Using Hydrodynamic Modeling and Fish Passage Windows to Evaluate Potential Barriers in River Systems Under Changing Climate Regimes

Matt Blank, Ph.D.
Mike Cox, P.E.
OASIS Environmental, Inc.

oasis | ENVIRONMENTAL

Overview of Talk

- Background
  - Aquatic Barriers
  - Factors Affecting Passage
  - Assessment Techniques
- Hydrodynamic Modeling and Passage Windows
- Climate Change Scenario Evaluation

Aquatic Barriers in Lower 48 and Alaska

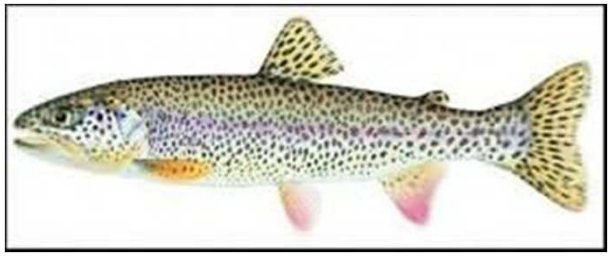
- Estimated 1.4 million stream-road crossings in U.S. (U.S. Fish and Wildlife, National Fish Passage Program, unpublished data).
- 2.5 million aquatic barriers in U.S. by culverts, dams and canals (National Fish Passage Summit, 2006).
- 10,000 culverts on fish bearing streams on federal lands in Oregon and Washington: 2,600 barriers, $375 million cost to correct problem (USGAS, 2001).
- 30 of 38 culverts inventoried in the Hoonah Ranger District in Southeast Alaska were barriers to juvenile salmonids (Riley, 2003).

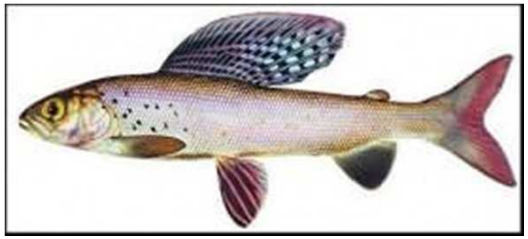
Physical Factors Influencing Fish Passage

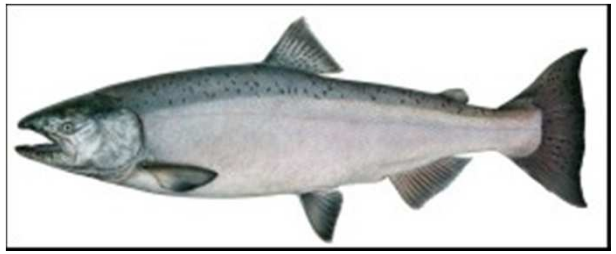
- High water velocity
  - excessive turbulence
- Shallow water depth
- Outlet drop
  - pool depth/leap height ratio
  - jump location
  - air entrainment
- Debris/sediment blockage

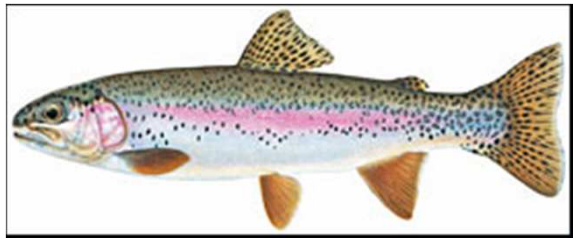
Fish Locomotion

- Species and size
- Temperature
- Dissolved oxygen
- Motivation
- Gender
- Physical condition
- Disease
- Sexual maturity



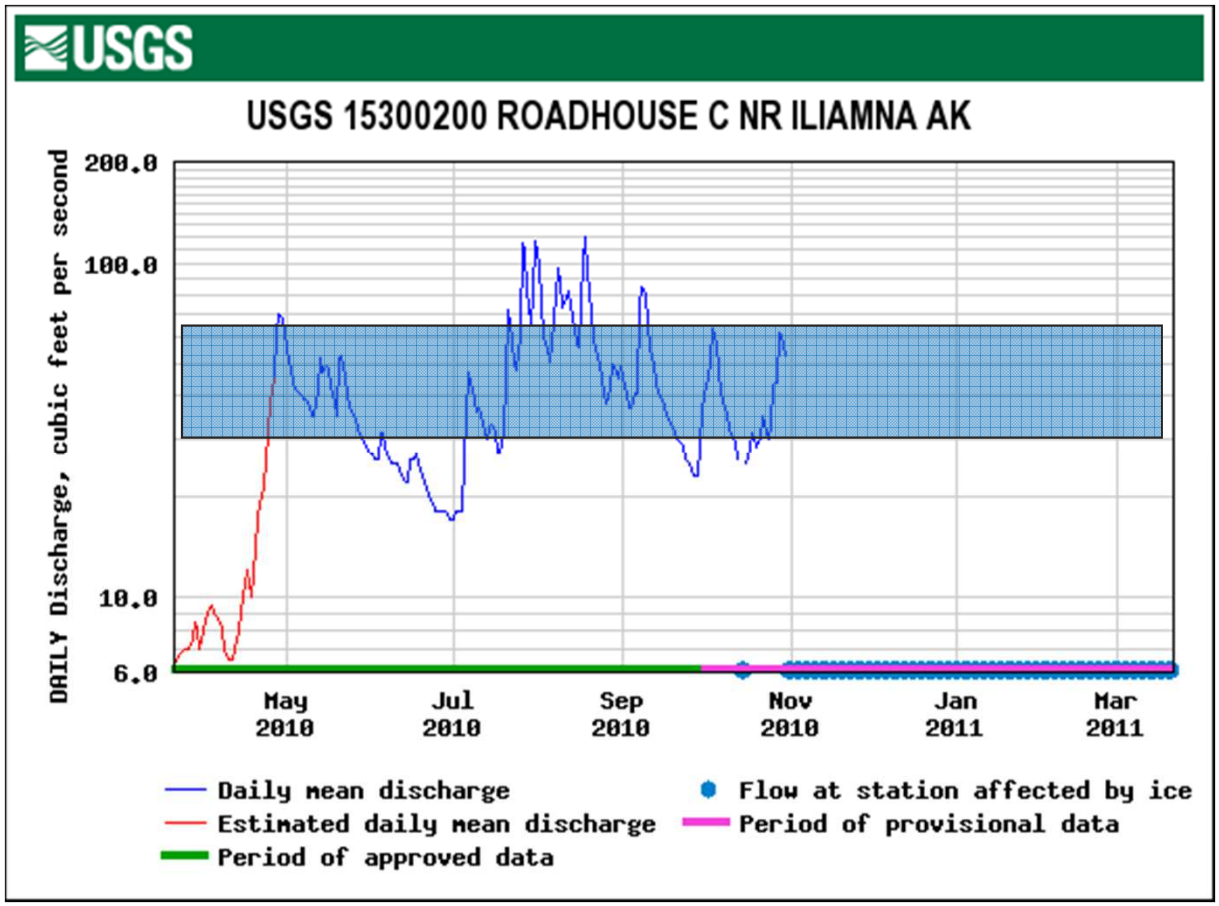






Types of Barriers and Passage Windows

- Total Barrier
- Partial Barrier
- Temporal Barrier
- No Barrier



Assessment Techniques

- Direct Approach Field experiment that directly measures fish movement.

•Mark-recapture study

•PIT tagging study

•Radio telemetry

•Visual observations

- Indirect Approach Approximate movement potential by comparisons.

•Regional screen/matrix

•Hydraulic/Hydrodynamic modeling

•Comparisons between upstream vs. downstream fish population characteristics

•Genetic differences

Assessment Techniques

Direct Approach Field experiment that directly measures fish movement.

- Mark-recapture study
- PIT tagging study
- Radio telemetry
- Visual observations

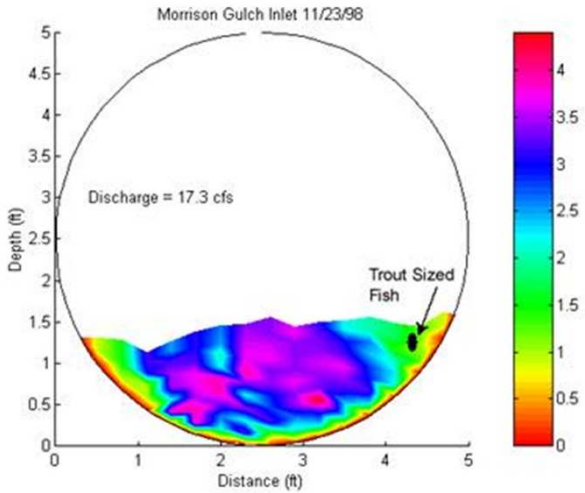
Indirect Approach Approximate movement potential by comparisons .

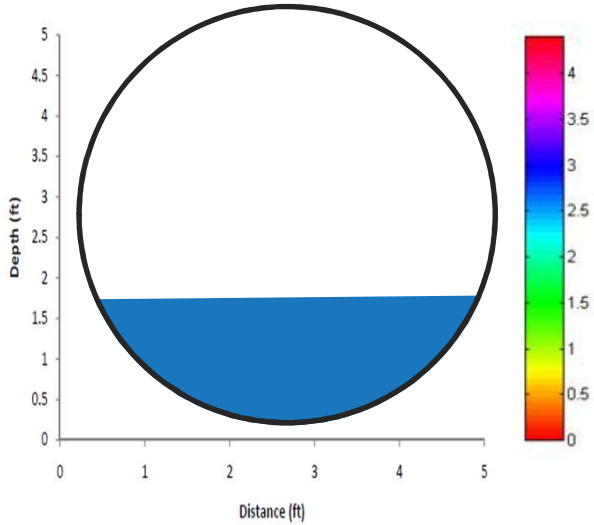
- Regional screen/matrix
- Hydraulic/Hydrodynamic modeling
- Comparisons between upstream vs. downstream fish population characteristics
- Genetic differences

Hydrodynamic Model Development

1) Developed a Computational Fluid Dynamics model using ANSYS CFX to analyze 3-Dimensional Flow through a Barrier.

2) Measured 3-D flow field using ADV.

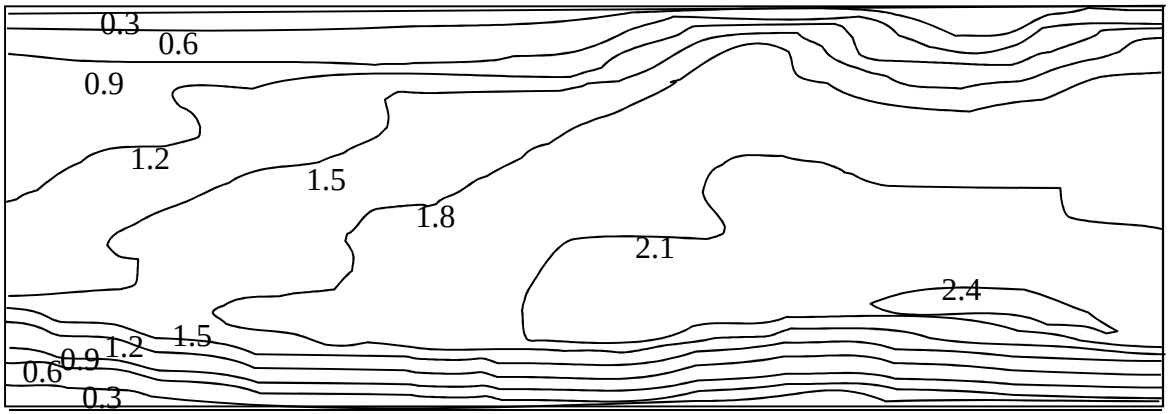




Cross section view of longitudinal velocity (x-velocity) in culvert (Powers, 1998)

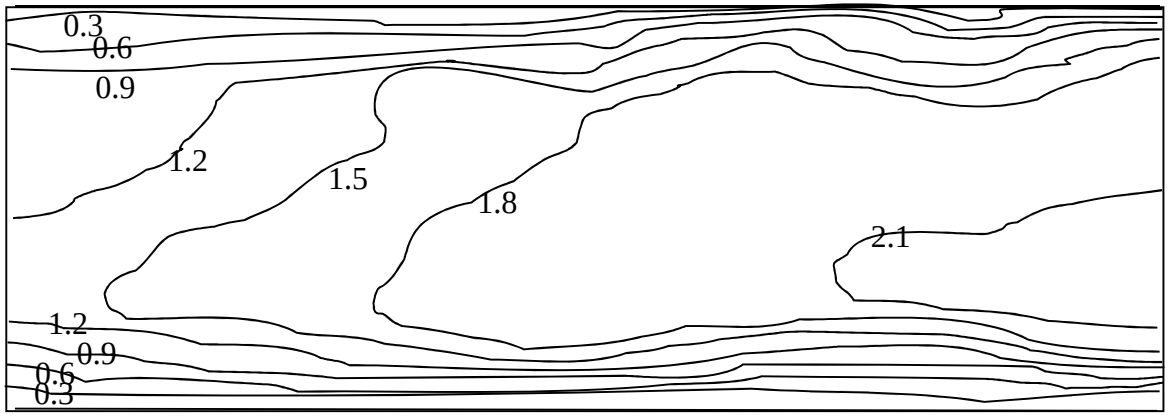
Model Validation

Observed Velocity

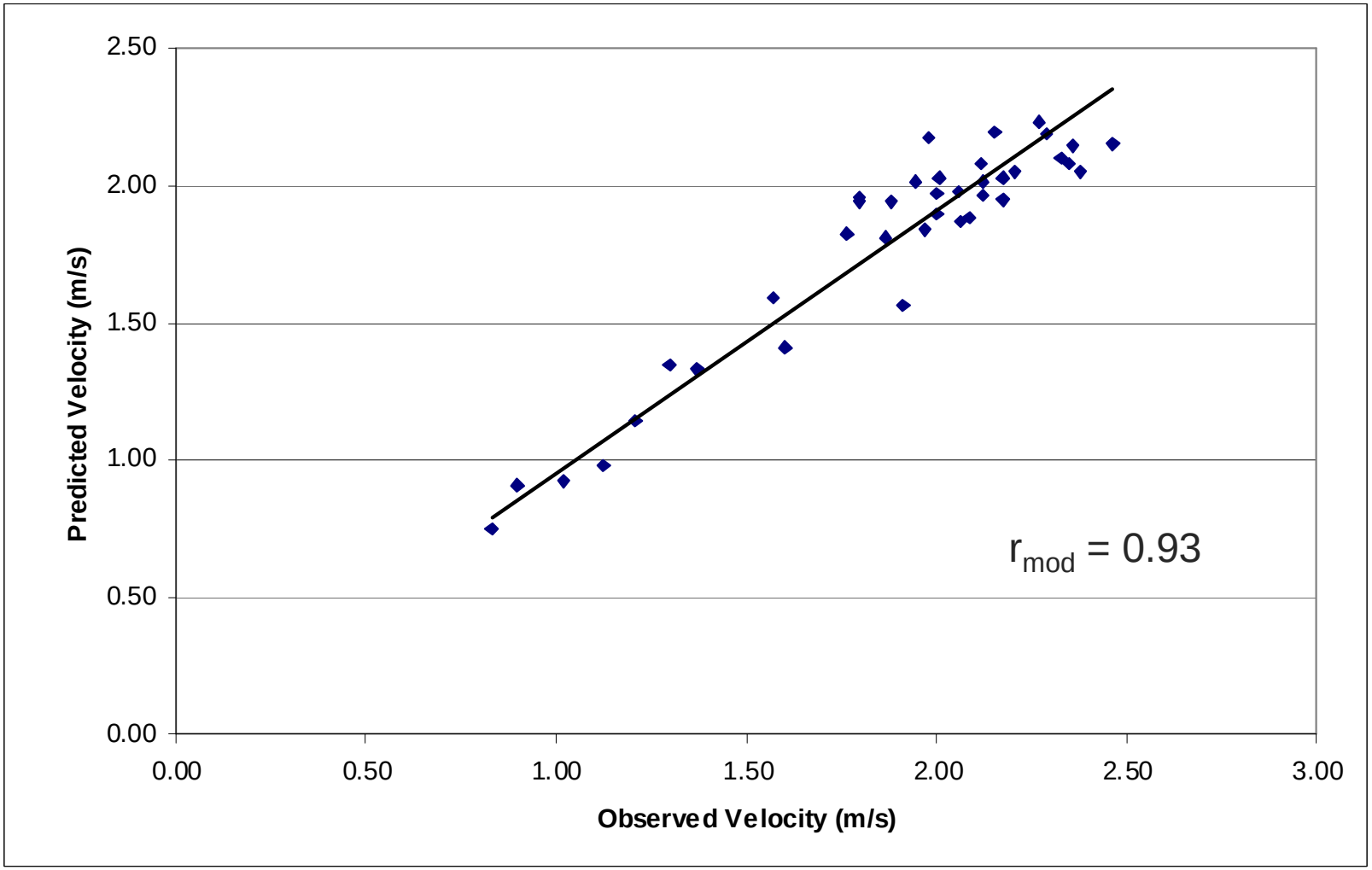


Flow

Predicted Velocity



Model Validation



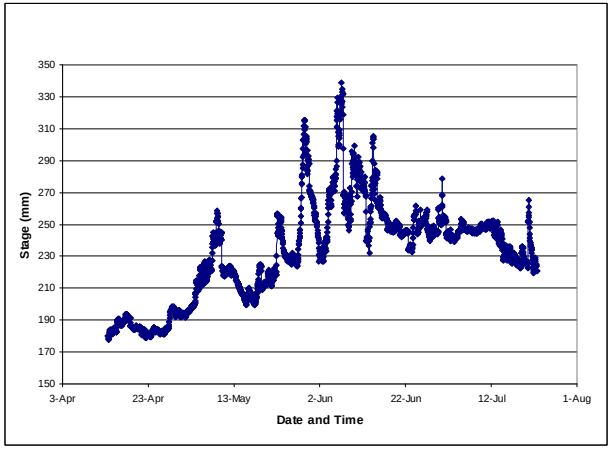
Energy Paths

Select flow rate of interest.

Model velocity through barrier using ANSYS-CFX.

Export velocity field on plane of interest in structure from ANYS-CFX.

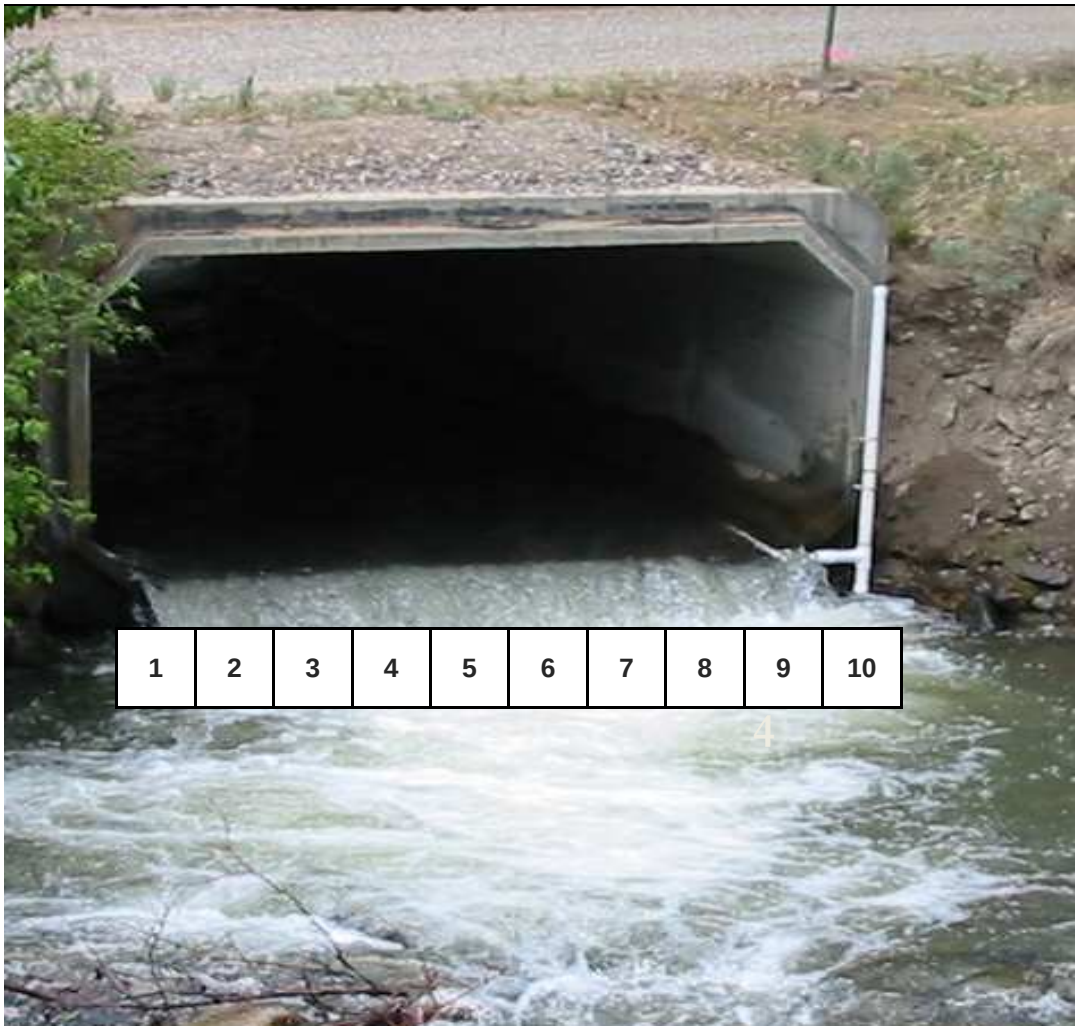
Calculate energy paths using Microsoft Excel with VBA code.



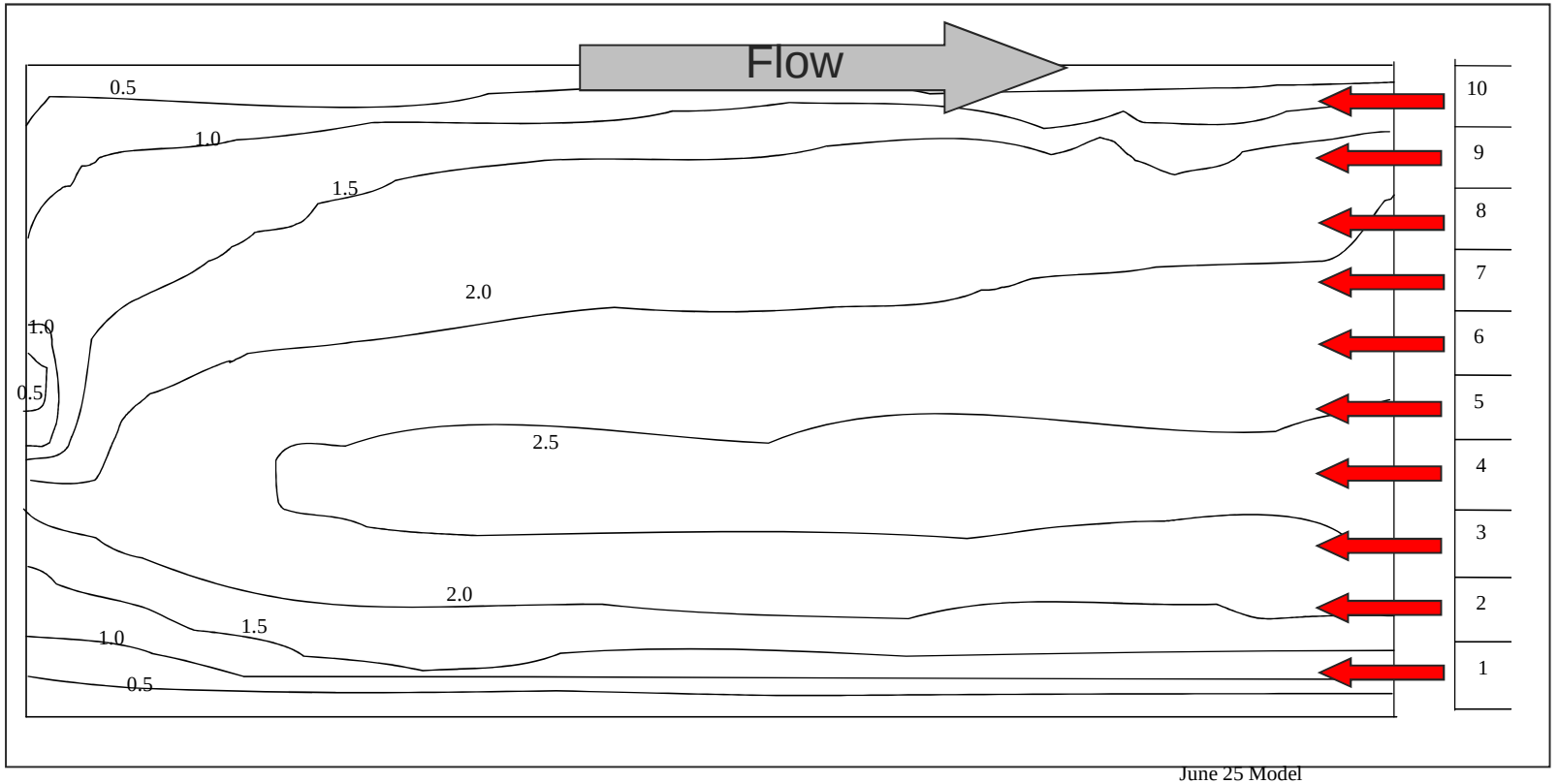
$$E = \int_0^s |F| ds$$

$$F = 0.5 C_d \rho A_s (V - V_f)^2$$

Energy Paths



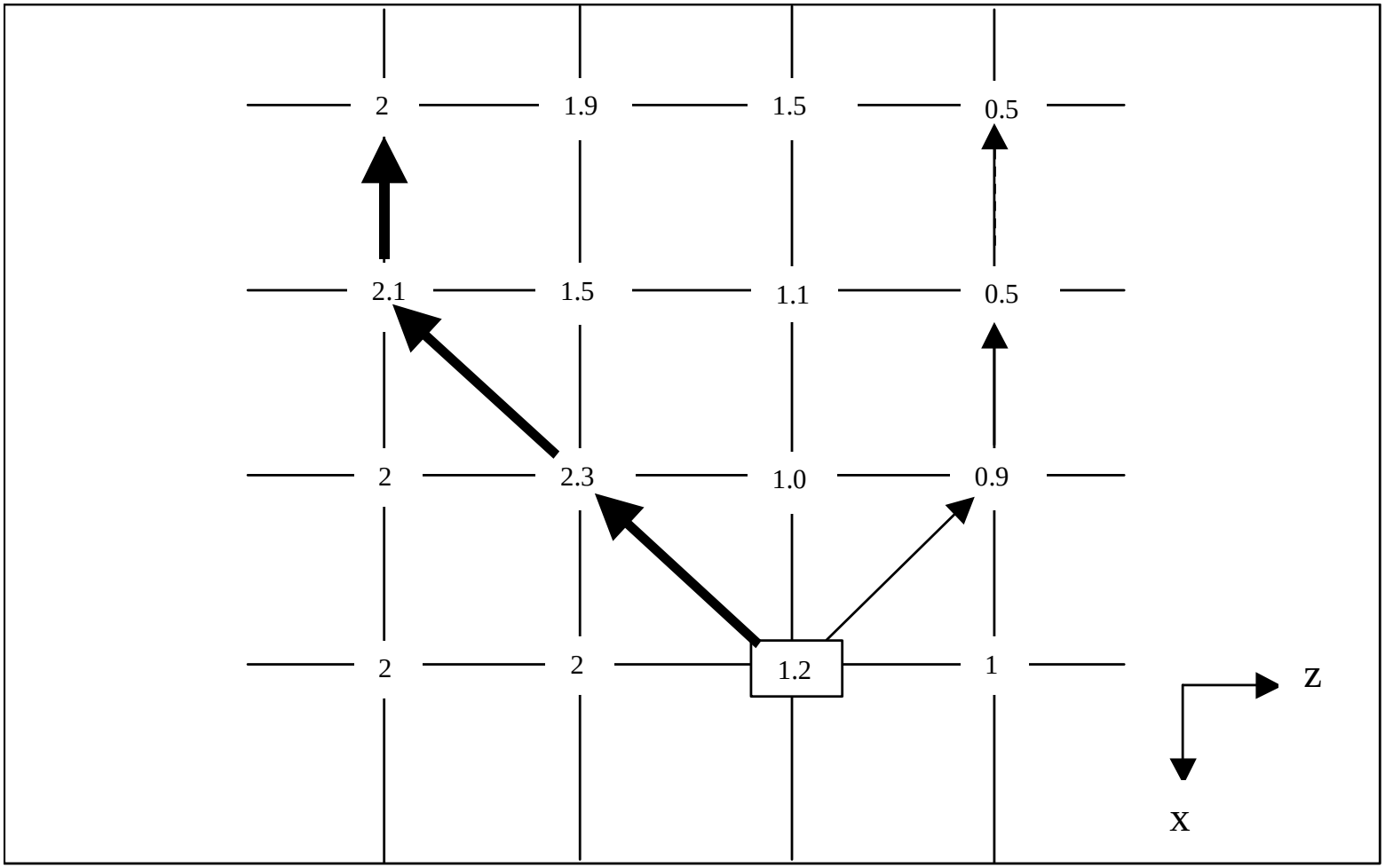
3-D Assessment



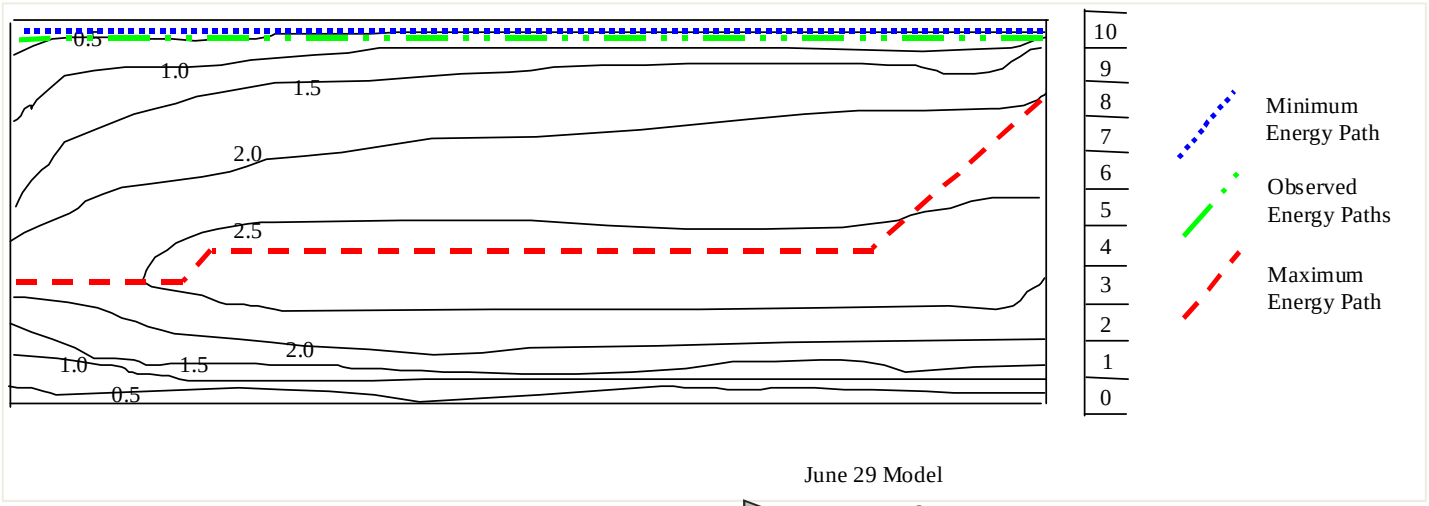
June 25 Model

- Estimate 3-D velocity field.
- Find minimum energy path for each starting point.
- Estimate passage using velocities along each path.

Energy Paths

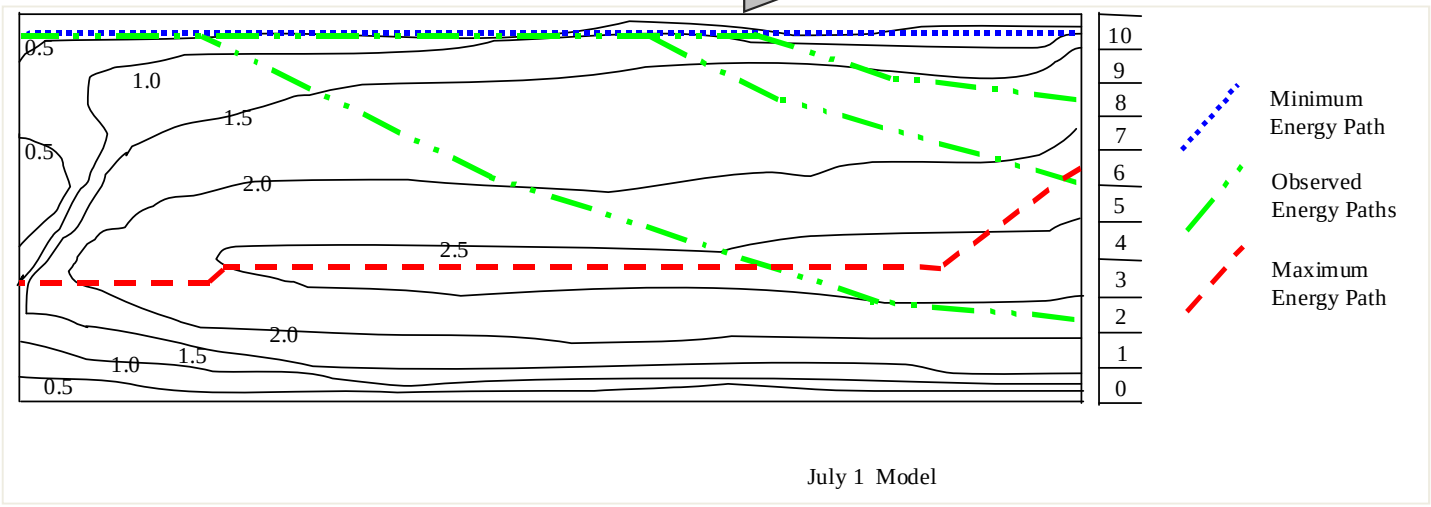


Energy Paths



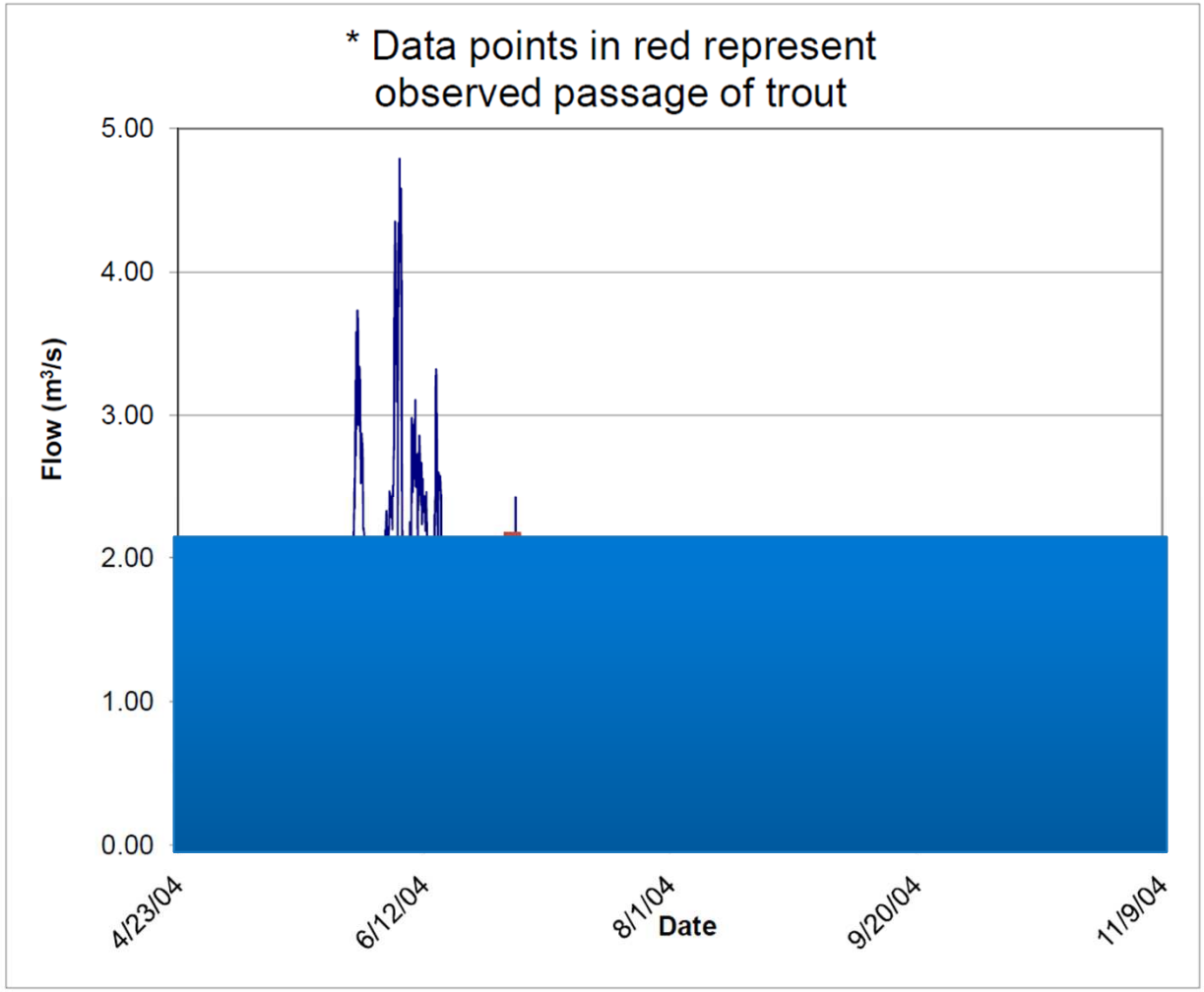
June 29 Model

Flow



July 1 Model

Comparison to Observed Data



15% of time – barrier

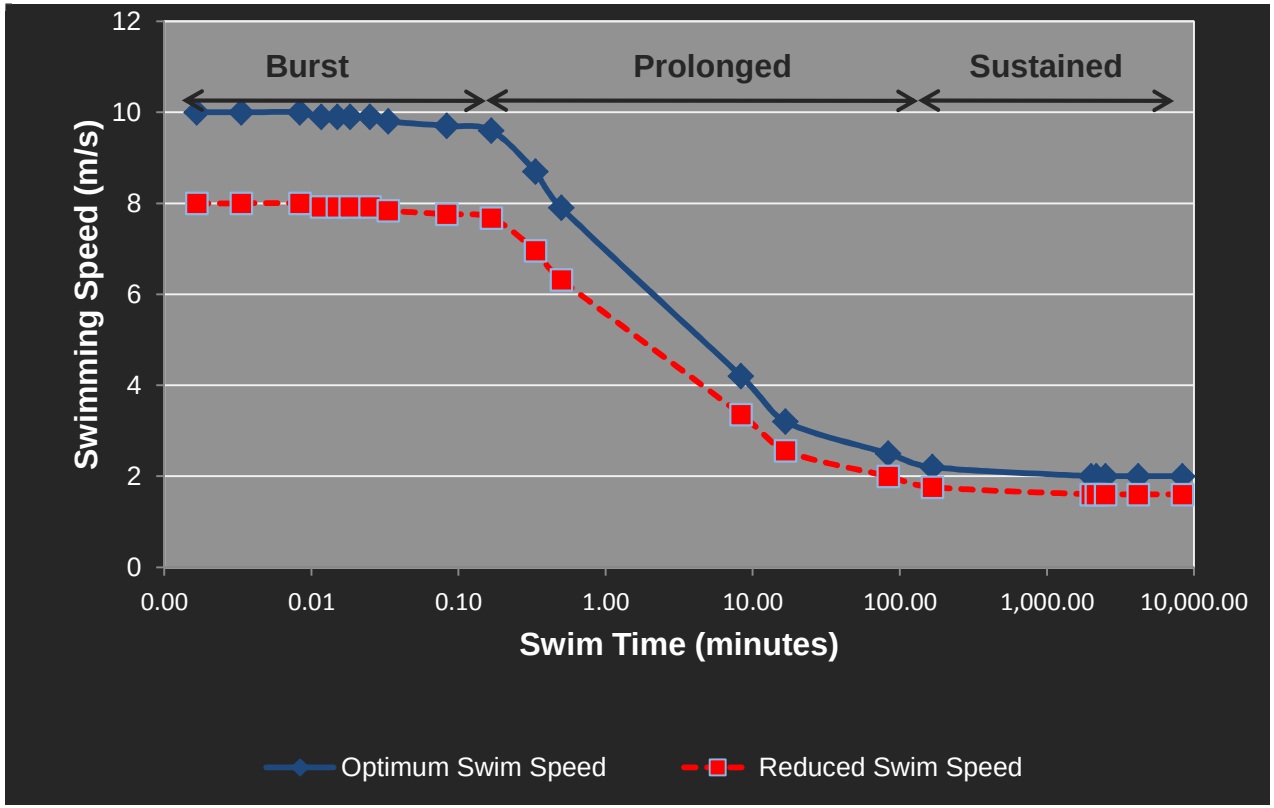
85% of time - passable

Climate Change Scenario

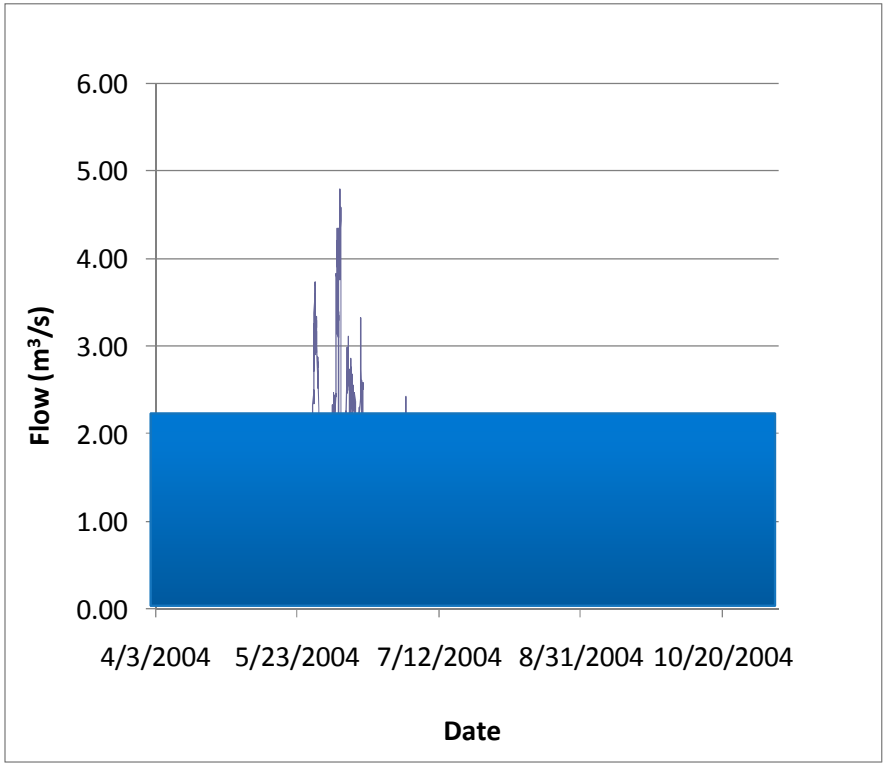
Predicted Hydrologic Alterations: Increased temperatures resulting in warmer water, changes in timing and magnitude of precipitation and runoff.

Scenario: Climate change results in warmer water (i.e. reduced swimming performance).

Question: How could this affect passage windows and fisheries management priorities?

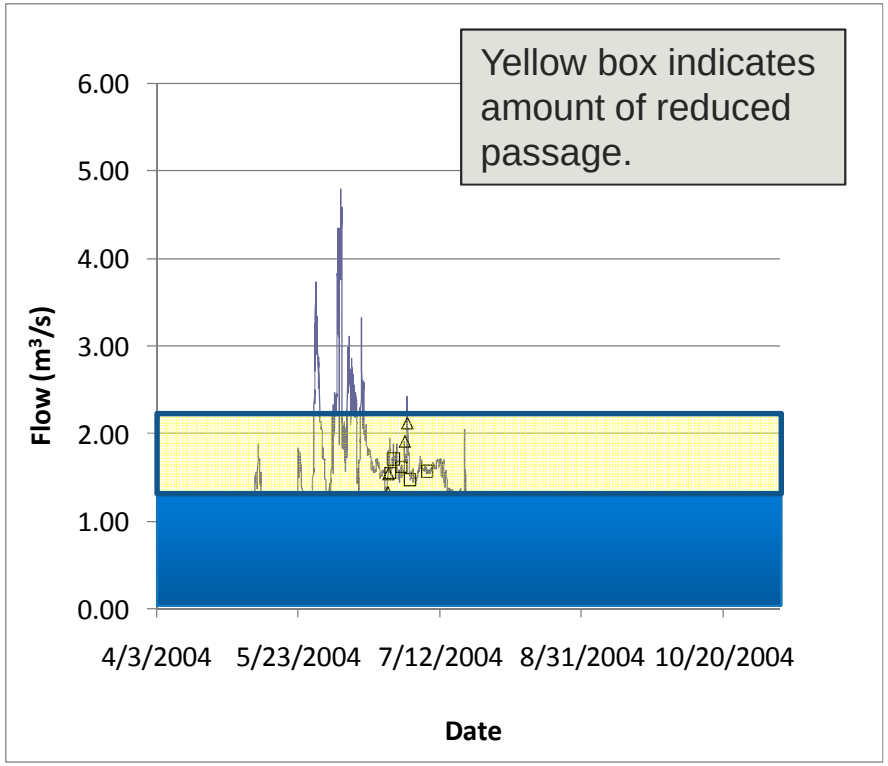


Climate Change Scenario: Passage Window



15% of time – barrier

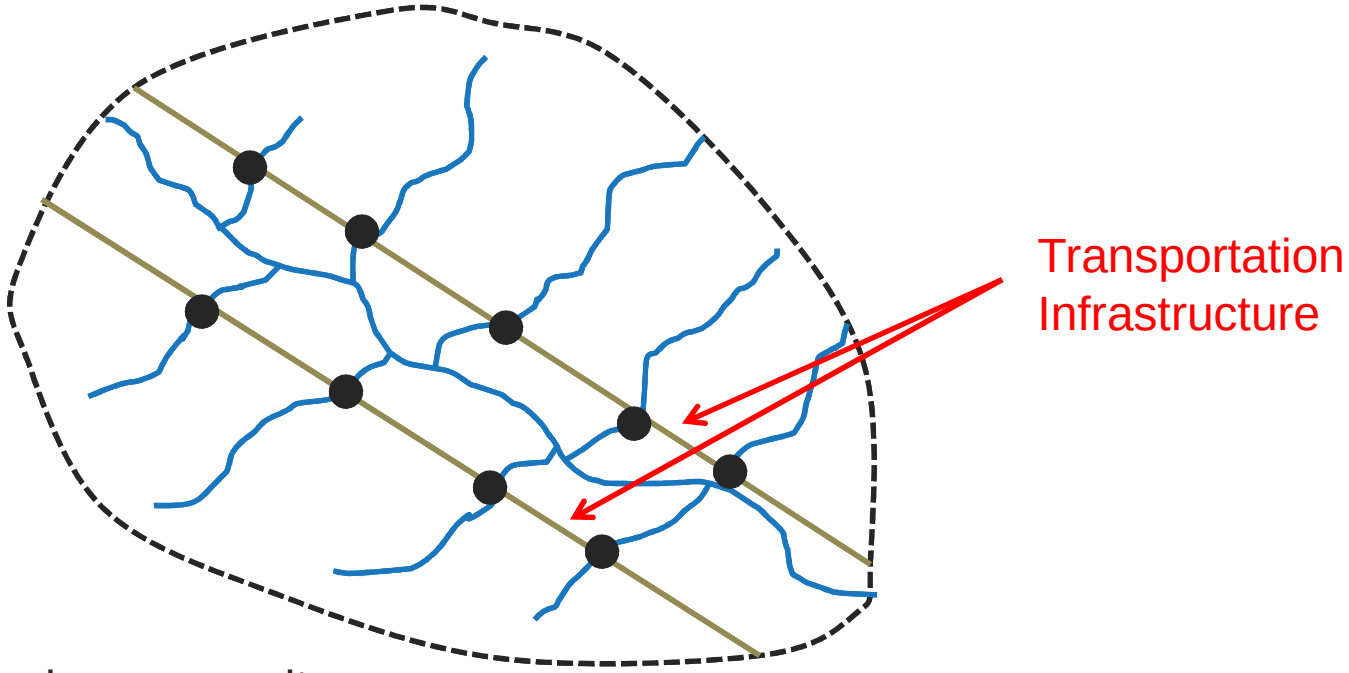
85% of time - passable



40% of time – barrier

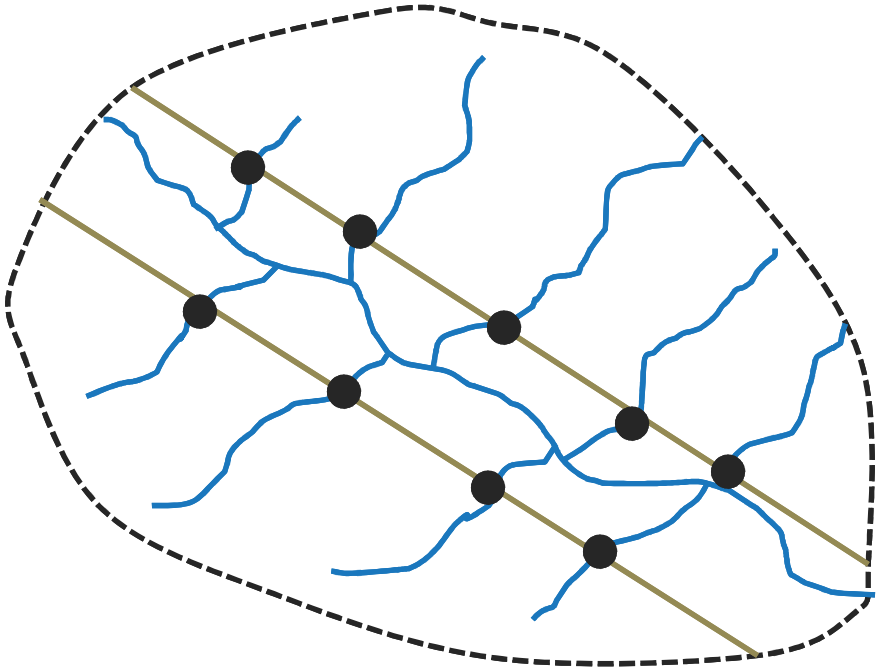
60% of time - passable

Climate Change Scenario: Prioritization with Passage Window



Scenario: Climate change results in warmer water during fish migration.

Climate Change Scenario: Prioritization with Passage Window



Scenario: climate change results in warmer water during fish migration.

	% of time as barrier		
Structure	Present Scenario	Climate Scenario	% Increase
1	15	40	167
2	36	52	44
3	54	67	24
4	78	100	28
5	30	50	67
6	35	47	34
7	62	76	23
8	55	82	49
9	40	65	63

Questions?