BUREAU OF RECLAMATION

A numerical model for juvenile salmon entrainment at river junctures

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Outline

- The Problem
- The Approach
- Results
- Findings
- Next Step

The Problem

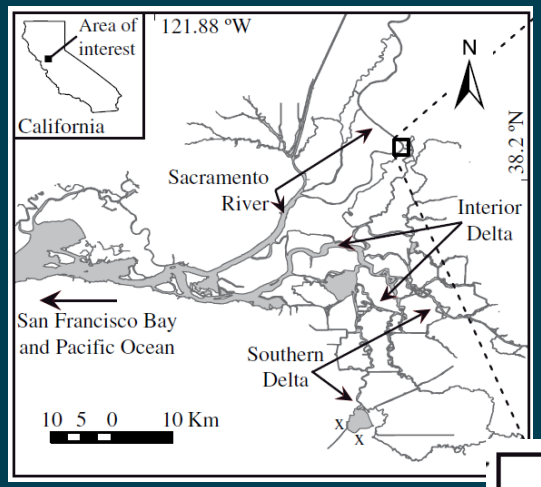
- Chinook-salmon are endangered in the Pacific Northwest
- Large amount of effort to “restore” fish population
  - Habitat restoration, WQ, …
  - Fish ladder, fish screen, …
  - Fish barrier, fish attraction, …

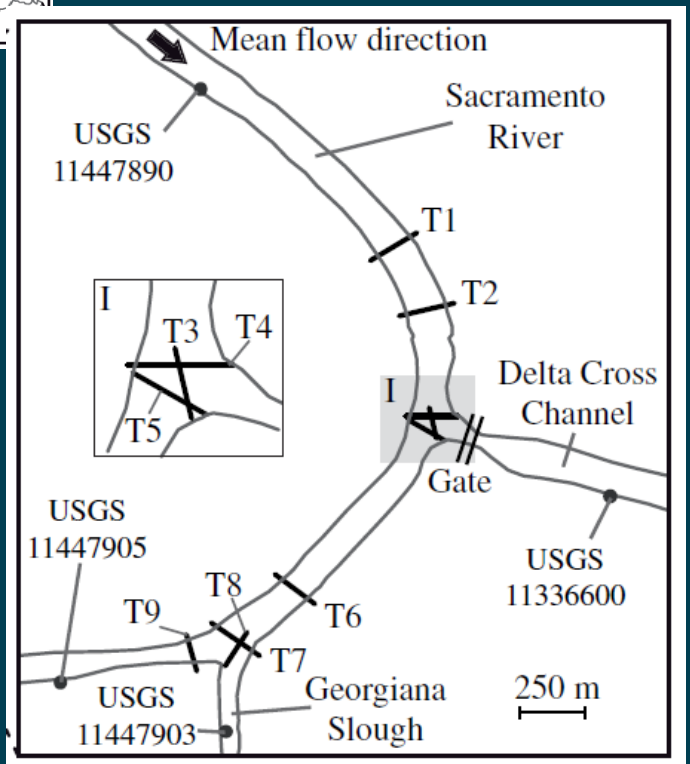
Focus of this Talk

- Juvenile Fish Out-Migration
  - Path Selection
  - Entrainment/rejection at a flow juncture
- A Science Based Approach?

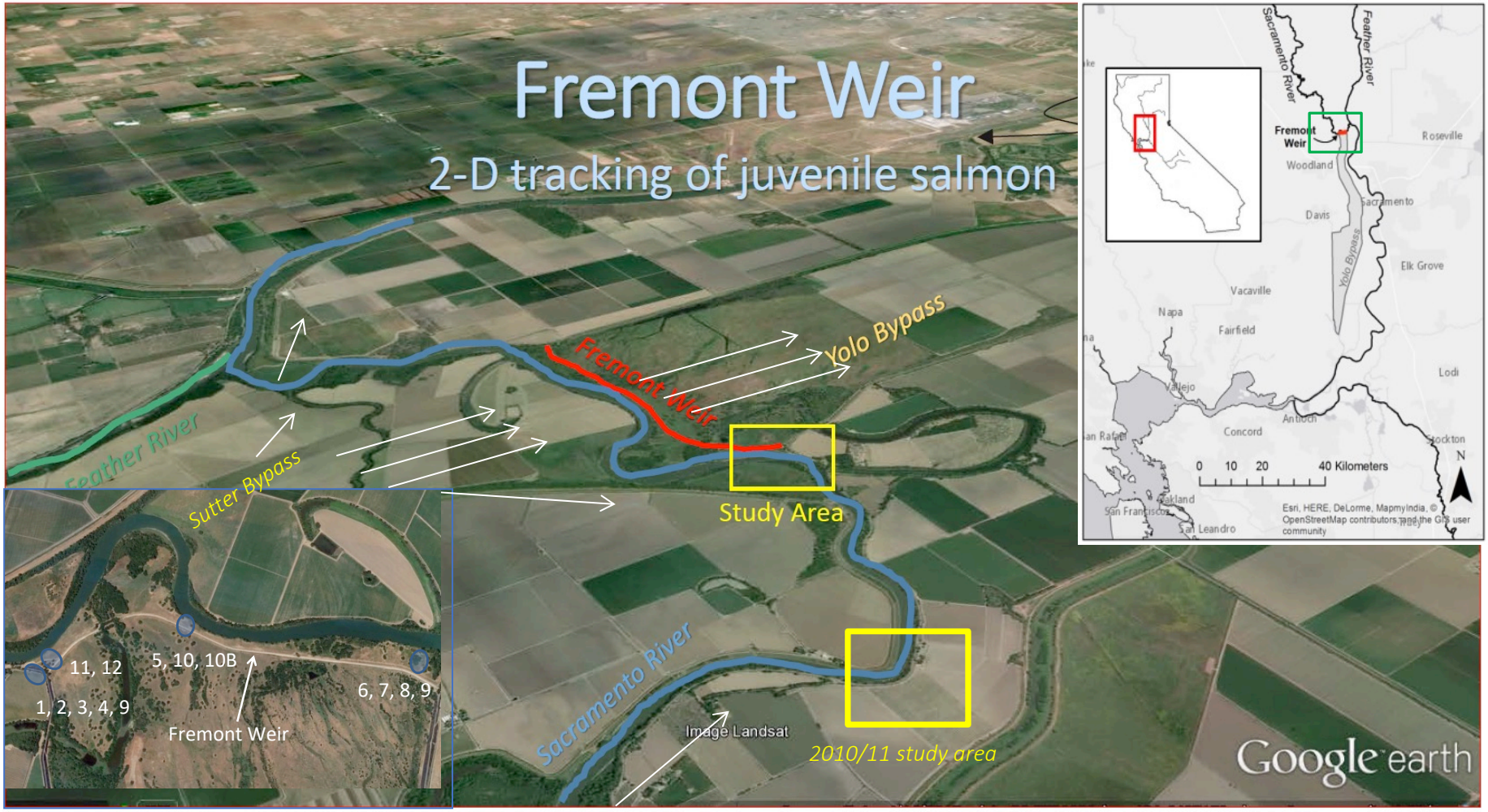
The Problem: Fish at Flow Junction Bay-Delta

- Two of the routes for out-migrating salmon on the Sacramento lead to interior Delta
  - Low survival
- Two Junctions are the Key
  - Delta Cross Channel & Georgiana Slough
  - Up to 50% entrainment!

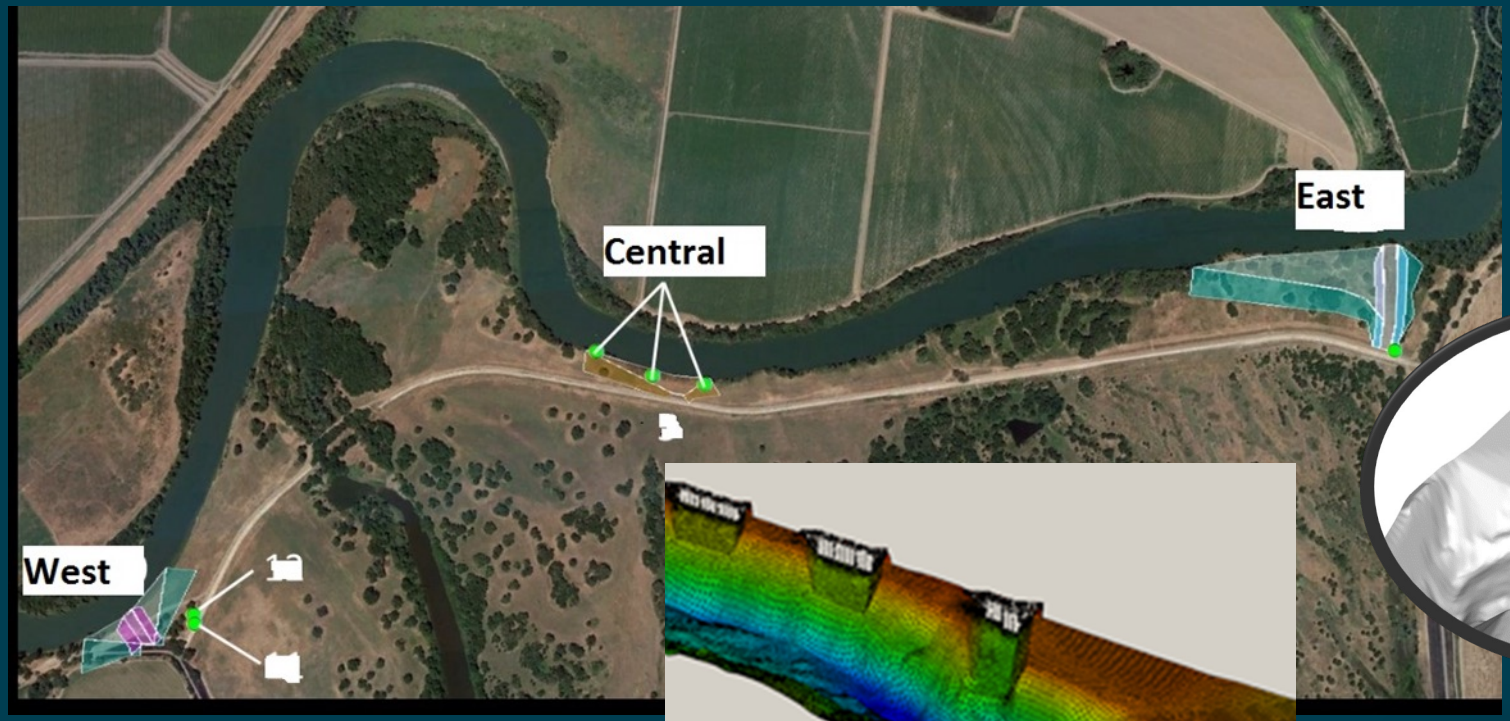


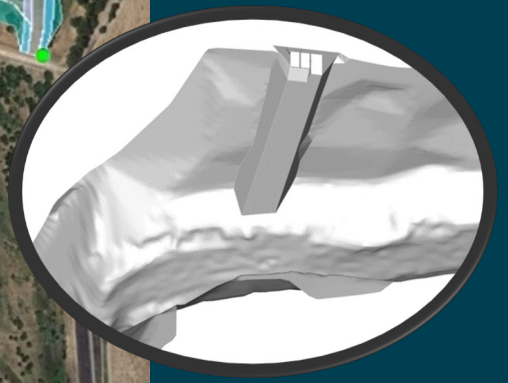


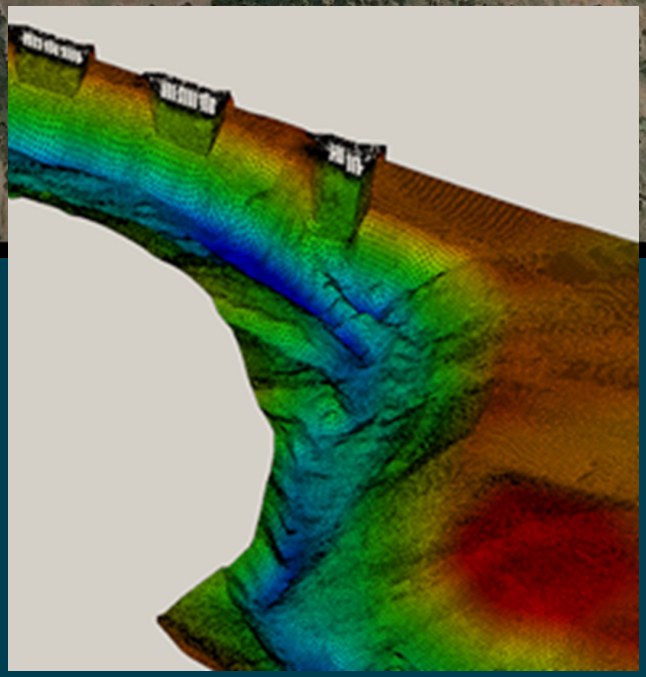
The Problem: Fish at Flow Diversion Yolo Bypass, Sacramento River



Sac-River: Fish at Flow Diversion



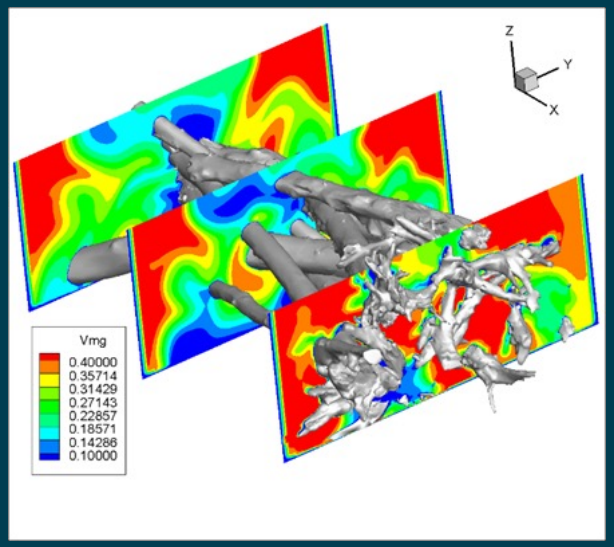




Fremont Weir diversion to the Yolo Bypass

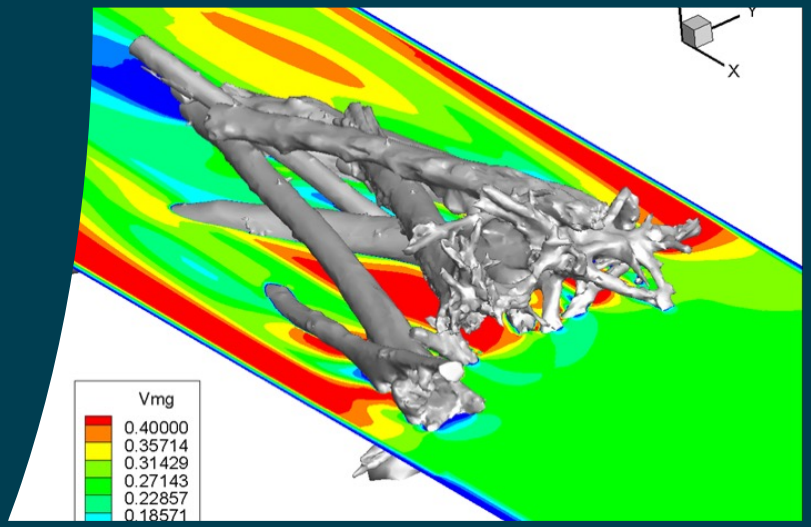
Science-Based Approach

- **Quantifiable**
- **Defendable**
- **At lease for Comparative Study**



Current State-of-the-Art

- Flow: 3D CFD Modeling
- Fish: Numerical Fish Tracking
  - ELAM



The Basis of the Approach

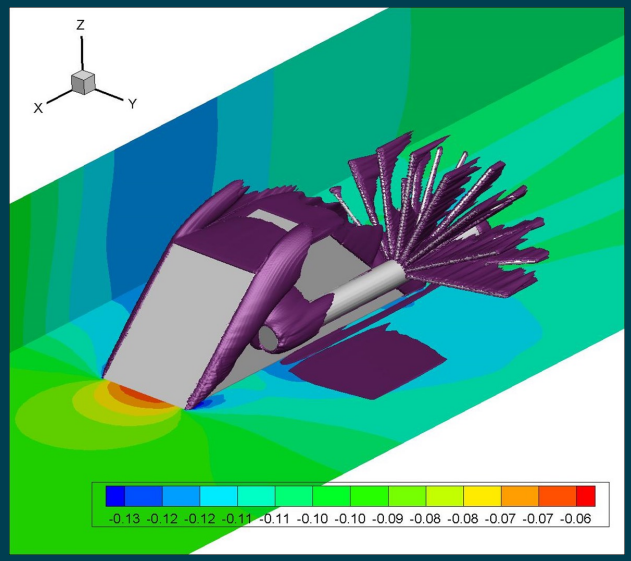
- **Assumption**
  - "Fish movement responds to flow hydrodynamics"
  - Fish mechano-sensory system tightly coupled to fluid variables

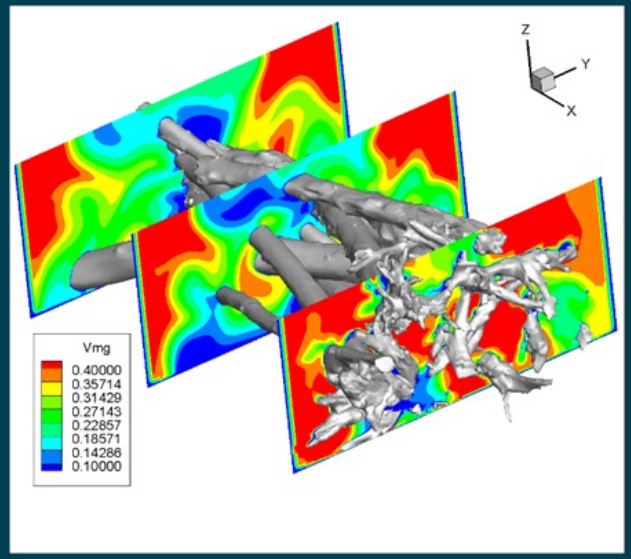
- **Any data support?**
  - Results in reservoirs in Pacific NW
  - Data in streams: fish is even passive in strong currents!
  - Data in flumes

Our Approach

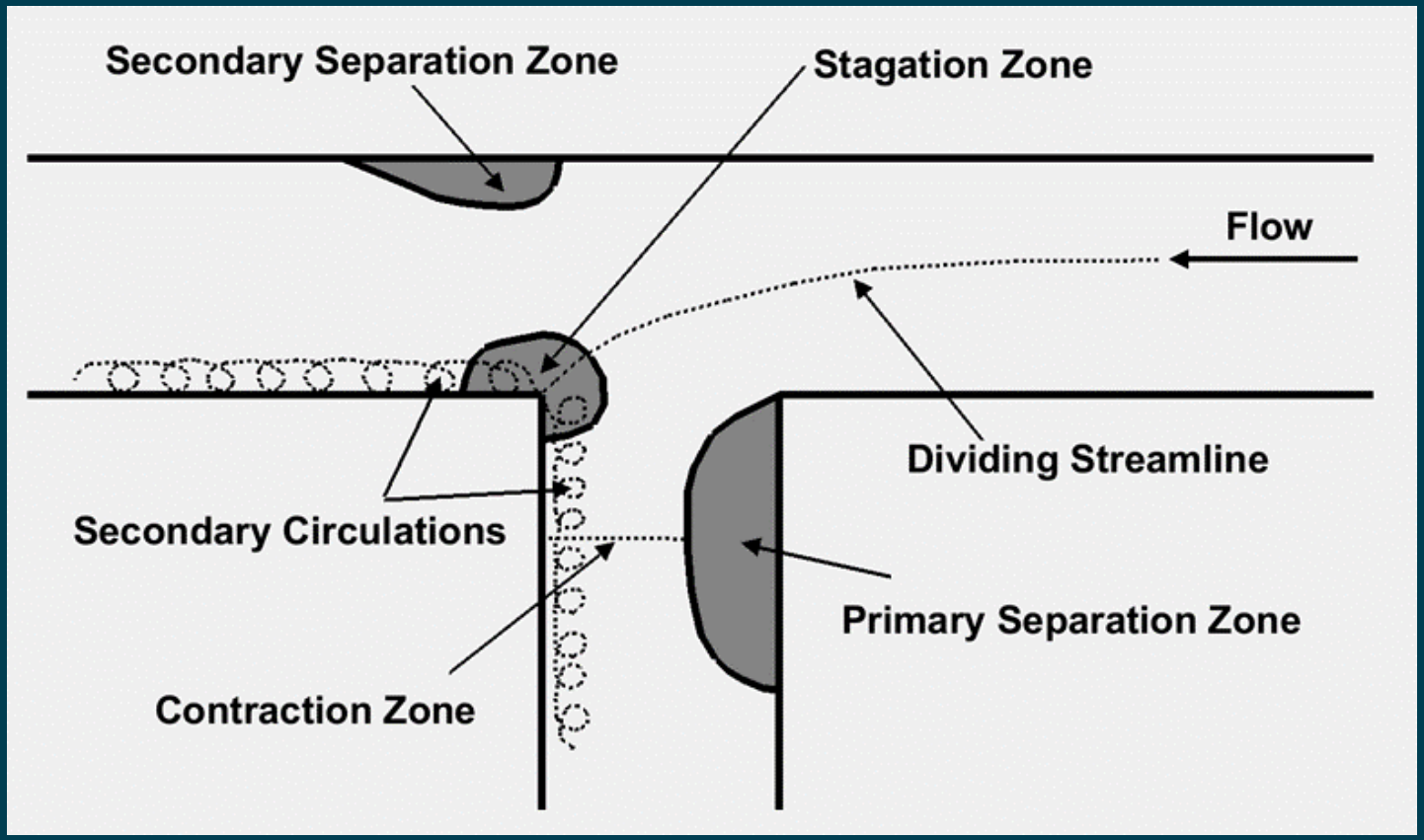
- Flow:
  - 3D CFD Modeling
  - U²RANS
- Fish:
  - Eulerian fish tracking
- Publication:

Lai, Y.G. Flow Characteristics at a River Diversion Juncture and Implications for Juvenile Salmon Entrainment. Fluids 2022, 7, 98. https://doi.org/10.3390/fluids7030098



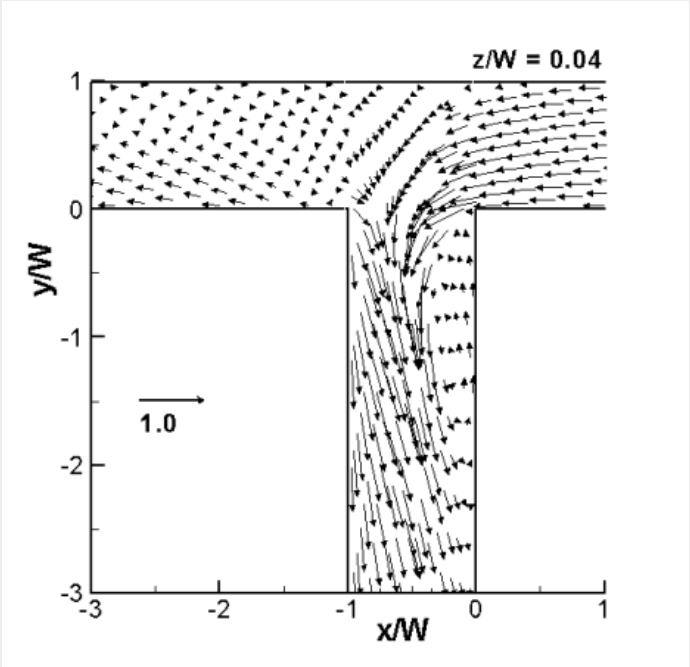


Complexity at Flow Juncture

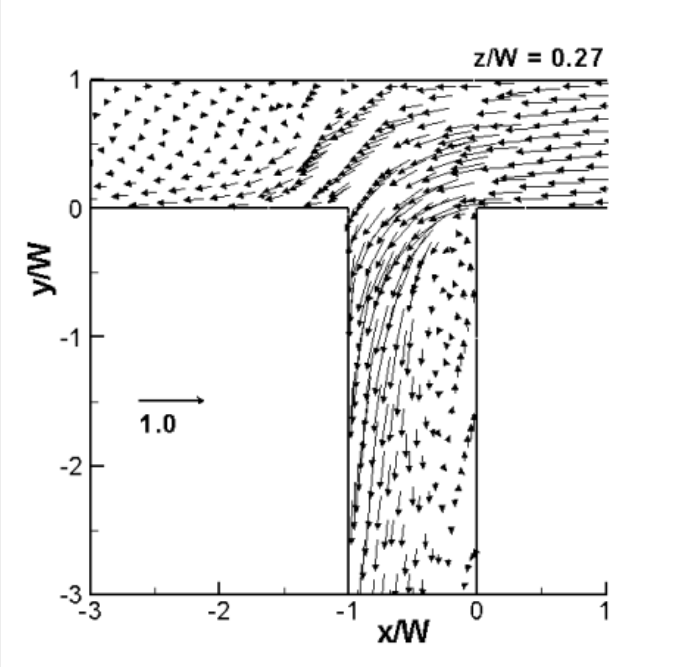


Bulle Effect at Junctures

90% entrainment bedload with 50% flow rate



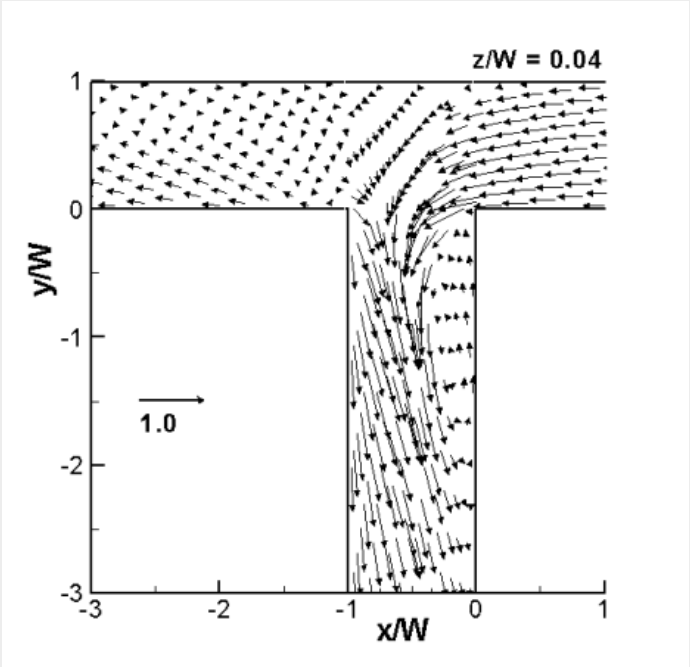
(**a**) Near Bed: z/W = 0.04



(**b**) Near Surface: z/W = 0.27

What about Fish Entrainment?

Lead to the present study



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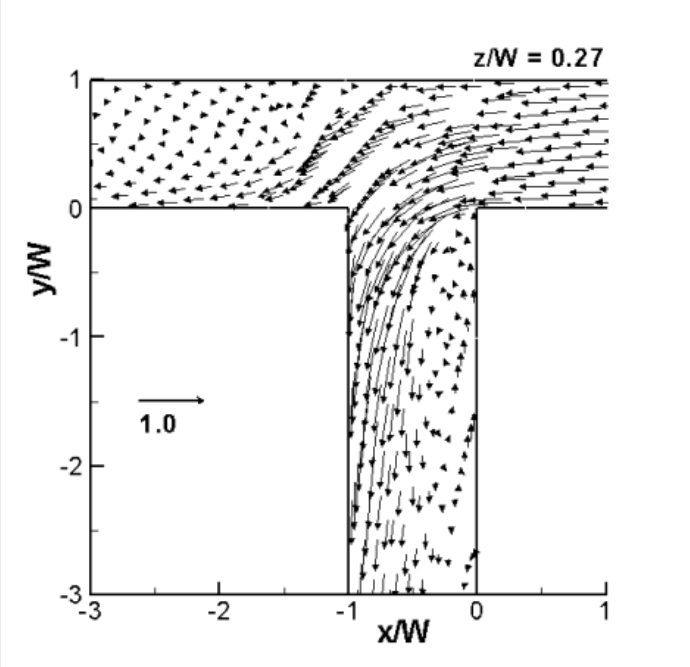

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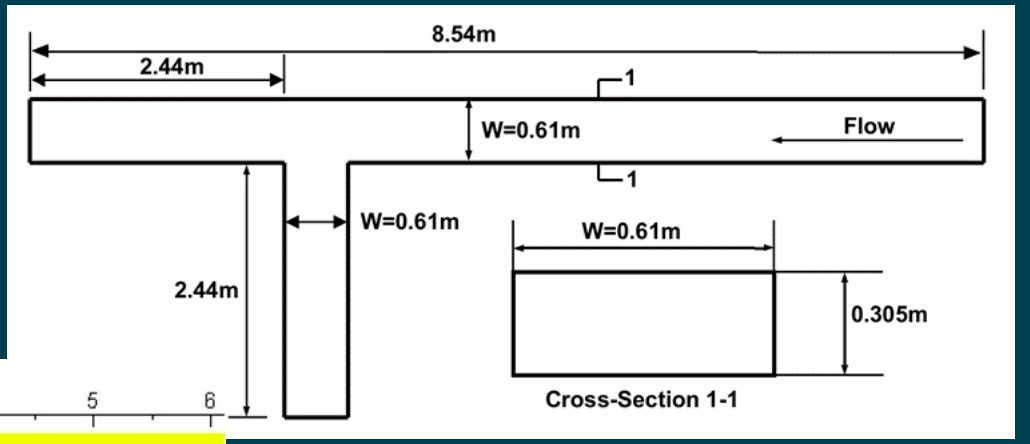
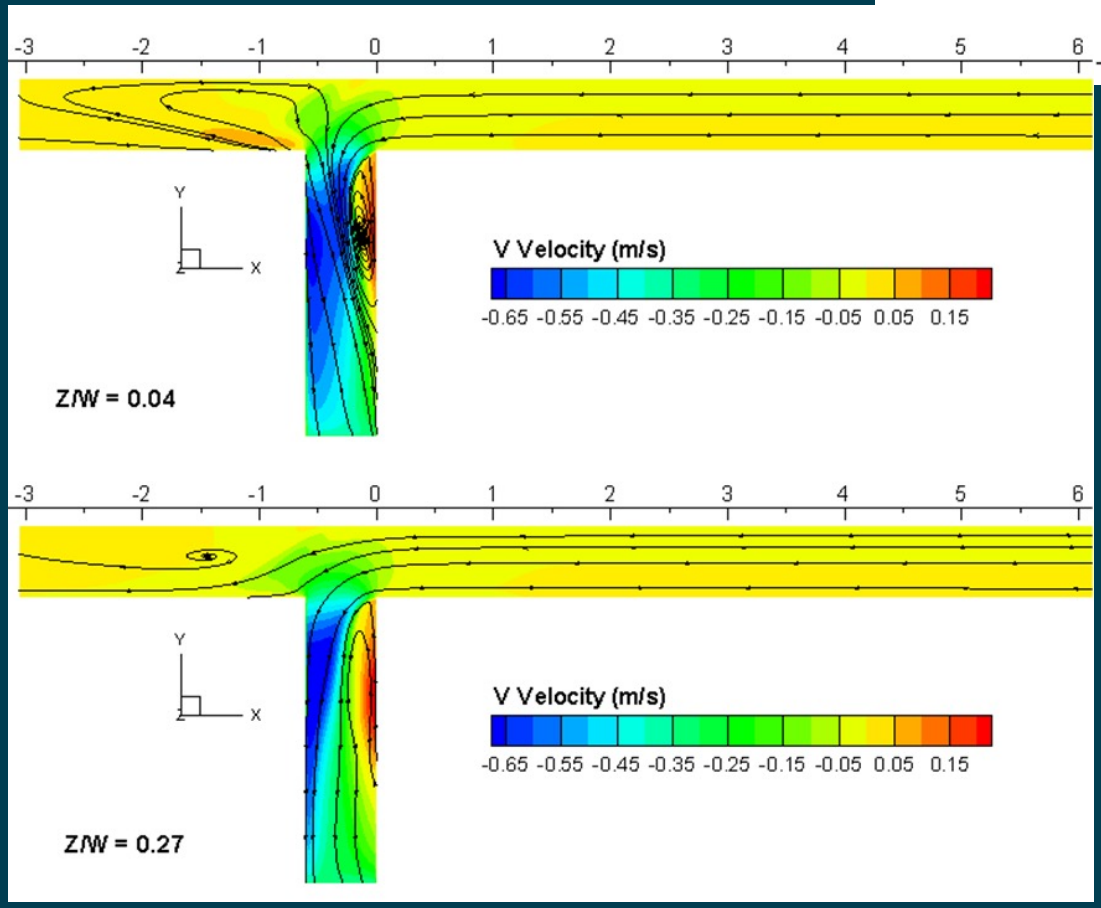
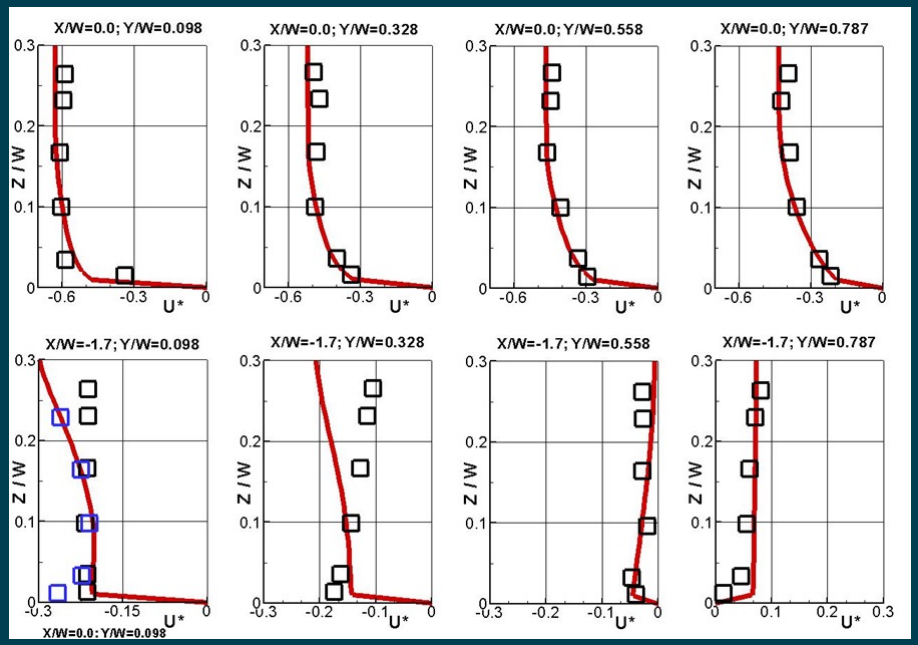
Step 1: CFD Model Validation



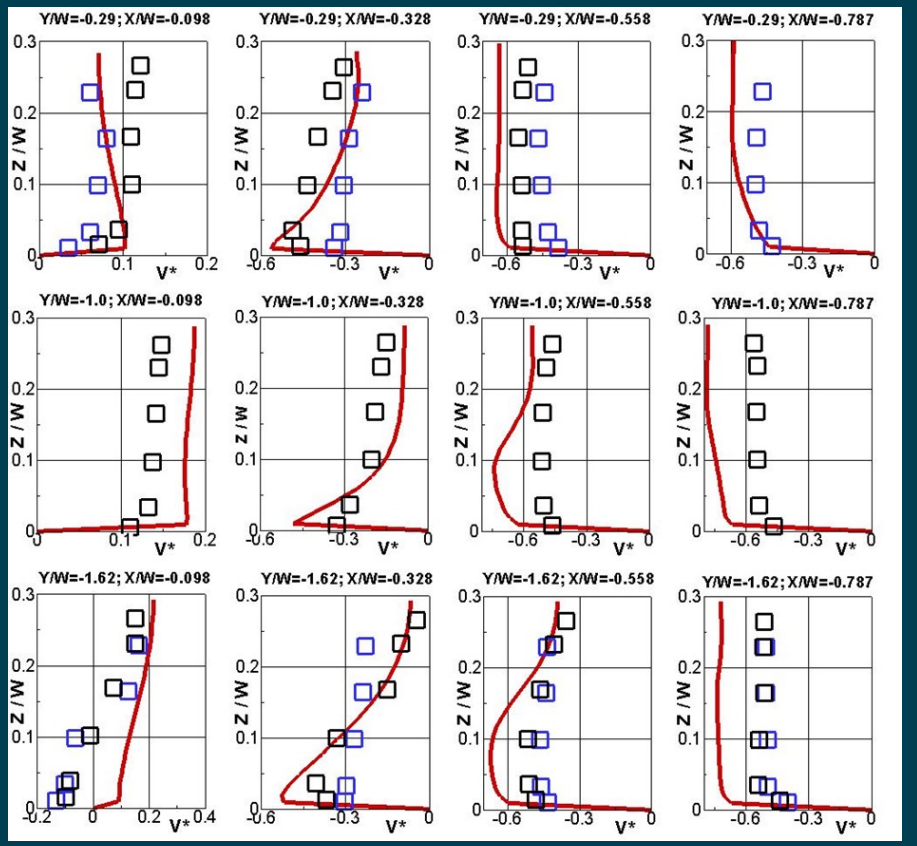


CFD Model Validation

Main-Channel



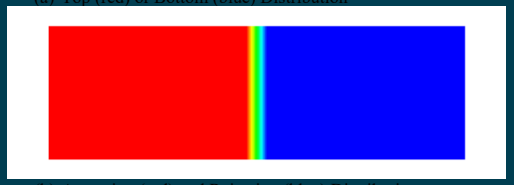
Side Channel



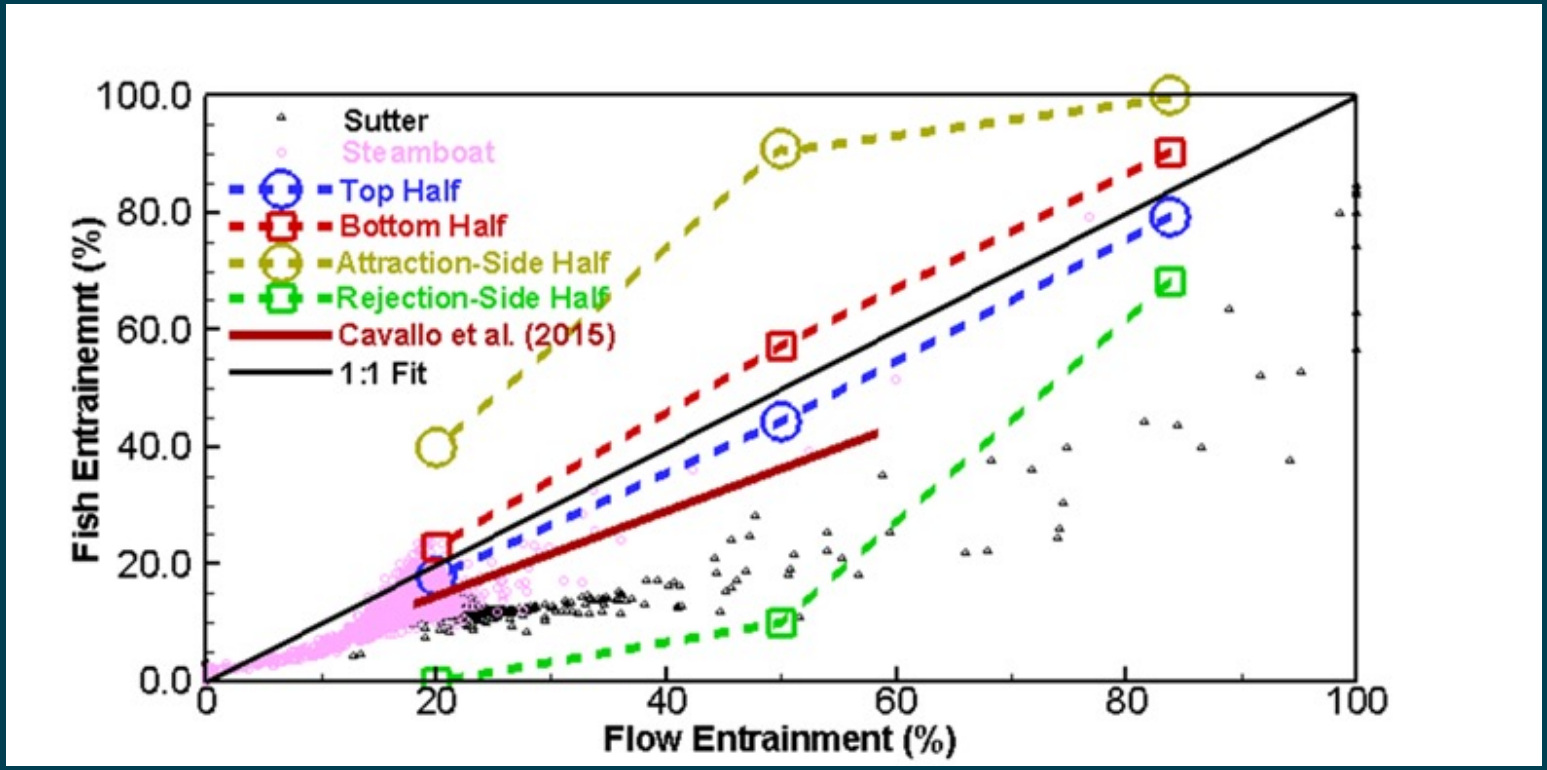
Step 2: Fish Entrainment Rate Prediction

- **Fish Distribution Scenarios**
  - Top ~ Bottom
  - Entrainment Side ~ Rejection Side
- **Entrainment Ratio**
  - 3 discharges
- **Field Data Comparison**

(a) Top (red) or Bottom (blue) Distribution



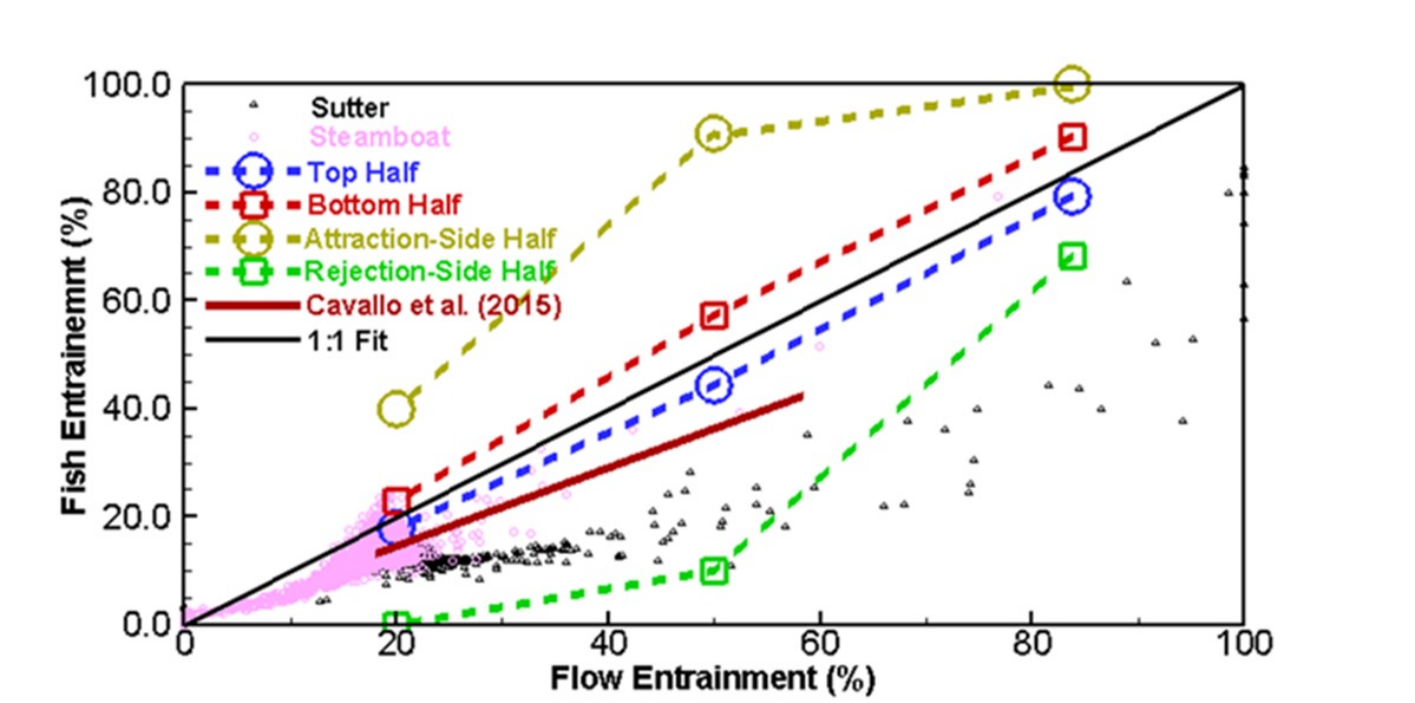
(b) Attraction (red) and Rejection (blue) Distribution



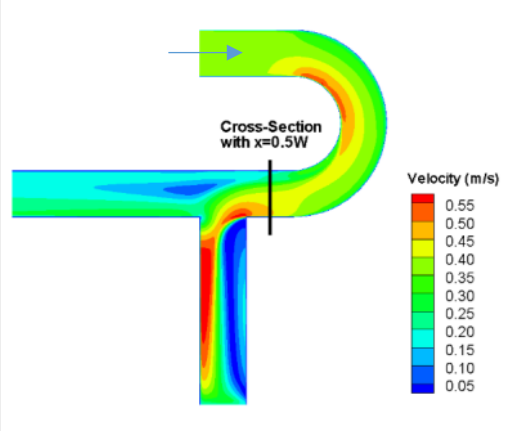
Finding #1:

Upstream fish distribution has a large impact on fish entrainment rate

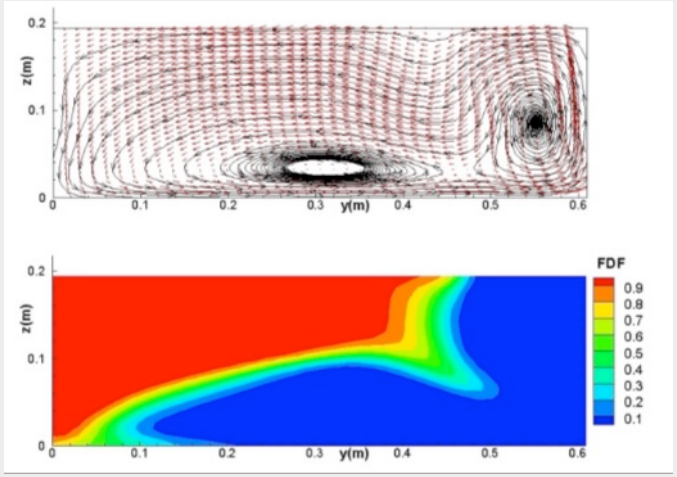
- Entrainment side vs. non-entrainment side
- Top vs. Bottom



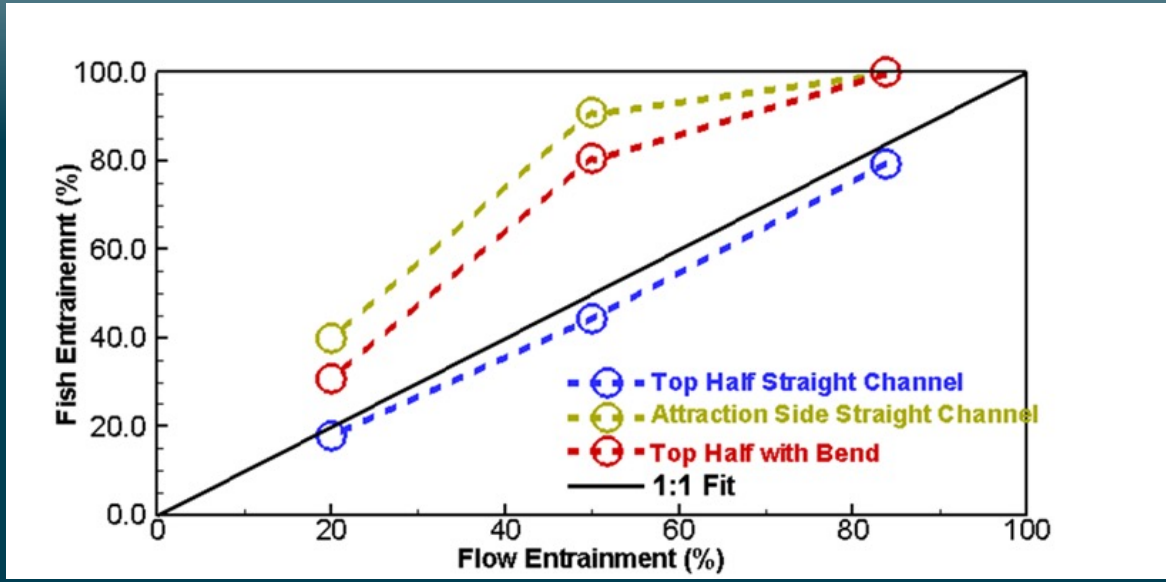
Secondary Flow Effect



(a) model Domain and velocity field



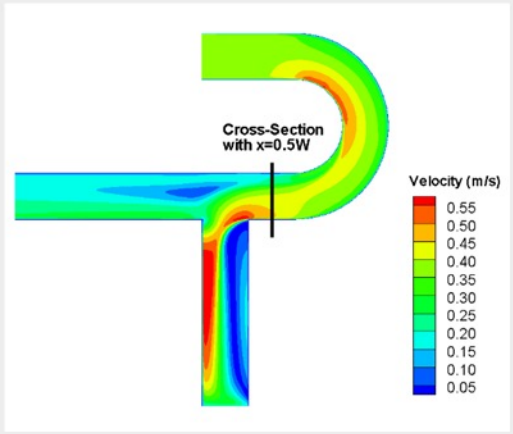
(b) secondary flow (top) and fish distribution function(bottom)



Finding #2:

Secondary flow may have a large impact on the fish entrainment

- e.g., Achieved through bend flow



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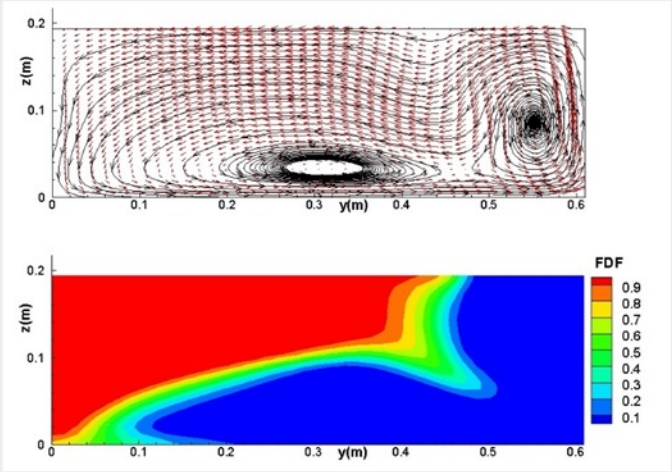
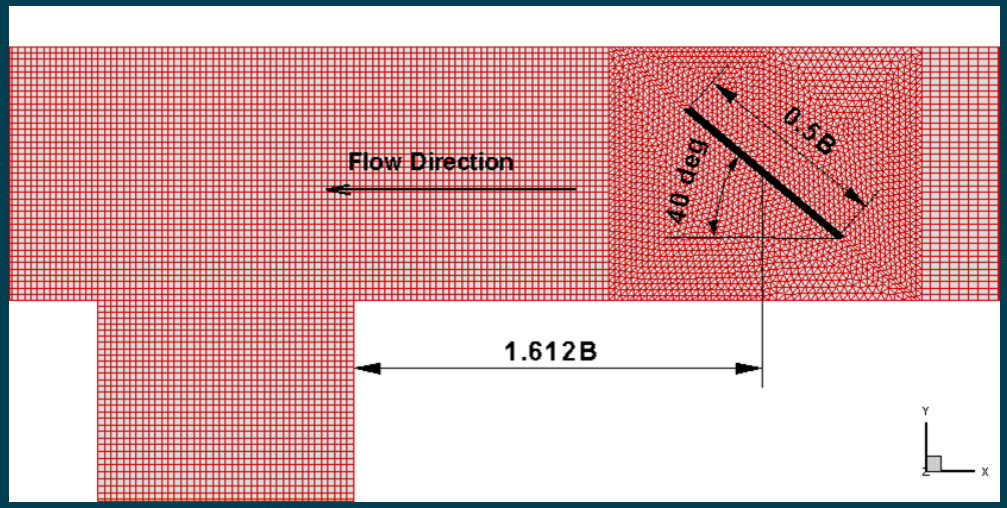
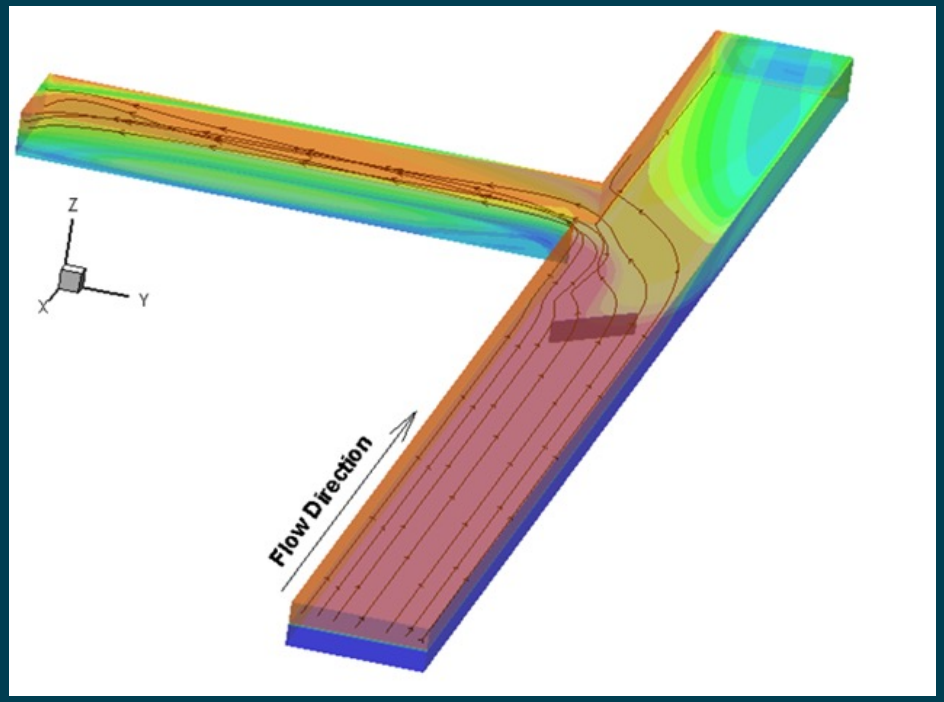


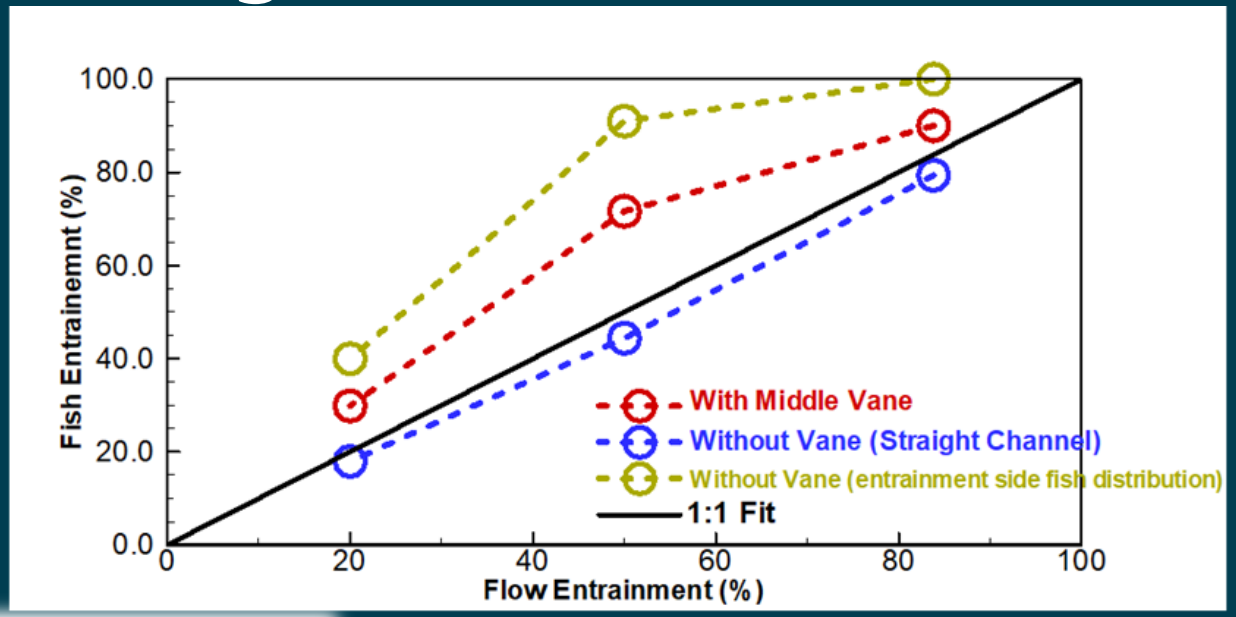
(b) secondary flow (top) and fish distribution function(bottom)

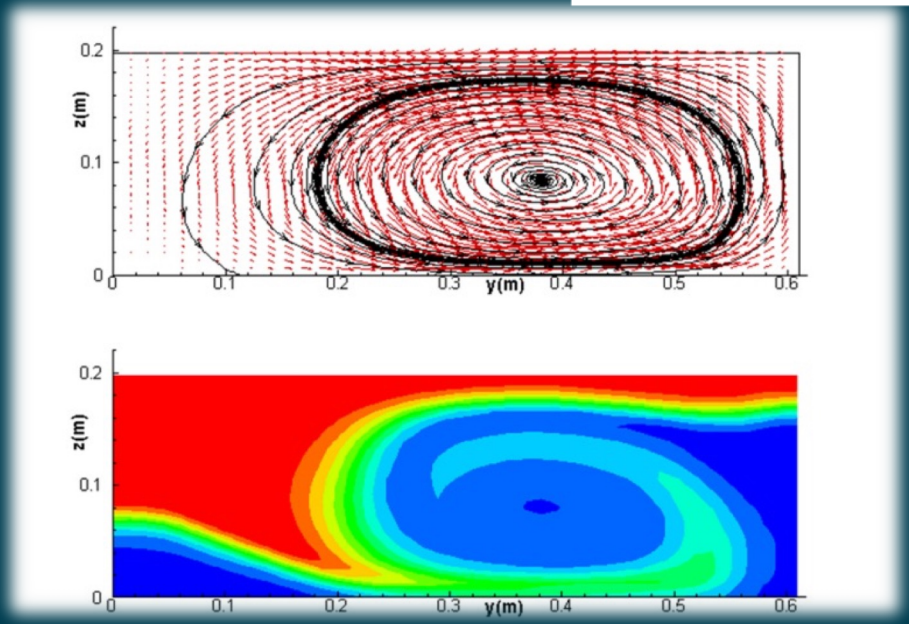
Effect of Submerged Vane





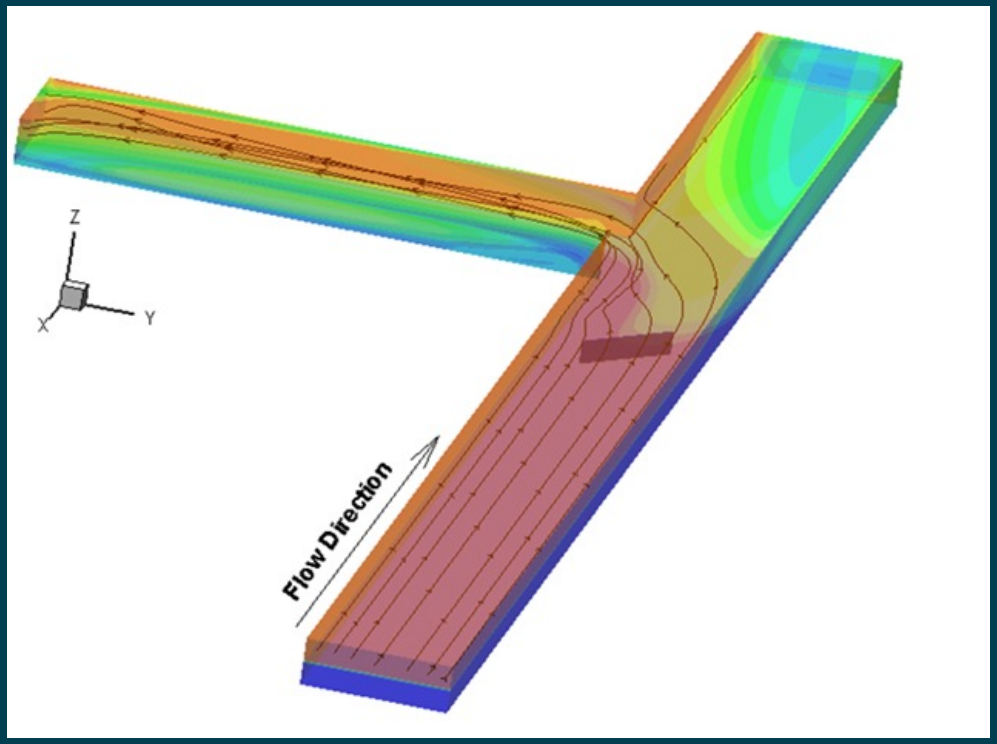
Effect of Submerged Vane





Finding #3:

Submerged vanes may be effective in altering the fish entrainment



Future Research

- More sophisticated fish tracking models (e.g., ELAM)
- Impact of instream structures on fish perception-and-response (e.g., Vane)
- Field modeling studies and applications


THANK YOU
QUESTIONS ?
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