Jun 27th, 10:25 AM - 10:45 AM

Concurrent Sessions D: Downstream Migrant Surface Collectors-What Works and What Doesn't Work - Evaluation of Possible Fish Injury in a Spillway Retrofitted with Deflectors

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Evaluation of Possible Fish Injury in a Spillway Retrofitted with Deflectors

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Safe Passage

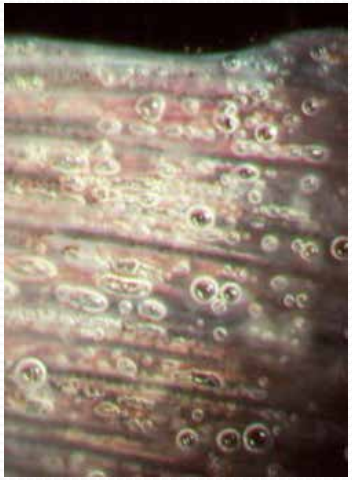
- Historically, spill was used to enhance fish survival. Spill is considered one of the safest passage strategy.

- However, large spill volumes can be harmful for fish due to:
  - Increased turbulence
  - Total Dissolved Gas (TDG) production
  - Deteriorated adult migration

- The planned spill program include spill until the TDG cap

Why is supersaturation a problem?

- High total dissolved gas (TDG) in the water can cause gas bubble disease (GBD) in fish. The process in the fish is similar to a diver getting the "bends."

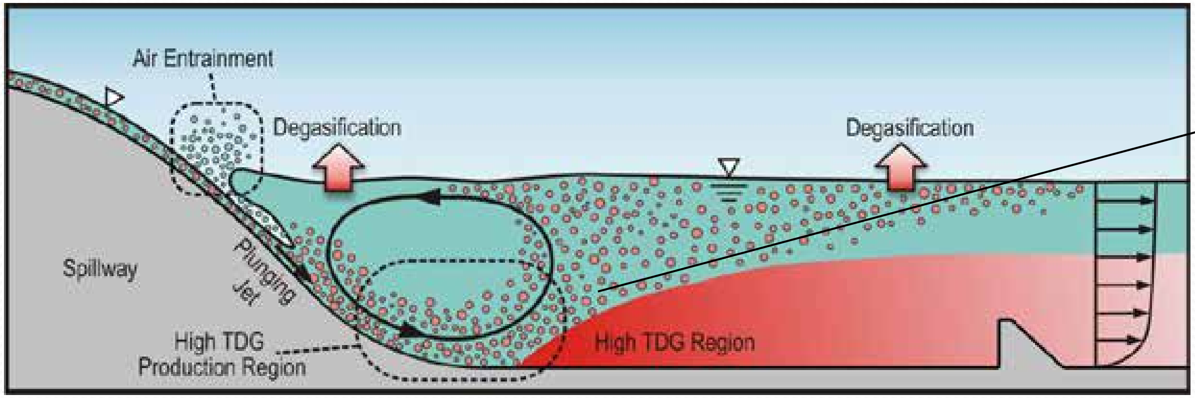


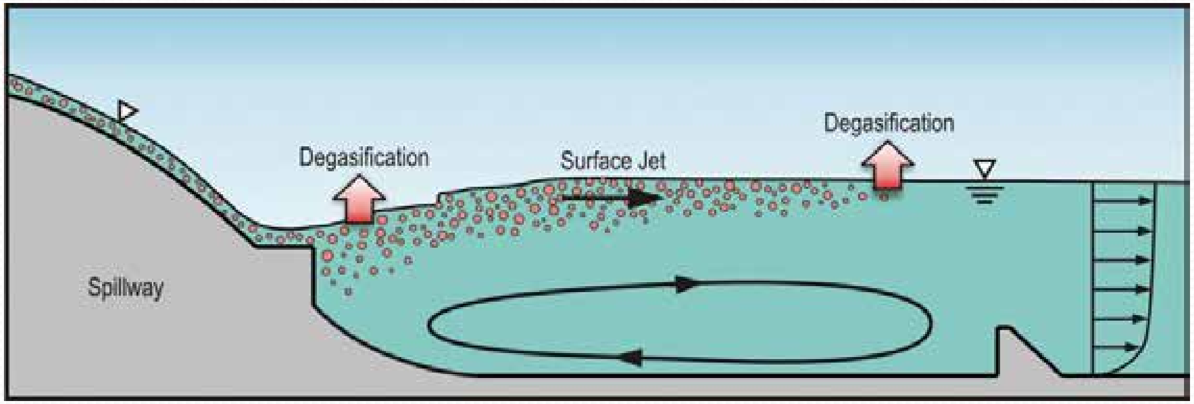
- GBD can lead to:
  - loss of swimming ability,
  - altered blood chemistry,
  - reduced growth,
  - increases stresses,
  - weakness, injury and death in affected fish.

How to prevent supersaturation?

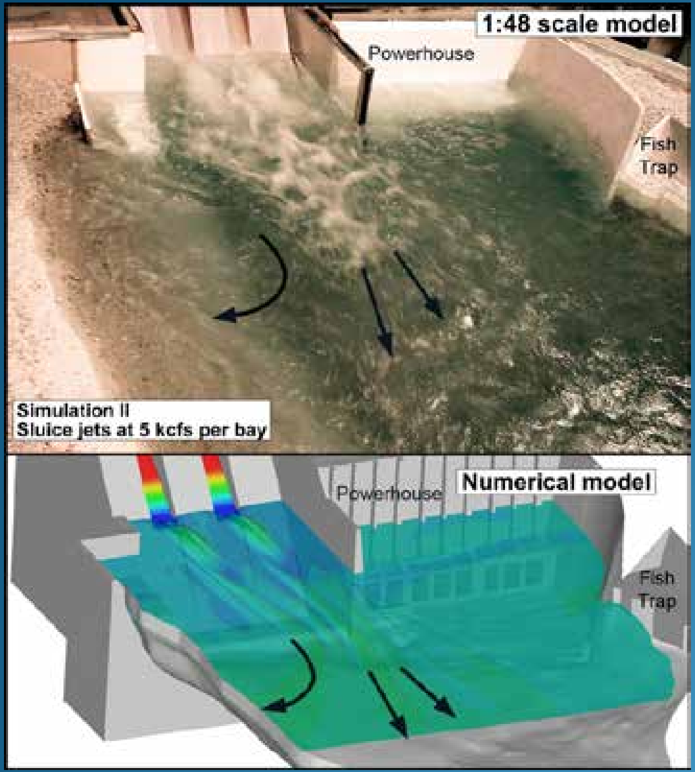
TDG supersaturation in the Columbia River Basin is mostly caused by spill from dams.

TDG Source:
Gas transferred from bubbles





Spillway deflectors can prevent bubbles plunging to depth in the stilling basin.

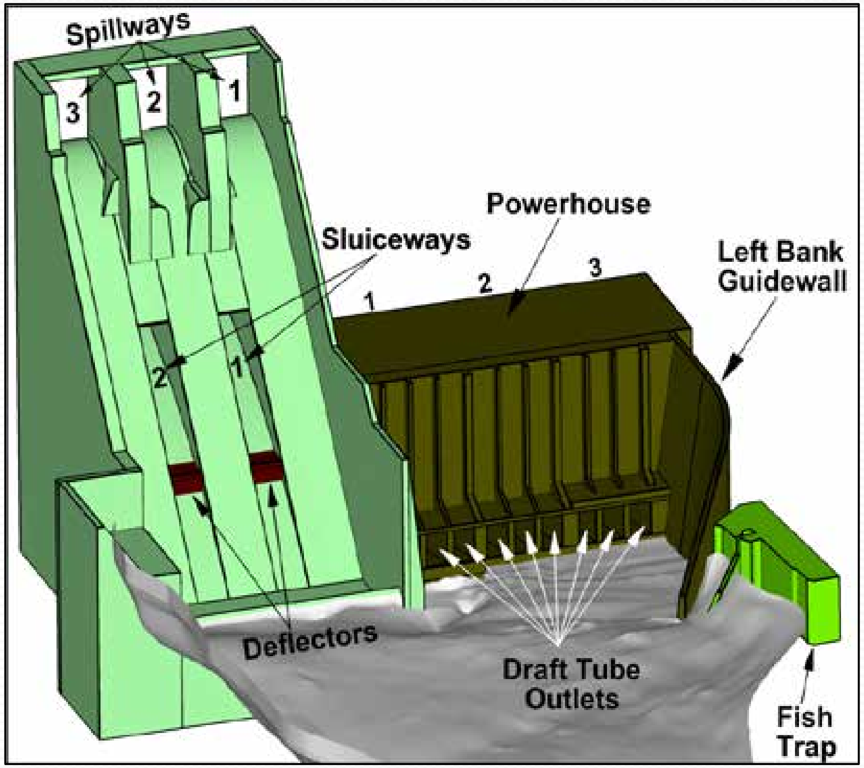


Goals and Objectives

The goal of this study was to evaluate various configurations of deflectors in the sluiceways of Hells Canyon Dam using a 3D two-phase flow CFD tool.

Based on the simulation results, a deflector design was selected and fish injury was estimated based on TDG field, acceleration and strain rate down the sluiceway.

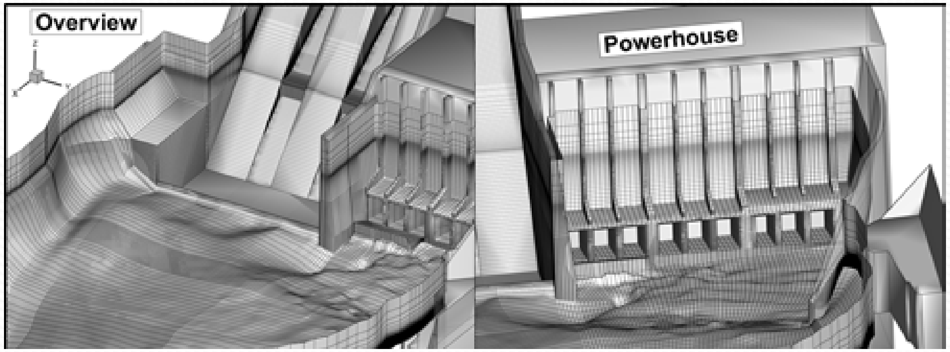
Hells Canyon Model



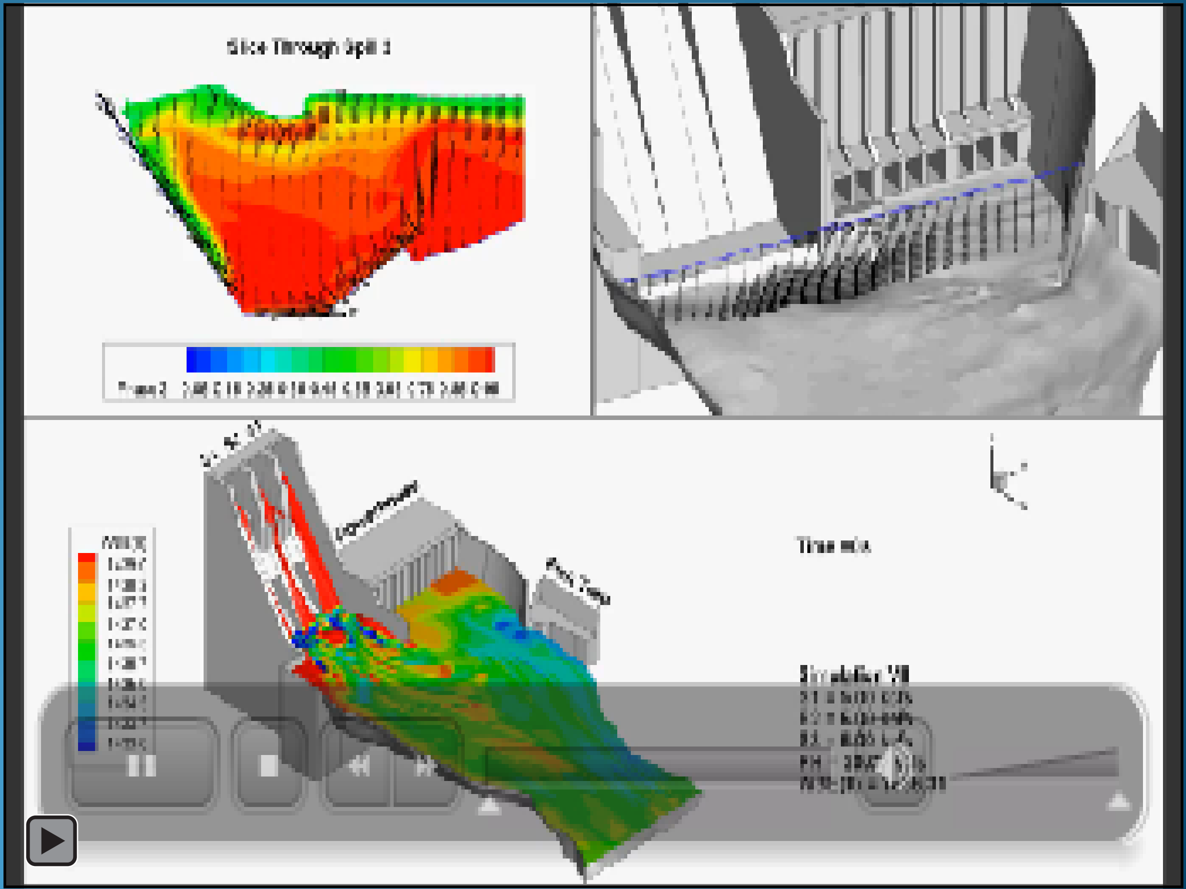
Three models were used in this study: a) a VOF model, b) a rigid-lid mixture model and c) a Lagrangian model

The performance of four deflector geometries was evaluated using two flowrates: 25 kcfs and 45 kcfs

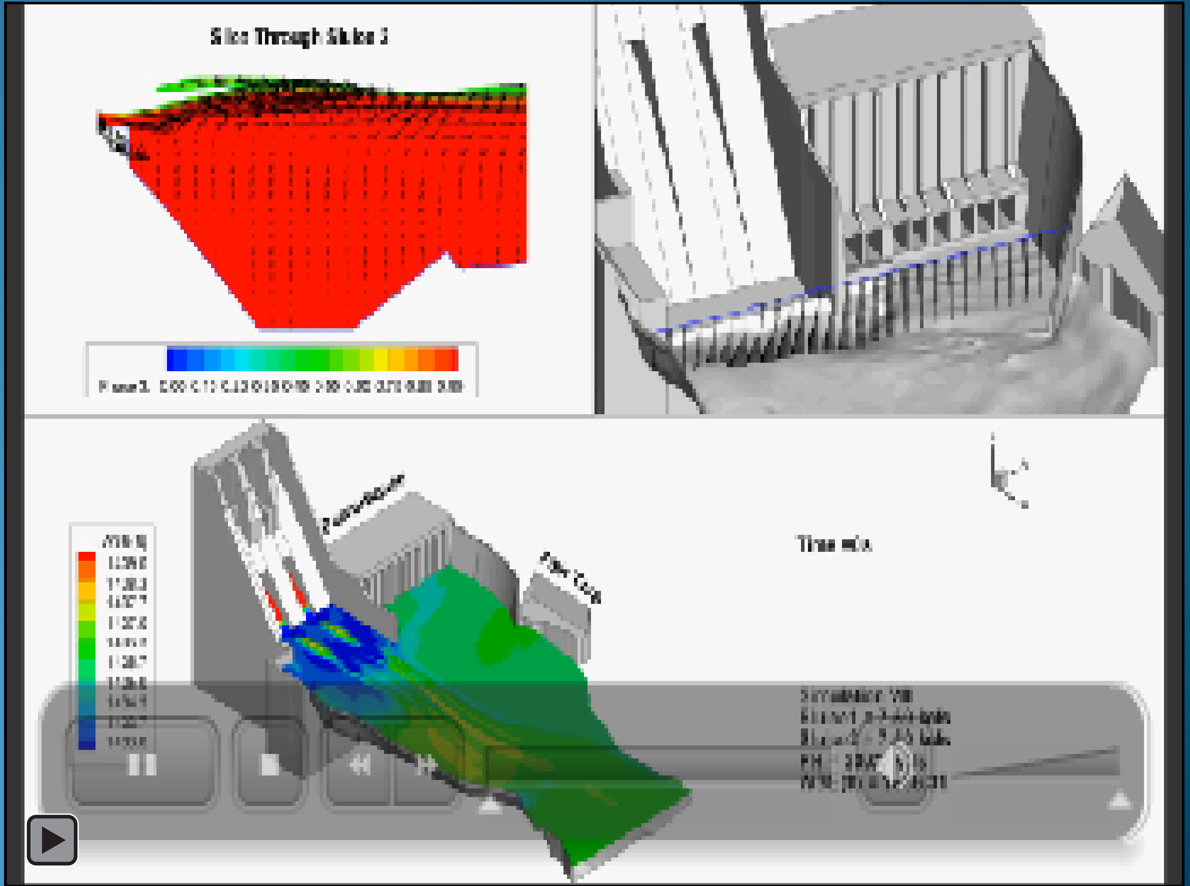
After a deflector was selected, the deflector was further evaluated for three flowrates: 37 kcfs, 45 kcfs and 71.5 kcfs

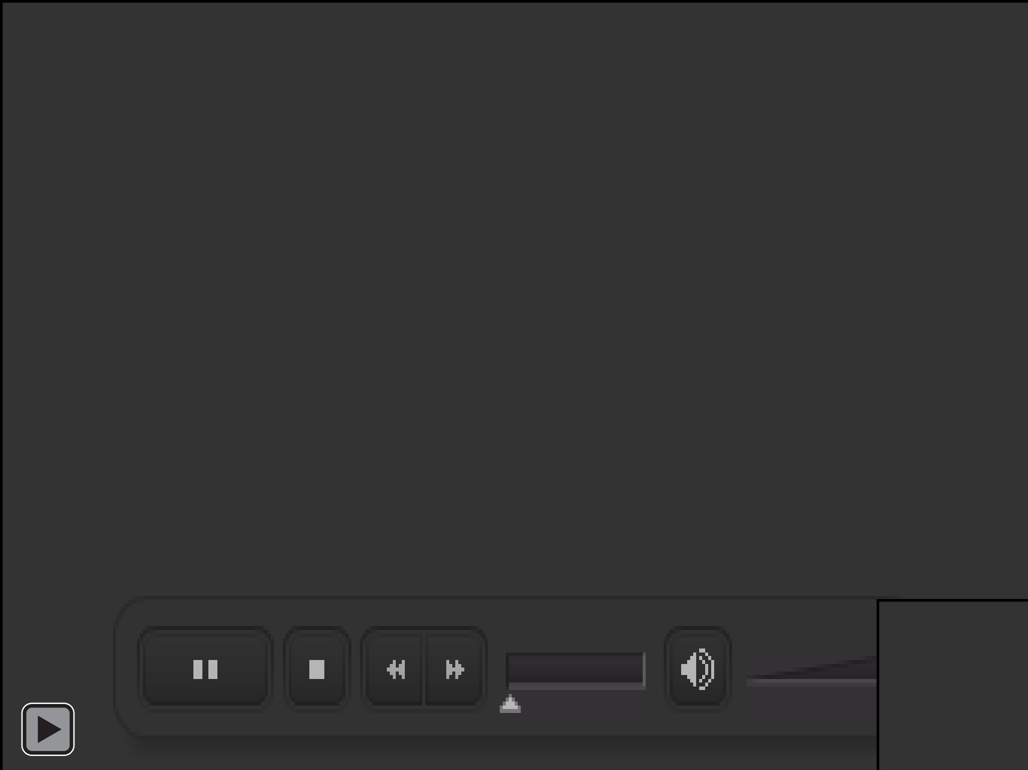


FLOW FIELD WITHOUT DEFLECTORS

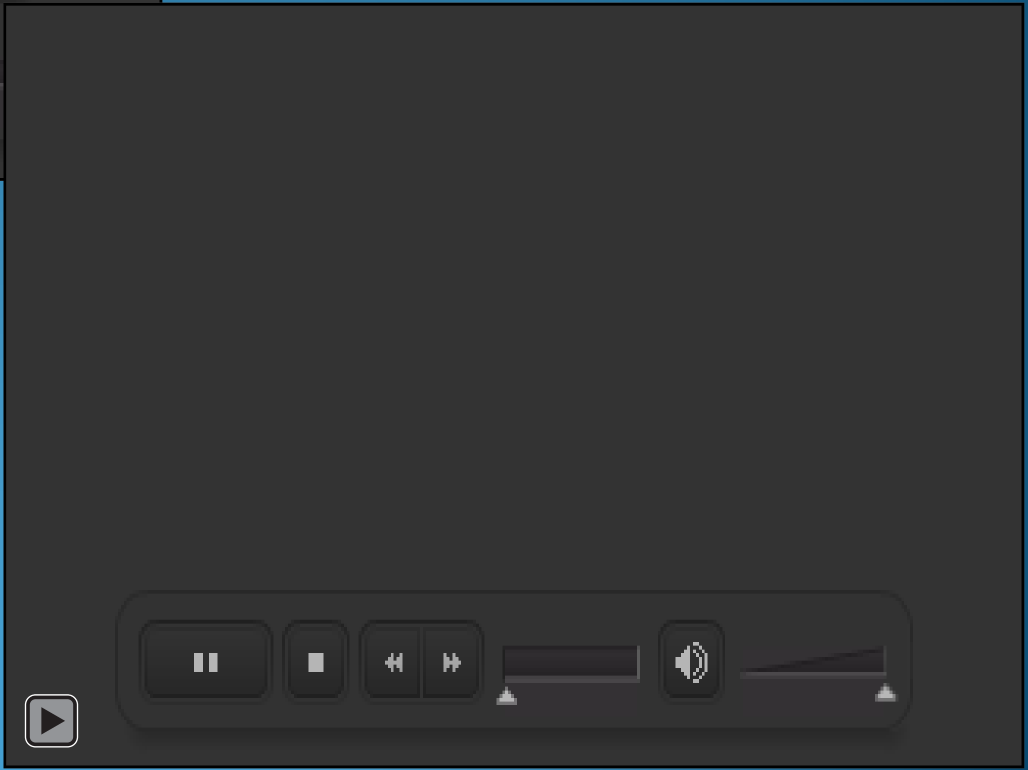


FLOW FIELD WITH DEFLECTORS

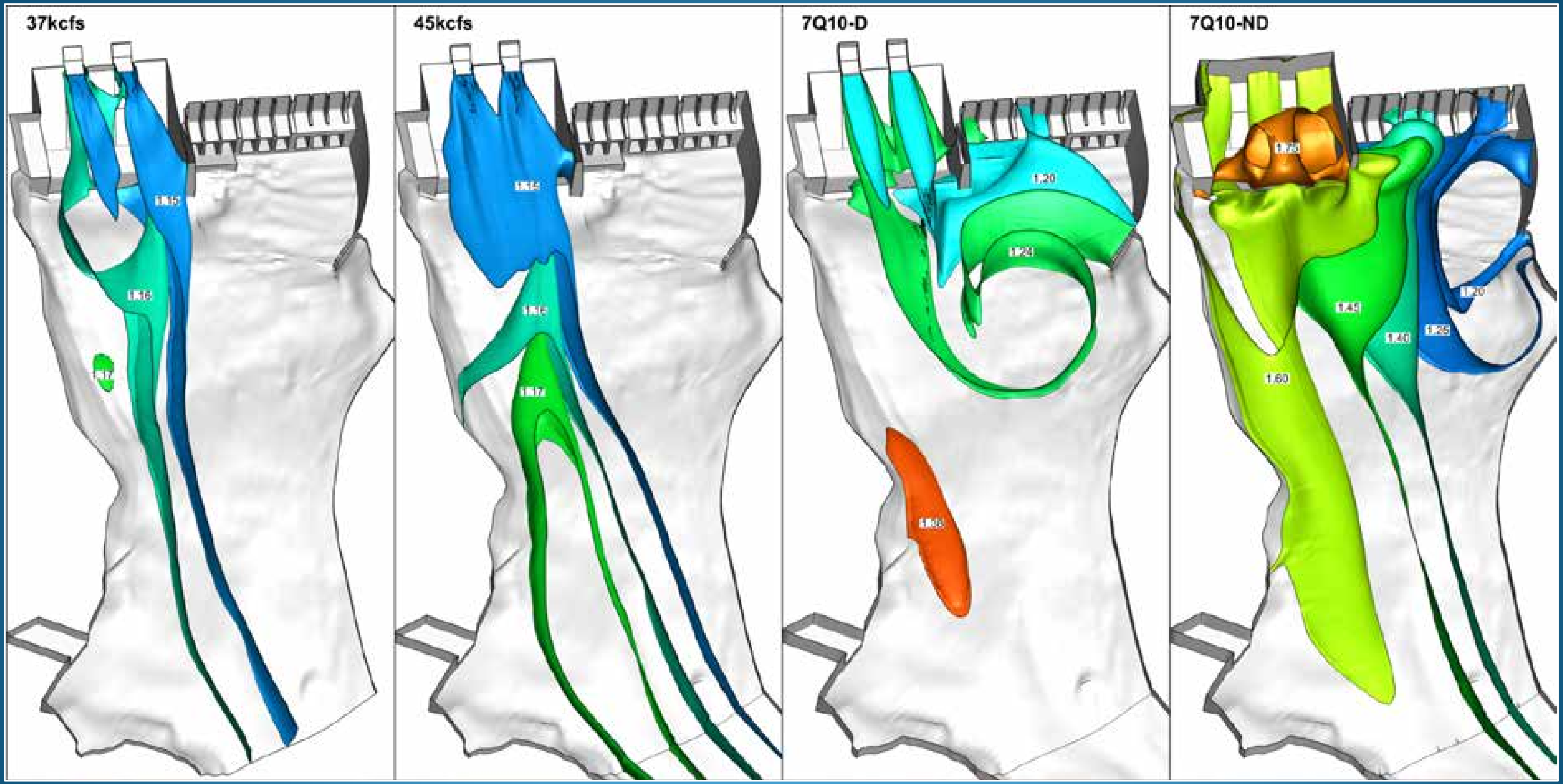




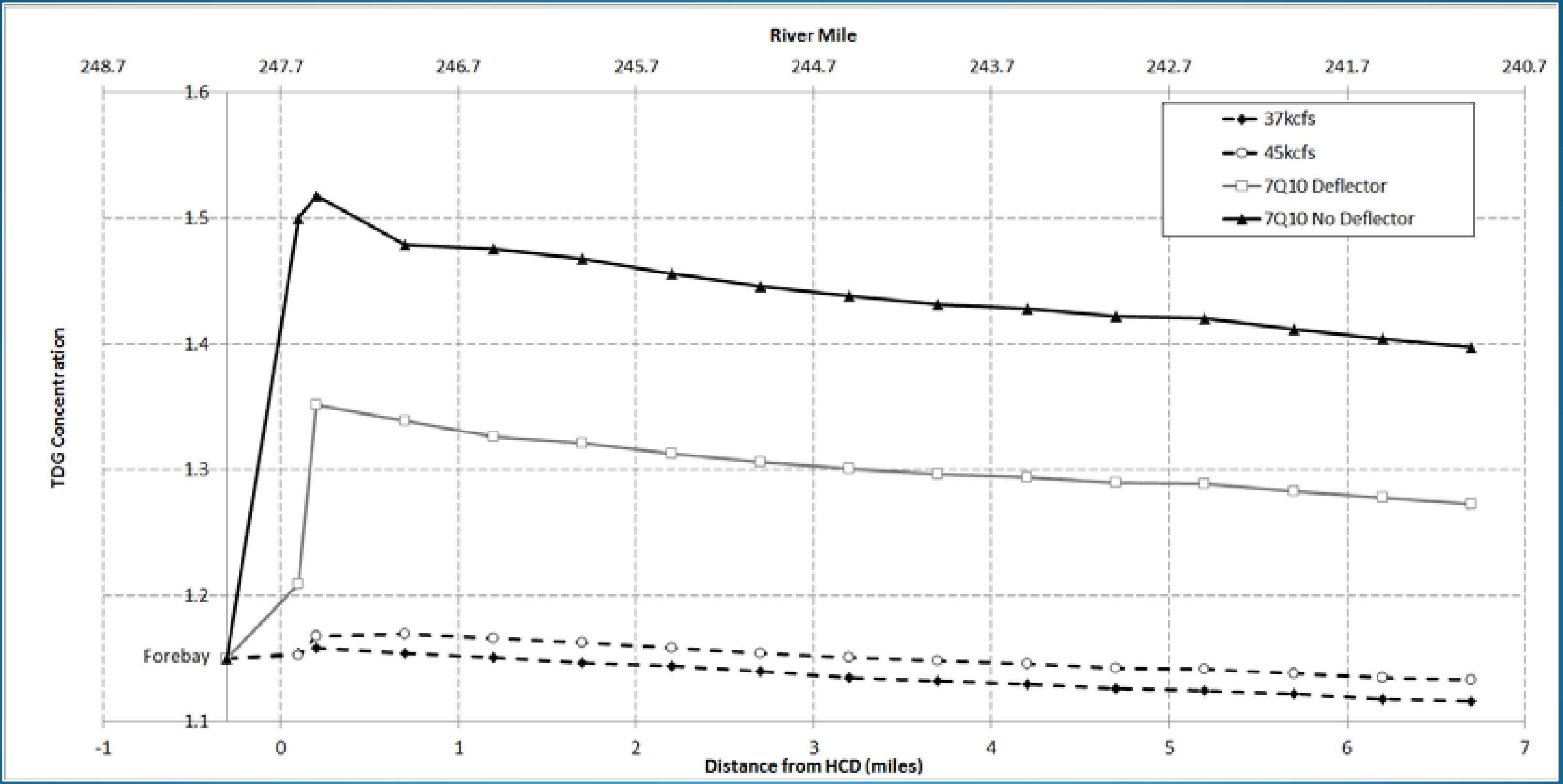
Numerical Results



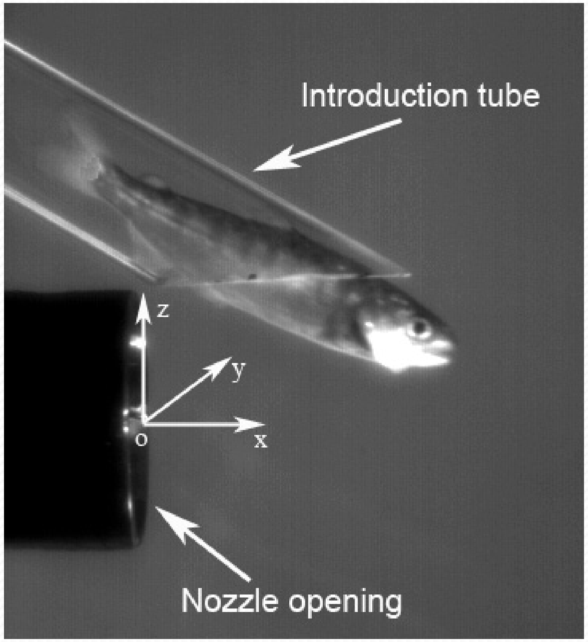
TDG isosurfaces



Average TDG downstream of Hells Canyon



Fish Injury



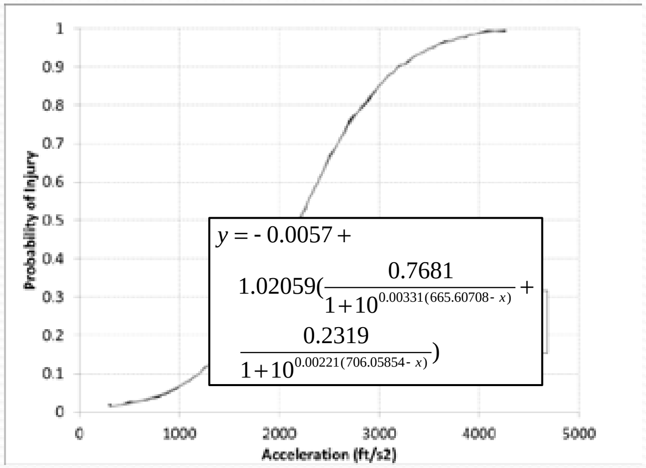
Deng et al. Evaluation of fish-injury mechanisms during
exposure to turbulent shear flow. Can. J. Fish. Sci. Aquat. 62: 1513–1522 (2005)

Deng et al. (2005) exposed juvenile salmonids to a laboratory-generated shear environment where fish were introduced into a high velocity water jet.
Acceleration was the strongest predictive variable to correlate eye and operculum injuries and overall injury level, and it is proposed to link laboratory studies of fish injury, field studies, and numerical modeling.

Neitzel et al. (2000) reported that exposures to **shear strain** rates above 850 s^{-1} would be harmful to juvenile fish. Later, Foust et al. (2010) found that values of strain rate above 360 s^{-1} can be harmful to fish. Neitzel et al. (2000) reported that injury or mortality is unlikely to occur at strain rates less than about 500 s^{-1} and Neitzel et al. (2004) reported that major injuries were not observed at or below a strain rate of 517 s^{-1}.

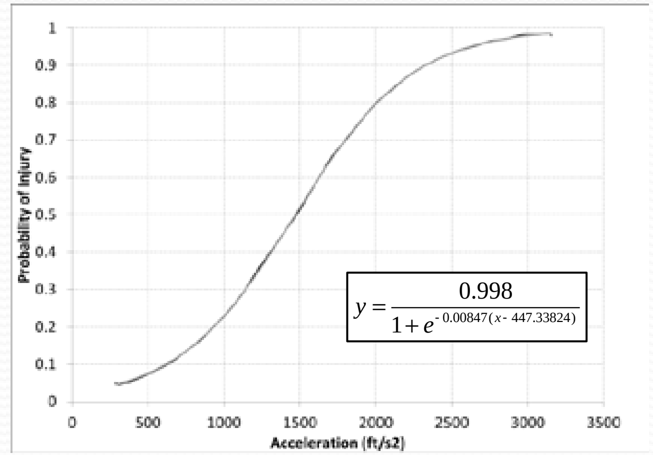
Fish Injury

Major injury



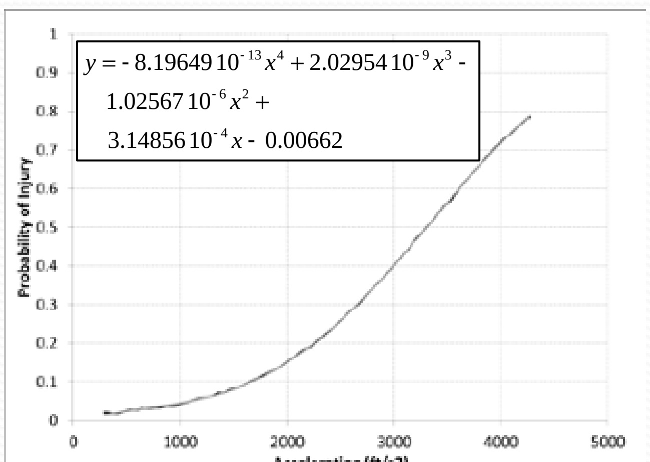
$$y = -0.0057 + 1.02059\left(\frac{0.7681}{1+10^{0.00331(665.60708-x)}} + \frac{0.2319}{1+10^{0.00221(706.05854-x)}}\right)$$

Minor injury



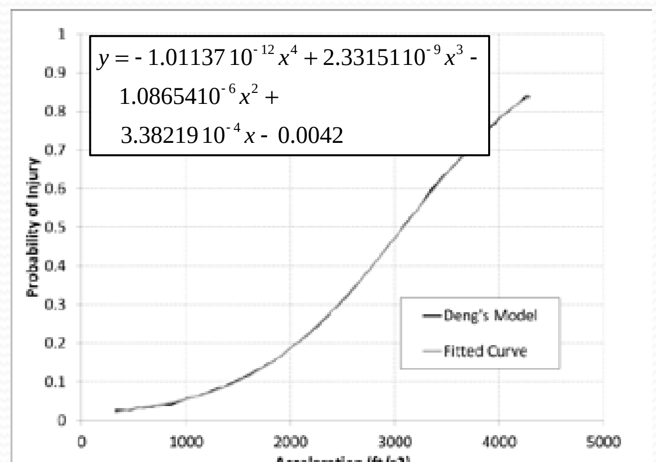
$$y = \frac{0.998}{1+e^{-0.00847(x-447.33824)}}$$

Eye injury



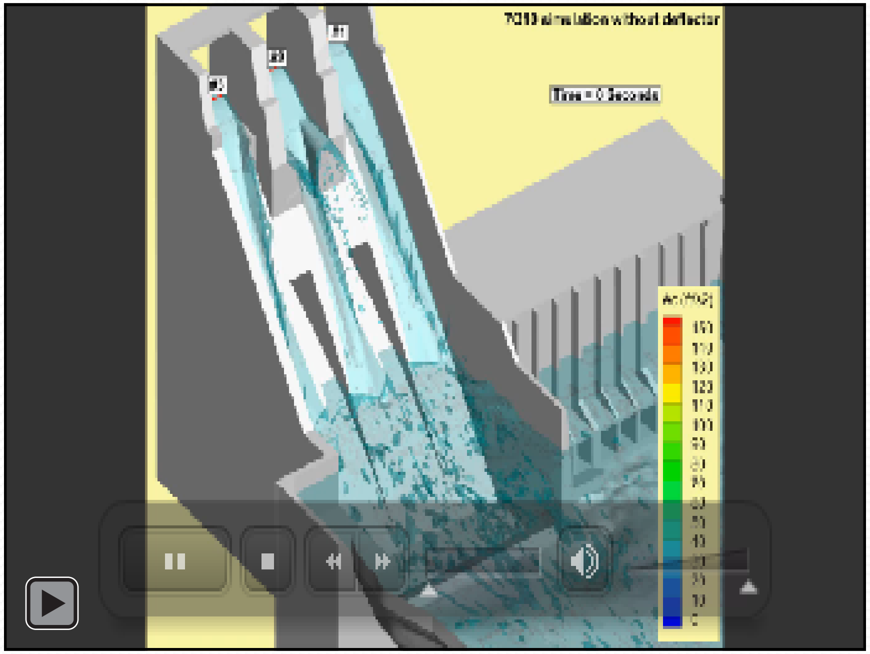
$$y = -8.19649\,10^{-13}x^4 + 2.02954\,10^{-9}x^3 - 1.02567\,10^{-6}x^2 + 3.14856\,10^{-4}x - 0.00662$$

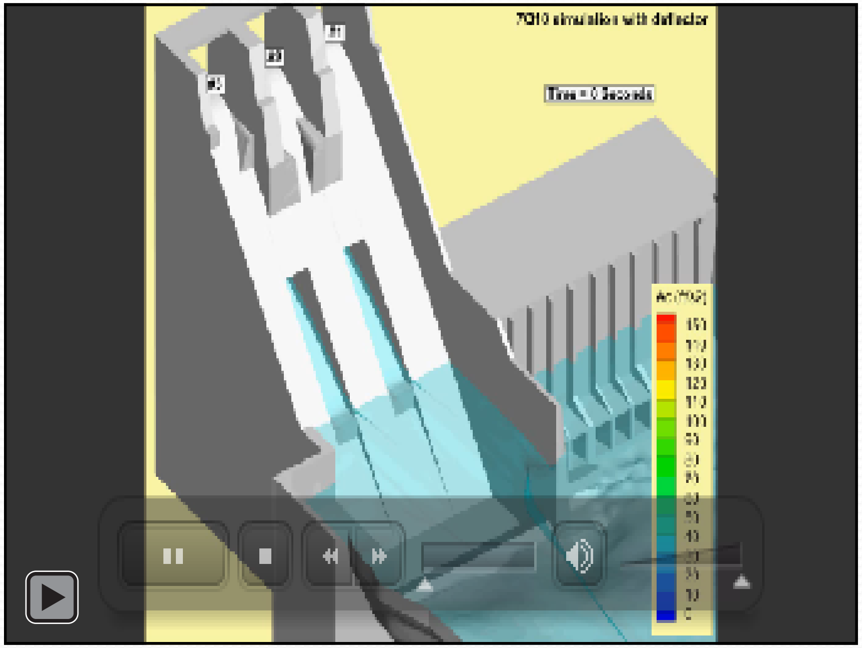
Operculum injury



$$y = -1.01137\,10^{-12}x^4 + 2.33151\,10^{-9}x^3 - 1.08654\,10^{-6}x^2 + 3.38219\,10^{-4}x - 0.0042$$

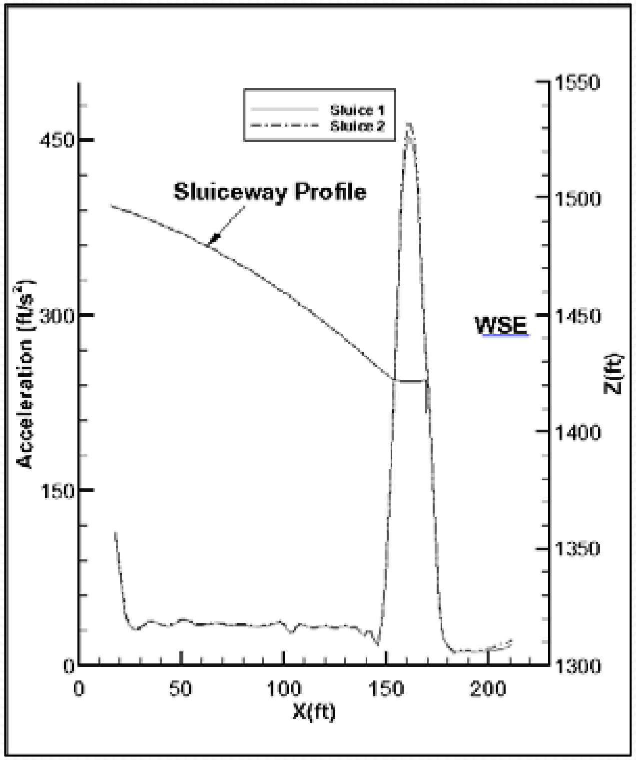
Fish trajectory colored by acceleration



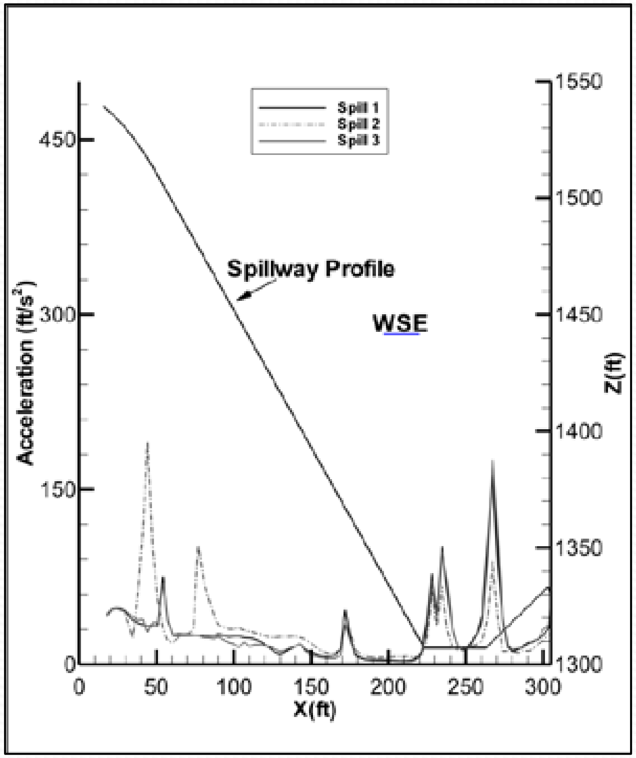


Average acceleration for 7Q10 simulations

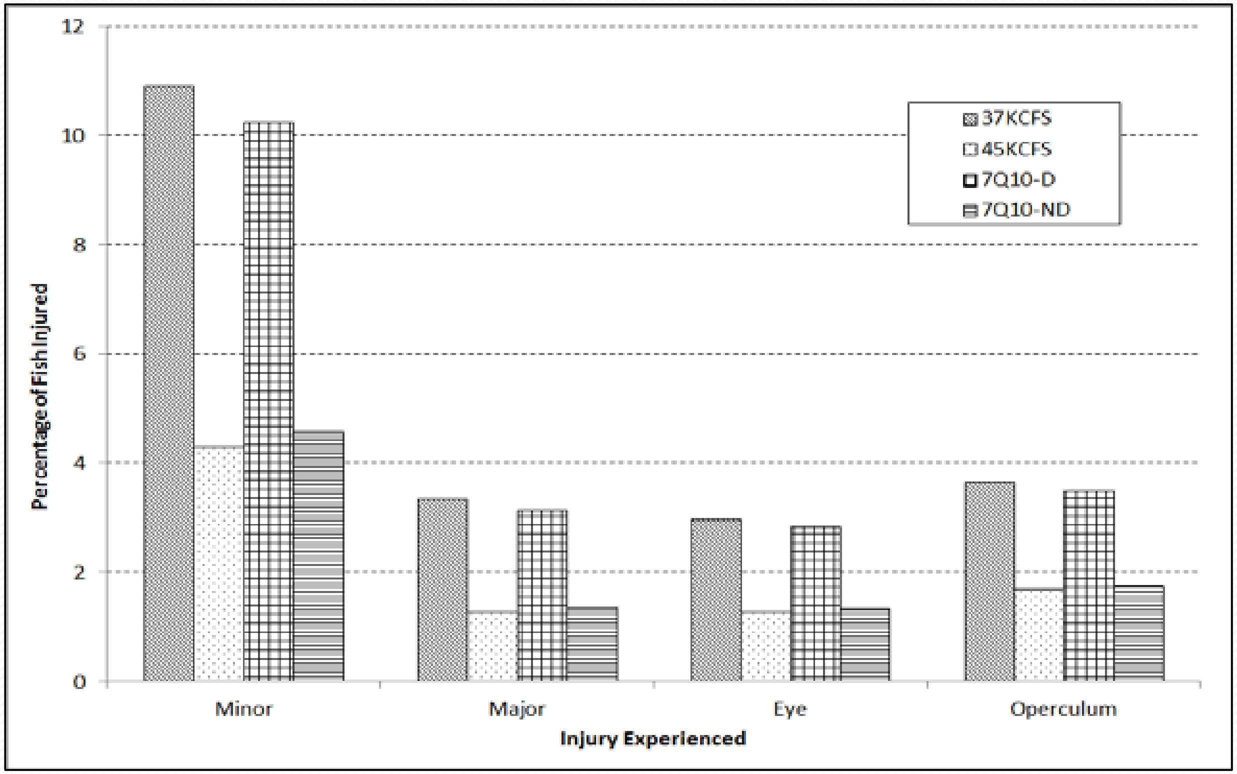
– Sluice flow with deflectors



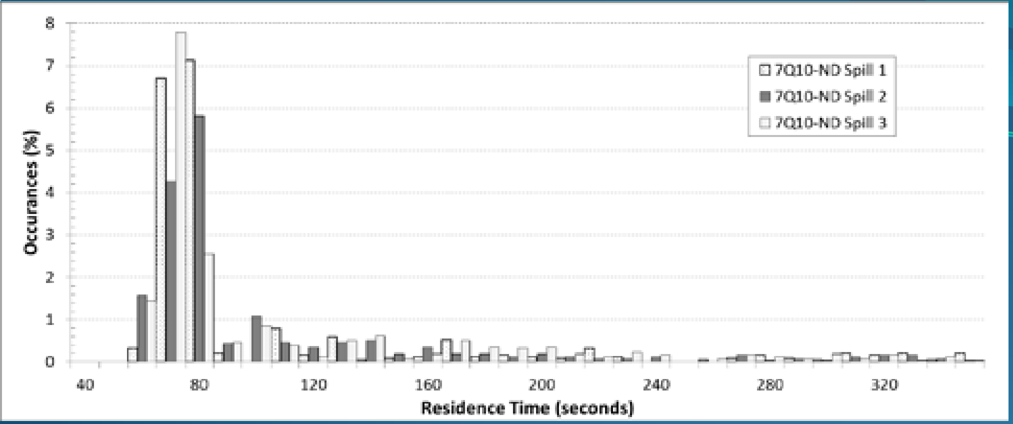
– Spillway flow without deflectors



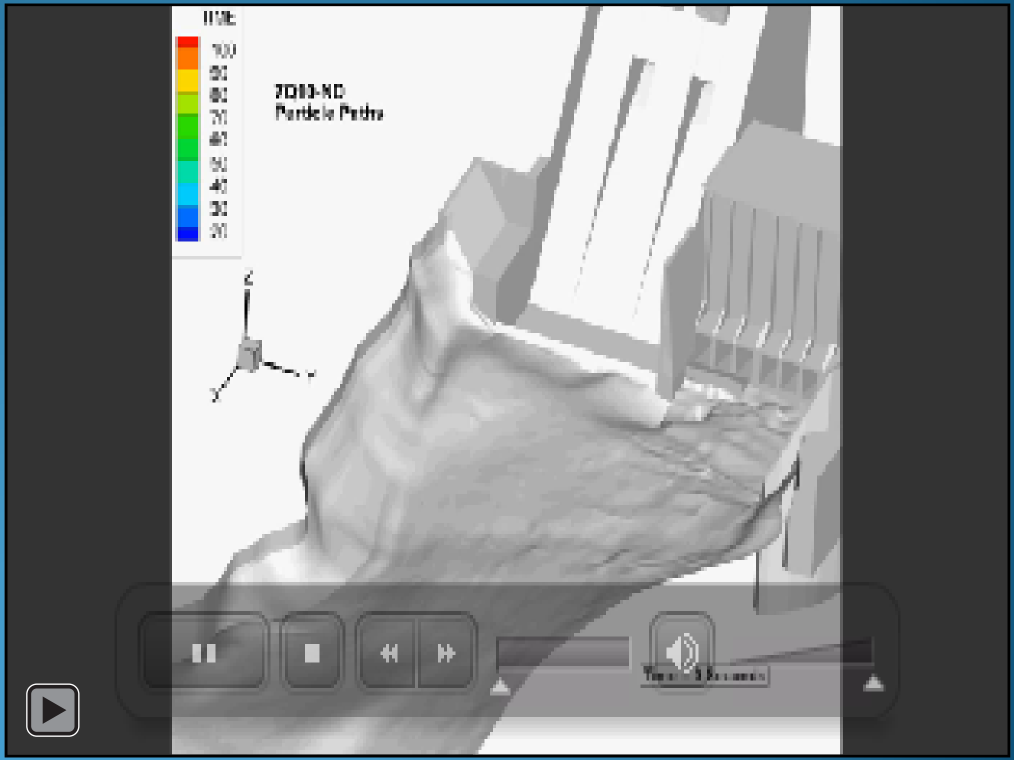
Percentage of fish injured by deceleration

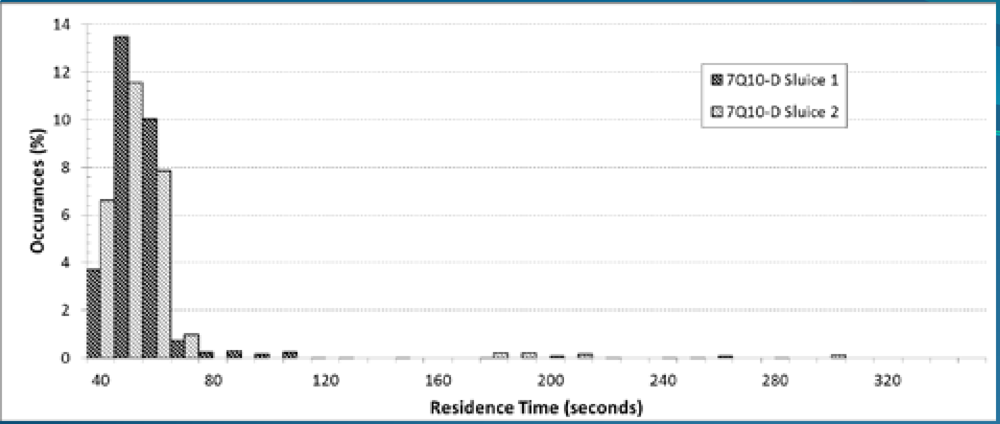


The largest values of **strain rate** occur when fish impact the deflector. The largest predicted value occurs for 37 kcfs and is of the order of 200 s^{-1}, which is well below the critical value of 517 s^{-1} where, according to Neitzel et al. 2004, major injuries were not observed.

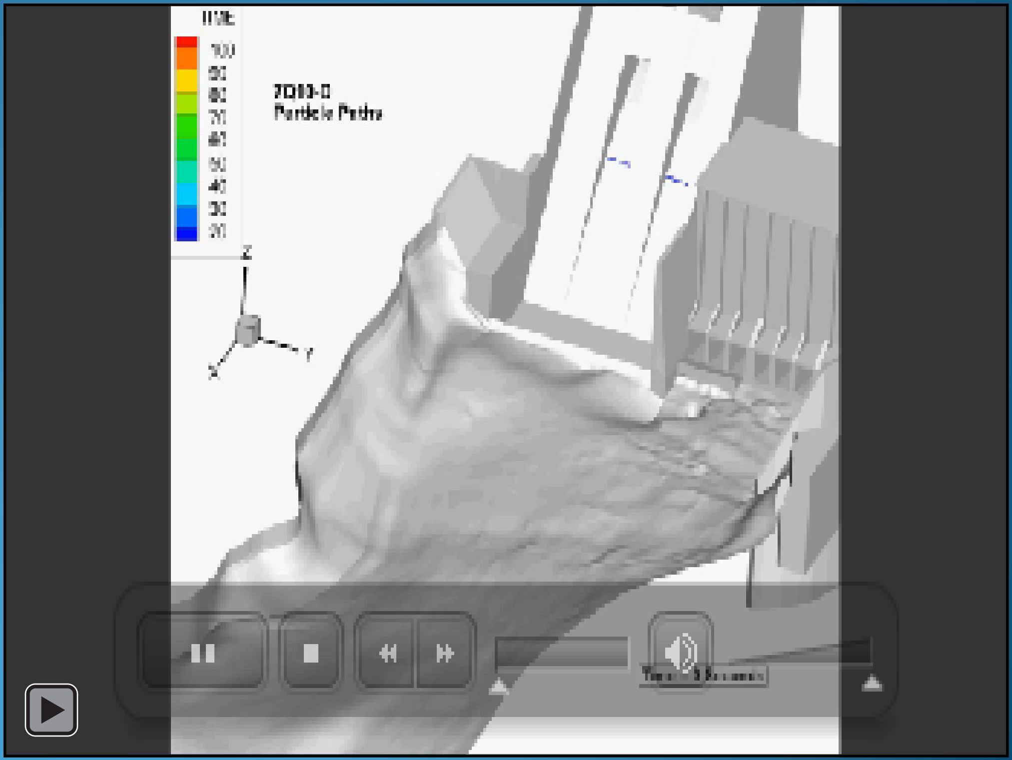


Residence time without deflectors





Residence time with deflectors



Conclusions

- The deflector recommended in a 1:48 IIHR reduced scale laboratory model was numerically evaluated. Three additional geometries, with modified elevation, length and transition radius, were analyzed. **The deflector tested in the laboratory was recommended** based on TDG production, spillway jet regime, and tailrace flow pattern.

- The performance of the selected deflector was evaluated for 37 kcfs, 45 kcfs and a 7Q10 flow. The **deflector prevents bubbles from traveling to depth**, thereby **minimizing** gas dissolution and **TDG production**.

- The **inclusion of deflectors slightly increases the probability of fish injury**. The most critical flow conditions for possible fish injury are 37 kcfs and 7Q10 flows. For these flows, about 10% and 3% of fish can suffer minor and major injuries, respectively. The inclusion of deflectors in a 7Q10 flow increases the percent of fish with minor injuries from approximately 5% to 10%. The percent of major injury increases from 1% to 3%. It is important to note that the above estimated percentages could be overestimated since fish injury reported by Deng et al. (2005) are based on fish aggressively introduced to a high shear jet, which is a condition much more severe than analyzed in this study.

- According to the model, **deflectors decrease the residence time** and therefore they are not expected to delay fish migration time.


Questions and Comments