Turbine Survival Program

Northwest Power and Conservation Council

February 9, 2011

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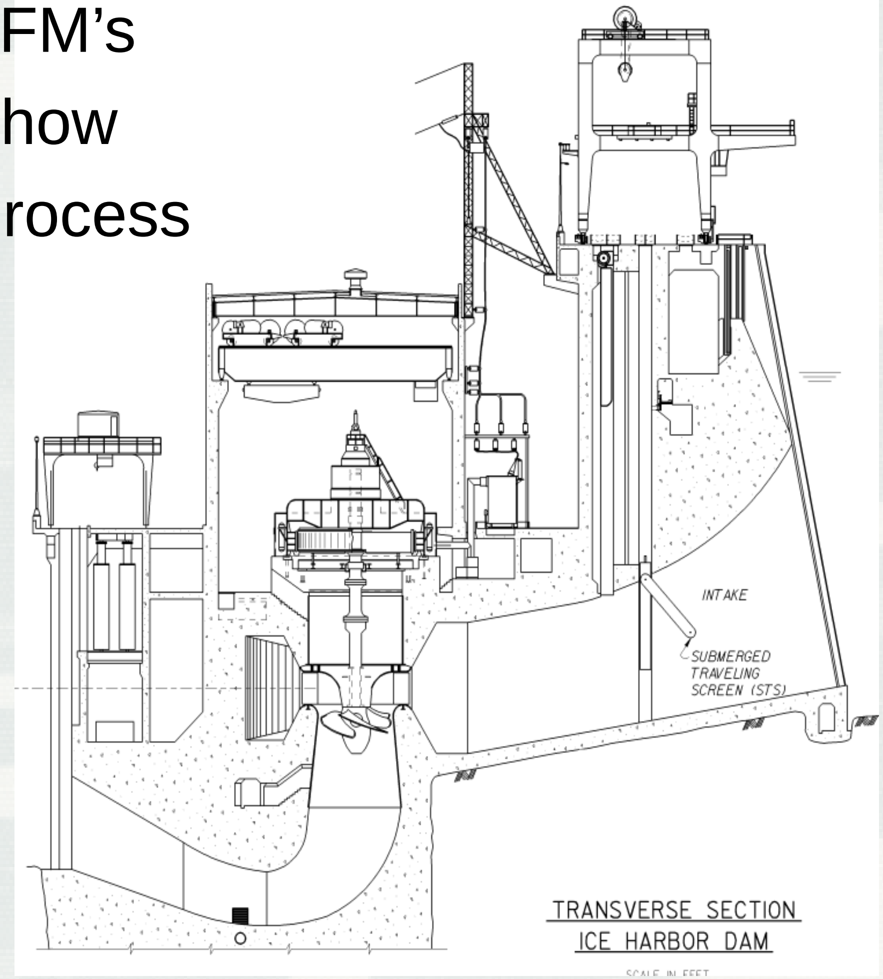
Briefing Purpose

Provide an overview of the CRFM's Turbine Survival Program and how it supports the Rehabilitation Process



Turbine Survival Program

TSP is an element of the CRFM Program; established to address NMFSs 1995 Biop measures and NPCC's request to enhance survival of adult and juvenile salmonids through the Columbia and Snake River Projects. Continues to Support the 2000 Biop

Specifically NMFS's RPAs # 59, 64, 88, 89, 90, 91, 92 , 93, 111 and NPCC's Conservation Measure No. 5 (Ref. Turbine Survival Program Technical Report 1997-2003)

Summarized – Improve the operation and design of turbines for safer fish passage.

TSP Support

TSP Team - Consists of Engineers and Biologists from the Portland and Walla Walla Districts, the Hydroelectric Design Center (HDC) and the Engineer Research and Development Center (ERDC)

With active support from NOAA, USGS and the Pacific Northwest National Laboratory

Funding – The TSP is funded by the Columbia River Fish Mitigation Program.

Many studies within TSP have also been cost shared with BPA and DOE.

TSP Study Goals

Improve our understanding of the turbine passage environment and the impact of that environment on juvenile fish passage

Optimize turbine operations for safer fish passage

Improve turbine designs for safer fish passage

TSP Take Home Message

- We have a better understanding of the turbine environment and the effects of that environment on juvenile fish than we had 15 years ago.
- Turbines can be a viable passage route for juvenile salmonids (and lamprey??)
- TSP has and will continue to support the operation and rehabilitation of turbines by providing operational and design guidance.

Turbine Survival

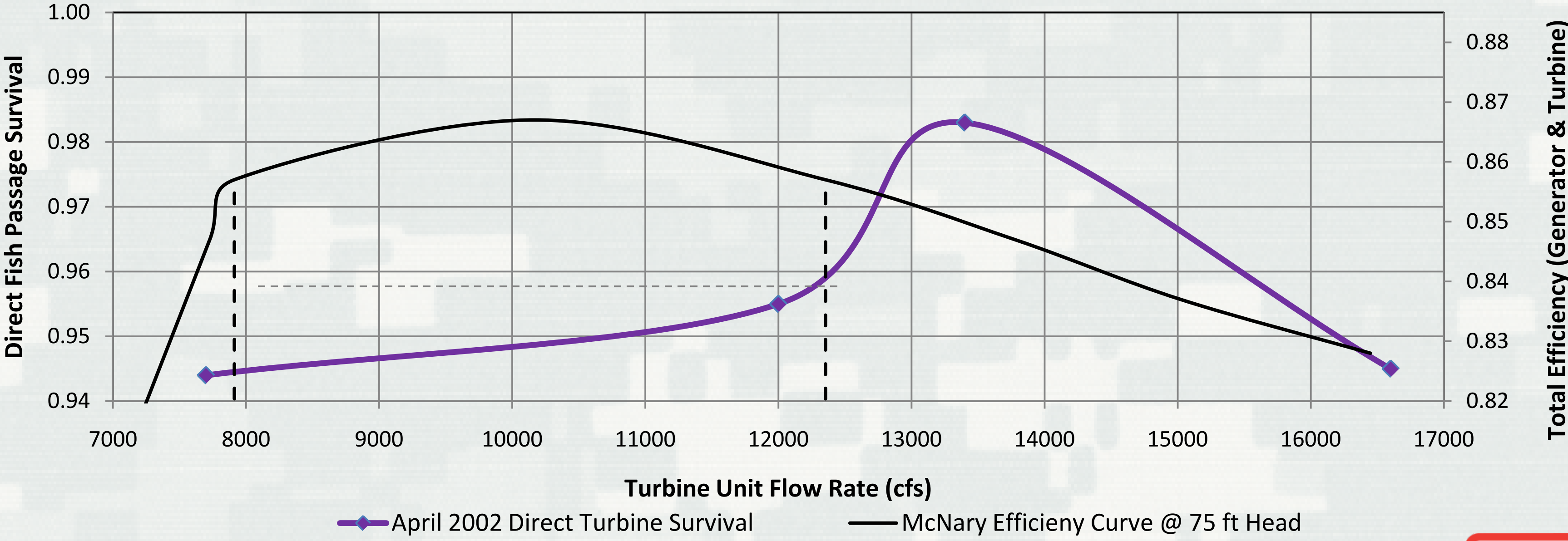
- Survival of juvenile salmonids passing through turbines has generally been considered to be between 85 and 95 percent.
- Survival estimates range from below 70 percent up to 100 percent.
- Survival has been estimated for both “direct” passage and “total” passage.

Direct Survival

- Estimated from intake releases with immediate recapture using HiZ tag methods.
- Provides estimates of injury and mortality caused by strike and shear forces.
- Estimates for a specific unit and operation(s)
- Does not fully account for pressure related injuries or immediate tailrace predation.

McNary Direct Turbine Survival

	2002 McNary Turbine Survival of Balloon Tagged Yearling Chinook					
Test Dates	April 4 - 20, 2002				May 7 - 30, 2002	
Target Operating Condition	Lower End 1%	Upper End 1%	2% Eff. Drop	Gen. Limit	Upper End 1%	Gen. Limit
Unit 9 Flow @~72.5 ft Head (cfs)	7700	12000	13400	16600	12000	16600
Reported Turbine Survival	0.94	0.96	0.98	0.95	0.93	0.95
Lower End of 95% Conf. Interval	0.91	0.93	0.96	0.93	0.90	0.92
Upper End of 95% Conf. Interval	0.98	0.98	1.00	0.96	0.97	0.98
Number of Treatment Fish (#)	350	360	270	360	391	390
Approx. Fish Length (mm)	155				140	



Reference: Normandeau Associates Inc. (2003). Survival/Condition of Chinook Salmon Smolts under Different Turbine Operations at McNary Dam, Columbia River. Prepared for USACE, Contract DACW-68-02-D-0002.

Total Survival

- Estimated from an upstream release to a downstream detection using telemetry
- Includes direct and indirect causes of mortality resulting from:
  - Strike and shear forces
  - abrupt changes in pressure
  - turbulent and disorienting flow, and
  - predation as a result of turbine passage.

John Day 2008 Turbine Survival

	2008 John Day Dam Fish Passage Survival Data		
Fish Studied	Juvenile Steelhead	Yearling Chinook	Subyearling Chinook
Date Range for Passage	4/30/08 - 5/27/08	4/30/08 - 5/27/08	6/23/08 - 7/12/08
Total Treatment Fish detected downstream (#)	2,448	2,445	2,483
% Turbine Passed *	3%	8%	17%
Reported Turbine Survival - Paired Release	**0.855**	**0.749**	**0.728**
Lower End of 95% Confidence Interval	0.821	0.687	0.672
Upper End of 95% Confidence Interval	0.889	0.811	0.784
Approx. Turbine Passed Fish (#)	73	195	422
Average Internal Tag Weight in Air (g)	0.485	0.485	0.425
Average Fish Weight (g)	75.1	37.2	14.7
Average Tag Burden (%)	0.6%	1.3%	2.9%
Approx. Average Powerhouse Flow (kcfs)	250	250	200

Reference: Weiland, MA et. al. (2009). PNNL-18890, Acoustic Telemetry Evaluation of Juvenile Salmonid Passage and Survival at John Day Dam with Emphasis on the Prototype Surface Flow Outlet, 2008. Pacific Northwest National Laboratory, Richland, WA.

B1 MGR – 2004 Turbine Survival

Radio Telemetry W/Direct Intake Release	**2004 Bonneville Fish Passage Survival**	
	Juvenile Steelhead	Yearling Chinook
Date Range for Passage	4/29/04 - 6/7/04	4/29/04 - 6/7/04
Powerhouse 1 - MGR treatment released fish	292	399
MGR Turbine Survival - Front Roller Control	**0.952**	**0.956**
Lower End of 95% Confidence Interval	0.9	0.83
Upper End of 95% Confidence Interval	1.003	1.042
MGR Turbine Survival - B2 JBS Outfall Control	**0.926**	**0.944**
Lower End of 95% Confidence Interval	0.861	0.913
Upper End of 95% Confidence Interval	0.992	0.976
Average Internal Tag Weight in Air (g)	1.4	1.4
Fish Weight from LoMo (g)**	102.0	34.0
Average Tag Burden (%)	1.4%	4.1%
Average Powerhouse 1 Flow (kcfs)	33.3	33.3
Average Total River Flow (kcfs)	218.4	218.4

Reference: Counihan, Timothy et. al. (2006). Survival Estimates of Migrant Juvenile Salmonids through Bonneville Dam Using Radio Telemetry, 2004. Western Fisheries Science Center (USGS), Cook, WA.

LoMo 2009 Turbine Survival

	2009 Lower Monumental Dam Fish Passage Survival Data		
Fish Studied	Juvenile Steelhead	Yearling Chinook	Subyearling Chinook
Date Range for Passage	4/27/09 - 5/23/09	4/27/09 - 5/23/09	6/10/09 - 7/3/09
Total Treatment Fish used in Study (#)	1,173	1,157	2,302
% Turbine Passed *	1%	3%	8%
Reported Turbine Survival - Uniform Spill	**1.08**	**0.956**	**N/A**
Lower End of 95% Confidence Interval	0.999	0.846	N/A
Upper End of 95% Confidence Interval	1.016	1.08	N/A
Total Turbine Passed Fish - Uniform Spill (#)	4	17	N/A
Reported Turbine Survival - Bulk Spill	**1.009**	**1.021**	**0.891**
Lower End of 95% Confidence Interval	1	1.08	0.841
Upper End of 95% Confidence Interval	1.018	1.034	0.941
Total Turbine Passed Fish - Bulk Spill (#)	8	16	156
Average Internal Tag Weight in Air (g)	0.8	0.8	0.691
Average Fish Weight (g)	84.1	26.3	12.6
Average Tag Burden (%)	1.0%	3.0%	5.5%
Reported Average Powerhouse Flow (kcfs)	68.75	68.75	68.2
Reported Average Total River Flow (kcfs)	101	101	87.3

Reference:

Hockersmith, Eric et. al. (2010). Passage Behavior and Survival for Radio-Tagged Yearling Chinook Salmon and Juvenile Steelhead at Lower Monumental Dam, 2009. National Marine Science Center, Seattle, WA.

Field Test Limitations

- Sample sizes are too small from in-season project survival studies to adequately estimate survival of turbine passed fish for specific units and unit operation.
- Survival studies of individual unit operations may need to be conducted without spill.
- New test methods and tags must be developed to minimize or eliminate pressure related biases
  - Currently working towards smaller injectable telemetry tags as well as neutrally buoyant externally attached telemetry tags

Evaluating the Turbine Environment

Tools and methods

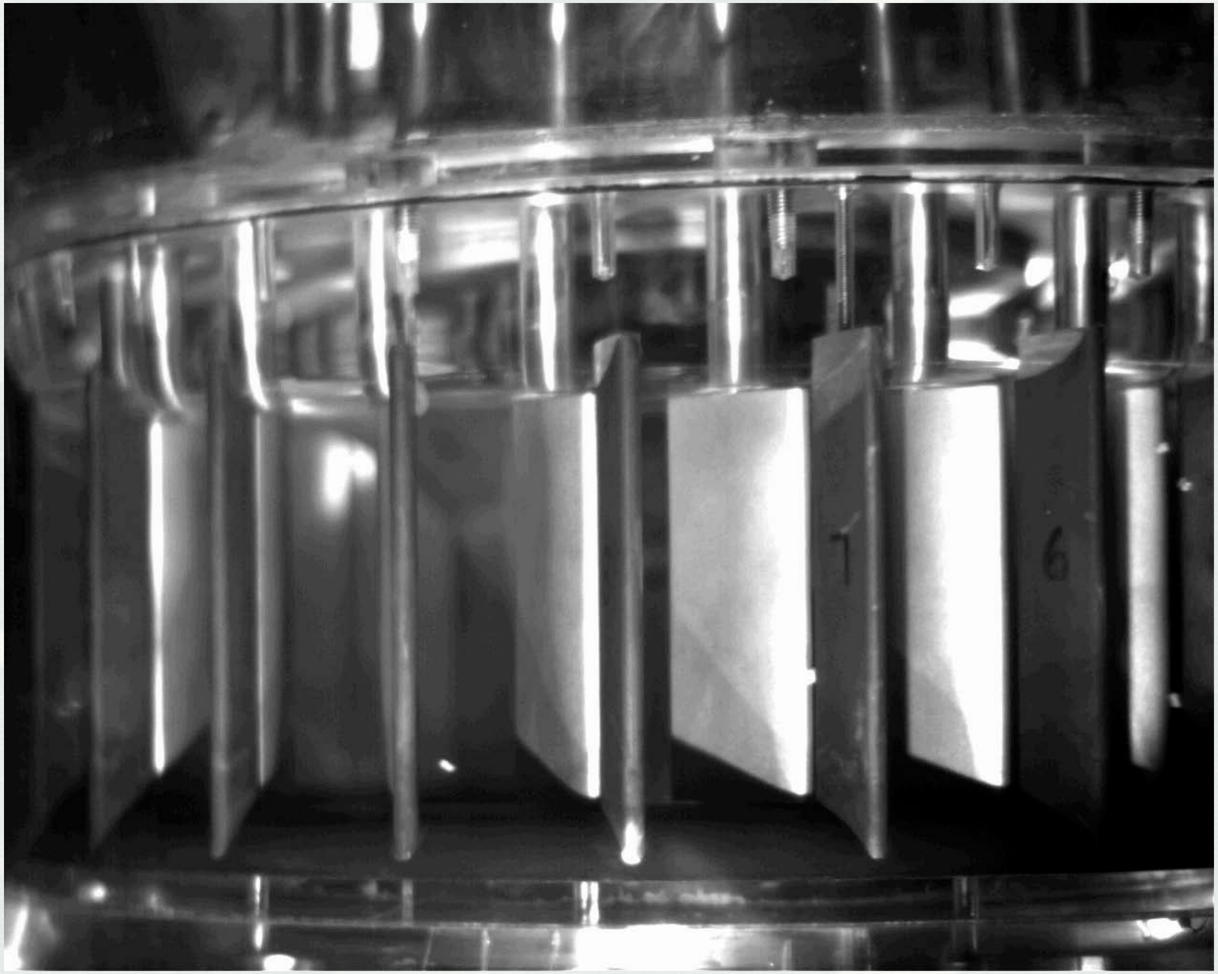
- Physical hydraulic models
- Computational fluid dynamics
- “Sensor Fish” measurements
- Hyper/hypobaric laboratory investigations

Physical Hydraulic Models

Investigate strike, shear and exposure to turbulence using high speed digital imaging and LDV (velocity) measurements.

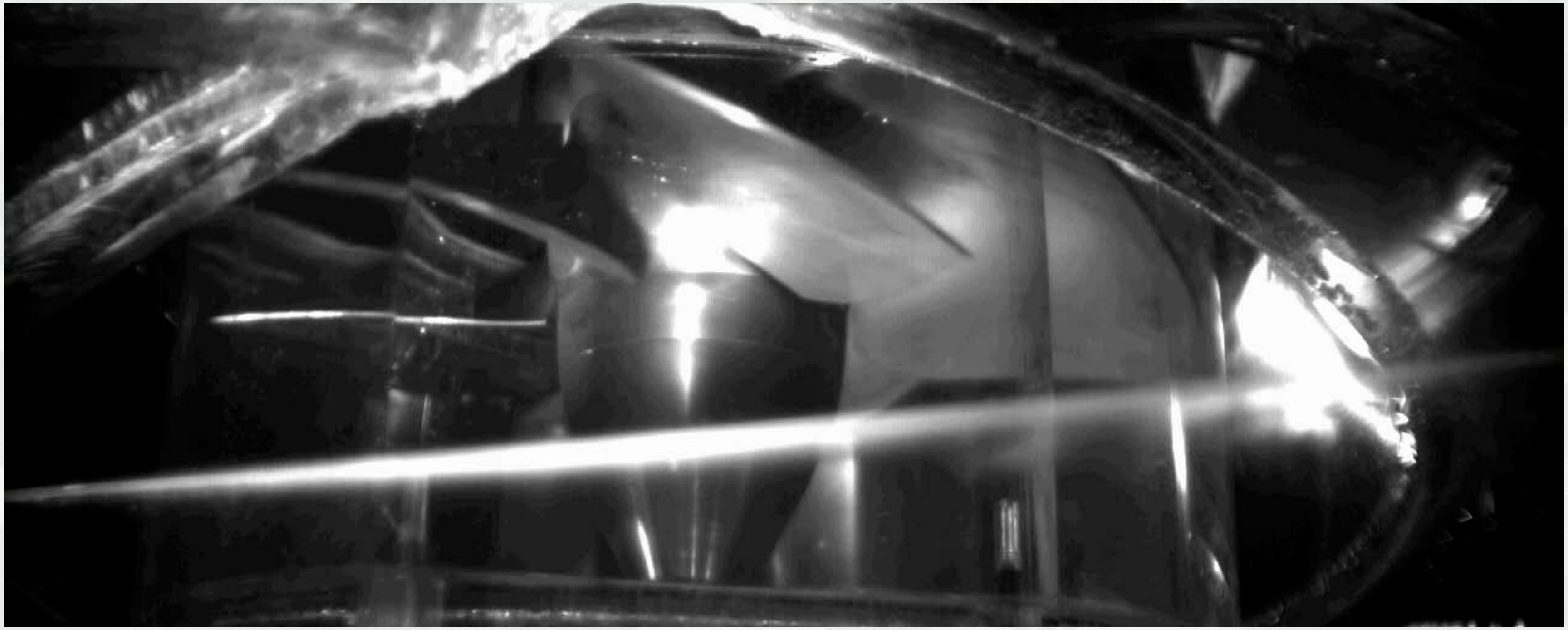
IHR Turbine Model
ERDC - 1:25 Scale

Stay Vanes and Wicket Gates

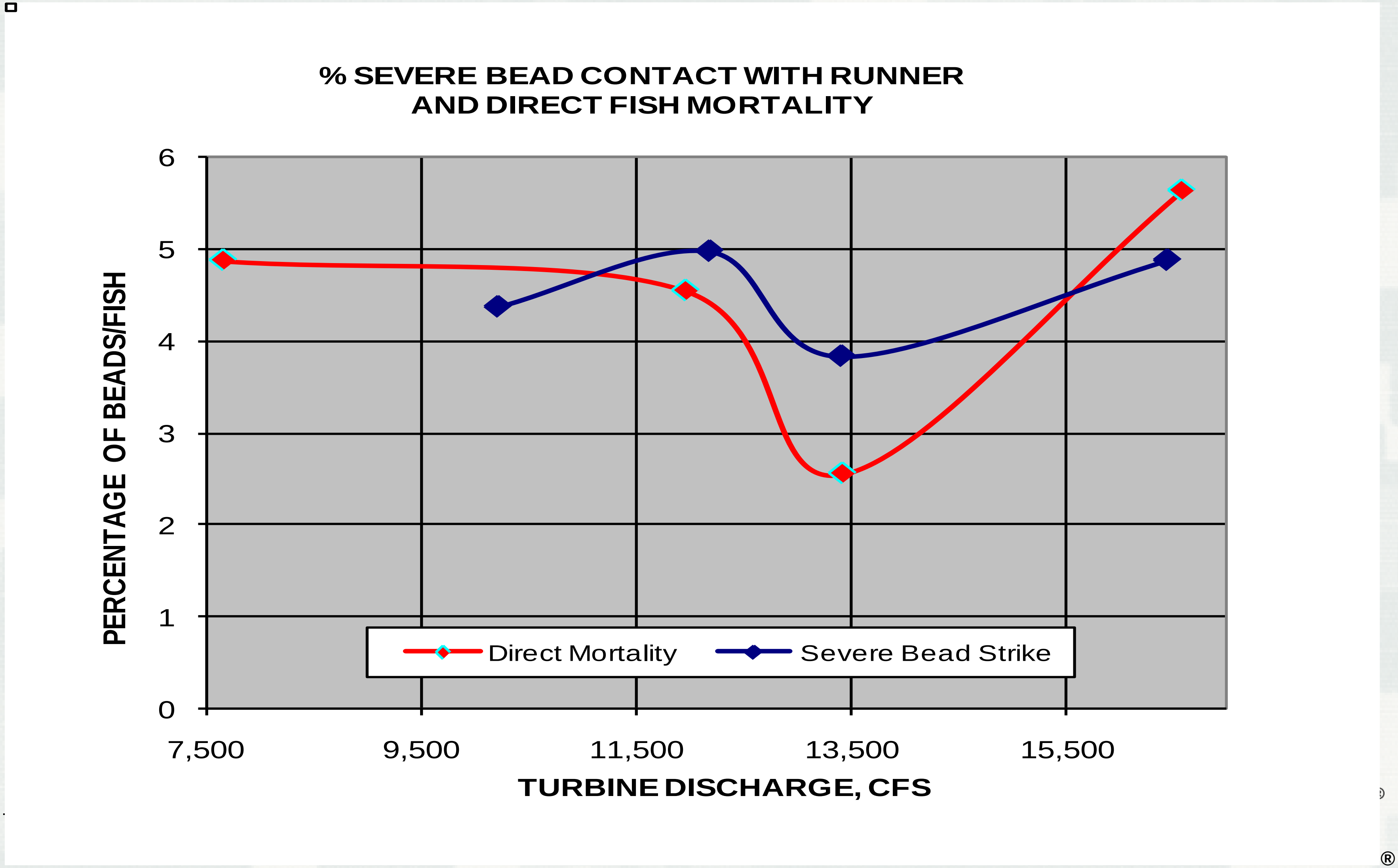


Near Hub Passage

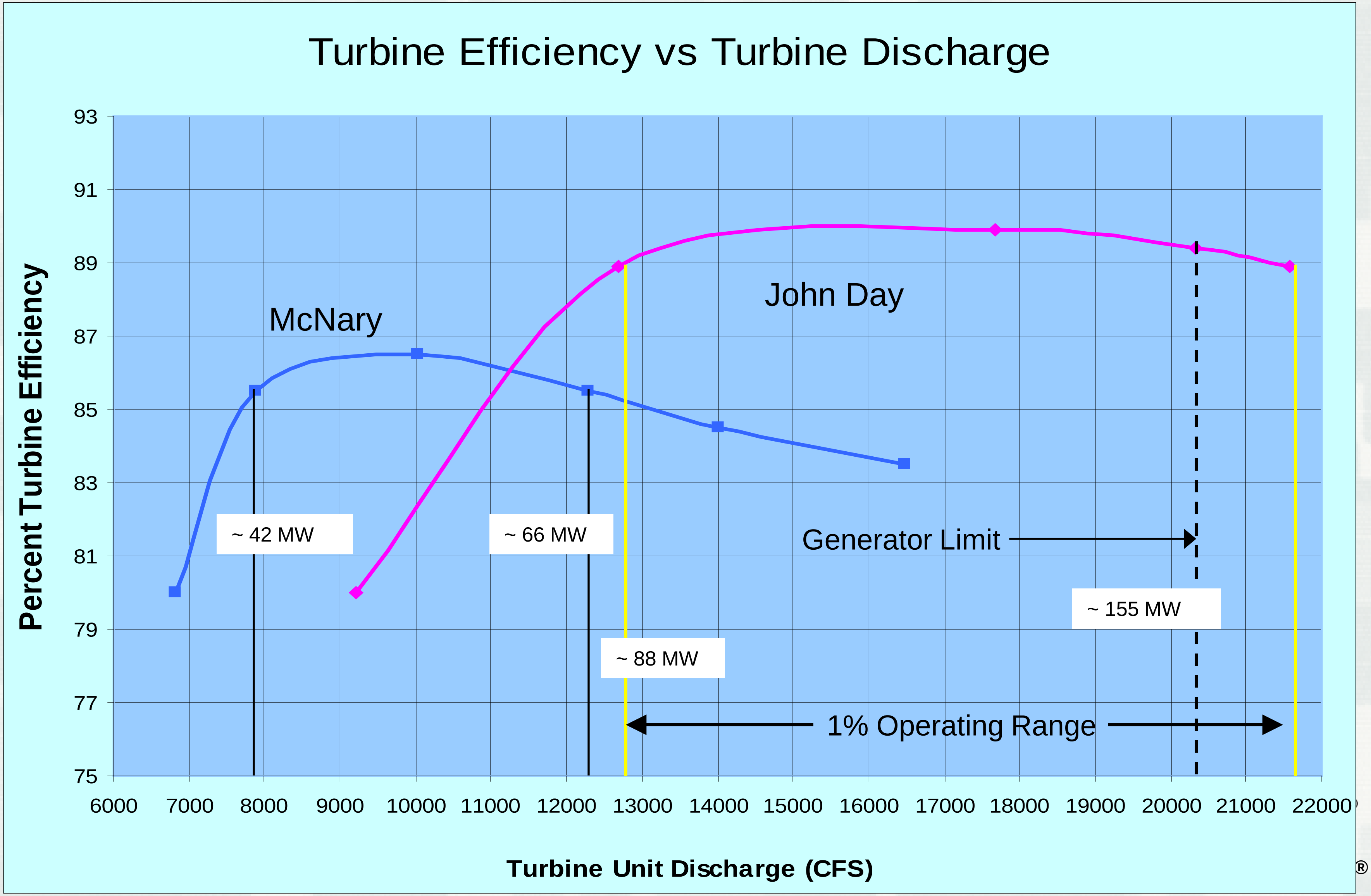
Near Tip Passage



Comparison of McNary Data

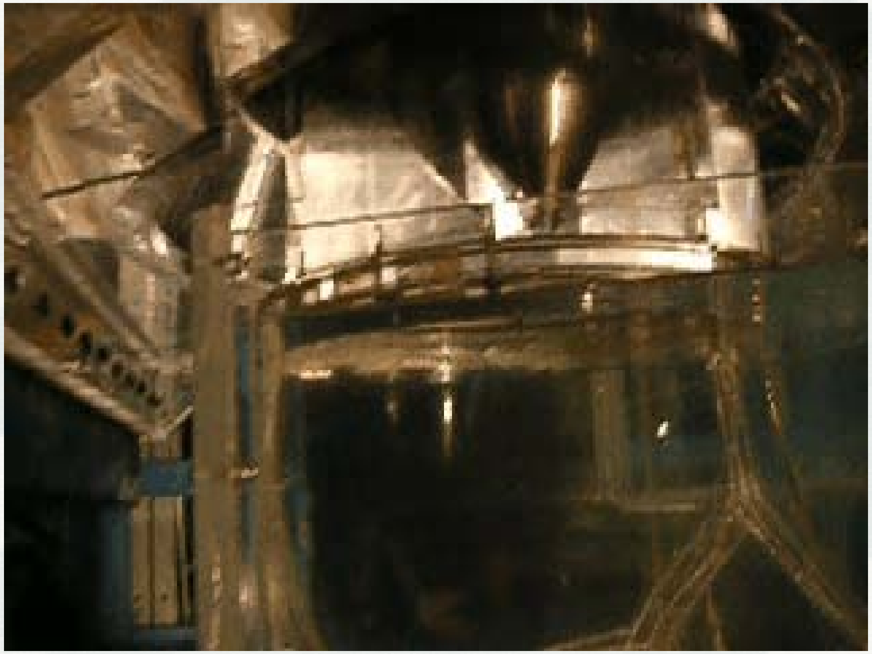


McNary and JDA Unit Operations

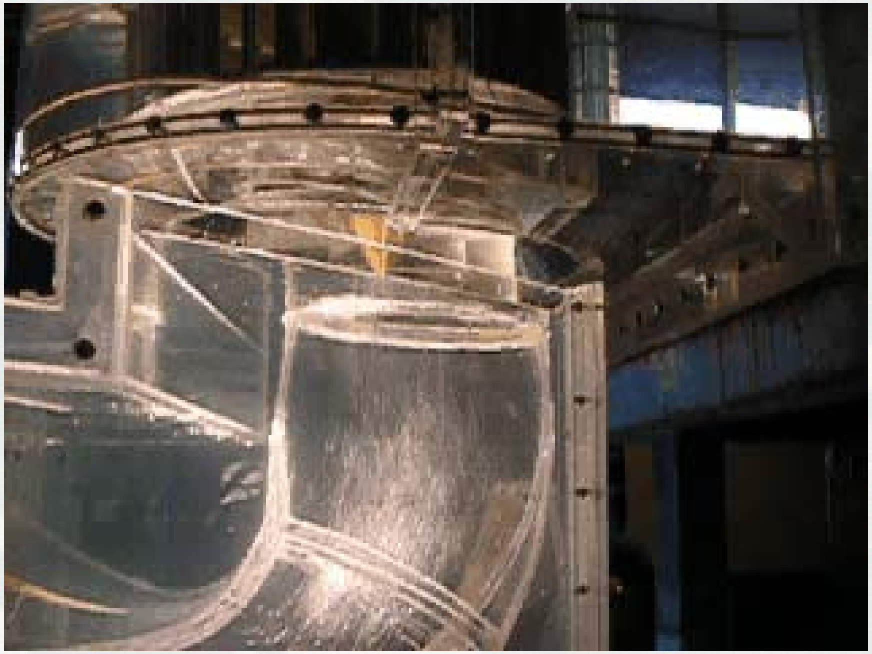


John Day Turbine Model

Lower 1% Operation



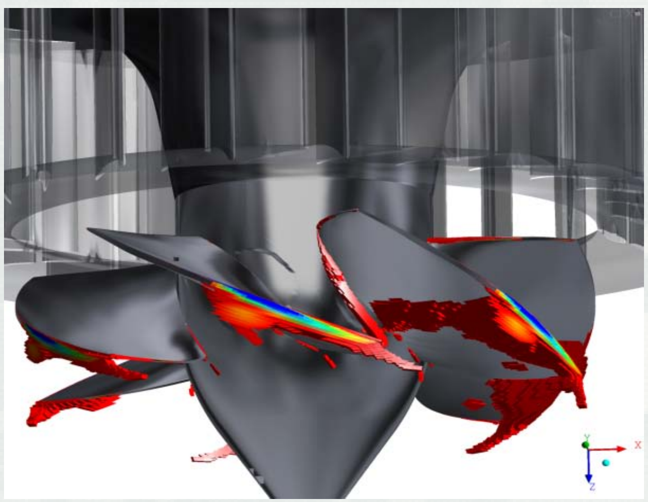
Assumed Best Operation



Computational Fluid Dynamics

Derives various flow characteristic including:

- Flow path and velocity
- Pressure
- Turbulence and energy loss.



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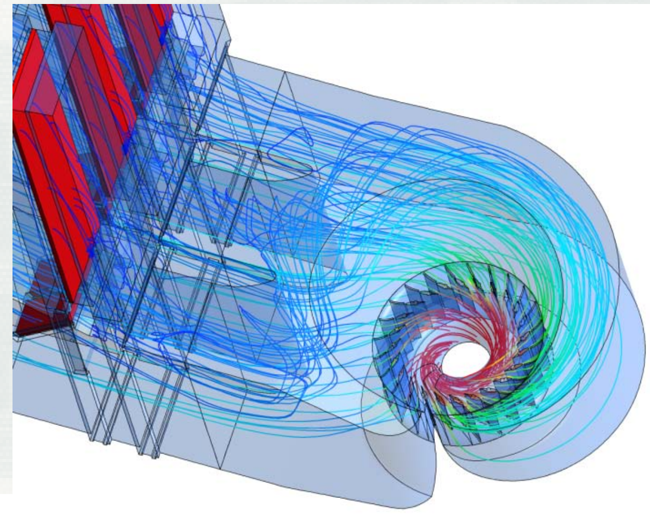
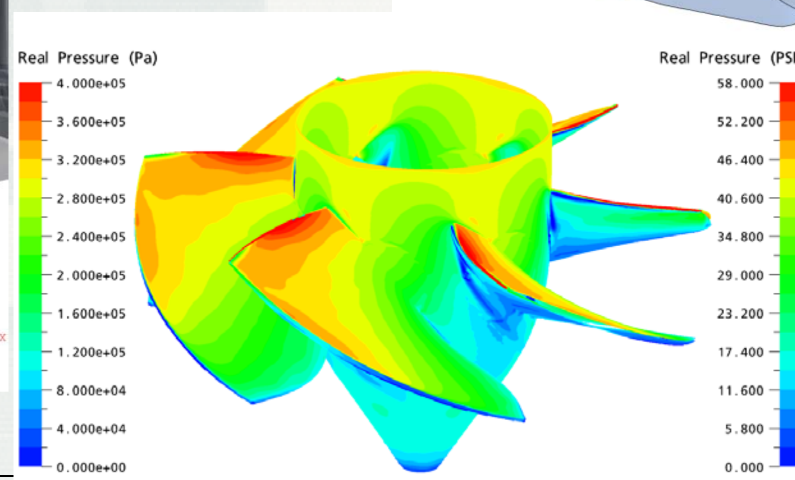
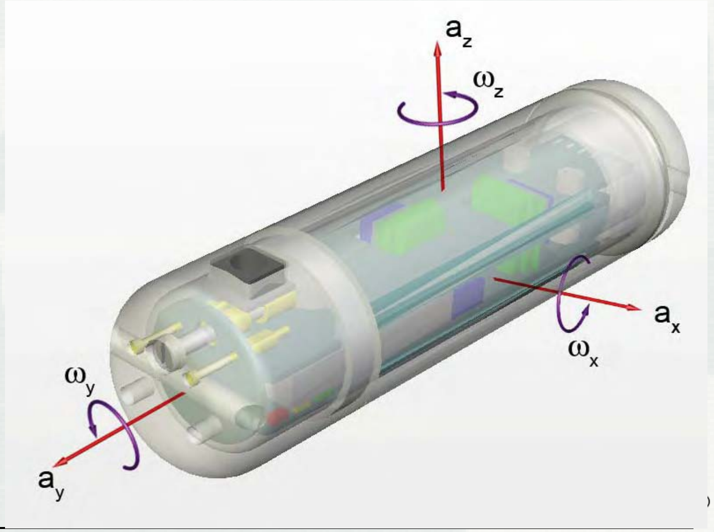




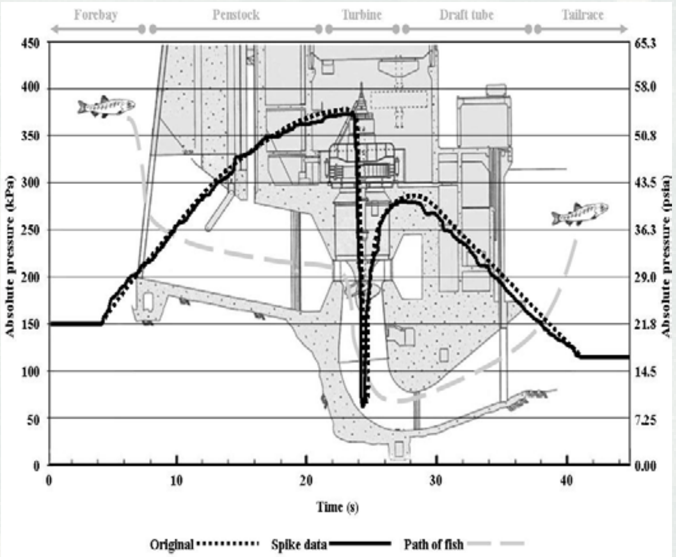
Sensor Fish

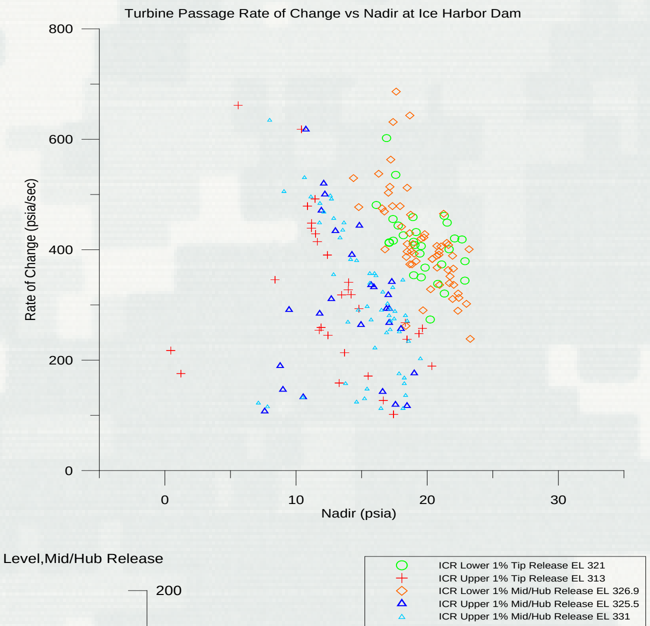
Sensor Fish (PNNL)
Carlson, Tom et. al. (2008)

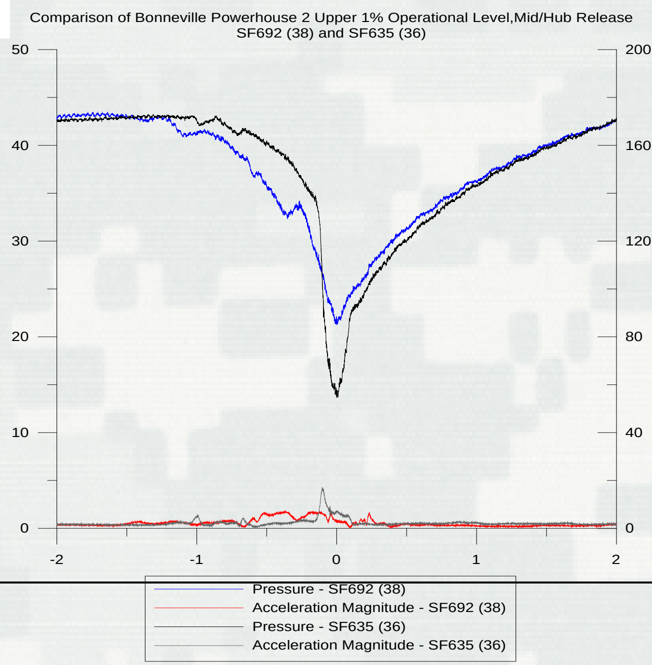
- Measures prototype pressure and acceleration
- Identifies potential for strike, shear and exposure to turbulence
- Supports laboratory pressure investigations, turbine operations and design.
- Validation of CFD and new prototype turbine designs.



Sensor Fish Results



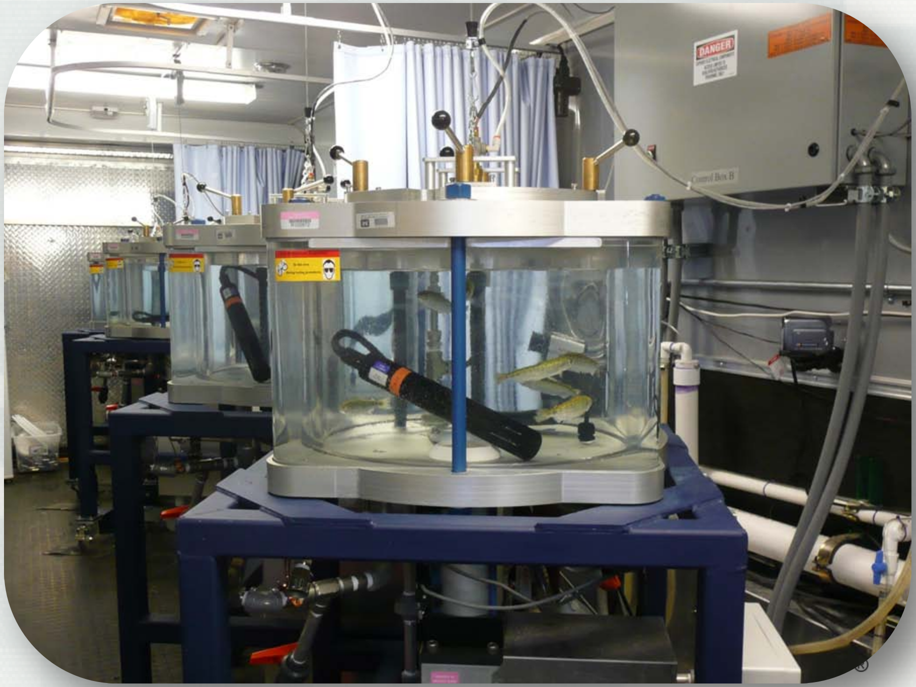




Laboratory Pressure Tests

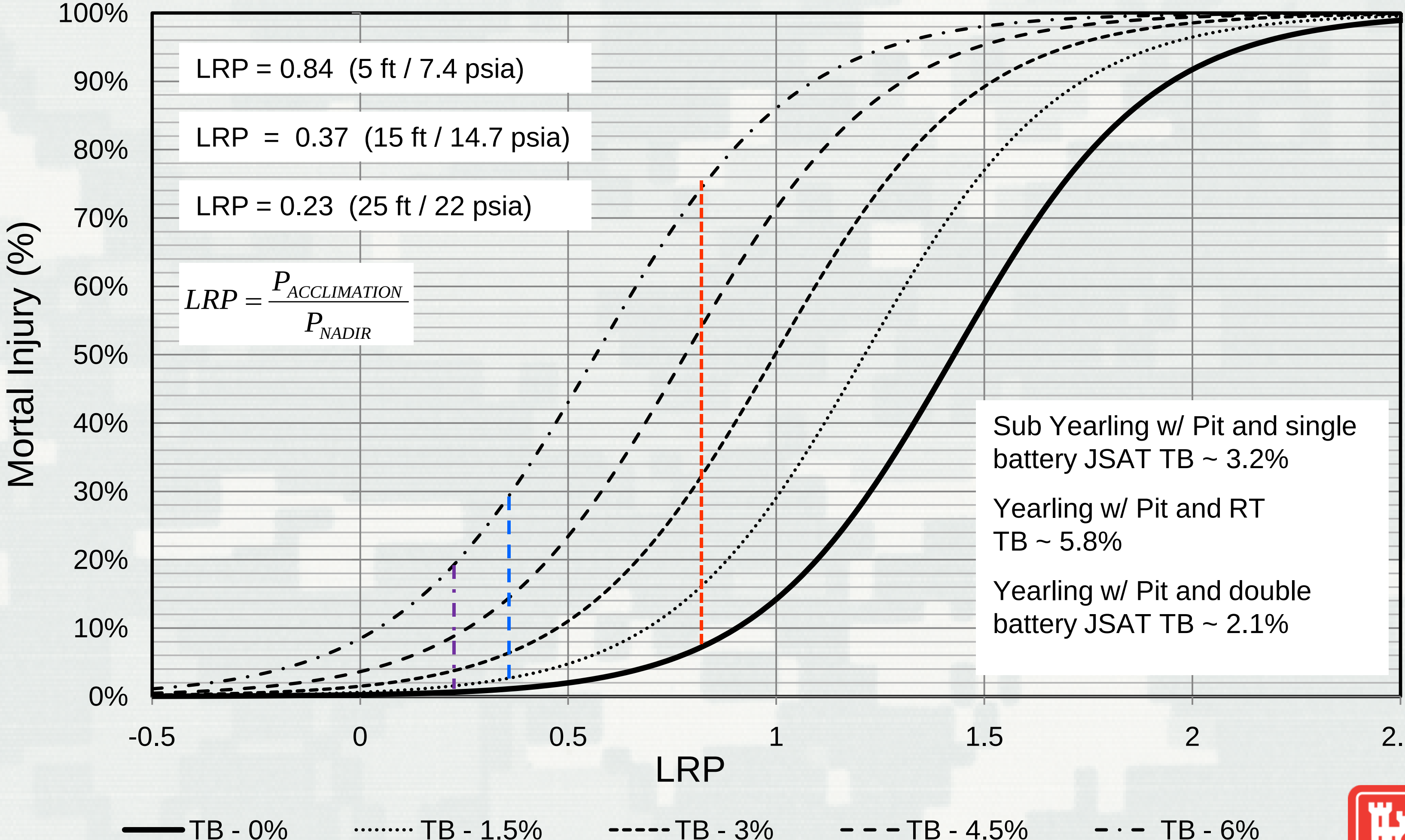
Hyper/Hypobaric pressure chambers designed to evaluate effects of simulate turbine pressures on juvenile salmonids

- Minimum (Nadir) pressures
- Pressure rate of change
- Acclimation pressures



Benchmarked effects of pressure on tagged and non-tagged fish

Pressure Mortality



TSP Findings

- The direct mortality and injury of fish passing through turbines due to strike is relatively low 2~4 percent
- Existing turbine pressures are not as extreme as previously perceived, generally greater than 10 psia
- Pressure has a greater effect on tagged fish than non-tagged fish
- Surgically implanted telemetry tags may negatively bias total turbine survival estimates.

TSP Findings

- We can reduce strike and shear related injuries by how we operate and design the turbine units.
- We can improve the “quality of flow” by how we operate the turbine.
- The “1-percent” operating range is not likely the best operating range for all FCRPS turbines.
- Downstream predation likely has the greatest impact on survival of turbine passed fish.
- To fully realize the benefits of turbine improvements, predation in the tailrace must be addressed.

Benefits of TSP

- TSP will help to meet and maintain performance standards through higher turbine survival rates.
- An increase in turbine survival will allow flexibility in managing other passage routes for the benefit of both juvenile salmonids as well as lamprey.
- TSP will continue to investigate and support the design and operation of turbines for safer fish passage.

What's Next for TSP

- Field verification/testing hypothesis of best operating condition.
  - Develop new or improved test methods
- Evaluate methods of minimizing tailrace predation.
  - Improving both unit, powerhouse and project operations for better egress conditions
  - Consider additional methods of predator control
- Sharing "state-of-knowledge" through outreach to other Stakeholders.
- Continue to support the operation and design of new turbines.

TSP and Turbine Rehabilitation

- Turbine rehab decisions are prioritized on the physical condition, reliability, economic benefits and age of individual turbine units.

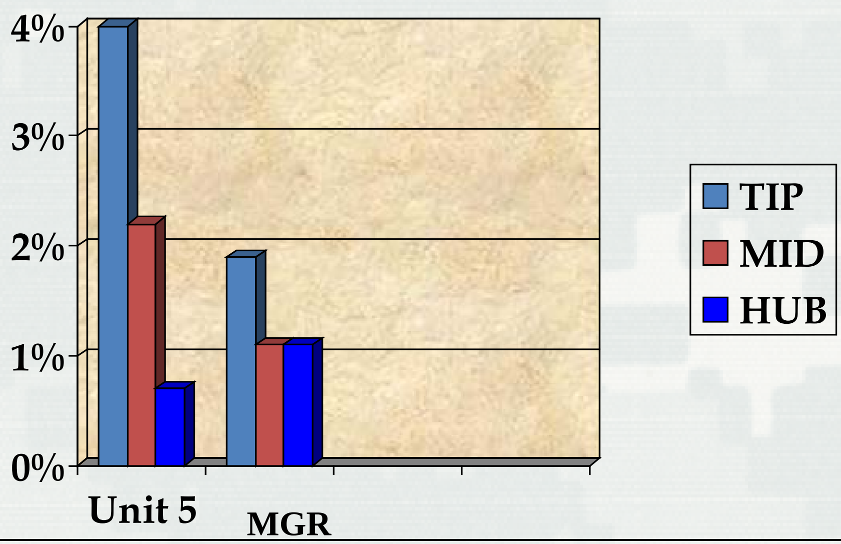
- Funding for turbine replacements would be prioritized within the Capital Work Group

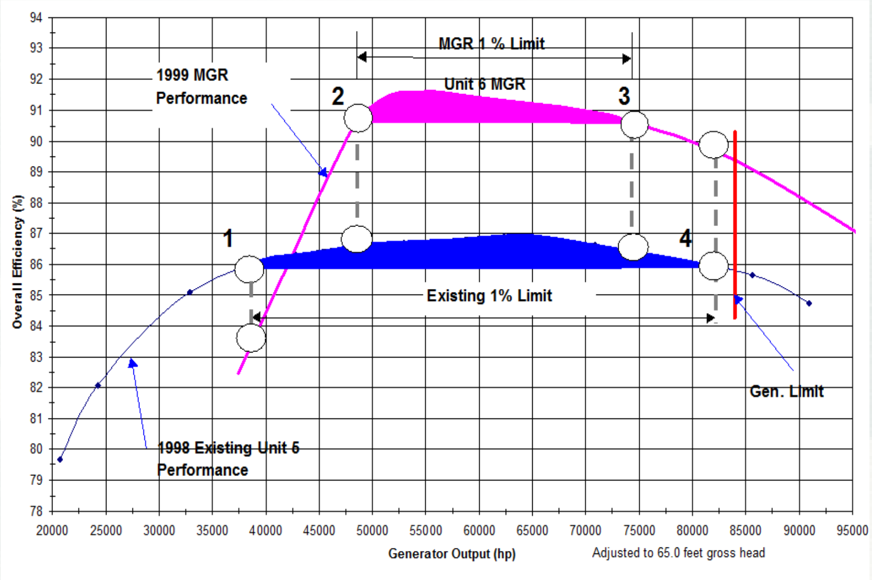
- The TSP supports turbine replacements by providing design guidance for safer fish passage but does not direct or prioritize turbine rehabilitations.

Current Status
Runner Replacements

Bonneville First Powerhouse

- 10 units replaced with new "MGR" runners
  - Higher efficiency with less injury to fish
  - Final Commissioning Completed Jan 2011
- Design was specified by the Government and developed by the Contractor. Focus primarily on power but included fish passage improvements





Runner Replacements

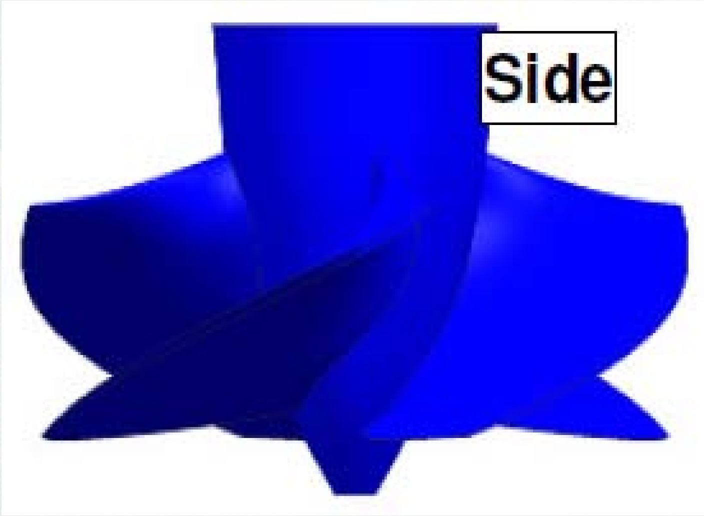
McNary Modernization

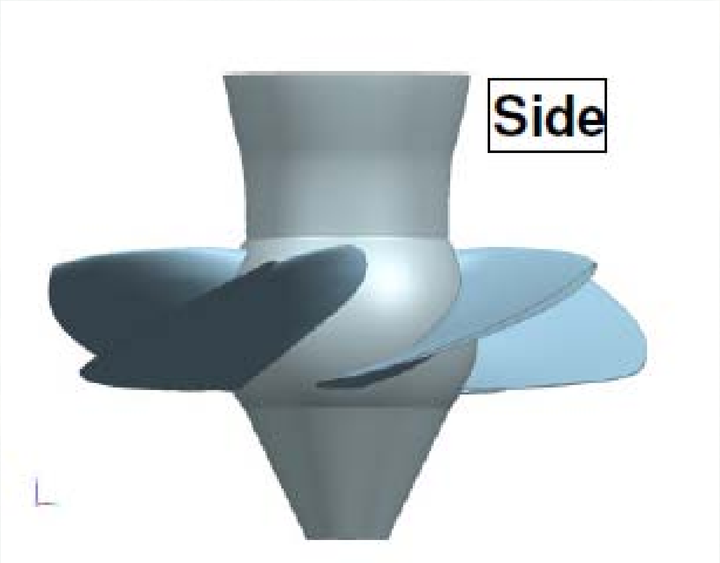
- Solicitation issued for design, manufacture and installation of new turbine runners. Evaluated and model tested 3 proposed designs having fish passage improvements. Based on proposals received and other economic considerations a contract was not awarded.

- Focus primarily on increased power and efficiency but was to include fish passage benefits. Designs were developed by multiple manufactures but evaluated for fish passage improvements by the Government prior to final selection.

Ice Harbor Units 2 and 3

- Contract awarded March 2010 for design and supply of fixed and adjustable blade turbine runners. Supply of adjustable blade runner is an “Optional” item. Installation 2014-2015.





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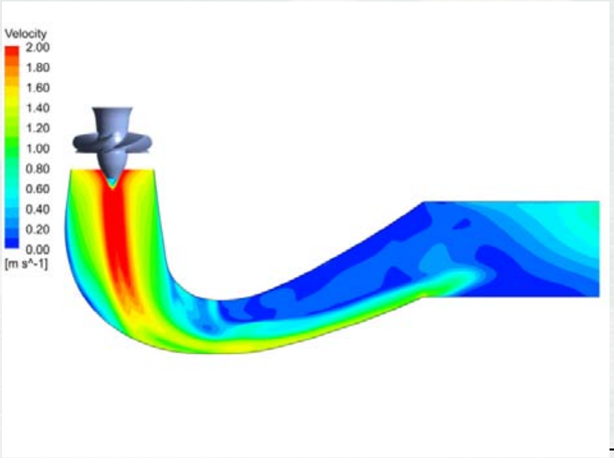
Ice Harbor Units 2 and 3

- Design focuses on improved fish passage. Contract includes specific fish passage criteria with no criteria for power or efficiency. Uses a collaborative and iterative design approach developed by the TSP.



Questions Comments ???