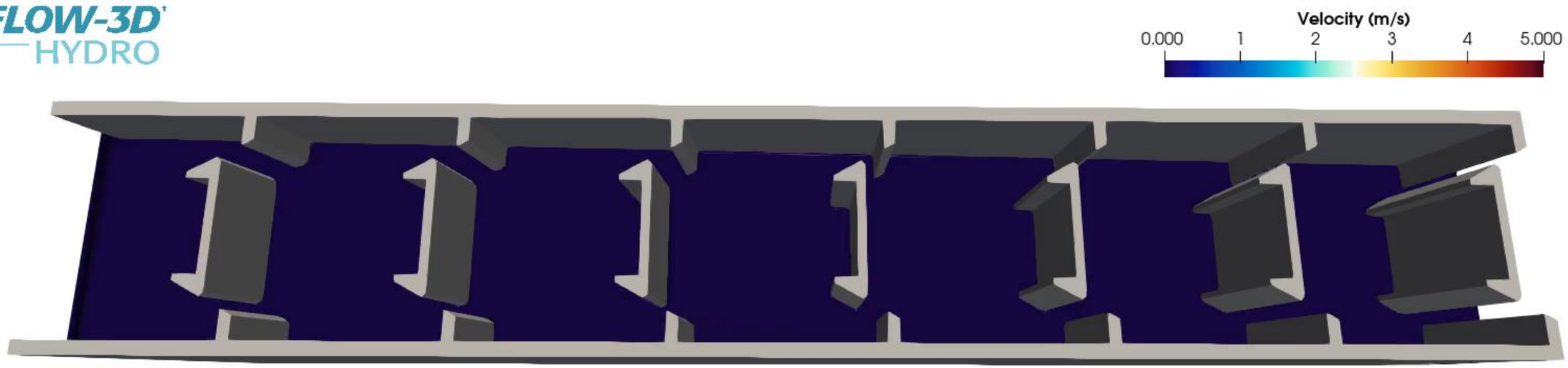
3D Hydraulic Modelling for Fish Passages



Australian Water School Webinar: Something's Fishy

12 May 2021

Introductions

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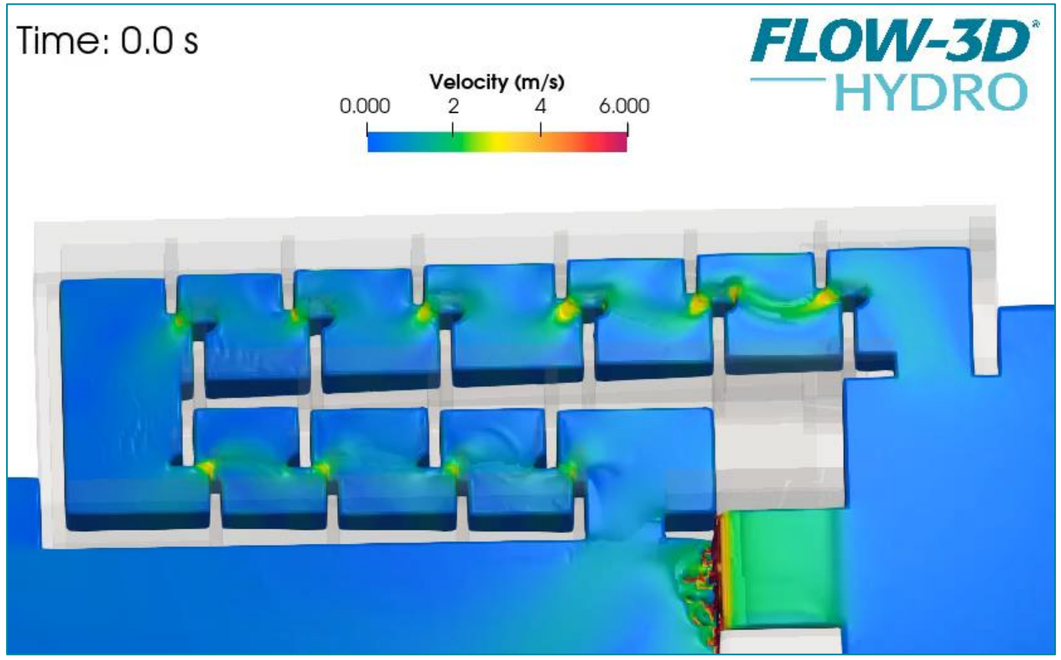
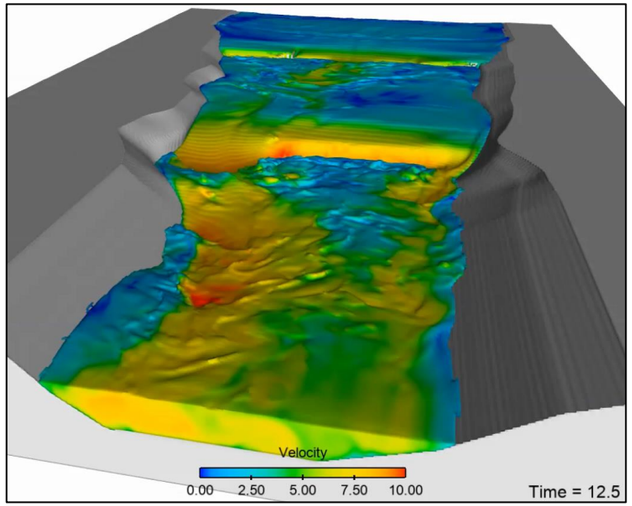
Agenda

1. Introduction to Flow Science & FLOW-3D
2. How is 3D CFD different from 1D/2D models?
3. Fishway hydraulic considerations
4. Examples of 3D CFD fishway models



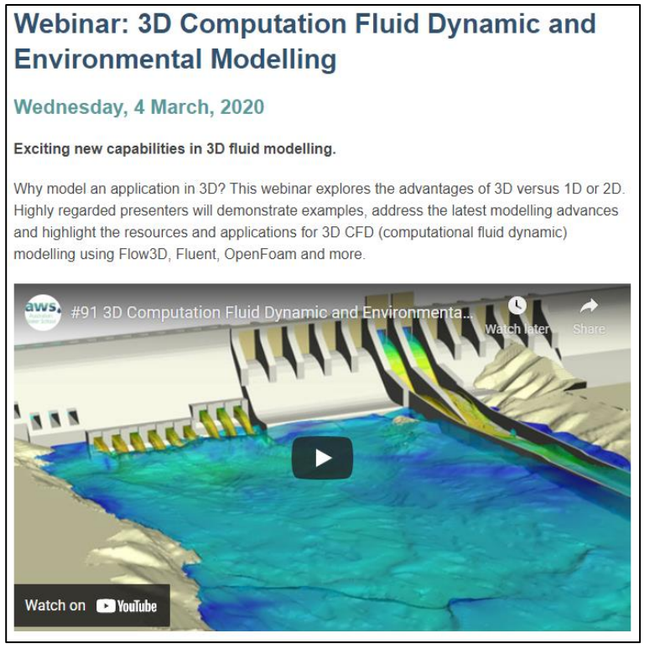
Flow Science & *FLOW-3D*

- Flow Science, Inc.
  - Developers of the 3D CFD software ***FLOW-3D***
- Flow Science Australasia Pty Ltd
  - Based in Brisbane, Australia covering ***FLOW-3D*** customers in Australia & New Zealand
- ***FLOW-3D* HYDRO**
  - User interface tailored to civil and environmental engineering hydraulics
  - Industry leading 3D free surface modelling capabilities
  - Simple meshing and geometry handling
  - Advanced engineering tool perfect for modelling complex hydraulics (including fishways!)



For More Detail…

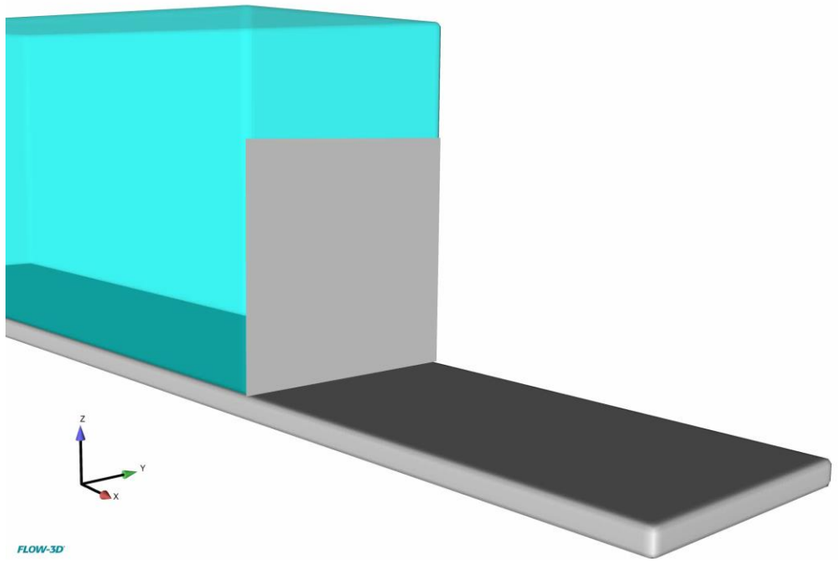
- Australian Water School: CFD Webinar (March 2020)
  - https://awschool.com.au/resources/webinar-3d-computation-fluid-dynamic-and-environmental-modelling/

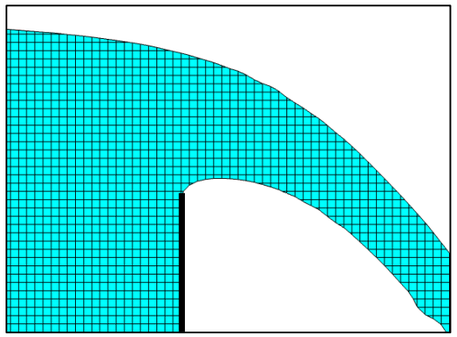


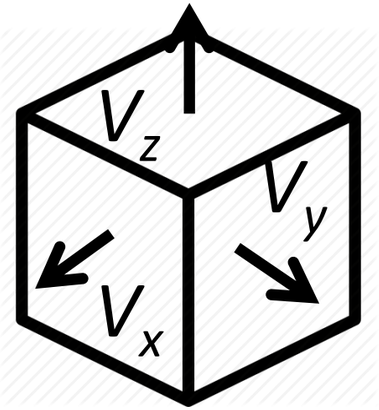
- ***FLOW-3D* HYDRO** Webinars
  - On-demand webinars:
    - https://www.flow3d.com/resources/webinars/
  - 2021 Technical Webinar Series
    - https://www.flow3d.com/products/flow-3d-hydro/webinars/

How is 3D CFD different from 1D/2D?

3 Dimensional







- Solution to the general 3D Navier-Stokes equations
  - Implications
    - **No assumptions** in regard to depth averaging
    - Capable of simulating complex hydraulics conditions
    - Applications to same class of problems reserved for physical models
  - Applications
    - Hydraulic structures
    - Variable density
    - Buoyant flows
    - Many more…!

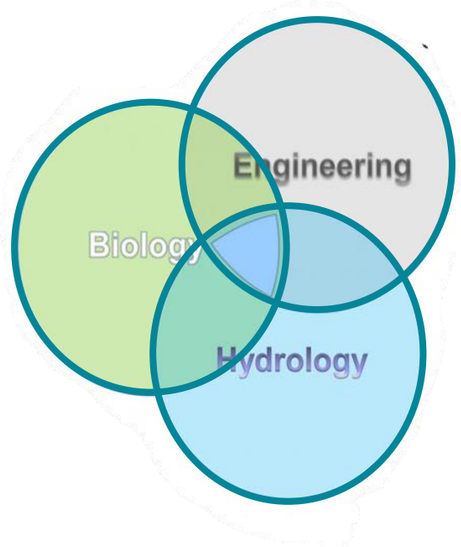
Fish Passage Hydraulic Considerations

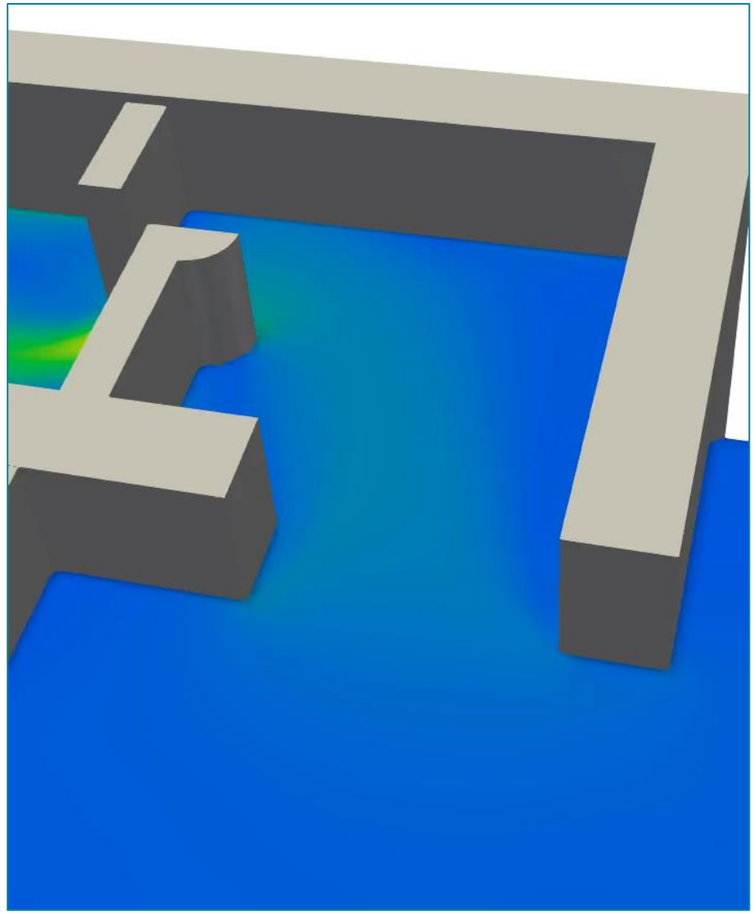
- General fishway design goal:
  - Create a structure that is transparent to the fish to enable passage through a waterway barrier (culvert, weir, dam)
- Multi-disciplinary design challenge:

Biology
- Swimming Ability
  - Speed
  - Leaping
- Behavioral
  - Motivation
  - Effort
  - Natural "cues"
- Habitat Quality
- Physiological Effects
- Passage Time
  - Energy Expenditure
  - Migration Delays
  - Temperature
  - Chemical

Hydrology
- Flow Regime
  - Natural
  - Altered
  - Climate Change

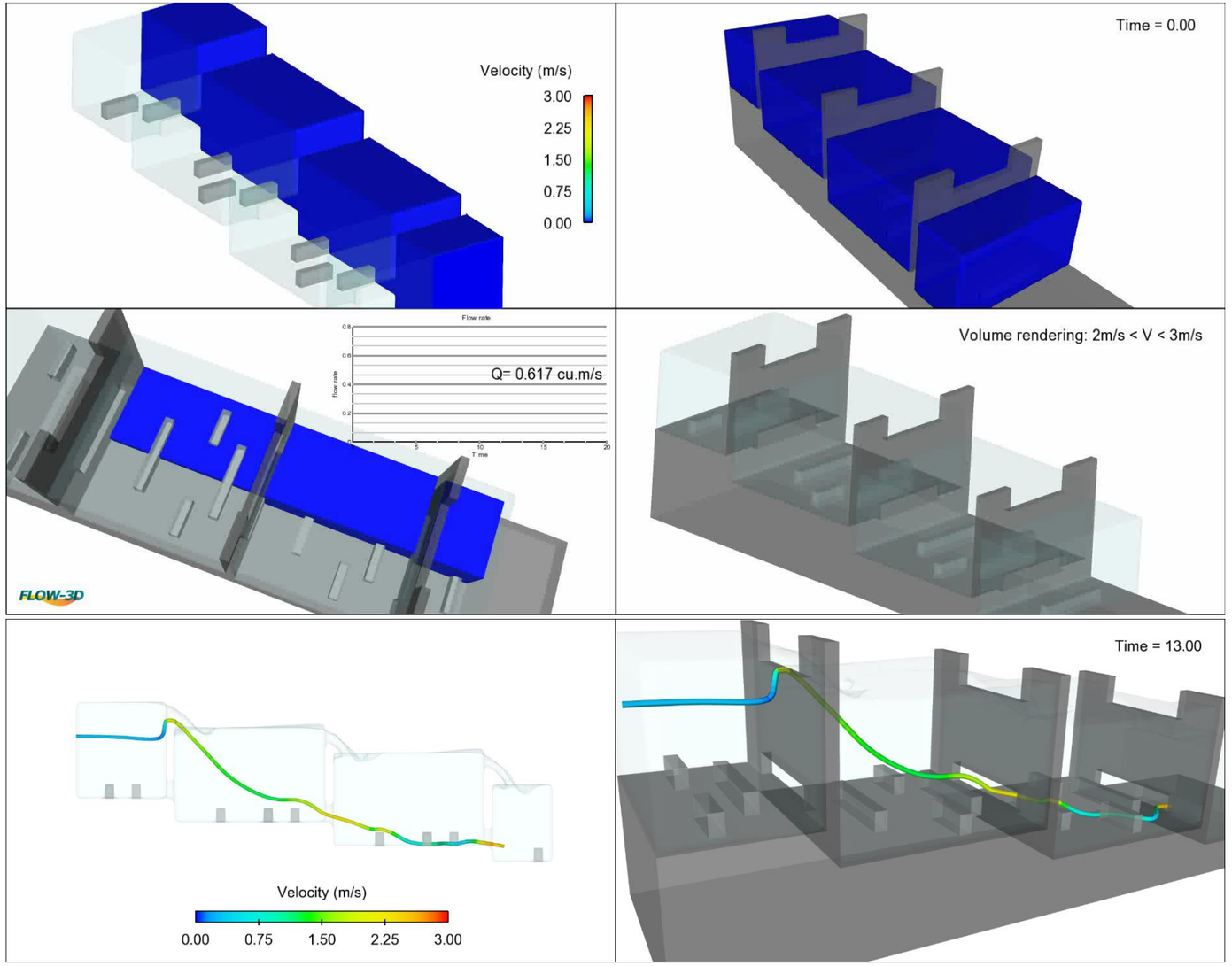
Engineering
- Structure Design
  - Velocity
  - Hydraulic drop
  - Flow Depth
  - Turbulence



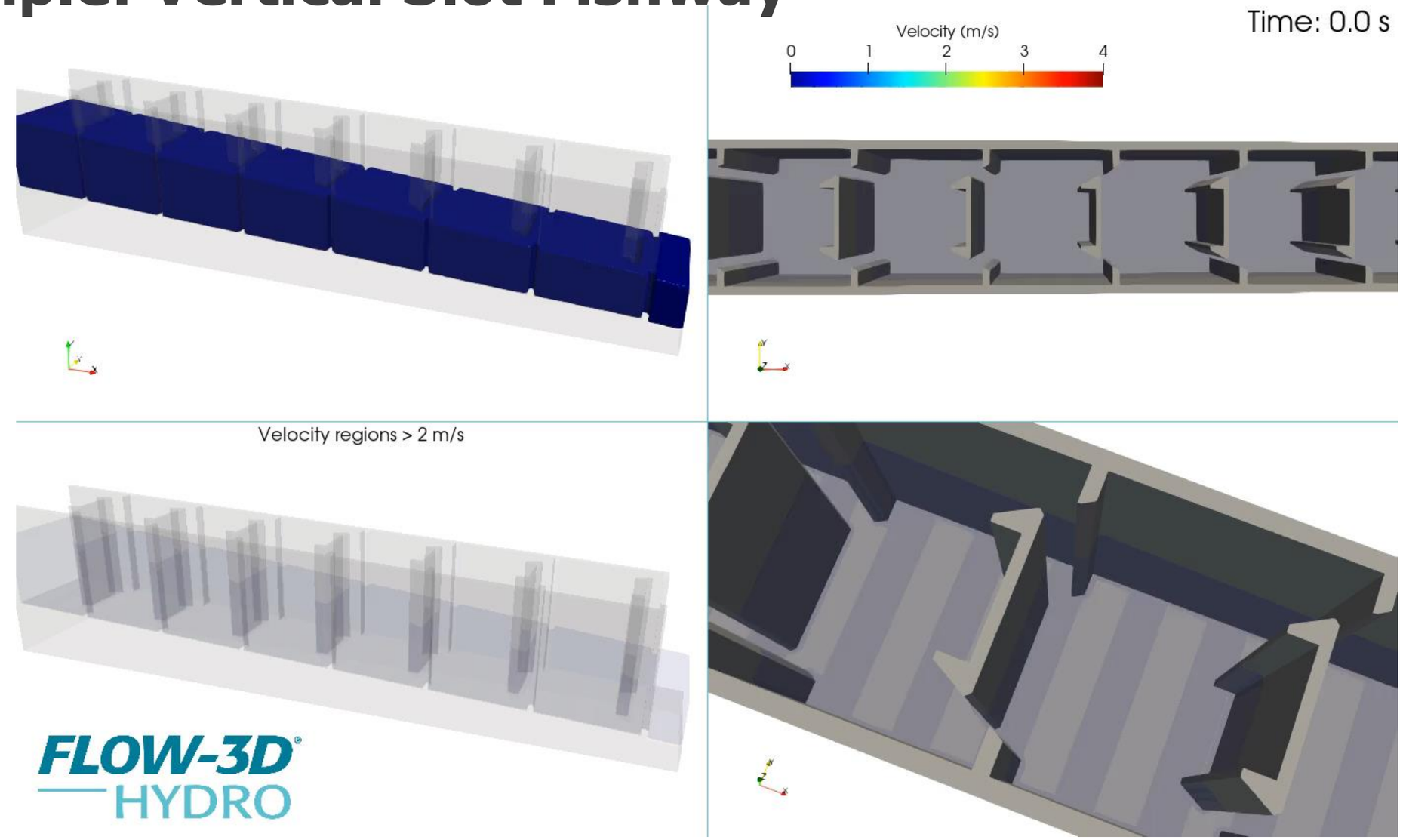


3D Hydraulic Modelling of Fishways

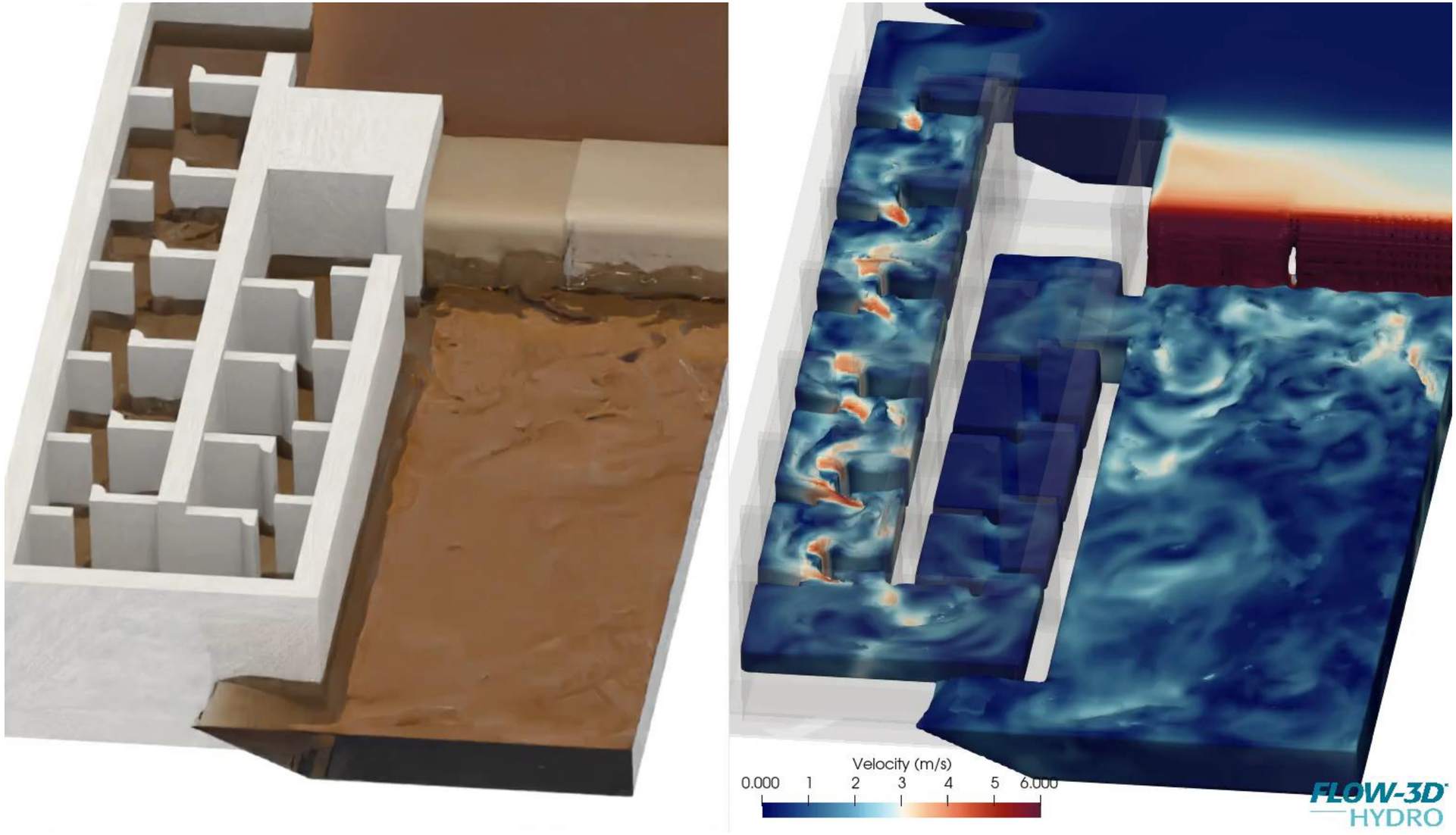
- CFD helps you assess the detailed fishway hydraulics
- Key simulation outputs
  - Detailed velocity field
  - Drop heights
  - Water elevation profiles
  - Turbulence characteristics
  - Entrance/exit (attraction flows)
- Ability to analyse hydraulics at the scale of a fish
  - Data available at every cell in the 3D model
- Efficiently model design iterations and various design flows



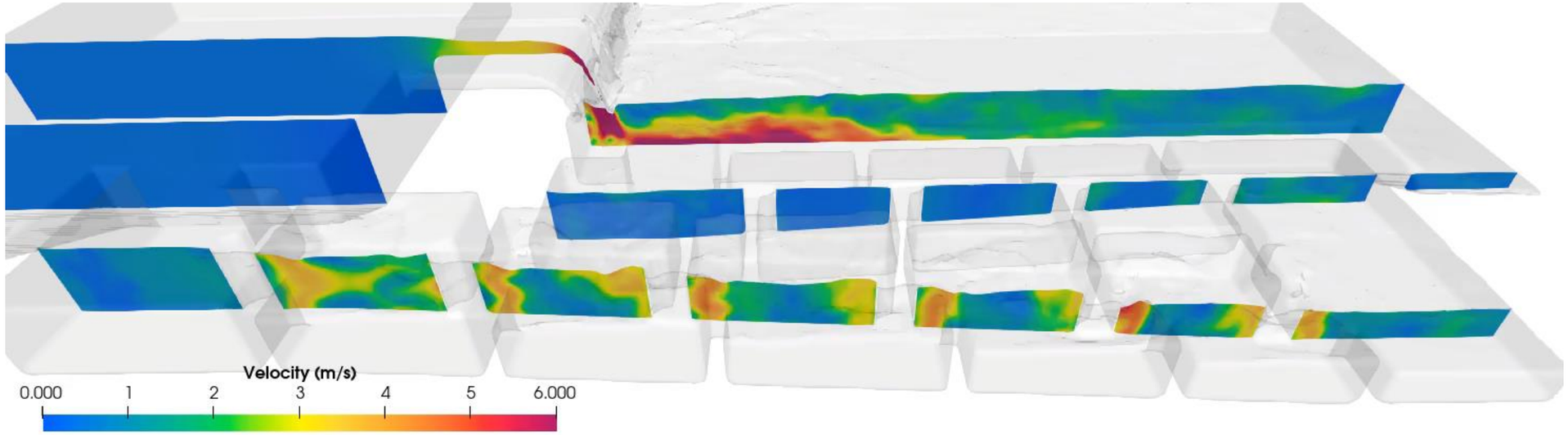
Example: Vertical Slot Fishway

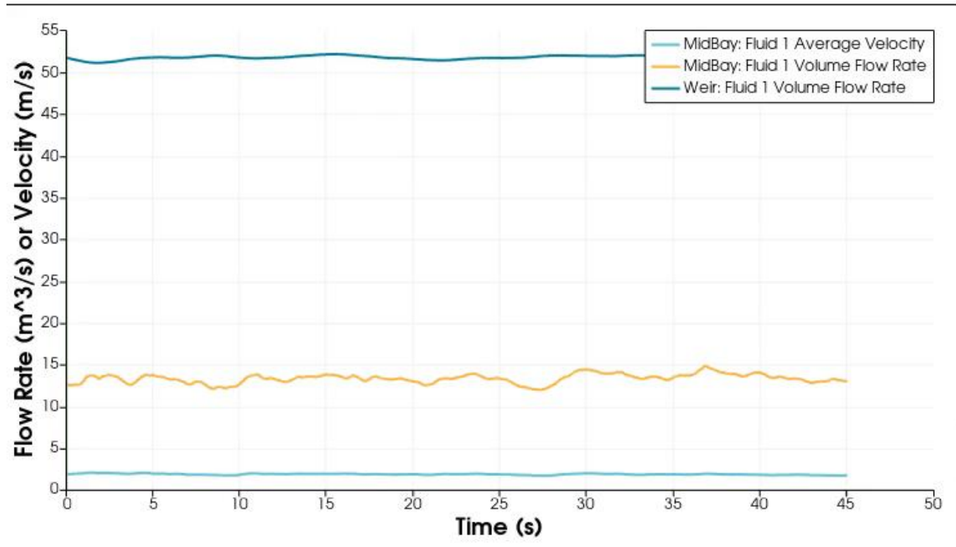


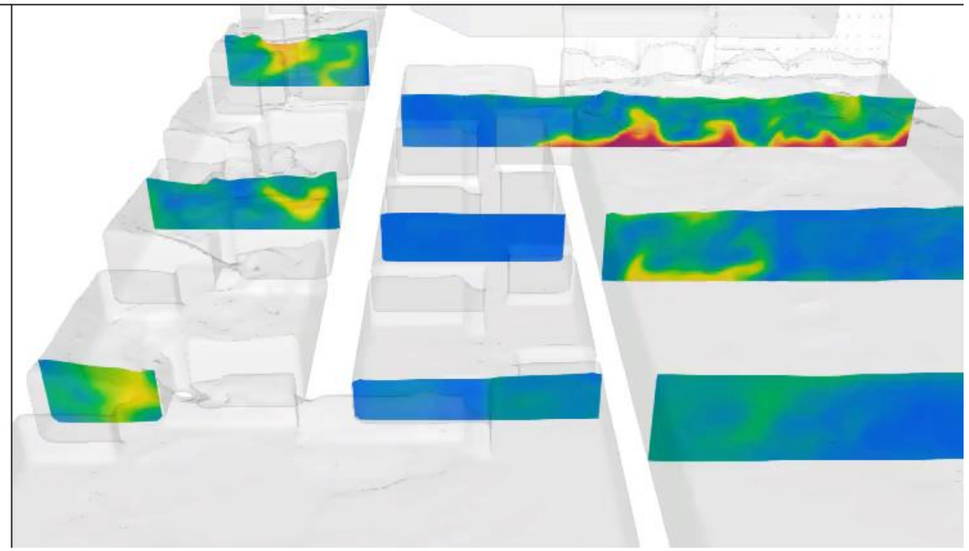
Example: Vertical Slot Fishway at a Weir



Example: Vertical Slot Fishway at a Weir

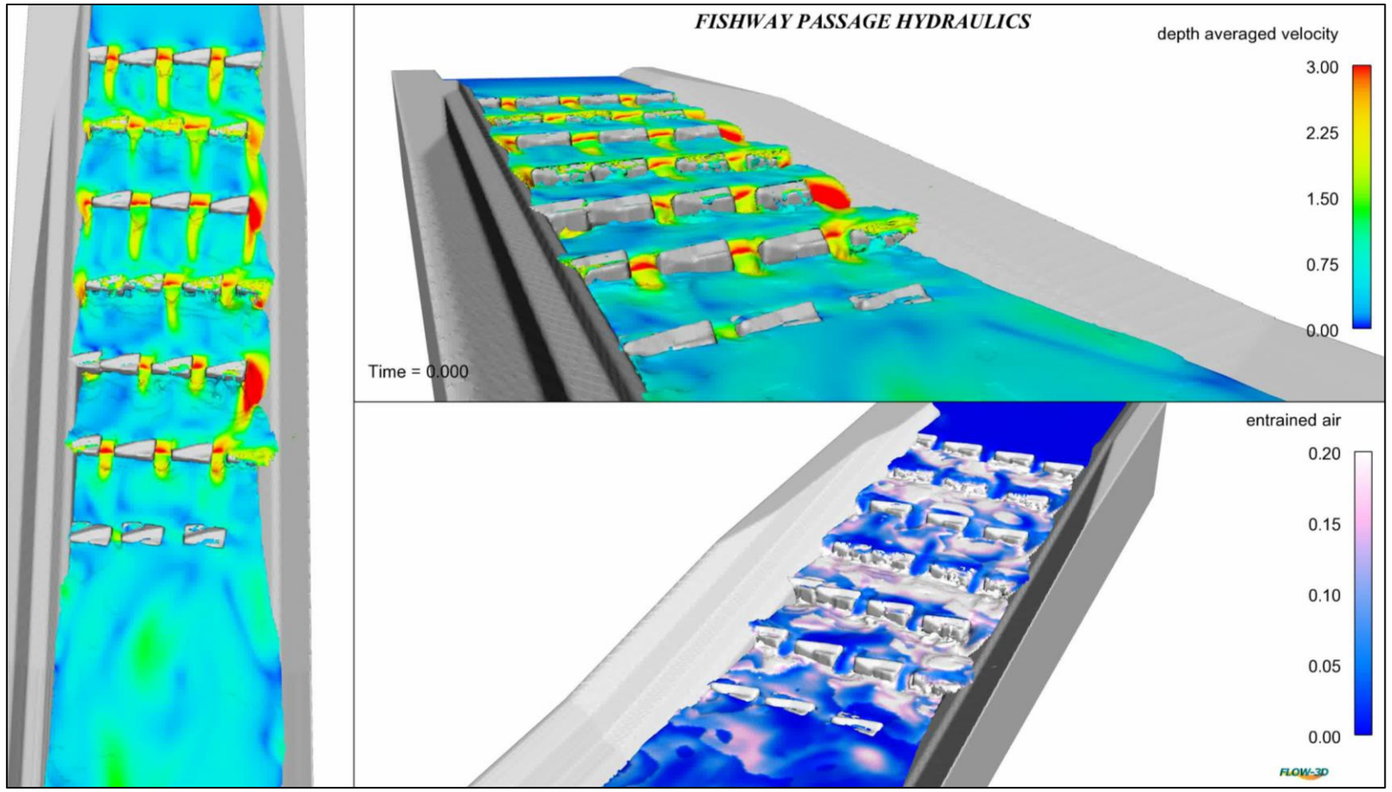






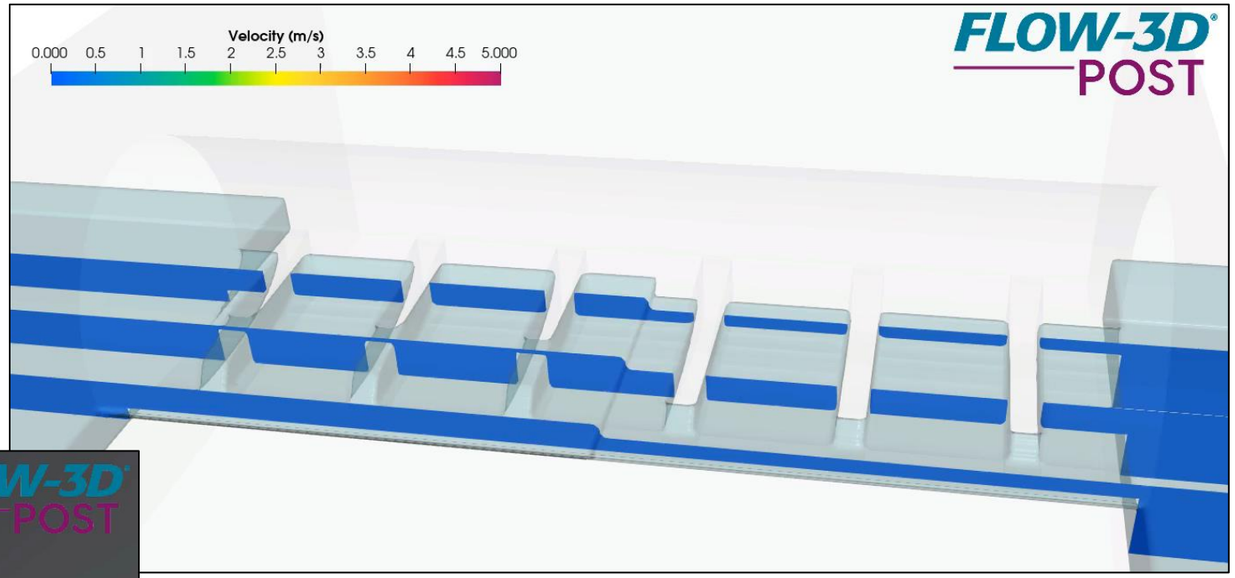
Example: Natural Fishway

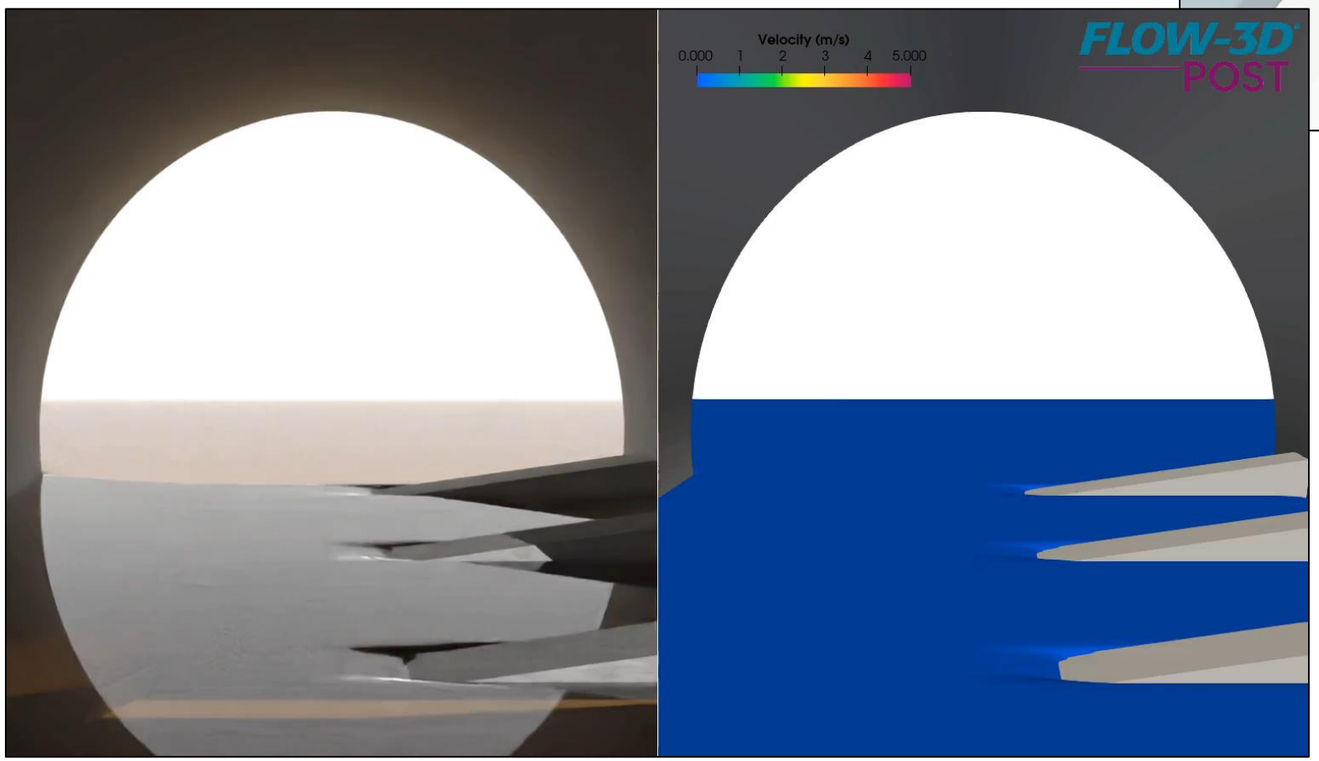
- Complex 3D geometry
  - LiDAR scan
  - 3D CAD of individual rocks
- CFD captures detailed flow around these complex roughness elements



Example: Culvert w/ Baffles

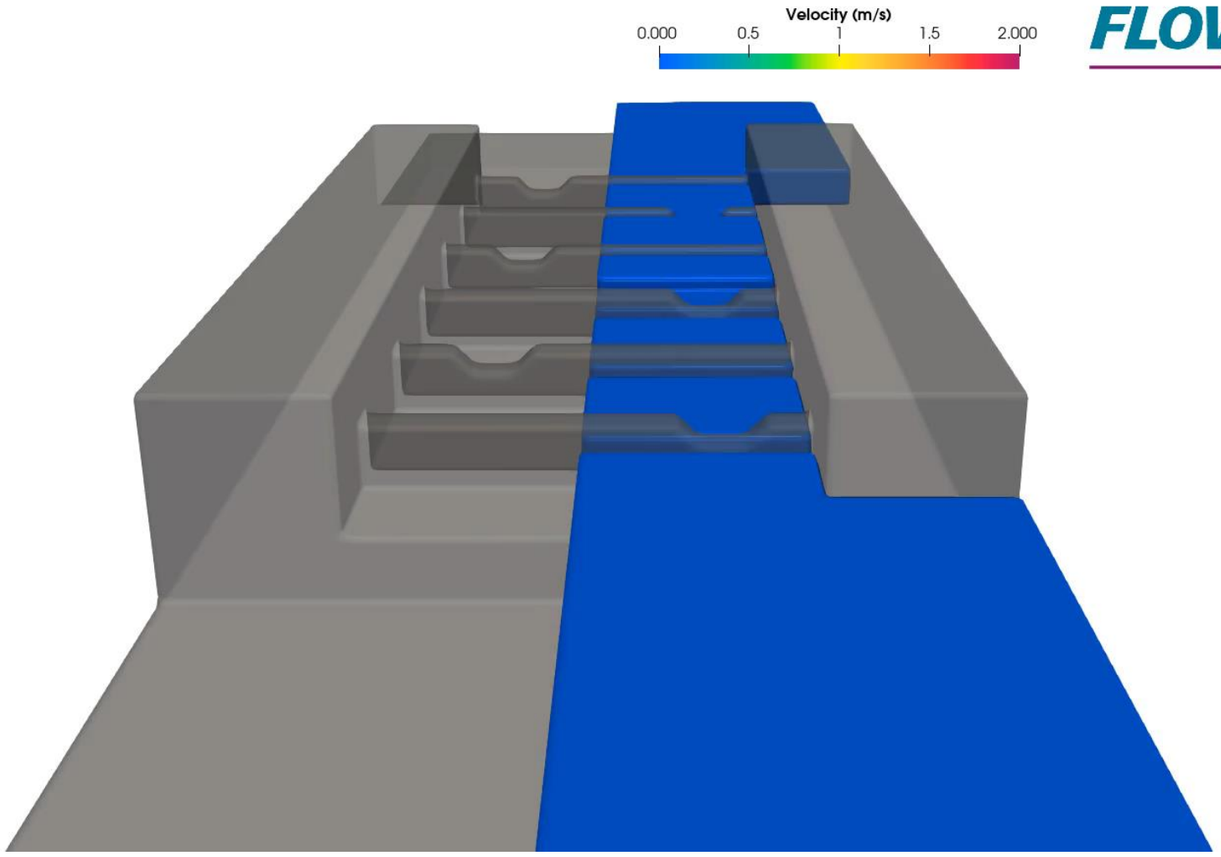
- Key simulation outputs
  - Detailed velocity field
  - Drop heights
  - Water elevation & velocity profiles





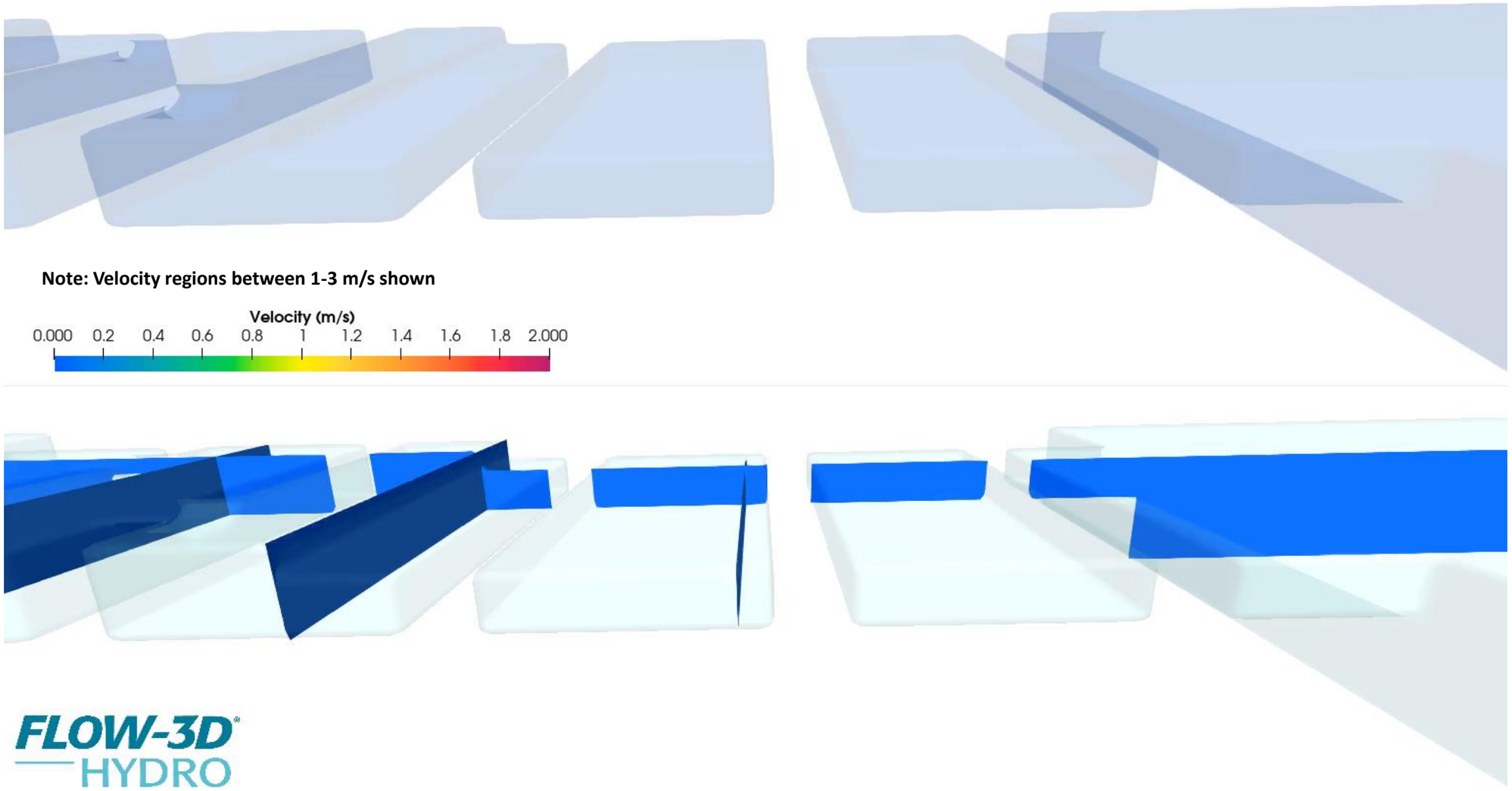
Fish passage in Gray, ME, USA by C.L.H. & Son, Inc.

Example: Culvert w/ Notched Baffles



Photos from The Langley Concrete Group (Chilliwack, BC, Canada)

Example: Culvert w/ Notched Baffles



Key Takeaways

- Fishways involve detailed hydraulic design criteria and complex 3D hydraulics.
- CFD modelling is an advanced engineering tool to help you assess fishway hydraulics.
- Quickly examine various designs, flow conditions, and design optmisations.
- For relatively minimal effort in the model setup, you obtain a wealth of insight.

3D CFD modelling is more accessible than you think!

- For reference, I'm running ***FLOW-3D* HYDRO** on a 6-core (12-thread) laptop.
- Many of these fishway video examples were created in the past 3-4 days
  - Geometry creation → model setup → simulation → post-processing = ~1 day per example
- ***FLOW-3D* CLOUD** can provide extra computing power when needed.