by particle size – Fate of finer fly ash grain sizes within Watts Bar Reservoir

Methods

- Determine annual Sediment load to Watts Bar Reservoir (Emory, Clinch, and Tennessee Rivers)
- Determine estimates of grain size distribution of annual load
- Long term simulation of natural sediment load into Watts Bar Reservoir
- Annual Estimates of Capping and Dilution