RSM-U Reservoir Sedimentation Workshop

Modeling Level Analysis Methods for Reservoir Sediment Management

Ian E. Floyd
Research Physical Scientist
ERDC-CHL River Engineering Branch

ERDC
Engineer Research and Development Center

Discussion Overview

- Topic: Modeling Level Analysis Methods for Reservoir Sediment Management
- Duration: Approximately 30 minutes
- Key Points:
  - ►Introduction and Background
  - ►Numerical Modeling and Reservoir Management
  - ►Case Study
  - ►Recap and Summary

Introduction and Background

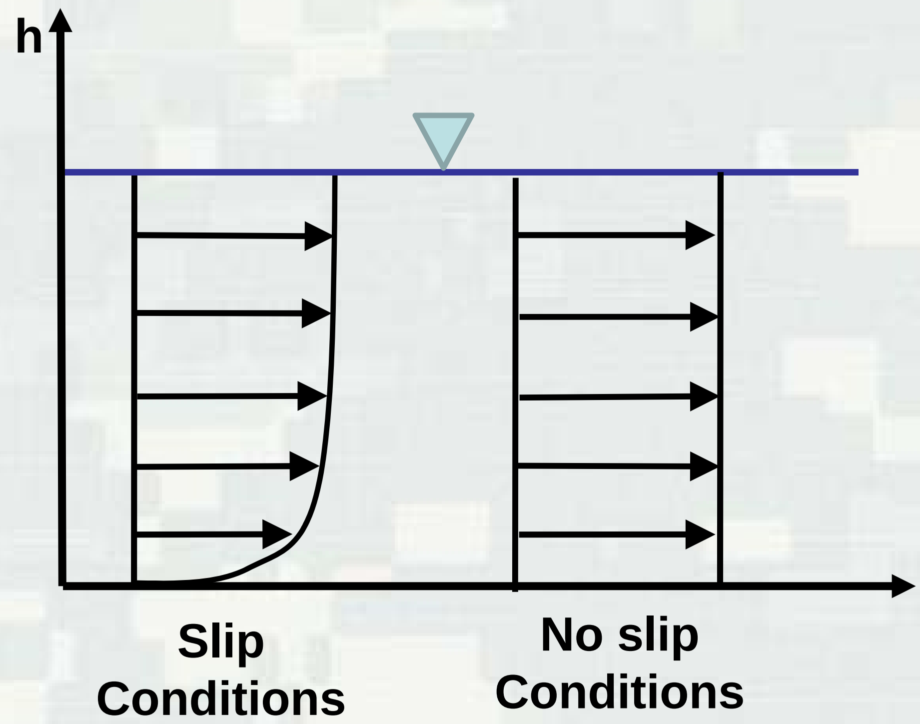
- What is a model?
  - ► An abstraction of reality – simplified version of the real world. Both Physical and Numerical Models
  - ► Range from simple to complex
- Numerical Models
  - ► Need detailed testing against – field results and physical model results
  - ► Can give entirely incorrect results, and not add to understanding (requires reflections)
  - ► Results are at best qualitative and require interpretation to become quantitative

Introduction and Background

- Numerical Models – Continued
  - Interpretation of qualitative results requires understanding of natural processes, equations, coefficients, numerical methods and pitfalls such as assumption, instability, numerical diffusion and dispersion.
- Numerical Model Interpretation
  - Benchmarking – reproducing analytical solutions
  - Calibration – reproduce measured field data
  - Validation – reproduce additional field data, and post-construction data with calibrated model
  - Subjective ‘knob turning’ to produce reasonable and sensible results
  - No replacement for calibration and verification
  - Sediment transport modeling interpretation should be conducted by subject matter expert.

Introduction and Background

- To mathematically and physically model the principles of incipient motion, we must first describe the velocity and stress distribution in the near-bed region. This region is the area of fluid where the flow is reduced from the free stream (or far-field) velocity, u_∞, to the velocity at the bed (or wall), usually zero.
- This principle of zero velocity at the surface is known as the no-slip condition. In an ideal fluid, we can imagine a completely inviscid fluid where a slip condition can exist.



Introduction and Background

- The flow can be approximated mathematically with the Navier-Stokes equations, which require a balance between the inertia of flow and the applied force

$$ma = \sum F$$

Flow inertia

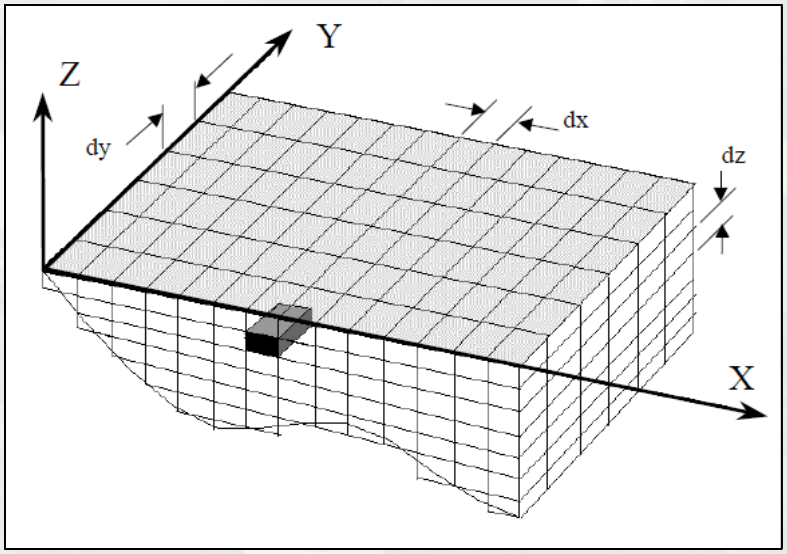
Applied forces

Introduction and Background

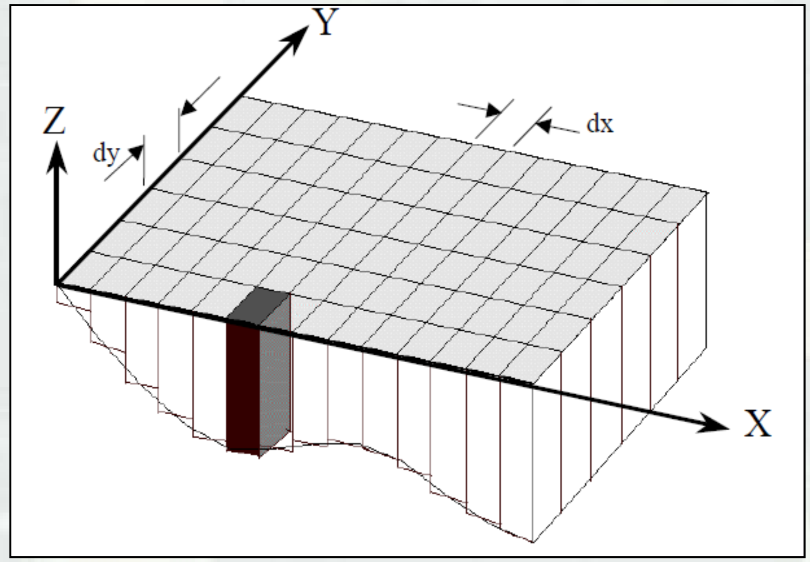
- Navier-Stokes (N-S) Equation Derivation
  - After some assumptions, non-dimensionalize of some terms, scaling, algebra, more algebra, re-dimensionalizing, even more algebra, accounting for turbulence, additional algebra, more assumptions and we get

$$\frac{\tau_{xz}}{\rho} = \underbrace{\gamma \frac{\partial \bar{u}}{\partial z}}_{\text{Viscous Stress}} + \underbrace{l^2 \left(\frac{\partial \bar{u}}{\partial z}\right)^2}_{\text{Turbulent Stress}}$$

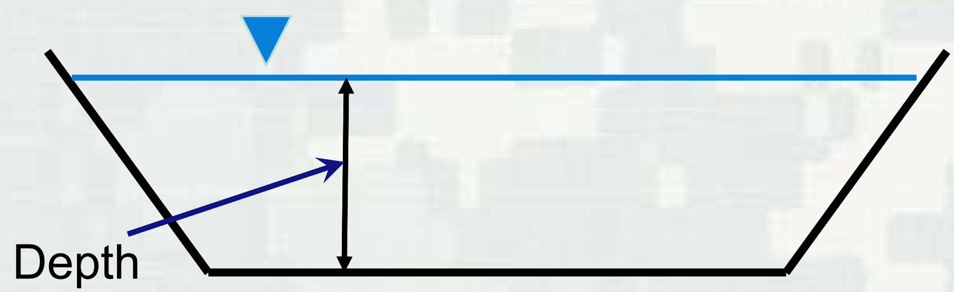
Numerical Modeling and Reservoir Management



3-D Numerical Model



2-D Numerical Model



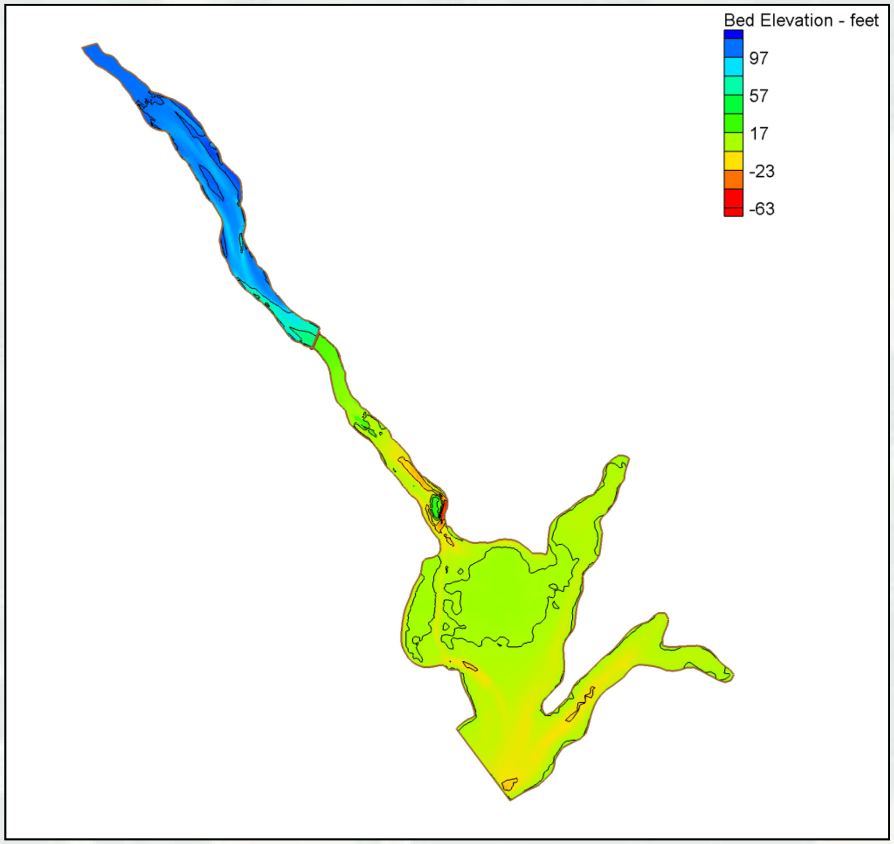
1-D Numerical Model

Numerical Modeling and Reservoir Management

- USACE Hydraulics and Hydrology Numerical Models – Shallow Water Models
  - Hydrologic Engineering Center River Analysis System (HEC-RAS), Hydrologic Modeling System (HEC-HMS), Adaptive Hydraulics (AdH), Sediment Transport Library (SedLib), and Gridded Surface Hydrologic Analysis (GSSHA).
- What data is needed to conduct a numerical model?
  - Geometry Numerical Initial Conditions
  - Hydrodynamics – Calibration and Validation
  - Sediment Transport – Calibration and Validation
  - Identify spatial and temporal domain

Case Study – Susquehanna

- The Susquehanna River flows through South Central New York, portions of Pennsylvania, and northeastern Maryland, draining approximately 27,000 square miles.
- Three hydroelectric dams results in a series of reservoirs located on the lower Susquehanna River upstream stream of Chesapeake Bay



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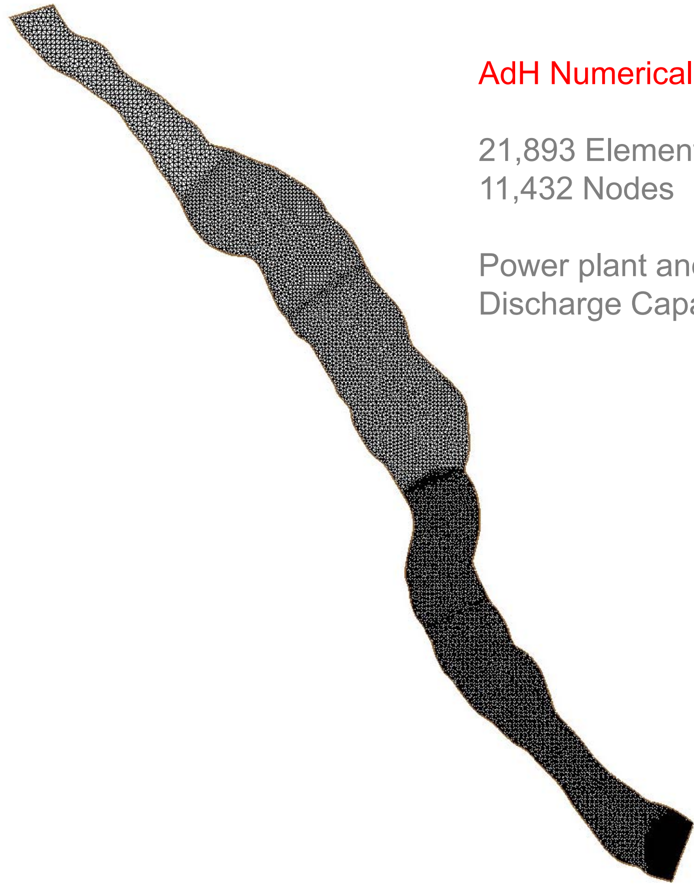
- Our discussion will be limited to the lower most reservoir, Conowingo Reservoir.
- Conowingo was constructed in 1928 with a water storage capacity of 300,000 acre-ft.



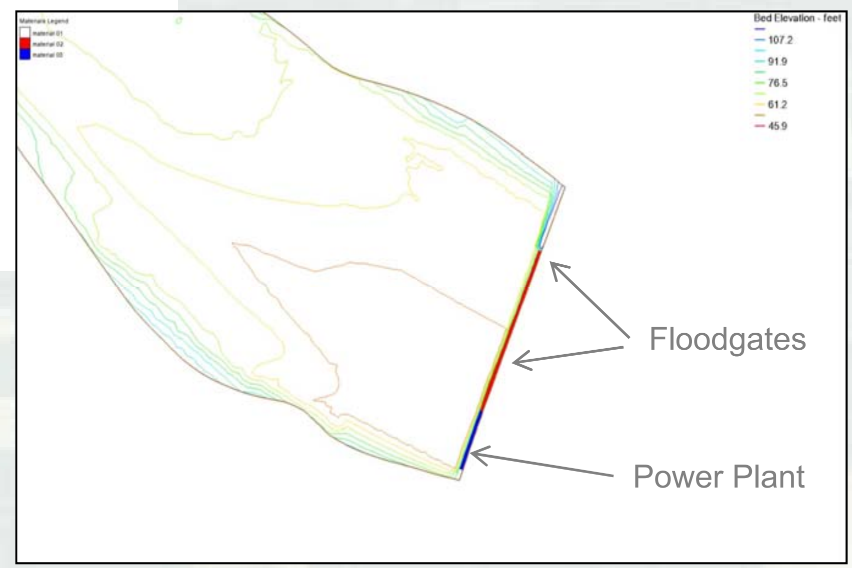
AdH Numerical Mesh Info

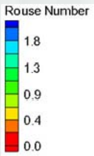
21,893 Elements
11,432 Nodes

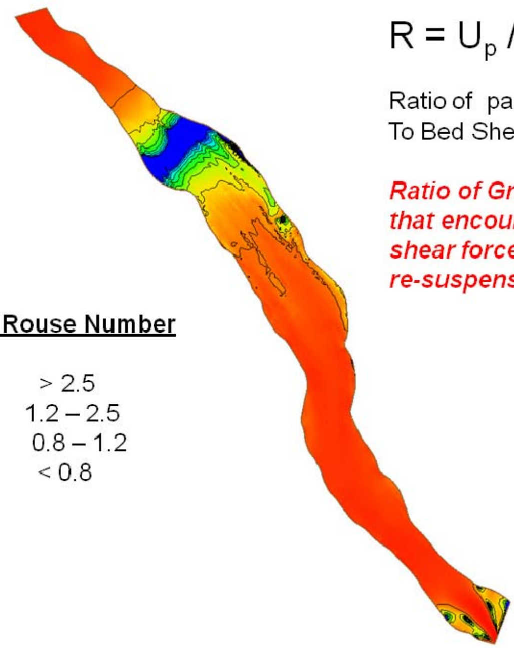
Power plant and Flood Gate Discharge Capability

VALIDATION CRITERIA

- USGS Studies on Conowingo Reservoir (Annual Load and Scour Predictions)
- Measured Suspended Sediment Concentrations out of Conowingo
- Reasonable Trap Efficiency Calculations







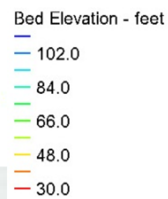
$$R = U_p / \kappa(\tau_B / \rho)^{0.5}$$

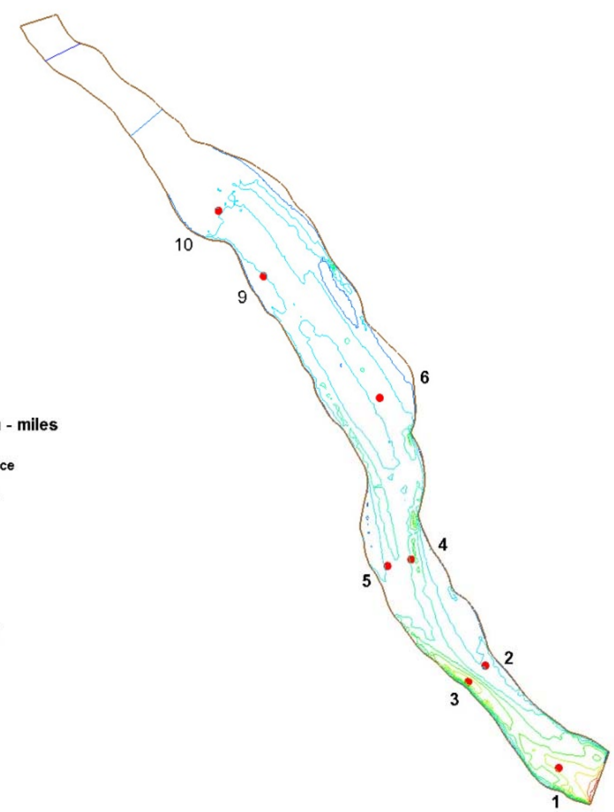
Ratio of particle fall velocity
To Bed Shear Stress

Ratio of Gravitational Force that encourages settling to bed shear forces that encourage re-suspension

Transport Mode	Rouse Number
Bed Load	> 2.5
50% Suspended	1.2 – 2.5
100% Suspended	0.8 – 1.2
Wash Load	< 0.8

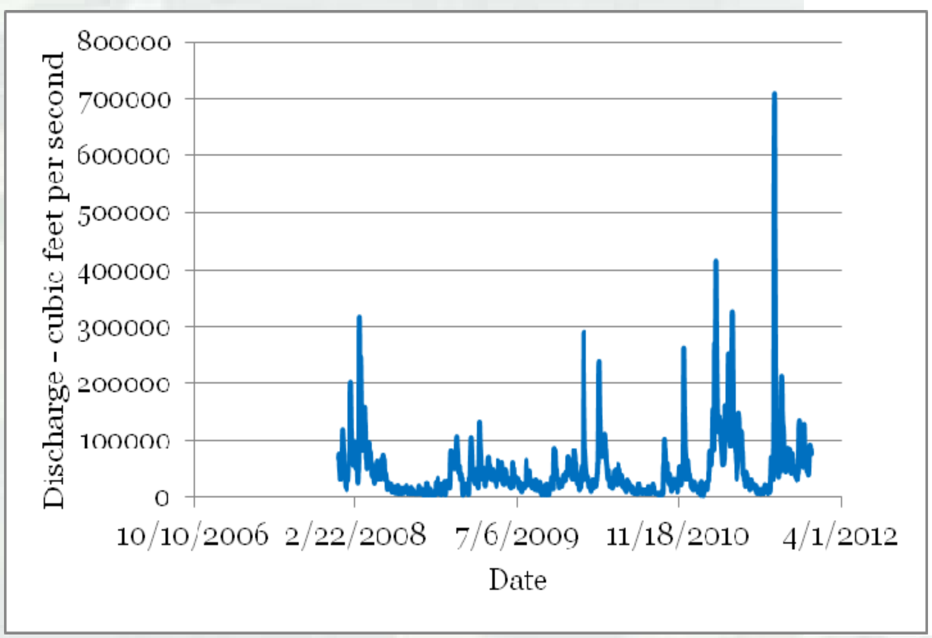
Field Collection Sites



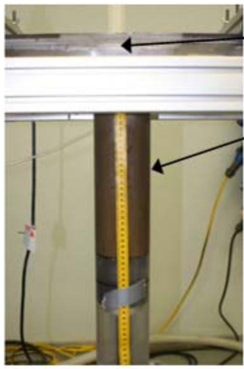


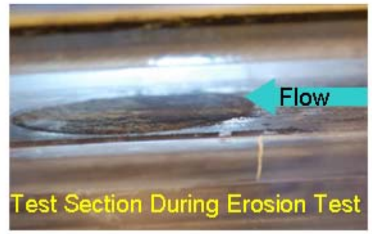
Distance From Dam - miles

Sample	Distance
1	0.54
2	2.5
3	2.5
4	4.5
5	4.5
6	7.0
9	9.5
10	10.7

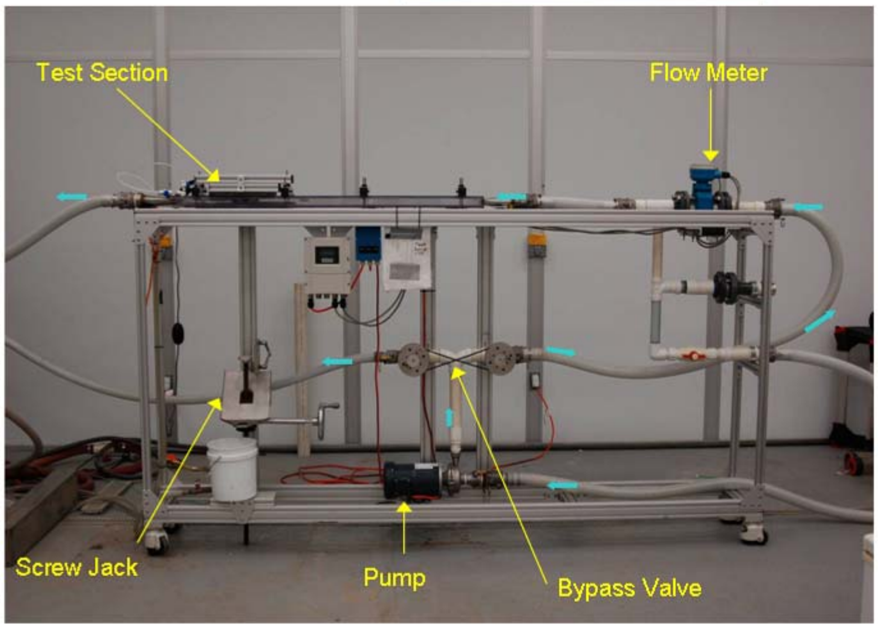


Case Study – Susquehanna



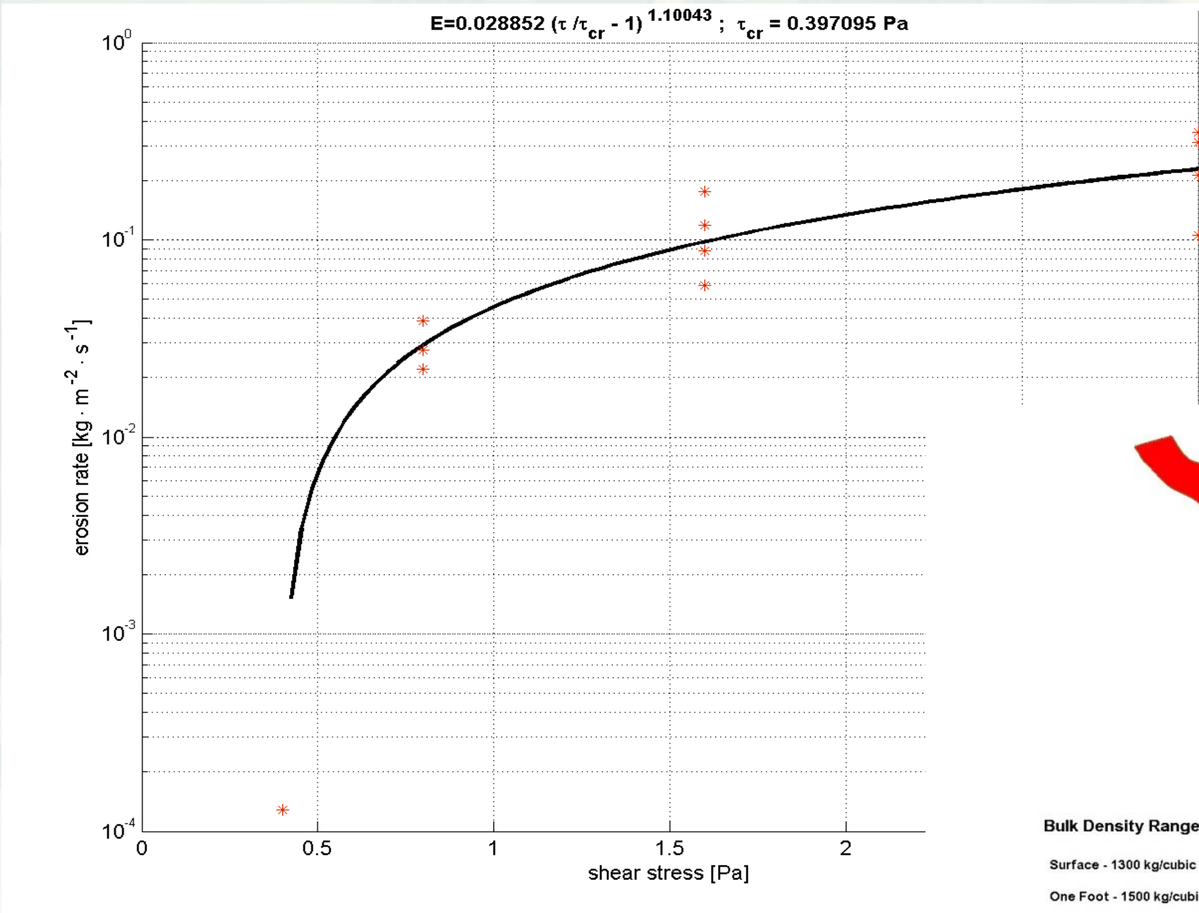


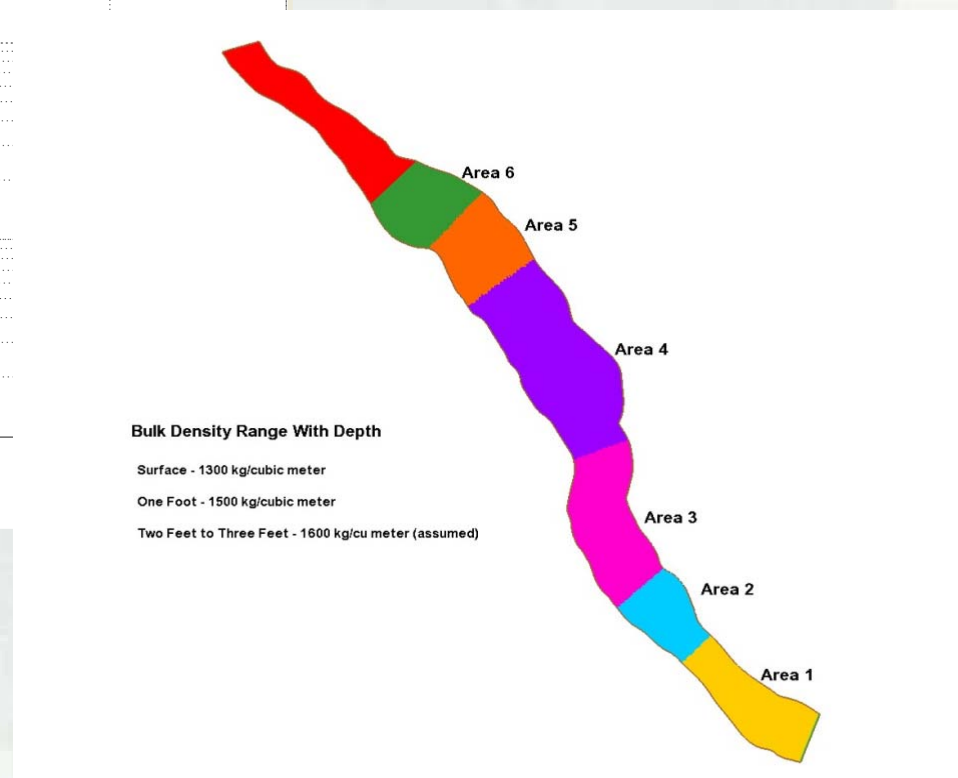
Shear stress t (Pa)	Flow Rate (GPM)
0.1	6.1
0.2	9.1
0.4	13.5
0.6	17.0
0.8	20.1
1.2	25.3
1.6	29.8
2.4	37.4
3.2	44.0
4	49.9
5	56.6
6.4	65.0
8	73.7
10	83.5
12	92.5
13	96.7
14	100.8



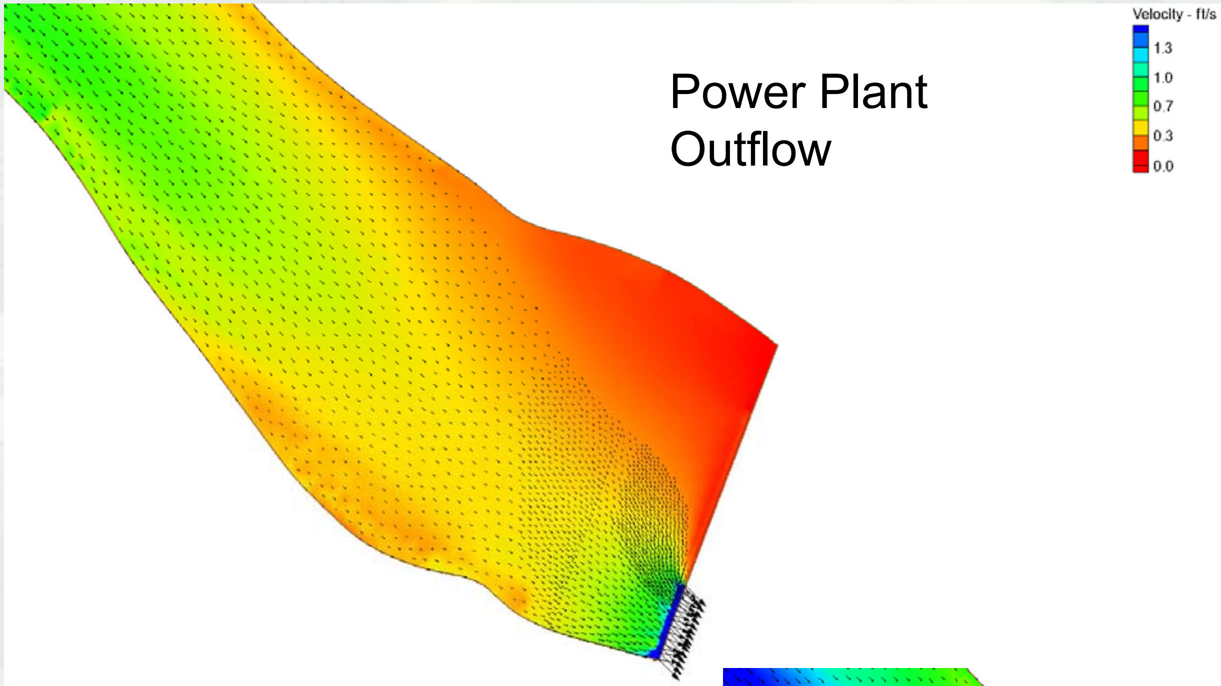
Methods to reducing uncertainty

Case Study – Susquehanna

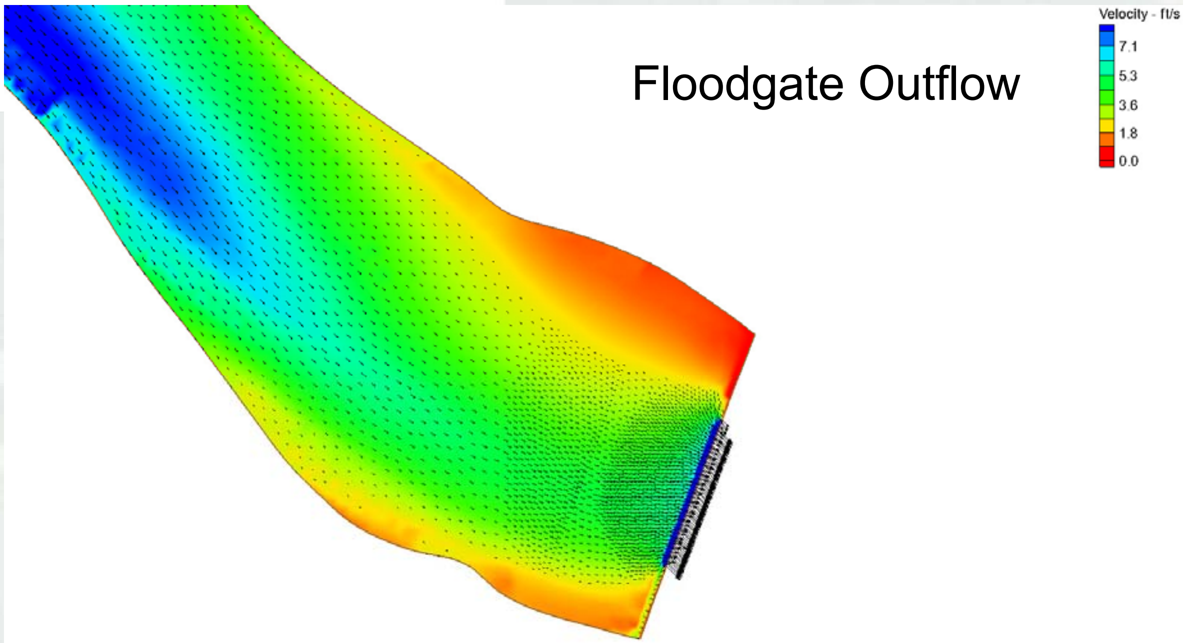




Power Plant Outflow



Floodgate Outflow



Summary and Questions