Hydroelectric Plant Turbine, Stream and Spillway Flow Measurement

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Jan Buermans

ASL AQFlow Inc. and

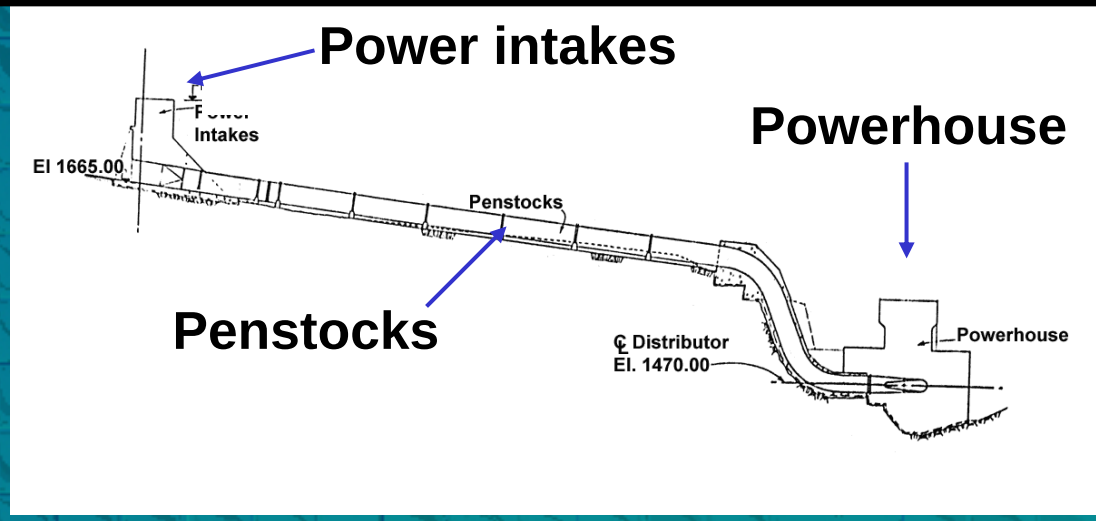
ALS Environmental Sciences Inc.

Sidney, British Columbia,

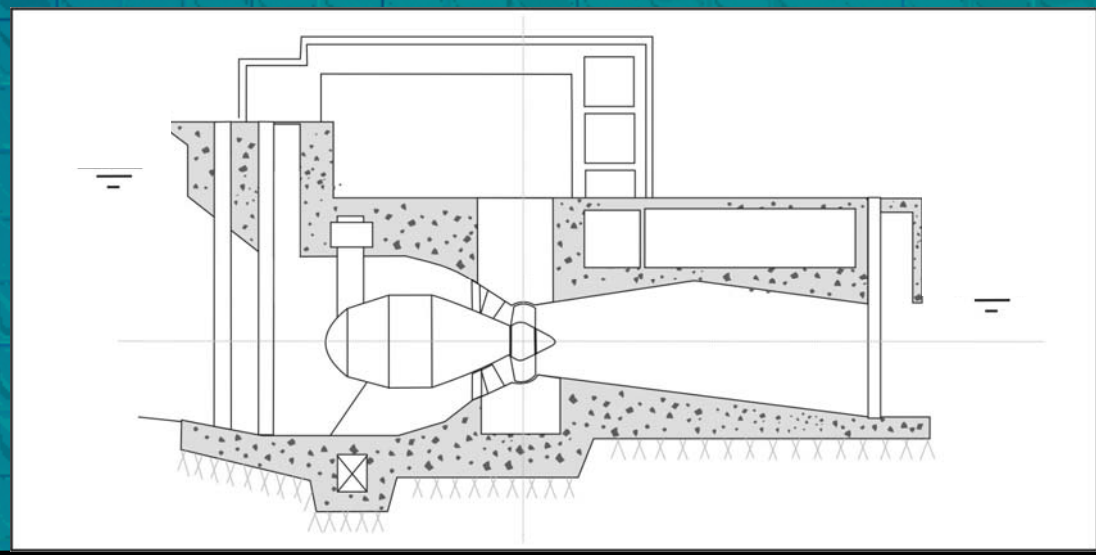
Canada

Turbine Flow Measurement

Kootenay Canal Plant, British Columbia, Canada



Typical bulb installation



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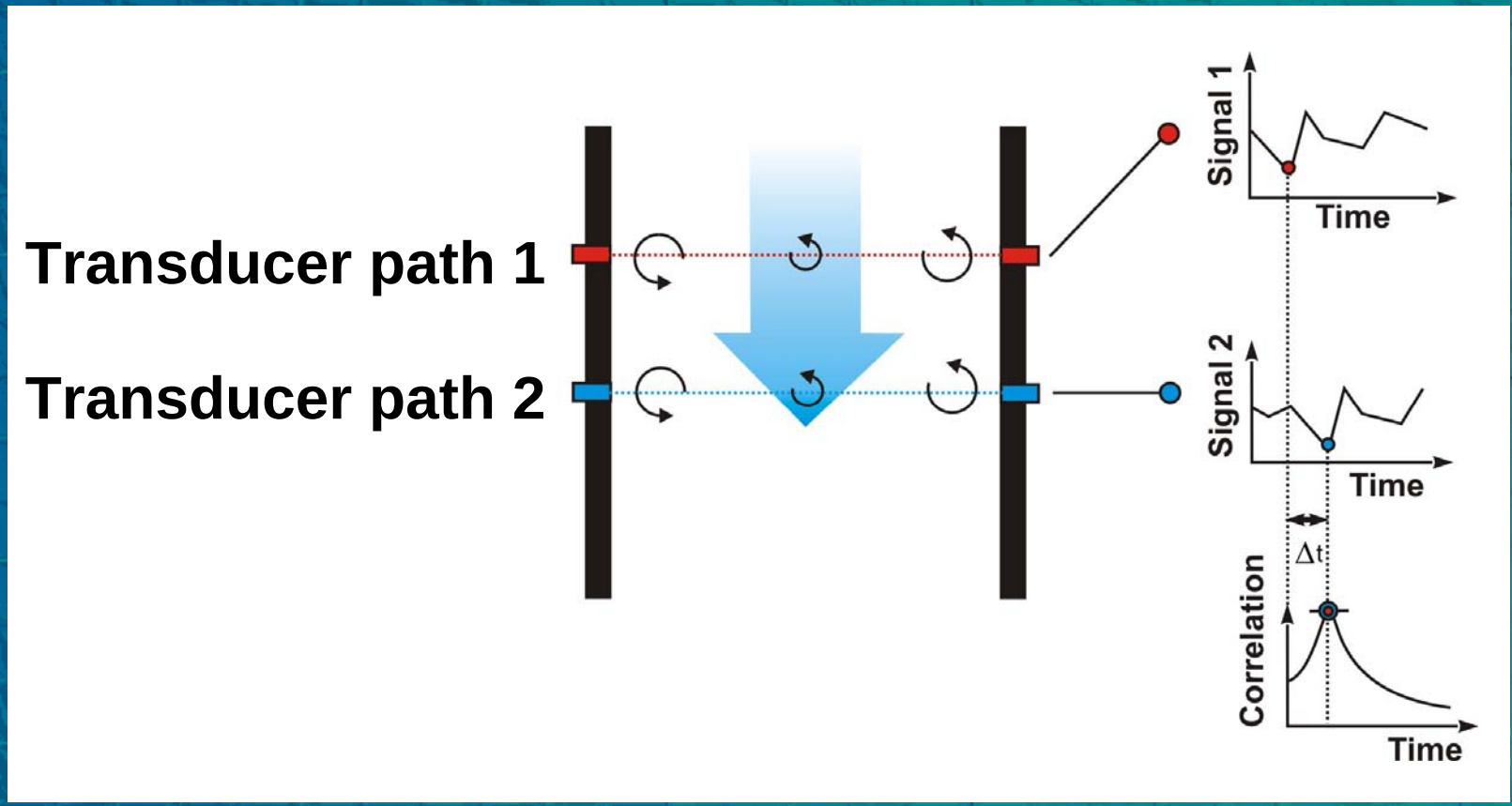
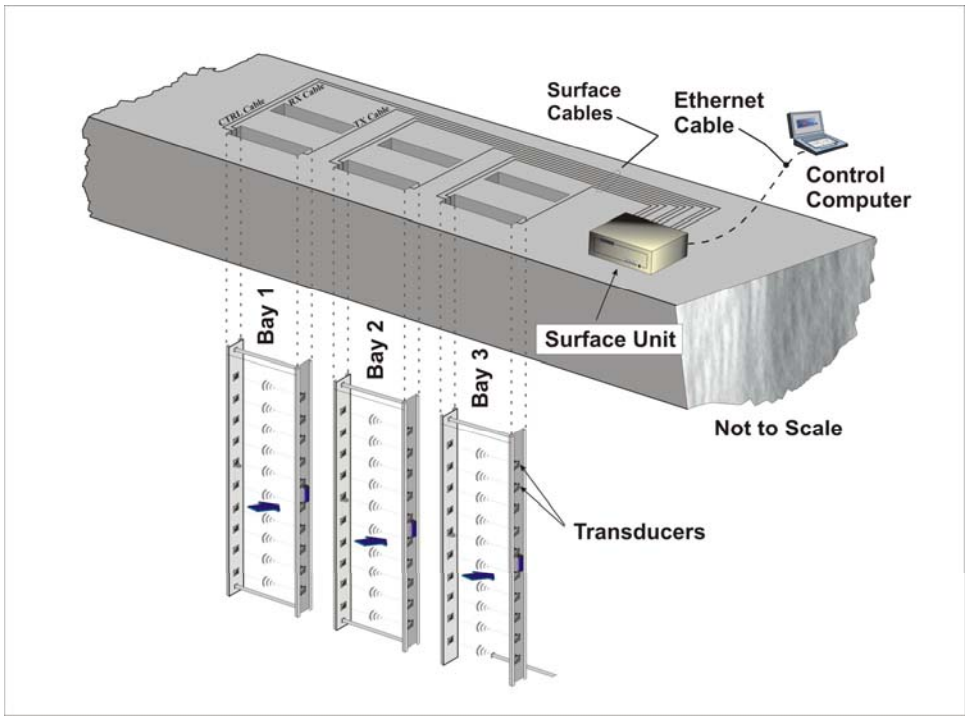
Representation of ASFM operation



Acoustic Scintillation

Typical Arrangement



- portable and flexible
- non-intrusive and non-vulnerable
- suitable for shortest intakes
- minimal maintenance and calibration
- cost effective
- repeatable
- accurate

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Lower Monumental Hydroelectric Project (6 x 135 MW)

Owner: COE, Walla Walla District, Washington State, USA

River: Snake

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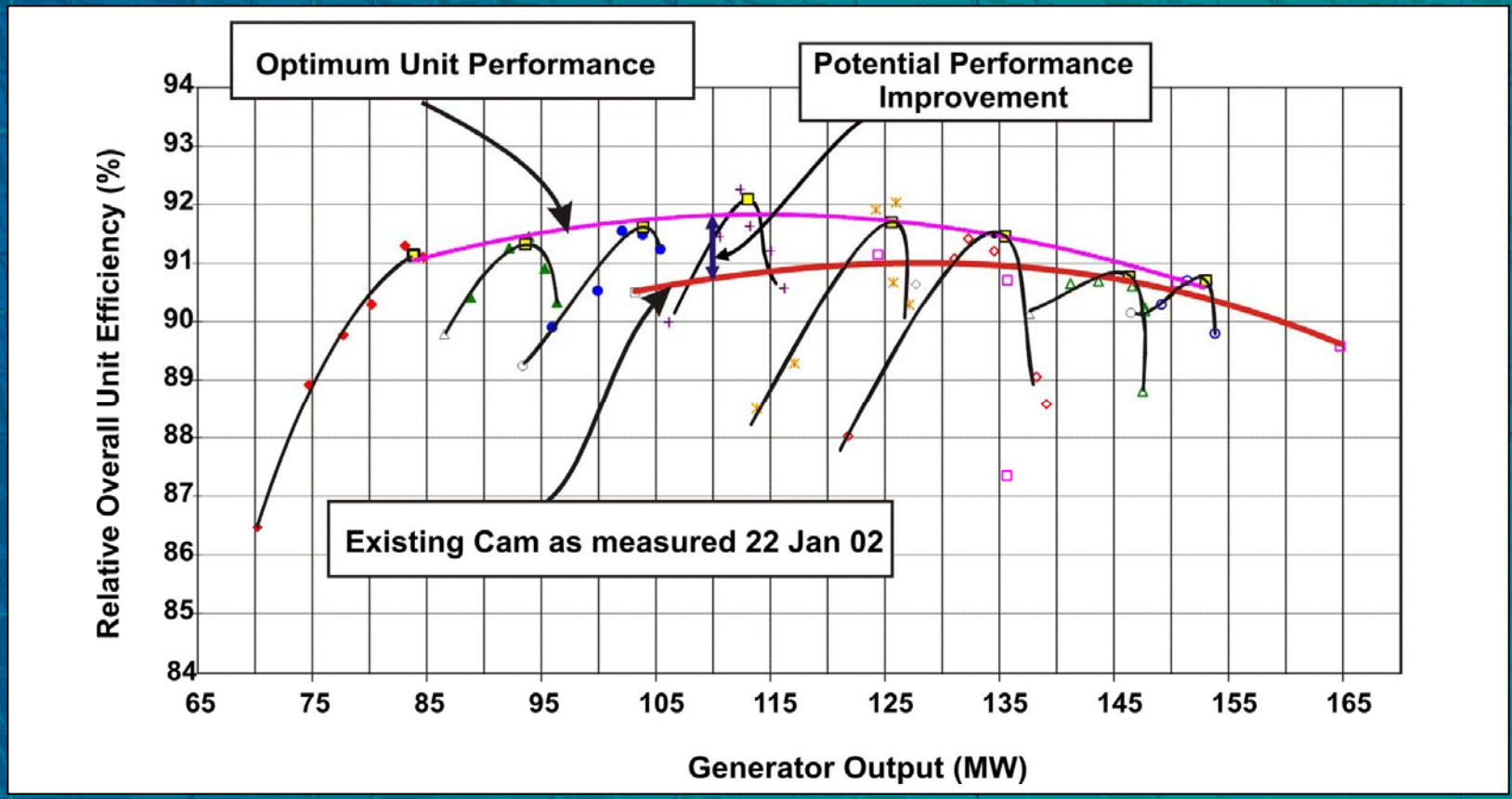
Lower Monumental Unit 2
Index test without screens



Key requirement: repeatability

Wells Hydroelectric Project
(10 x 85 MW)

Owner: Douglas County PUD, Washington State, USA

River: Columbia

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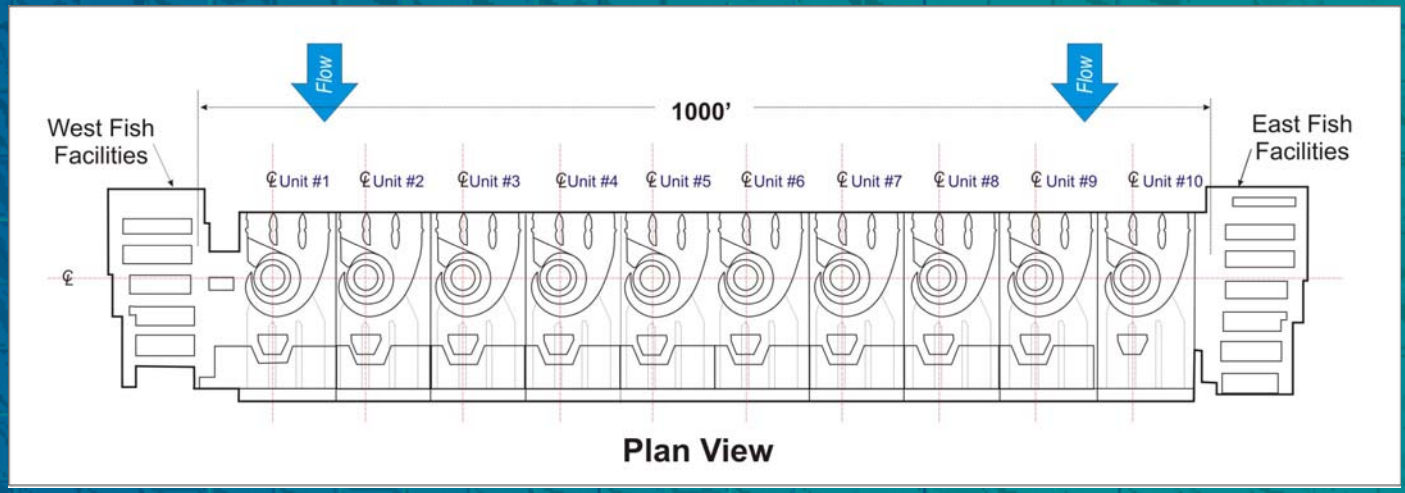
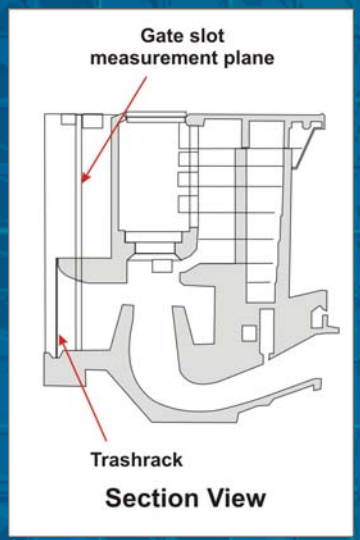
Wells Hydroelectric Project





- Sep-Oct 2002 Comparison & Diagnostic Testing - Unit #3
- Jan 2004 Diagnostic Testing - Units # 1,2,6 & 10
- Aug-Sep 2004 Performance Testing - Units #3 & 4
- 2005-2008 Performance Testing of Remaining Units

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Key requirement: accuracy

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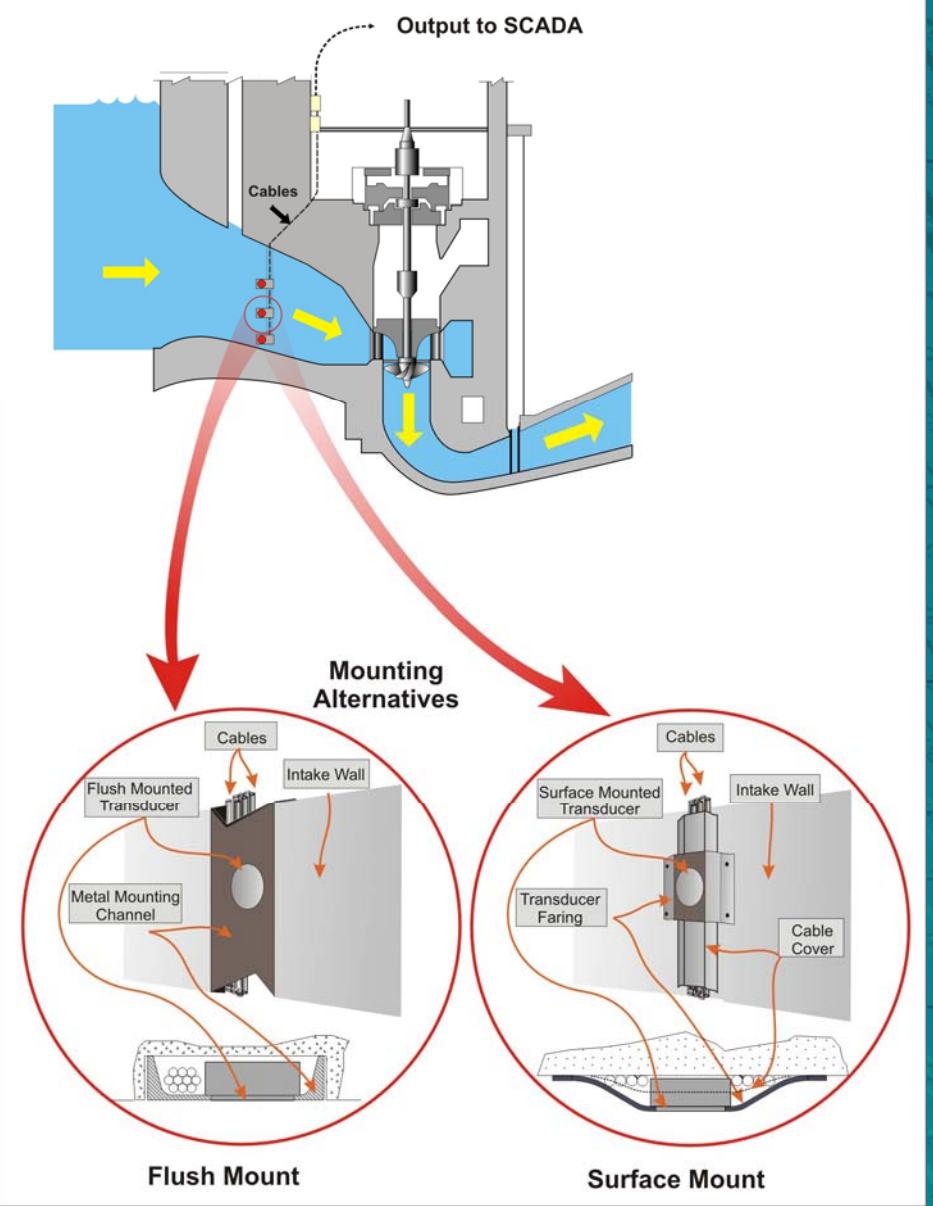
Acoustic Scintillation Monitor



- non-intrusive and non-vulnerable
- suitable for shortest intakes
- minimal maintenance and calibration
- repeatable
- accurate

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Key requirement: long-term performance

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Summary

For short intakes of low head plants,

acoustic scintillation provides cost-effective:

- **Repeatable performance testing of individual units**
- **Accurate performance testing of multiple units**
- **Reliable long-term monitoring in real-time**

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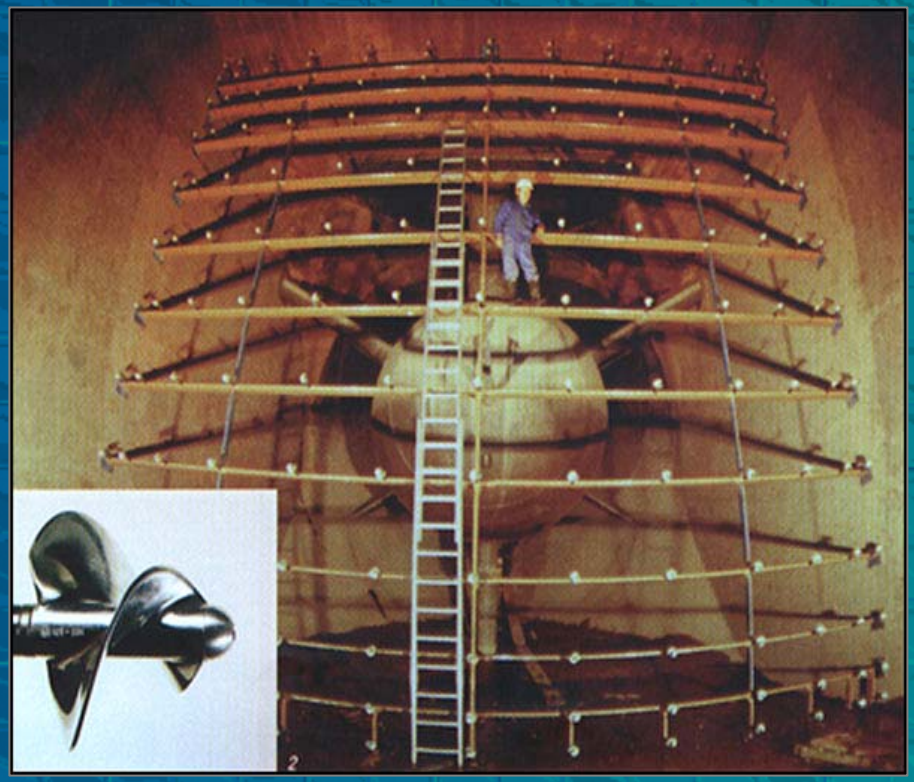
Current meters



Courtesy of Turboinstitut,

Slovenia

Acoustic scintillation

Courtesy of COE, USA

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Turbine flow measurement in short intakes
Comparison between Current meters and Acoustic scintillation

	Current meter	Acoustic scintillation
Portable and flexible	NO	YES
Non-intrusive and non-vulnerable	NO	YES
Suitable for shortest intakes	YES	YES
Minimal maintenance and calibration	NO	YES
Low cost	NO	YES
Repeatable	YES	YES
Accurate	YES	YES

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Stream Flow Measurement

- Downstream areas are environmentally important for fish, habitat
- Circulation can be defined and effects of changes assessed by a combination of field measurements and numerical modelling
- High resolution field measurements of flow provide calibration and verification of the model
- The model then simulates the effects of changes, and gives detail in regions inaccessible for measurements

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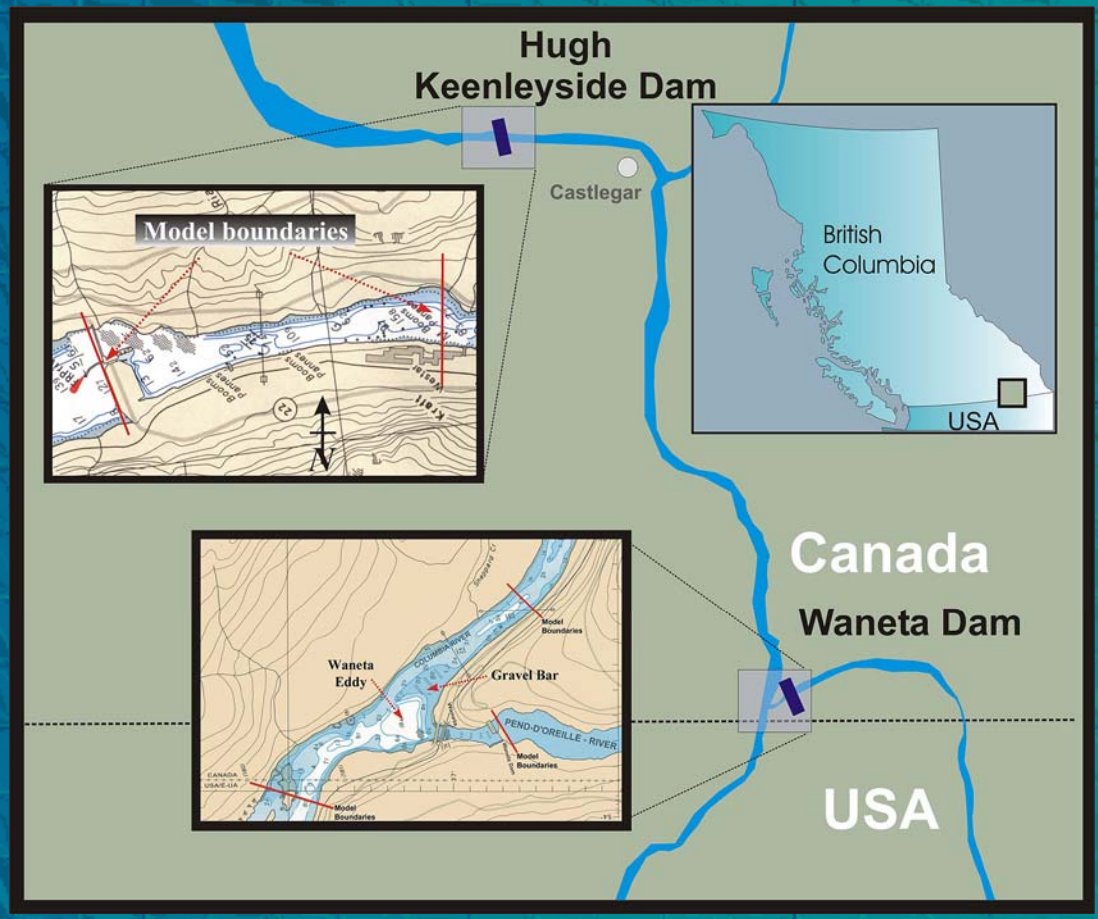
Field Measurement Methods for Circulation

- At least two sets needed: one for model calibration, one for model verification
- Acoustic doppler current profilers from manned boats or unmanned vessels for spatial patterns
- Moored profilers for time series
- Examples from Keenleyside and Waneta Dams

Columbia River, Arrow Lakes to US-Canada border



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Acoustic Doppler current profiler mounted on workboat

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Unmanned vessel for acoustic Doppler current profiler

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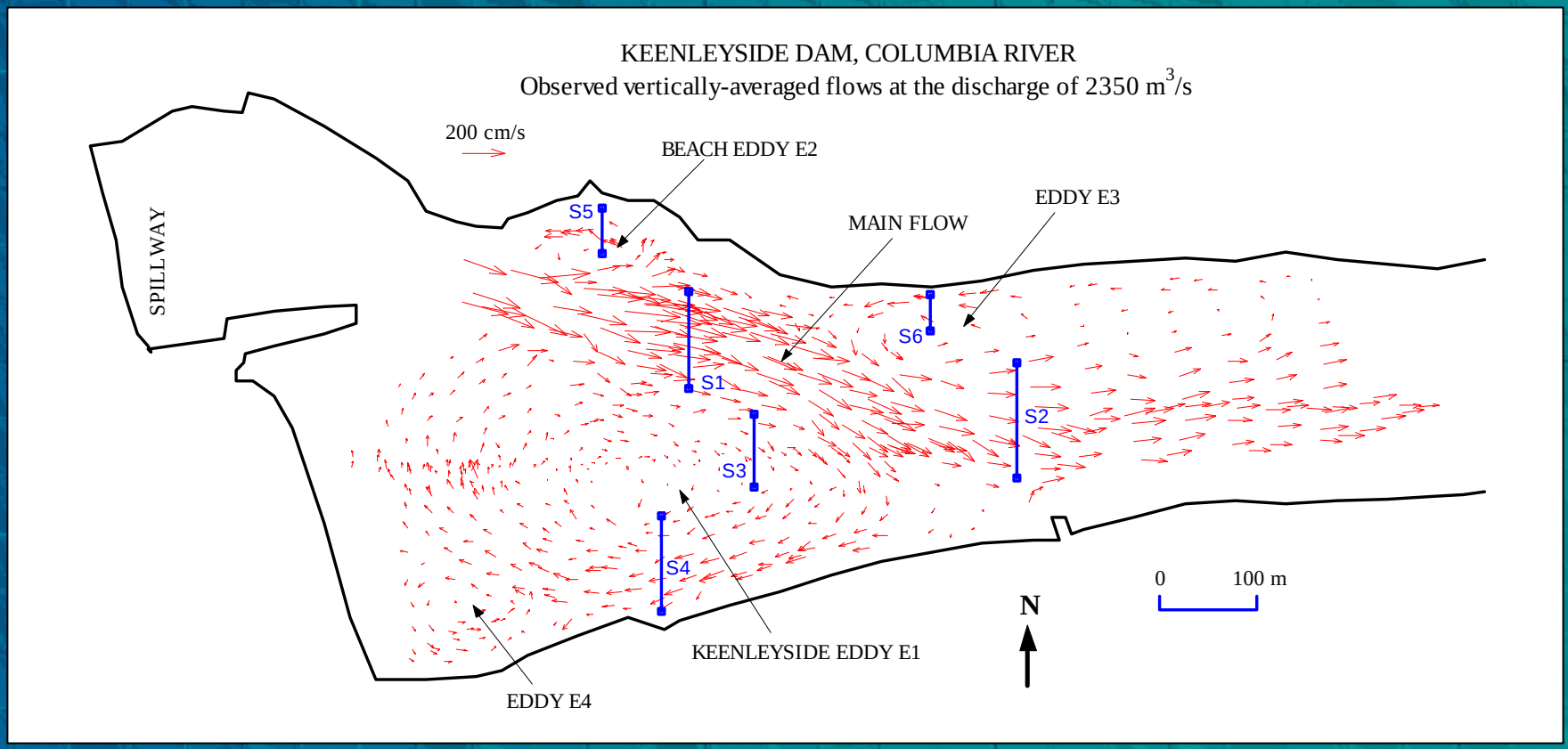
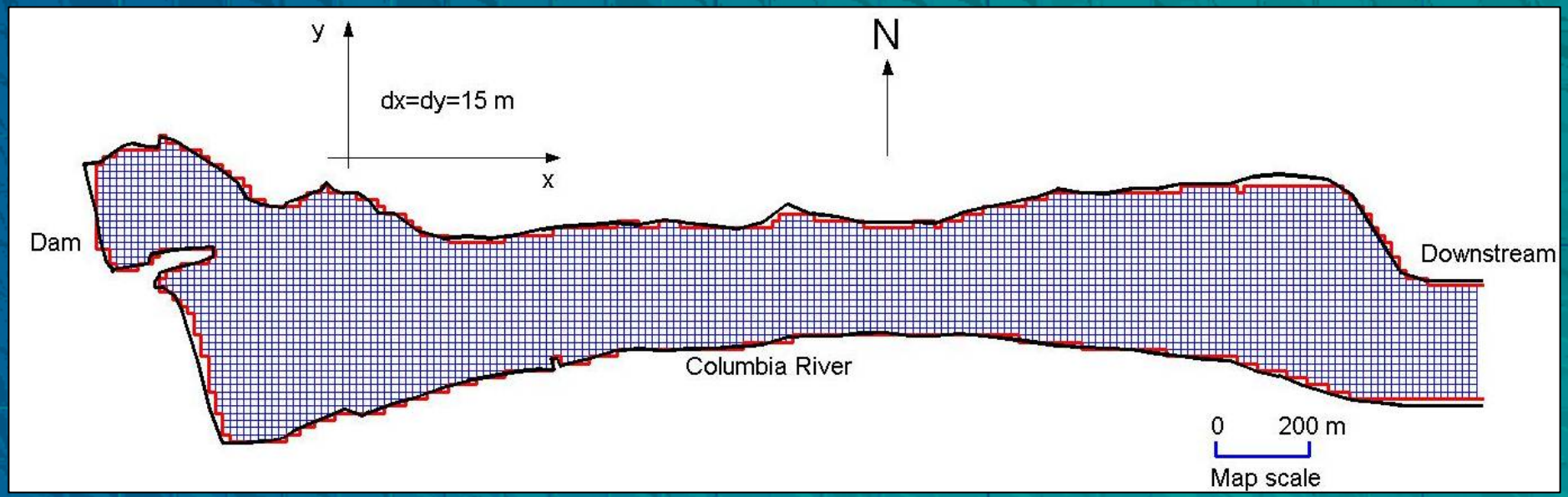
Measured circulation downstream of Keenleyside Dam



Grid mesh for numerical model of the area downstream of Keenleyside Dam



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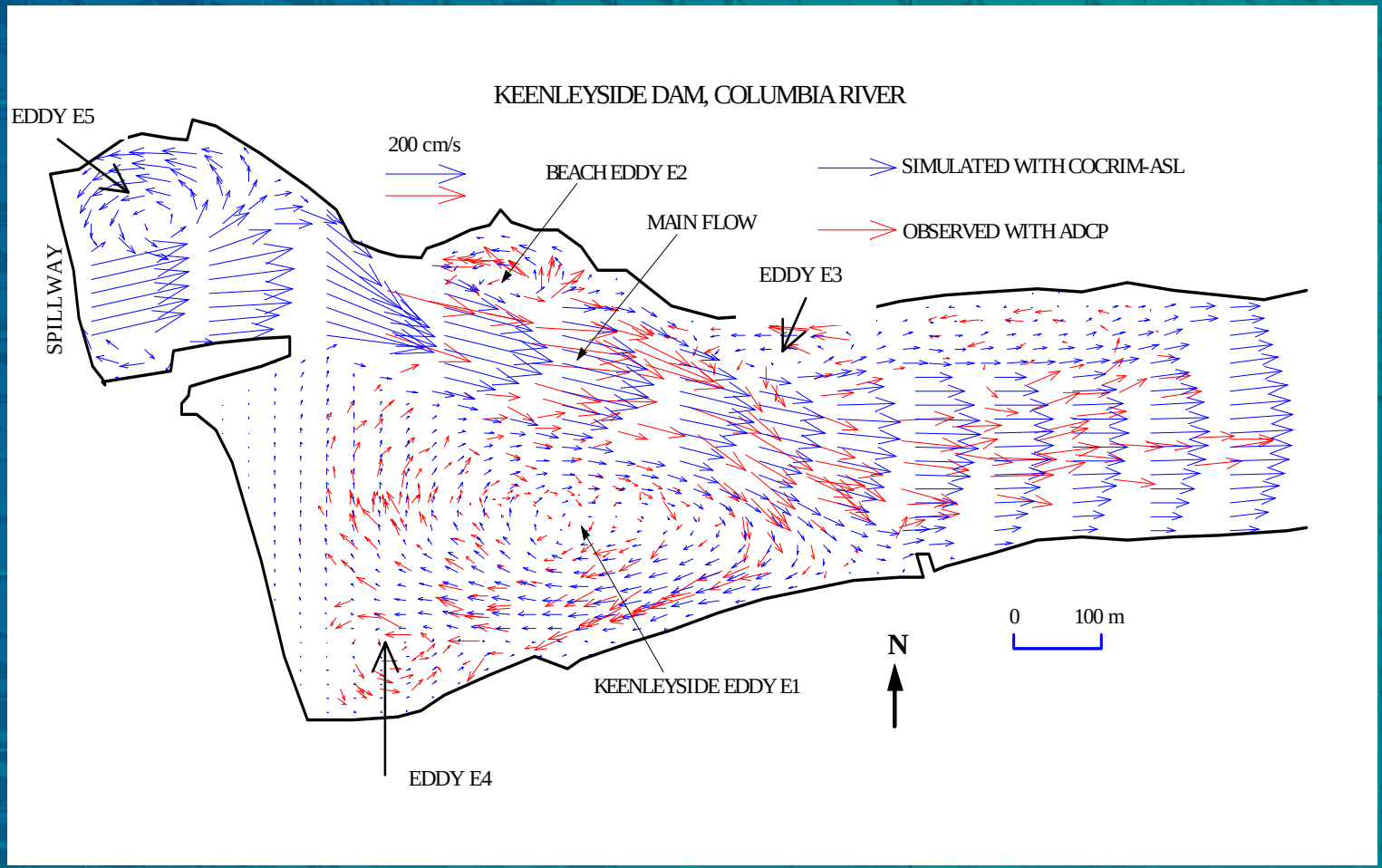
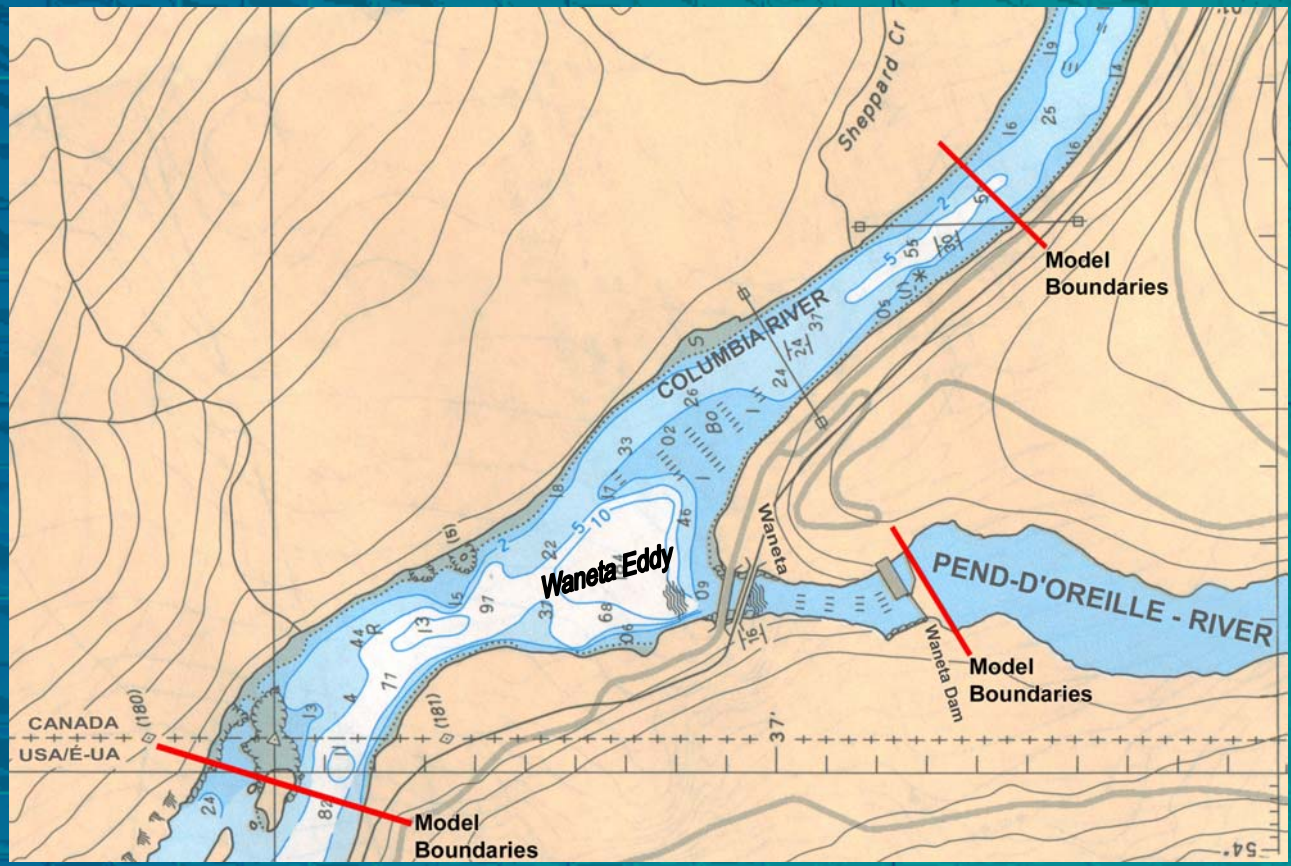
Measured and modelled flows at Keenleyside Dam



Confluence of the Columbia and Pend d'Oreille Rivers



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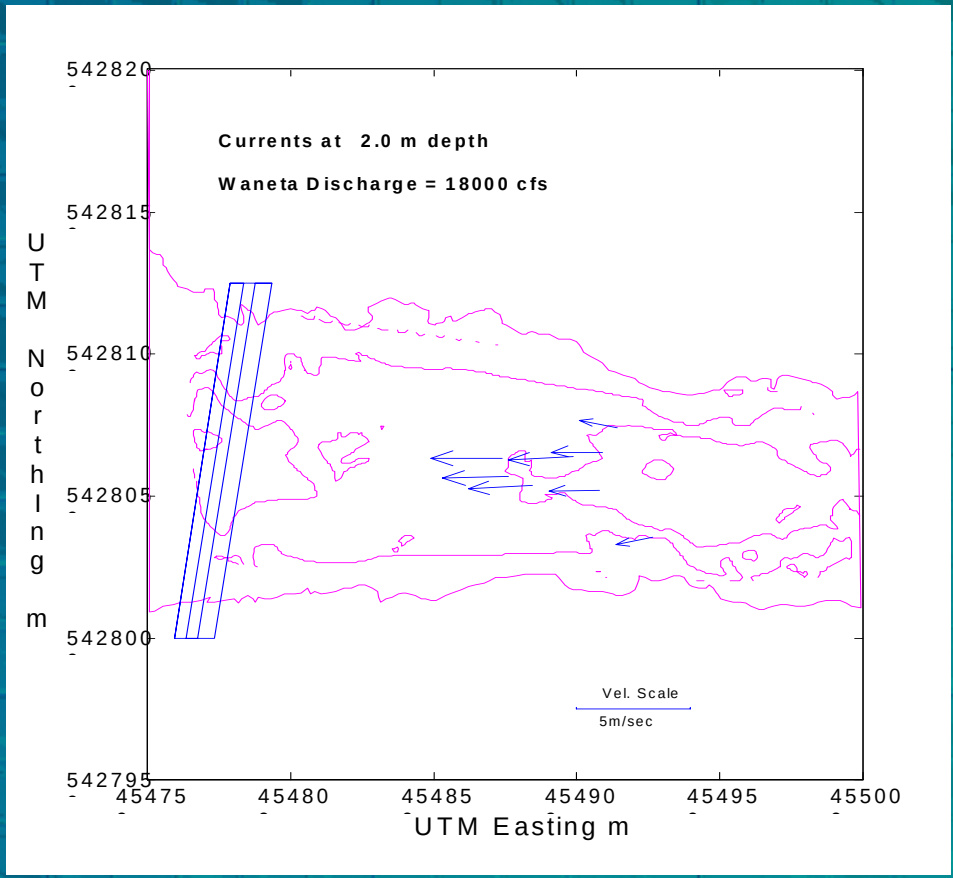
Flow measured in the Pend d'Oreille,

using the unmanned vessel and 1200 kHz Acoustic Doppler Current Profiler



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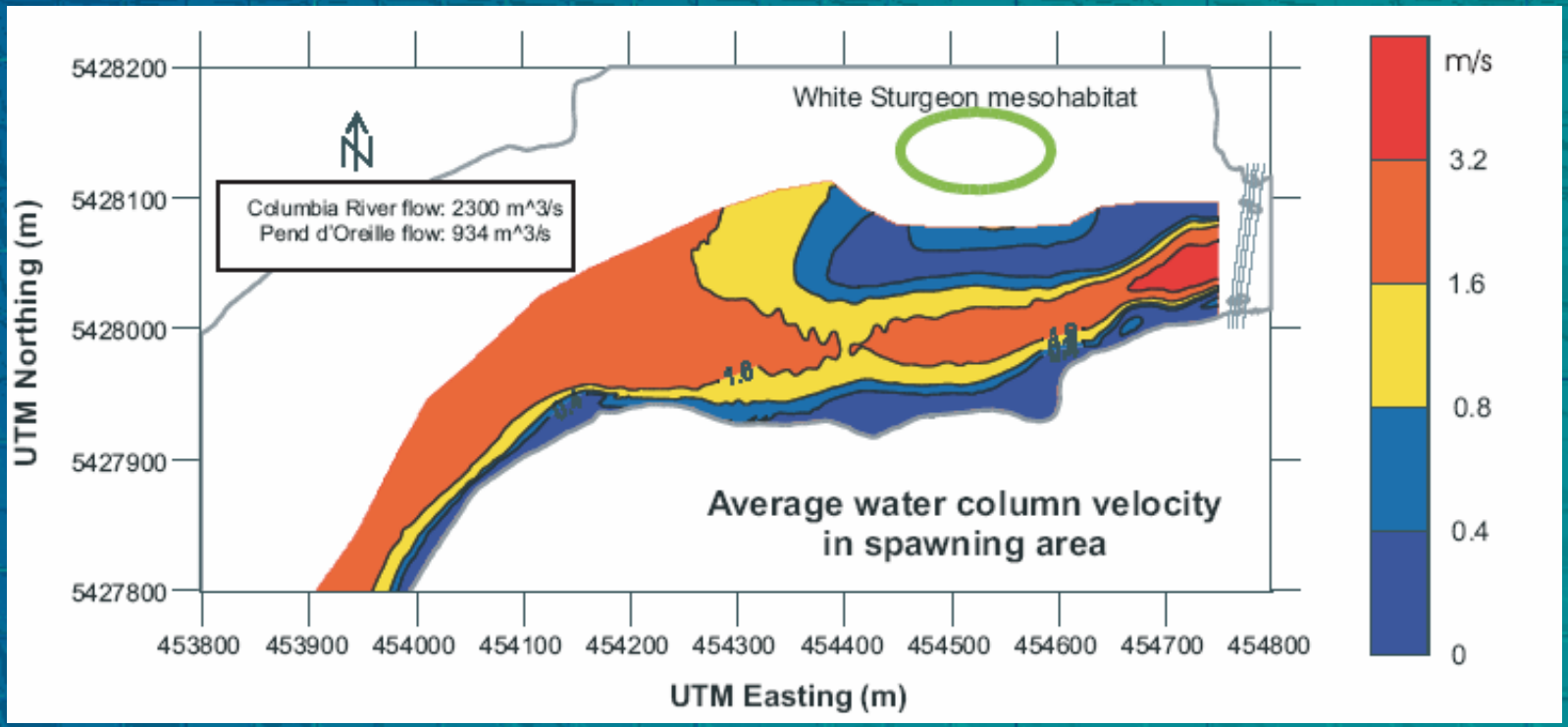
Model Flow at the Confluence



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Spillway Flow Measurements

Introduction

- Why?
- Alvkarleby, Swed Power
- Le Coteau, Hydro Quebec
- Computational Fluid Dynamics (CFD)
- River Transects
- Future Flow Measurements

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Spillway Discharge Measurements by Acoustic Scintillation Flow Meter in Spillway B at Mellanfallet Dam, Alvkarleby Hydro

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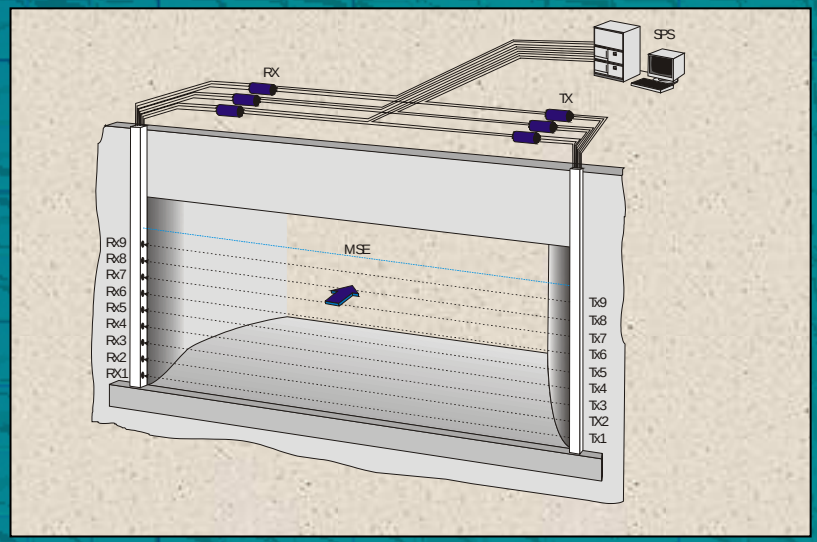
Alvkarleby, Continued

Installation of ASFM



Test #	Water Elevation (m)	Gate (m)	Discharge – Q M^3/sec	
			Curves	ASFM
7	22.38	0.5	28	20
8	22.40	0.5	28	19
3/4	22.44	1.0	52	47
5/6	22.40	FG	124	72

Summary:

- Only at 0.5 m opening were all ASFM paths operational
- Results not credible
- No inter-comparison measurement to evaluate possible bias

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November 2000, Hydro Quebec's spillway discharge measurements at their Le Coteau Spillway using their ASFM

Small opening

Medium opening

Full gate

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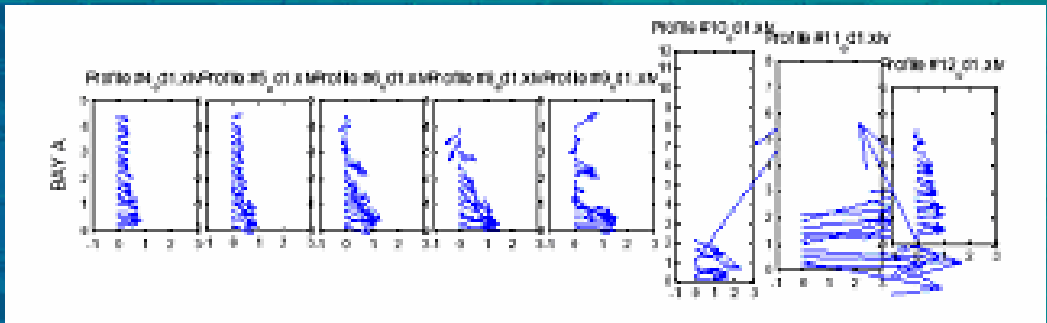
Le Coteau Spillway Flow Values

Profile	Opening (m)	Flow (m^3/s)	Max Elevation for ASFM measurements (m)	Elevation free surface (m)
#12	0.55	31	All	4.5
#4	0.57	28	All	4.5
#5	0.75	30	All	4.5
#6	0.97	31	All	4.5
#8	1.30	37	3.650	4.5
#9	1.30	40	3.865	4.5
#10	1.87	84	2.068	4.2
#11 FG	4.50	264*	2.068	4.2

* This flow has a large uncertainty associated with it since velocities in the top half of the flow area were not measured



Summary:

- Results not consistent
- Unable to make accurate measurements at larger openings
- No inter-comparison method to evaluate possible bias

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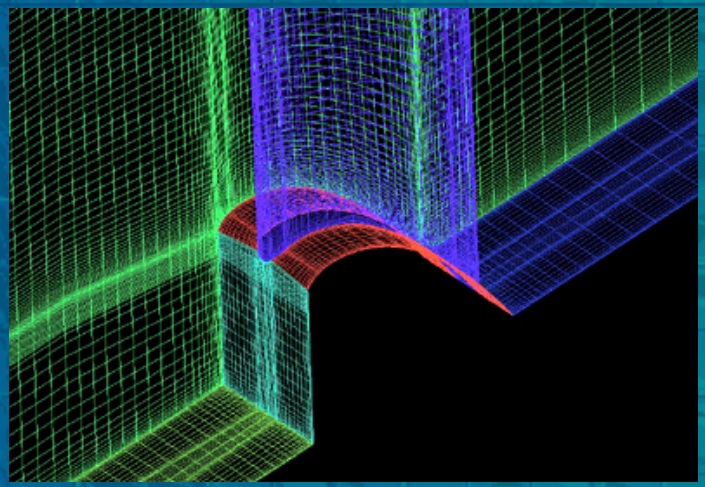
Three Dimensional Numerical Simulation of Turbulent Flow Over Spillways

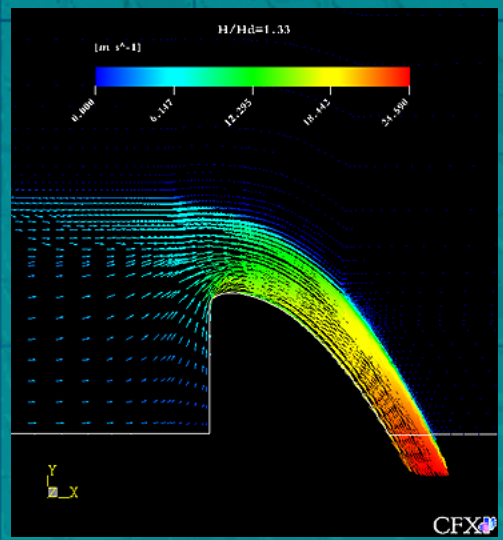
Dr. L Bouhadji Email: *lbouhadji@aslenv.com*

ABSTRACT: Turbulent flows over a spillway structure are investigated using computational fluid dynamics (CFD). Simulations are carried out to validate two and three dimensional CFD models in these structures. The numerical results are compared to available experimental data published by the US Army Corps of Engineers

Turbulence models and multi-phase models are used to simulate multiple fluid streams, bubbles, droplets, solid particles and free surface flows.



Topology



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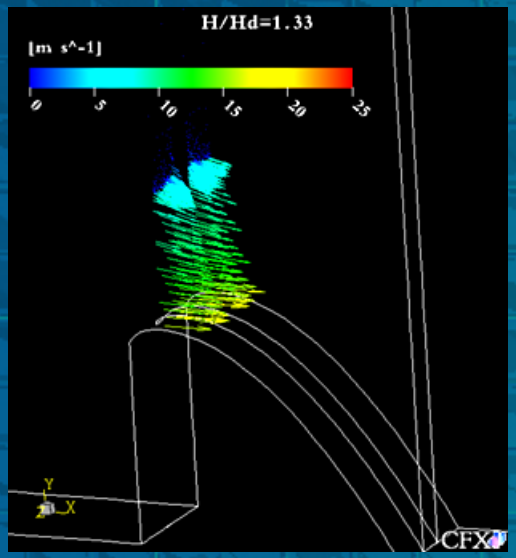

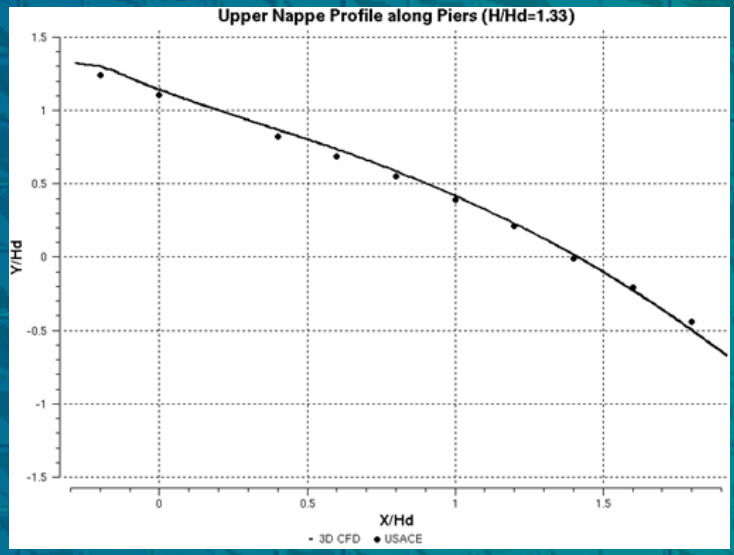

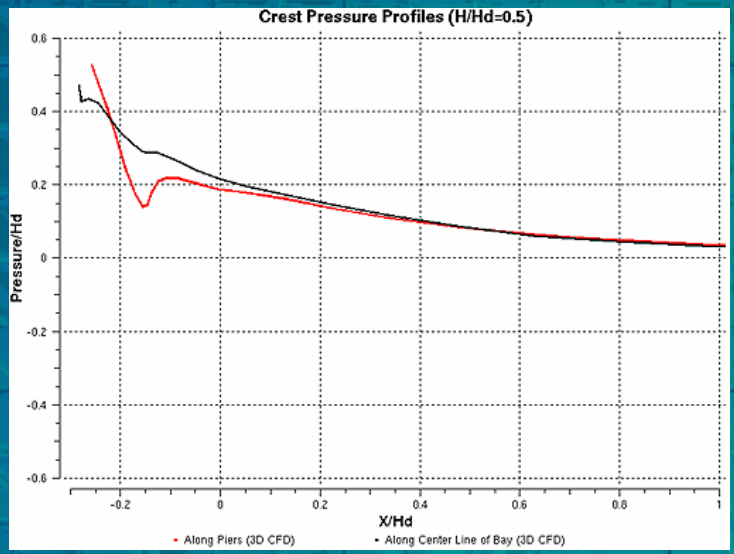

CFD Results

Summary:

- CFD Modeling appears promising
- More work is necessary
- We need to apply CFD to Le Coteau and Alvkarleby spillways

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River Transects

- Cumbersome
- Spill lots of water
- Needs time to stabilize
- Acoustic Doppler Current Profilers with bottom tracking capability
- ASL expert
- Excellent for inter-comparison flow measurement

An ADCP attached to a small jet-boat for river transect work. A fairing has been attached to the ADCP to reduce drag and entrainment of bubbles.

ASL Environmental Sciences owns and operates a number of RDI ADCP Workhorse Sentinels.

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Recommended action for next field spillway flow measurement

- Conduct CFD analysis first to predict surface profile and side turbulence.
- Use ASFM in lower portion of the flow section,
- Use several ADCP's in upper portion, and,
- Use a river transect to confirm flow measurement where possible.

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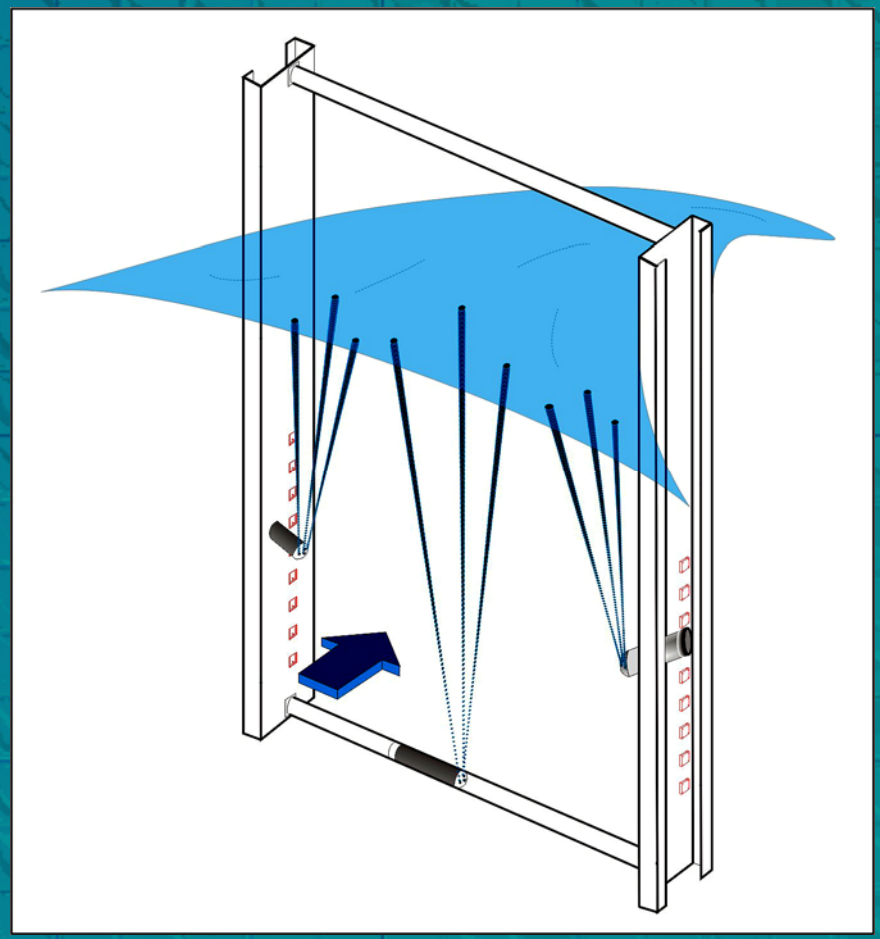
Possible Measurement Frame for Spillways

- ASFM does not work in the upper portion of the flow
- Acoustic Doppler Current Profilers



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