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Prediction of Total Dissolved Gas below Overthrough Spillways

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Prediction of Total Dissolved Gas at Overthrough Spillways

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Outline

1. Background on overthrough spillways
2. TDG challenge
3. Projects for TDG prediction
4. Numerical method
5. Results and discussion
6. Conclusions

Background on Overthrow Spillways

- Spillways that dissipate energy by “throwing” spilled water over the plunge pool.

futurepowersystem.blogspot.com

Total Dissolved Gas Challenge

There are three conditions necessary to result in high TDG concentrations in a spillway tailwater:

1. An energetic flow with a substantial amount of turbulent energy,
2. Air entrainment that occurs, and
3. Air bubbles that are carried to depth within the tailwater.

Reduction of any of the three will likely result in lower TDG concentrations.

Projects for TDG Prediction

Cabinet Gorge Project

- Montana-Idaho Border
- 270 MW capacity
- 1080 cms powerhouse discharge
- 2270 cms 7Q10 spill discharge
- Spillway fall height = 18 m
- Combined TDG =132%
- TDG regulations = 110%
- Proposed tunnel for spill rejected
- Alterations to gate structures believed to be best solution

Projects for TDG Prediction
Boundary Project

- Pend Oreille River in northeastern Washington – boundary with Canada
- 1040 MW capacity
- 1500 cms powerhouse discharge
- 750 cms 7Q10 spill discharge
- 60 m fall from spillway
- TDG regulations = 110%
- Alterations to spillways and gate structures believed to be best solution

Numerical Method

- FLOW3D
- Model Velocities
- Particle tracking for bubbles
- Mass transfer calcs. on bubbles

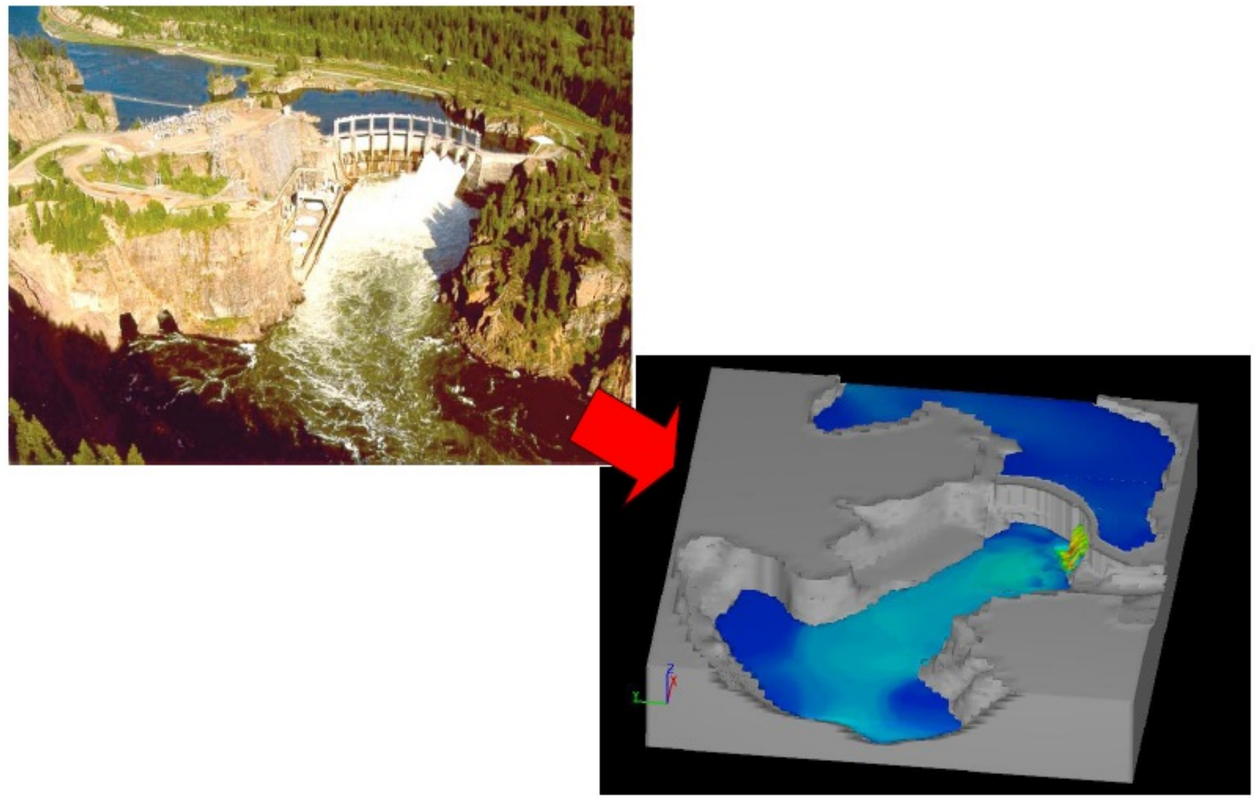

Figure 5.3

Cabinet Gorge Bypass Tunnels

Reference Case R3 – Velocity Contour Overview

HATCH ACRES

Spillway Discharge

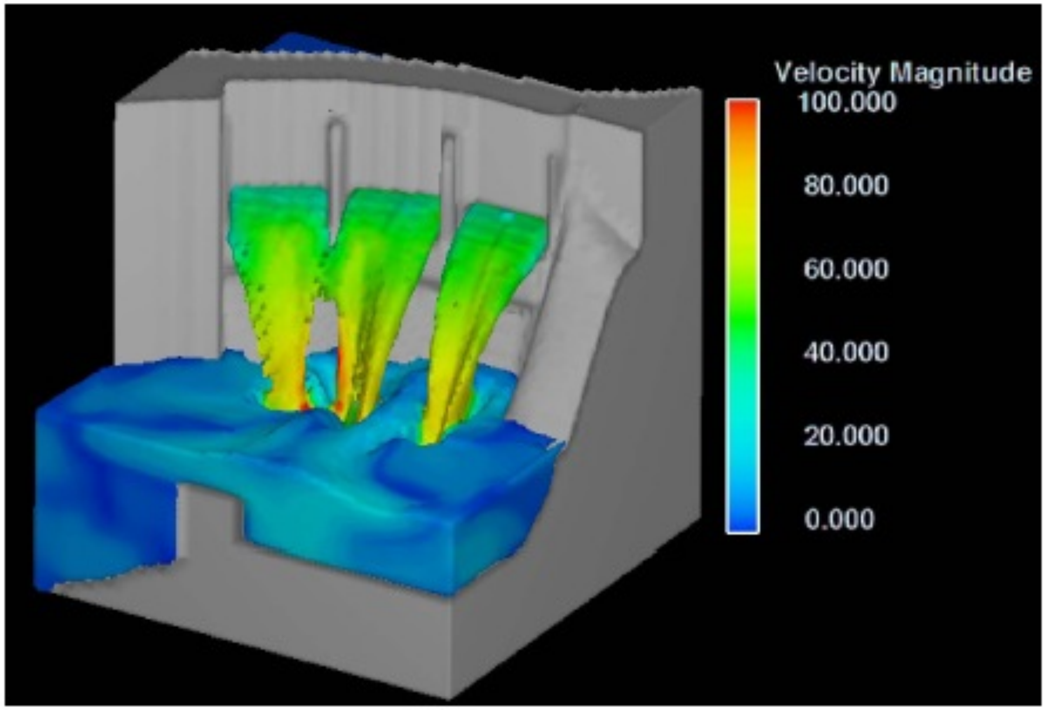

Figure 5.4

Cabinet Gorge Bypass Tunnels

Reference Case R3 – Velocity Contours at Spillway

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Note: Velocities are in ft/s

Assumptions for Gas Transfer

- There is sufficient air entrainment so that the rate of air entrainment is not a limiting factor.
- TDG concentration in the tailwater pool has reached steady state.
- The bubbles are exposed to a similar water concentration throughout the pool.
- The mass transfer across the water surface is negligible (probably the least reliable assumption).
- TDG from the powerhouse can be used in a flow-weighted mean with the spillway TDG

Gas transfer computations

- Particle tracking of bubbles with rise velocity of 0.2 m/s
- Bubbles change size and concentration with hydrostatic pressure
- Applied mass transfer relations to each bubble
- Optimized to steady state water concentration of TDG
- NO fitted coefficients

Mass transfer relationships

- Mass transfer

$$\frac{1}{AC_s}\frac{dM}{dt} = K_L\left(\frac{C}{C_s} - \frac{C_E}{C_s}\right)$$

- Bubble concentration, C_E

$$\frac{C_E}{C_s} \cong 1 + \frac{depth(m)}{10.3}$$

- Liquid film coefficient

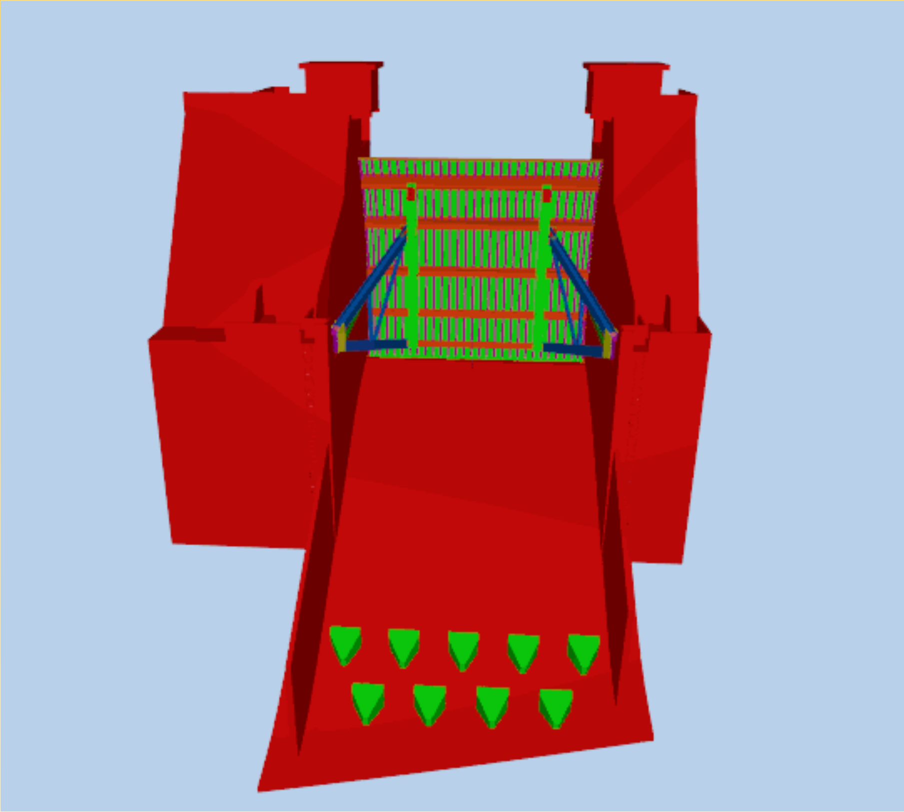
$$K_L = (2\pi D)^{1/2}\frac{U^\eta}{L^{1-\eta}\nu^{\eta-1/2}}$$

  – L = 0.7*dia. (Nezu and Nakagawa, 1994)
  – η = 0.75 (Azbel, 1980)

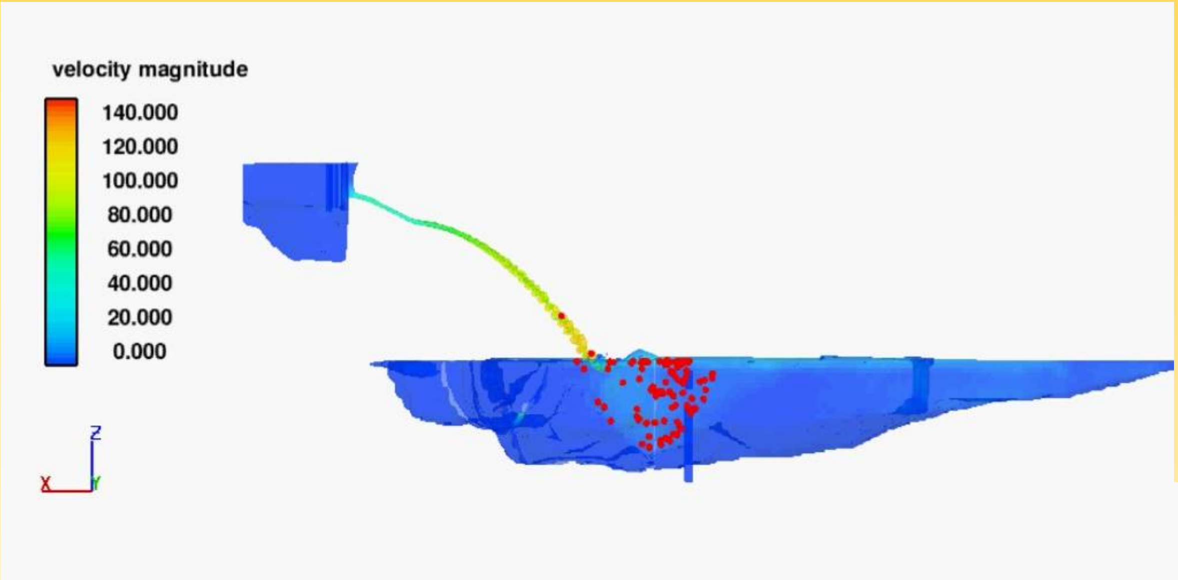
Verification Spillway Results

Spillway Discharge (CMS)	Powerhouse Discharge (CMS)	Predicted Spillway TDG (%)	Powerhouse TDG (%)	Predicted Combined TDG (%)	Measured TDG (%)
Cabinet Gorge					
1200	1060	149	115	133	132
Boundary Dam					
420	480	150	101	124	127
340	1500	147	122	126	127
750	1480	158	128	138	134

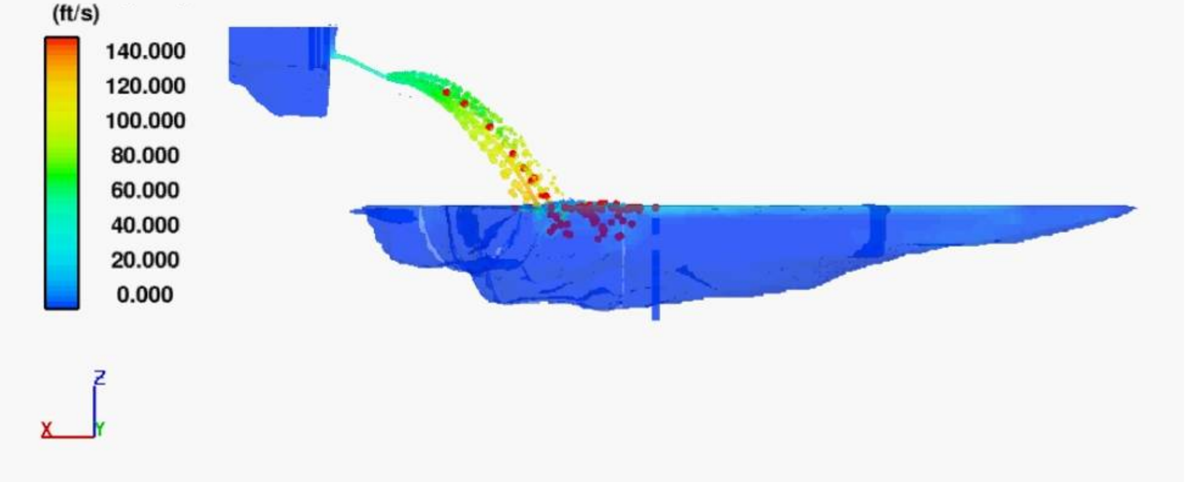
Boundary Spillway Alterations



Visualization of bubble paths



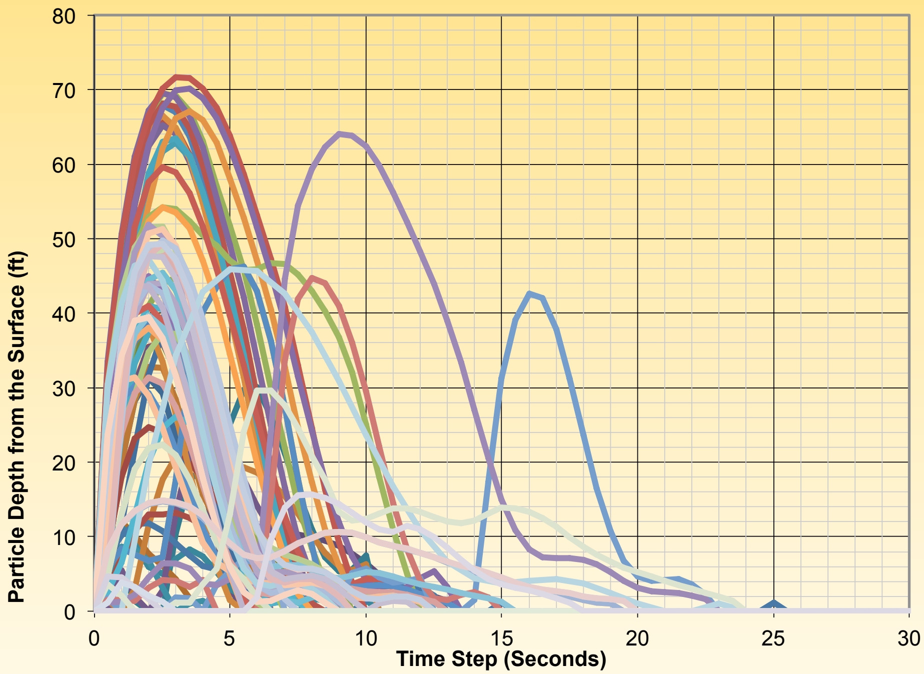
Before Spillway Alteration



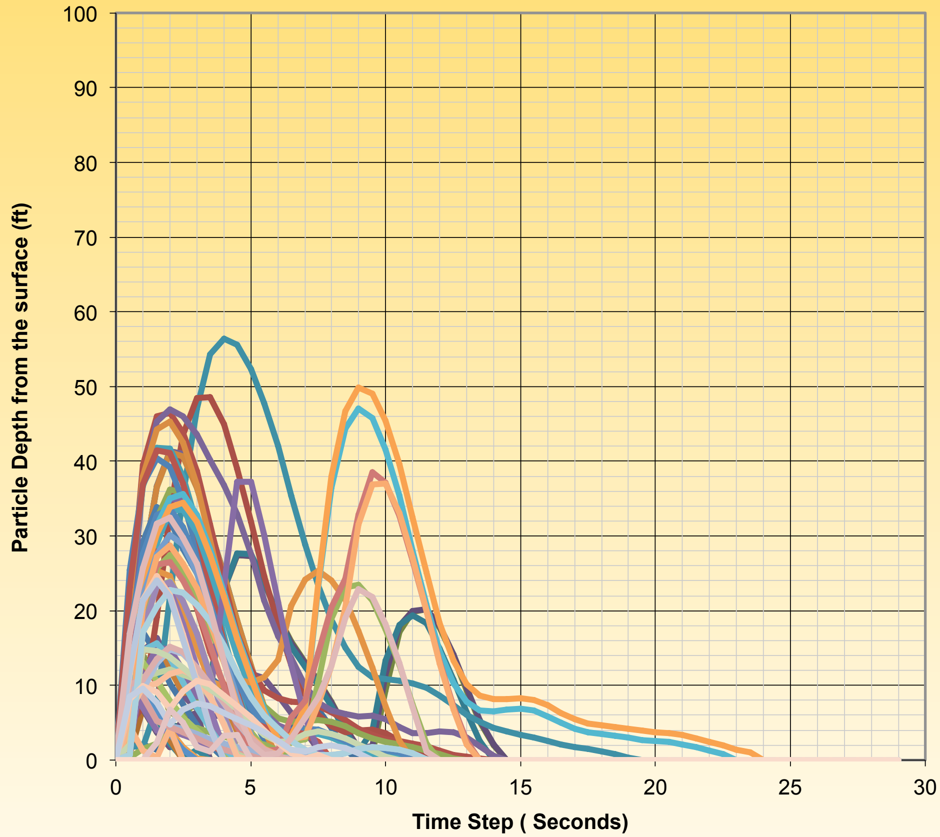
After Spillway Alteration

Bubble Depths

Before Spillway Alteration
= 135.3%

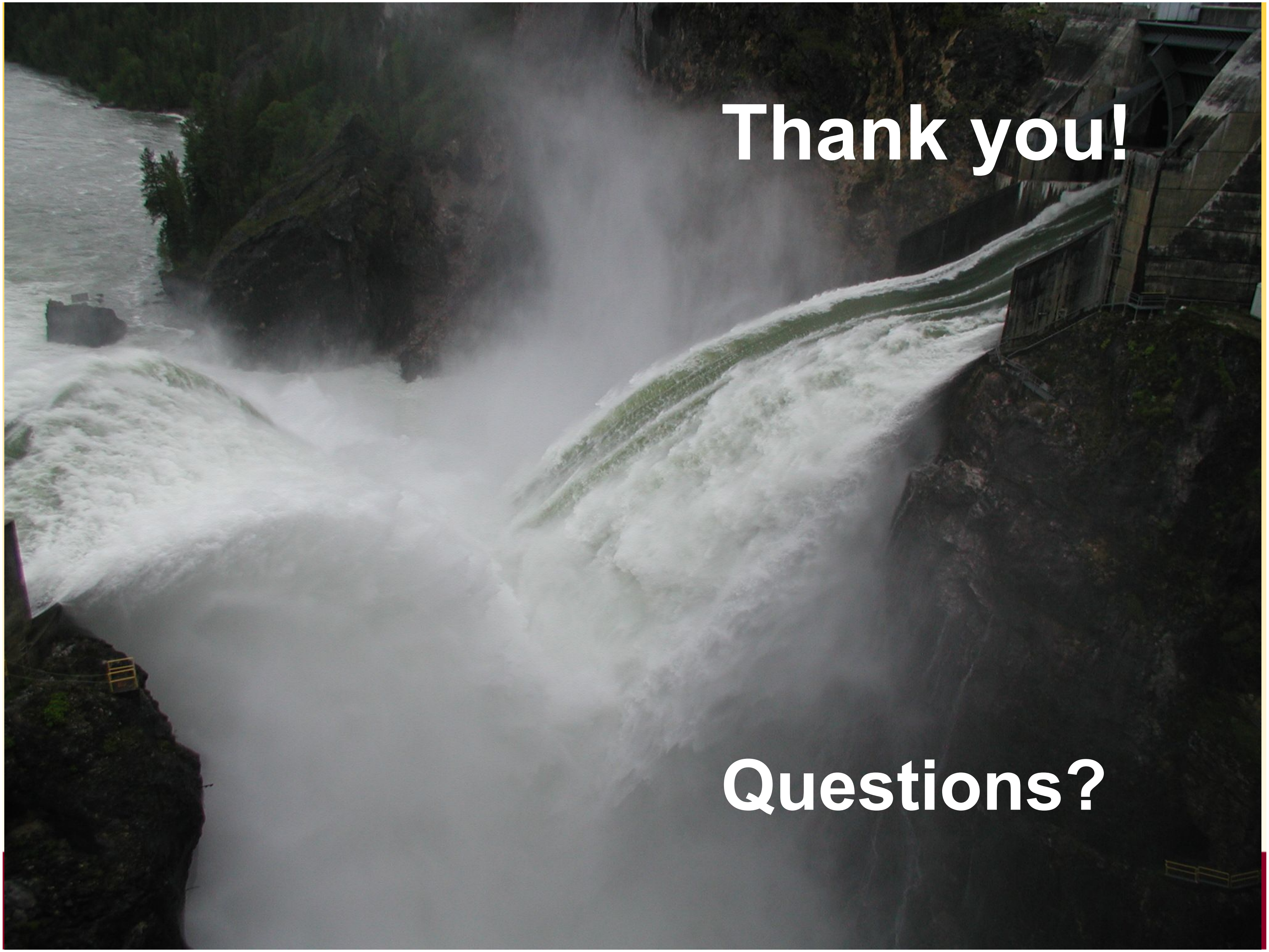


After Spillway Alteration
= 126.6%



Conclusions

- Assumptions are designed for overthrow spillways with plunge pools
- CFD particle tracking
- Mass transfer model
- No fitted coefficients with these assumptions
- TDG predicted to within +/- 4%.
- Alterations to spillway and gate design can be tested.


Thank you!
Questions?