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Taming Total Dissolved Gas using Advanced Computer Simulations and Reduced Scale Models

M. Politano
University of Wisconsin - Madison

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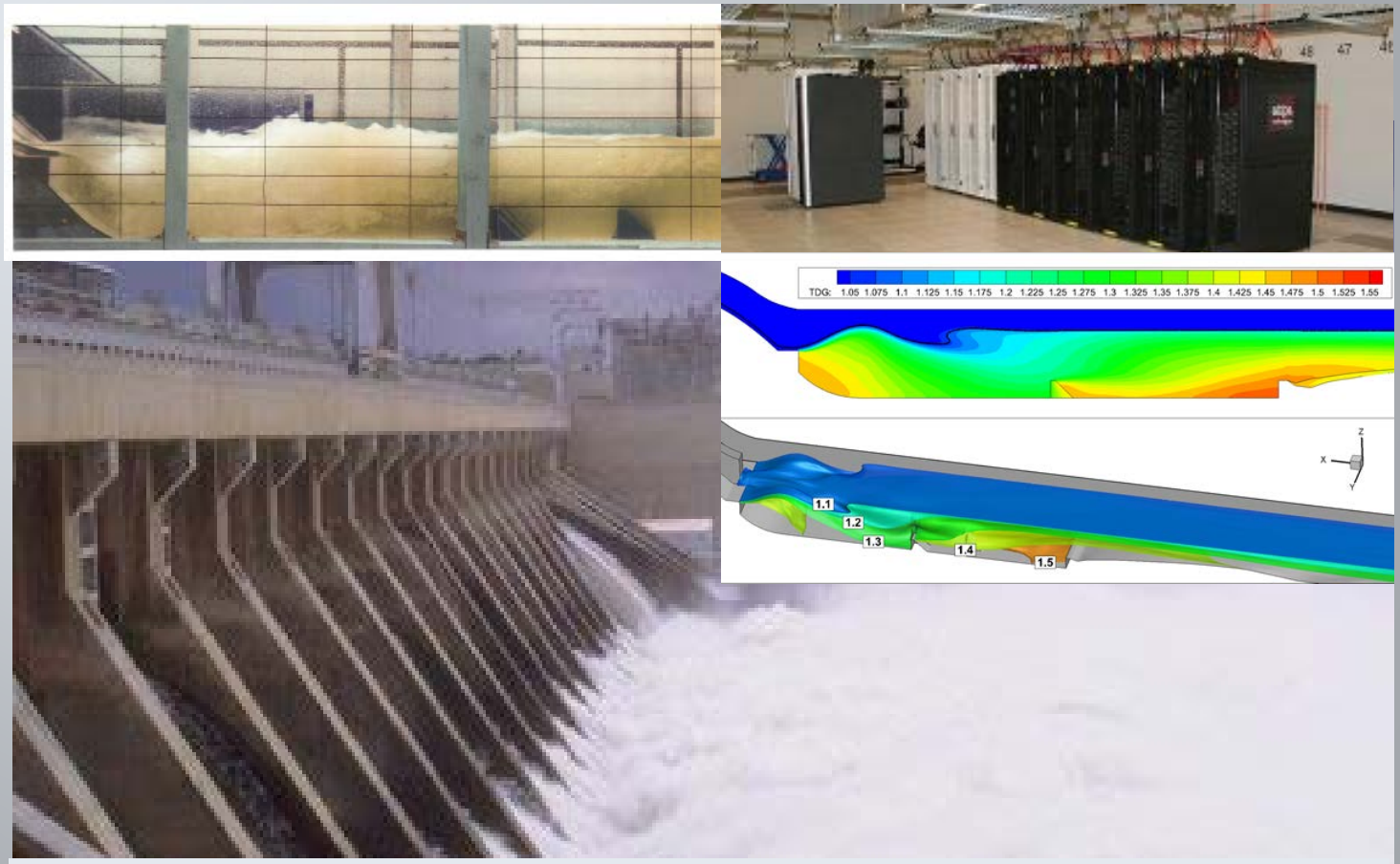
TAMING TOTAL DISSOLVED GAS USING ADVANCED COMPUTER SIMULATIONS AND REDUCED SCALE MODELS



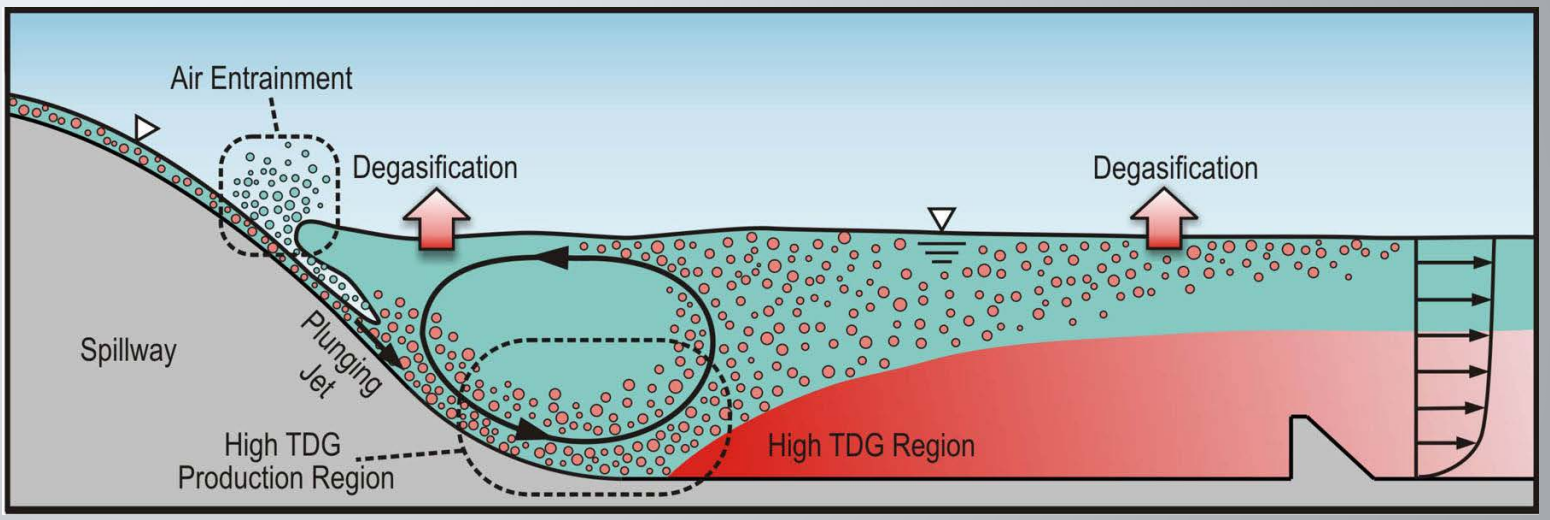
M. Politano, L. Weber, T. Lyons, A. Arenas Amado, A. Craig, C. Turan, Y. Wang, J. Dvorak, M. Carbone. IIHR – Hydroscience & Engineering. The University of Iowa.

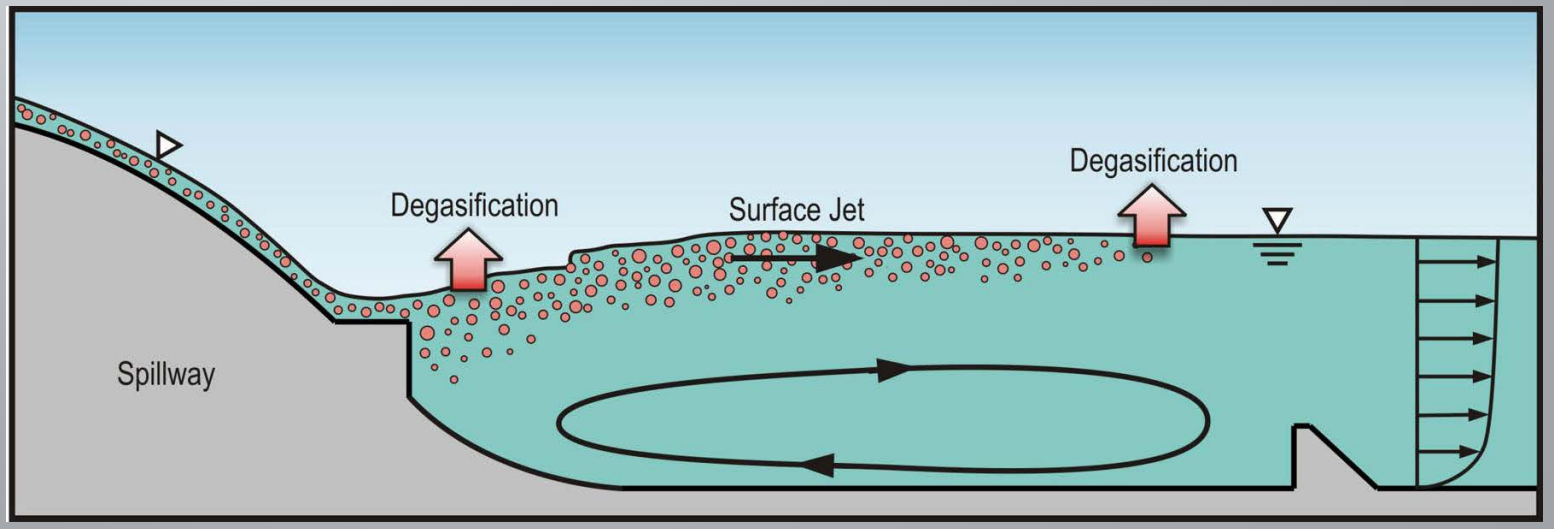
TOTAL DISSOLVED GAS AND GAS BUBBLE DISEASE

- TDG refers to the total amount of gases present in water.
- TDG supersaturation can cause gas bubble disease (GBD) in fish. GBS in fish is similar to a diver getting the "bends".

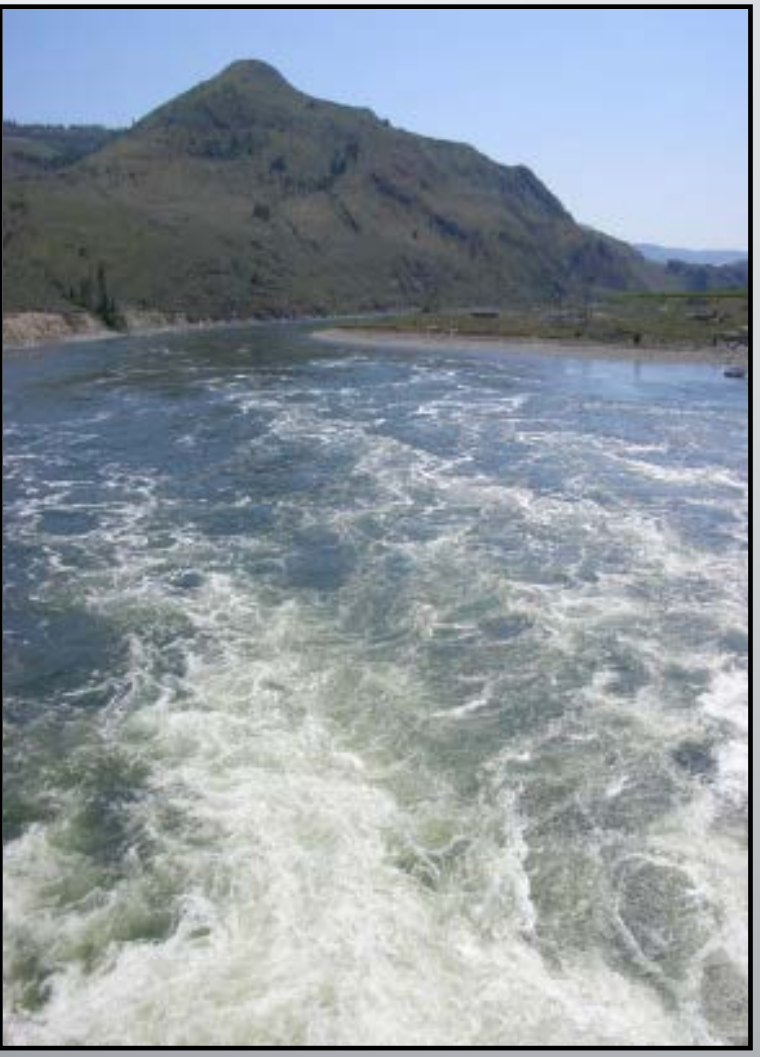
- In order to protect fish, Federal and State agencies have established water quality standards for TDG.

TOTAL DISSOLVED GAS ABATEMENT OPTIONS





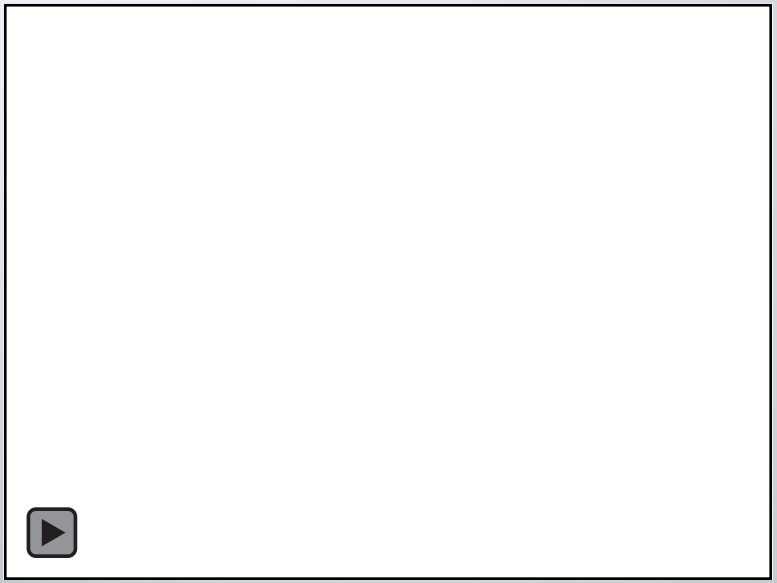
INSIGHTS FROM LABORATORY AND NUMERICAL MODELS



Reduced-scale laboratory and numerical models were developed with the purpose of:

- Improving our understanding of the underlying phenomena leading to TDG supersaturation in tailraces
- Evaluating the effectiveness of plant operations in reducing TDG production
- Evaluating the effect of structural modifications on TDG production

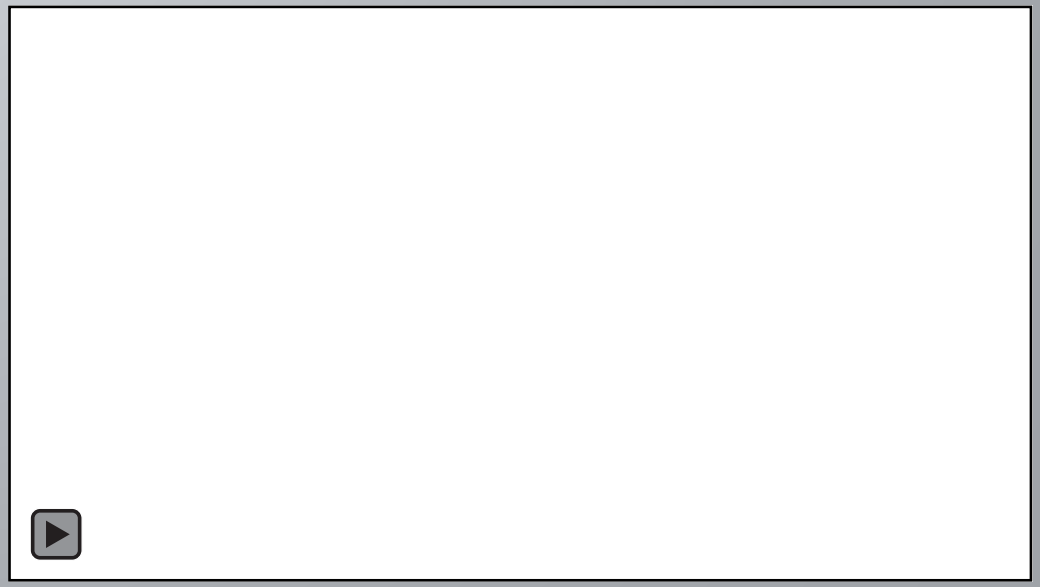
TAILRACE FLOWS



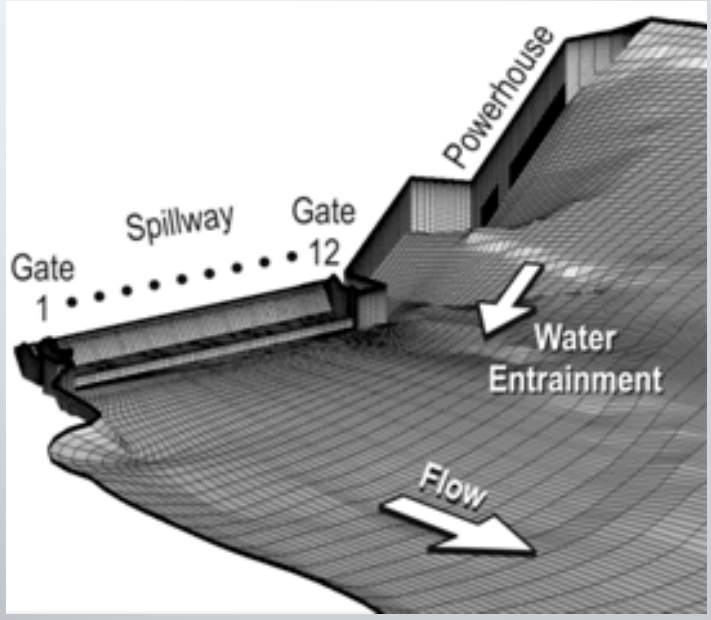
The flow in the tailrace is very complex. The large energy contained in spillway flows introduce massive amount of **bubbles** and created waves and sprays.

The development of a reliable numerical tool can be achieved only if **transport, mixing and production** of TDG can be adequately modeled.

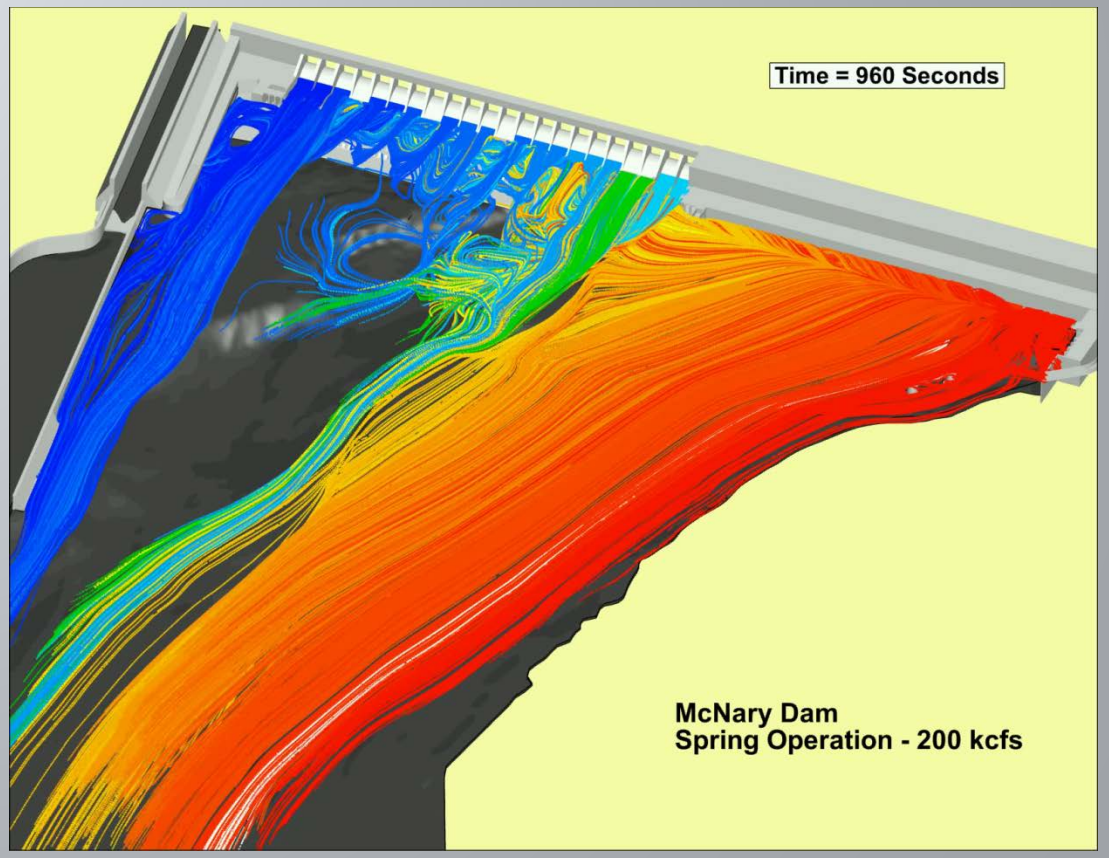
The TDG **production** depends on pressure, temperature and interfacial area of the bubbles.



WATER ENTRAINMENT



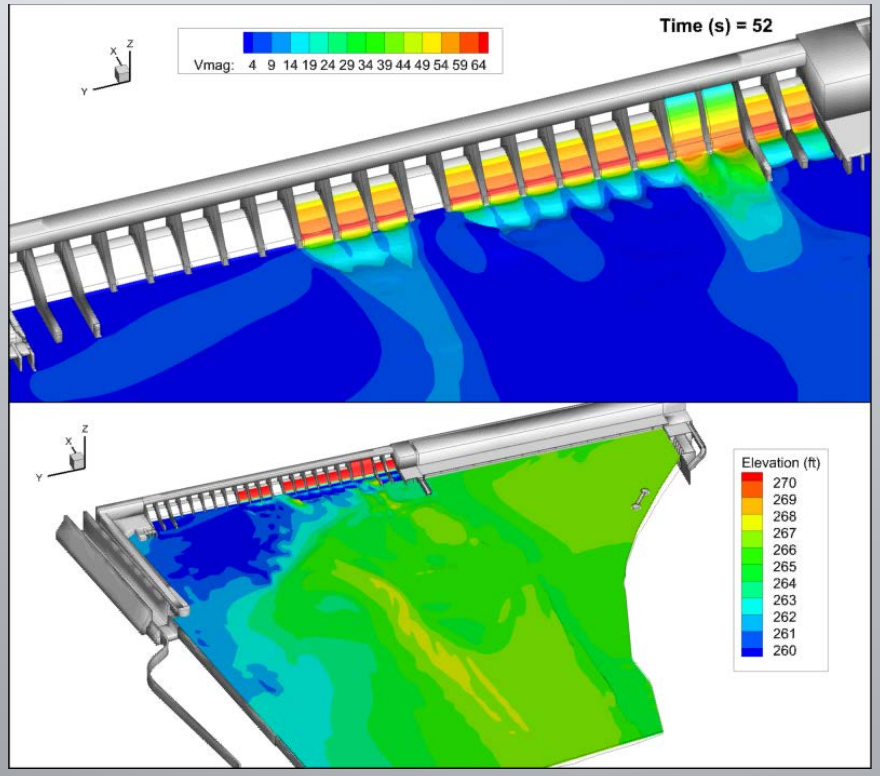
The flow pattern in the tailrace is completely modified after installation of spillway deflectors since spillway surface jets attract water toward the jet region, a phenomenon called water entrainment.

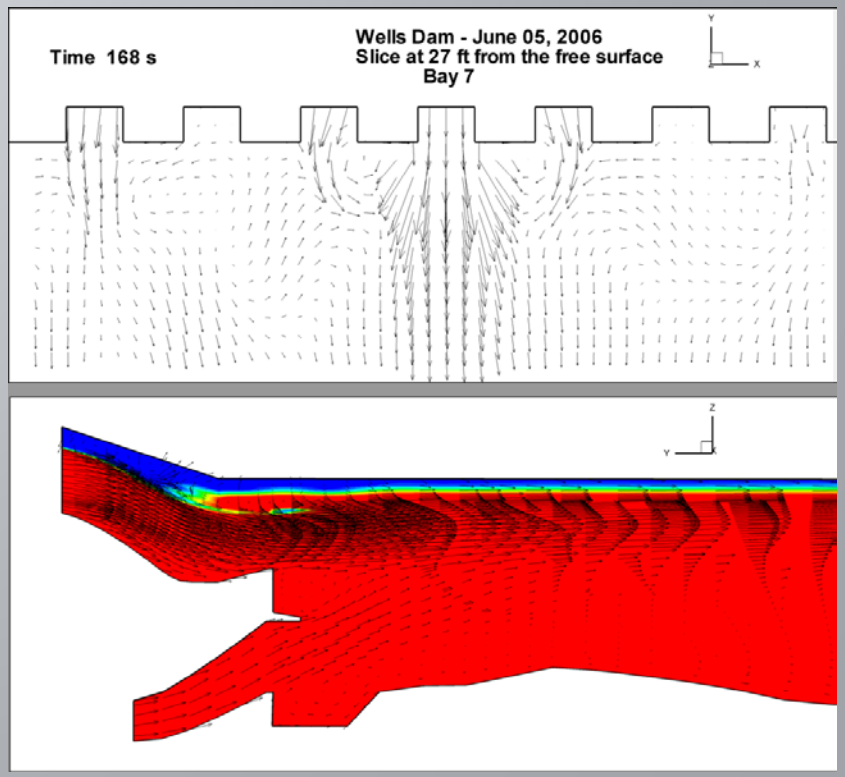


NUMERICAL MODEL

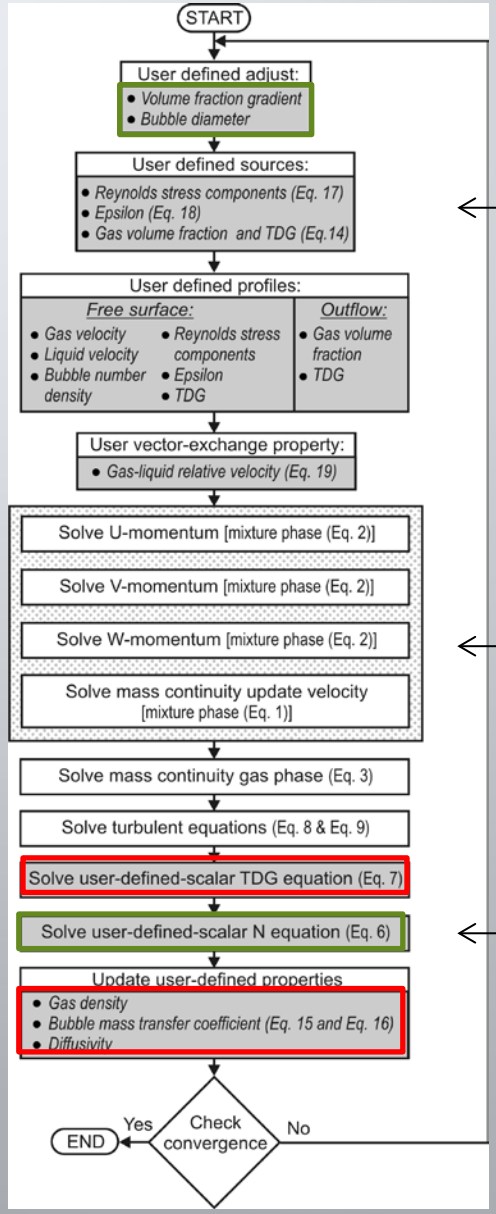
- Two models were used in the study; a volume of fluid (VOF) model and a rigid-lid two-phase flow model.

- The VOF method is used to estimate the regime of spillway jets and the free surface shape in a domain close to the spillway region.





TWO-PHASE RIGID LID MODEL



Anisotropic turbulence and effect of the bubbles on the turbulence

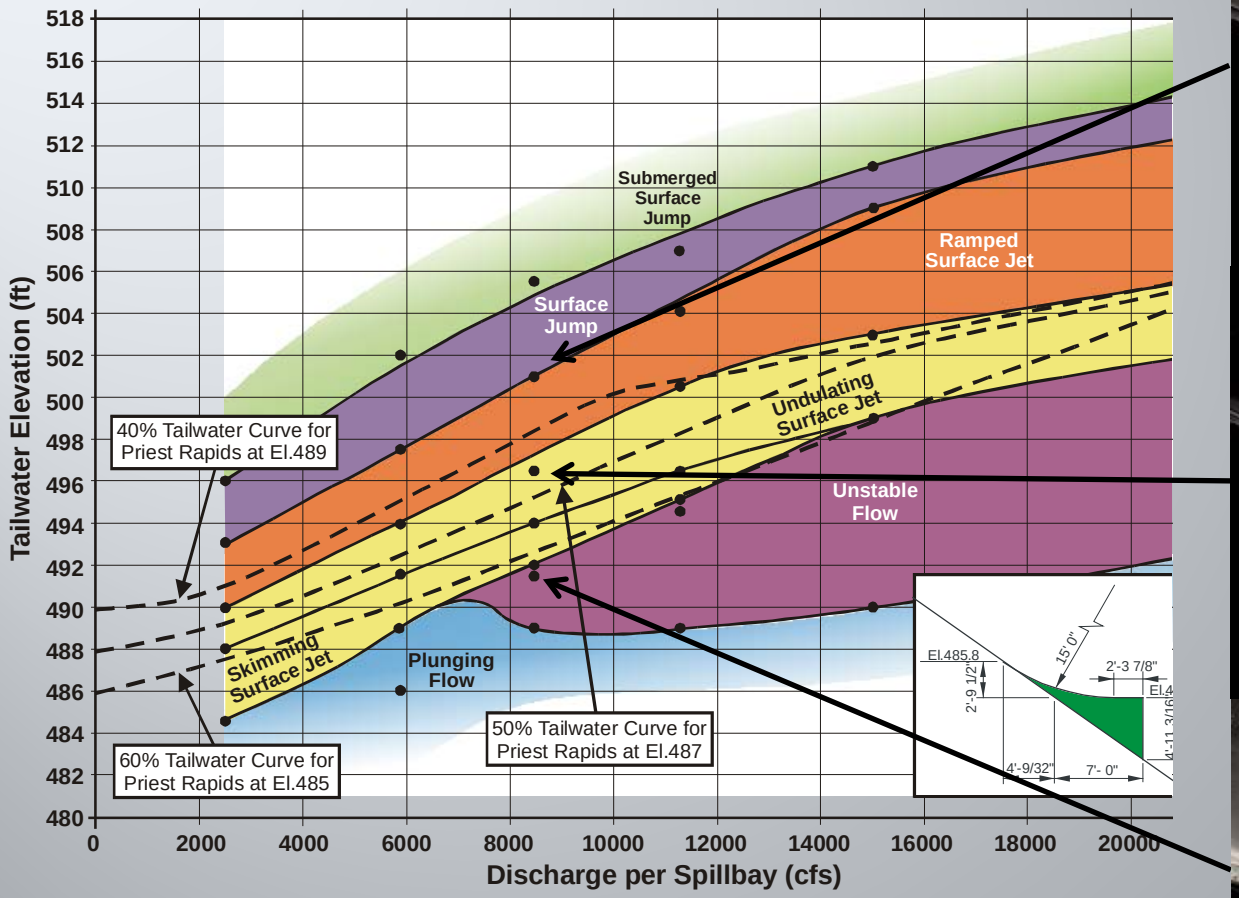
Mixture model: considers the volume occupied by the bubbles, the effect of bubbles on the density and viscosity, and takes into account the forces bubbles exert on the liquid phase.

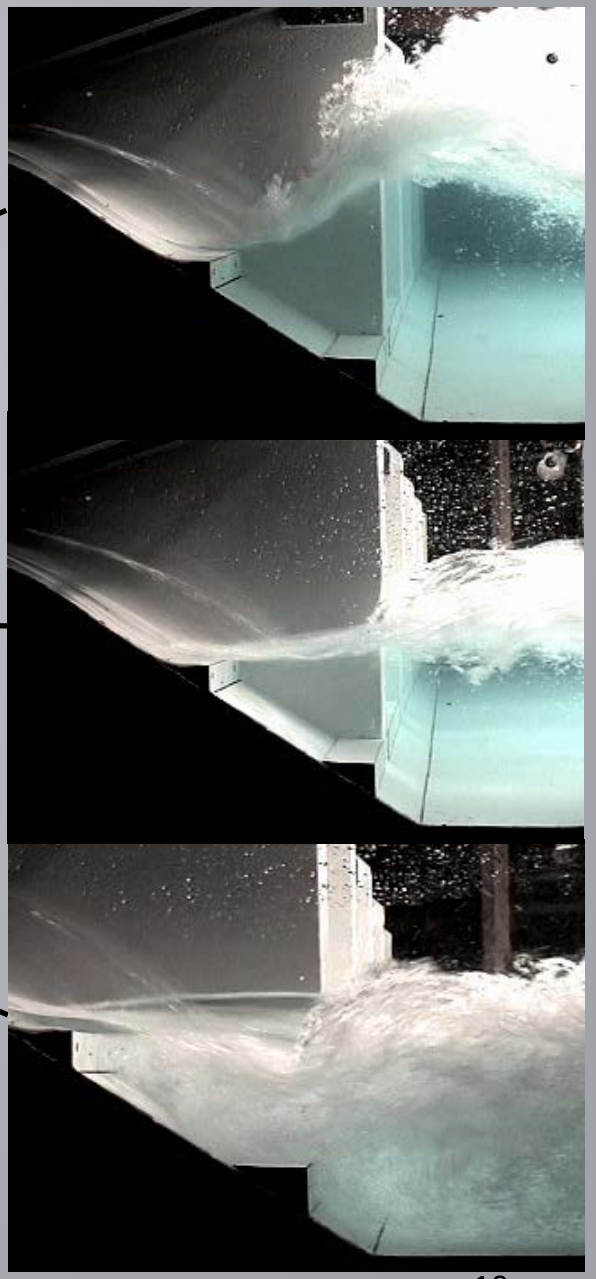
Bubbles size changes due to compression and dissolution

MODEL APPLICATIONS

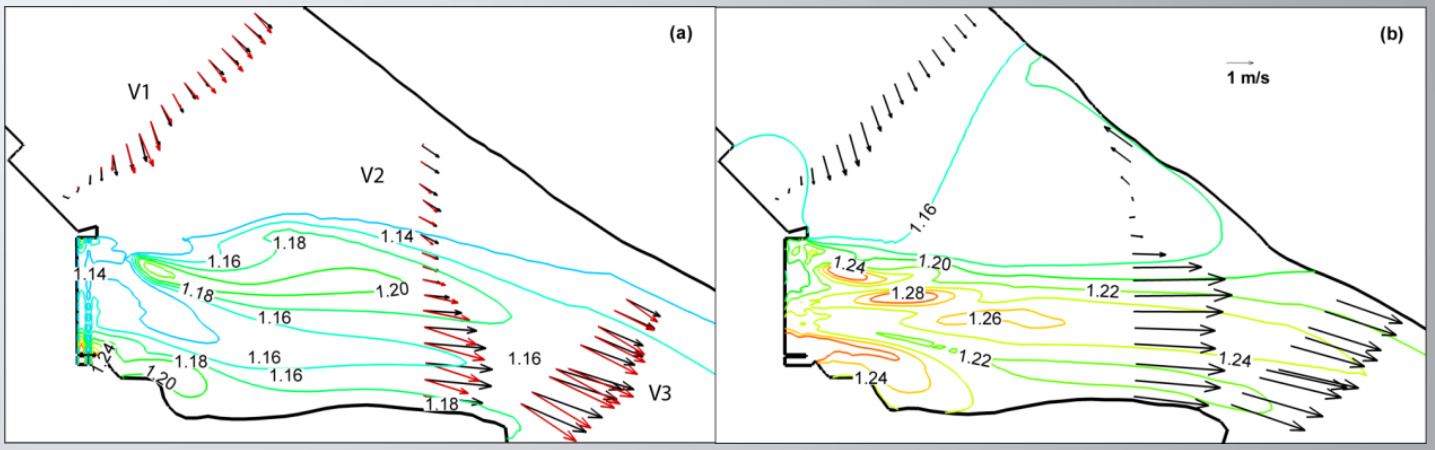
- Brownlee Dam
- Wanapum Dam
- Wells Dam
- Hells Canyon Dam
- McNary Dam

WANAPUM DAM

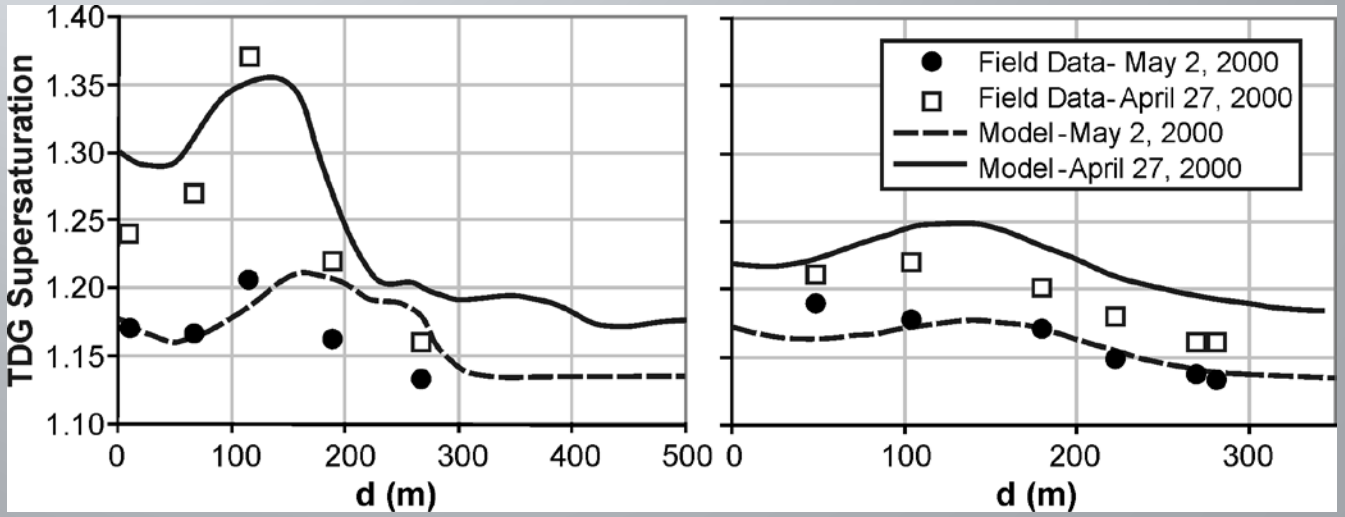

Tailwater Elevation (ft)
Discharge per Spillbay (cfs)
518
516
514
512
510
508
506
504
502
500
498
496
494
492
490
488
486
484
482
480
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Submerged Surface Jump
Ramped Surface Jet
Surface Jump
Undulating Surface Jet
Unstable Flow
Skimming Surface Jet
Plunging Flow
40% Tailwater Curve for Priest Rapids at El.489
50% Tailwater Curve for Priest Rapids at El.487
60% Tailwater Curve for Priest Rapids at El.485
El.485.8
2'-9 1/2"
15'-0"
2'-3 7/8"
4'-9/32"
7'- 0"



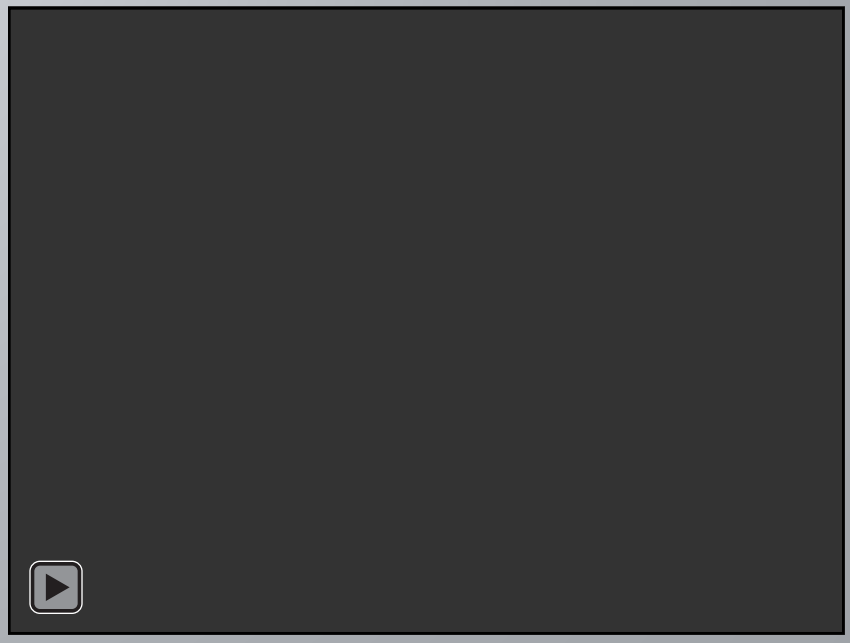
WANAPUM DAM



Black vectors: predicted velocities and blue vectors: field data.
Left: May 2, 2000 and right: April 27, 2000

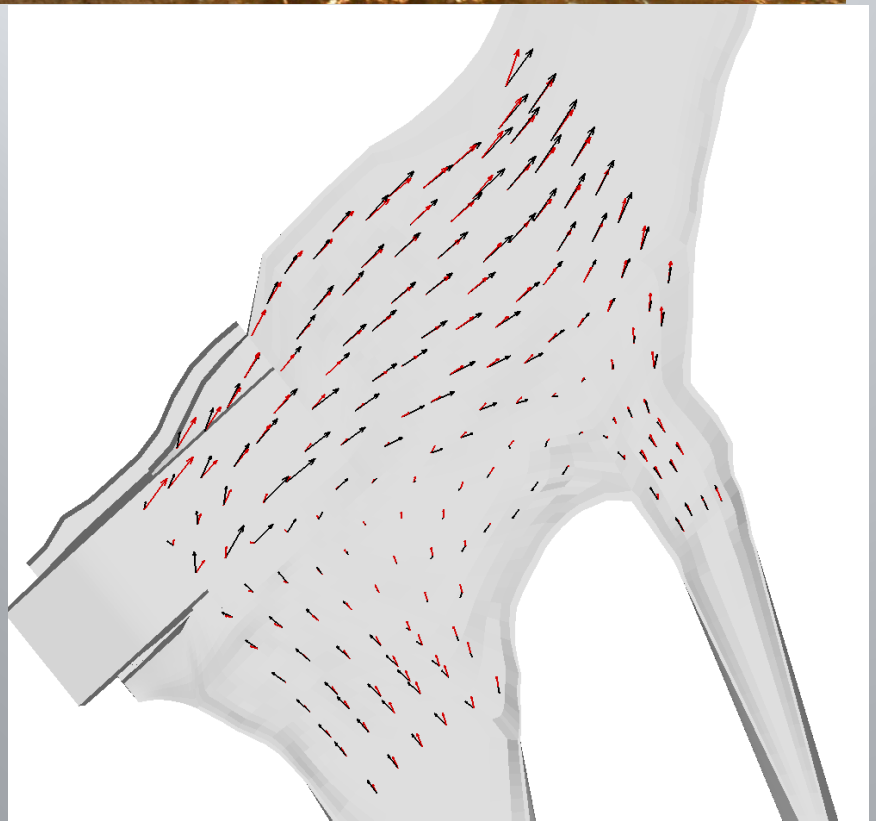


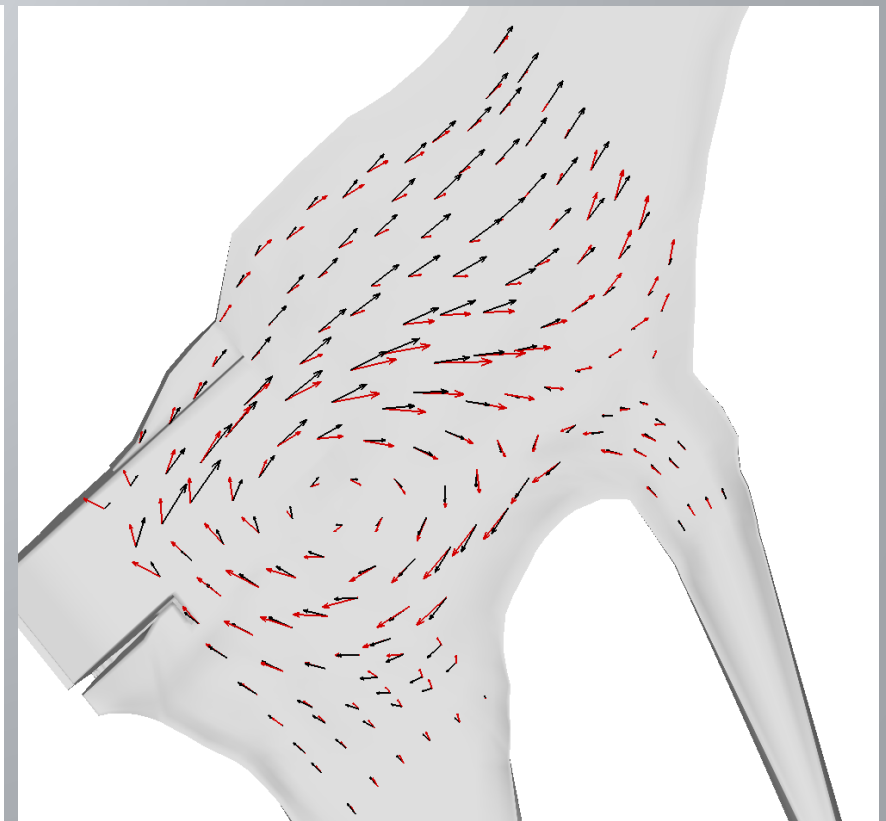
WANAPUM DAM: FLOW PATTERN AND TDG DISTRIBUTION

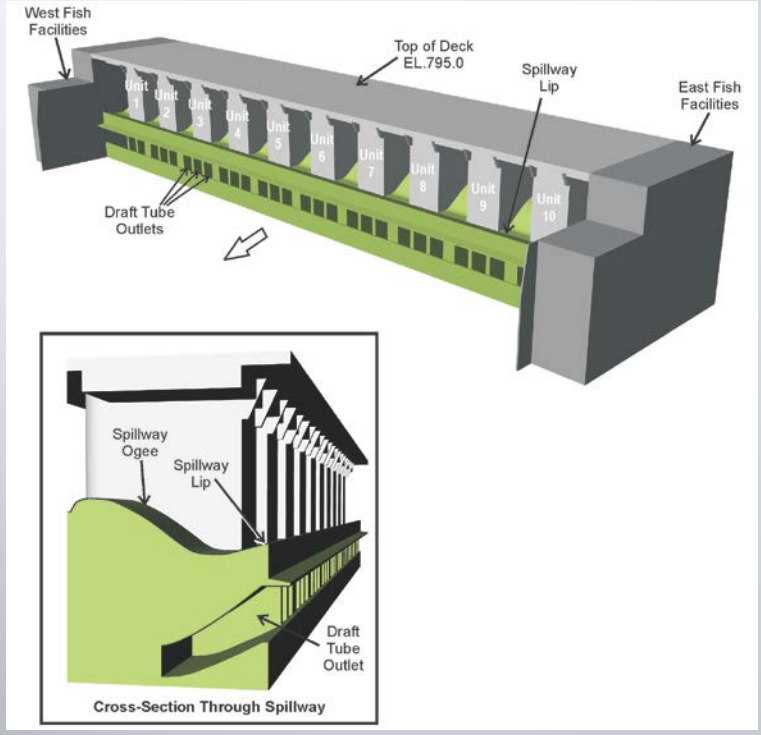


BROWNLEE DAM

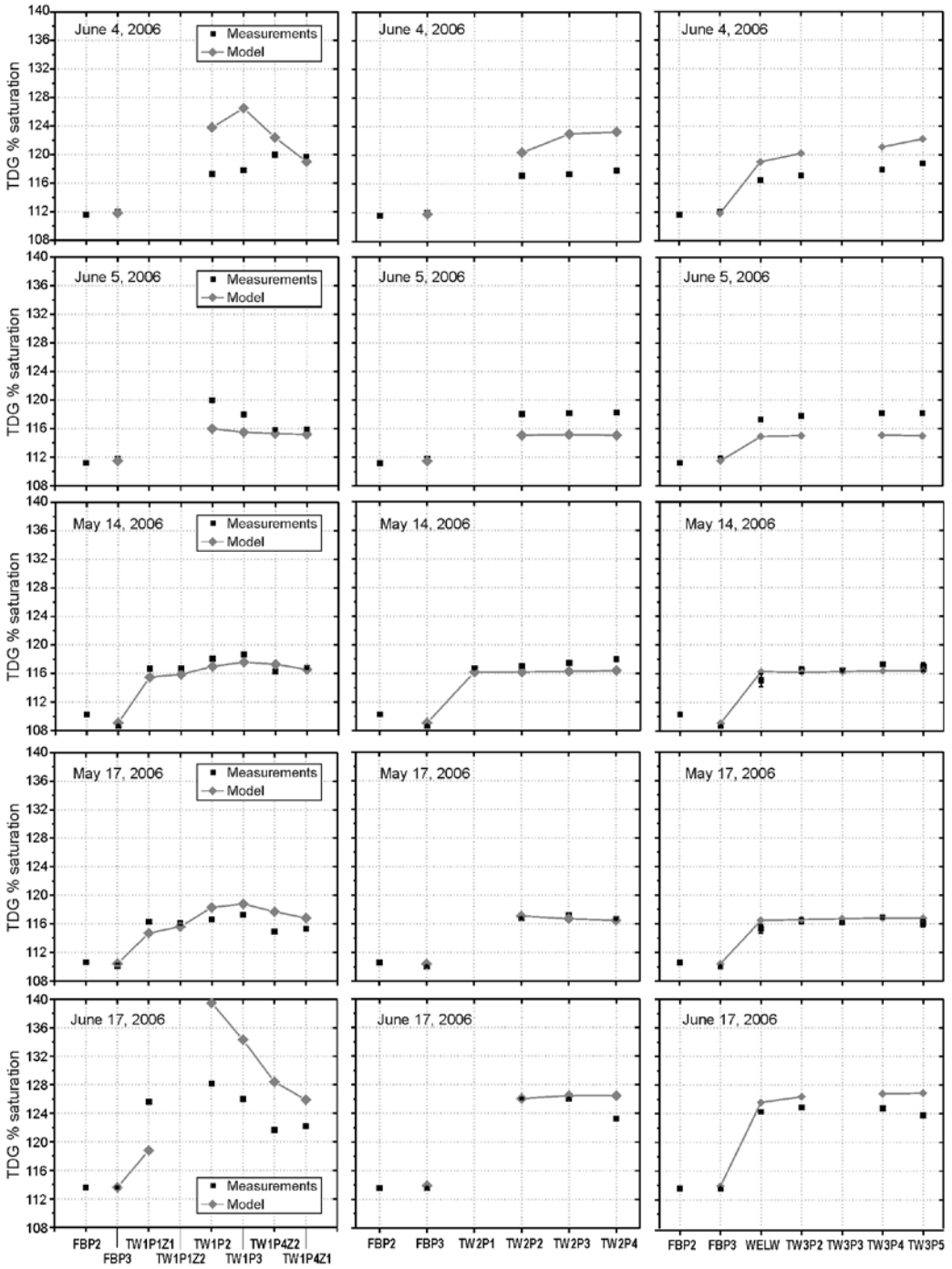
Velocity comparison with obtained in a 1/48 reduced-scale model



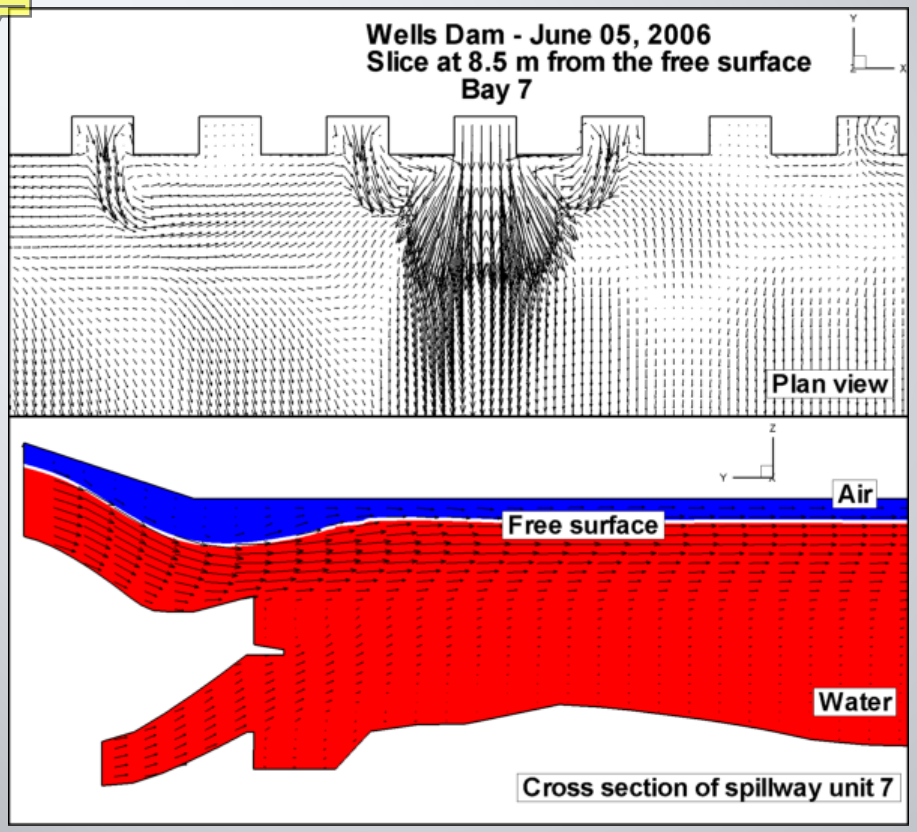


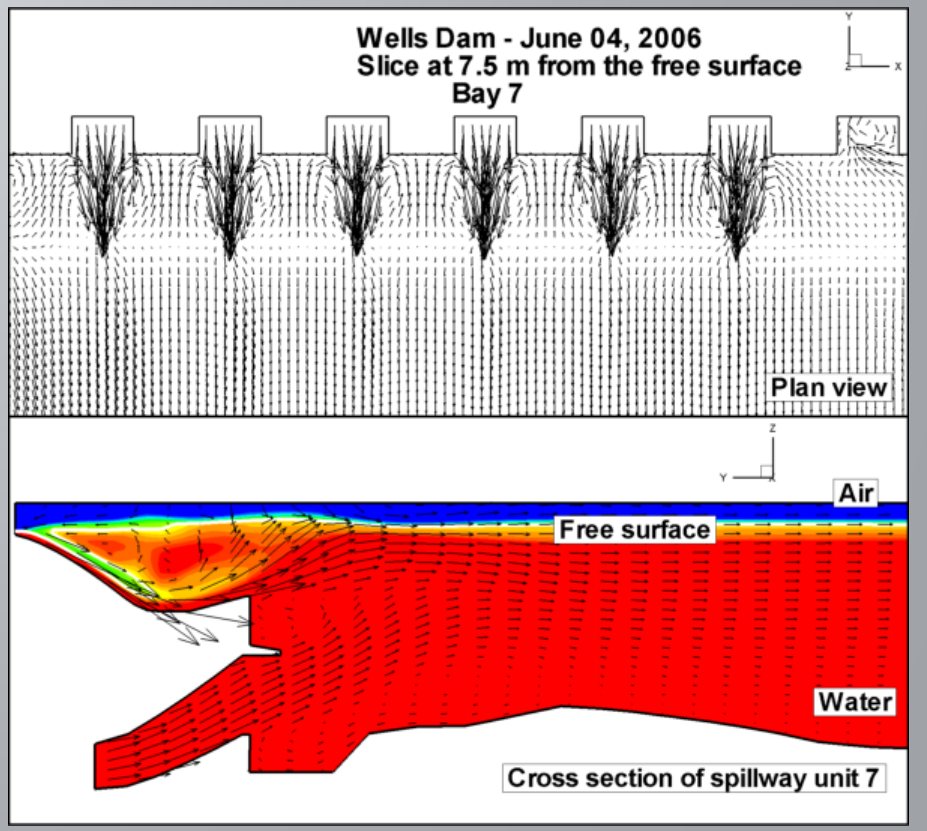


WELLS DAM TDG COMPARISON AGAINST FIELD DATA

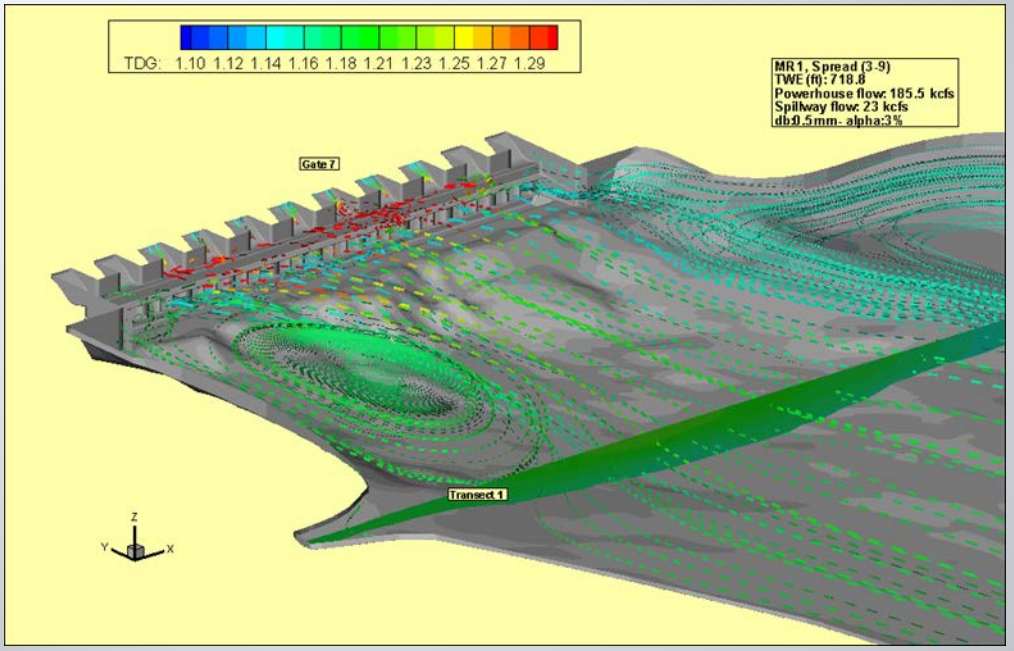


SPILLWAY REGIME

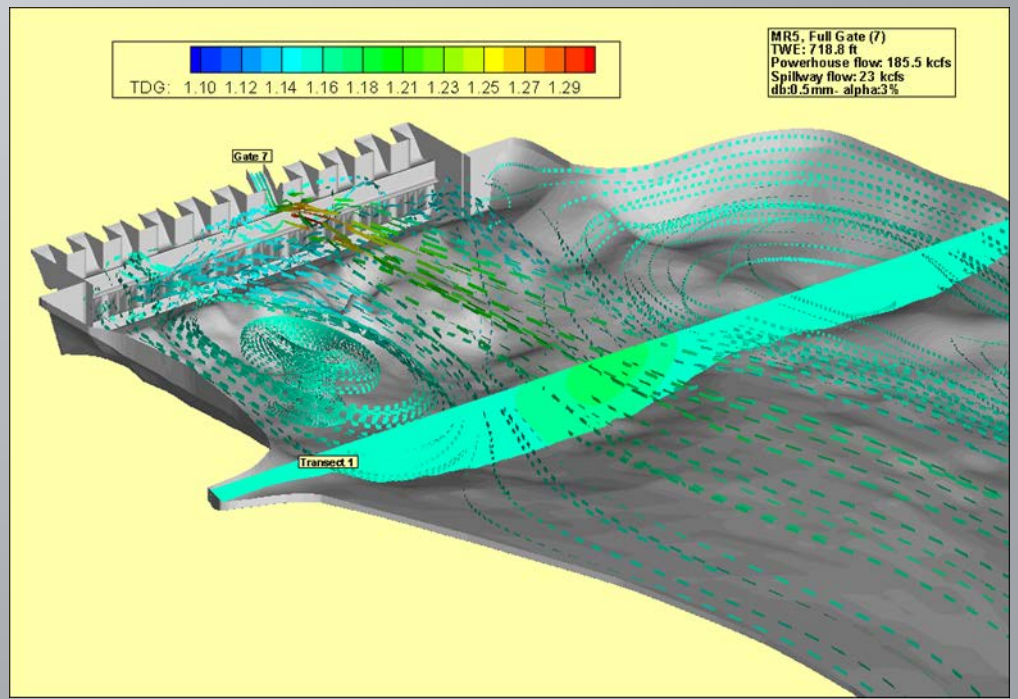




WELLS DAM TDG AT DIFFERENT OPERATIONAL CONDITIONS

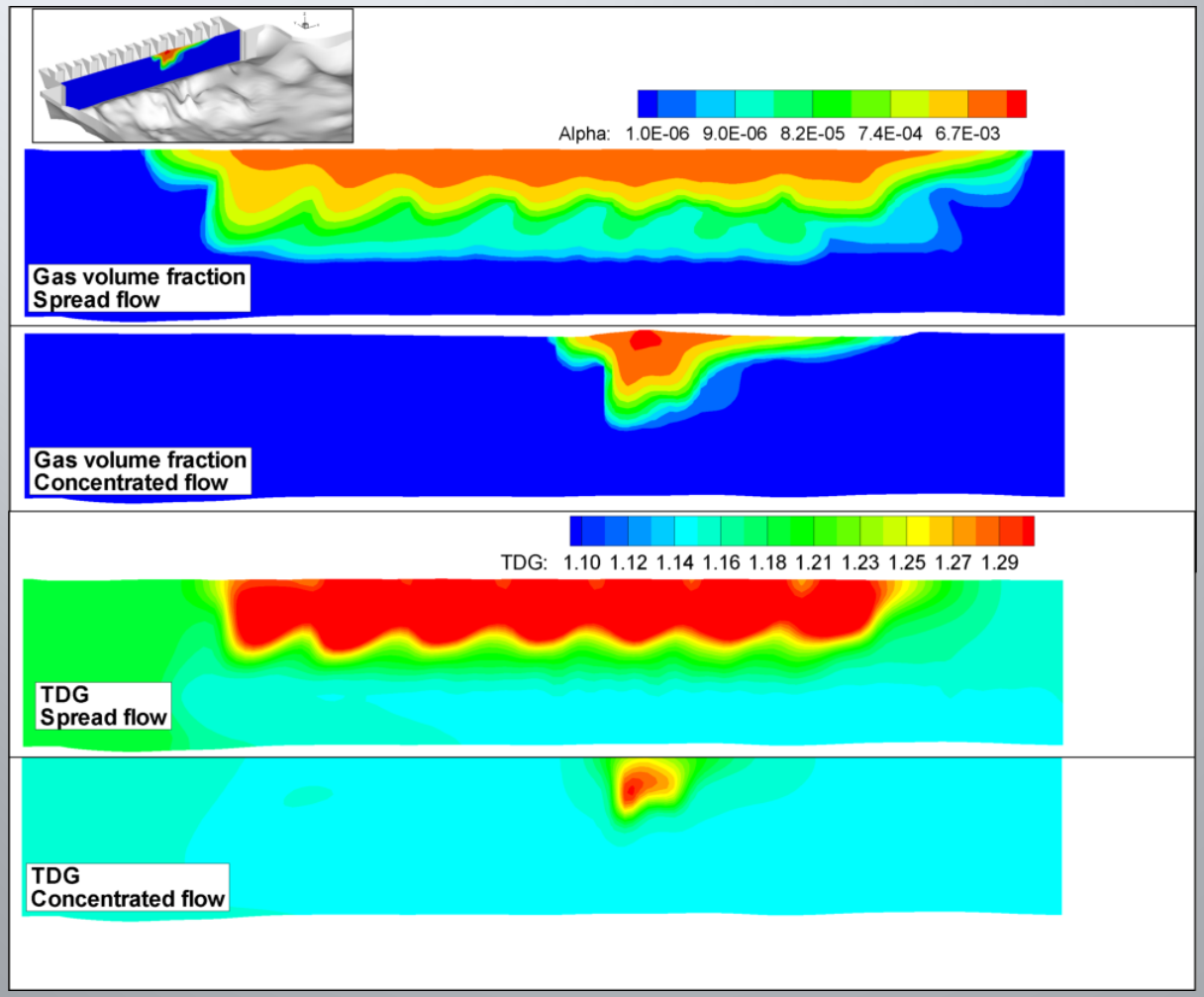


Historic Operation



Proposed Operation

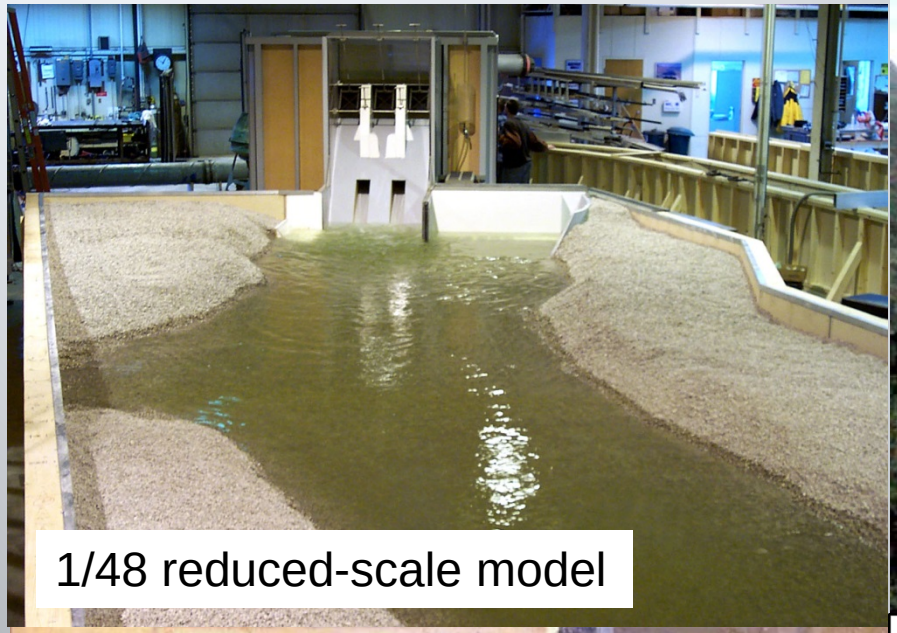
WELLS DAM
TDG AT DIFFERENT OPERATIONAL CONDITIONS

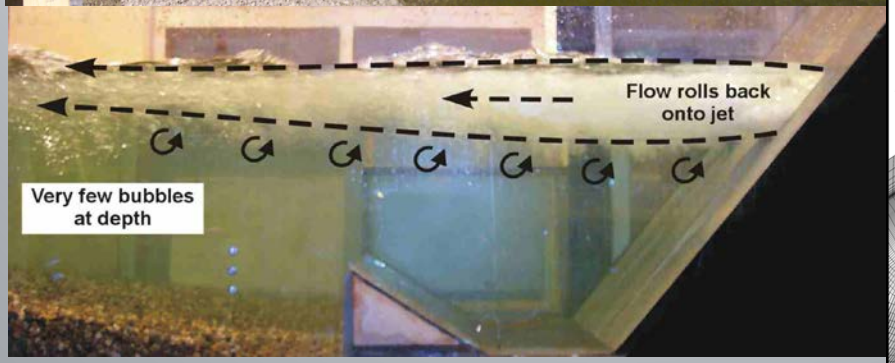


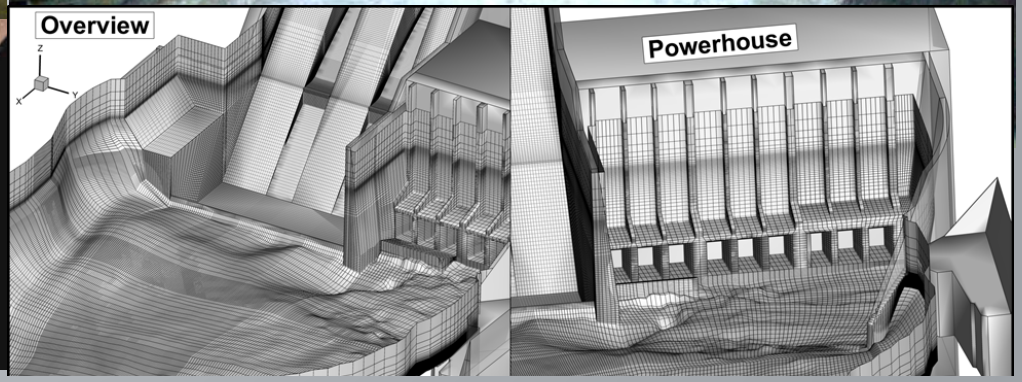
Historic Operation

Proposed Operation

HELLS CANYON DAM

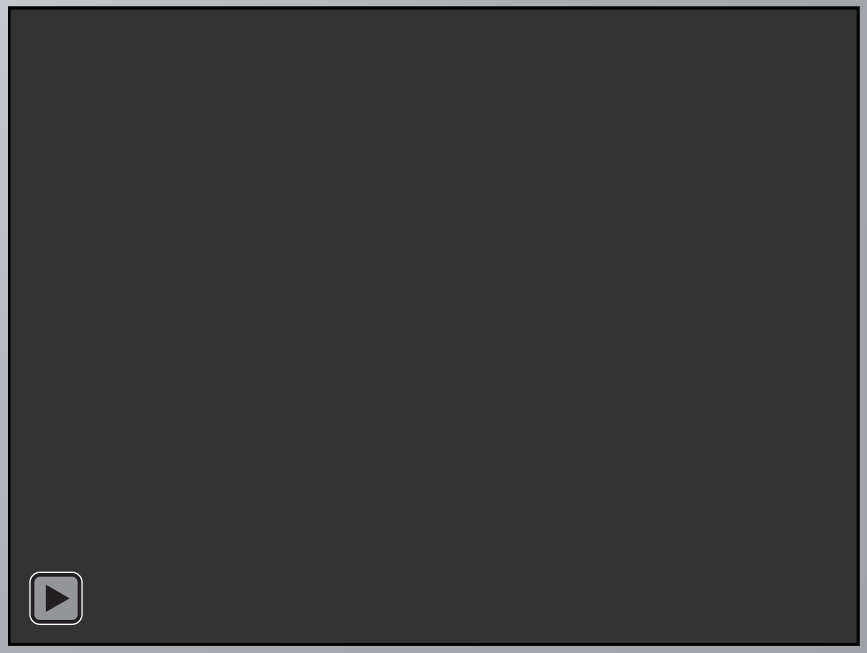




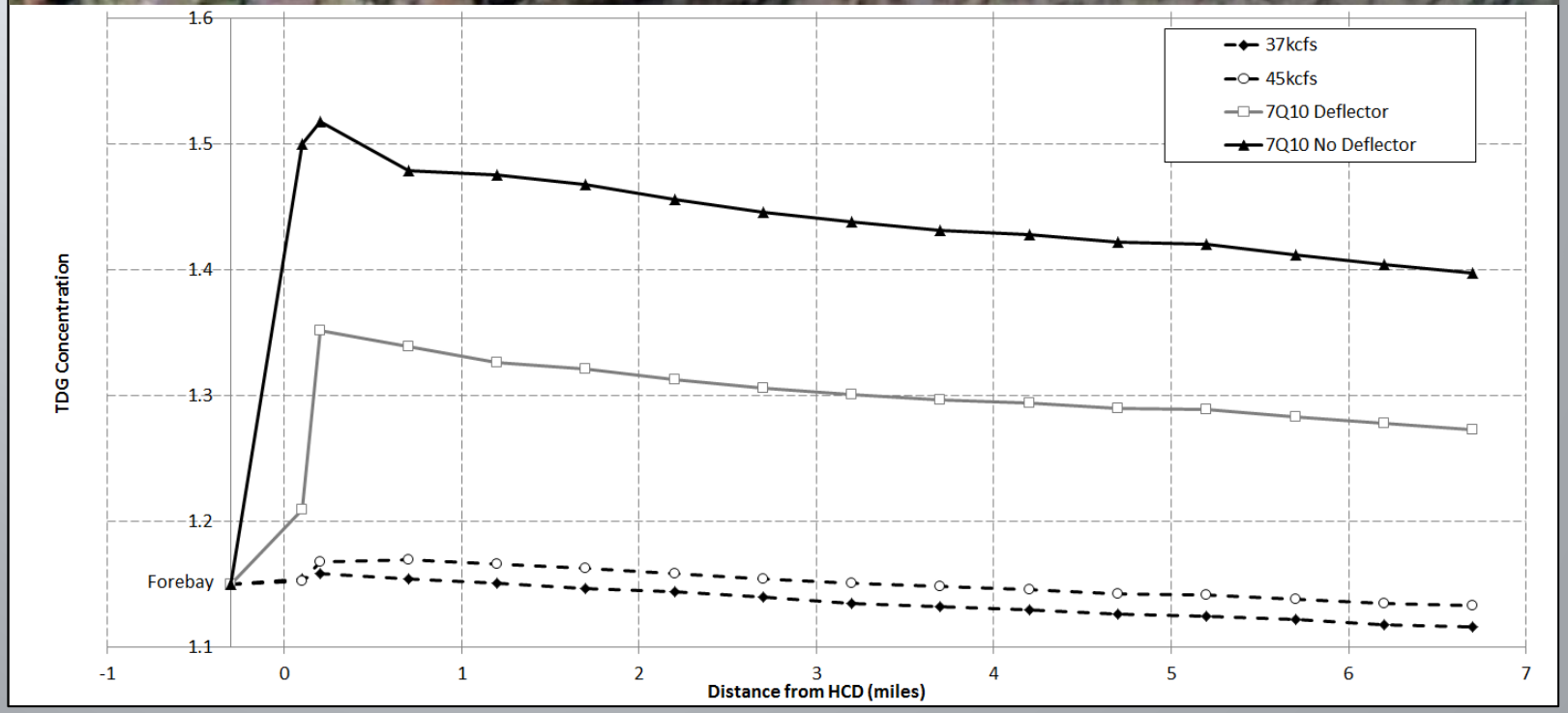


HELLS CANYON DAM - PLUNGING FLOW

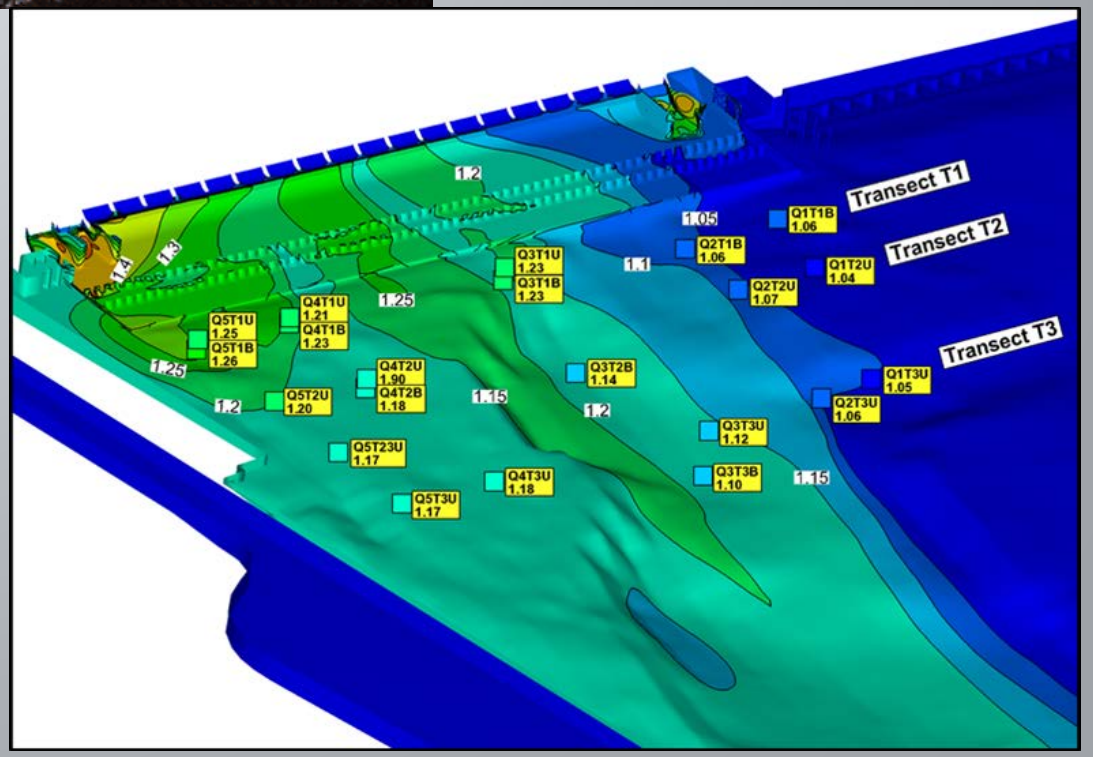
HELLS CANYON DAM – FLOW WITH DEFLECTORS



HELLS CANYON DAM
TDG: 1.25 1.28 1.30 1.33 1.36 1.38 1.41 1.43 1.46 1.49

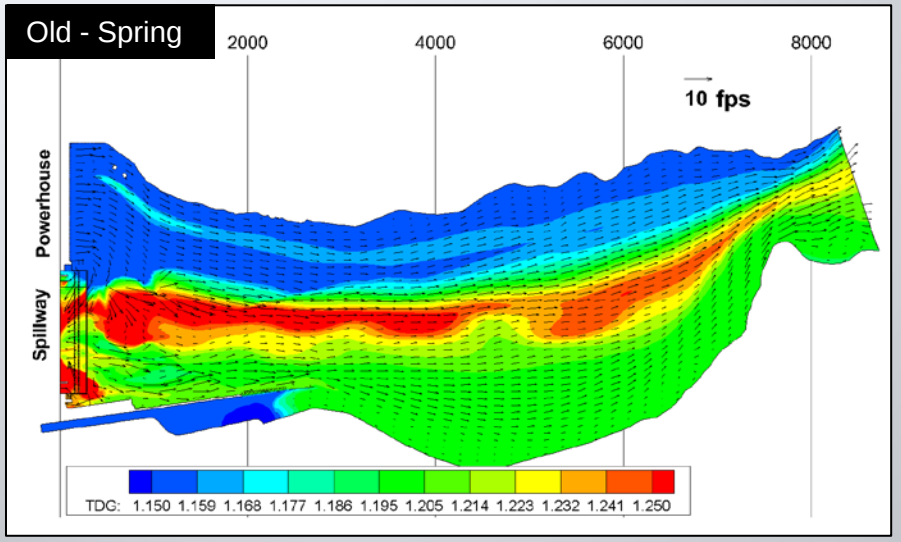

37kcfs
45kcfs
7Q10 Deflector
7Q10 No Deflector
TDG Concentration
Distance from HCD (miles)
Forebay
1.6
1.5
1.4
1.3
1.2
1.1
-1
0
1
2
3
4
5
6
7

MCNARY DAM

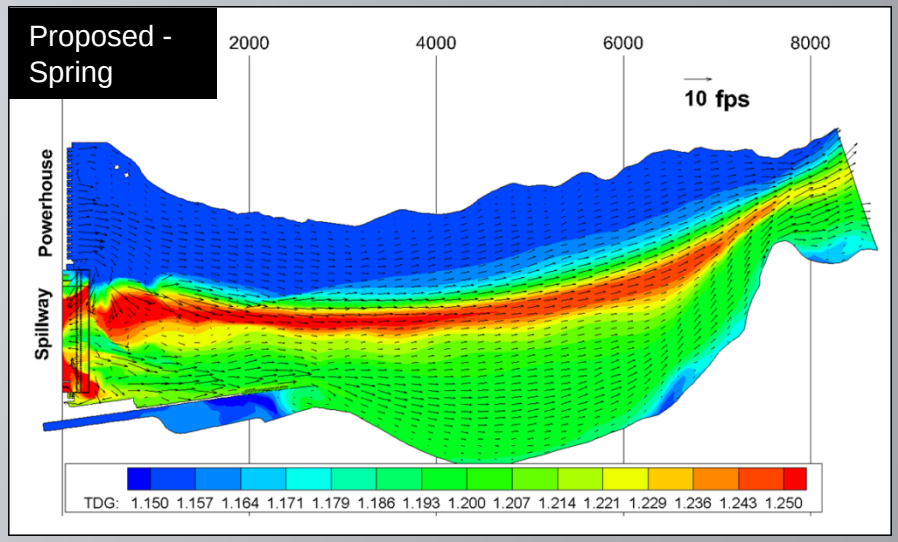

Transect T1
Transect T2
Transect T3
1.2
1.3
1.4
1.25
1.1
1.05
1.15
Q1T1B 1.06
Q2T1B 1.06
Q3T1U 1.23
Q3T1B 1.23
Q1T2U 1.04
Q2T2U 1.07
Q4T1U 1.21
Q4T1B 1.23
Q5T1U 1.25
Q5T1B 1.26
Q4T2U 1.90
Q4T2B 1.18
Q5T2U 1.20
Q3T2B 1.14
Q1T3U 1.05
Q2T3U 1.06
Q3T3U 1.12
Q3T3B 1.10
Q4T3U 1.18
Q5T23U 1.17
Q5T3U 1.17

MCNARY DAM –TDG DISTRIBUTION FOR OLD AND PROPOSED OPERATION

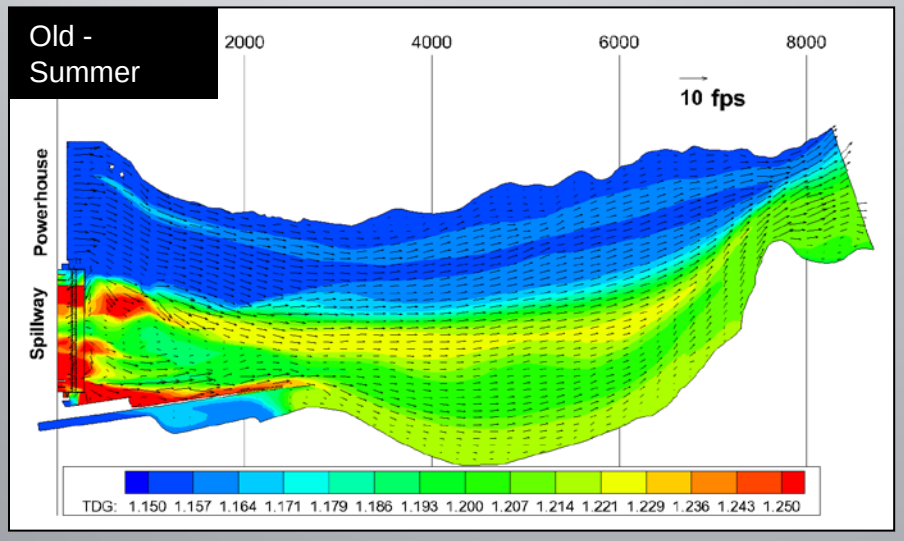
Old - Spring



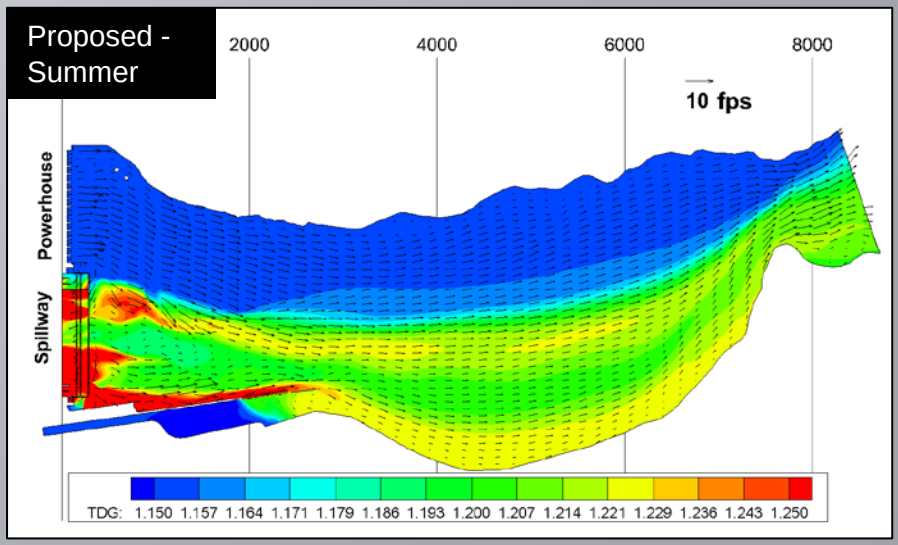
Proposed - Spring



Old - Summer



Proposed - Summer



Sponsors: Federal and public hydroelectric utilities: USACE, Grant County PUD, Douglas County PUD, Idaho Power Co. NSF. Hydro Research Foundation.

Questions/Comments

marcela-politano@uiowa.edu
http://www.iihr.uiowa.edu/totaldissolvedgas/