Fishway Effectiveness, Design, & Prescriptions

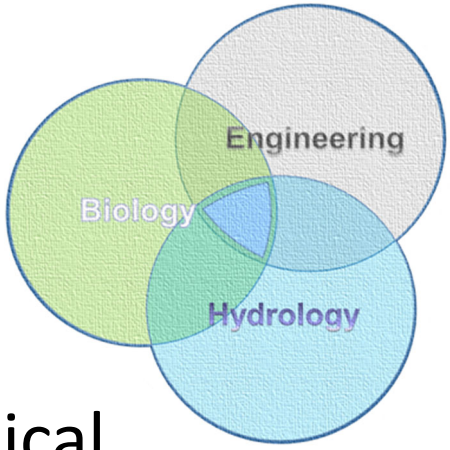
at Hydroelectric Facilities

Brett Towler, USFWS

USFWS North Atlantic Appalachian Region

Fish and Aquatic Conservation

Fish Passage Engineering



"…to provide consulting services and technical assistance for federal programs and external agencies related to the planning, design, construction and operation of fish passage facilities in the (legacy) Northeast region"

FY 2020 (to date) Hydropower Engineering Support

- *48 hydro projects (FERC and non-jurisdictional)*
- *14 different U.S. states and Canada*
- *12 T&E species and resident fish*

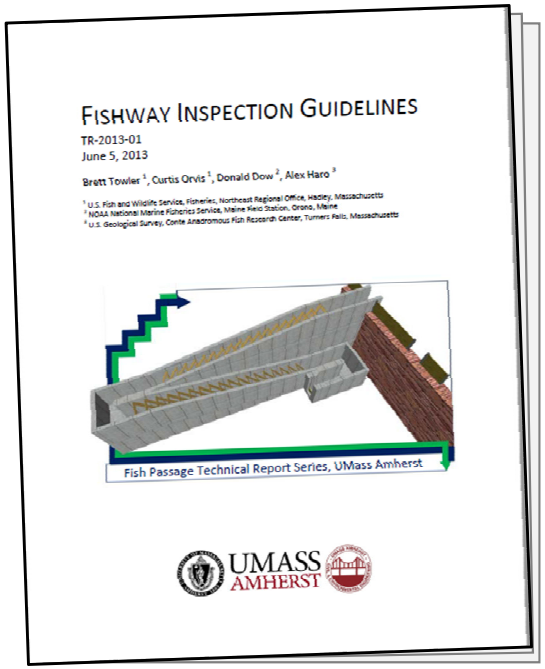
USFWS North Atlantic Appalachian Region

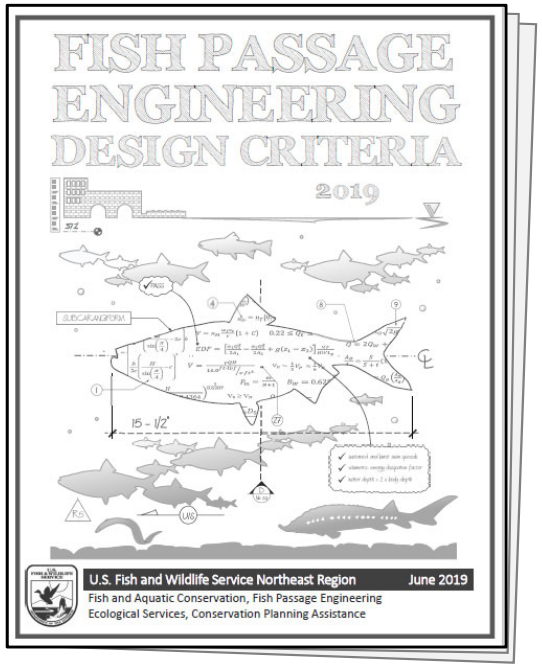
Fish and Aquatic Conservation

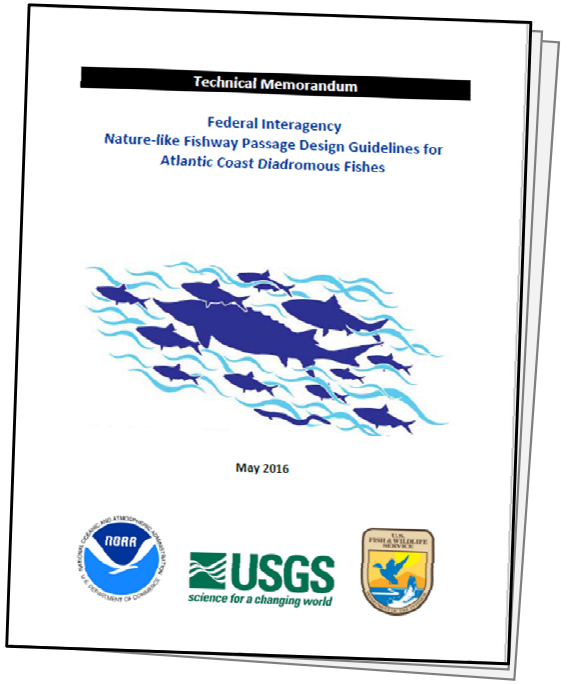
Fish Passage Engineering

Types of support we typically provide…

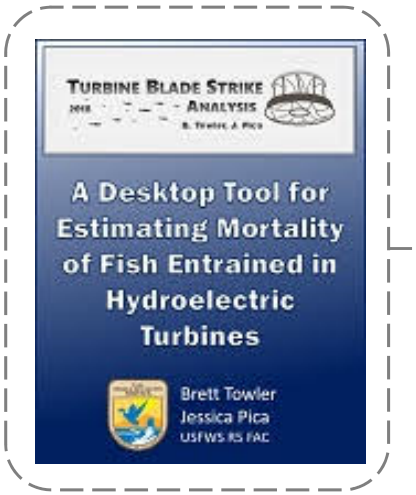
- Study development
- Fishway assessment
- Hydrologic analyses
- Conceptual design
- Fishway Design review
- Quality control
- New tech evaluations
- Fishway inspections
- Hydraulic modeling
- Energy modeling
- Criteria development
- and more!

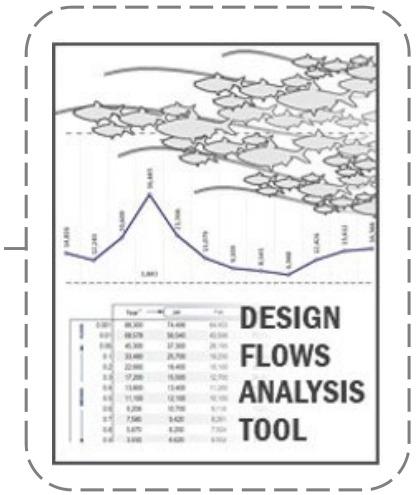






www.fws.gov/northeast/fisheries/fishpassageengineering.html





- **Fishway Effectiveness**
  - What does this term mean?
  - How is it **measured** and how is it **applied**?
- **Fishway Prescriptions**
  - What (technical) information should be in an Rx?
- **Fishway Design**
  - What is the **process**?
  - When does design and implementation occur?

This is an engineer's perspective, but fish passage is truly interdisciplinary!

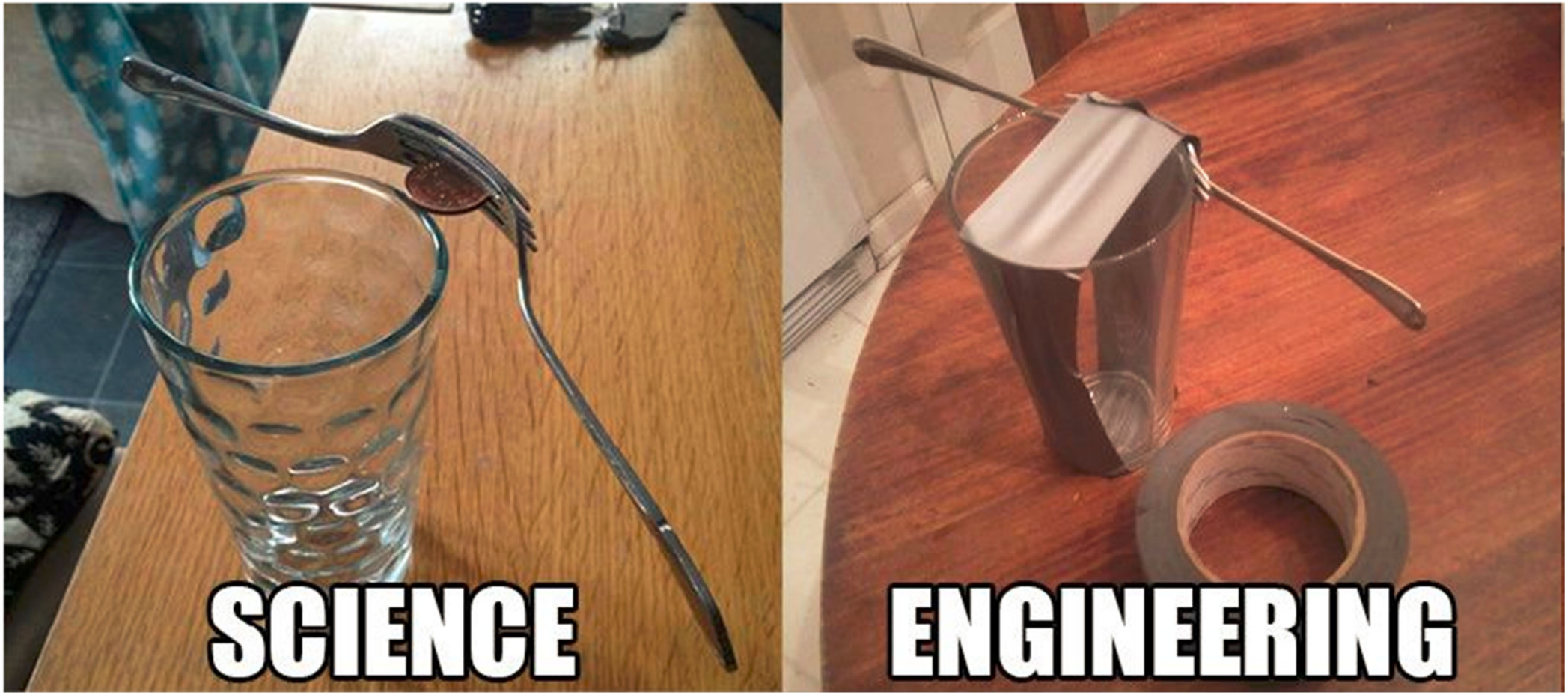
interdisciplinary

in·ter·dis·ci·pli·nar·y /ˌin(t)ərˈdis(ə)pləˌnerē/

adjective

- *combining or involving two or more academic disciplines or fields of study*

"First, build your team." Successful fish passage needs **both scientists and biologists**… because we often look at the same problem *in very different ways*!


SCIENCE
ENGINEERING

Fishway Effectiveness

Meaning and **origin** of "effectiveness" in the context of fish passage

A characterization, a standard, or a metric for comparison?

Applying the Safe, Timely and Effective terms to fishway design

Quantifying effectiveness through monitoring and evaluation

for FERC jurisdictional projects in the U.S.:

"That the items which may constitute a 'fishway' under Section 18 for the **safe** and **timely** upstream and downstream passage of fish shall be limited to physical structures, facilities, or devices necessary to maintain all life stages of such fish, and project operations and measures related to such structures, facilities, or devices which are necessary to ensure the **effectiveness** of such structures, facilities, or devices for such fish."

16 U.S.C. § 811 (1994)

Meaning and origin of “effectiveness” in the context of fish passage

A **characterization**, a **standard**, or a **metric** for comparison?

Applying the Safe, Timely and Effective terms to fishway design

Quantifying effectiveness through monitoring and evaluation

characterization of effectiveness

Qualitative or *quantitative* assessment of factors that may contribute to successful function or improvement of fishway

EXAMPLE

Maintenance procedures inadequate to ensure effective operation through season

a standard for effective passage

- *quantitative* standards set to achieve goals; fishway is **effective** if the standard is met
- elements of a Performance Standard:

PROPORTION – TIME – EFFECT

- e.g., 95% US passage w/in 2 days with no latent mortality for adult fish approaching within 200 meters of dam

Performance Standard for Upstream Passage of Atlantic Salmon

The performance standard for upstream fish passage effectiveness is 95% at Milford and West Enfield. That is, 95% of adults at Milford and West Enfield that enter the project tailraces (defined as 200 meters downstream of the lowermost turbine discharge structure), locate the fishway entrance, and pass within 48 hours. This criterion applies to ambient water temperature conditions below 23ºC, which are not anticipated to delay upstream Atlantic salmon migration. Higher water temperature is expected to delay migration such that the 48-hour passage time may not be achieved. Upstream migrants will be evaluated for signs of trauma6, loss of equilibrium, or descaling greater than 20% of the body surface on a case-by-case basis and efforts will be made to determine the cause. Fish displaying these injuries or signs of trauma could be categorized as not having passed safely and will be considered failures.

from Milford HEP FERC #2534, Species Protection Plan, June 2012

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PROPORTION

95% of adults

200 meters downstream

pass within 48 hours

TIME

descaling greater than 20%

EFFECT

from Milford HEP FERC #2534, Species Protection Plan, June 2012

comparing effectiveness of options

- Effectiveness is often used as metric in *comparing* passage options.
- "*no less protective*" with respect to **safe**, **timely**, and **effective**.

(but how do we apply that…?)

Meaning and origin of “effectiveness” in the context of fish passage

A characterization, a standard, or a metric for comparison?

Applying the Safe, Timely and Effective terms to **fishway design**

Quantifying effectiveness through monitoring and evaluation

Safe, Timely, and Effective

HAZARDS	BIOLOGICAL CAPACITY	EFFICIENCY
Limiting mortality and injury to fish	Capacity to move fish and minimize delay	Efficiency in attraction, entry and passage rates
Has this technology (e.g., fish lift, Ice Harbor ladder) demonstrated the ability to move target species safely?	*Is the facility sized to provide passage to the design population (i.e. fish per year) without causing delay?*	*Can the location, attraction flow, and design achieve the efficiency required by fisheries managers?*
FISHWAY TYPE	FISHWAY SIZE	FISHWAY EFFICACY

Safe, Timely, and Effective

HAZARDS

Limiting mortality and injury to fish

EXAMPLE

Will turbine entrainment through a large Kaplan or a dedicated bypass into a deep plunge pool result in greater mortality?

BIOLOGICAL CAPACITY

Capacity to move fish and minimize delay

EXAMPLES

How large do fishway pools need to be to pass 1 million alewife per year? How large must a lift holding pool be?

EFFICIENCY

Efficiency in attraction, entry and passage rates

EXAMPLE

How much attraction water is need to ensure fish find and enter a fishway adjacent to the powerhouse?

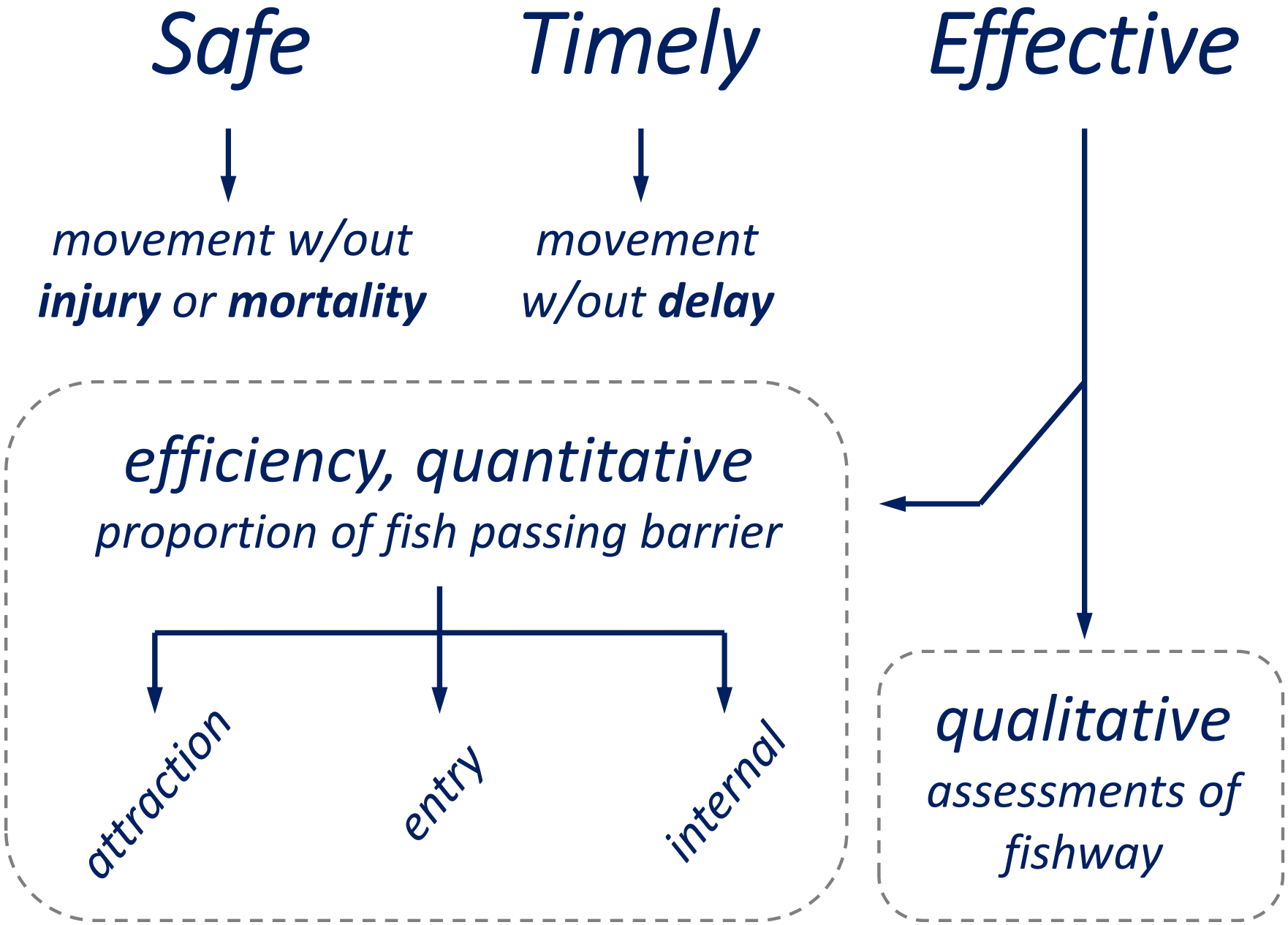
*STE provide context for the **primary** fishway design parameters.*

Meaning and origin of “effectiveness” in the context of fish passage

A characterization, a standard, or a metric for comparison?

Applying the Safe, Timely and Effective terms to fishway design

Quantifying effectiveness through **monitoring** and **evaluation**


Safe
Timely
Effective
movement w/out injury or mortality
movement w/out delay
efficiency, quantitative
proportion of fish passing barrier
attraction
entry
internal
qualitative
assessments of fishway

Why Evaluate a Fishway?

- **Verify performance** (*hydraulic and biological*)
- Define **operational range**
- Identify and **correct problems**
- **Gain information** for improving fishway (*lessons learned*)
- **Assess success** in meeting management/restoration/recovery goals

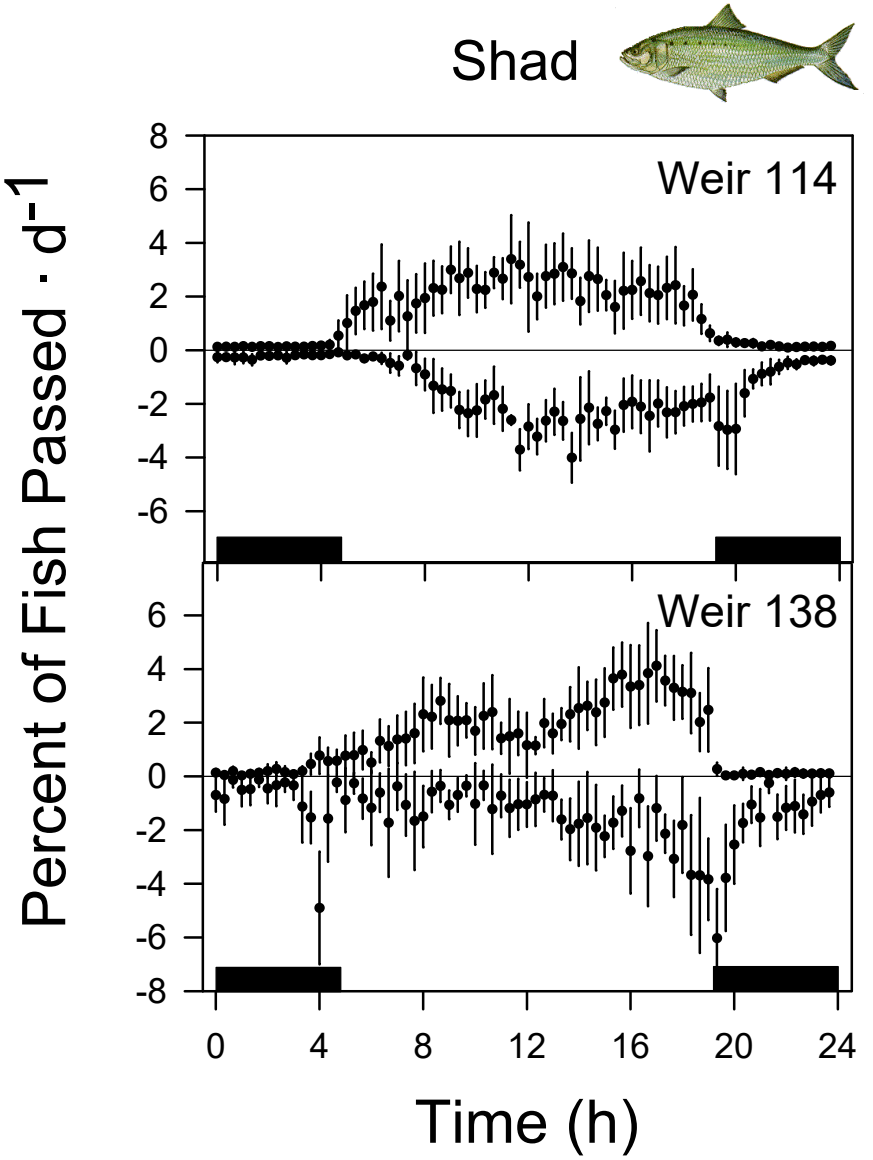
Post-Construction Evaluation: Hydraulics & Surveying

e.g., design conformity, hydraulic performance, photo document

Biological Evaluation: Observation/Capture

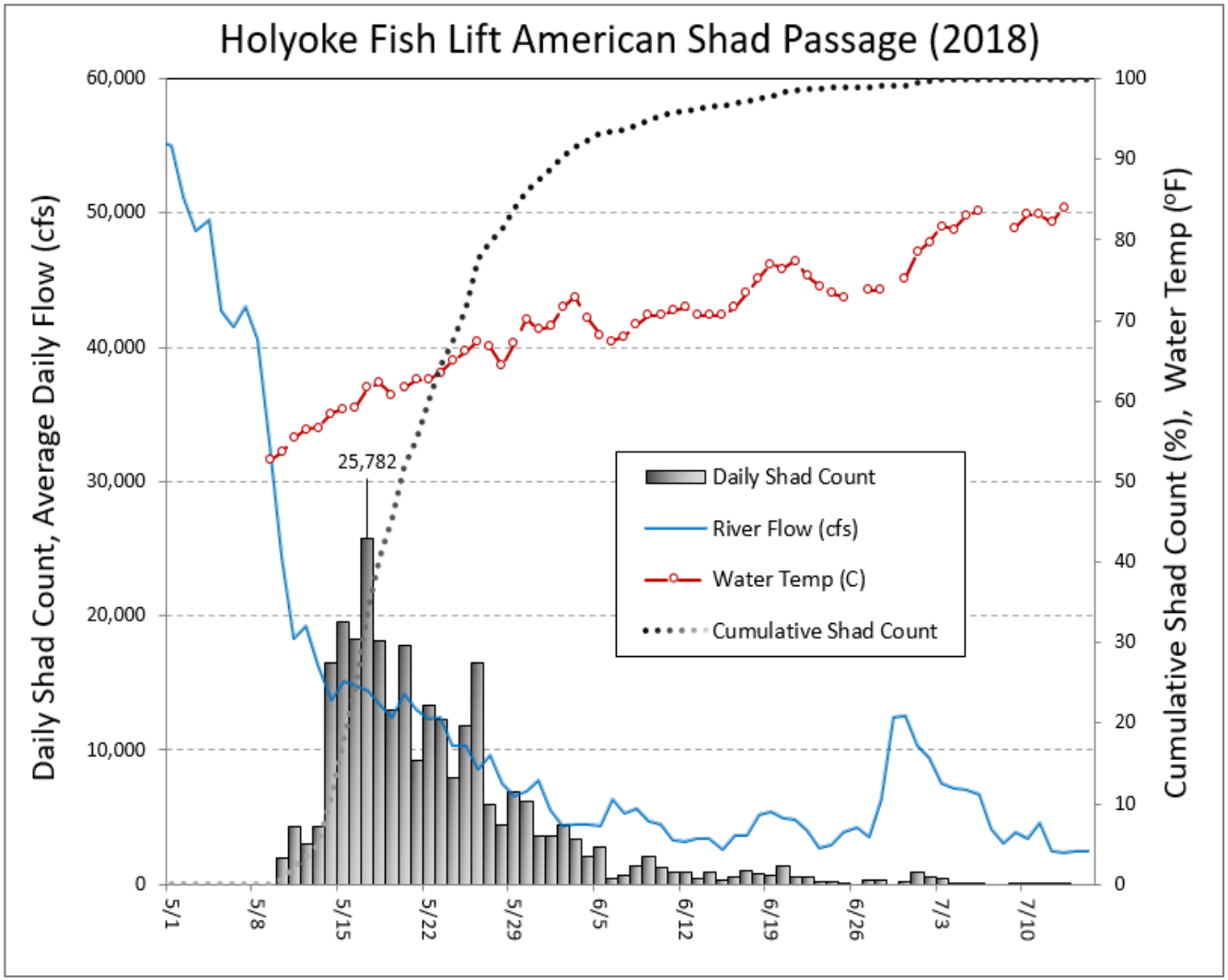
e.g., trapping, netting, electrofishing, video, hydroacoustics

Biological Evaluation: Observation/Capture



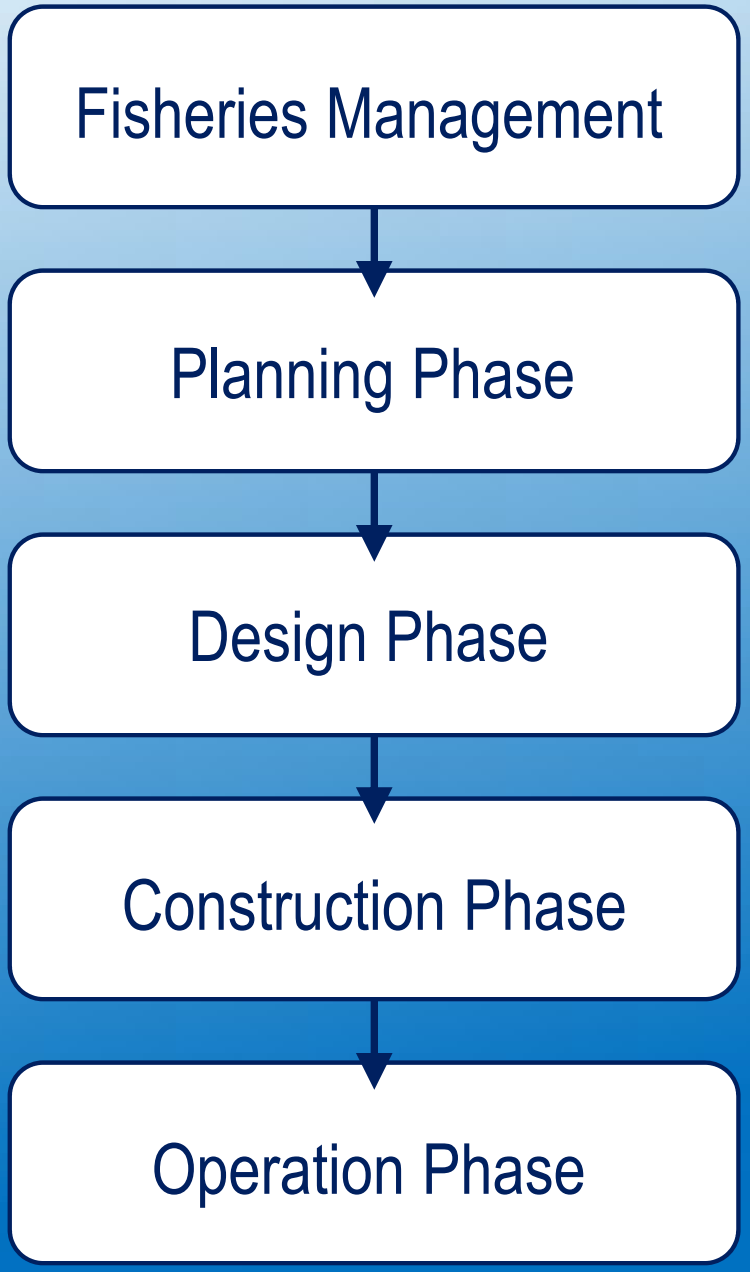
Biological Monitoring

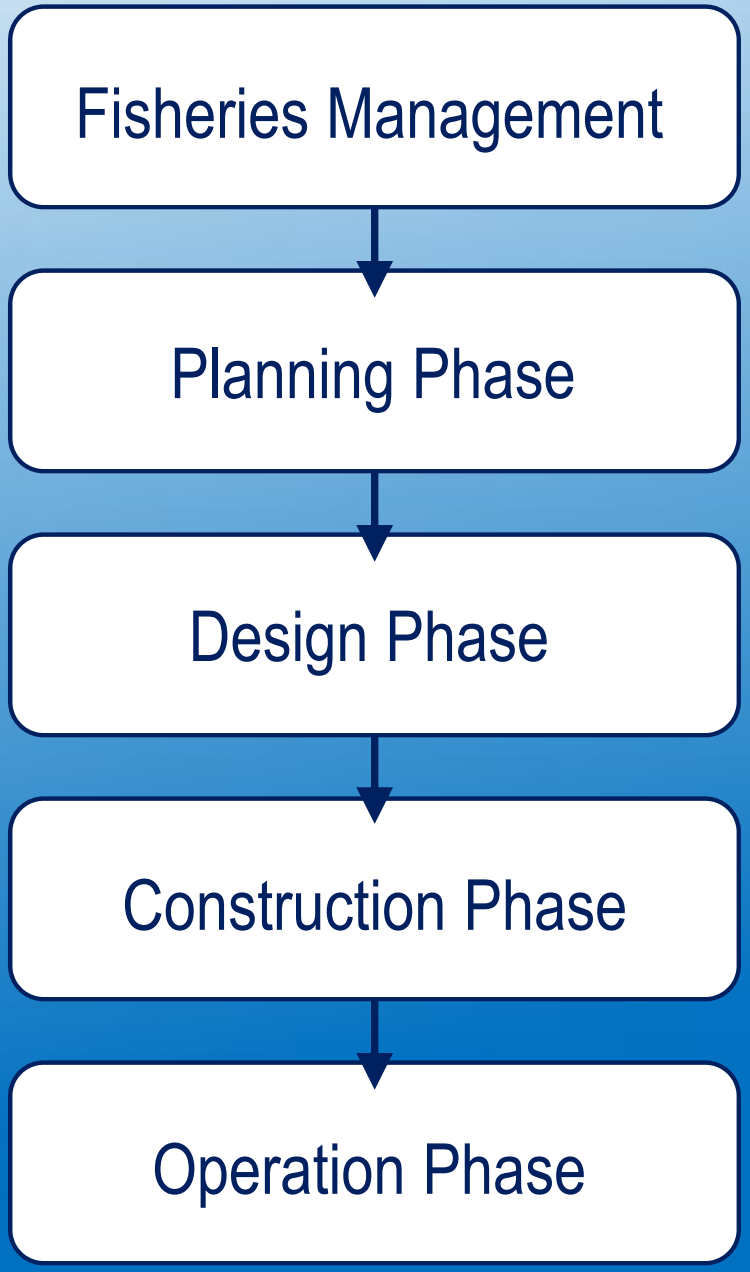
e.g., live counting, video counting



Fishway Design

Considerations on the design and implementation of fish passage.


Fisheries Management
Planning Phase
Design Phase
Construction Phase
Operation Phase


Fisheries Management
Planning Phase
Design Phase
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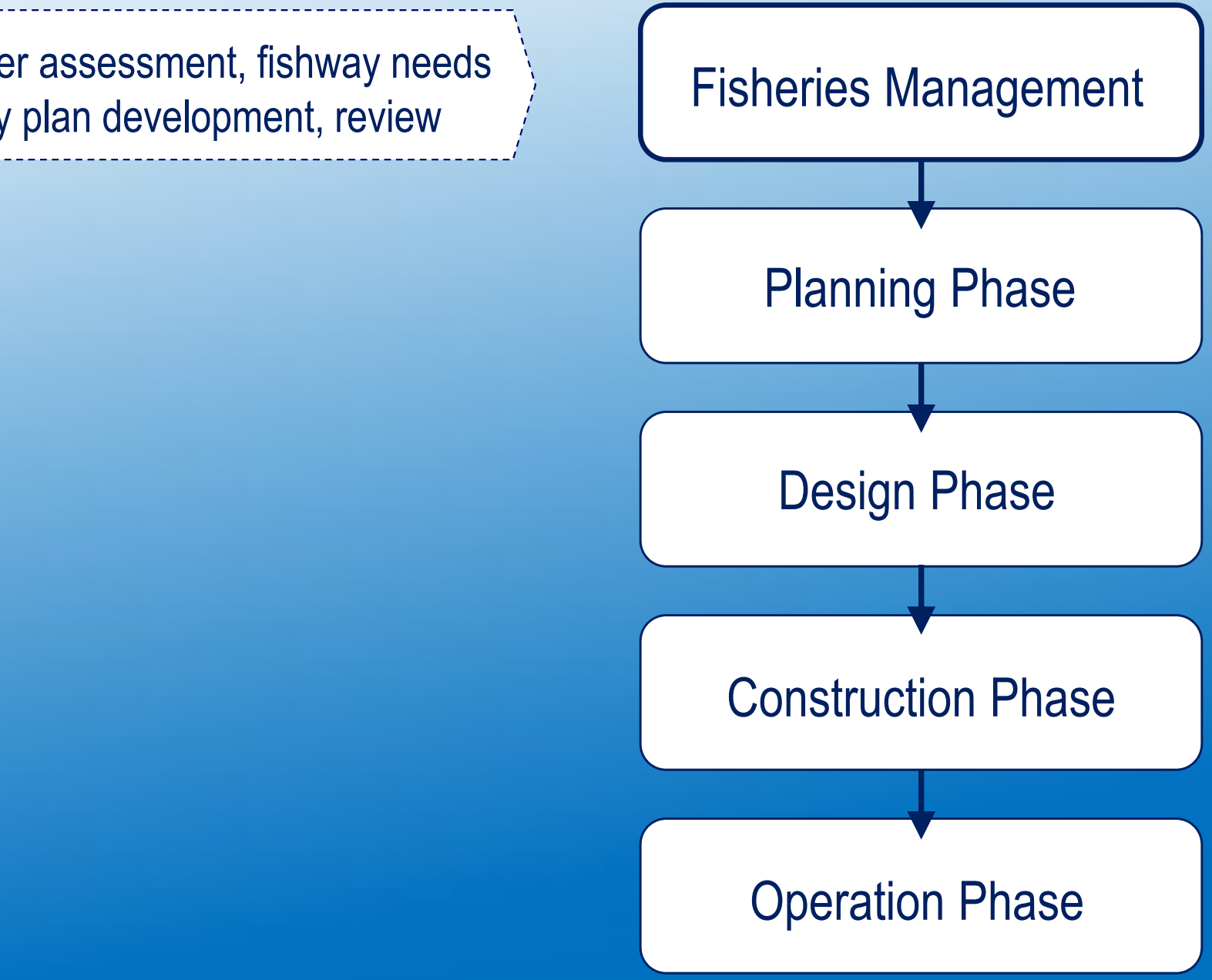
Operation Phase

- Barrier assessment, fishway needs
- Study plan development, review



Desktop studies to evaluate impact of turbine entrainment on fish

Influence of turbine speed and size of fish

EXAMPLE

Kaplan turbine

- diameter = 10 ft
- 5 blades
- head = 50 ft
- discharge = 1,800 cfs
- efficiency 93%

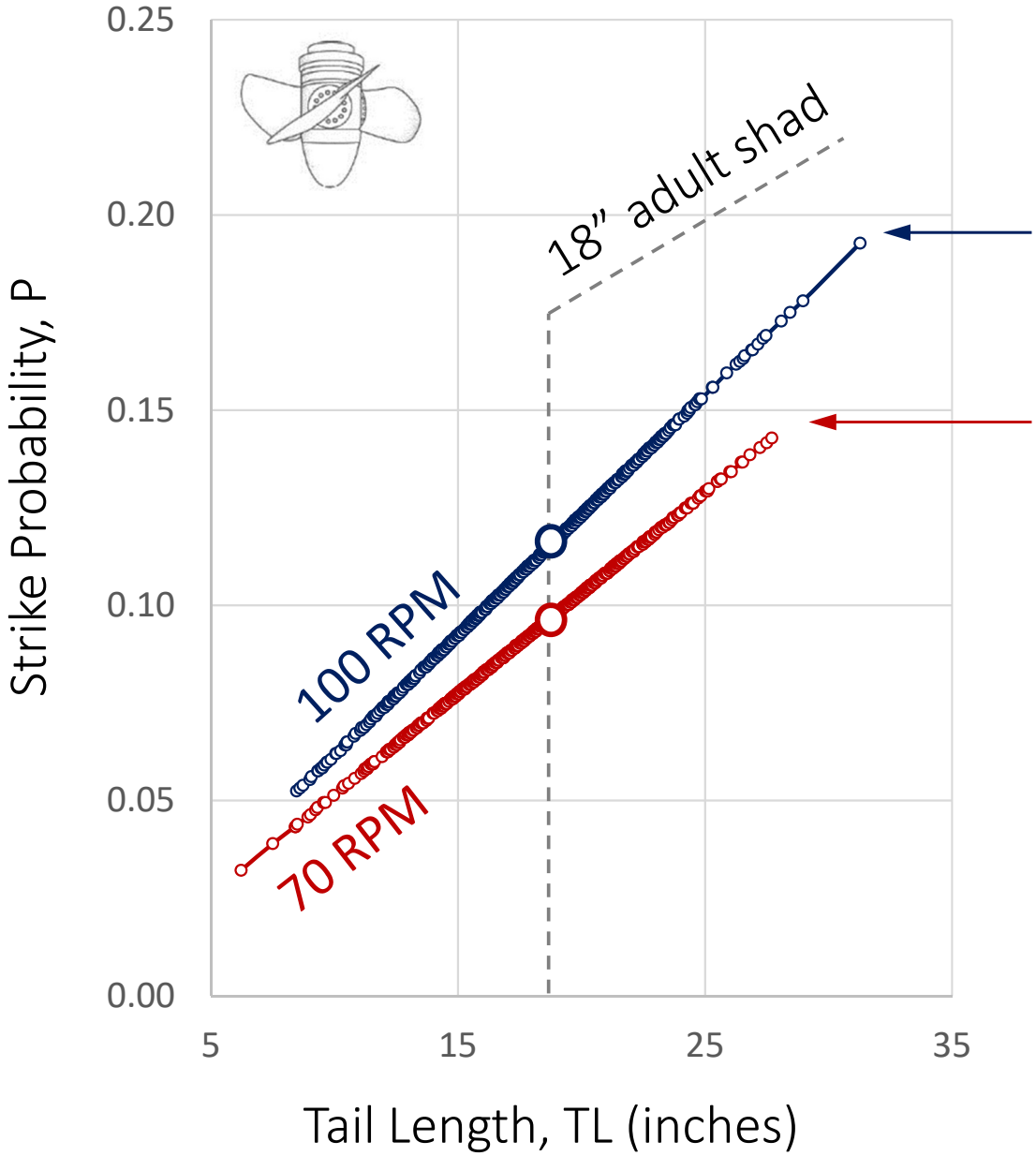
*What is the influence of **runner speed** on fish mortality?*

*What is the influence of **tail length** on fish mortality?*

Kaplan runner

Desktop studies to evaluate impact of turbine entrainment on fish

Influence of turbine speed and size of fish



11.1% blade strike probability for 18" shad at 100 rpm

9.3% blade strike probability for 18" shad at 70 rpm

mortality increases with turbine speed and (roughly) linearly with TL

- Barrier assessment, fishway needs
- Study plan development, review

- Fishway capacity and sizing
- Hydrology, operating range
- Alternatives, conceptual designs

Fisheries Management

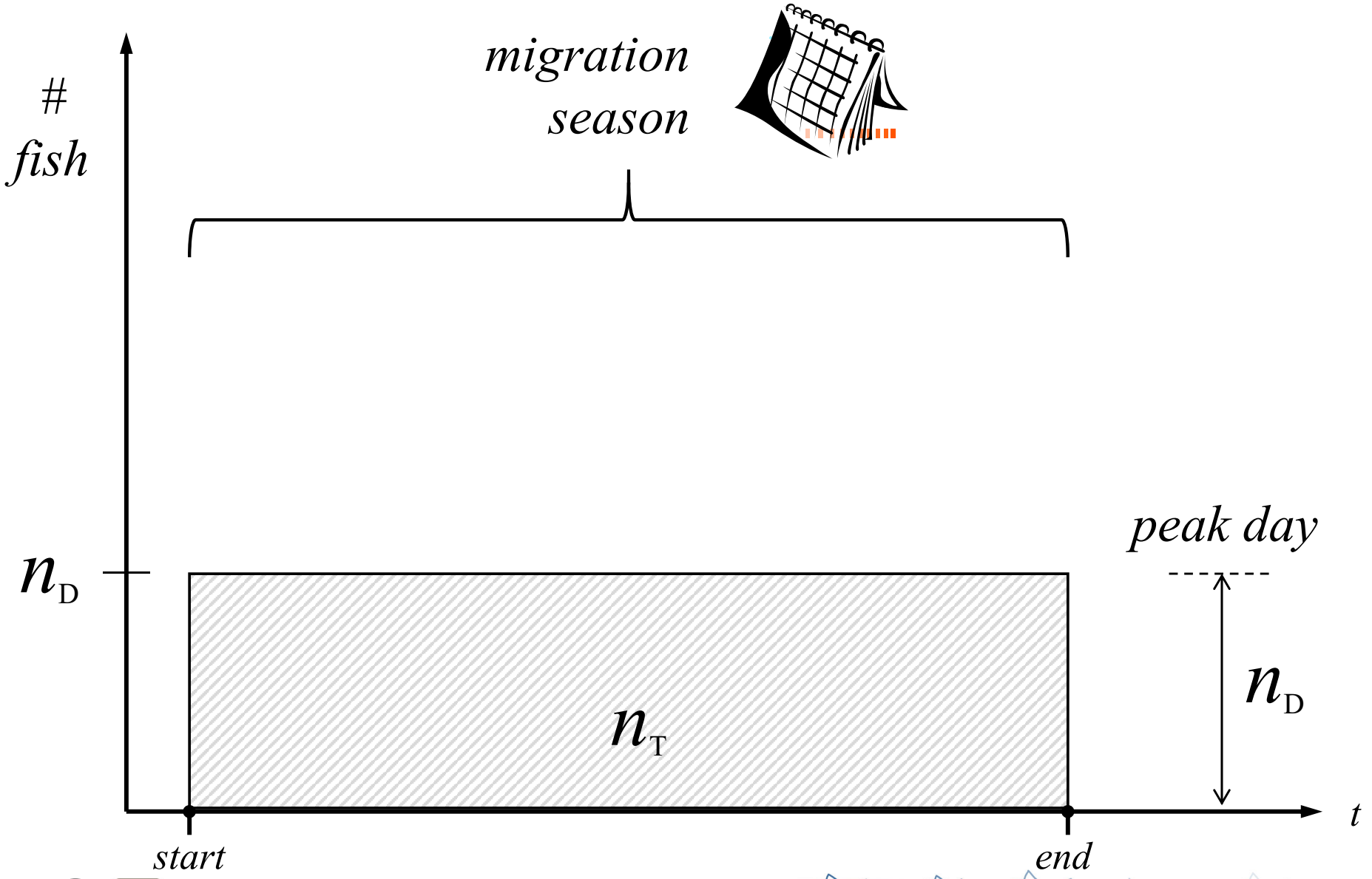
Planning Phase

Design Phase

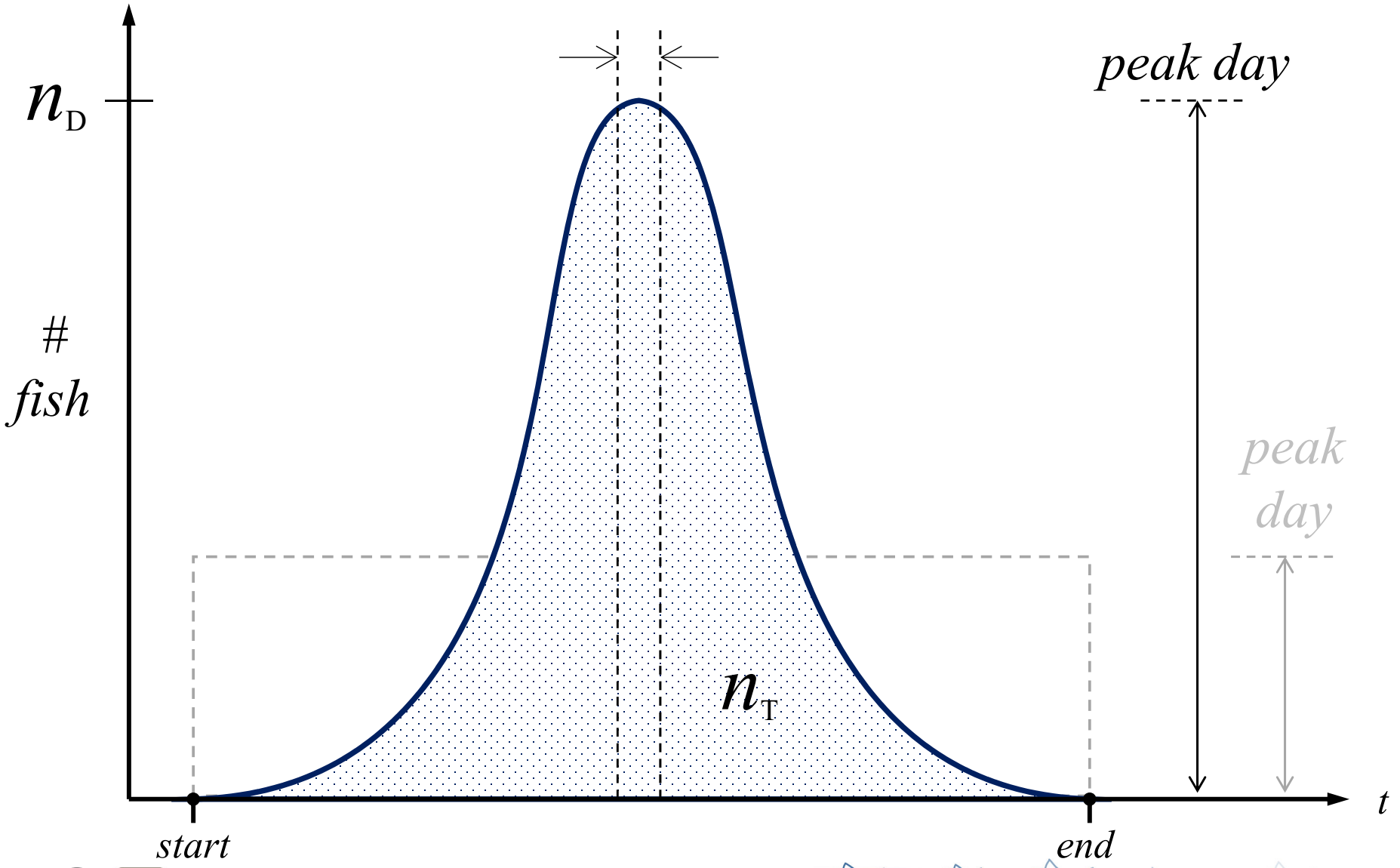
Construction Phase

Operation Phase

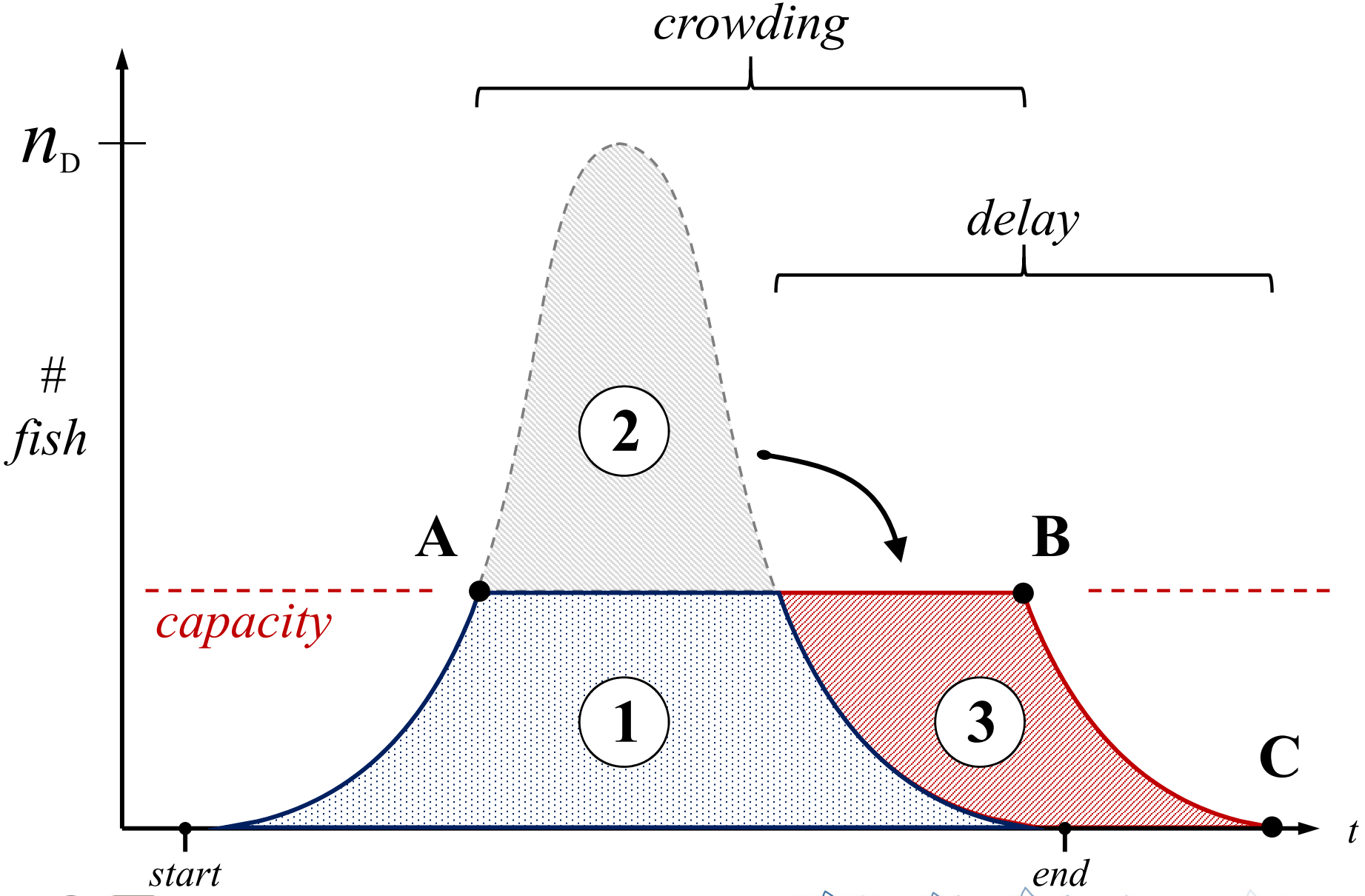
Idealized Uniform Fishway Loading



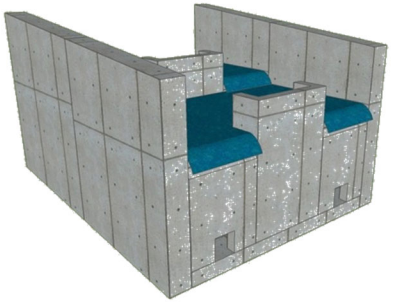
Idealized Peak Fishway Loading



Consequences of Inadequate Fishway Capacity



Capacity of an Ice Harbor Ladder



Determine the capacity of a 5’ deep, 8’ by 10’ Ice Harbor ladder designed to pass American shad. Assume the impacts of coincident runs of other species contribute to a 15% non-target species allowance.

$$n_H = 400 ft^3 \left(\frac{60\ min}{1\ hr}\right) \frac{0.250\ min^{-1}}{(4\ lbf)\left(0.5 \frac{ft^3}{lbf}\right)[115\%]} \cong 2{,}600 \frac{fish}{hr}$$

Assuming the peak hourly loading is approximately 10% of the peak daily loading, and (based on regression analyses) the peak day typically passes 8% of the overall annual run.

$$n_T = \left(2600 \frac{fish}{hr}\right)\left(\frac{1\ hr}{10\%\ day}\right)\left(\frac{1\ day}{8\%}\right) = 325{,}000\ fish$$

- Barrier assessment, fishway needs
- Study plan development, review

- Fishway capacity and sizing
- Hydrology, operating range
- Alternatives, conceptual designs

- Preliminary, 30% Design review
- Final, 90% Design review

Fisheries Management

Planning Phase

Design Phase

Construction Phase

Operation Phase

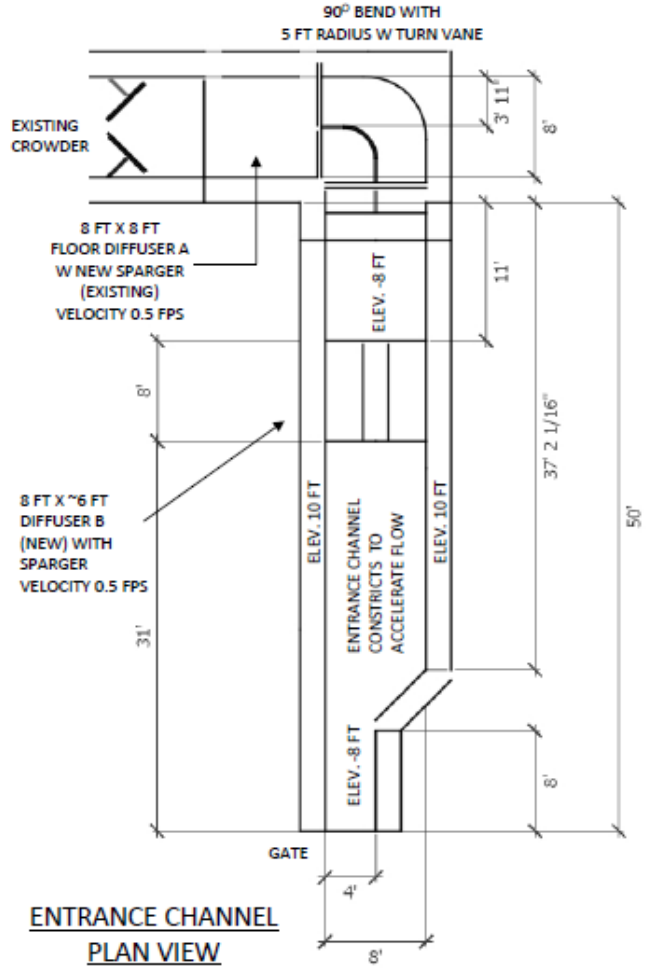
Evaluation of Design Concept Using CFD

- Main-stem river in northern New England
- Existing 1990s era fish lift plagued by attraction issues
- Settlement provided resources to address issues with a new fishway entrance extension
- Service engineers and biologists developed new design concept
- Licensee (and its consultants) used computational fluid dynamics (CFD) model to evaluate hydraulics prior to starting 30% design

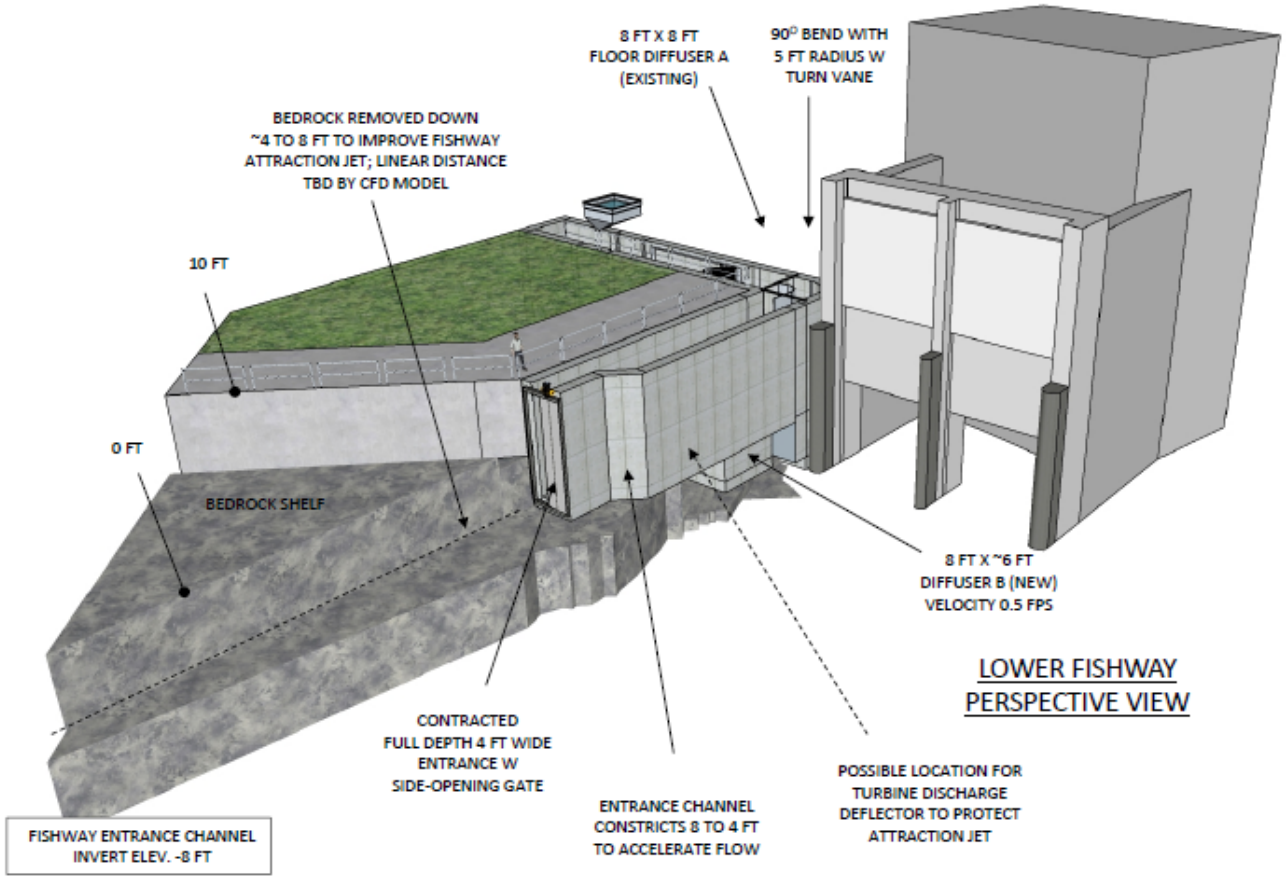

powerhouse
turbine discharge disrupts fishway's attraction jet
bedrock at bank disrupts fishway's attraction jet
fish lift entrance

SHAD SALMON TROUT STURGEON EEL ALEWIFE LAMPREY BLUEBACK

CONCEPTUAL DRAFT ISSUED FOR COMMENT



ENTRANCE CHANNEL
PLAN VIEW



LOWER FISHWAY
PERSPECTIVE VIEW

GENERAL NOTES:

1. DIMENSIONS, ELEVATIONS, AND DETAILS OF EXISTING CONSTRUCTION ARE BASED ON HISTORICAL DRAWINGS.
2. VERTICAL DATUM IS UNVERIFIED; MATCHES ELEVATIONS IN HISTORICAL DRAWINGS.
3. FOR REVIEW OF CONCEPT ONLY; NOT FOR CONSTRUCTION
4. OPTION 3 IS A MOD. OF OPTION 2 DEVELOPED BY BROOKFIELD/ALDEN, DIST. 10/23/2019

* FOR ALL EXISITING DIMENSIONS AND ELEVATIONS, REFER TO "EAST CHANNEL EXCAVATION PLAN", 11/29/1993, and "EAST CHANNEL – LOWER FLUME CONCRETE PLAN & SECTIONS", 12/2/1993

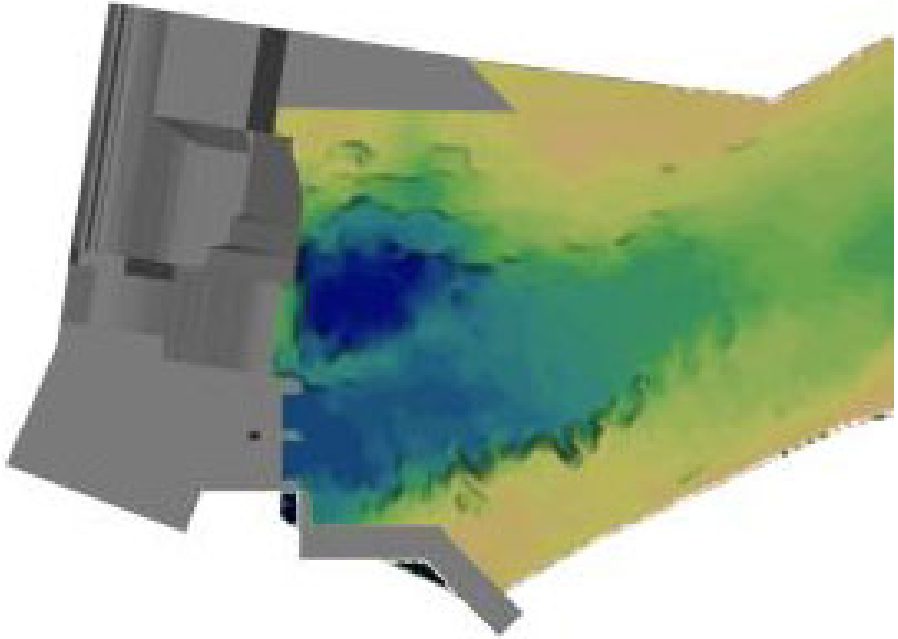
DRAWING TITLE	DATE	BY	CHK	APPD
	11/26/2019	BT		

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
NORTH ATLANTIC-
APPALACHIAN REGION
FISH AND AQUATIC CONSERVATION
FISH PASSAGE ENGINEERING

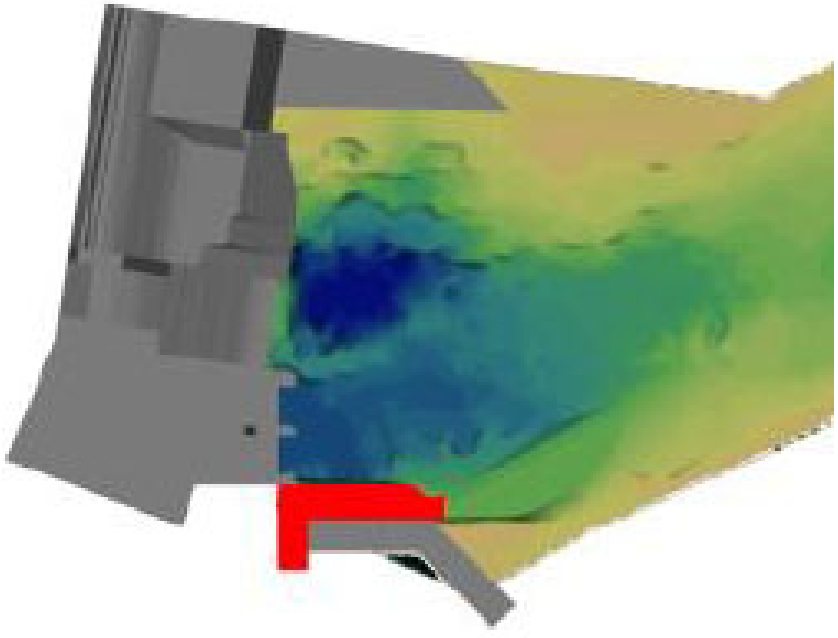
DWG. NO.: SHEET 2 of 2

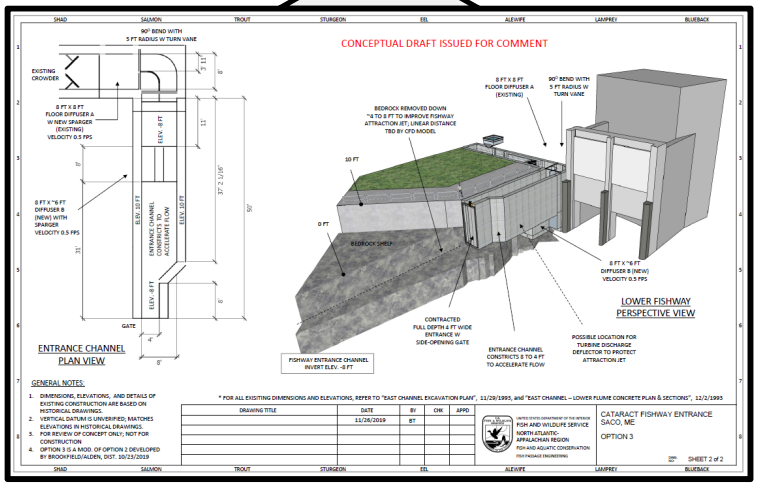
SHAD SALMON TROUT STURGEON EEL ALEWIFE LAMPREY BLUEBACK

Service proposed alternative



bathymetry in model



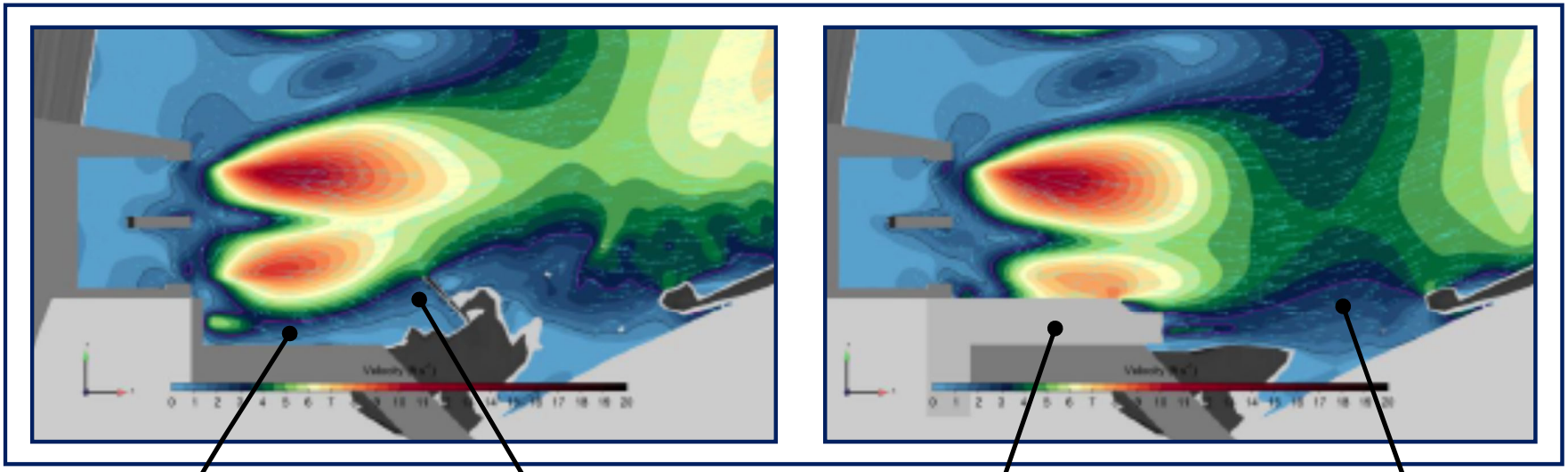


existing conditions

proposed alternative

CFD to Evaluate Design Options

existing conditions *proposed alternative*



turbine disrupts attraction jet

bedrock disrupts attraction jet

entrance extension

improved attraction jet

Significance the 30% Design drawings

- show how the functional requirements will be met;
- indicate the designer's solution to technical problems; and
- show compliance with design criteria or provide justification for noncompliance

The 30% design should show "form and function" of the fish passage!

- Barrier assessment, fishway needs
- Study plan development, review

- Fishway capacity and sizing
- Hydrology, operating range
- Alternatives, conceptual designs

- Preliminary, 30% Design review
- Final, 90% Design review

- Construction review
- Documentation, Commissioning
- QC, Evaluation

Fisheries Management

Planning Phase

Design Phase

Construction Phase

Operation Phase

- Barrier assessment, fishway needs
- Study plan development, review

Fisheries Management

- Fishway capacity and sizing
- Hydrology, operating range
- Alternatives, conceptual designs

Planning Phase

- Preliminary, 30% Design review
- Final, 90% Design review

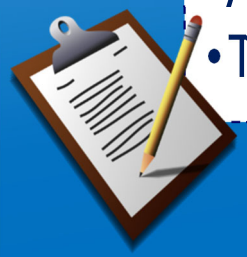
Design Phase

- Construction review
- O&M, Commissioning
- QC, Evaluation (shake-down)

Construction Phase

- Annual inspection, stewardship
- Assist w compliance activities
- Technical support

Operation Phase



Inspections covered in detail during the May 6th webinar!

Prescriptions

What design information should be included in a Section 18 prescription?

Recommendations on Fishway Prescriptions:

- Include only primary design parameters
  - fishway type (fish lift or 4-foot wide Denil)
  - location (at right abutment or at PH)
  - attraction flow (how many cfs?)
  - fishway capacity (# fish per year)
  - operational constraints (river flows, dates of operation)
  - and more, as necessary

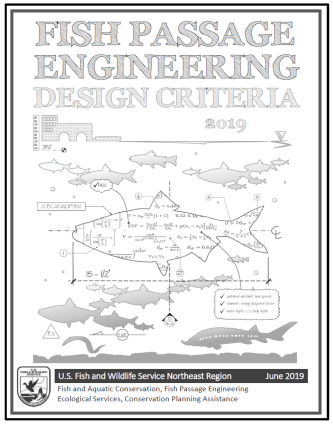
Not an exhaustive list!

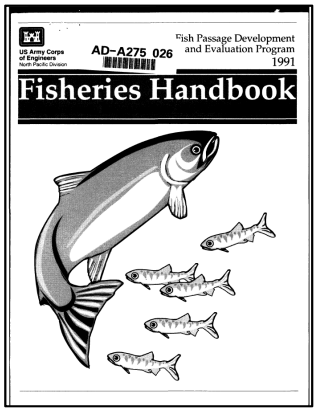
Recommendations on Fishway Prescriptions: *(continued)*

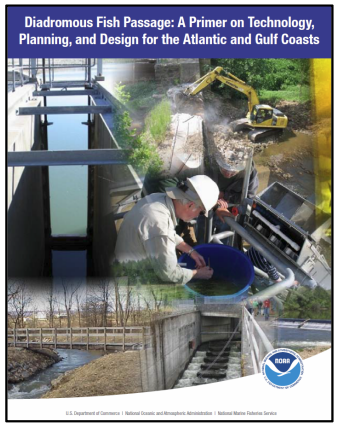
- Be cautious about including secondary design parameters (e.g. velocity over weirs)
  - Without careful QC, you risk requiring design values that conflict with each other
  - You may unintentionally inhibit innovation
- Require agency approval at both the 30% and 90% design stages
  - This will create opportunity for agency to provide input into the secondary design parameters

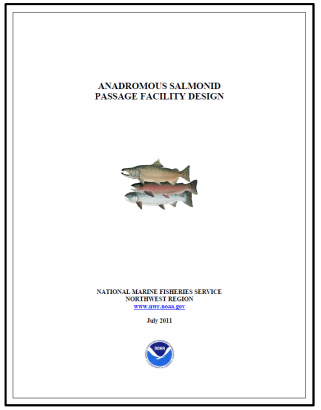
Recommendations on Fishway Prescriptions: *(continued)*

- As a default, consider referring to an established agency criteria or standard
  - Ideally, established agency criteria is not itself prescriptive but provides transparent guidance to licensee of agency expectations (best practices)









Summary

- In fish passage, the terms “effective” and “effectiveness” *are used different ways* through design, construction, and operational phases
- Fishway design is a *multi-step process*; the critical phase for agency input is at the *30% design drawings*
- Recommend including only *primary design parameters* in a Rx; *primary parameters influenced by STE*; secondary input should be handled through design process

Questions?

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