NW FISH PASSAGE TRAINING AND FACILITIES WORKSHOP

DAY 1

Fish Passage and Protection at Northwest Hydro

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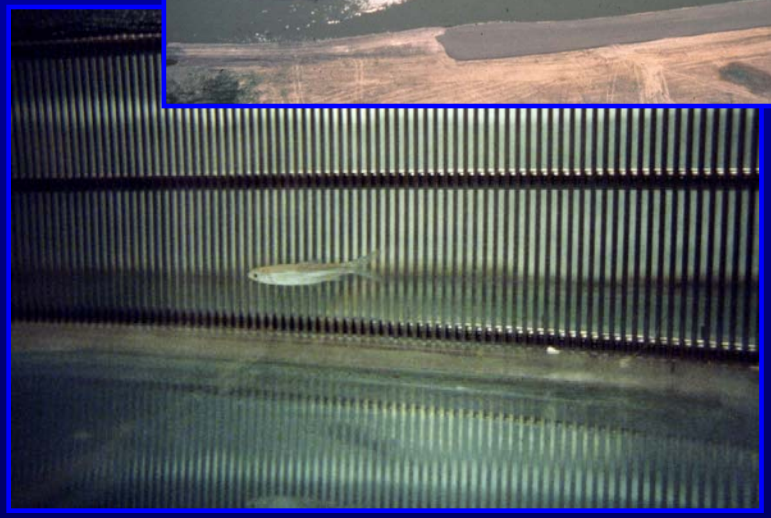


Objectives of training

- “Fish passage 101” for Northwest hydro
- Common styles of upstream, downstream passage
- Understand basic principles, concepts, and features and how to apply them
- Applying NMFS fish passage design guidance

What we're going to talk about

- Intro and background to fish passage at hydro
- Hydraulic Calcs for Fish Passage
- Upstream Passage Concepts and Examples
- Downstream Passage Concepts and Examples
- NMFS NW fish passage design guidance

We're not going to talk about other fish-hydro issues:

- In-stream flows, bedload, water quality, habitat, …

Intro to Fish Passage

- Typical hydro layouts and fish passage issues
- Fish passage expectations
- Target species
- Keys to fish passage design
  - Concepts that work
  - Design standards
  - Swimming behavior and ability
  - Operations

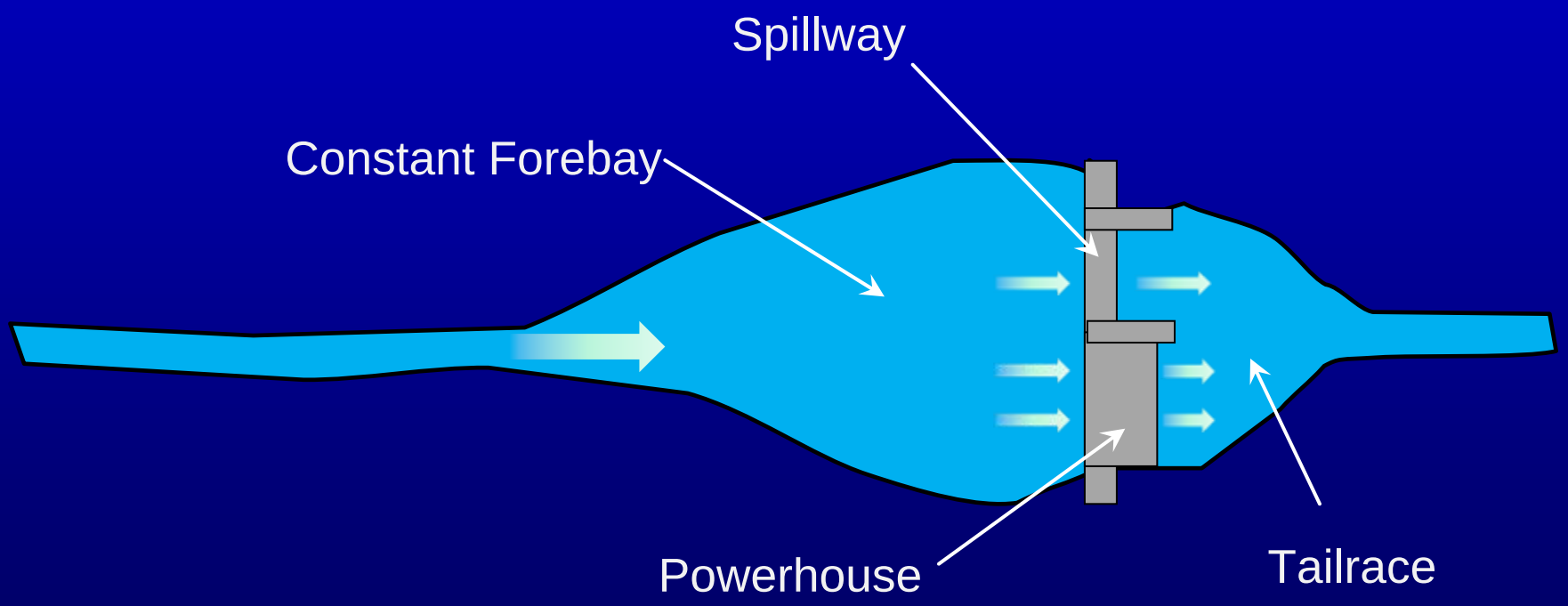
Typical hydro layouts and What they mean to fish passage

Layouts, nomenclature, issues

Increasing Complexity

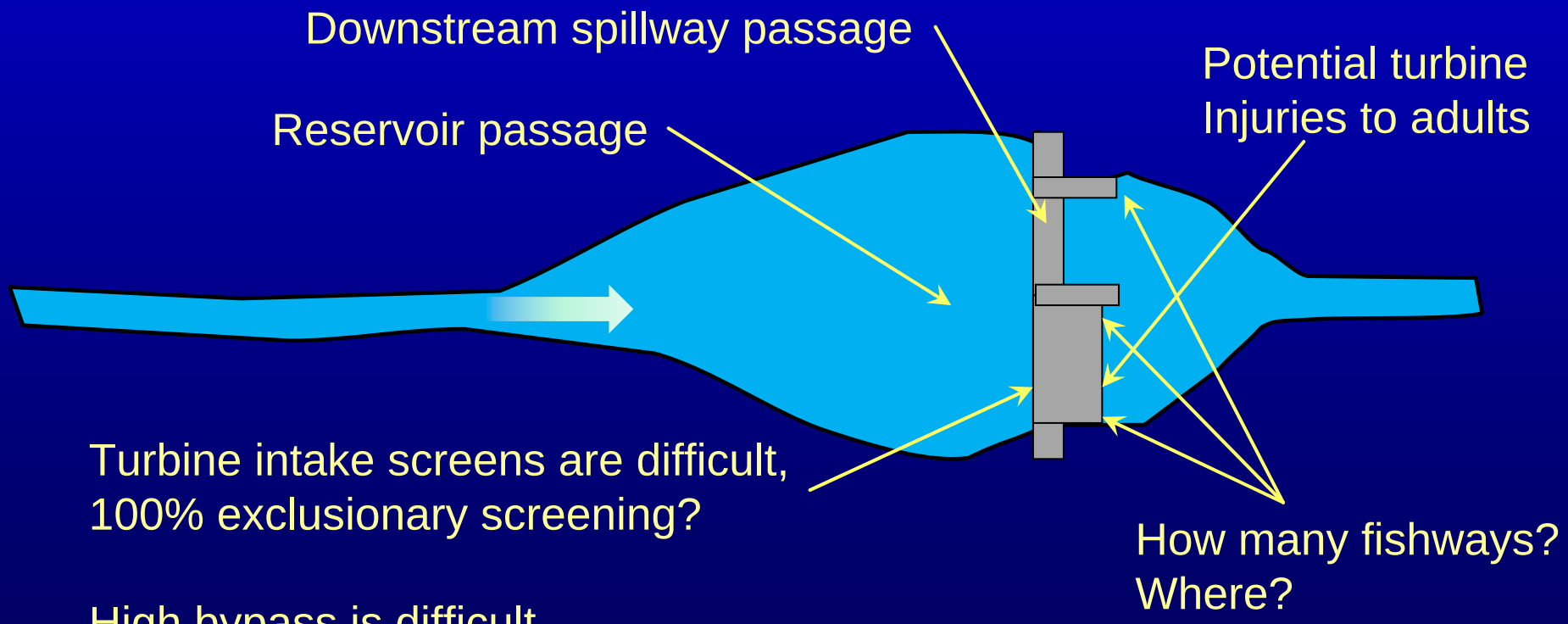
1. Run-of-the-river with powerhouse at dam
2. Run-of-the-river with powerhouse downstream
3. Series of dams
4. Series of dams with tributaries
5. Storage reservoirs

1. Run of the River Powerhouse at Dam



1. Run of the River Powerhouse at Dam

Fish Passage Issues



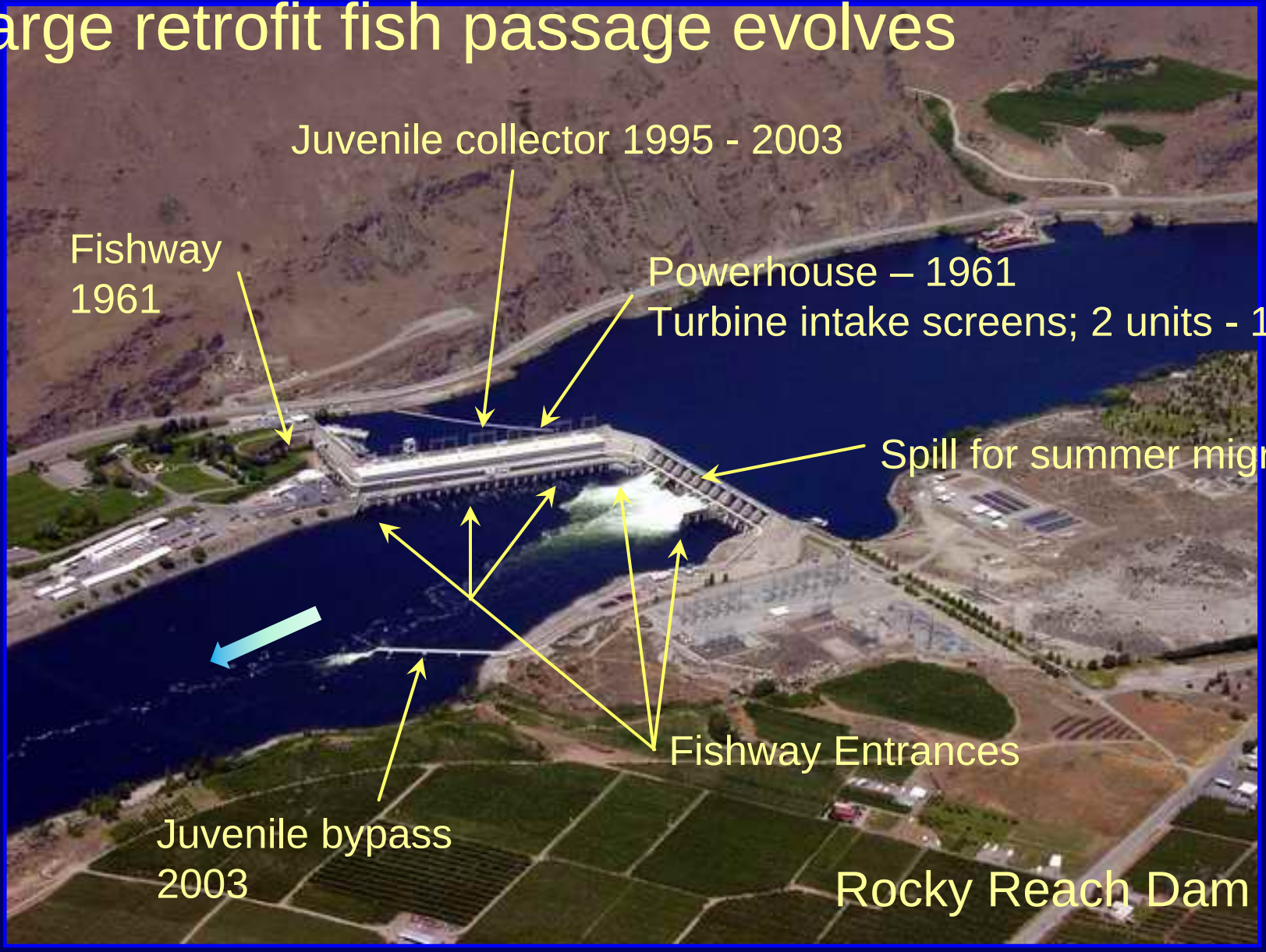
High bypass is difficult

This is simple

Screened intake

Fishway entrance

So this is simple?
Large retrofit fish passage evolves



Surface smolt collector, pumped attraction flow

Fishway

Smolt bypass, fishway

Elwha Dam,
Glines Canyon Dam

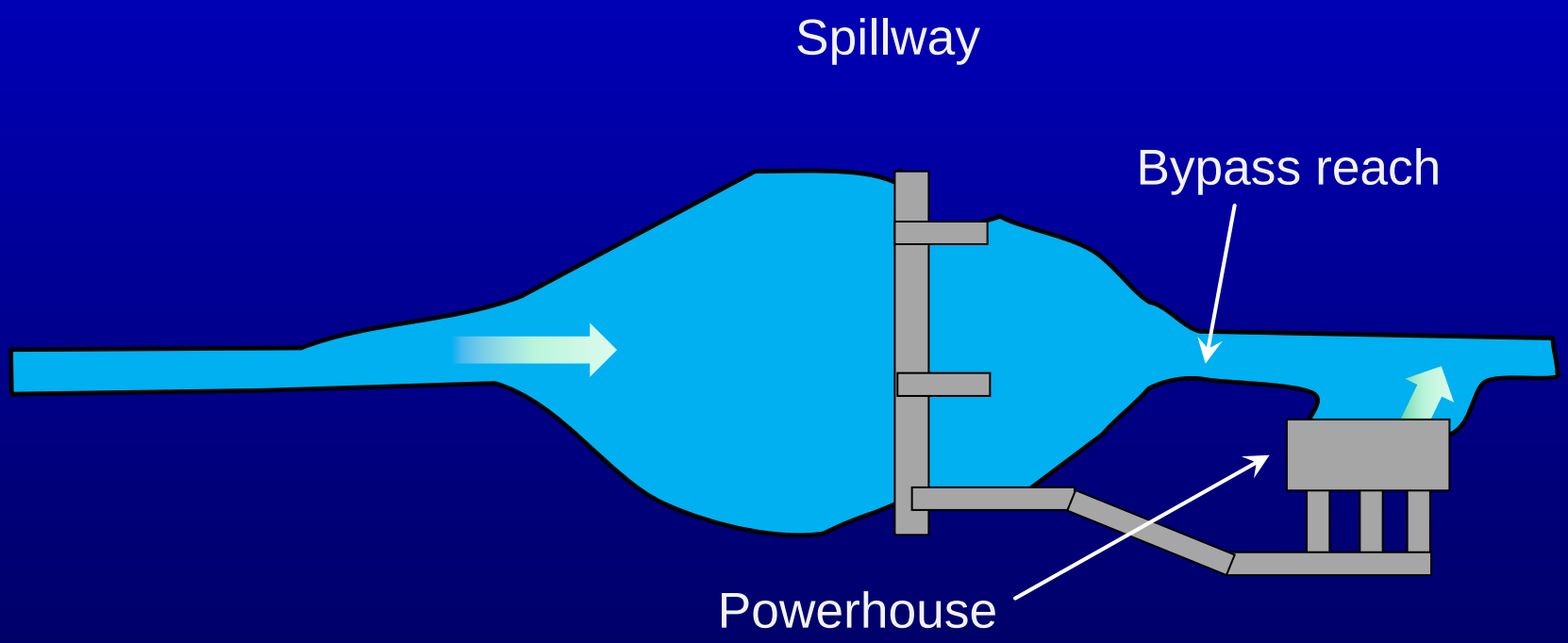
Reservoir and spillway passage

Final shutdown 6/1/11

Demolition began last Thursday

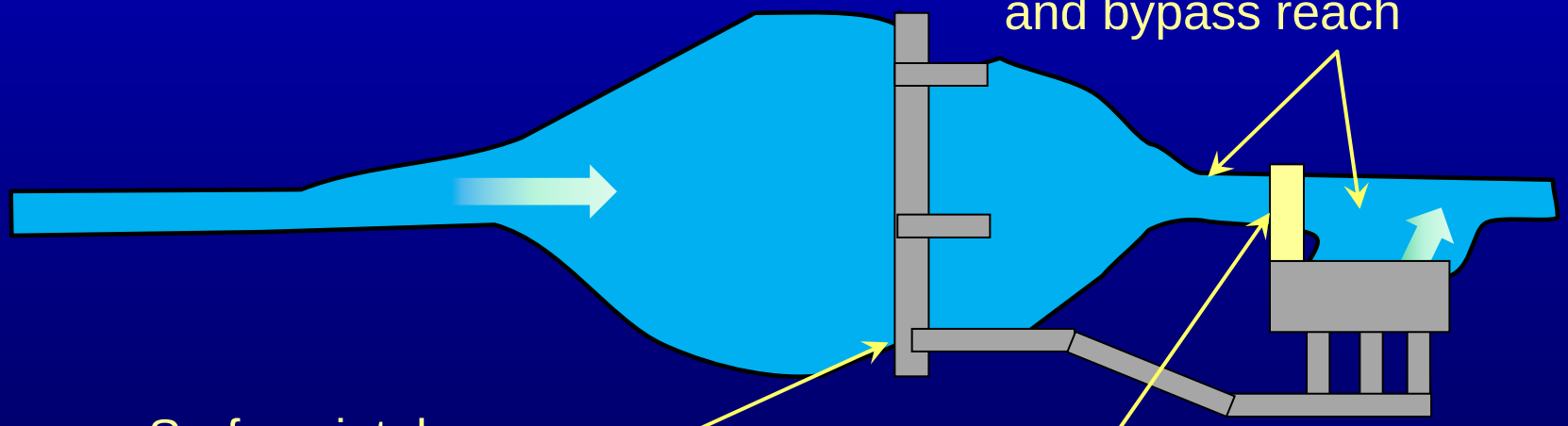
Seattle Times photo

2. Run of the River Powerhouse Downstream



2. Run of the River Powerhouse Downstream

Add'l Fish Passage Issues



Where's the fishway?
Fish attraction to powerhouse and bypass reach

Surface intake
100% screening is easier

Barrier dam,
Add' habitat loss

Imagery Date: 6/11/2010
lat 46.975213° lon -122.635194° elev 107 ft

T. O'Keefe photo

Soda Springs
Tailrace barrier

HydroWorld photo

Chester Morris
Tailrace barrier

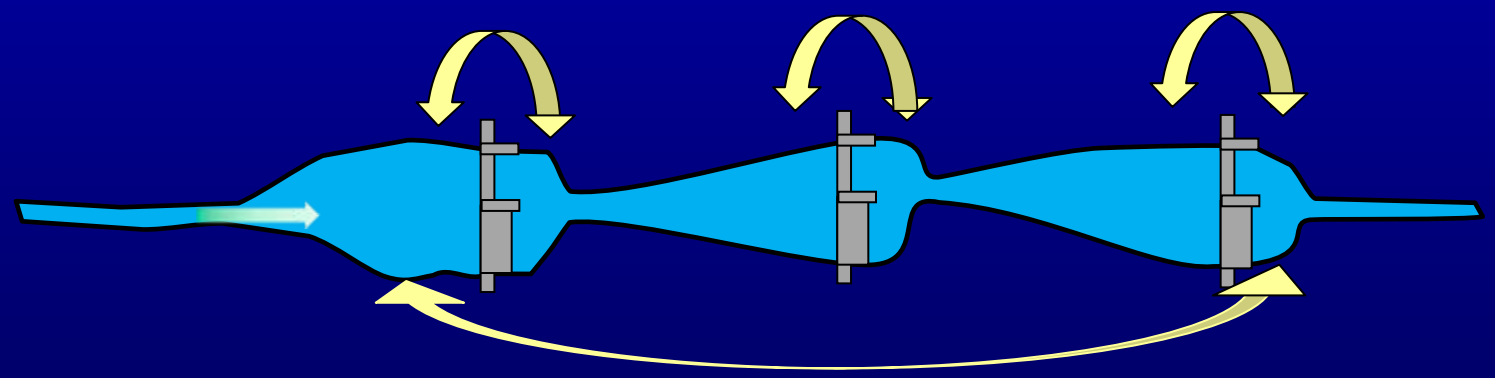
Baker
Barrier dam

3. Series of Dams

Add'l Fish Passage Issues

Cumulative delay and losses.
To achieve overall passage goal,
better passage required at each …

Connectivity of species.
How about ecosystems?

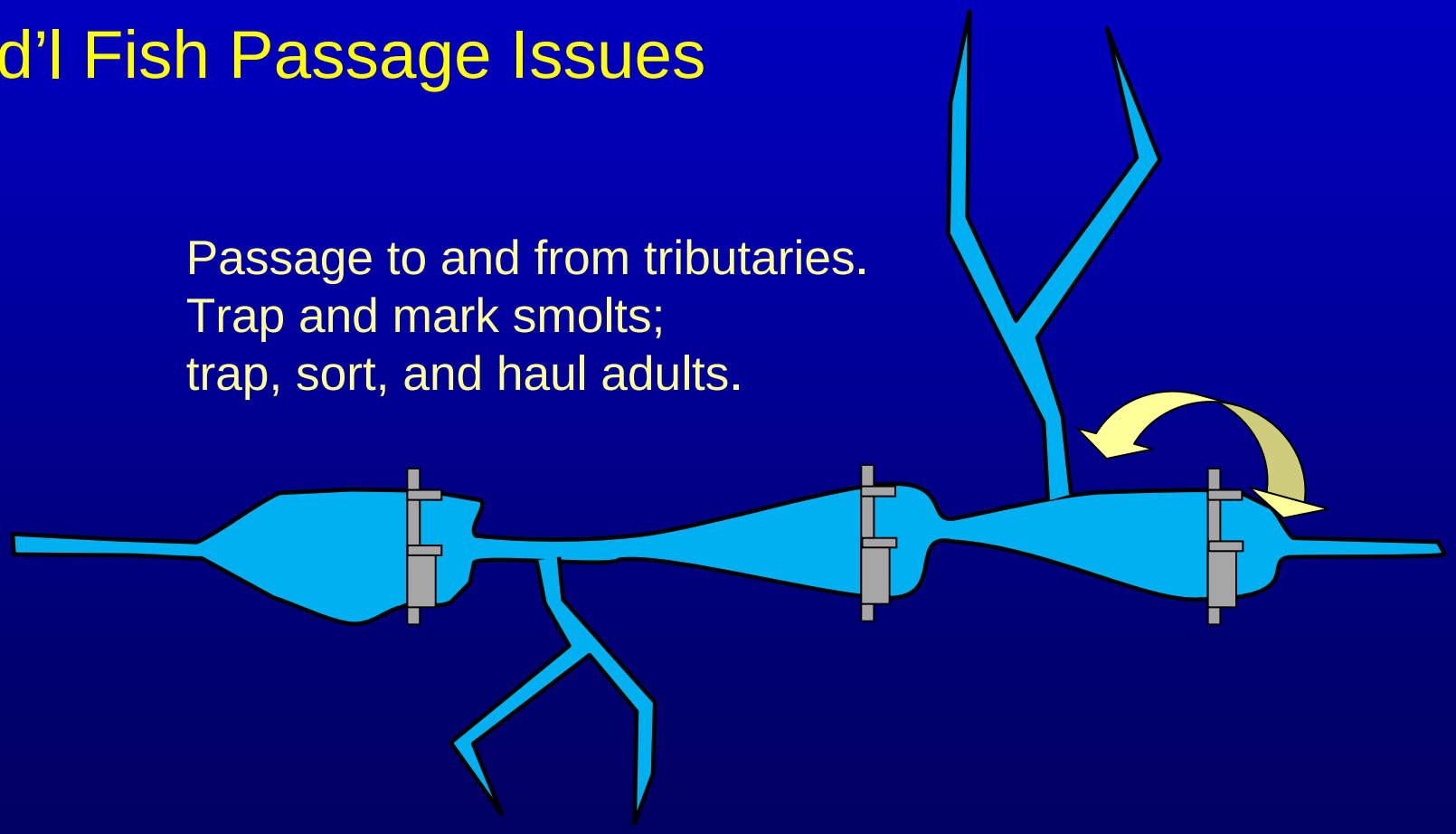


… or trap and haul to bypass series

4. Series of Dams with Isolated Habitat

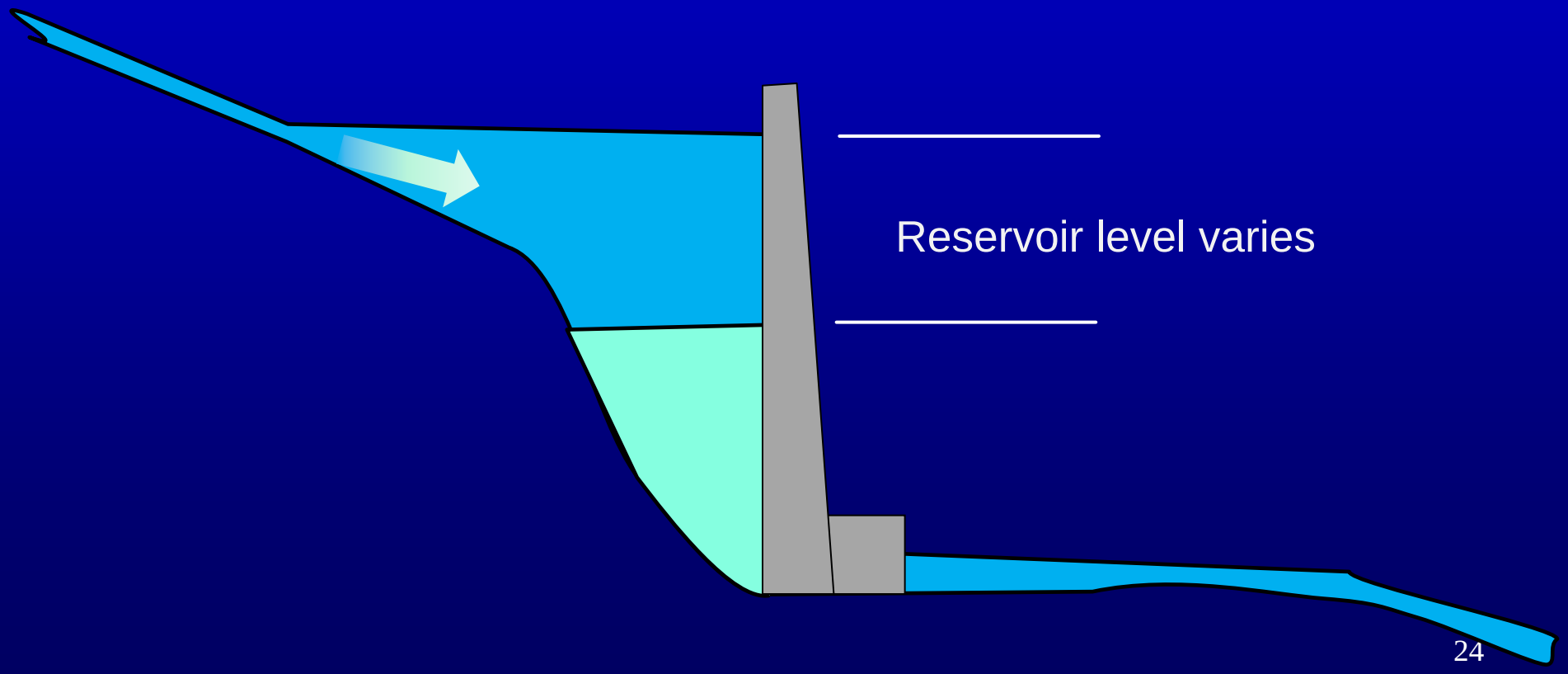
Add'l Fish Passage Issues

Passage to and from tributaries.
Trap and mark smolts;
trap, sort, and haul adults.



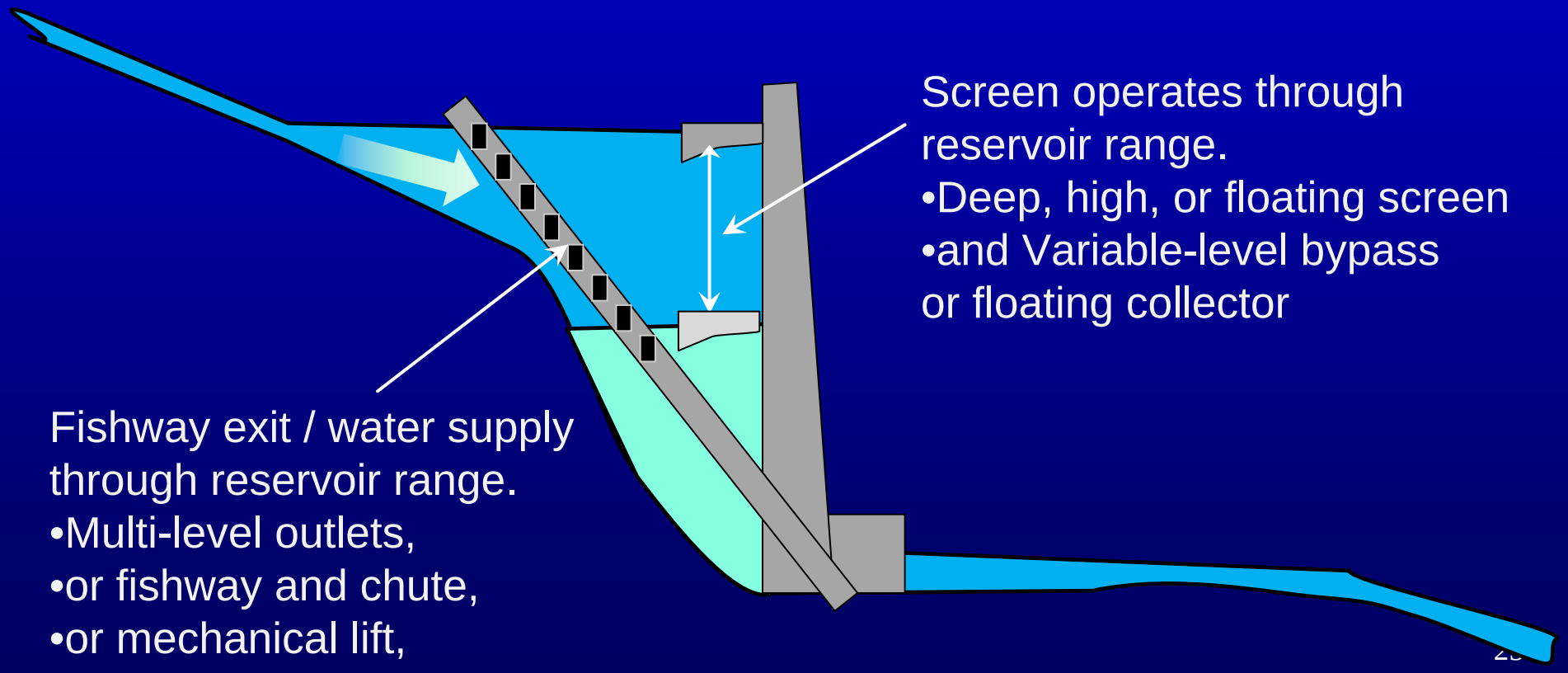
Fishway, trap, sort, haul

5. Storage reservoir



5. Storage reservoir

Add'l Fish Passage Issues



Screen operates through reservoir range.
- Deep, high, or floating screen
- and Variable-level bypass or floating collector

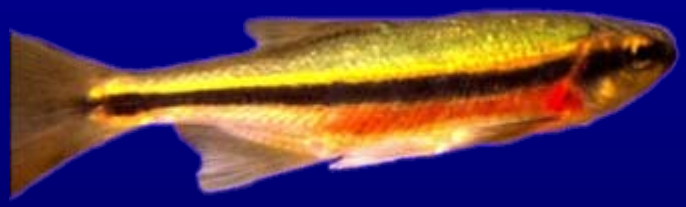
Fishway exit / water supply through reservoir range.
- Multi-level outlets,
- or fishway and chute,
- or mechanical lift,
- or trap and haul.

Fish passage expectations

- Pass and protect entire migrating population
  - Optimize upstream passage
  - Efficiency goal for downstream passage
- Safely
- Minimize delay – it's inevitable
- Reliable and durable
- Volitional is preferred
  - "Fish passage made continuously available without trap or transport". (NMFS 2008)
- Efficient; water, dollars, operation

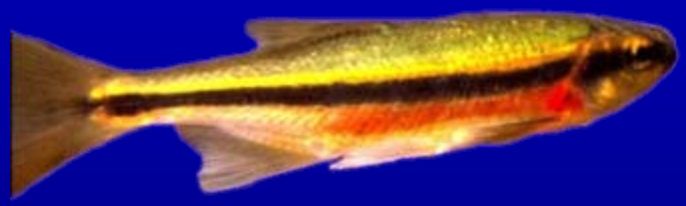
Biological Parameters

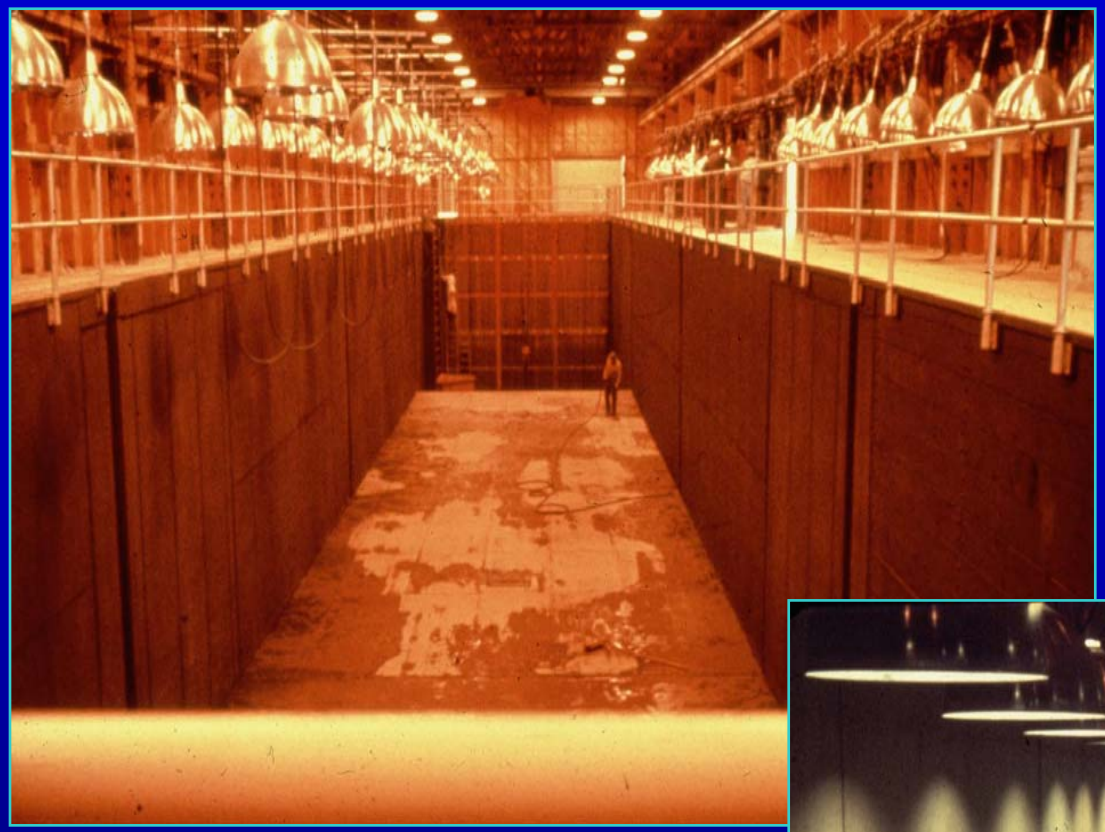
- Target species, Non-target species – what are they?
  - Weakest fish of the species
  - Allowable delay
  - Migration timing / hydrology
  - Swimming ability and behavior
  - Migration behavior
  - Peak number of fish per day



Physical Parameters

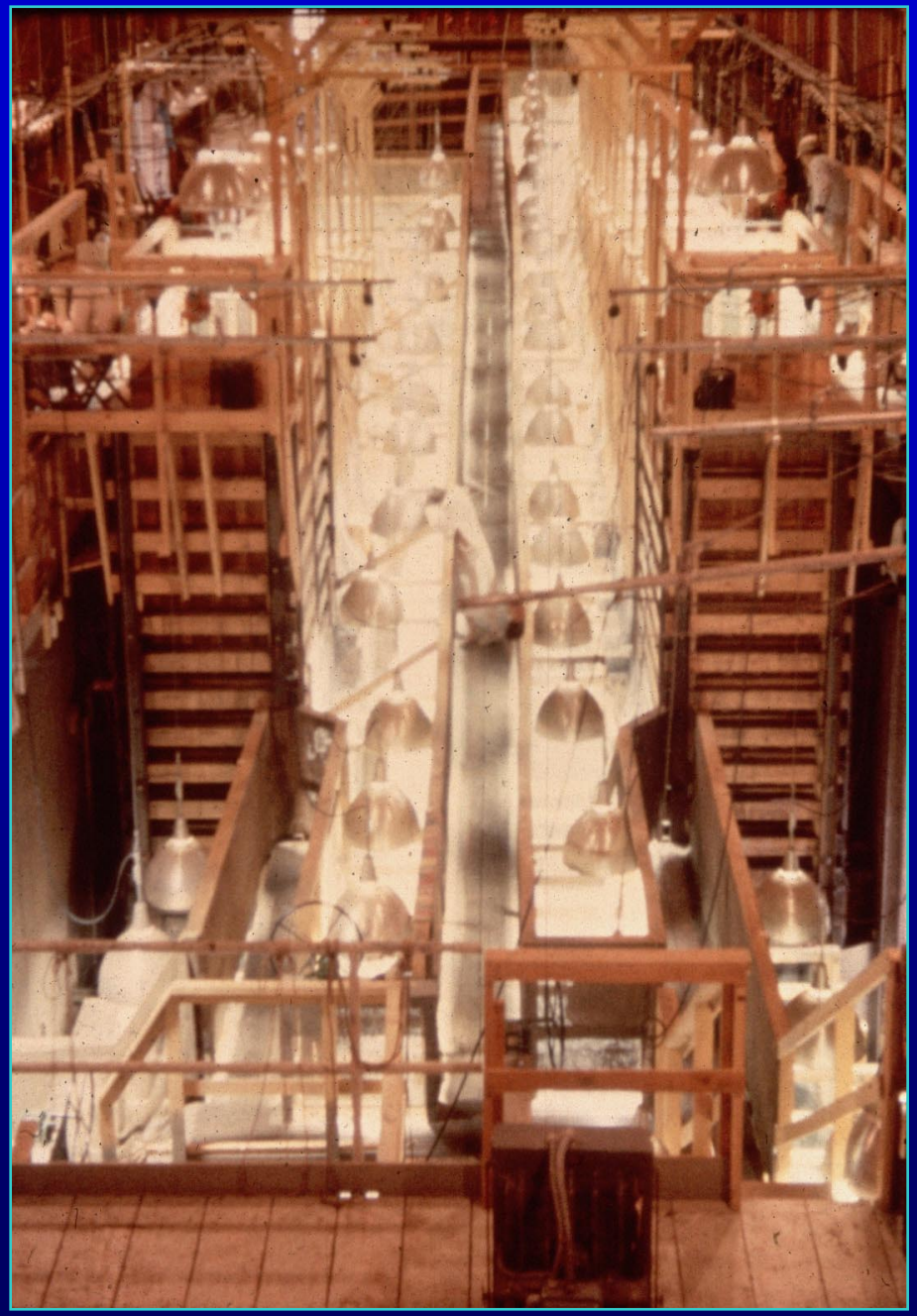
- Hydraulics
  - Velocity, direction of flow
  - Depth
  - Turbulence
  - Hydraulic jumps
- Physical
  - Light
  - Dimensions
  - Walls
  - Attachment surfaces



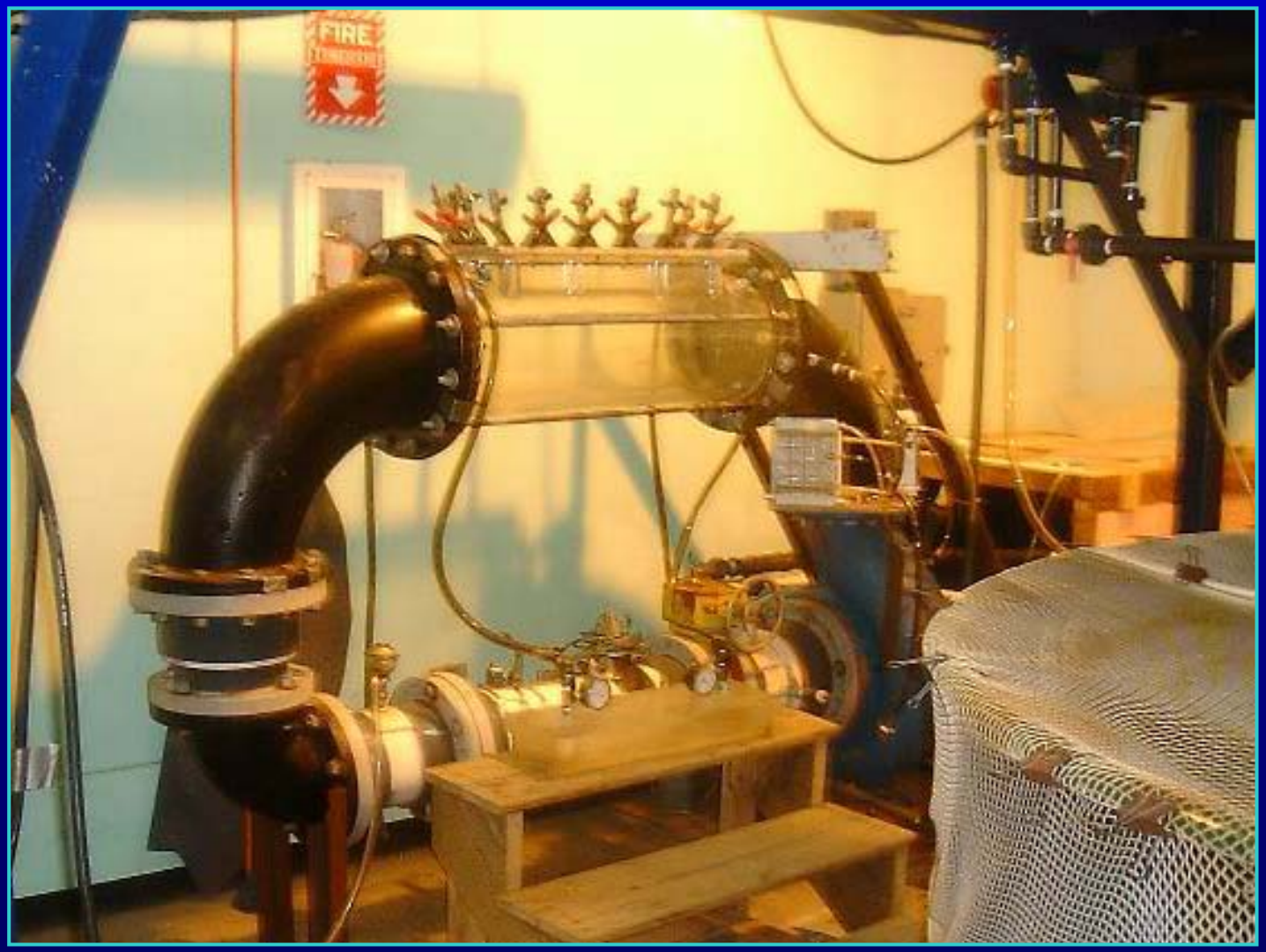


Bonneville fish passage research laboratory

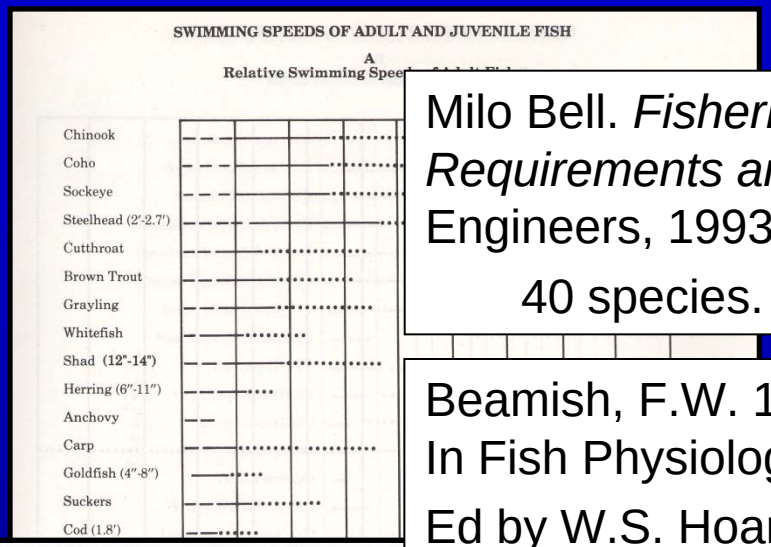
Upstream passage is optimized



Fish Swimming Speeds



Swim Speed Summaries



Milo Bell. *Fisheries Handbook of Engineering Requirements and Biological Criteria*. US Army Corps of Engineers, 1993.

40 species. Temperature, oxygen corrections

Beamish, F.W. 1978. *Swimming Capacity*. pp101-187. In Fish Physiology Vol 7 Locomotion

Ed by W.S. Hoar and D.J. Randall, Academic Press Inc.

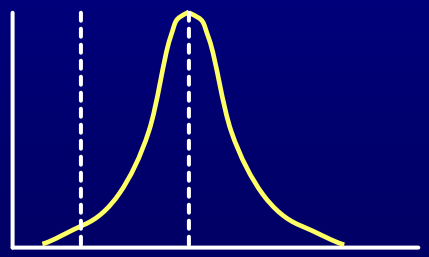
70+ species. References cited.

ICHTH

Table 3 (con't). Fish swimming performance data summary. Test: IV - increasing velocity, CV - constant velocity
F/A: FW-freshwater, AN-anadromous; # - number of fish; ? - information not given.

Scientific Name	Common Name	Test	Temp. T (°C)	Length l (m)	LM	M	F/A	Time t (s)	Speed U (m/s)	#	Flag	Notes	Reference
Oncorhynchus gorbuscha	Pink salmon	IV	15	0.487	SL	A	AN	3600					
Oncorhynchus gorbuscha	Pink salmon	IV	15	0.466	SL	A	AN	3600					
Oncorhynchus gorbuscha	Pink salmon	IV	15	0.490	SL	A	AN	3600					
Oncorhynchus gorbuscha	Pink salmon	IV	15	0.461	SL	A	AN	3600					
Oncorhynchus gorbuscha	Pink salmon	IV	15	0.472	SL	A	AN	3600					
Oncorhynchus keta	Chum salmon	IV	10	0.038	FL	J	AN	300					
Oncorhynchus keta	Chum salmon	IV	10	0.039	FL	J	AN	300					
Oncorhynchus keta	Chum salmon	IV	10	0.039	FL	J	AN	300	0.190	1	None	- all data in this table is based on freshwater experiments.	Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.041	FL	J	AN	300	0.212	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.041	FL	J	AN	300	0.242	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.041	FL	J	AN	300	0.181	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.042	FL	J	AN	300	0.260	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.045	FL	J	AN	300	0.280	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.045	FL	J	AN	300	0.302	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.046	FL	J	AN	300	0.308	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.047	FL	J	AN	300	0.254	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.047	FL	J	AN	300	0.324	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.047	FL	J	AN	300	0.342	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.048	FL	J	AN	300	0.246	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.048	FL	J	AN	300	0.252	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.048	FL	J	AN	300	0.300	1	None		Houston (1959)
Oncorhynchus keta	Chum salmon	IV	10	0.048	FL	J	AN	300	0.316	1	None		Houston (1959)
Oncorhynchus kisutch	Coho salmon	IV	10	0.084	FL	J	AN	600	0.497	.	None	Purpose: effect of oxygen and temperature on swimming speed	Davis et al (1963)
Oncorhynchus kisutch	Coho salmon	IV	12	0.127	FL	J	AN	1200	0.594	.	None	of juvenile coho salmon.	Davis et al (1963)
Oncorhynchus kisutch	Coho salmon	IV	15	0.077	FL	J	AN	600	0.517	.	None	- data in table is for air-saturation oxygen levels.	Davis et al (1963)
Oncorhynchus kisutch	Coho salmon	IV	15	0.133	FL	J	AN	1200	0.701	.	None	- each point represents a number of fish (exact number not given).	Davis et al (1963)
Oncorhynchus kisutch	Coho salmon	IV	20	0.080	FL	J	AN	600	0.564	.	None		Davis et al (1963)
Oncorhynchus kisutch	Coho salmon	IV	8	0.040	FL	J	AN	3600	0.213	1	None	Purpose: effect of temp. & salinity on critical swimming speeds	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	8	0.060	FL	J	AN	3600	0.295	1	None	of coho salmon fry to smolt.	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	8	0.080	FL	J	AN	3600	0.360	1	None	- data in this table was taken from the speed vs length plot	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	8	0.100	FL	J	AN	3600	0.400	1	None	for freshwater data (see Fig.2 in paper).	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	8	0.120	FL	J	AN	3600	0.450	1	None	- additional data for temp. of 3 & 23 C is available (see paper).	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.040	FL	J	AN	3600	0.260	1	None	- paper also includes isopleths of critical swimming speed	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.060	FL	J	AN	3600	0.366	1	None	based on temperature and salinity.	Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.080	FL	J	AN	3600	0.453	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.100	FL	J	AN	3600	0.517	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.120	FL	J	AN	3600	0.570	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	18	0.040	FL	J	AN	3600	0.306	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	18	0.060	FL	J	AN	3600	0.426	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	18	0.080	FL	J	AN	3600	0.504	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	18	0.100	FL	J	AN	3600	0.565	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	18	0.120	FL	J	AN	3600	0.600	1	None		Glova & McInerney (1977)
Oncorhynchus kisutch	Coho salmon	IV	13	0.064	FL	J	AN	3600	0.362	10	None		Howard (1975)
Oncorhynchus kisutch	Coho salmon	IV	13	0.064	FL	J	AN	3600	0.421	10	None	Purpose: effect of pulp mill effluent on critical swimming ability	Howard (1975)
Oncorhynchus kisutch	Coho salmon	IV	13	0.064	FL	J	AN	3600	0.420	10	None	of juvenile coho salmon.	Howard (1975)
Oncorhynchus kisutch	Coho salmon	IV	13	0.064	FL	J	AN	3600	0.357	10	None	- data in this table is for the control fish.	Howard (1975)
Oncorhynchus kisutch	Coho salmon	IV	13	0.064	FL	J	AN	3600	0.368	10	None		Howard (1975)

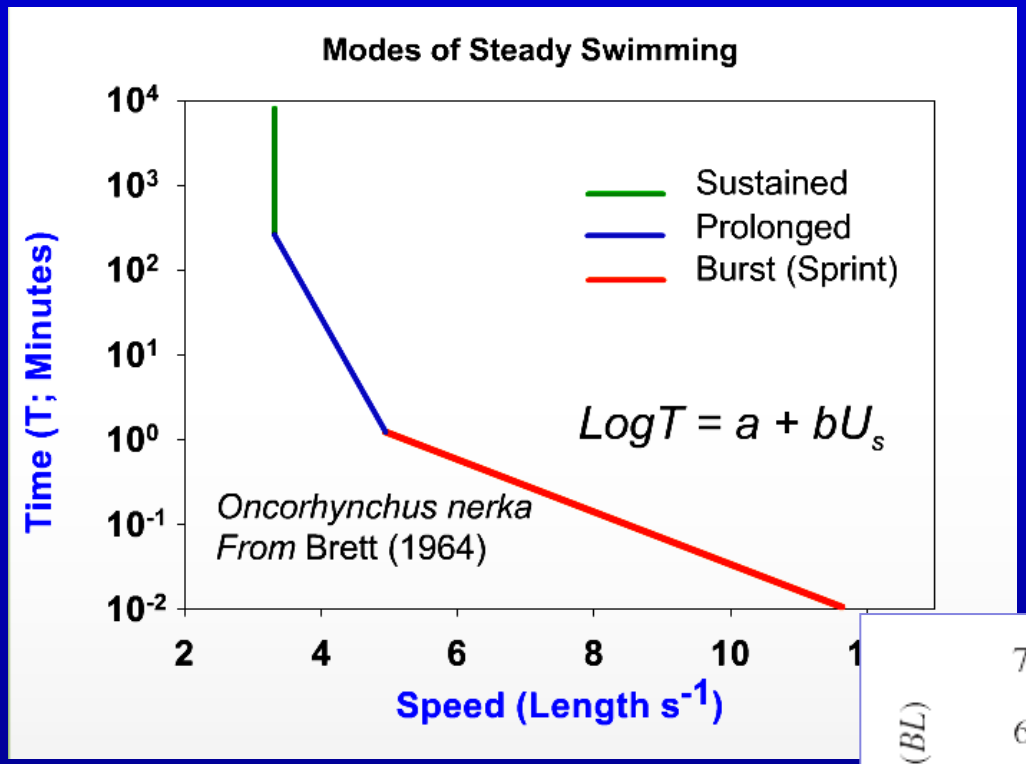
These available through FishXing



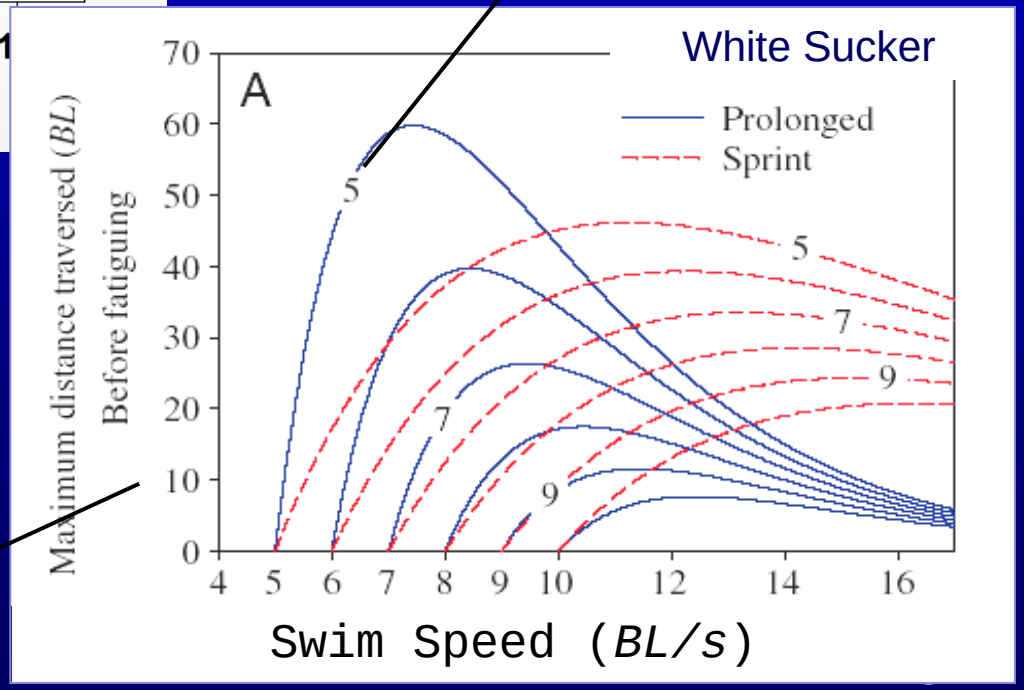
Swim Speed

Swimming modes

	Sustained (Cruising)	**Prolonged**	**Burst** (Darting)
Exercise	Aerobic →		← Anaerobic
Duration	Indefinite	Minutes	Seconds
How we use it	Walk	Jog	Sprint
How fish use it	Normal movement, Holding	Avoid obstacles, Avoid screen	Escape predators, Enter fishway, Pass weirs, Leap



Water velocity (BL/S)



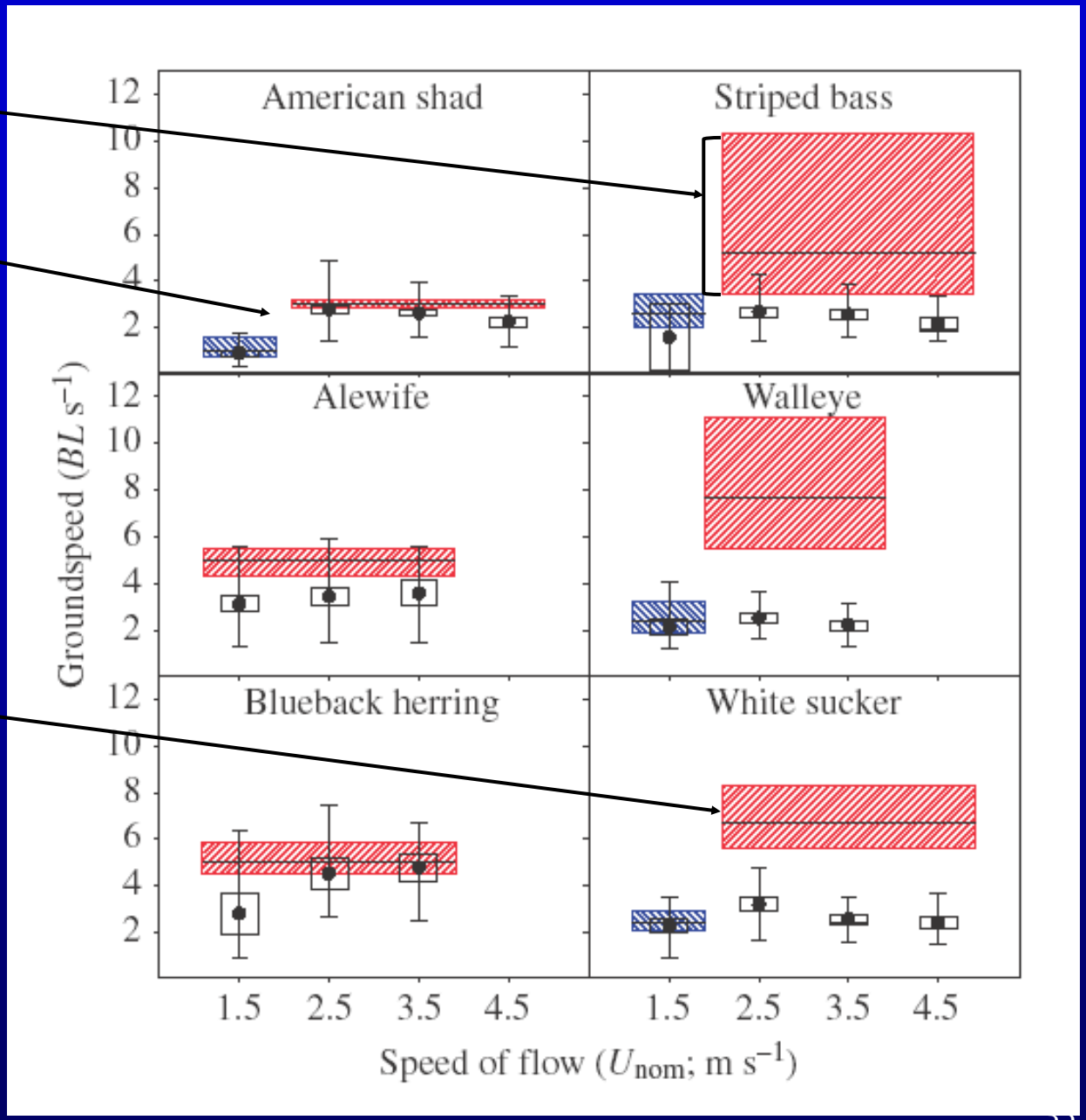
Distance (BL)

Ted Castro-Santos, USGS, 2004

Burst capability

Anadromous species burst to optimum speed.

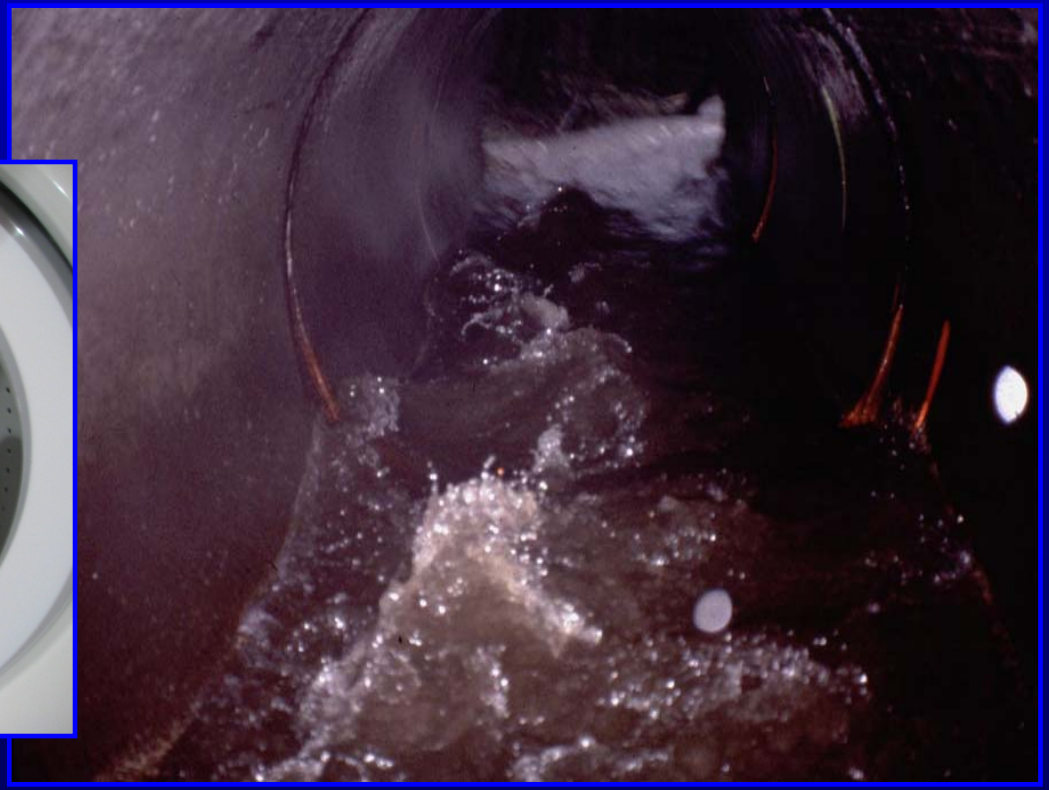
Non-anadromous species didn't.



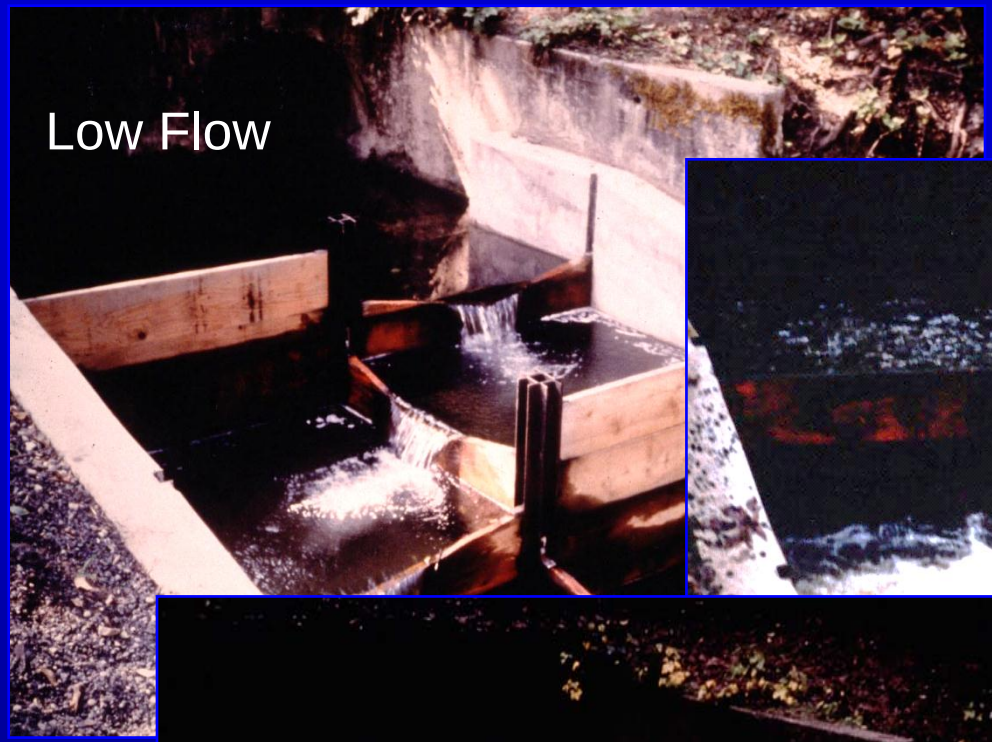
Ted Castro-Santos, USGS, 2004

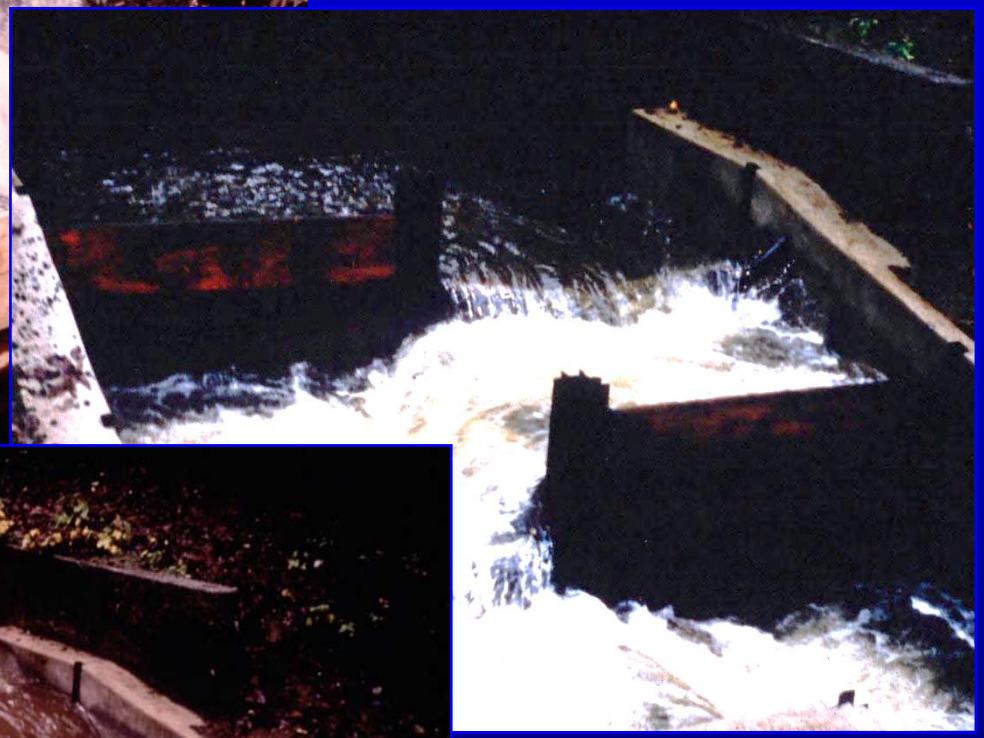
Turbulence

- Turbulence limits fish passage
- Quantified by Energy Dissipation Factor (EDF)



Turbulence, EDF





Fish passage design flow
EDF = 4 ft-lb/sec/ft3

Two times fish passage design flow
EDF = 8 ft-lb/sec/ft3

Energy Dissipation Factor (EDF)

- A measure of turbulence
- Energy dissipated per unit volume of water
- Include effective volume only

$$EDF = \frac{\gamma Q h}{Effective Volume}$$

- Suggested EDF for pool fishways
  - Salmon: 4.0 ft-lb/sec/cuft
  - Trout: 3.0

Target Species

Anadromous Fish
In Washington State

- Steelhead
- Chinook, coho, pink, chum, sockeye salmon
- Cutthroat trout
- Pacific lamprey
- American shad

Some Non-anadromous Migrating Fish In Washington State

- Juvenile coho, chinook, and steelhead
- Kokanee
- Rainbow and Cutthroat trout
- Brown and brook trout
- Bull trout / Dolly Varden
- Mud minnow
- Stickleback
- Sculpin

- Pygmy and Mountain whitefish
- Minnows
- (Pacific Lamprey)
- Suckers
- Nooksack dace
- Sturgeon (adult and juvenile)
- Crayfish
- Peamouth

Columbia River White Sturgeon

- One of the largest and most productive populations in the world
- Sturgeon “seldom ascend existing fishways” and use them differentially
- Populations persist at low abundance
- Physical and biotic characteristics vary among impoundments
  - Sturgeon condition, growth, and size vary
  - Some impoundments have spawning but limited by density
  - Other impoundments have rearing habitat but no recruitment

Parsley etal, 2006

How to block Pacific lamprey…

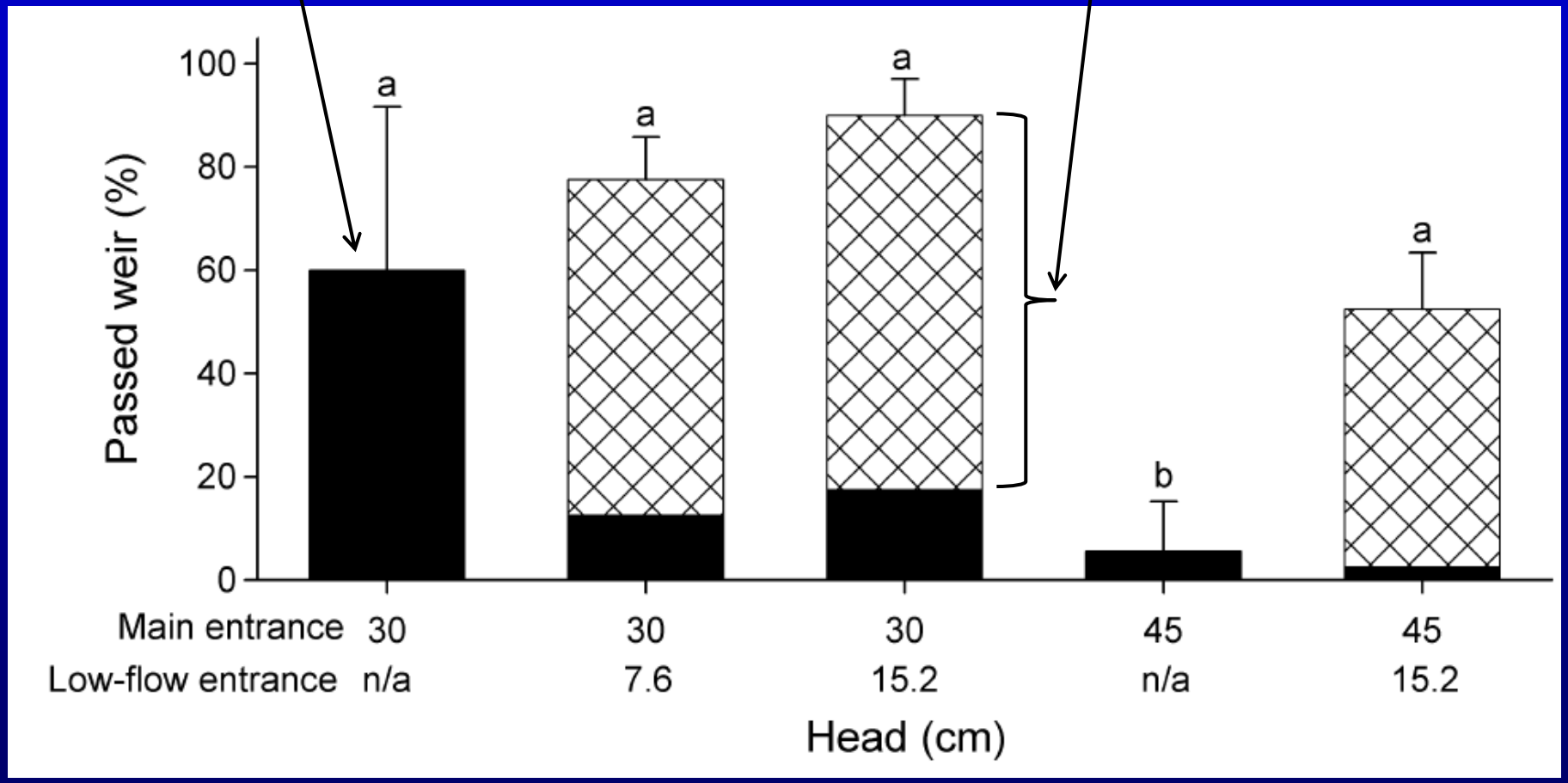
U of Chicago, 2006

Abrupt corners, velocity

Corners, no wall passage, velocity, bar grating

Moser, Ogden, Peery; 2005

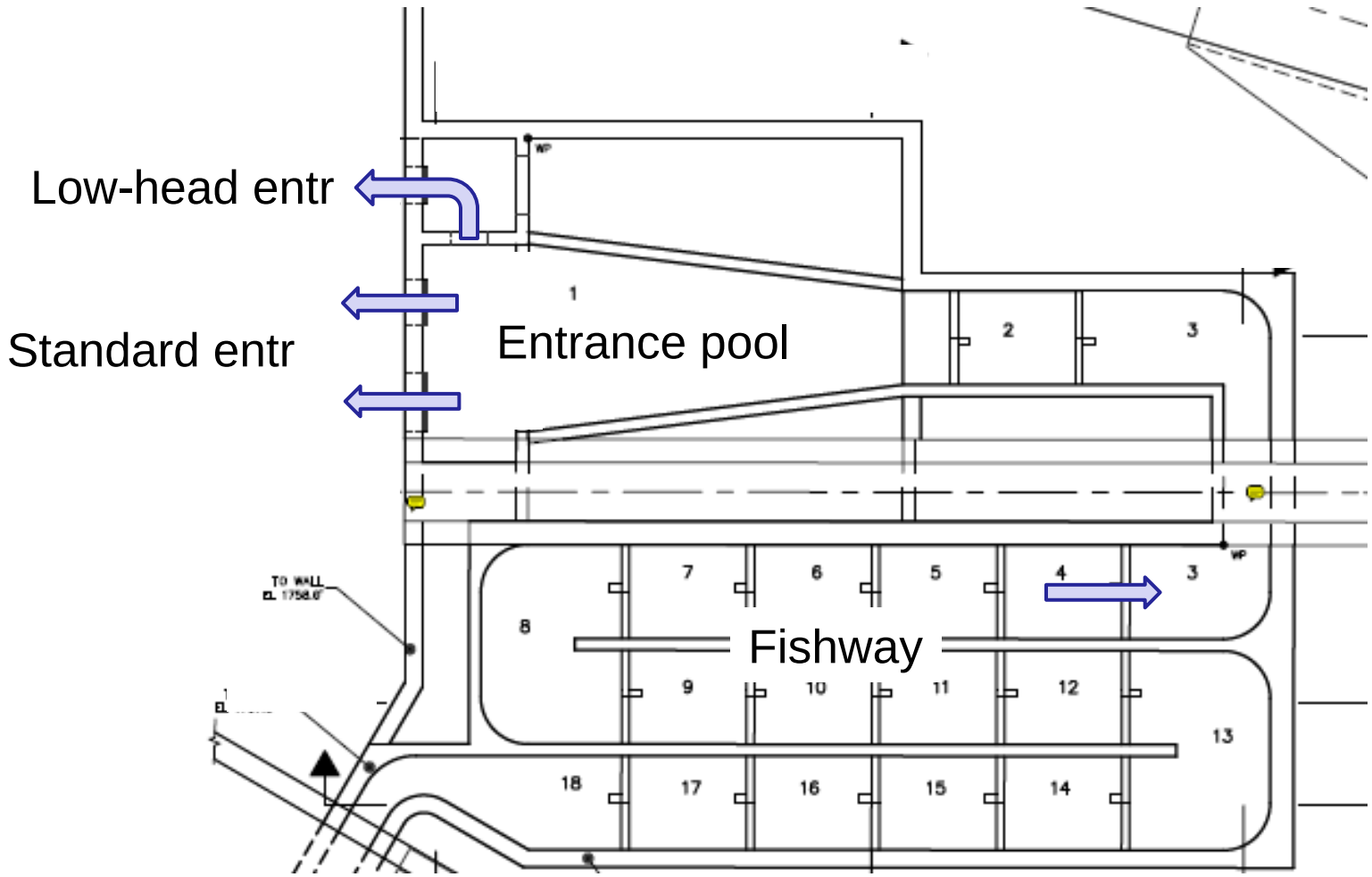
Comparing lamprey entering standard entrance (vertical slot) and low-flow entrance



Also tested ramps, velocity refuge, bollards

Keefer et al, 2011

Special entrance for lamprey or others



Experimental lamprey passage structure

Moser et al; 2006

Connectivity issues

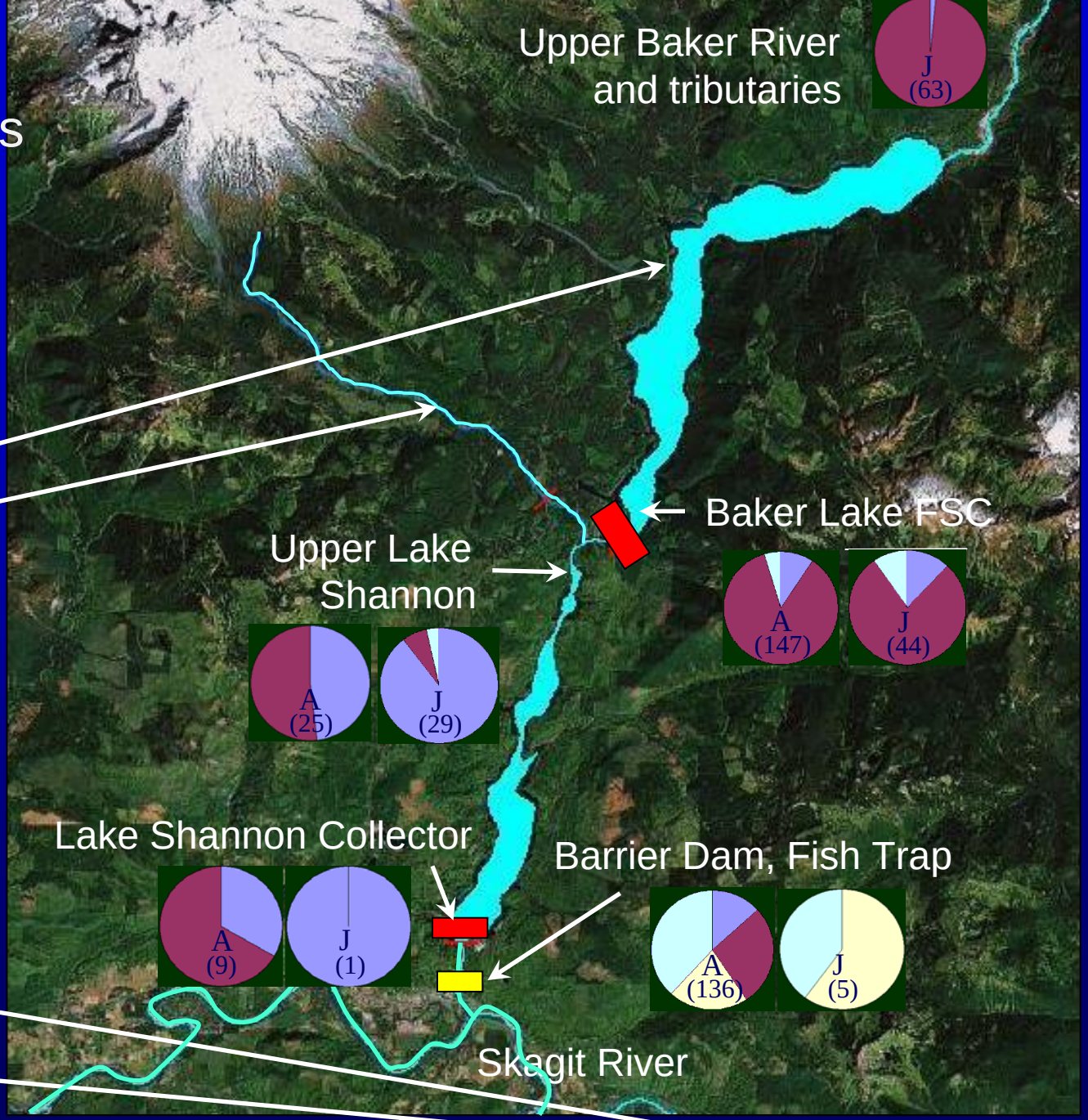
- Barriers to non-anadromous species subdivide or isolate population segments
- Smaller and more isolated populations are more vulnerable to:
  - Reduced viability
  - extinction due to chance events
  - genetic changes
- Ecosystem depends on other organisms that move

Connectivity plan

- Objective: Stock co-mingling (or segregation) to achieve genetic integrity
  - Genetic studies to identify populations
  - Design connectivity protocols
- Required effort varies
  - Structural fishway
  - Or collection, sampling, tagging, and transport
    - Angling or trap collection. Temporary / permanent
  - Tissue sampling for genetic origin
  - PIT tags to manage individual fish

Baker Basin Bull Trout Origins 2002-2010

J: Juvenile
A: Adult/sub-adult



Upper Baker
Sulphur Creek
Sauk River
Illabot Creek

From PSE slide

This is a connectivity programmatic "fishway" at Upper Lake Shannon

Table 7. Proposed 2011 angling effort in Lake Shannon. Efforts will be distributed across the Lake Shannon gulper, Lake Shannon tributary confluences, and the Upper Baker tailrace including the shoreline between Rocky Creek and the Depression Lake outflow.

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Lake Shannon Gulper												
Crew				2	2	2	2					
Frequency (X/month)				4	4	4	4					
Expected effort (min)[a]				30	30	30	30					
Tributary confluences[b]												
Crew						2	2	2	2	2		
Frequency (X/month)						1	1	1	1	1		
Expected effort (min)[a]						180	180	180	180	180		
Upper Baker Tailrace[c]												
Crew							2	2	2		2	
Frequency (X/month)							1	1	1		1	
Expected effort (min)[a]							60	60	60	0[c]	60	
Rocky Ck. – Dep. Lake[c]												
Crew							2	2	2		2	
Frequency (X/month)							1	2	2		1	
Expected effort (min)[a]							180	180	180	0[c]	180	

Current Baker Barrier Dam
Trap, Sorting, and loading
5. Flume sort
4. Lock lift
7. Load truck
6. Crowd
8. Haul
3. Crowd
2. Enter fishway, trap
1. Upstream

Baker fish hauling destinations as an example of holding and sorting requirements

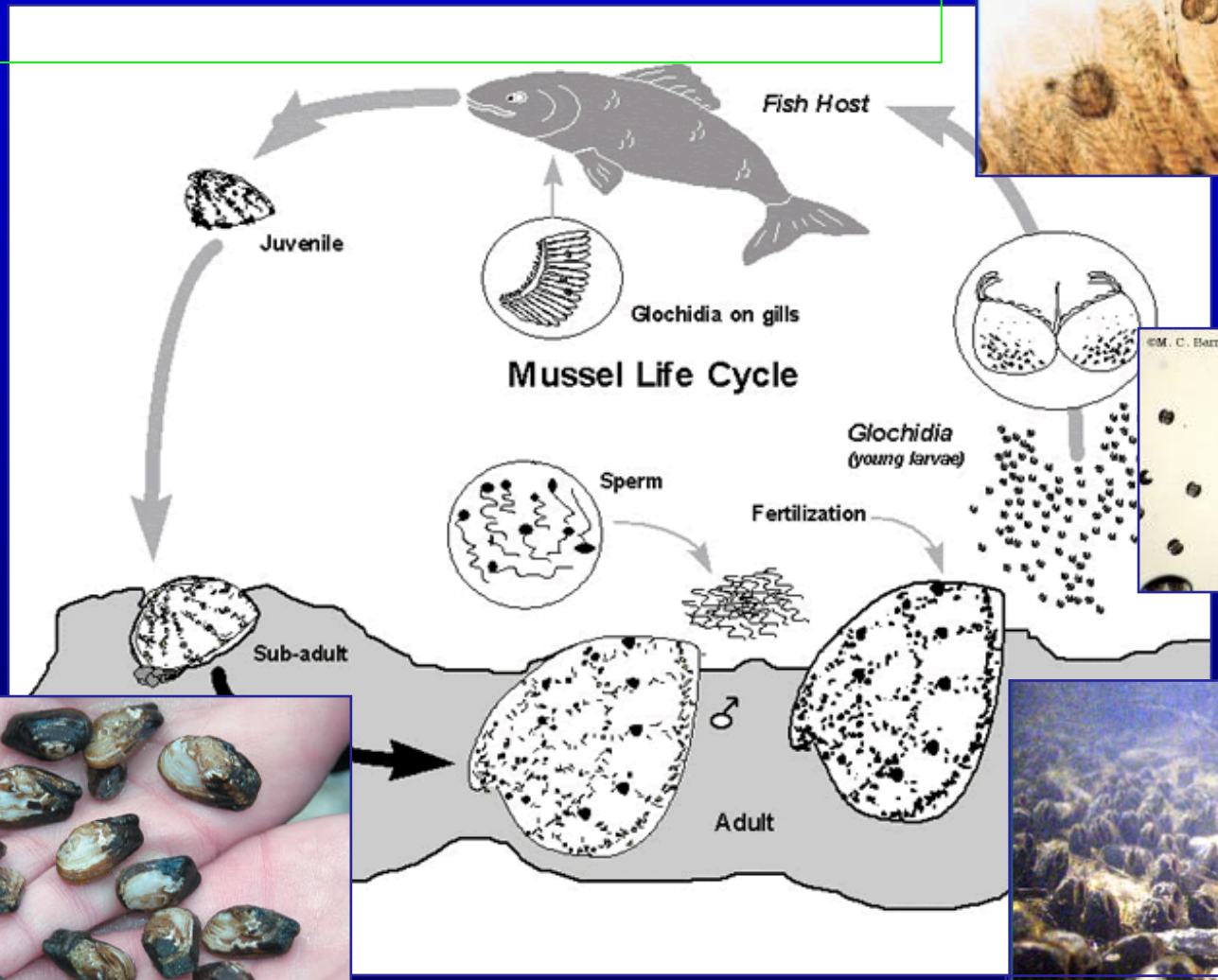
Species		Potential Destinations								
		Baker Lake	Lake Shannon	Beach 4	Old Beaches	Sulfur Creek Hatchery	Skagit River	Marblemount Hatchery	Tribal C & S	Tribal Hatchery
Chinook	Spring									
Chinook	Summer/Fall									
Sockeye										
Coho										
Chum										
Pink										
Steelhead	Summer									
Steelhead	Winter									
Cutthroat										
Rainbow										
Native Char										

= yes = maybe = no

Connectivity for Juvenile Salmonids

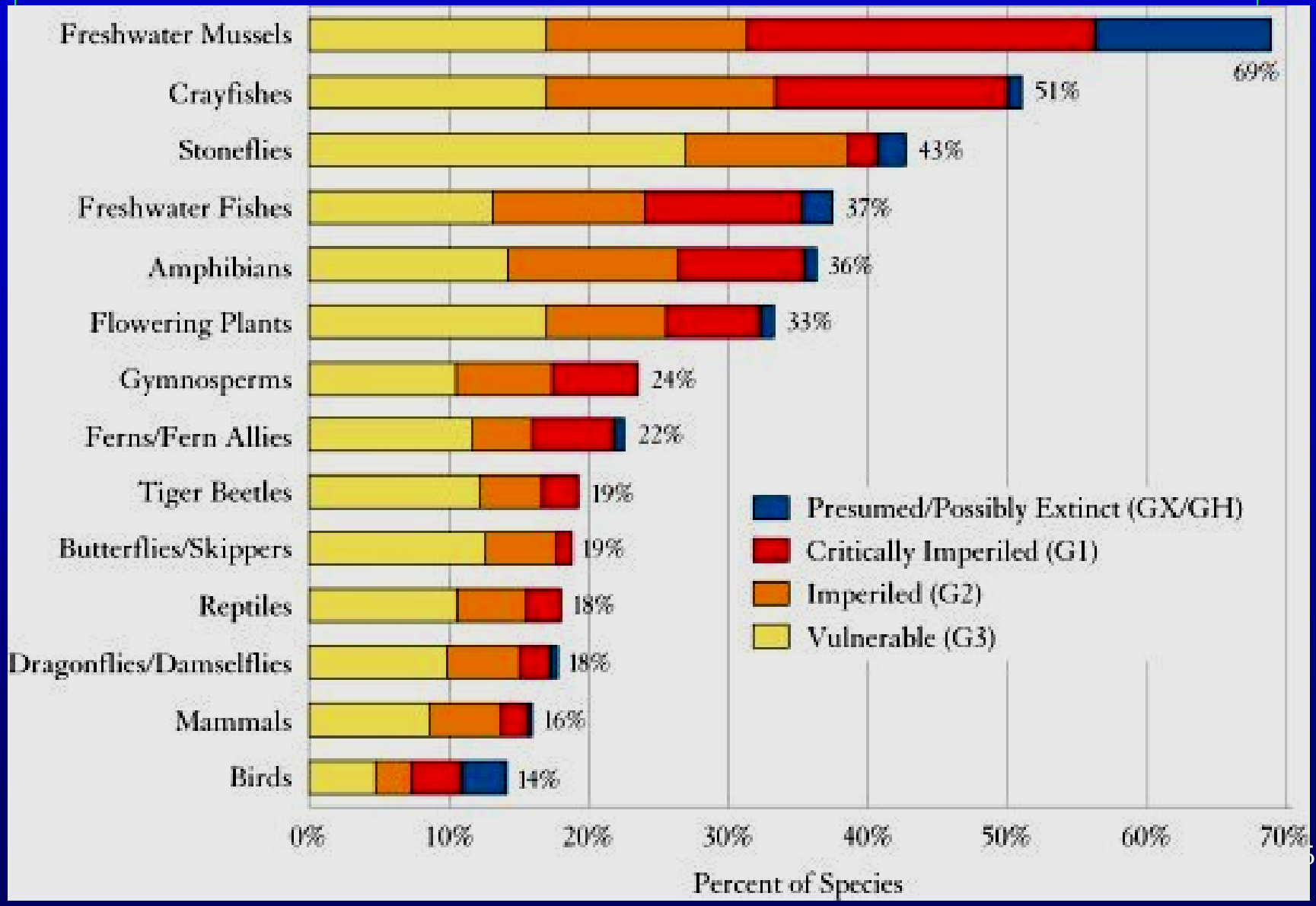
- Importance of movement
  - Daily movements
  - Changes in habitat conditions
  - Exploit vacant habitat
  - Dispersal
- The default is to expect juvenile passage even when the benefit is not known

Other aquatic organisms. So what?



Micah Wait, WT

Proportion of U.S. Species at Risk



Source: Precious Heritage: The Status of Biodiversity in the United States

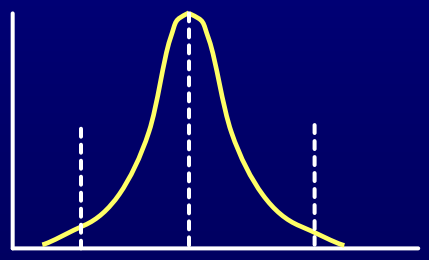
Freshwater Mussels in Bear Cr, WA

- Freshwater mussel population is depressed
- Mussel density: 20/sq m
- Normal summer flow: 20 cfs

Theoretically the entire summer flow is filtered every 1.6 days.

Ten Final Keys to Fish Passage Design

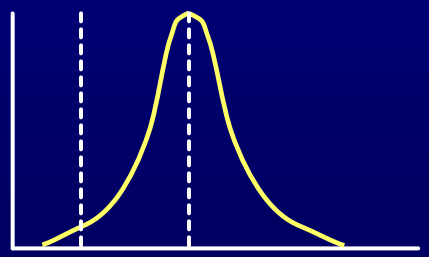
1. Fish collection is 90% of fish passage success
   - Where is the barrier? Where do fish accumulate?
   - How to attract fish?
3. Good O&M is another 50% of success
4. Fish behavior is as important as swimming ability.
   - Corollary: there are also fish that don't behave like they should



Behavior

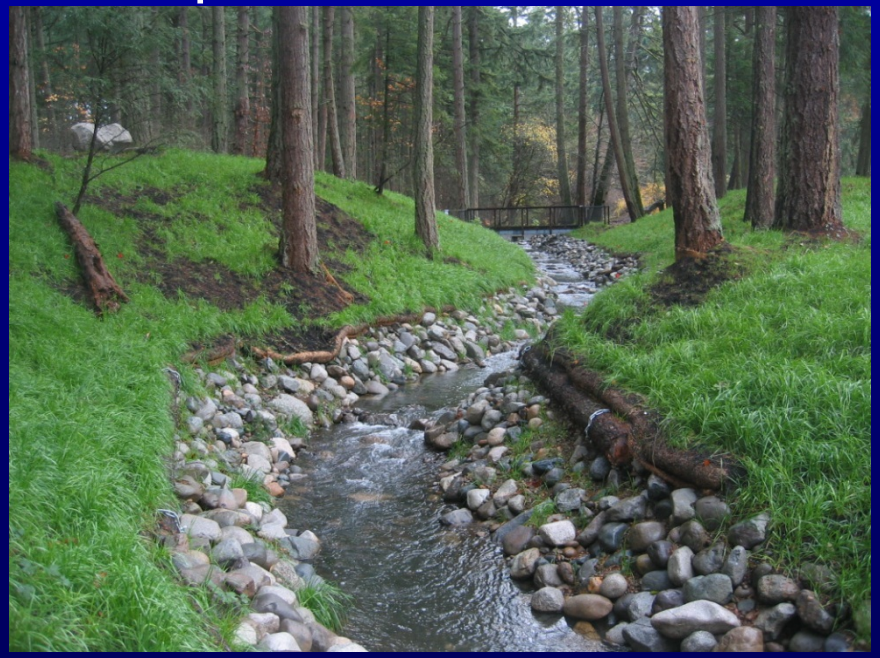
…

5. Design for target species but their viability depends on an ecosystem
6. Design for weakest fish of species, not the average
7. Consider non-target species.
8. There are often trade-offs among species, age classes, attraction / passage.



…

9. Account for uncertainties conservatively and with flexibility
10. Use tried and true concepts, evolve new ideas
11. Use diverse systems for diverse species
12. …



Tools for Fishway Design Development

Bryan Nordlund, P.E.

National Marine Fisheries Service

Lacey, Washington

Note: this presentation represents the views of the presenter, and in most cases, is based on fishway design experience in working for NMFS.

Special thanks to Larry Swenson for the assistance with slide content

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Evolution of NMFS Design Manual

- Fishway designs based on design and operations experience of NMFS engineers and biologists dating back into the 1960's.
- Successful designs retained with improvements made where noted.
- Current manual based on workshop discussions with state and Federal fisheries agencies, Native Tribes and others experienced with fishway design.
- Considered a working document, subject to revision when design improvements are discovered, or biological criteria refined.

Evolution of NMFS Design Manual

- Fishway designs are based on design and operations experience of NMFS engineers and biologists dating back into the 1950's.

Swenson, Meyer and Nordlund?

Fishway Design Development

- NMFS works with anadromous salmonid passage.
- NMFS fishway design manual was developed specifically for anadromous salmonid species.
- Integrating passage of other species (eg. Lamprey, Bull Trout, others) is becoming more prevalent in fishway design work or design modification.
- What works for Pacific Salmon species may or may not work for other species.

NMFS Design Manual – Design Basis

- Based on matching fishway design to biomechanical and behavioral traits
- Conclusive scientific data is sparse for specific criteria/guidelines. Design Manual is based on extracting criteria from successful designs and scientific data where it exists.
- Fishways are expected to pass the weakest swimmers in marginal water conditions.

NMFS Design Manual chapters include:

- Juvenile fish screens and bypass systems
- Upstream adult passage
- Adult traps and handling facilities
- Exclusion barriers
- Culverts and road crossings
- Upstream juvenile passage
- Definitions, design flows, experimental tech development, O&M, temporary facilities, evaluations

NMFS Design Manual – chapters in development include:

- Tide Gates
- Infiltration Galleries
- Reservoir Passage Systems
- Roughened Stream Channels (update)
- Juvenile Traps and Handling Facilities
- Horizontal Screens (exp. Tech development)

NMFS Design Manual – Current Version can be located at:

- http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish-Passage-Design.pdf)

Safe, Timely and Effective Passage

Safe, Timely and Effective Passage

- Safe passage means that fish are passed with facility induced injury and mortality rates less than agreed to for a specific project.
- Timely passage means that median delay is low, as defined for a specific project.
- Efficient passage means that passage opportunity is continually maintained by vigilant operation and maintenance.

Safe Passage

- In general, passage facilities are designed to minimize the potential for injury or mortality.
- For example, this involves design scrutiny looking for strike potential, high turbulence and shear, safe landing zones, predation potential, rejection of passage facility, delay mechanisms etc.
- For a passage facility designed using NMFS criteria, injury and mortality are rare. However, designs fail and stuff happens….

Safe Passage

- Example: PIT detector data for Rock Island, Rocky Reach and Wells dam fish ladders show that 99.9% of the active spring Chinook adult migrants are passed safely upstream.

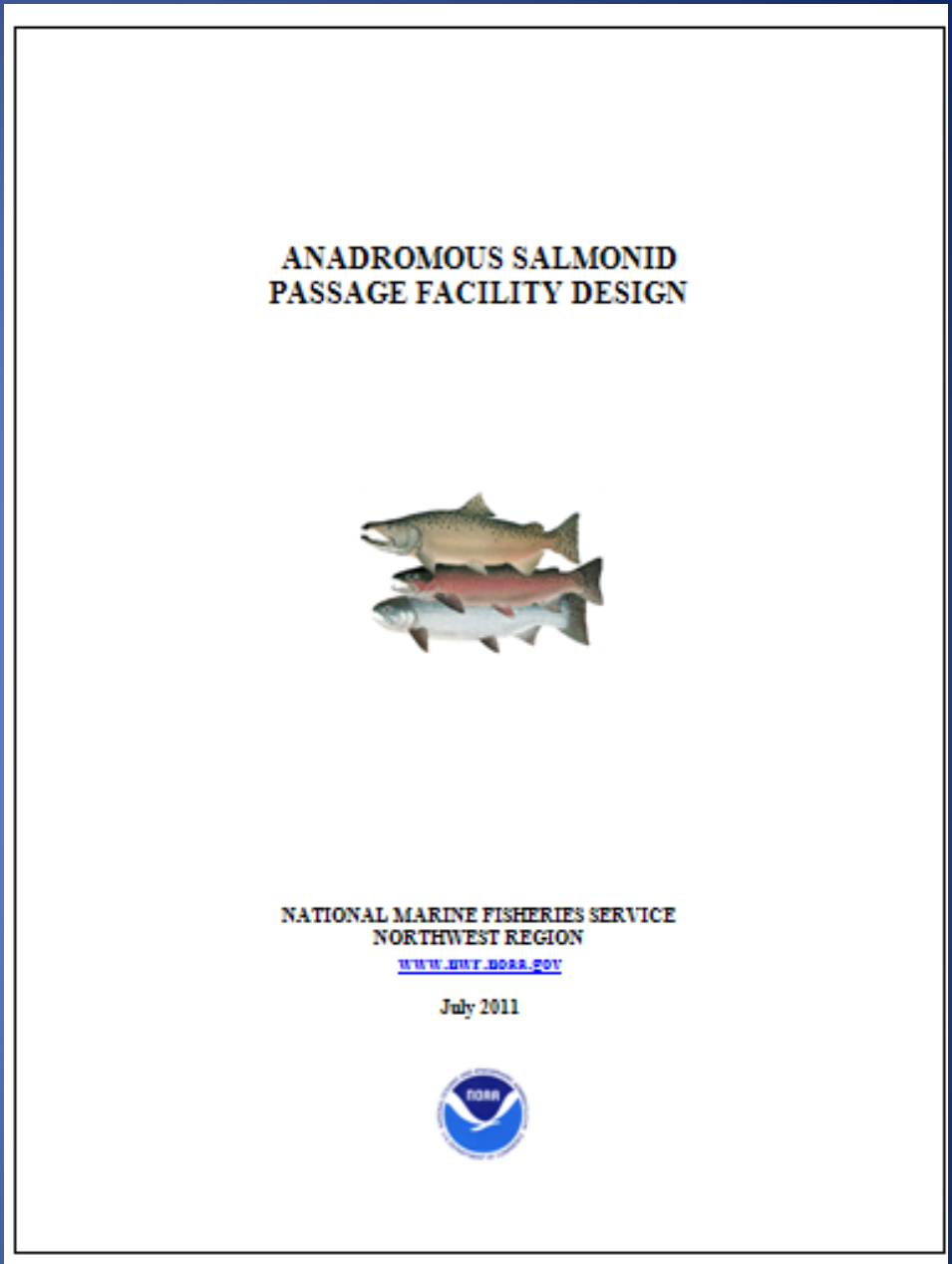
Timely Passage

- Rule of Thumb: the median delay (time between tailrace entry and ladder exit) for active migrants will be measured at less than 24 hours, with no more than 5% of the test fish taking longer than 1 week to pass.

Effective Passage

- Example: Effective passage means that facilities are maintained and operational per design criteria at any time during the passage season.

NMFS Fishway Design Manual



ANADROMOUS SALMONID
PASSAGE FACILITY DESIGN

NATIONAL MARINE FISHERIES SERVICE
NORTHWEST REGION
WWW.NWR.NOAA.GOV

July 2011

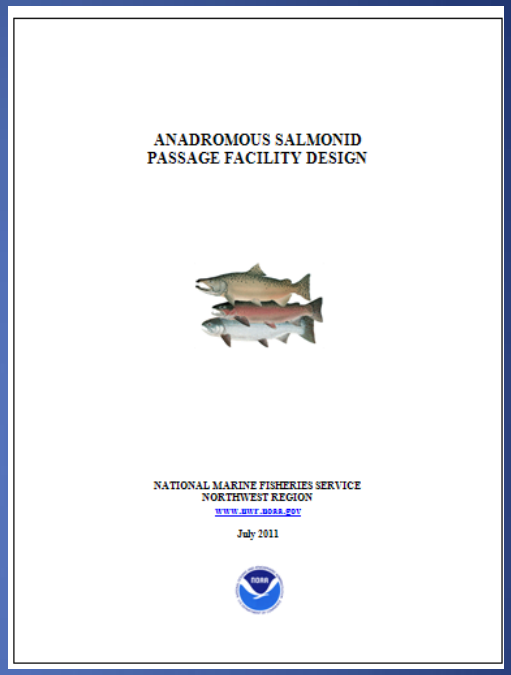
http://www.nwr.noaa.gov/Salmon-Hydropower/FERC/upload/Fish-Passage-Design.pdf

Using NMFS design manual

- Original intent - document was developed for “batch processing” of similar passage facilities under a single programmatic Biological Opinion.

- Frequently used as a starting point for design criteria for a wide variety of fish passage projects.

- Design criteria and guidelines may require some degree of modification for specific sites.


ANADROMOUS SALMONID
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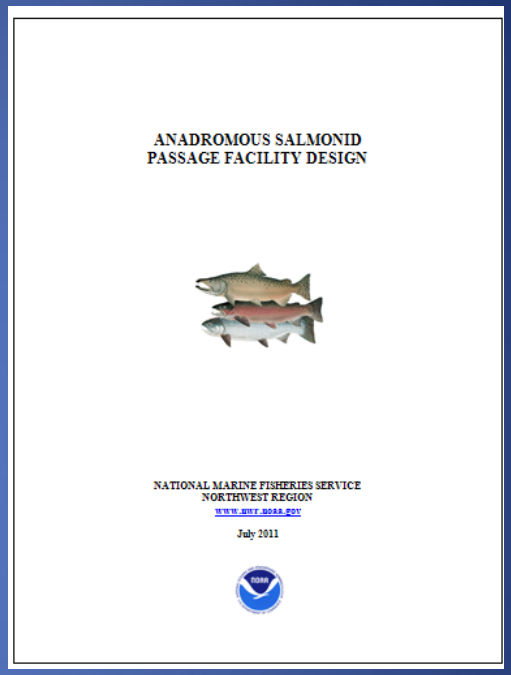
Using NMFS design manual

- All state fisheries agencies, U.S. Fish and Wildlife Service and some Tribal fishery agencies have adopted NMFS screen criteria for use in waters containing anadromous salmonids, through collaborative process and consensus vote of the Fish Screen Oversight Committee of the Columbia Basin Fish and Wildlife Authority.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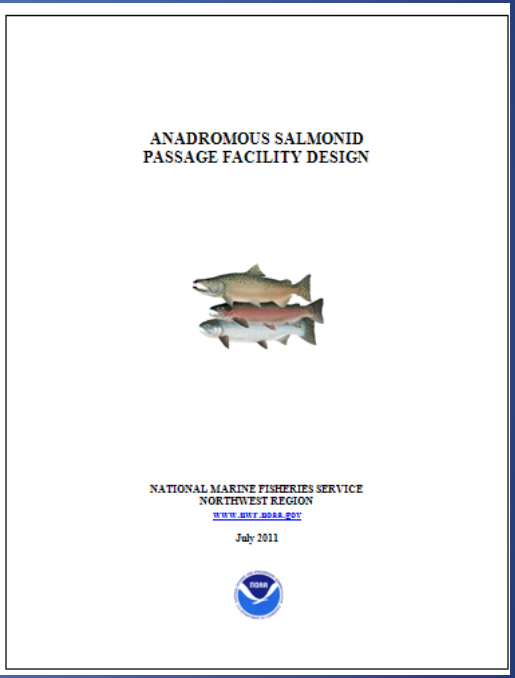
- Other sections of the document do not have this same consensus endorsement, although design inconsistencies regarding agency criteria for anadromous salmonids are somewhat rare.

Applying NMFS criteria to specific projects

- Criteria are specific biologically based standards that cannot be changed without a written waiver from NMFS. Criteria are preceded by the word "must."

- A criterion can not be changed unless there is site-specific biological rationale for doing so.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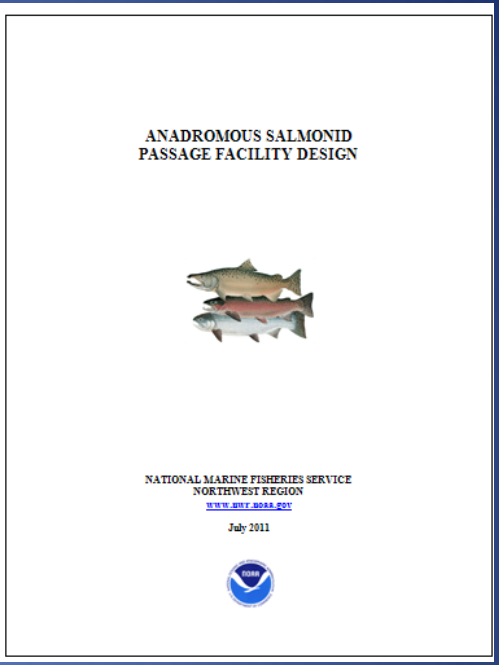
Applying NMFS guidelines to specific projects

- A guideline is a range of values or a specific value that may change when site conditions are factored into the conceptual design. Guidelines are preceded by the word "should."

- Guidelines should be followed in the fishway design unless site-specific information indicates that a different value would provide better fish passage conditions or solve site-specific issues.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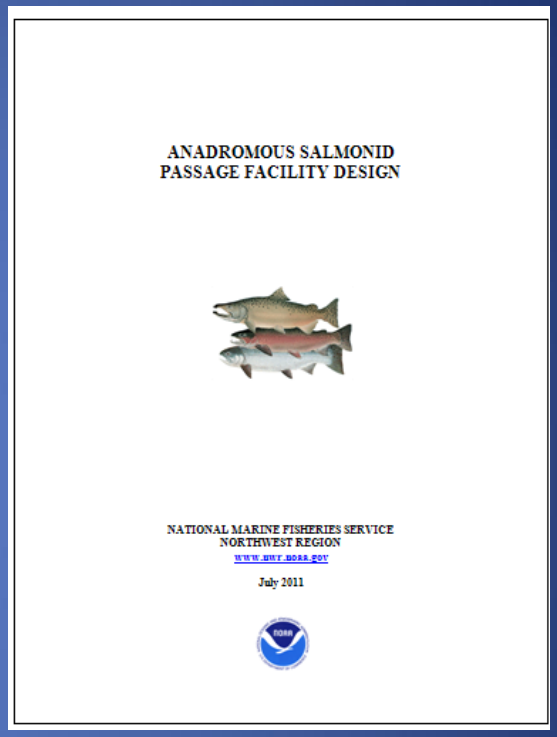
Applying NMFS design manual to specific projects

Bottom Line - It is up to the design developer to provide compelling site specific evidence in support of any proposed waiver of criteria or modification of a guideline for NMFS approval early in the design process.



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Fishway Design Flows

Determining Fishway Design flows

1. Locate daily average streamflow records (USGS, BOR, other) and import into Excel.
2. Determine Passage Season by discussion with agency fish biologists.
3. Truncate daily flow records outside of Passage Season.
4. Sort remaining records by highest to lowest flow, keeping date associated with flow record.
5. Fishway Design Flow range is the stream flow range where all criteria should be achieved with design.
6. NMFS Design Flow Ranges: 95% - 5% exceedence flows (90% of Passage Season flows)

Example: Determining Fishway Design flows

For example, if the truncated flow records contain 2000 records:

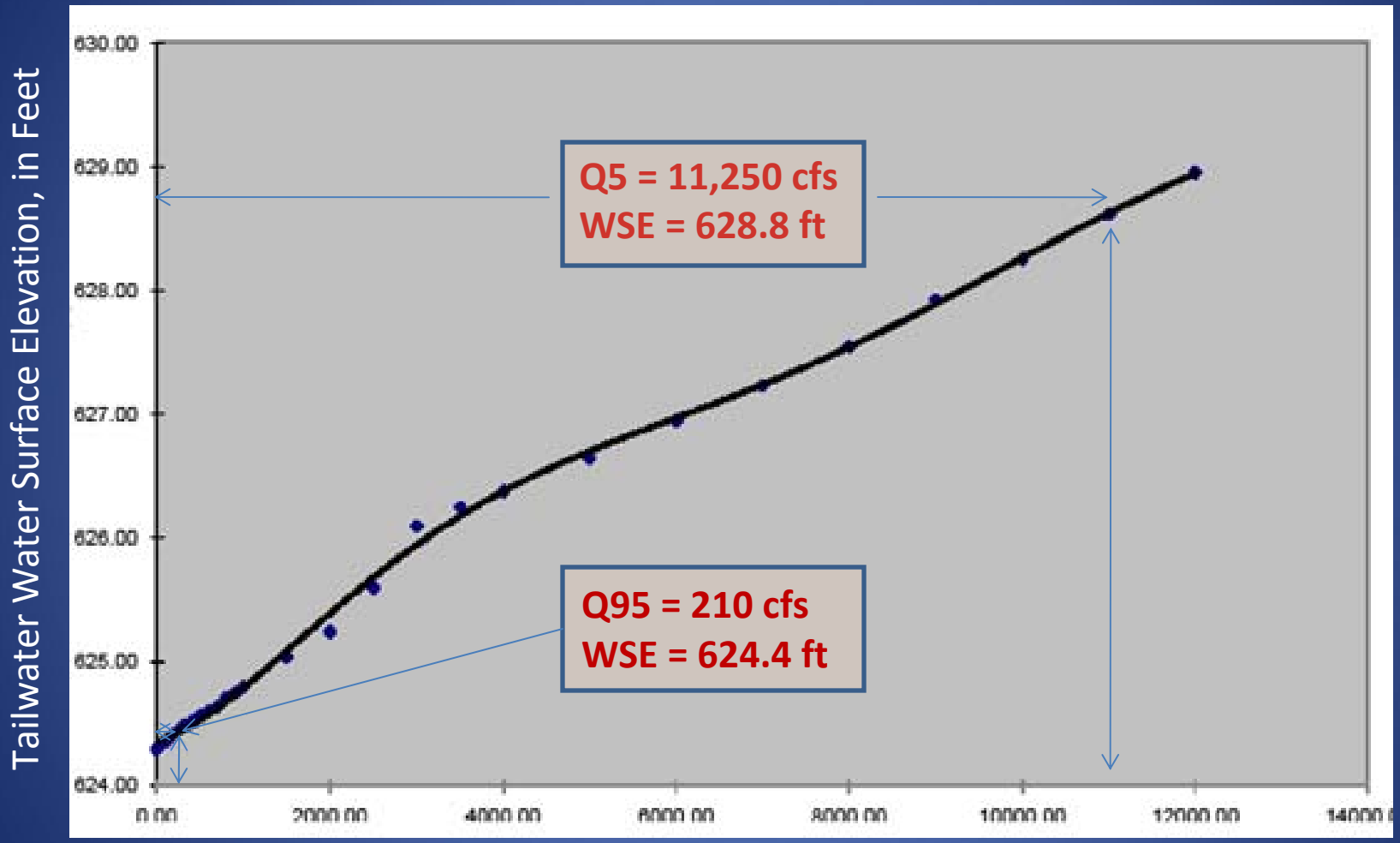
- The 5% exceedence flow (Q5) is the streamflow exceeded 5% of the days in the passage season.
- The 95% exceedence flow (Q95)is the streamflow exceeded 95% of the days in the passage season.
- Q5 is the 100th highest flow record of the sorted data set. (0.05 x 2000 = 100)
- Q95 is the 1900th highest (or 100th lowest) flow record of the sorted data set. (0.95 x 2000 = 1900)

Example: Using 5% and 95% exceedence flow range in fish passage design

- Assessment using previously demonstrated method yields: Q5 = 11,250 cfs and Q95 = 210 cfs.

- Using a tailwater rating curve, the water surface elevations for an adult fishway entrance can be determined.

Some Dam Tailwater Rating Curve



More About Design Flow guidelines

- Modification of the design flow guideline should be considered because specific migration timing information may contract, expand or shift the design flow range.
- Providing optimal passage for 90% of the passage season does not mean that 10% of the run is not passed.

In some rivers, passage may be impaired by extreme flow events.

Note: Flow in lower ladder is flowing UP the ladder

Bonneville Dam – May31, 1948 985,000 CFS

More About Design Flow guidelines (continued)

- Passage of the entire run is expected to occur as streamflow conditions improve.
- Passage facilities can provide passage beyond the design flow range even if the facility is not within design criteria.

Hydraulic Calculations in Fishway Design

Hydraulics - Objective:

Given: hydrology, biological criteria, and the design criteria --

Determine: size and hydraulic capacity of key fishway components

Three Goals:

Understand:

1. Forms of energy in water.
2. Energy loss in moving water.

Calculate:

3. Flow rates and energy losses in:
   a) Weirs
   b) Orifices and Slots
   c) Pipes
   d) Open Channels

And another Big Goal: Understand the meaning of the terms “hydrology” and “hydraulics”

Hydrology relates to the science dealing with the occurrence, circulation and distribution of water on the earth's lands and in the atmosphere.

Hydraulics refers to fluids in motion.

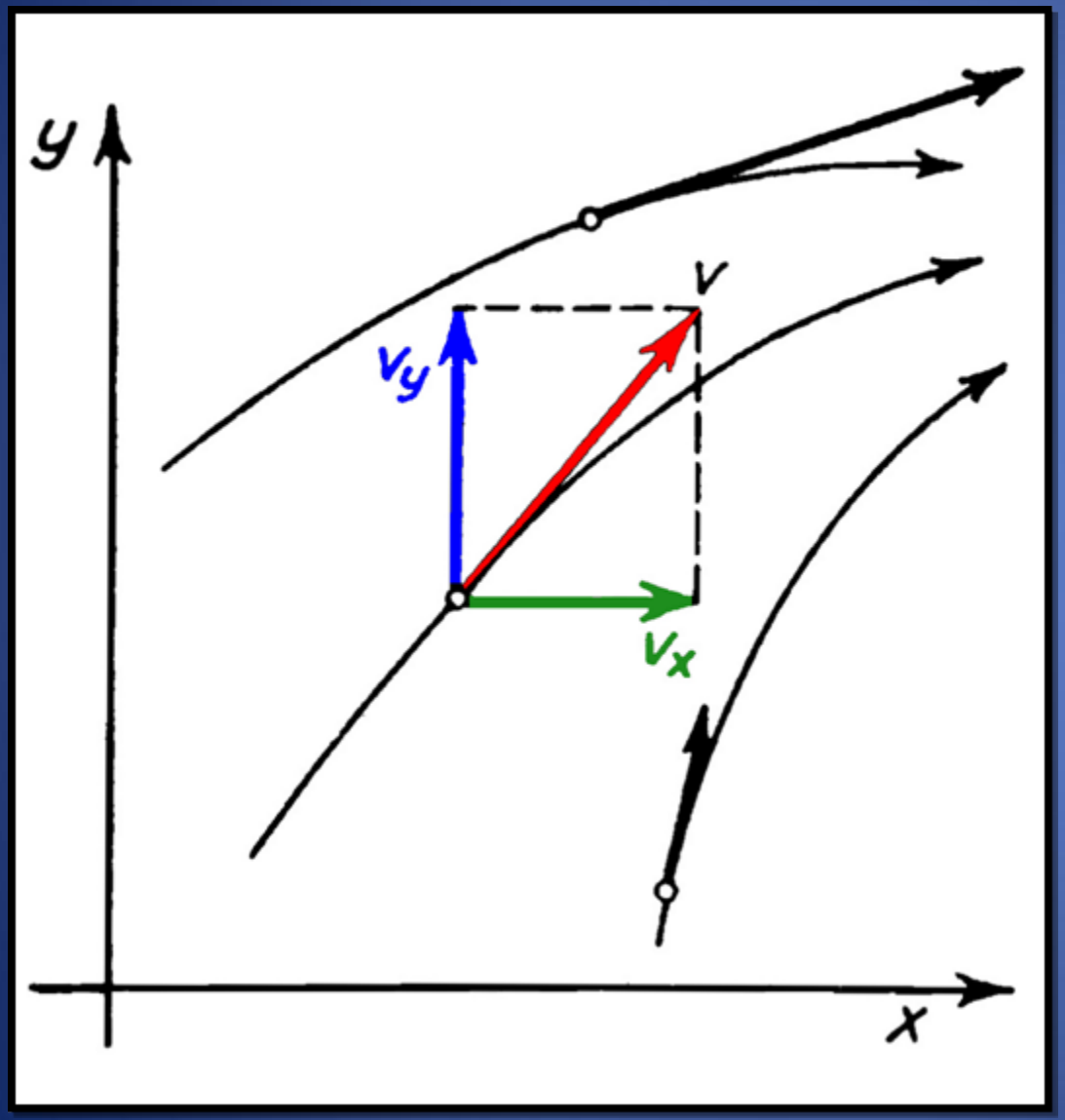
Hydrology doesn't make fish barriers (unless streamflow gets too low or too high), but hydraulics can create a barrier.

Basics of Fluid Mechanics

1. Streamlines
2. Stream tubes
3. Energy Concepts
4. Turbulence and Energy Loss

Streamlines

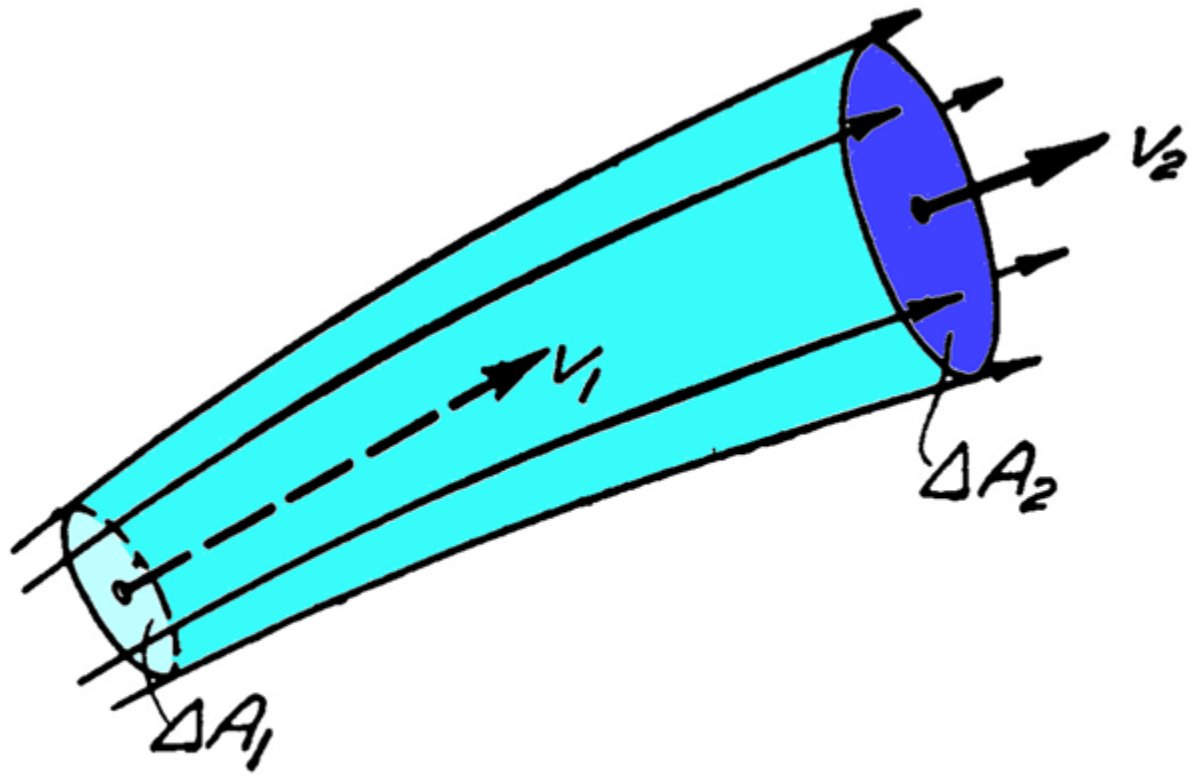
Streamlines



Instantaneous direction of flow at every point over its entire length . . .

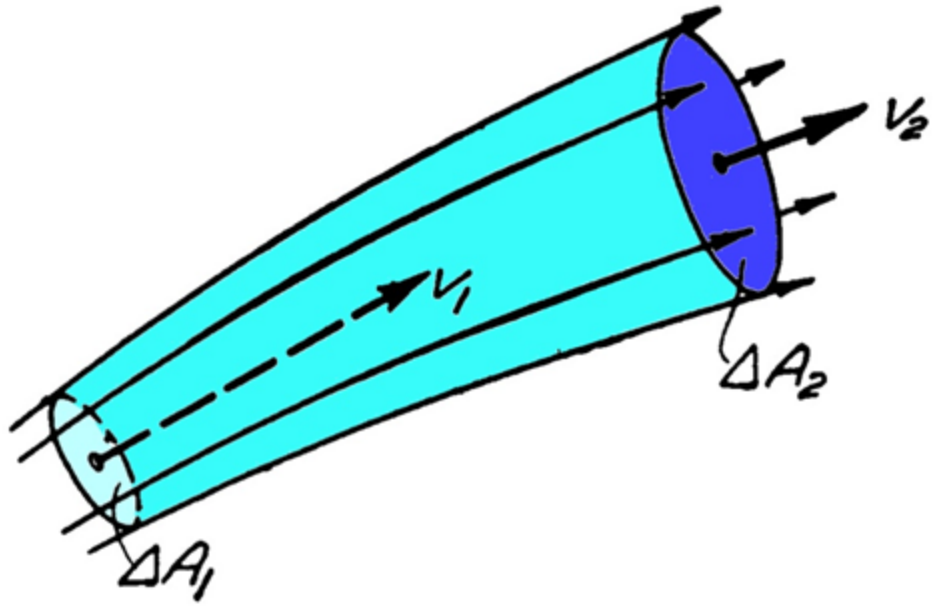
. . . Flow has no component at right angles to the streamline

Stream Tubes



Velocity Variation through a Stream Tube

Stream Tubes



Velocity Variation through a Stream Tube

$$Q = \mathbf{D}A_1V_1 = \mathbf{D}A_2V_2$$

Hydraulic Analysis . . .

It's all about the **energy!**

. . . usually on the basis of
unit weight or *unit volume*

Hydraulic Analysis . . .

What is **energy?**

. . . the ability to do work, or move weight through a distance

A (very) Little Review: Properties of Water

$$Density = \frac{Mass, m}{Volume} = \rho$$

$$Weight = mg \quad where \ g$$
$$= gravitational\ acceleration$$

$$Unit\ Weight = \frac{Weight}{Volume} = \gamma$$

$$Viscosity = Resistance\ to\ Shear = \mu$$

$$Kinematic\ Viscosity = \frac{\mu}{\rho} = \nu$$