Jun 22nd, 3:15 PM - 3:40 PM

Session B2: An Overview of the Ice Harbor Turbine Replacement Project

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Ice Harbor Turbine Replacement - Overview

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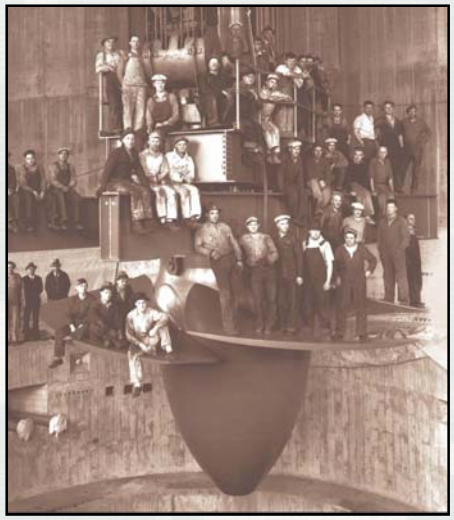

Walla Walla District
US Army Corps of Engineers
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Background

USACE operates **8 major hydropower dams** on the lower Snake and Columbia Rivers – Part of the Federal Columbia River HydroPower System (FCRPS)

Construction of the 8 dams began in the early **1930's** and was completed in the late **1970's**

Total **94 Kaplan** turbines

7.1 m to 8.4 m in diameter

Total system capacity – **10,394 MW**

Impact has forced strict management practices to support both upstream and downstream migration of **endangered anadromous fish** species.

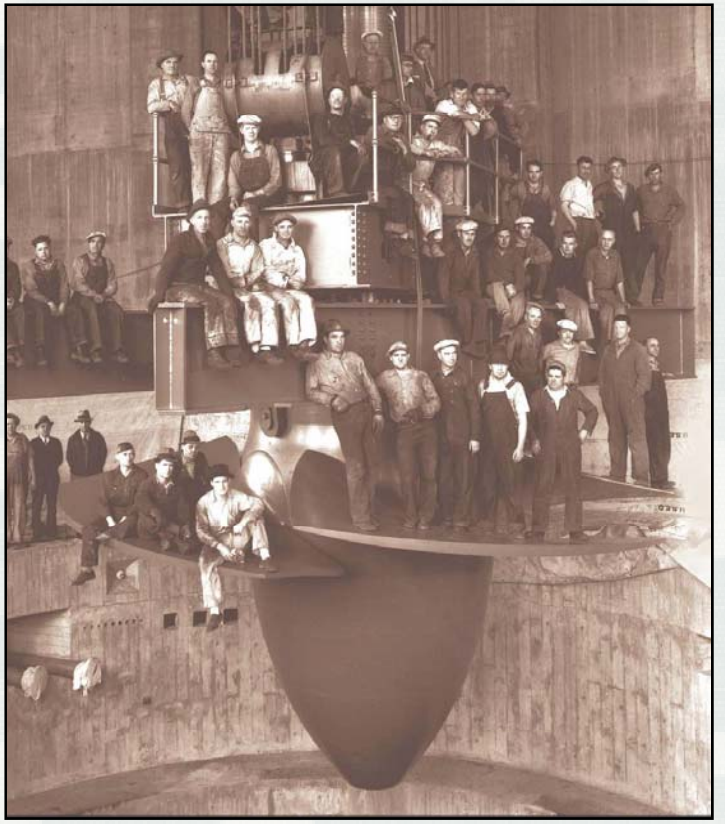
Background

Turbines within the FCRPS are nearing end of design life - experiencing increased rate of failure

Rehabilitation and replacements are critical to maintaining system reliability

Provides opportunity to improve turbine designs for fish passage and increased efficiencies.

Concern for endangered fish species and reliable generation led to development of the Turbine Survival Program (TSP) and the **Ice Harbor Test Turbine Project**



Turbine Survival Program

A USACE Program Established in 1995

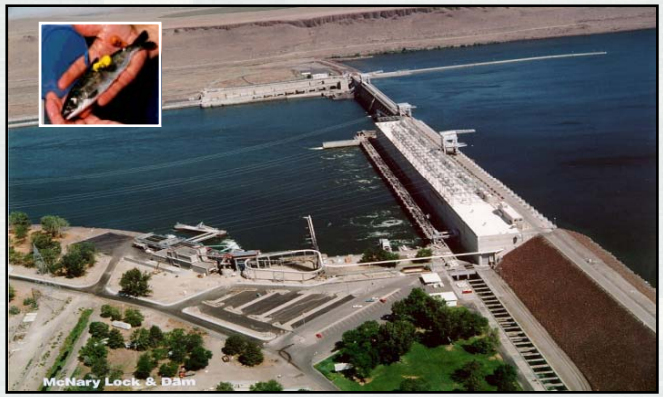
TSP Goals and Objectives:

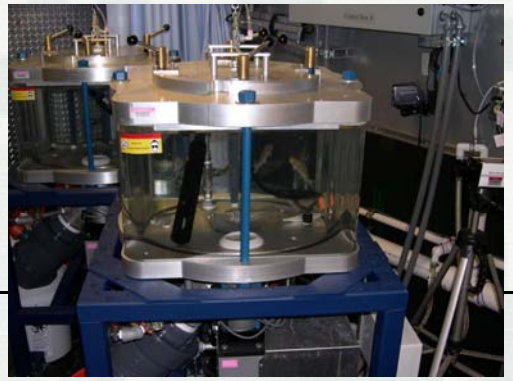
- Improve our understanding of turbine passage
- Determine effects of turbine passage on juvenile salmonids
- Develop design criteria/guidelines to improve turbine design and operation for safer fish passage.

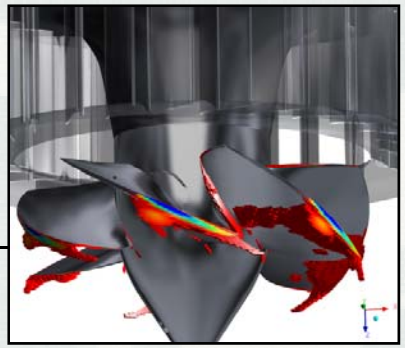
Focused on large propeller (Kaplan) style turbines.

Program efforts included:

- Field Studies
- Physical hydraulic models
- Numerical hydraulic analyses
- Laboratory Research







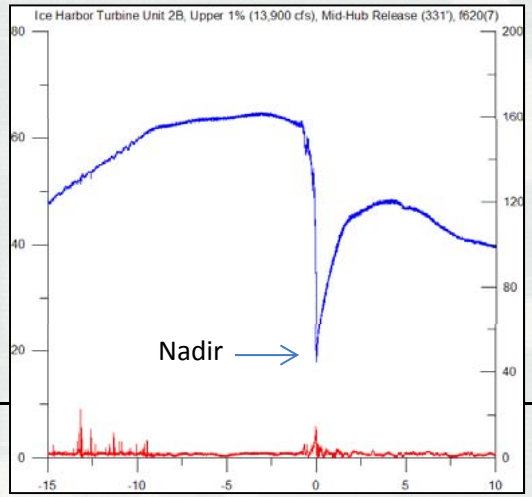
TSP – Field Studies

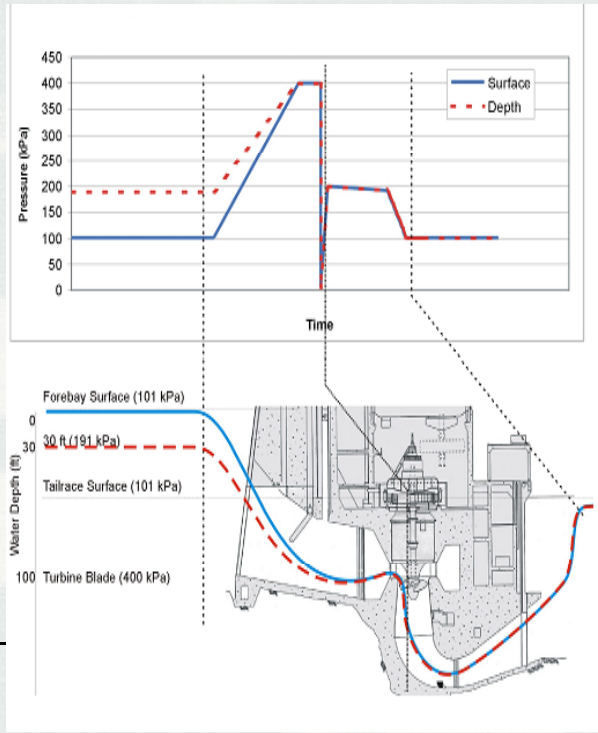
Turbine Survival Studies

- Direct turbine survival – Balloon (HiZ) tag studies
- Total turbine passage – Telemetry based studies
- Vertical distribution / Depth acclimation studies

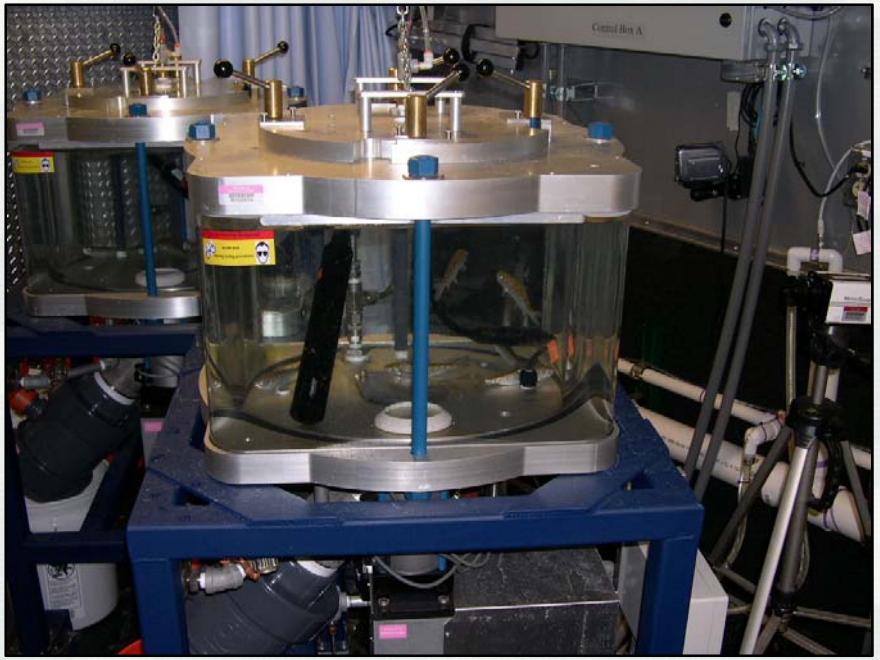
Turbine Characterization

- Sensor Fish Data Collection
  - Turbine Pressure
  - Acceleration





Laboratory Research (PNNL)

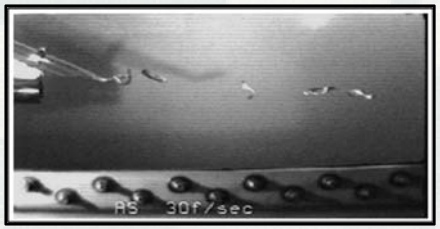


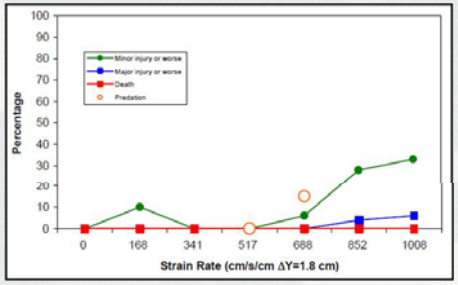
Pressure studies

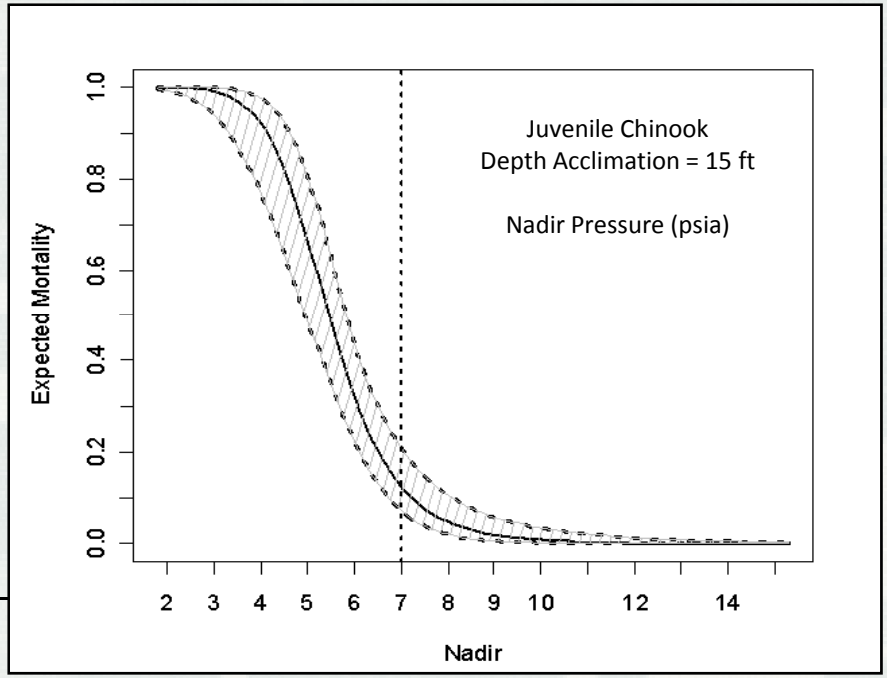
- Simulated turbine pressures on juvenile Chinook salmon
- Primary variables:
  - Acclimation depth
  - Nadir pressure

Shear Studies

Criteria for new designs







Survival of Juvenile Salmonids Through Turbines

Mortality of turbine passed juvenile salmonids generally ranges from **~5 to ~25 percent** (75 to 95 percent survival)

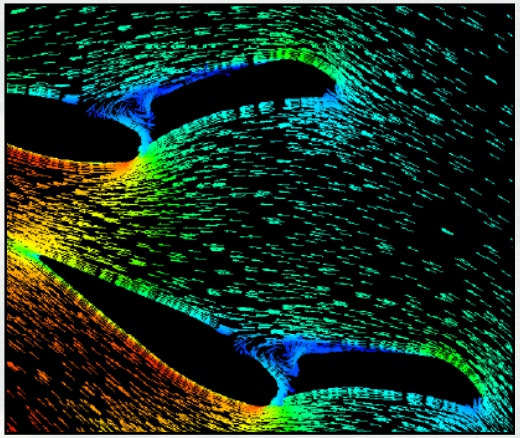
Direct mortality caused by blade strike, impact, pinching and shear ranges from **~ 4 to ~8 percent**

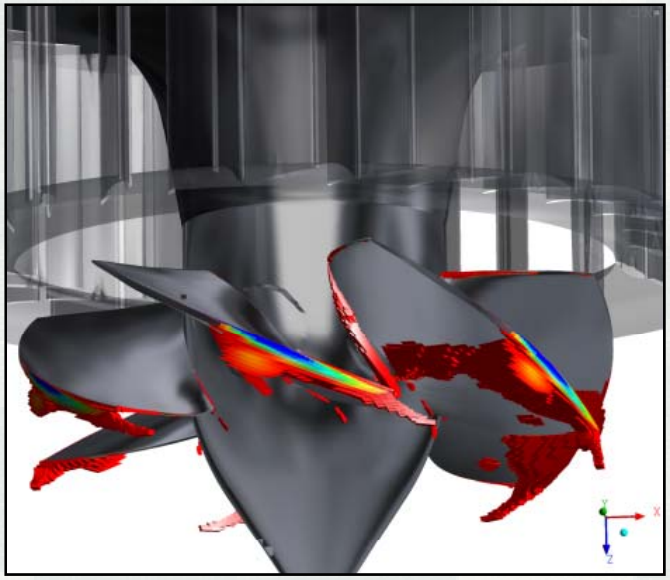
Exposure to sub-atmospheric pressures can be lethal depending on fish acclimation depth prior to turbine passage, and Nadir pressure.

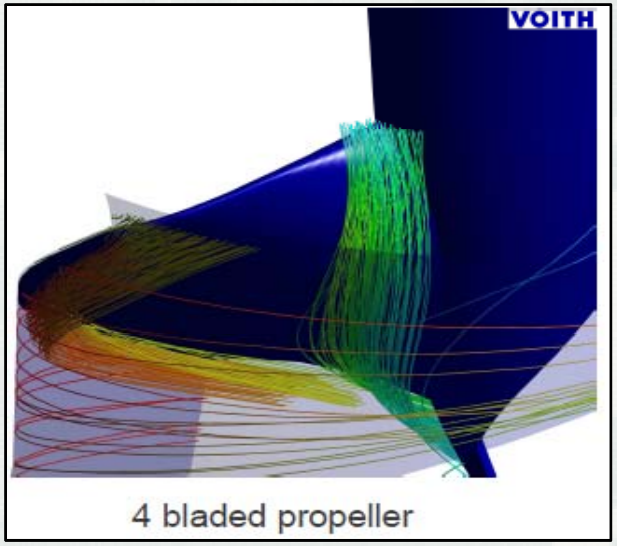
Predation on turbine passed fish within the immediate tailrace can be high

Combined mortality from consecutive dam passages is significant.

Computational Fluid Dynamics

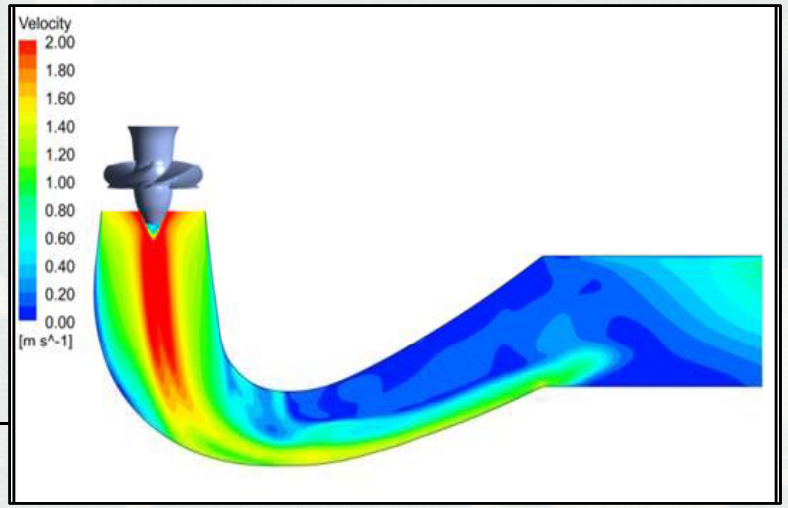






4 bladed propeller

Flow lines
Velocity
Pressure
Turbulent Kinetic Energy
Efficiency Estimates



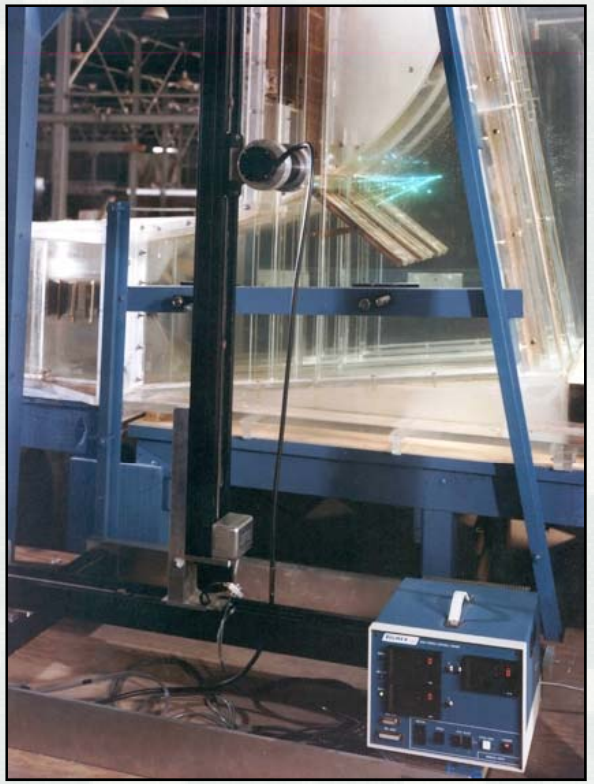
ERDC Turbine Model

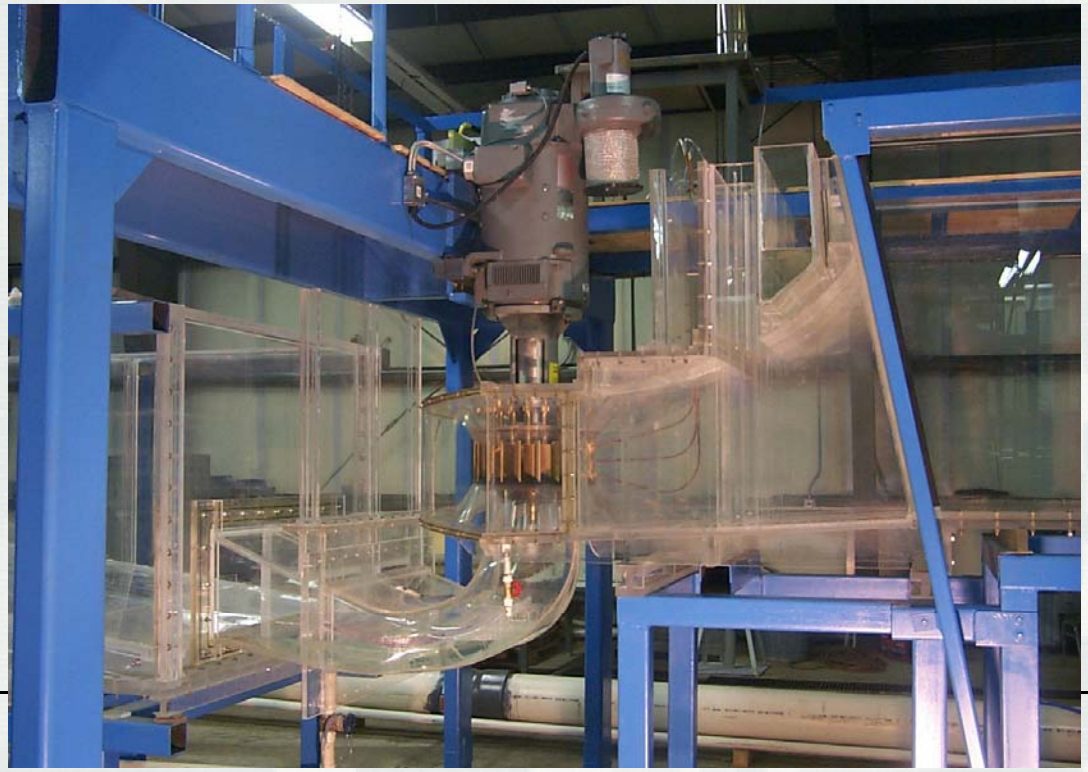
1:25 Froude Scale

Observations of hydraulic conditions

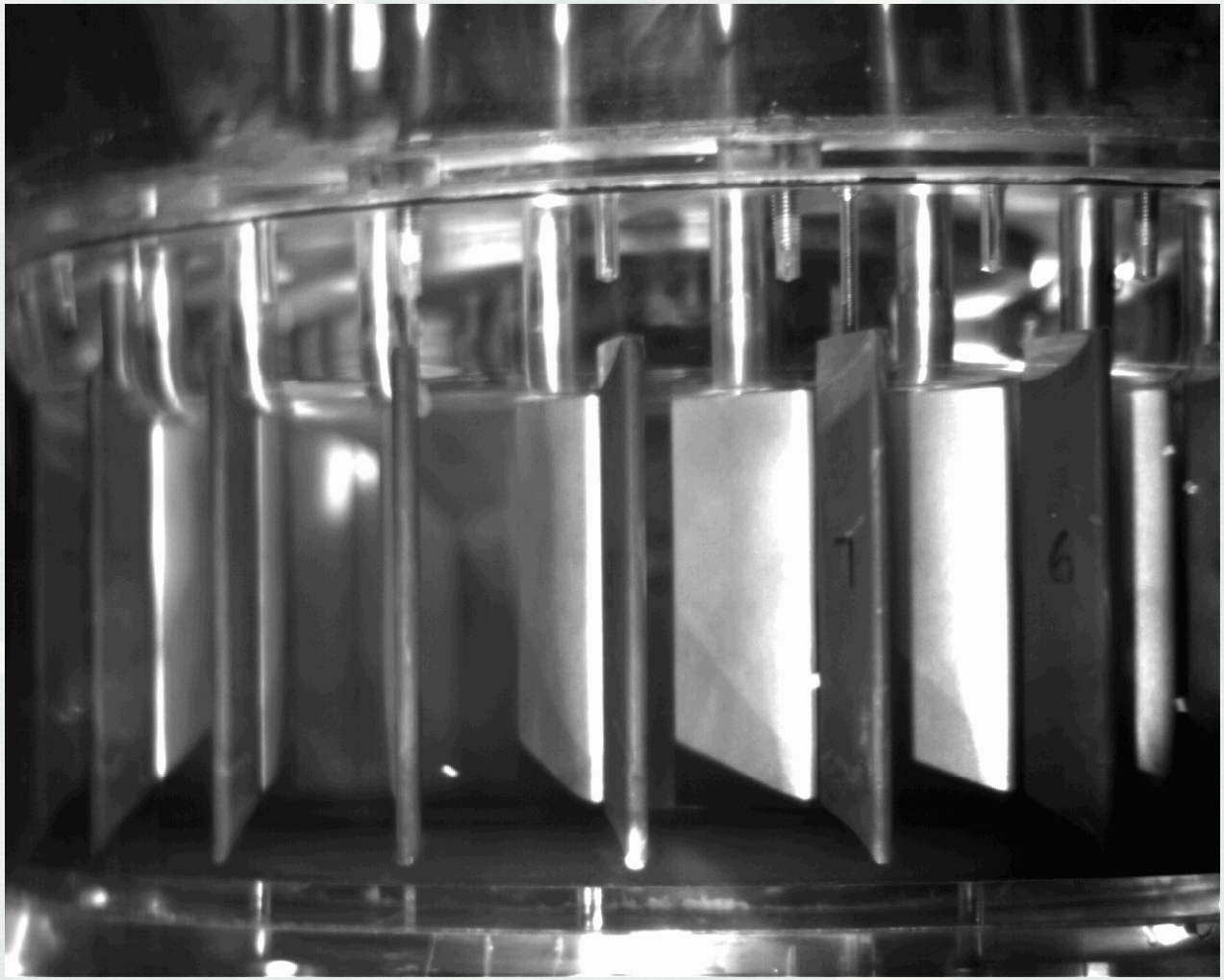
High speed digital imaging of neutrally buoyant beads

Laser velocity measurements

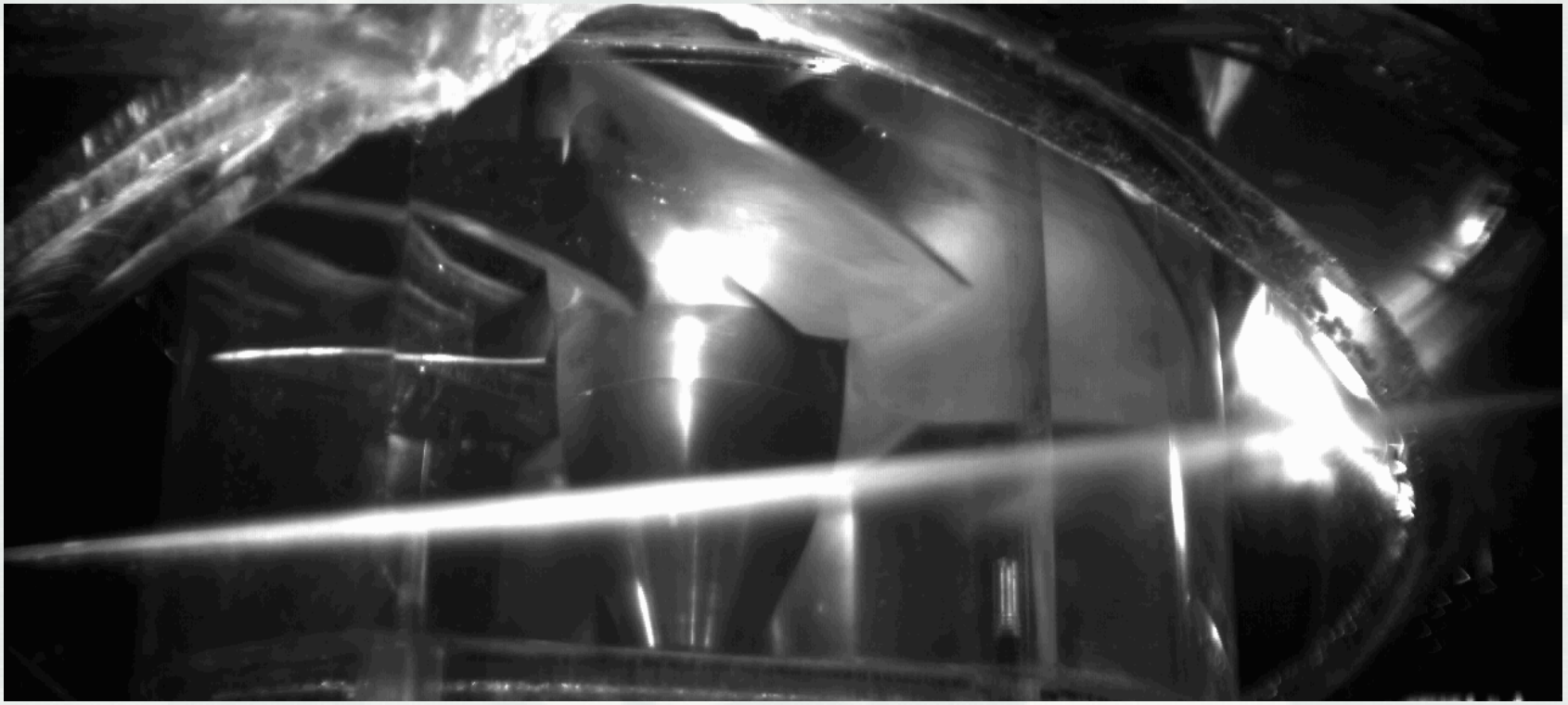




Ice Harbor – Stay Vane /Wicket Gate



Ice Harbor – Tip Release



TSP Design Guidance

- Align and minimize the gaps between the stay vanes and wicket gates.
- Minimize runner blade gaps at hub and periphery
- Target a minimum turbine design pressure of 1 atm (14.7 psia) but not less than 10 psia.
- Minimize blade strike on leading edge, blade surfaces and trailing edge.
- Minimize swirl and turbulence below the runner blades
- Streamline flow through the draft tubes.
- Incorporate the ERDC turbine models into the design and evaluation process.

Ice Harbor Lock and Dam

Location - Lower Snake River near the confluence with the Columbia river – Washington State – USA

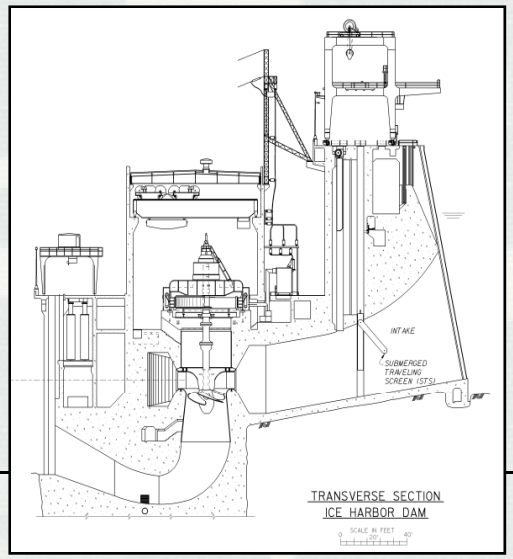
Original construction completed in mid **1960's**

Prominent Features

- Powerhouse **- 6 Kaplan turbine units**
- 10 gated spillway bays
- Navigation Lock
- North and south shore adult fish ladders
- Juvenile fish by-pass facility

Unit 2 and Unit 3 chronic oil leaks. Hub Oil removed and blades welded to fix position.

Selected as TSP Test Project.



Ice Harbor Test Turbine

Goal – Validate the new TSP design process and criteria. Replace failing units.

2010 - Contract awarded to **Voith Hydro**
Design and Supply two new turbine runners

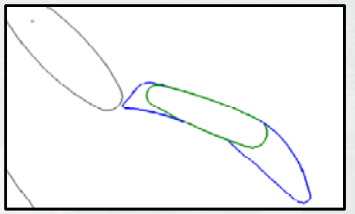
- One Fixed Blade Propeller
- One Adjustable Blade (MGR) Propeller

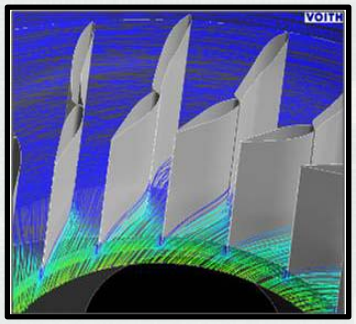
Design for **Safe Fish Passage** and Increased Efficiency.

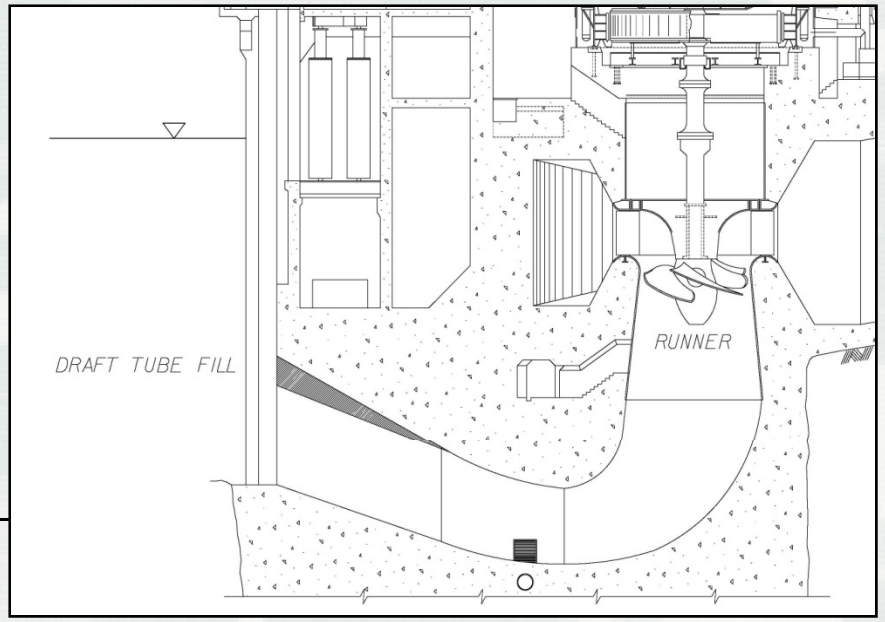
Installation of the first runner will begin in 2016 with field testing in 2017

New Turbine Design

- Turbine Runners
  - Designed to reduce blade strike and increased pressures.
- Stay vane leading and trailing edge extensions
  - Improve alignment with flow
  - Minimize gaps between stay vane & wicket gate
- Draft tube modifications (roof fill)
  - Reduce turbulence
  - Streamline flow
  - Improve exit conditions

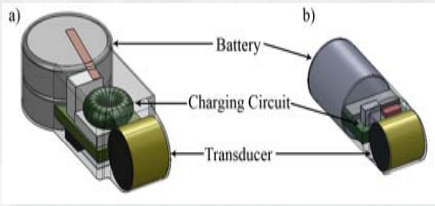


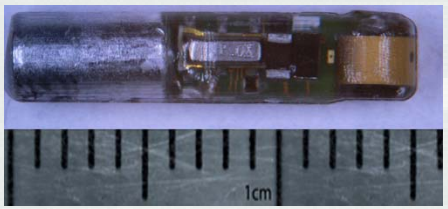


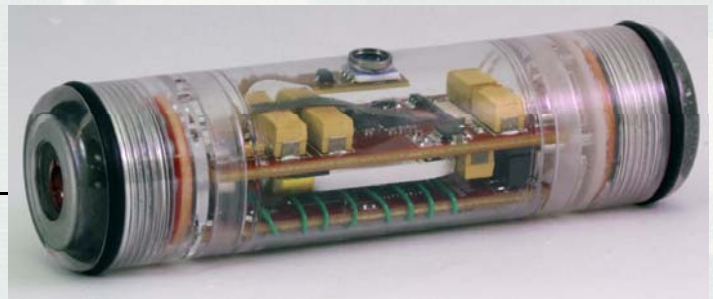


Bio-Testing the New Turbines

- Acoustic Telemetry Tag Method
  - **Total Turbine Passage Survival** including Immediate Tailrace
- Balloon Tag Methods (HiZ)
  - **Direct Turbine Effects** - injury and mortality of the immediate turbine passage
- Sensor Fish data collection
  - **Pressure and Acceleration** data
    - Estimates probabilities of exposure to low pressure
    - Estimates probabilities of strike and exposure to shear
  - Will compare to Baseline (Existing Turbine) data

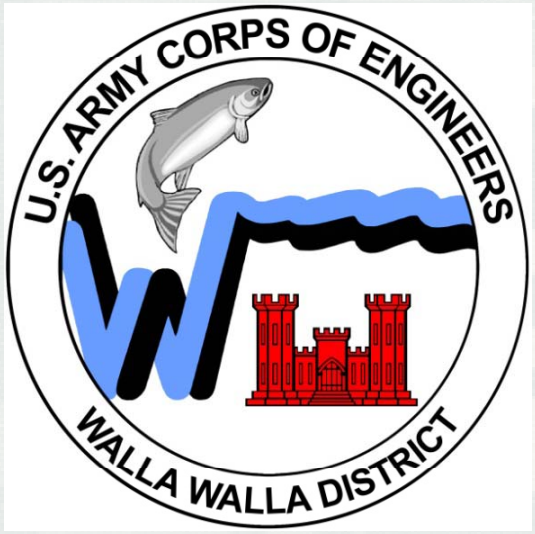






Ice Harbor Test Turbine

- Established a contract that incorporates TSP criteria, guidance and evaluation methods into the design process
- Focused design on fish passage as a primary goal, efficiency as a secondary goal
- Used a **Collaborative Team** approach to support the design and make trade-off decisions. **Fish / Power / Cost**



Questions