# Smolt Responses to Hydrodynamic Characteristics in the Forebay of Surface Flow Outlets, 2007

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## Goal

Use fish behavioral responses to formulate general design guidelines for hydraulic conditions that readily pass juvenile salmon at surface flow outlets (SFOs).

Model of the Wells Dam SFO, Mike Erho

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## SFO Design Questions

- We integrated data on smolt movements and hydrodynamic conditions at SFOs at McNary and The Dalles dams during 2007 to address the following questions:
  - Which hydraulic variables are most strongly associated with fish behavioral responses?
  - Of these, are there threshold levels that could be used to support SFO design guidelines?

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## Scope

**Study Sites**: Sluiceway at The Dalles Dam and the Top Spill Weir at McNary Dam

**Focus Area**: SFO Decision Zone (< 20 m from the SFO entrance)

**Study Periods**:

- MCN = April 23-26, 2007
- TDA May 1 to July 12, 2007 (six 4-d blocks)

**Objectives**:

- Characterize fish behaviors and water velocities.
- Examine statistical relationships between juvenile salmonid movements and hydraulic variables immediately upstream of the SFO entrances.
- Provide recommendations for design guidelines for SFO entrance conditions.



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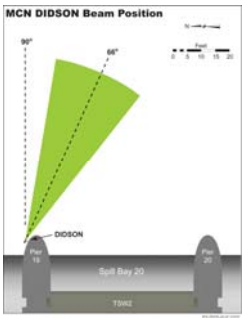
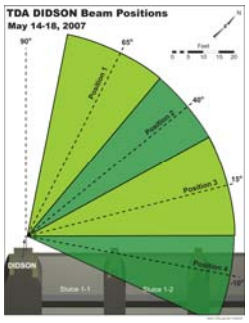
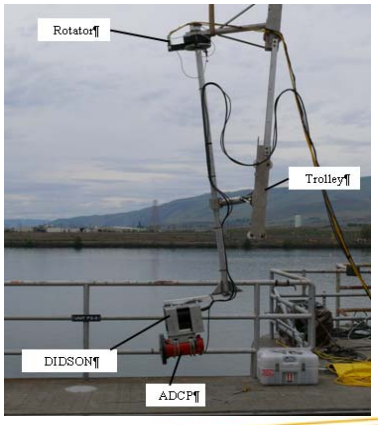
# Methods

Simultaneous DIDSON (fish) and ADCP (water) measurements *in situ*

Post-season CFD



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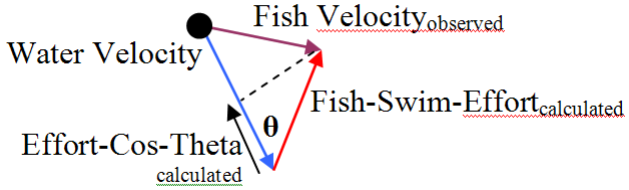
# Variables

- Fundamental Biological Response: Fish swimming effort vector




- Hydraulics:
  - Water velocity
  - Turbulence index: root-mean-square of velocity
  - Acceleration index: time derivative of velocity
  - Shear index: spatial derivative of velocity

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## Reporting Phases

- Phase 1 – Provided descriptive behavioral data (presented at AFEP Annual 2007)
- Phase 2 – Merged fish/ADCP data (presented at SRWG March 2008)
- Phase 3 – Incorporated CFD results (presented at FFDRWG and in draft final report, June 2008)

**Important Note**: Comparison of the ADCP and CFD results for TDA revealed a problem with our application of the ADCP. The instrument was functioning properly, but the assumption that water currents were sufficiently homogenous for a given range in the ADCP beams was not met, producing anomalous water velocity vectors. Thus, all water-related and fish effort variables reported today are for TDA and were calculated using CFD data.

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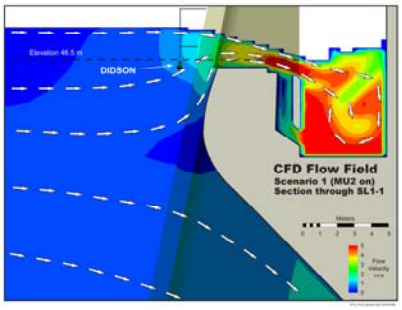
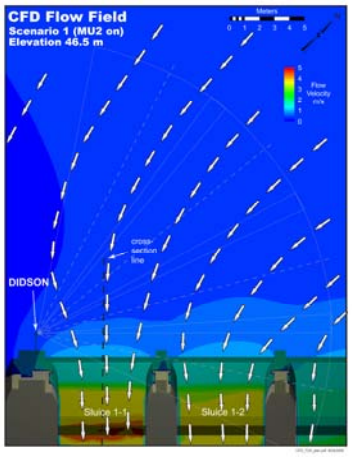
## Water Velocities

Flow abruptly accelerated as it neared and passed over the sluiceway sill at The Dalles Dam.




(Total discharge 273, spillway 110, powerhouse 163 kcfs. Sluice 1-1 and 1-2 2.7, MU1 9.9 and MU2 9.8 kcfs.)

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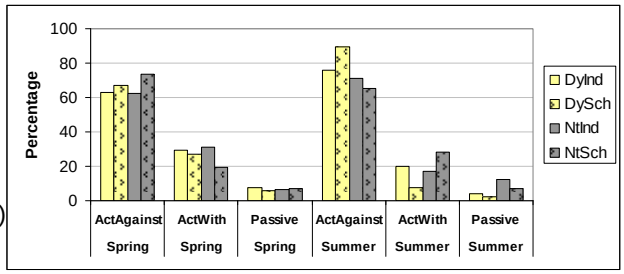
# Fish Behavior: Swimming Effort Relative to the Flow Field

The majority behavior was active swimming against the flow (65-85%). A small fraction of swimming behavior was passive (~5%). Swimming against the flow (positive rheotaxis) was more common in summer than spring at The Dalles Dam. Generally, individual fish were less likely to swim against the flow than schools of fish.




(Percentages based on effort-cos-theta were calculated seasonally for individual fish and schools during day and night separately, e.g., for spring/day/individuals, the sum of percentages for active against, active with, and passive equals 100.)

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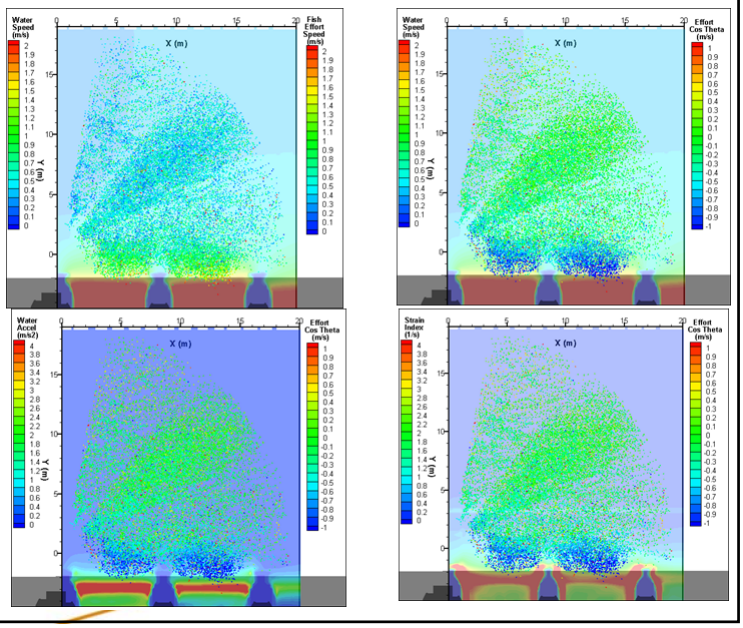
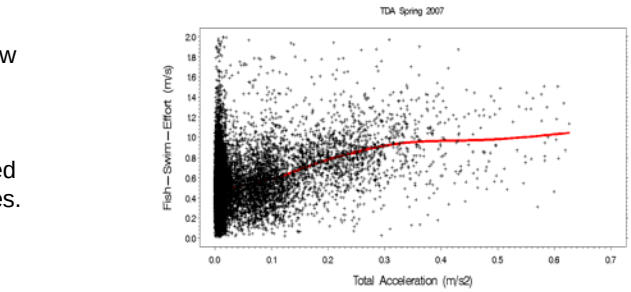
# Fish Effort Superimposed on Flow Conditions

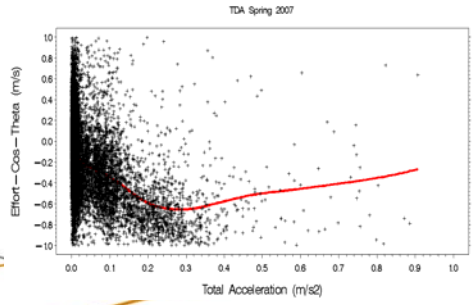
Relatively high fish-swim-effort values and negative effort-cos-theta just upstream of the sluice entrances. Water velocity increases in this region, as does acceleration and strain.



## Non-Linear Regression Analysis

Example fish/flow relationships indicate the potential for empirically-based design guidelines. Leveling of the effort variables could indicate a response threshold.

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## Summary and SFO Design Implications

- Schooling behavior was dynamic and prevalent
  - the implication is that SFO entrance area must be large enough to accommodate fish schools.
- Fish behavior was dependent on distance from the SFO entrance
  - this supports the notion that SFO flow nets need to be expansive enough spatially for smolts to discover despite competing flow fields.
- Passive fish behavior was observed less than 5% of the time in the SFO flow nets we studied
  - this implies that SFO designs cannot rely only on fish following bulk flow.
- Active swimming against the flow was the most common behavioral response
  - thus, SFO performance evaluations should include a metric for fish swimming effort in SFO flow fields.
- Fish effort variables were correlated with water velocity, acceleration, and strain.
  - these are likely design variables
- The non-linear regressions indicate potential for this approach of merging fish/flow data
  - this could lead to SFO design guidelines in the future as the fish/flow dataset is further populated.

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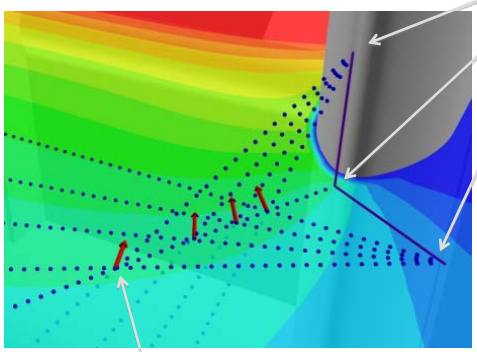
## New Approach: Velocity Measurement using Modified ADCP, i.e., a Large-Scale Acoustic Doppler Velocimeter



3 individual ADCP units on movable frame

Measurement volume at intersection of three individual beams

Pros

- Address measurement issues with standard ADCP in non-homogeneous flows
- Smaller measurement volume
- Minimally invasive

Cons

- More complex deployment
- Point measurements
- Potential for beam interference



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## Expected Outcome and Management Implications

- Merged fish&flow data from a diversity of sites in multiple years
- Different hydraulic signatures at each site
- Identify relationships between smolt responses and hydrodynamic conditions
- Development of general design and operations guidelines for surface flow bypass structures

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## Acknowledgements


- Ann Setter and Bob Wertheimer (Corps technical leads)
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- Mechanics, electricians, and operators at The Dalles Dam
- PNNL staff, including Dennis Dauble, James Hughes, Julie Hughes, and Shon Zimmerman


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## Thank You


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# Correlation Analysis

- Effort-cos-theta had higher correlations with hydraulic variables than did fish-swim-effort.
- The highest correlations (0.46-0.47) were between effort-cos-theta and water velocity magnitude, V (water speed's y-component, perpendicular to the dam), W (water speed's vertical-component), total acceleration, and strain.
- Most of spatial derivatives of velocity were not strongly correlated with the fish behavior variables.

| | U | V | W | VelocityMag. | dUdX | dVdX | dWdX | dUdY | dVdY | dWdY |
|---|---|---|---|---|---|---|---|---|---|---|
| Xeffort | 0.04 | -0.17 | 0.16 | 0.17 | -0.13 | 0.08 | -0.06 | 0.08 | 0.15 | -0.14 |
| Yeffort | 0.06 | -0.41 | 0.41 | 0.41 | -0.29 | 0.07 | -0.16 | 0.12 | 0.36 | -0.37 |
| Fish-Swim-Effort | 0.03 | -0.36 | 0.36 | 0.36 | -0.26 | 0.09 | -0.16 | 0.12 | 0.33 | -0.32 |
| Effort-Cos-Theta | -0.19 | 0.47 | -0.47 | -0.46 | 0.36 | -0.04 | 0.13 | -0.10 | -0.42 | 0.42 |

| | dUdZ | dVdZ | dWdZ | AU | AV | AZ | Total Accel. | Strain |
|---|---|---|---|---|---|---|---|---|
| Xeffort | 0.05 | -0.15 | -0.16 | -0.05 | -0.14 | 0.12 | 0.15 | 0.17 |
| Yeffort | 0.17 | -0.38 | -0.39 | -0.02 | -0.34 | 0.32 | 0.34 | 0.39 |
| Fish-Swim-Effort | 0.13 | -0.35 | -0.35 | -0.03 | -0.32 | 0.28 | 0.32 | 0.35 |
| Effort-Cos-Theta | -0.26 | 0.43 | 0.44 | 0.00 | 0.37 | -0.37 | -0.38 | -0.46 |