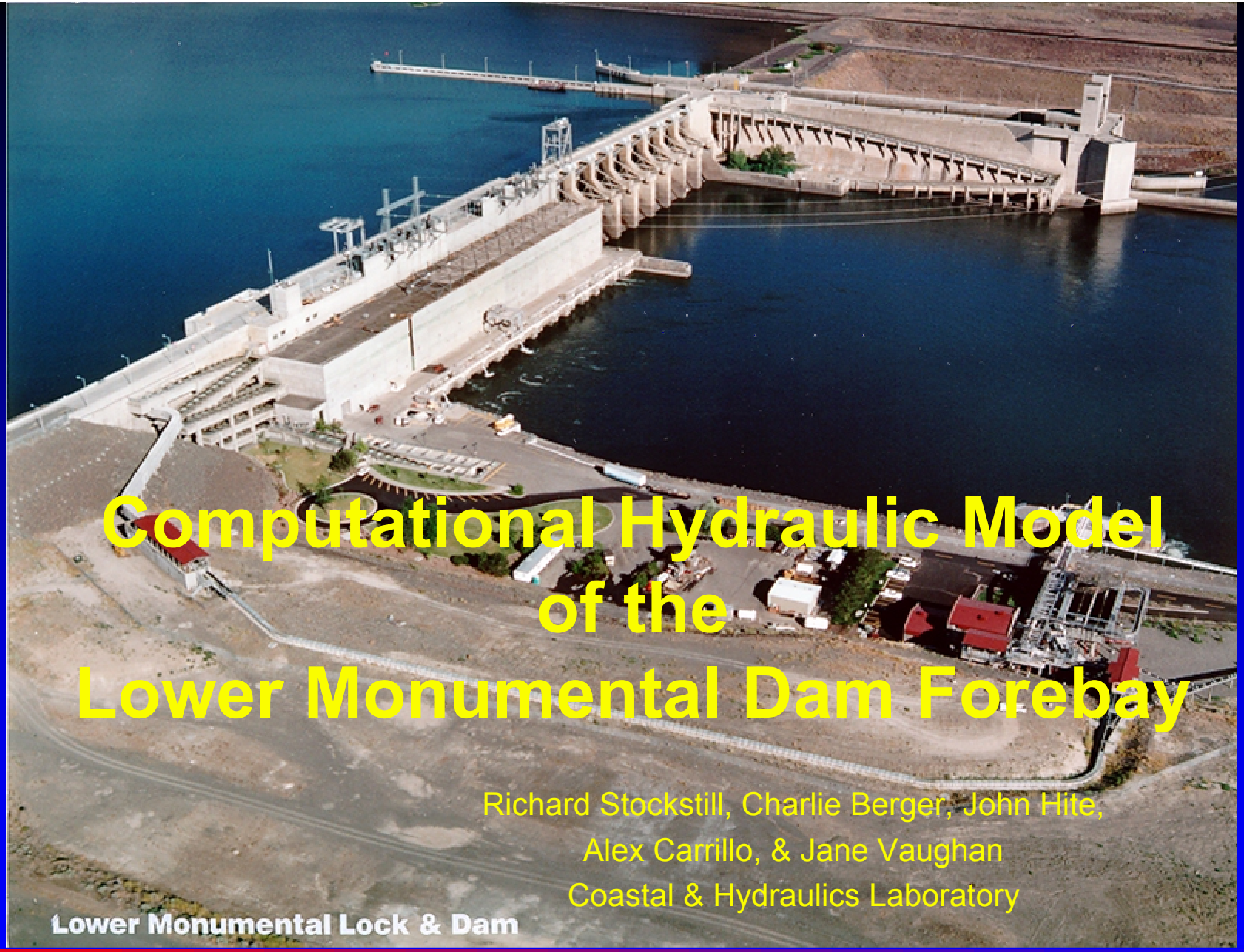



# Computational Hydraulic Model of the Lower Monumental Dam Forebay

Richard Stockstill, Charlie Berger, John Hite,
Alex Carrillo, & Jane Vaughan
Coastal & Hydraulics Laboratory

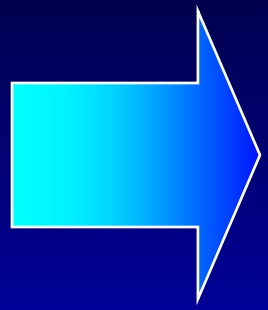
US Army Corps of Engineers

US Army Engineering R & D Center

# The ADH Model

## Needs

- Irregular boundaries and material distributions.
- Steep and moving gradients
- Interflow and lateral migration, heterogeneous infiltration and seepage, runoff.
- High resolution --- large algebraic systems to solve
- Portable to many computer architectures

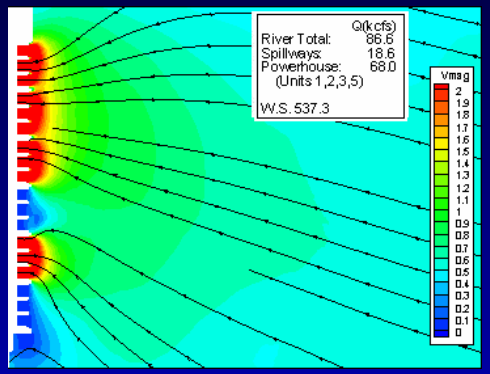


## Model Decisions

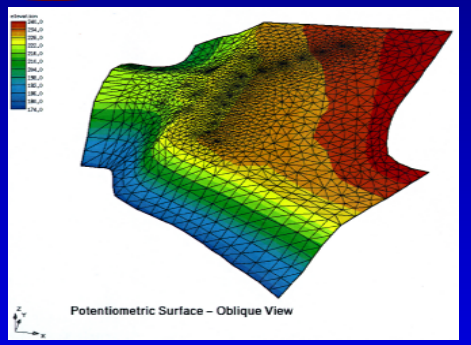
- Unstructured meshes
- Adaptive mesh refinement/coarsening
- Multi-physics coupling (groundwater/surface water).
- Parallel computing
- Assume distributed memory and standard message passing libraries

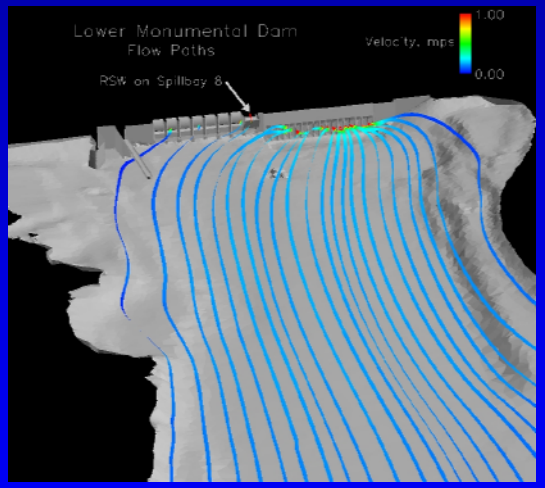
# ADH Philosophy

Navier-Stokes Equations

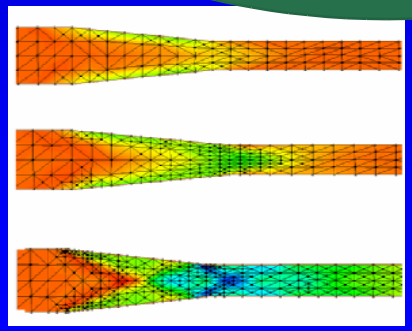



Unsaturated Groundwater Equations

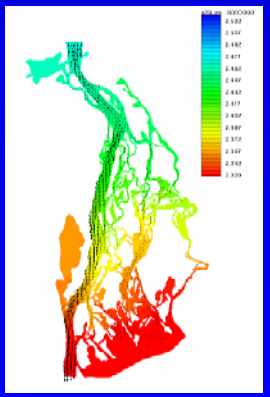


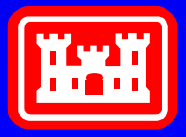

Computational Engine
(FE utilities, preconditioners, solvers, I/O to xMS GUIs)



Shallow Water Equations

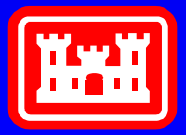


# ADAPTIVE MESH

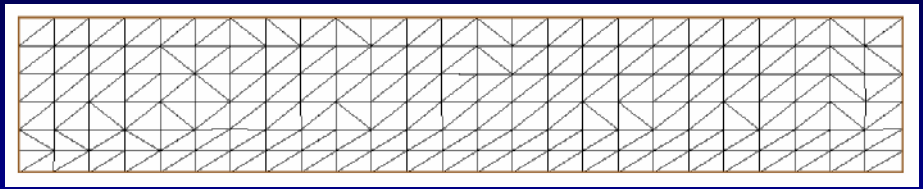


# ADH - Adaption

- Grid resolution required to match the differential equations
- High resolution likely only needed in select regions
- Intelligent adaption saves computational effort
- Adaption doesn't require the user to have a reasonable idea of the solution ahead of time



# How important is grid resolution?

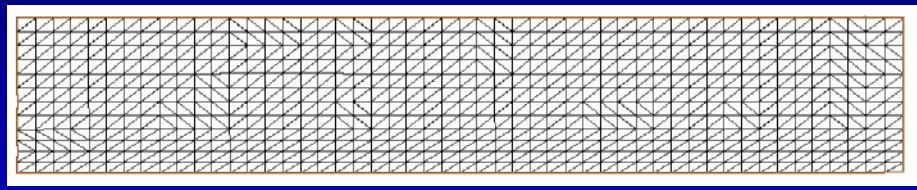


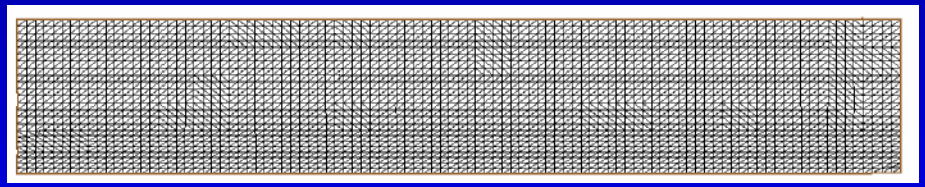
**Coarse Mesh**

182 nodes/300 elements

**Refined Mesh #1**

663 nodes/1200 elements



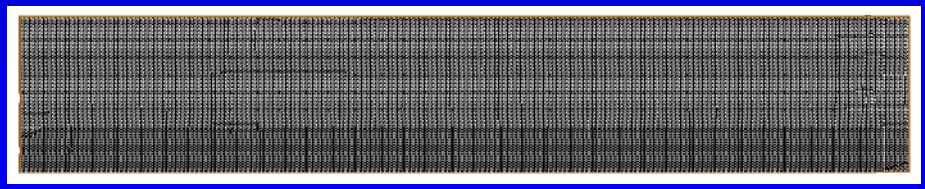


**Refined Mesh #2**

2525 nodes/4800 elements

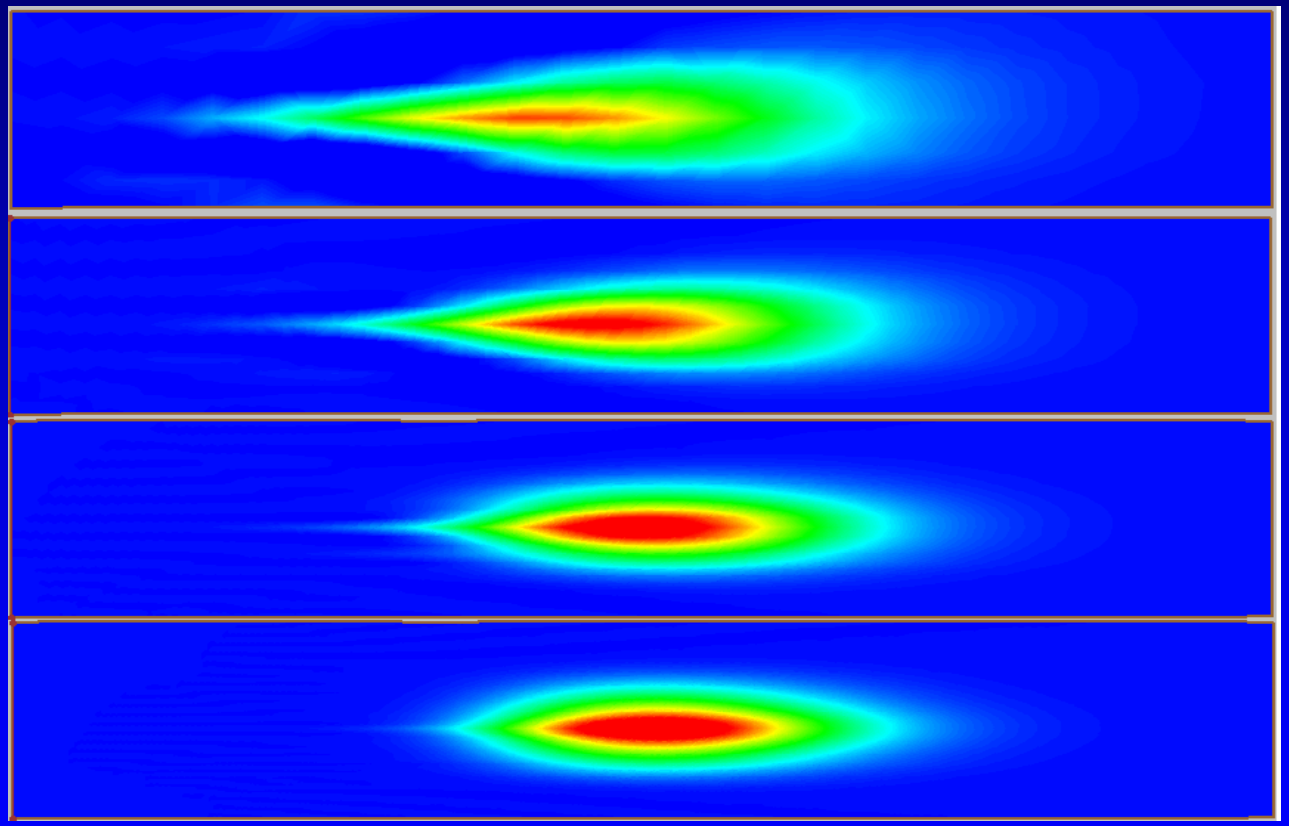
**Refined Mesh #3**

9849 nodes/19200 elements



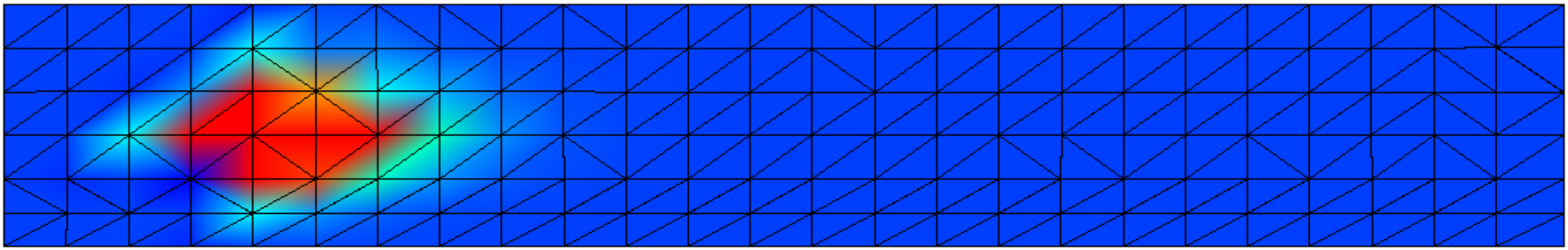
**Initial Concentration Cloud**

# Grid Resolution Results…



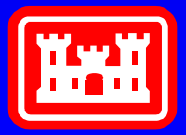

at timestep = 380 seconds

# Adaptive Mesh with Concentration Plume



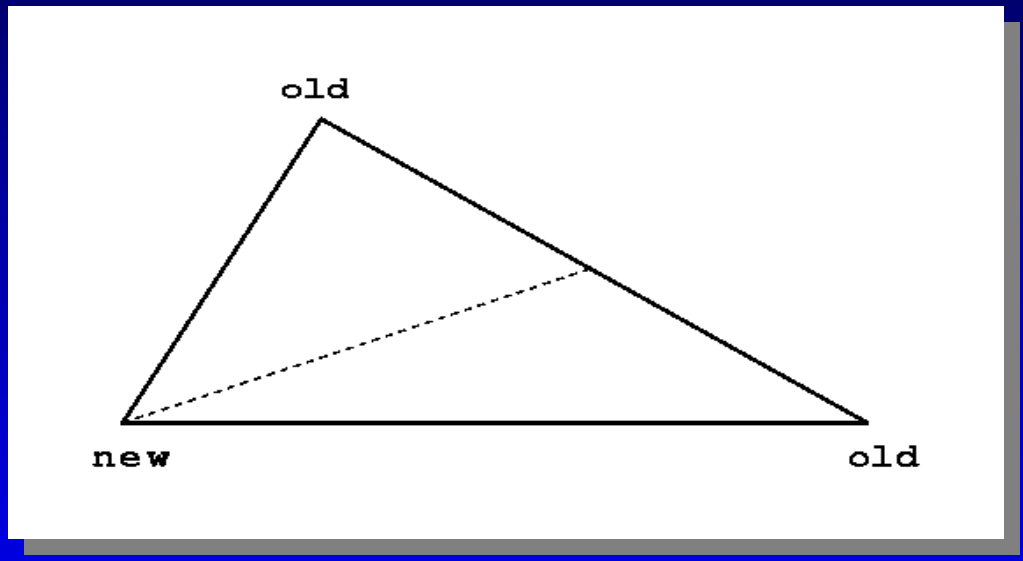
# Adaption Details

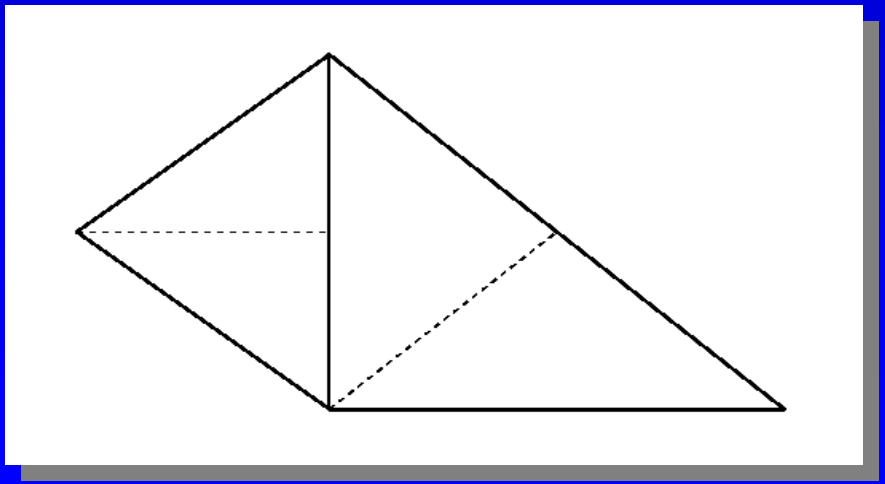
- Refinement
  - Error Indicator (conservation of mass)
  - Splitting Edges
  - Closure
- Coarsening
  - Finding duplicate elements



# Modified Longest Edge Bisection

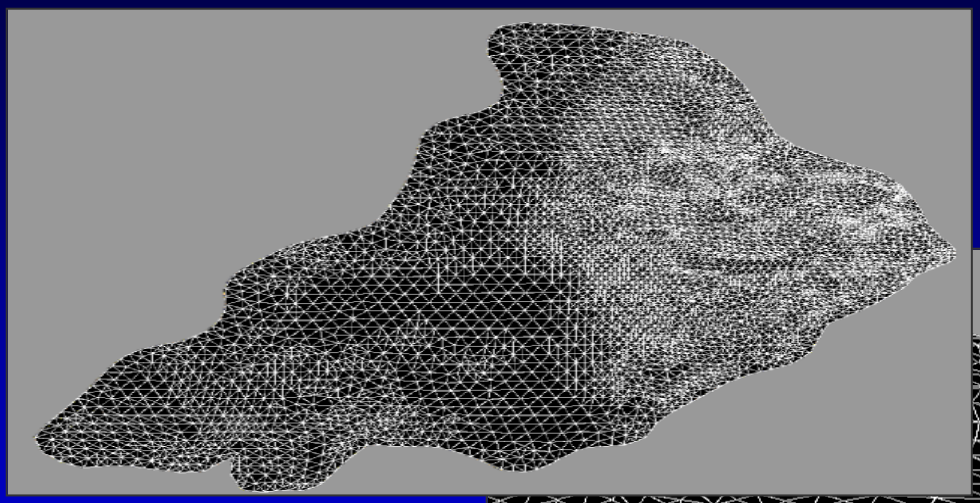
- Split oldest edge first.
- If edges are tied, then split the longest edge.

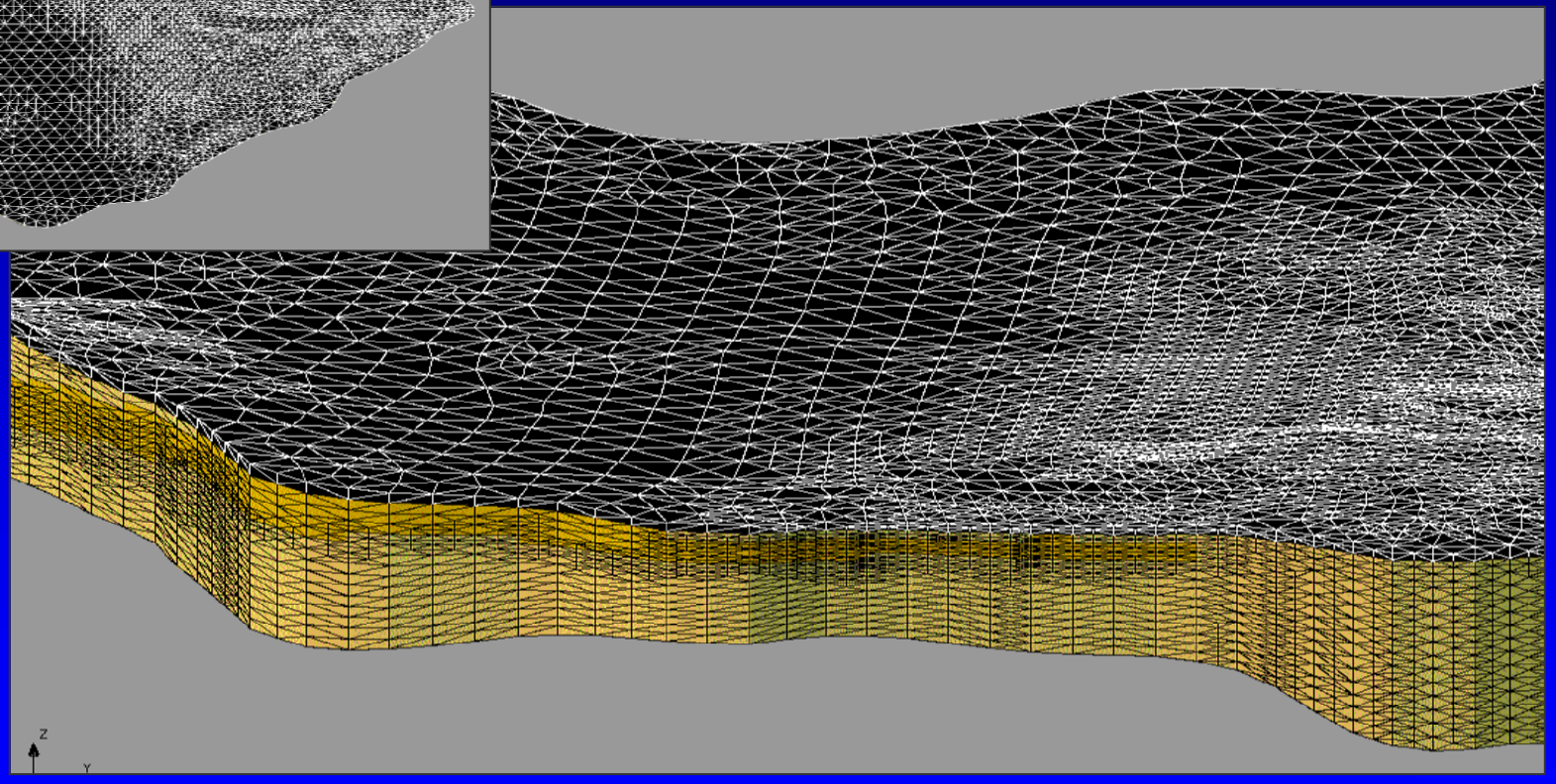


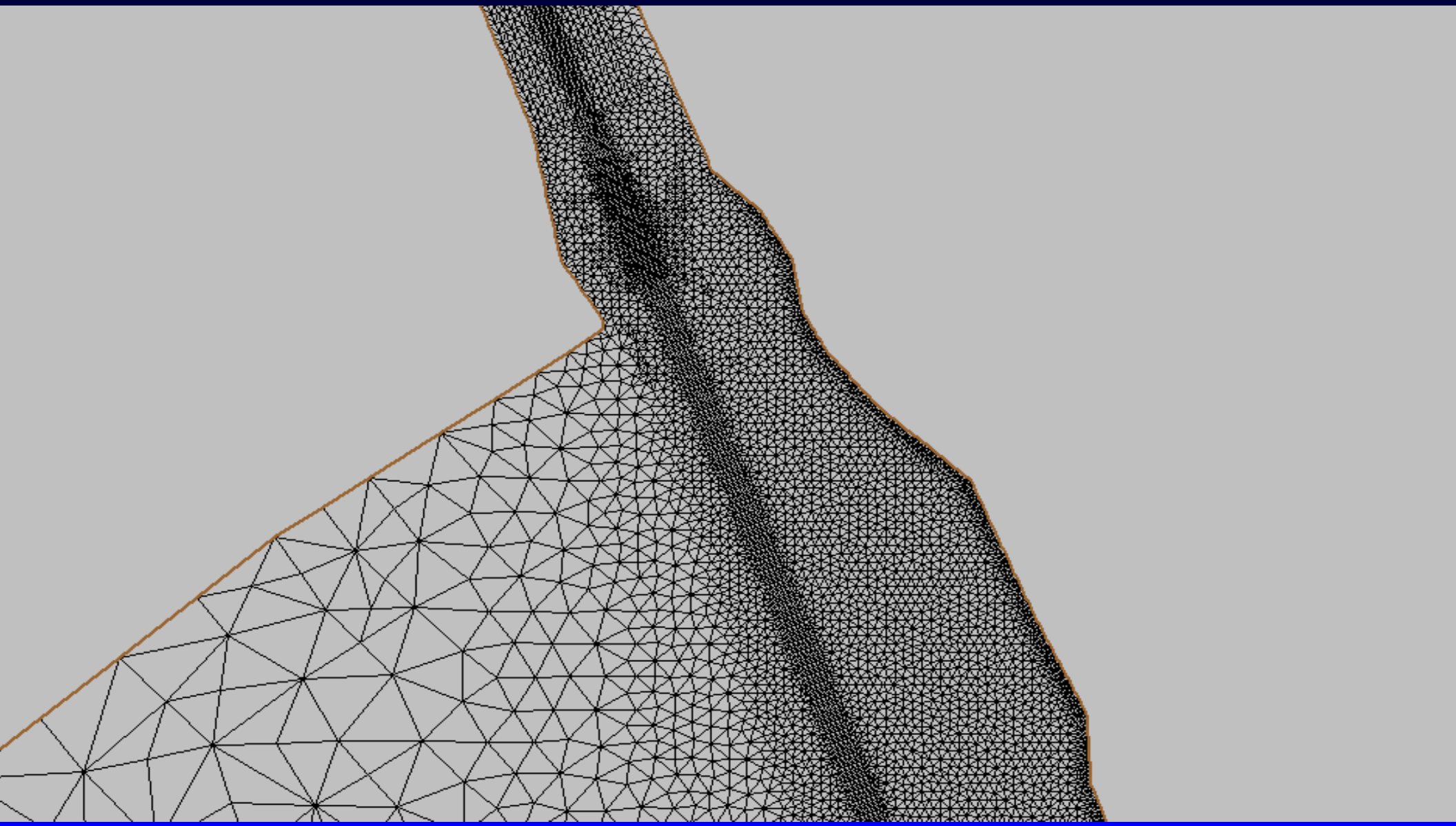
- Green closure required for non-conforming elements.

# Mesh Adaption in the Subsurface

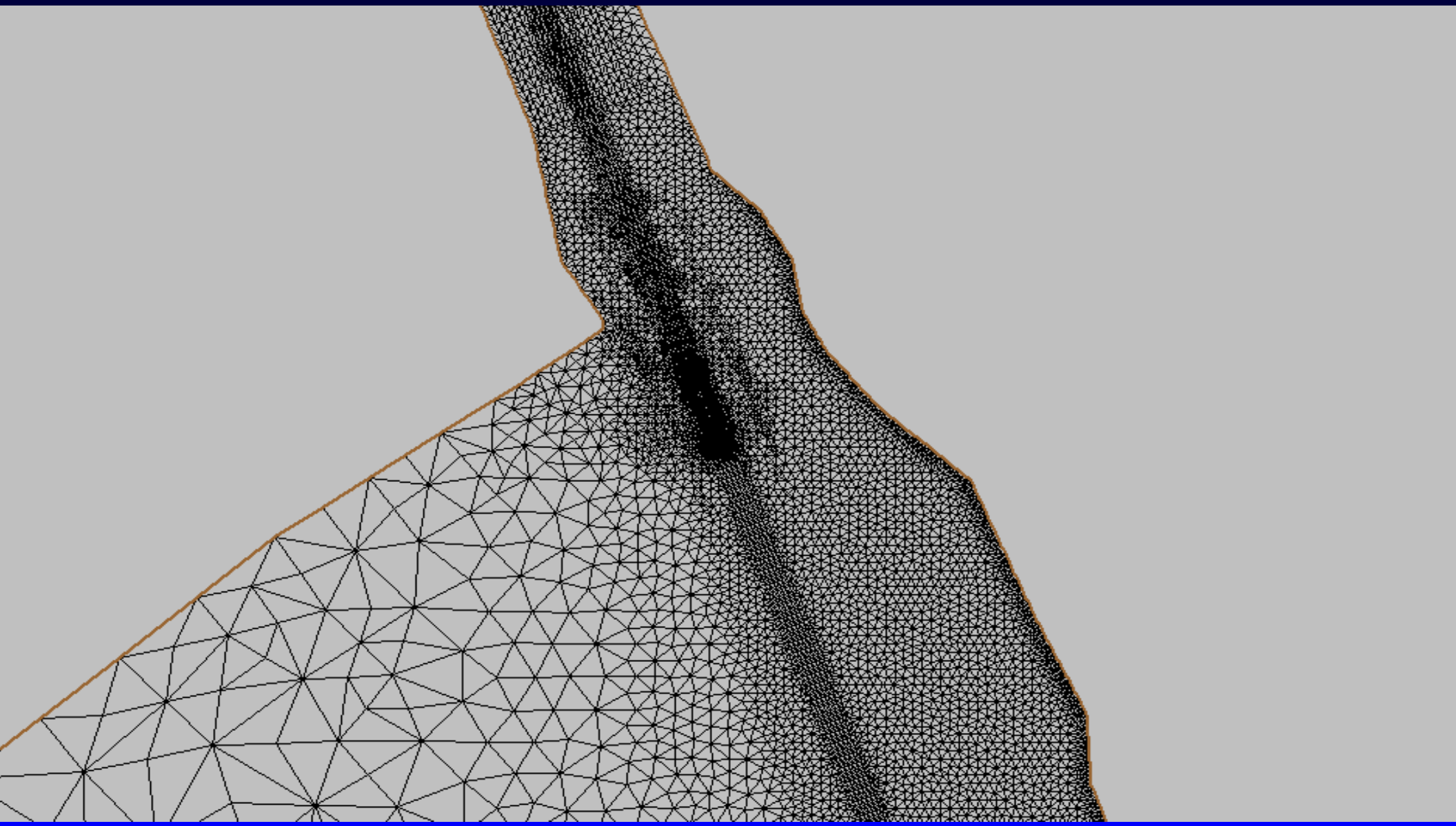




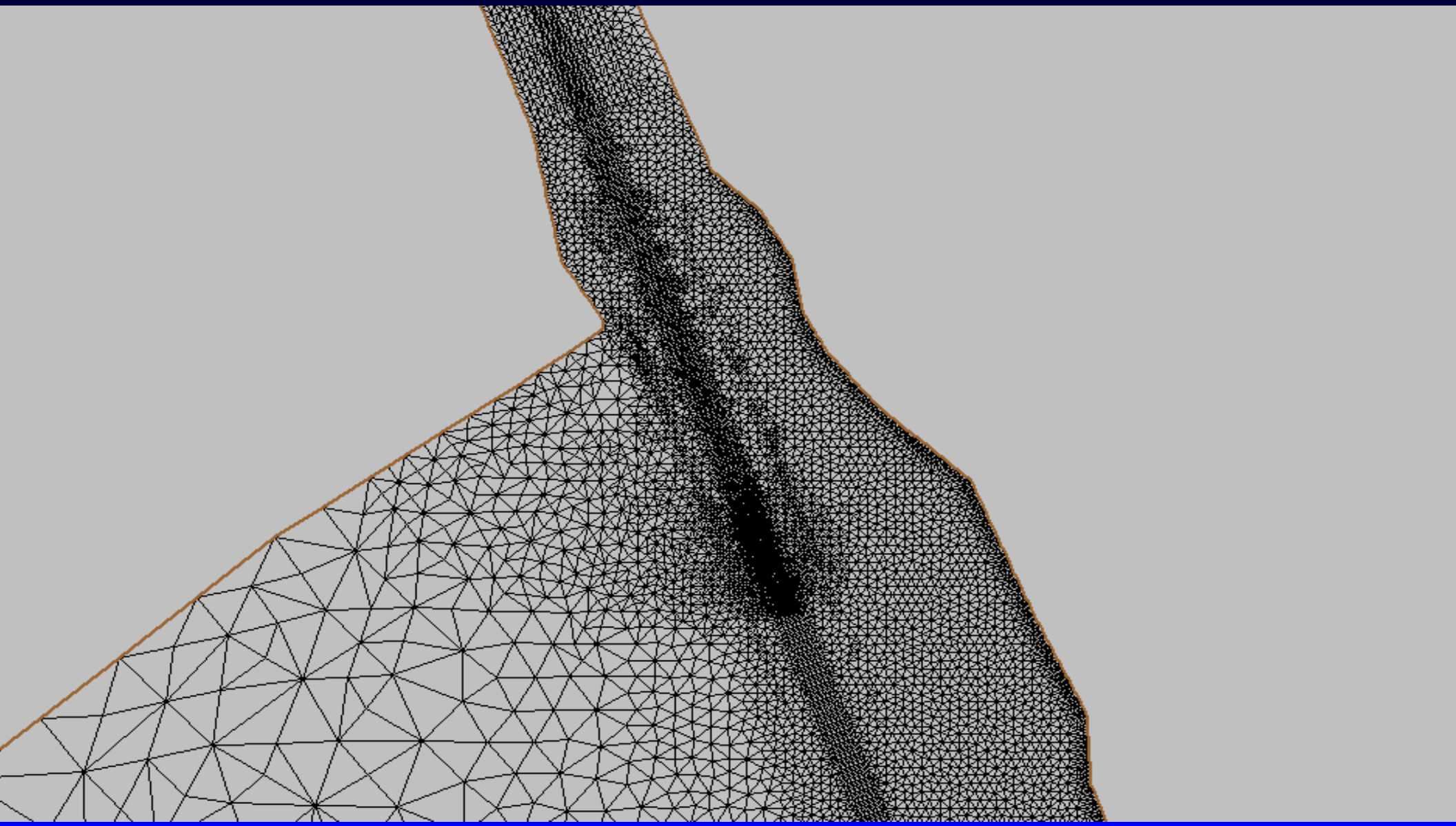
# Adaption 1



# Adaption 2



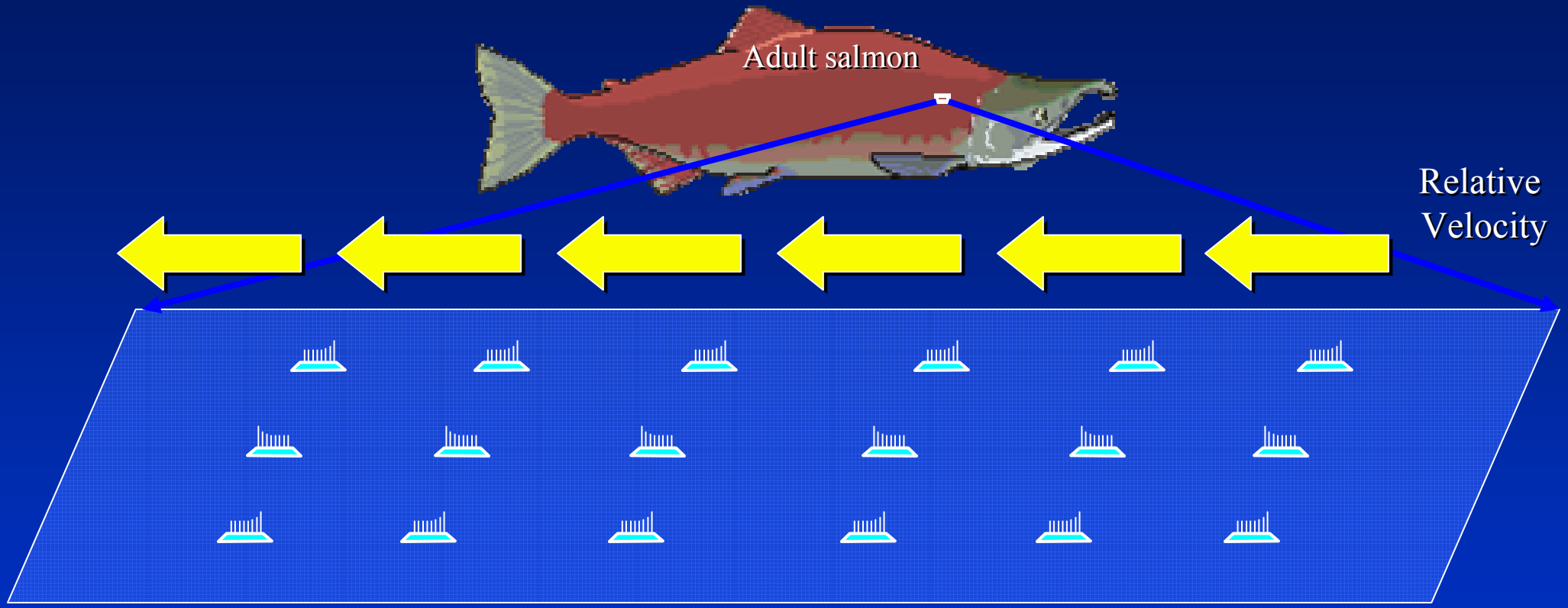
# Adaption 3



# Fish Behavior

# Hydrodynamics from Fish's Point of View

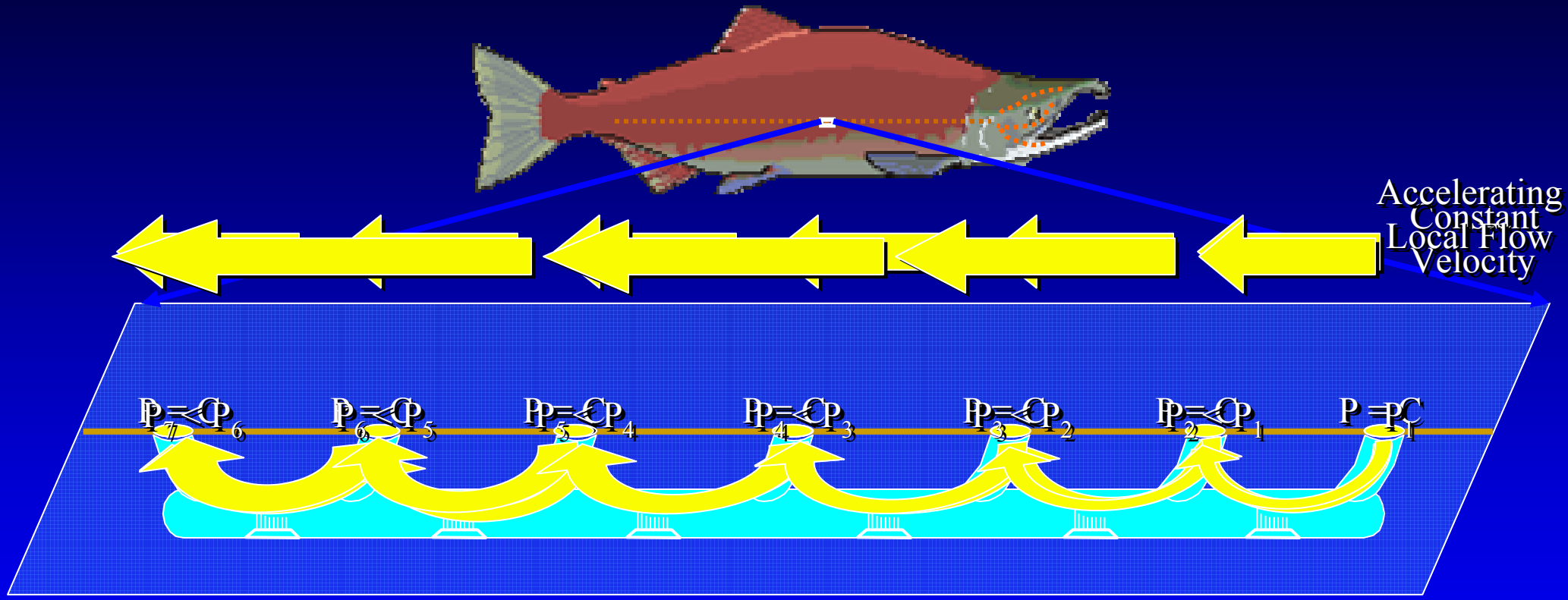
## Mechanosensory System – Superficial Neuromasts




- Abundantly distributed spatially over the head and body of fish.
- Have the appropriate anatomical distribution and physiological properties to signal the strength and direction of flow.
- Have a preferred axis of sensitivity, or directional tuning, that would provide fish with the ability to detect current strength and direction at various positions on its body, enabling it to detect flow gradients or areas of current shear along its body.

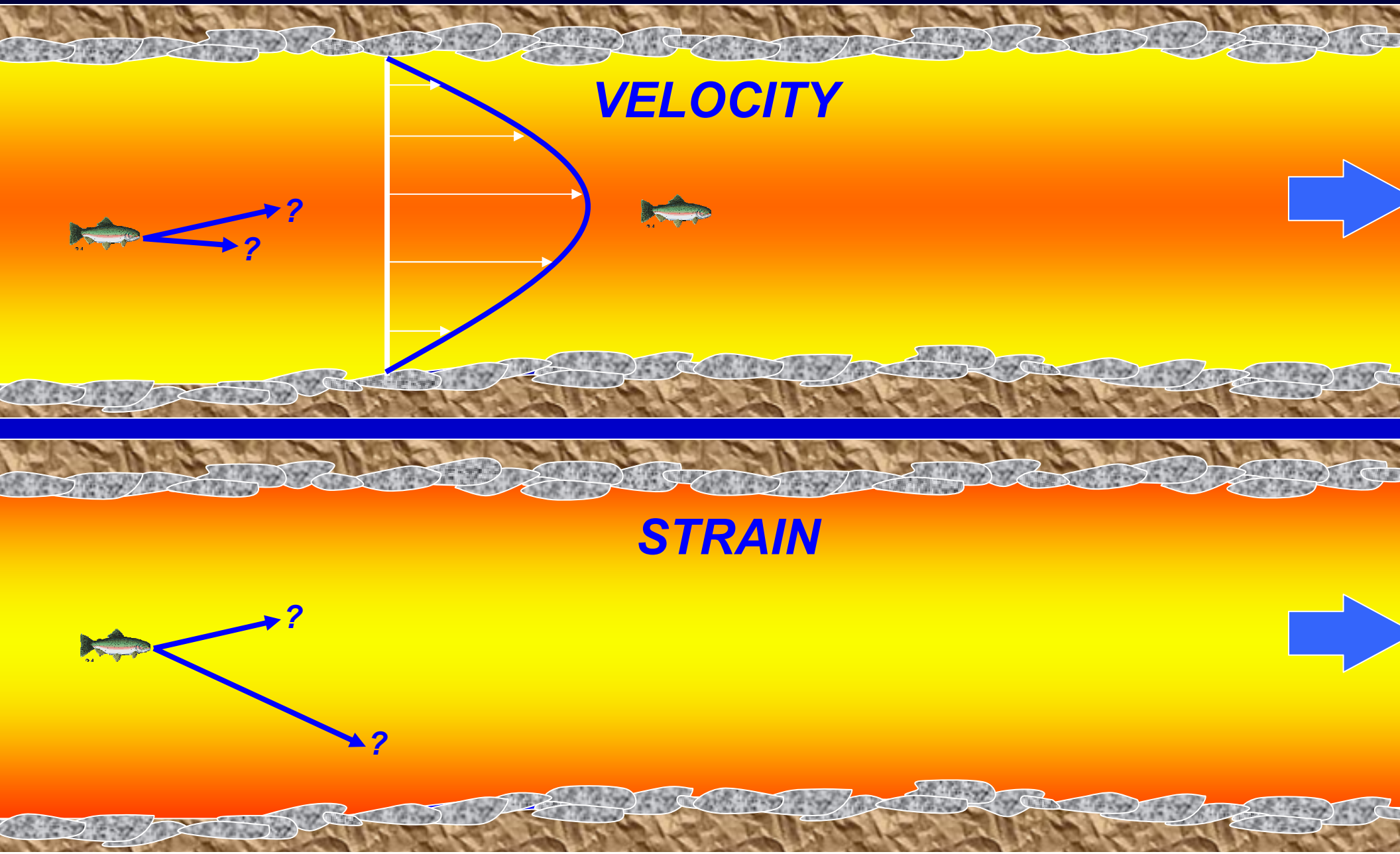
# Hydrodynamics from Fish's Point of View

## Mechanosensory System – Canal Neuromasts



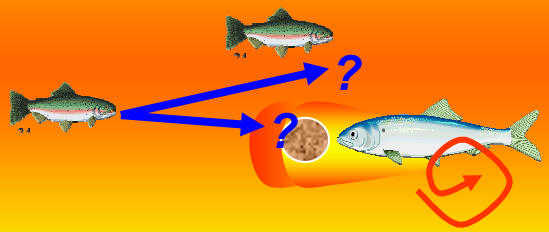

- Fluid accelerations vary greatly in strength and direction over very short distances close to a disturbance source, but provide the spatial nonuniformity the canal system is most sensitive to.
- Lateral line can be used to detect inanimate and stationary objects.
- Exposing the lateral, as opposed to frontal, portion of their 'lateral line' to disturbance sources provides fish with greater amount and breadth of information on the stimulus field.

# Open River

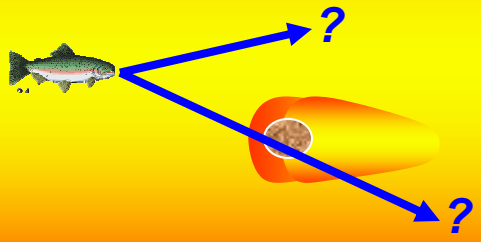


# Obstacles in Open River

## VELOCITY

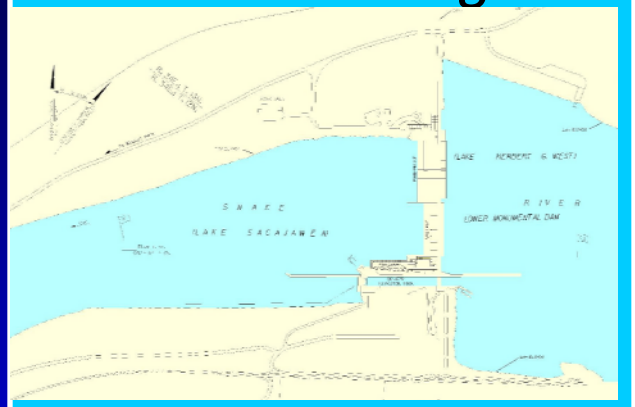



## STRAIN

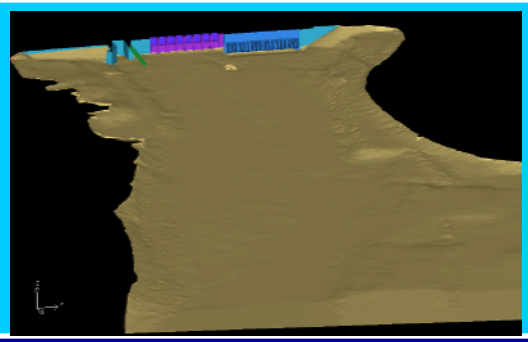


# Modeling Process

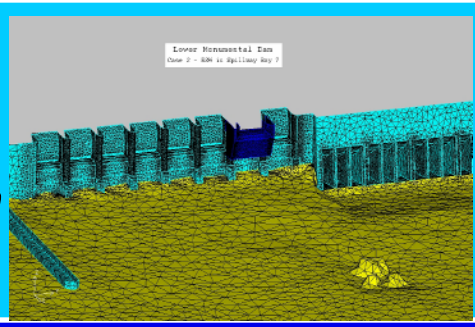
Line Drawings




CAD Surface Model

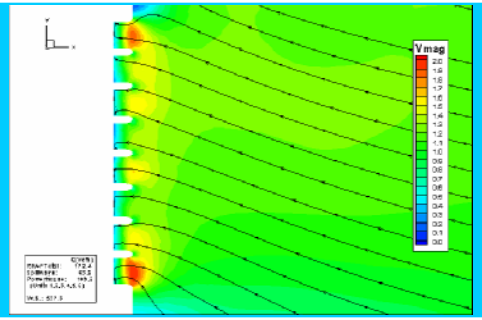


3D Mesh using Tetrahedra

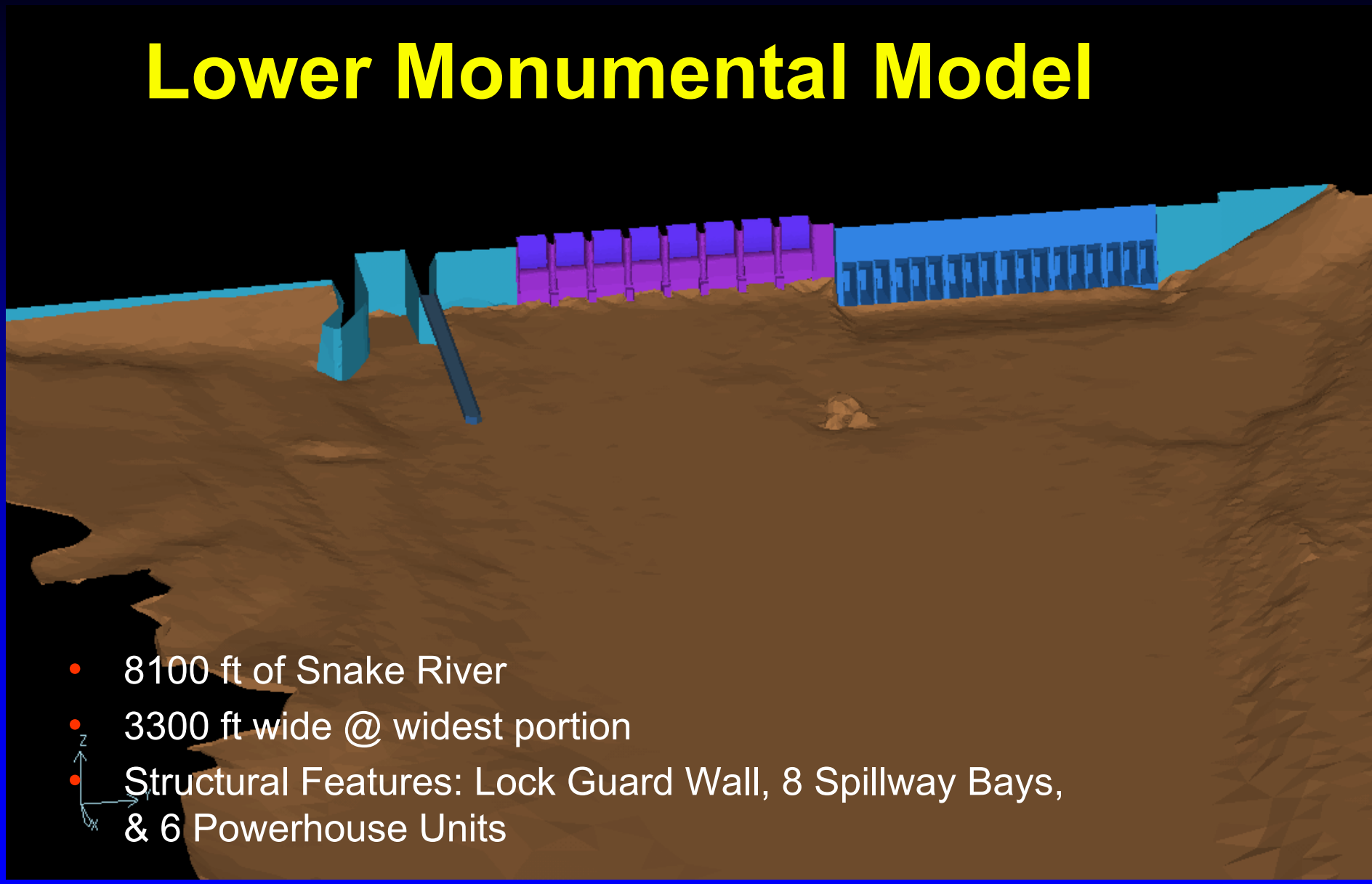



Flow Solver
(*AD*aptive *H*ydraulic Model)
*Files: Geometry, B.C.'s, I.C.'s*

Post Processing
(Visualization)

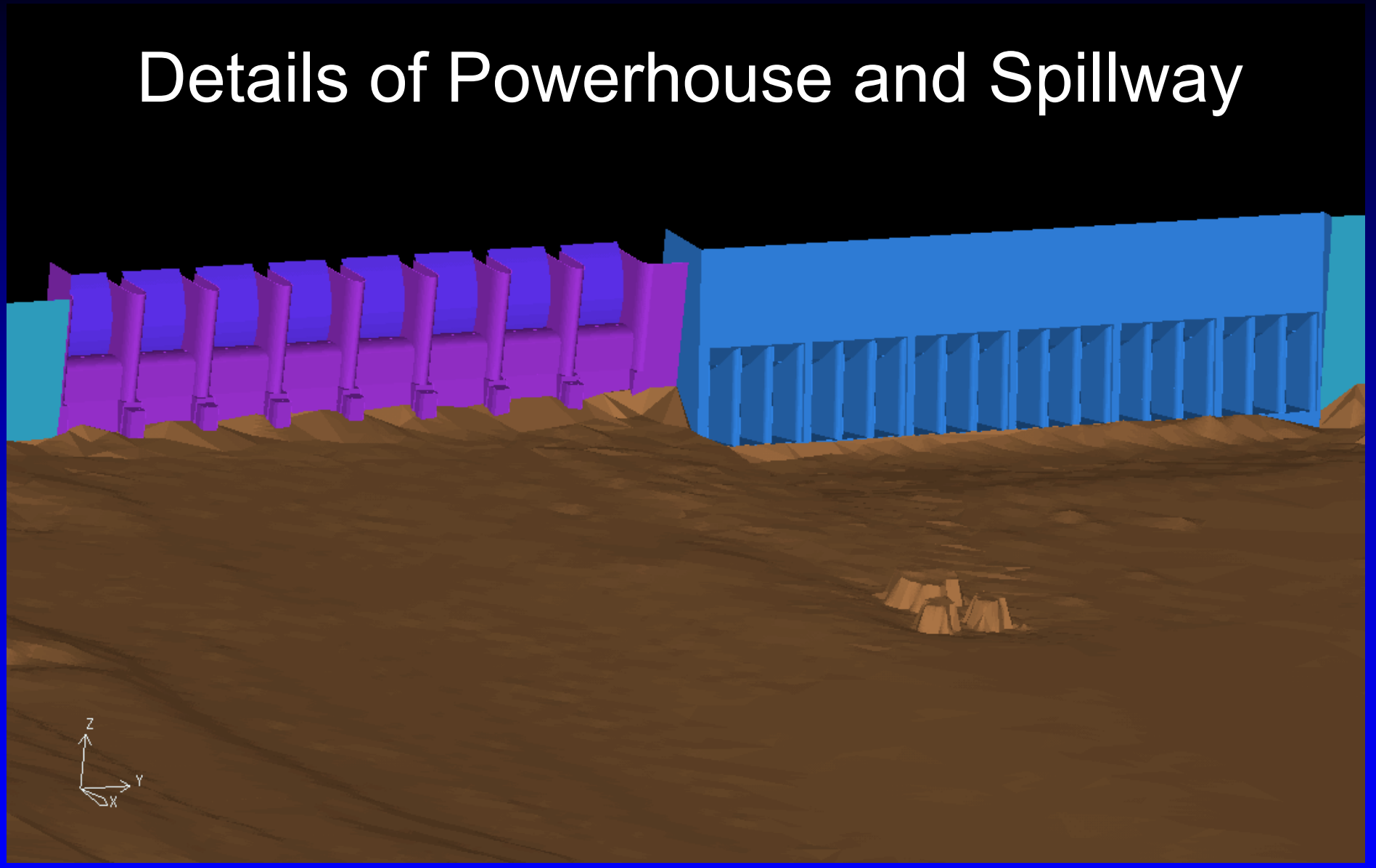


# Lower Monumental Model



- 8100 ft of Snake River
- 3300 ft wide @ widest portion
- Structural Features: Lock Guard Wall, 8 Spillway Bays, & 6 Powerhouse Units

# Details of Powerhouse and Spillway

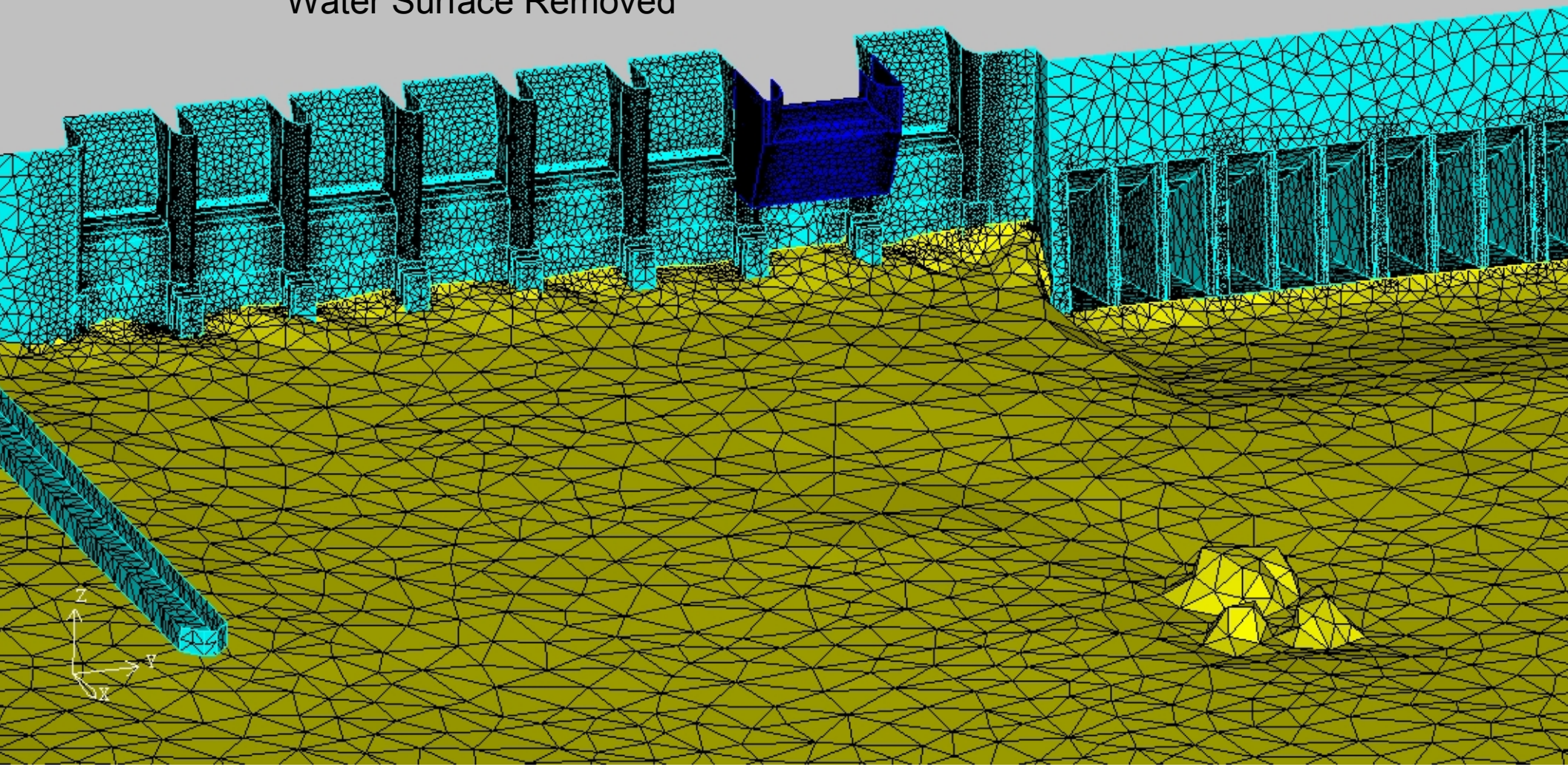


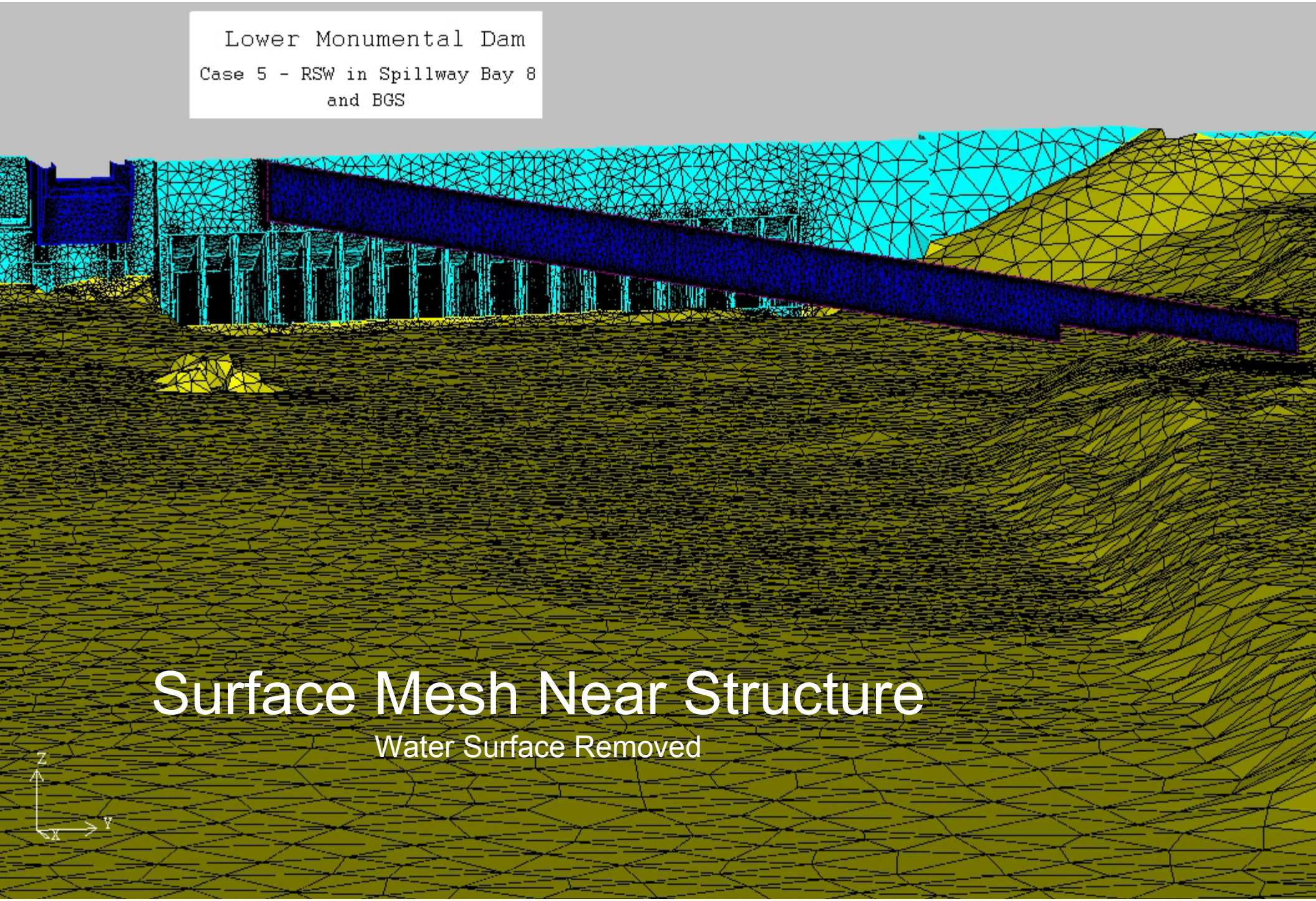
Lower Monumental Dam

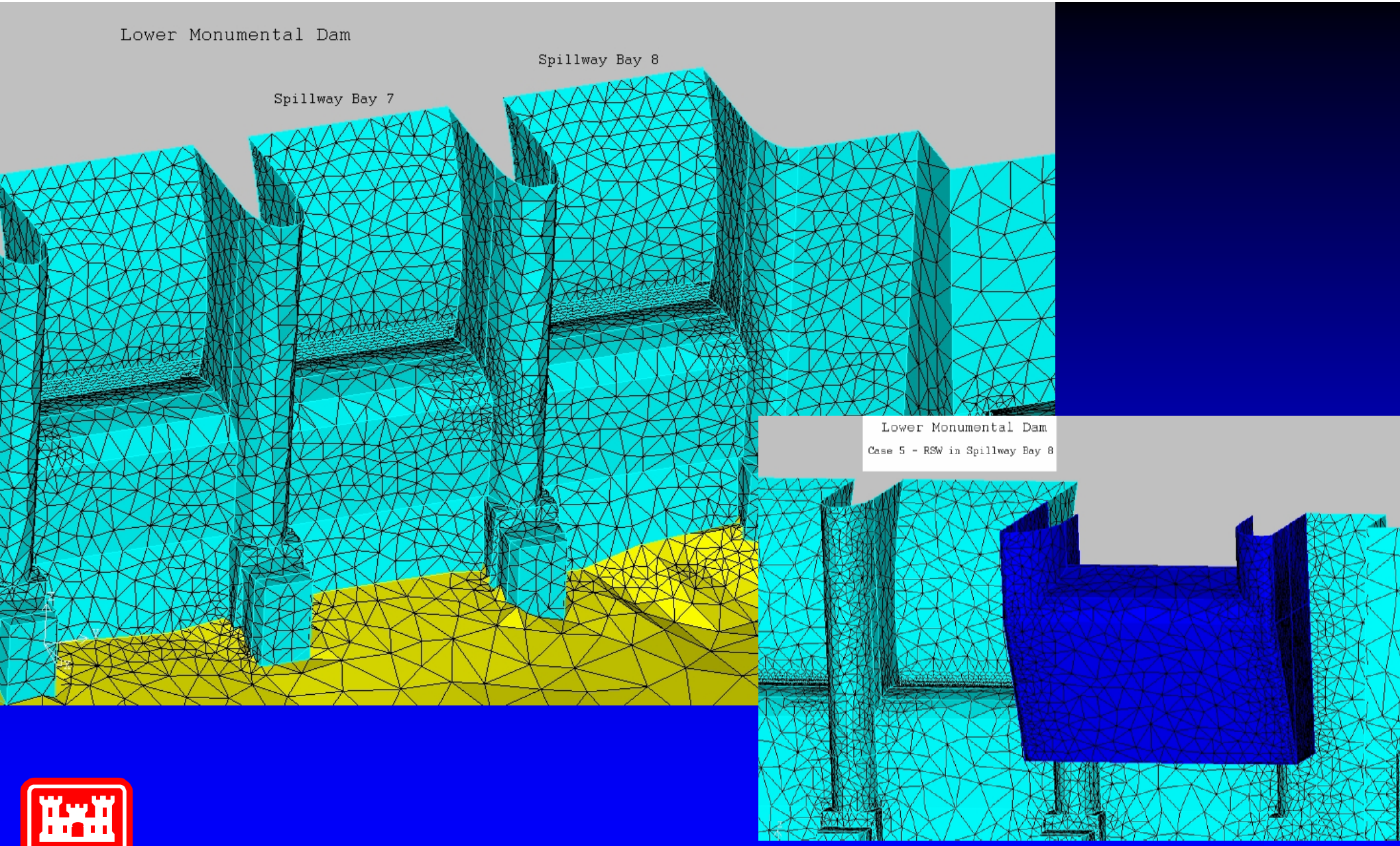
Case 2 - RSW in Spillway Bay 7

# Surface Mesh Near Structure

Water Surface Removed




Lower Monumental Dam
Case 5 - RSW in Spillway Bay 8
and BGS
Surface Mesh Near Structure
Water Surface Removed
Z
Y
X

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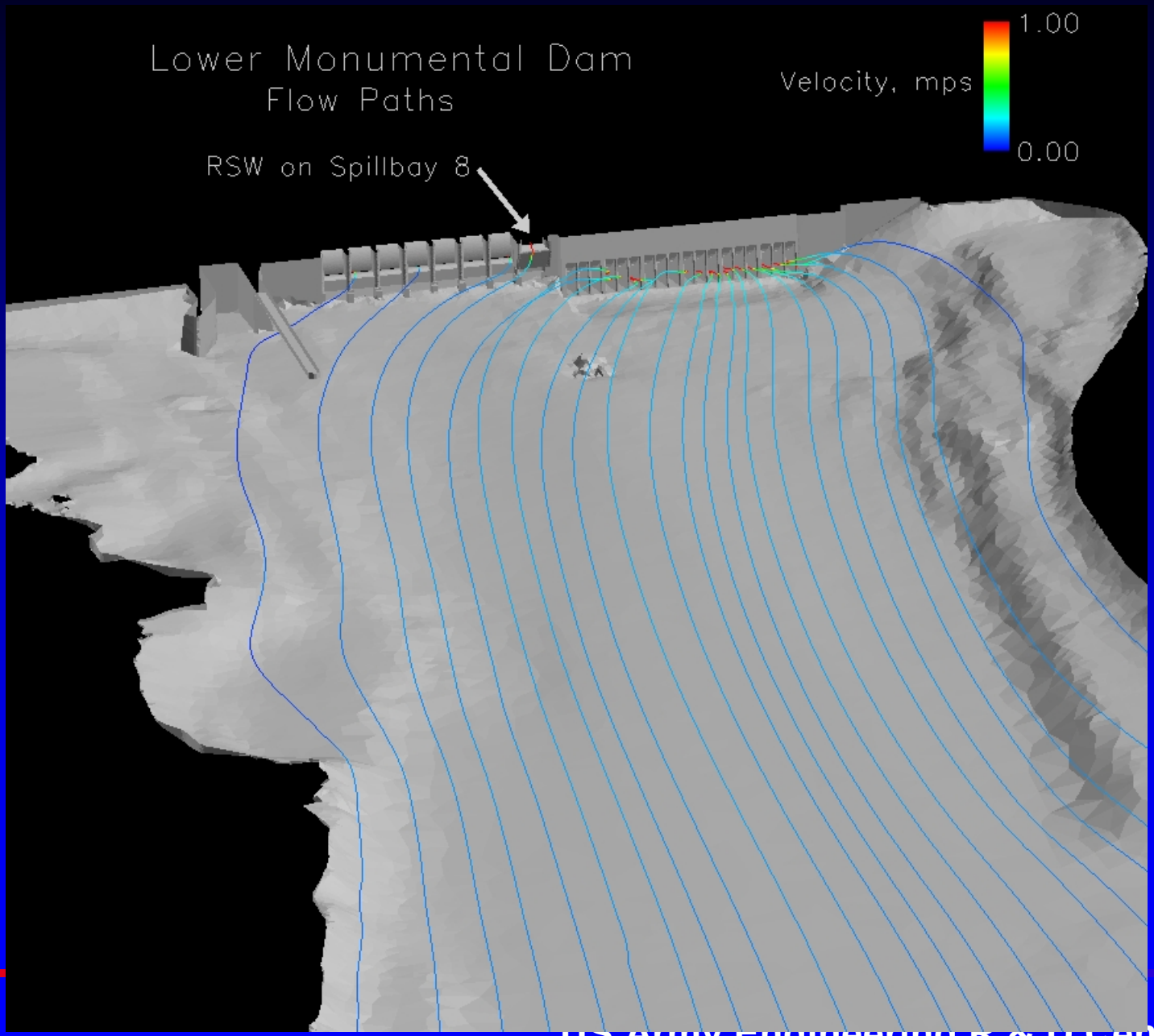


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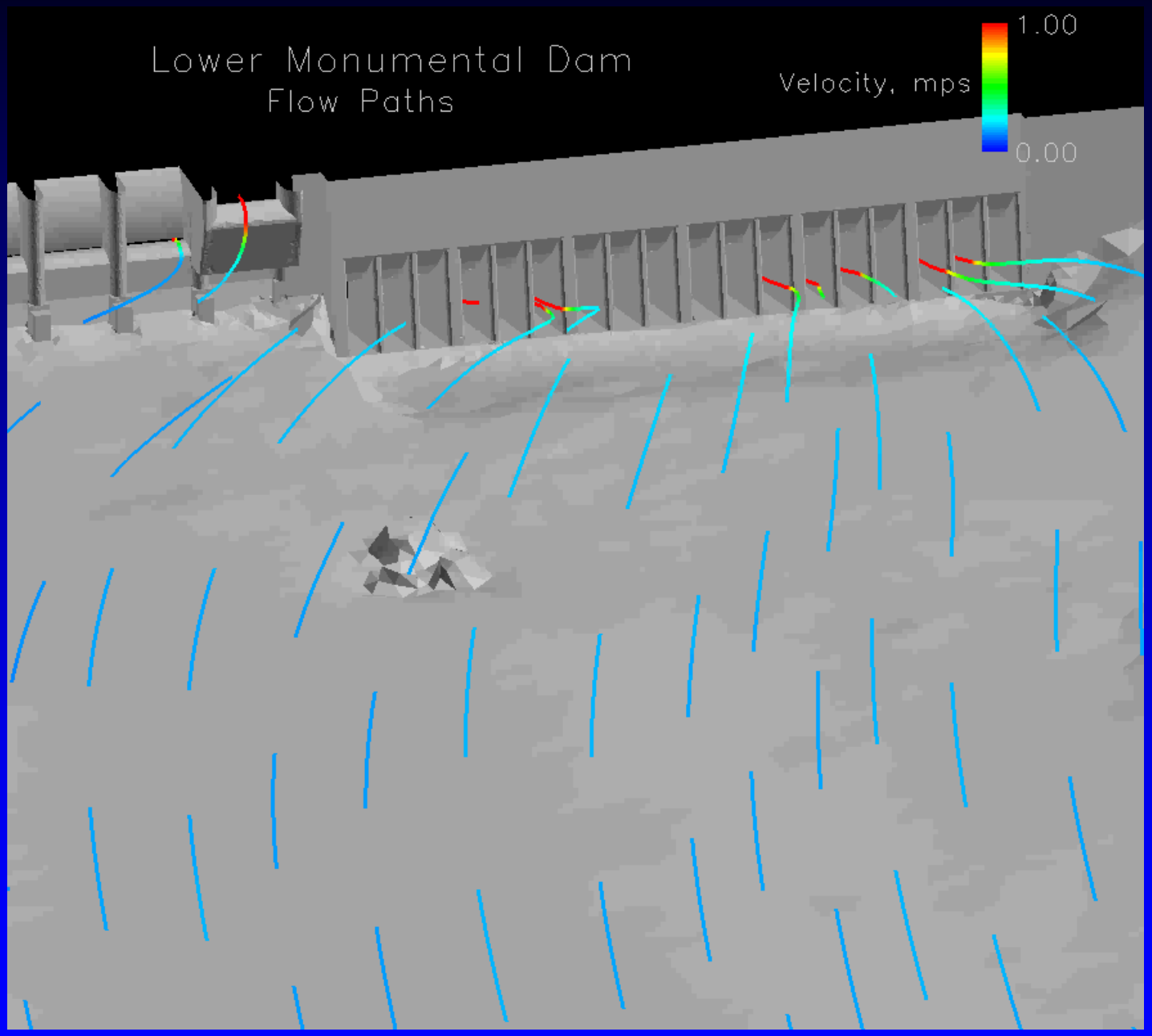
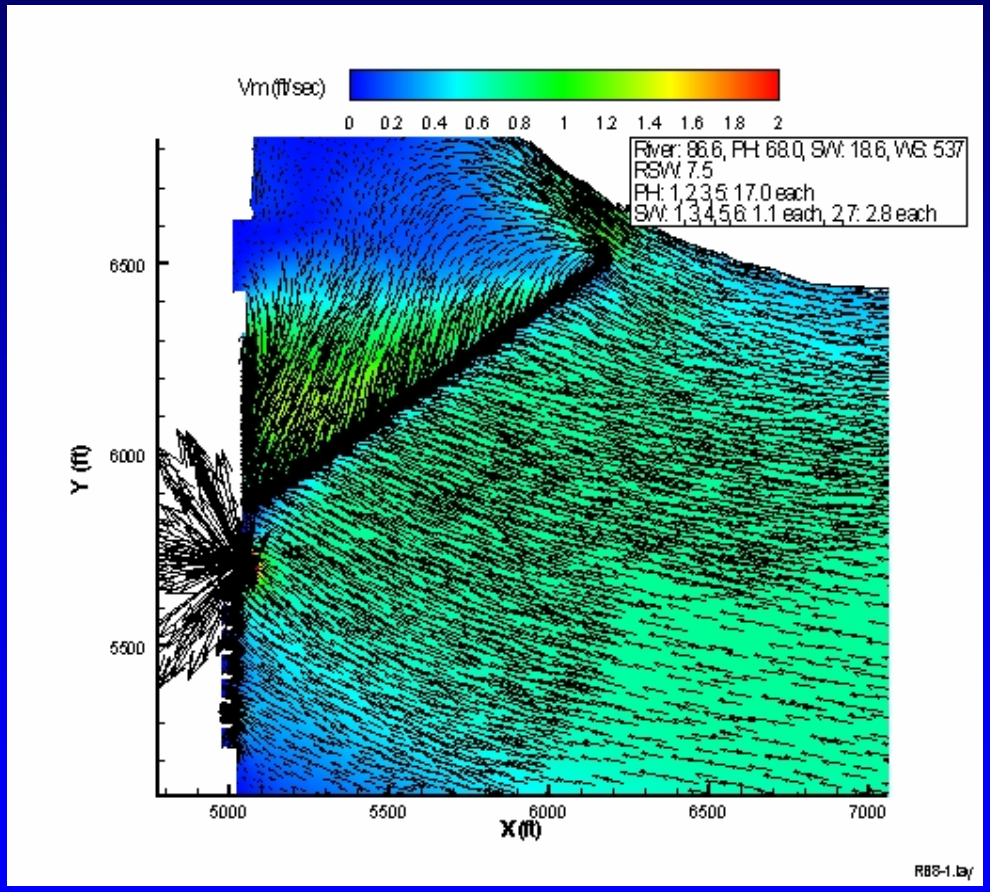

Lower Monumental Dam
Flow Paths
Velocity, mps
1.00
0.00

# Lower Monumental Reservoir Surface Currents

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# ADH_Navier-Stokes Solver Future Efforts

- Wind stresses: in PNW, setup sometimes drives surface currents upstream
- Unsteady flow patterns: at various time scales (e.g.unit operations, eddies, etc.)
- Capability to model contorted water surface (e.g. breaking waves, spillway flow, etc.)
- Incorporation of moving mechanical parts (bulkheads, gates, valves, etc.)