Session D1 - Application of CFD Models in Support of Fish Passage Facilities Design

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Applications of CFD Modeling in Support of Fish Passage Facilities Design

Mizan Rashid, PhD, PE, D.WRE - AECOM
Daniel Katz, PE - USACE Seattle District
Presentation Outline

• Modeling needs and types of models
• How modeling fits into the design process
• Guidelines for model Selection and application
• Project examples, challenges, and lessons learned
• Summary
Passage System Components and Design Questions to be Answered All Tied to Hydraulics

• Site-specific and not easily calculable
  – Where to collect?
  – How to collect?
  – How to bypass?
  – Where to release?
  – How to release?
When and Where is Modeling Needed?

• Complex flow conditions and difficult to predict without modeling

• Insurance policy – We know what we need, but just in case!

• Stakeholder buy-in – Let me show you how we are going to do it so you will buy it!

• Voyage of discovery – We know what we don’t know, we think!

• Most studies are a combination of all 4 types
Typical Flow Chart-Application of Hydraulic Models

- Review of Existing Information/Data
- Additional Data Required?
  - Yes: Field Data Collection
  - No: Design Review and Conceptual Design
- Additional Data Required?
  - Yes: Additional Data Required?
    - Yes: Physical Model Study
    - No: No
  - No: Numerical Model
- Design Development

Additional Design Optimization?
  - Yes: Additional Design Optimization?
  - No: Design Report
Available Models and Project Examples
Available Modeling Tools

- Numerical Models
  - 1-D
  - 2-D
  - 3-D

- Physical Models

- Hybrid Physical and Numerical Modeling
Computer Models

• Hydrologic – HEC-HMS (HEC-1)

• Hydraulic – HEC-RAS, HEC-6, RMA2, HIVE2D, and SED-2D

• Hydrodynamic – EFDC, and Princeton Ocean Model (POM)

• Computational Fluid Dynamic (CFD) – STAR CD, FLOW3D, and FLUENT

• Water Quality – CE-Qual-W2, QUAL2E, and BETTER
CFD Model Studies - Objectives

• Hydrologic analysis to determine discharges, velocities, and stages

• Simulation of flow field near and within the fish passage facilities

• Determination of optimum locations for fish passage facilities

• Sediment transport and morphological changes

• Simulation of flushing/sweeping flows
Upper Baker Power Plant

Site Plan

Puget Sound Energy
Baker River Project
Downstream Passage Facilities
Floating Surface Collector
Installation Site Plan

30% Submittal
Not For Construction
Upper Baker Fish Collection and Handling Facility

• Identify the best location for collection intake and guide net

• Evaluate and develop design modifications to the screens to meet the fisheries design criteria

• Ensure proper approach flow to the flow attraction pumps

• Studies:
  – 3-D CFD model of forebay and fish collection facilities
  – Physical hydraulic model of fish collection facility
Upper Baker - Particle Tracks to Fish Collection Intake

Scenario 1
Units On

Scenario 2
Units Off

Figure
Particle Tracks to the FSC for Scenario 1
Upper Baker River CFD Model Study
Puget Sound Energy, WA

Drawn: L. Khan
Date: 27 Sep 2004
Project: 08729-060

File: D:\projects\BakerLakeCFD\ModelRuns\Scenario1\TPFSC01a.lay
CHECKED: M. Rashid

Figure
Particle Tracks to the FSC for Scenario 2
Upper Baker River CFD Model Study
Puget Sound Energy, WA

Drawn: L. Khan
Date: 27 Sep 2004
Project: 08729-060

File: D:\projects\BakerLakeCFD\ModelRuns\Scenario2\TPFSC02a.lay
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Upper Baker - 3D View of Model Grid of the Fish Net
Upper Baker - Physical Hydraulic Model Studies

- Design and optimization of intake including screens
The Dalles Dam

- Numerical model studies of reservoir flow to aid in fish collection design
- 3-D CFD model of project forebay and powerplant developed and calibrated
- Developed trash rack occlusion design
Sectional View of Powerhouse Intake
The Dalles Dam Turbine Intake J-Block Studies

• Model type: 3-D CFD (STAR-CD)
• Studies:
  – Forebay flow patterns that may influence fish movement
  – Effect of trash rack blockage on flow patterns

Figure 5-4: Grids for the Existing and J-Shaped Blocked Trashrack
Comparison of CFD Model of The Dalles Dam With Data From 1:25 Scale Physical Model
No Blocked Trashrack, Inflow = 7,360 cfs
Centerline Velocity With J-Shaped Blocked Trashrack, Q=7360 cfs

Distance From Powerhouse Intake (ft)

Elevation (ft)

-100 -50 0 50 100

40 60 80 100 120 140 160 180 200

vmag

2.461 2.297 2.133 1.969 1.805 1.641 1.477 1.312 1.148 0.984 0.820 0.656 0.492 0.328 0.164
Bonneville Dam
Cascade Island Fish Ladder

• Model type: 3-D CFD (STAR-CD)
• Studies:
  – Effect of additional structural elements
  – Development of variable-width entrance weir
  – Alternative lamprey entrances
Howard Hanson Fish Passage Facility

- Reservoir provides flood control and water storage for low flow augmentation
- New project purposes include drinking water storage and ecosystem restoration
- Downstream fish passage facility is being designed as part of the project
Howard Hanson Fish Passage Challenges
Existing Passage Conditions

Low-flow outlet:
- Passage delay
- Mortality
- High Velocity
- Pressurized

Outlet Tunnel:
- Passage delay
- Injury potential
- Shallow, high velocity flow
Howard Hanson Fish Passage Facility

Primary Project Goals

• Minimize juvenile passage delay

• Improve juvenile passage survival

• No impact on existing project function
Howard Hanson Proposed Fish Passage Facility

Fish Passage Features – Plan View
Howard Hanson Fish Passage Facility

• Conduct a physical hydraulic model study
• 1:15 scale model of the overall facility
• 1:8 scale model of screen structure
• CFD model used to define upstream model boundary
Howard Hanson Fish Passage Facility

Application of CFD Model to determine physical model boundaries
Physical Modeling Results

• Relatively balanced modular inclined screens
• Evaluated debris loading on the screen
• Determined torque of the fish screens under various operating condition
• Rating curve for the AWC gate
• Rating curve for the flood control tunnel
Howard Hanson Fish Passage- Design Challenges Ahead

- **Latest Construction Estimate:** higher than the congressionally authorized budget.

- **O& M Spending.** Design requires high O&M spending, and budget is very limited.

- **Surface Passage.** New concepts emphasizing true surface passage have emerged recently.
Summary

• Hydraulic models can aid fish passage design
  – Many types of facilities may require modeling
    • Ladders, exclusion screens, fish traps
    • Diversion structures, juvenile migrant passage, screens, outfalls
    • Ancillary systems (bypass conduits, pumps)

• Physical & computational tools available
  – Selection of model type depends on problem being addressed
  – Range from simple to complex

• Useful tool for evaluating design performance before construction and stakeholder buy-in

• Part of an iterative process.
  – Design is not necessarily complete when hydraulic criteria are met.
Questions?

What is a fish dewatering facility?
Presenters

• Mizan Rashid, PhD, PE, D.WRE
  – PhD (Civil Engineering), Washington State University
  – 22 years of experience
  – Specialization:
    • Numerical modeling
    • CFD modeling
    • Sedimentation modeling
    • Physical modeling
Presenters

• Daniel Katz, PE
  – Chief, Hydraulic Engineering Section, Seattle District Corps of Engineers
  – 22 years of experience
  – Specialization:
    • Design and operation of hydraulic structures
    • Application of hydraulic modeling