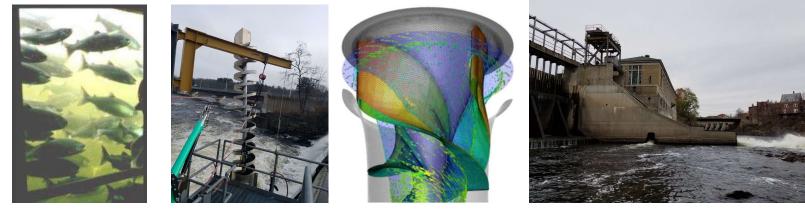


Waterpower. Signature HYDRO BASICS COURSE

JULY 10-11, 2023 // Charlotte, North Carolina, USA

INSTREAM FLOWS AND FISH PASSAGE



Dan Parker and Steve Amaral



a verdantas company

Co-located with: HYDROVISION

Organized By: HYDRC

Instream Flows and Fish Passage Presentation Outline

- Types of Fish
- Instream Flows

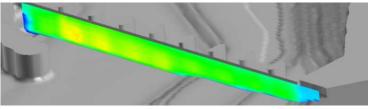




Fish Passage



 Tools for Developing Effective Mitigation





Types of Fish LIFE HISTORY STRATEGIES

Potamodromous, Anadromous, and Catadromous (Oh my!)

- Potamodromous: Complete entire life cycle in freshwater
- Anadromous: Spawn and rear in freshwater, mature in marine environment
- Catadromous: Spawn in marine environment, rear and mature in freshwater

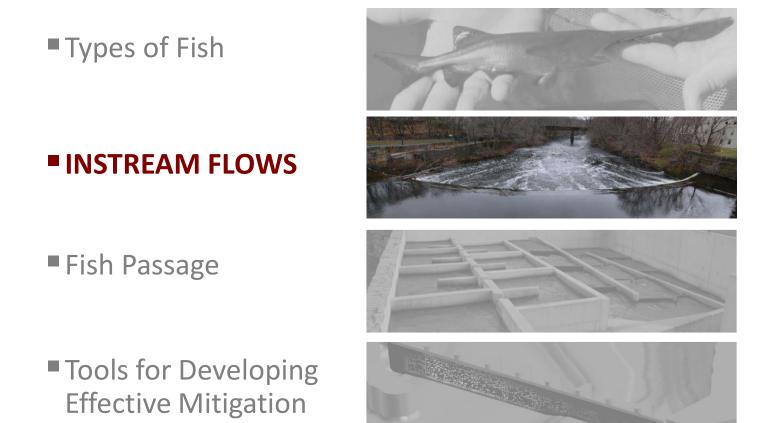








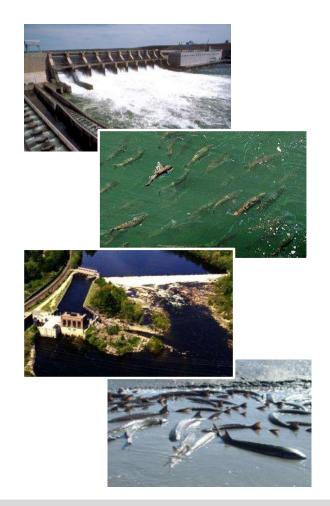
Instream Flows and Fish Passage





Instream Flows

- Project Operation (peaking/run-of-river) and Configuration (bypass reach)
- Aquatic Resource Impacts (habitat, migration, stranding, water quality)
- Other Impacts (recreation, navigation, aesthetics, sediment transport)
- Determination of Instream Flow Needs (field evaluations and modeling)
- Mitigation Options (seasonal minimum flows, schedule releases, ROR operation, ramping rates)





Instream Flows PROJECT OPERATION

Peaking

- Pond water during night
- Release (generate) during day

Pulsing

- Based on power demand and storage limitations
- Run-of-the-River (ROR)
 - No ponding
 - River flow in = flow out





Instream Flows PROJECT CONFIGURATION





Instream Flows AQUATIC IMPACTS

- Habitat (depth, velocity, substrate)
- Fish migration
- Fish stranding
- Water quality
- Primary production





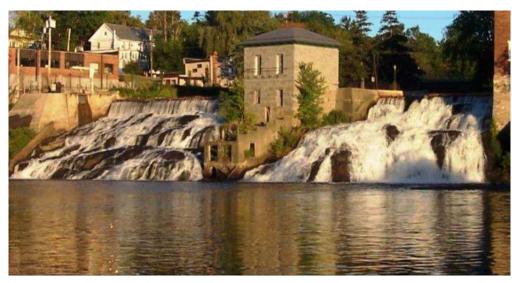






Instream Flows OTHER IMPACTS

- Recreation and Navigation
- Sediment/silt Deposition
- Aesthetics









Instream Flows DETERMINATION OF INSTREAM FLOWS

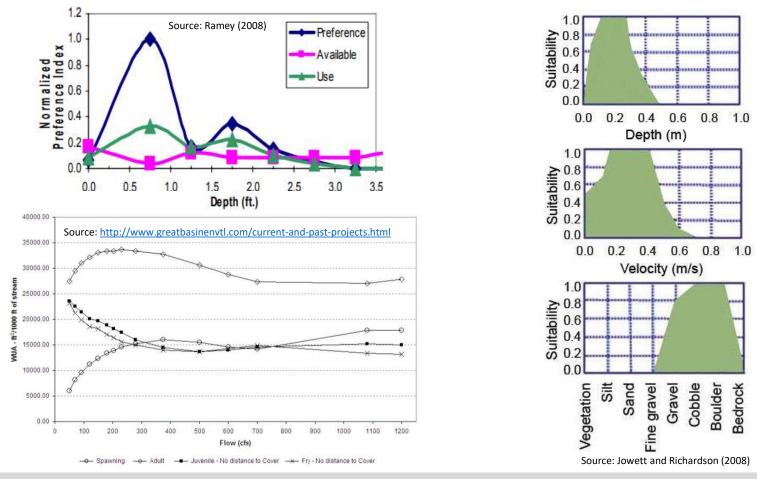
- Instream Flow Incremental Methodology (IFIM)
- Demonstration Flow Assessment (DFA)
- Habitat Evaluation Procedures (HEP)
- Aquatic Base Flow (ABF)
- Tennant (Montana) Method
- Wetted Perimeter
- Best Professional Judgment aka BOBSAR (Bunch Of Biologists Standing Around a River)





Instream Flows

HABITAT AVAILABILITY AND SUITABILITY



Instream Flow MITIGATION OPTIONS

- Bypass reach minimum flows (fixed, seasonal, or for specified bioperiods) for habitat and zone of passage
- Minimum flow turbines
- Run-of-the-river operation or restoration to normative hydrograph
- Scheduled flow releases for:
 - Sediment flushing
 - Channel maintenance
 - Fish migration (zone of passage)
- Ramping rates (gradually increasing or decreasing flow & generation)
- Alternative measures to address specific water quality issues (e.g., tailwater temperature regimes)



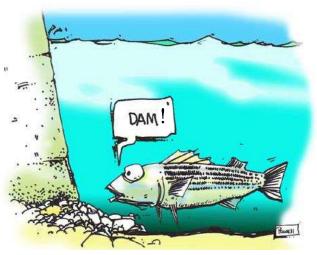


Instream Flows and Fish Passage

• Types of Fish• Instream Flows• FISH PASSAGE• Tools for Developing
Effective Mitigation

Fish Passage

- Need:
 - Biological Impacts
- Application Considerations:
 - Biological
 - Engineering/Operational
- Available Technologies:
 - Upstream Passage
 - Downstream Passage







Fish Passage BIOLOGICAL IMPACTS

- Upstream migration blockage and delays
- Downstream migration delays
- Turbine passage mortality
- Habitat fragmentation
- Invasive species and disease pathways

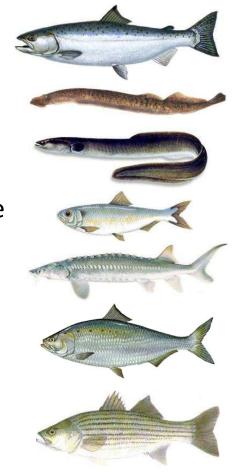


Goal is to provide fish passage that is: Safe, Timely, and Effective



Fish Passage BIOLOGICAL CONSIDERATIONS

- Target species
- Life stage
- Migration timing/seasonal occurrences
- Migration behaviors (diel activity, bottom or surface oriented)
- Swimming capabilities (burst, prolonged, and sustained swimming speeds)
- Hydraulics (flow rate, velocity, acceleration, turbulence)





Fish Passage

ENGINEERING/OPERATIONAL CONSIDERATIONS

- Project configuration/head
- Hydraulic requirements of passage systems:
 - flow rate
 - velocities
 - acceleration
 - turbulence
- Fishway entrance:
 - Iocation relative to turbine discharge and spill
 - attraction flow requirements volume, velocity
- Tailrace/draft tube and bypass reach attraction





Fish Passage

ENGINEERING/OPERATIONAL CONSIDERATIONS

- Downstream bypass location relative to turbine intake; hydraulic zone of influence
- Use of existing structures for passage (spill or sluice gates for downstream passage)
- Bypass discharge outlet/plunge pool location and design
- Installation, maintenance, and operational requirements
- Minimize fish injury and mortality using appropriate design criteria and materials
- Capital cost & maintenance costs









Fish Passage OPERATIONAL IMPACTS AND COSTS

- Loss of generation due to non-turbine spill
- Modifications to unit priority
- Construction, operation, maintenance
- Seasonal generating restrictions or limitations during migratory periods (24/7 or during specified daily hours)





Fish Passage UPSTREAM PASSAGE TECHNOLOGIES

- Fish ladders
- Nature-like (engineered) channels
- Fish lifts (elevators)
- Fish pumps
- Trap and transport
- Juvenile eel passage
- Whoosh Passage System
- Fishheart Hydraulic Fishway



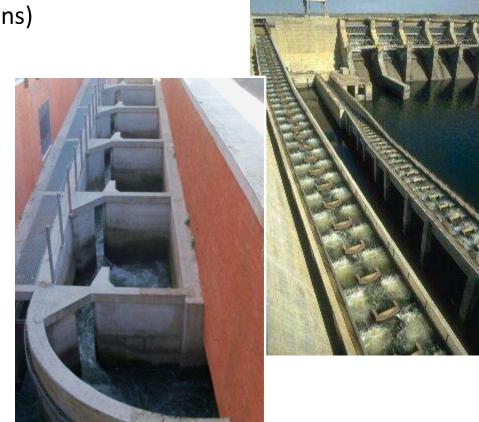
CALIFORNIA FISHERIES BIOLOGISTS DEVELOP NEW PLAN TO SAVE SACRAMENTO RIVER SALMON,



Upstream Fish Passage FISH LADDERS

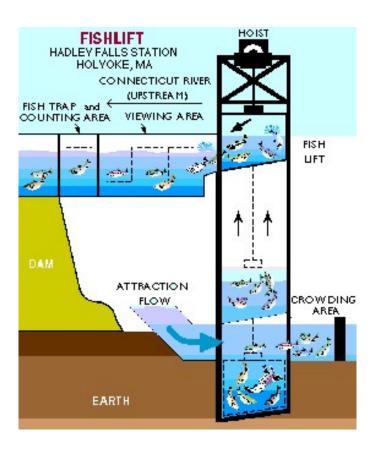
- Denil and Alaska steeppass (baffled designs)
- Pool and weir
- Vertical slot
- Alternative designs



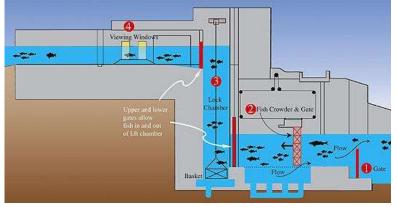




Upstream Fish Passage FISH LIFTS AND LOCKS







Upstream Fish Passage NATURE-LIKE CHANNELS

- Bypass channels
- Rock ramps and weirs







Upstream Fish Passage Options

TRAP AND TRANSPORT

The Washington Post

50-year pact gives migratory fish a boost in passage through Conowingo Dam

By Scott Dance April 30

Wildlife advocates say the numbers of American shad journeying from the Atlantic Ocean to spawning grounds in the Susquehanna River each year could climb to 2 million over the next 50 years as a result of a deal struck this week with the owner of Conowingo Dam.

In an agreement with the U.S. Fish and Wildlife Service, Chicago-based Exelon Corp. agreed to do more to help shad and river herring migrate over the dam straddling the river between Harford and Cecil counties in Maryland. The company will increase the capacity of a fish lift that carries them 100 feet from the dam's bottom to its top and also will trap fish and drive them upstream by truck.

The agreement is part of Exelon's efforts to renew its federal license governing dam operations for the next 50 years and comes after years of discussion about how to help the fish migration.

Fish and Wildlife Service officials called the plan a once-in-a-generation chance to help more migratory fish bypass the Conowingo and a series of other dams.

"We're anticipating the fish populations will grow over time, and the needs for fish passage will grow," said Sheila Eyler, a project leader with the service's Mid-

Atlantic Fish and Wildlife Conservation Office. But apart from the federal licensing process, "we don't have a mechanism to come to a dam owner and ask them to do something."

The numbers of shad, herring and other fish that successfully bypass the Conowingo and other dams along a 60-mile stretch of the river are at their lowest since the 1980s.



Upstream Fish Passage Options EEL LADDERS







Upstream Fish Passage Options WHOOSHH FISH TRANSPORTATION SYSTEM





Upstream Fish Passage Options FISHHEART HYDRAULIC FISHWAY



Fish Passage

DOWNSTREAM PASSAGE TECHNOLOGIES

Physical Exclusion

- Narrow-spaced bar racks
- Barrier nets
- Wedgewire screens

Guidance/Collection

- Angled bar racks
- Louvers
- Flat-panel screens
- High-velocity screens
- Surface collectors
- Guidance walls and floating panels

Behavioral Deterrents

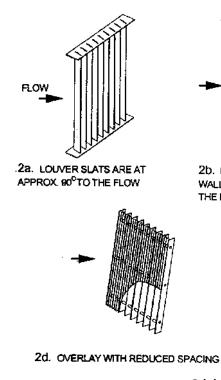
- Light (strobe and continuous)
- Sound (infrasonic, ultrasonic, and sonic)
- Electric barriers
- Flow enhancement systems
- Chemicals/gases, air curtains, chains, EMF

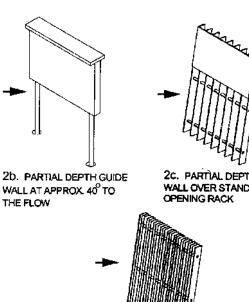
Bypass Design

- Location
- Flow and entrance velocities
- Discharge location and plunge pool design

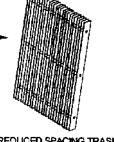


Downstream Fish Passage Options GUIDANCE/COLLECTION TECHNOLOGIES Angled Structures





2C. PARTIAL DEPTH CURTAIN WALL OVER STANDARD OPENING RACK



20. REDUCED SPACING TRASH RACK

Odeh and Orvis (1997)





ALDEN

Downstream Fish Passage *GUIDANCE TECHNOLOGIES* Diversion Screens (Vertical or Inclined)





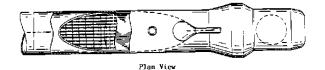


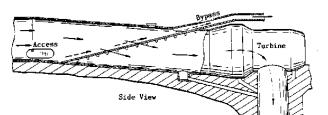
Downstream Fish Passage GUIDANCE TECHNOLOGIES In-pipe Diversion Screens

High-velocity Inclined Screens

- Eicher Screen
 - Puntledge (BC, Canada)
 - T. S. Sullivan (Oregon)
- Modular Inclined Screen (MIS)





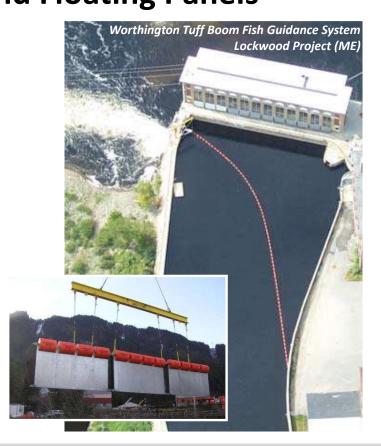






Downstream Fish Passage GUIDANCE TECHNOLOGIES Guidance Walls and Floating Panels

Guidance Wall - Bellows Falls Project (VT)



Downstream Fish Passage GUIDANCE TECHNOLOGIES Behavioral Deterrents

- Strobe light
- Sound
- Air bubble curtains
- Electrical barriers
- Turbulent/induced flow
- Combined systems







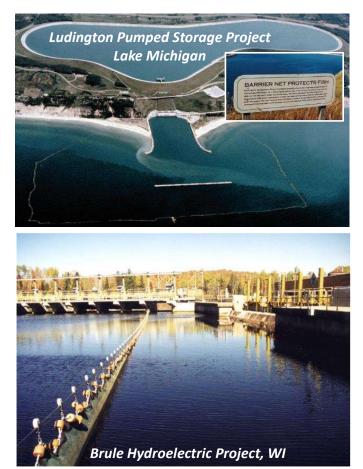


Downstream Fish Passage PHYSICAL BARRIERS

- Narrow-spaced Bar Racks
- Barrier Nets
- Flat-panel Screens



Osage Hydroelectric Project, MO





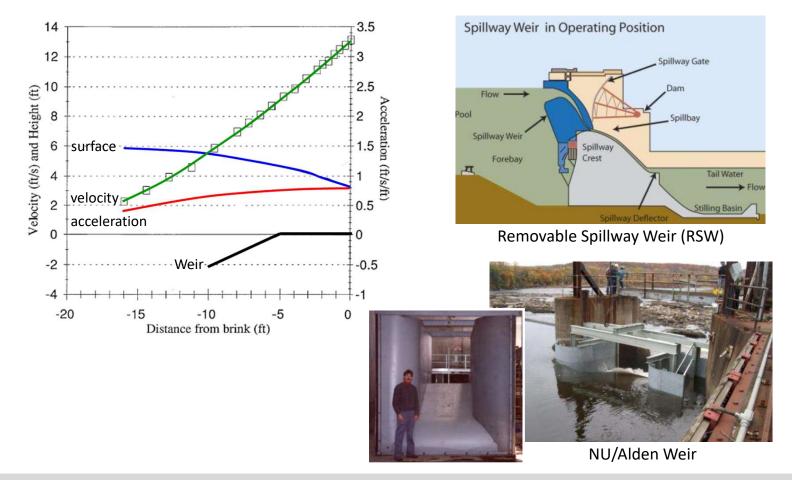
Fish Impingement and Entrainment SURFACE COLLECTORS

Upper Baker Surface Collector

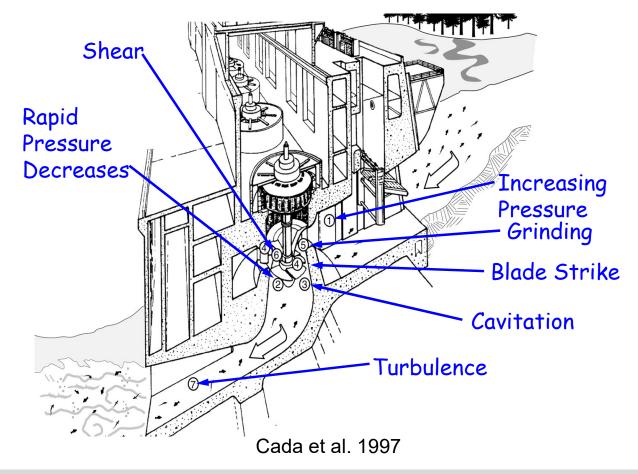




Fish Impingement and Entrainment UNIFORM ACCELERATION WEIRS AND BYPASSES



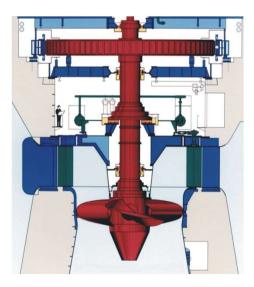
Downstream Fish Passage FISH-SAFE TURBINES





Fish-Safe Turbines CONVENTIONAL TURBINE DESIGNS

- Kaplan, propeller, and bulb turbines
- Small number of blades
- Large diameter/low rotational speeds
- Low head







Fish-Safe Turbines

LOW HEAD TURBINE DESIGNS

Archimedes Screw Turbines < 10 m head

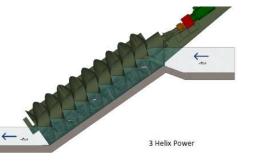
MJ2 Technologies Very Low Head turbine (VLH) < 6 m head



Turbine Survival: 95 to 100% for salmonids and eels

Gault Green Energy Vaneless Turbine < 6 m head







Leclerc (2008)



de Montmorency (2008)

Fish-Safe Turbines LOW HEAD TURBINE DESIGNS

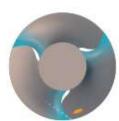
Natel Energy Restoration Hydro Turbine (RHT)

- Laboratory blade strike tests conducted at Alden demonstrated high strike survival of blade leading edge design.
- Field testing of full-scale unit conducted by Natel and PNNL demonstrated 100% survival of rainbow trout (up to 15 inches in length) at an installation in Oregon.



Curved Blade (deflects fish around)





Tip Slant (reduces severity of strike)



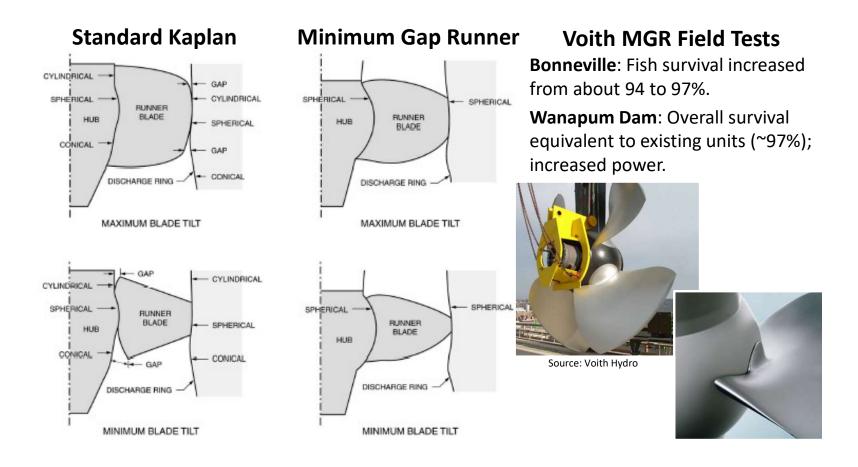
Rainbow trout passing through turbine https://www.natelenergy.com/



Source: https://www.energy.gov/eere/water/articles/pnnl-testing-campaign-verifies-fish-passage-performance-natel-energy-s



Fish-Safe Turbines MINIMUM GAP RUNNERS



Fish-Safe Turbines ALDEN TURBINE



Pilot-scale tests conducted with:



- Three helical blades
- Few/long gates
- Smooth downturn
- Shroud attached to blades
- No gaps
- Favorable hydraulics
- High minimum pressure
- Voith model efficiency = 93.9%

Ideal Prototype Design

- Head: 20 to 100 ft
- Flow: 500 to 2,500 cfs



PREDICTED FULL-SCALE SURVIVAL: 97 – 100%

Fish-Safe Turbines

ICE HARBOR FISH-FRIENDLY TURBINES

US Army Corps of Engineer has installed and is evaluating new fishfriendly turbines at Ice Harbor Dam

- Ice Harbor is most downstream dam on the Snake River.
- Significant focus at the project on improving survival of downstream migrating juvenile salmonids some of which are listed under the ESA.
- Collaborative design effort with COE, BPA, NMFS, and Voith Hydro.
- Two adjustable and one fixed-blade unit to replace 3 Kaplan Units.
- Used pressure studies to develop design criteria of limiting areas below 12 psia while reducing strike, shear, and turbulence





Instream Flows and Fish Passage

Types of Fish

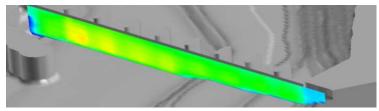
Instream Flows



Fish Passage



TOOLS FOR DEVELOPING EFFECTIVE MITIGATION





Tools for Developing Effective Mitigation at Your Project

- Literature Review
- Alternative Technology Feasibility Assessment
- Physical and Numeric (CFD) Hydraulic Modeling
- Biological and Engineering Laboratory Evaluations
- Pilot-scale Field Evaluations
- Full-scale Installation and Evaluation

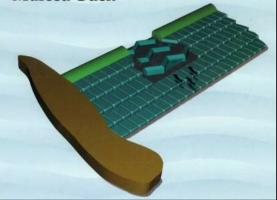


Tools for Developing Effective Mitigation *LITERATURE REVIEW*

Innovations in Fish Passage Technology

Edited by

Mufeed Odeh



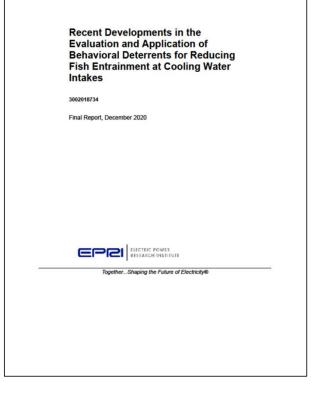
SCHOLARWORKS @UMassAmherst

Home > ENGAGEMENT > Fish Passage Community > FISHPASSAGE_DATABASE

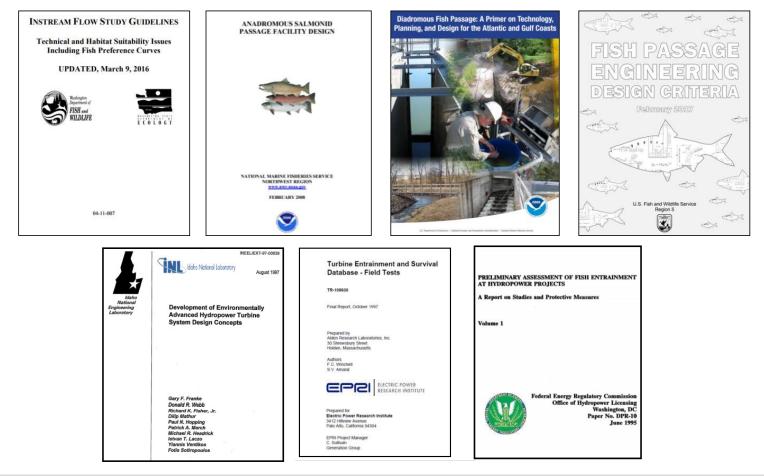


About This Page

This site serves as a portal to access citations of current and historic literature on fish passage engineering, biology, design, and relevant disciplines. It is meant as an open resource for fishery biologists, managers, engineers, and the public and private sectors to find information on fish passage that is both published and unpublished (i.e., reports, grav literature), and a clearinghouse for new literature as it becomes available. The database was conceived, designed, and funded through the efforts of the American Society of Civil Engineers Environmental and Water Resources Institute (ASCE/EWRI) – American Fisheries Society Bioengineering Section (AFS/BES) Partnership Development Ad Hoc Committee in June of 2011 as part of its goal to develop initiatives for new projects to assist fish passage information and technology transfer. This database is a compilation of existing literature databases and bibliographies from multiple sources (e.g., USGS S.O. Conte Anadromous Fish Research Laboratory).

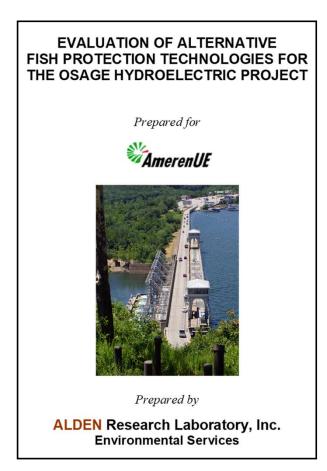


Tools for Developing Effective Mitigation ESTABLISHED GUIDLINES AND CRITERIA



Tools for Developing Effective Mitigation FEASIBILITY STUDY

- Preliminary and detailed screening for:
 - Biological Feasibility
 - Engineering Feasibility
- Development of conceptual designs
- Order-of-magnitude cost estimates



Tools for Developing Effective Mitigation *PHYSICAL HYDRAULIC MODELING*



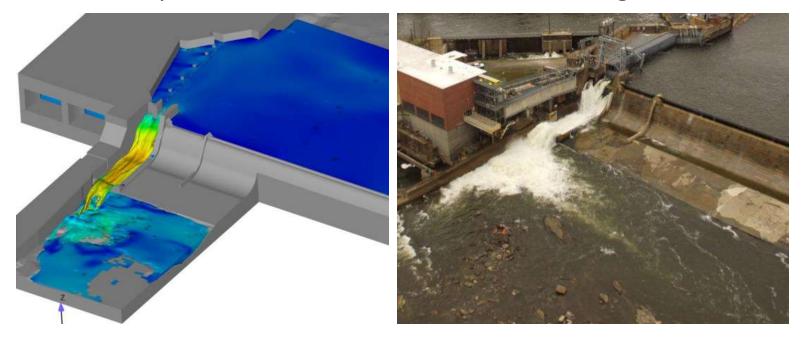


Fish Ladder Models



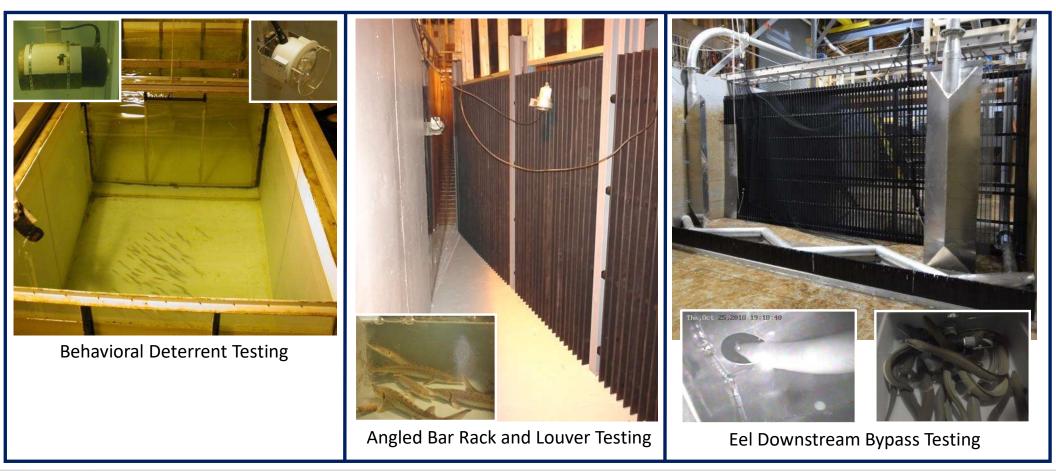
Tools for Developing Effective Mitigation *NUMERIC HYDRAULIC MODELING*

Computation Fluid Dynamics (CFD) Model Upstream and Downstream Fish Passage





Tools for Developing Effective Mitigation *LABORATORY EVALUATIONS*





Tools for Developing Effective Solutions FIELD EVALUATIONS

Instream Flow Assessment

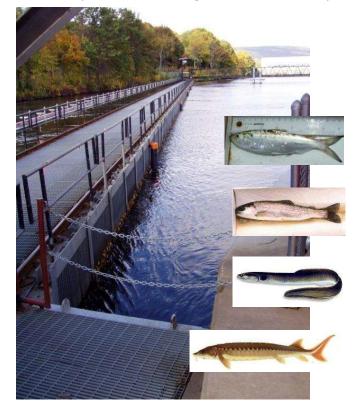


Shad Upstream Passage Evaluation



Tools for Developing Effective Solutions FULL-SCALE INSTALLATION AND EVALUATION

Holyoke Canal Angled Louver Array



Eel Downstream Bypass Evaluation





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a verdantas company

