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

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

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
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
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.
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**

**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.

**Anisotropic turbulence** and effect of the bubbles on the turbulence

**Bubbles size** changes due to compression and dissolution
MODEL APPLICATIONS

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

Discharge per Spillbay (cfs)

Tailwater Elevation (ft)

- Skimming Surface Jet
- Surface Jump
- Plunging Flow
- Undulating Surface Jet
- Ramped Jet
- Submerged Surface Jump
- Unstable 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
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

1/48 reduced-scale model

Flow rolls back onto jet

Very few bubbles at depth
HELLS CANYON DAM - PLUNGING FLOW
HELLS CANYON DAM – FLOW WITH DEFLECTORS
MCNARY DAM
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.