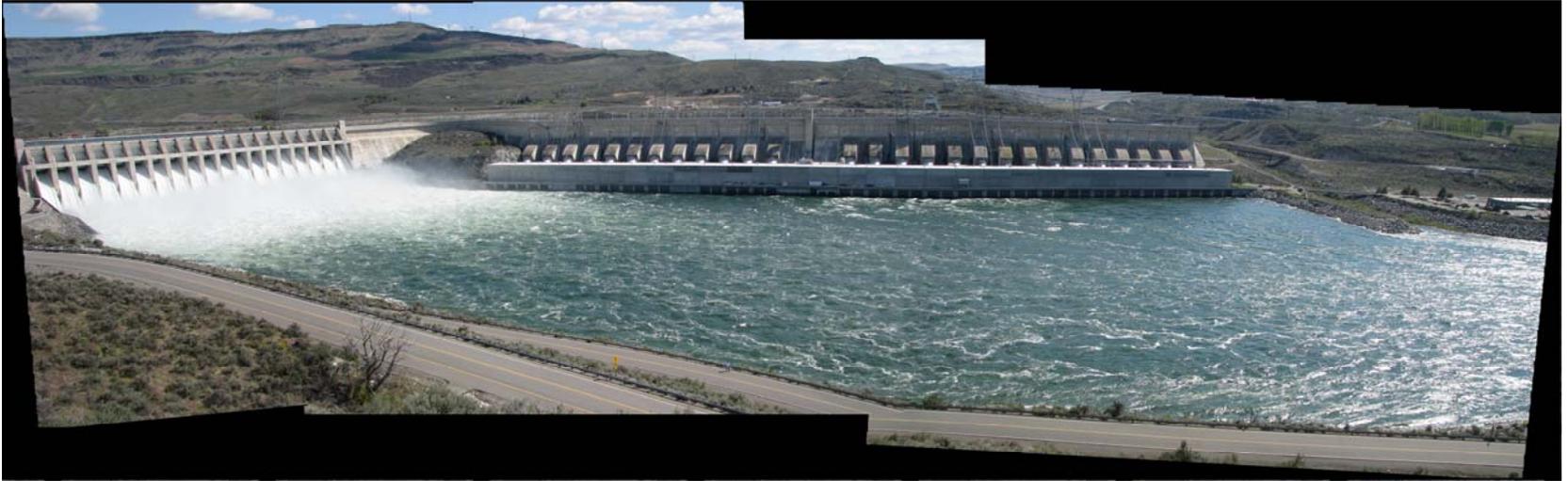


Chief Joseph Dam, Spillway Flow Deflector

DRAFT Total Dissolved Gas Exchange Assessment



Michael L. Schneider
Coastal and Hydraulic Laboratory
U.S. Army Engineer Research and Development Center

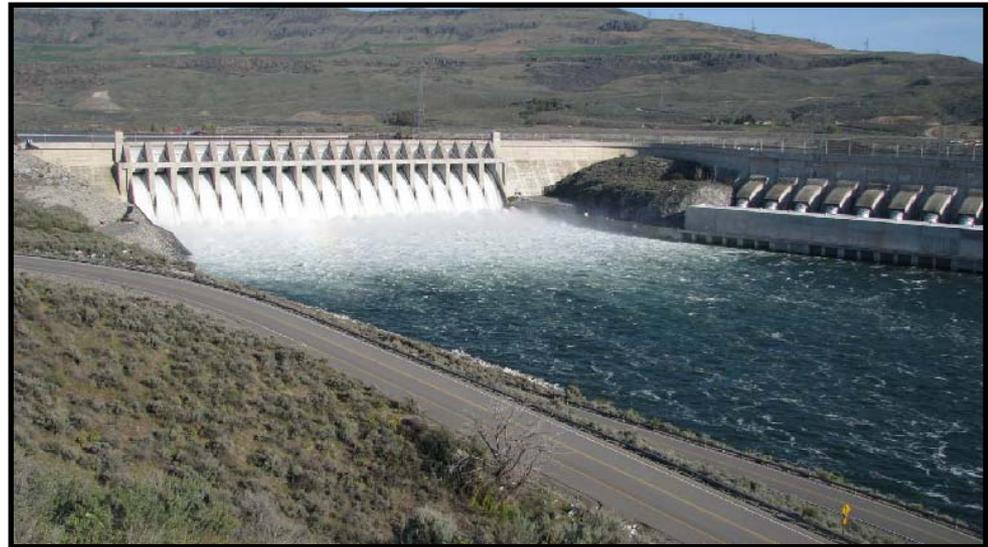
and

Kent B. Easthouse
U.S. Army Corps of Engineers Seattle District

Chief Joseph Dam, Spillway Flow Deflector

DRAFT Total Dissolved Gas Exchange Assessment

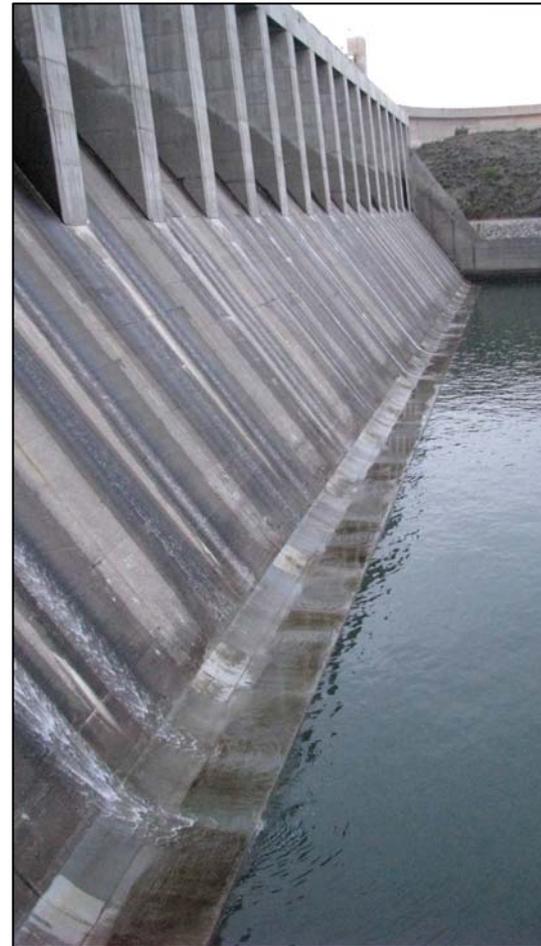
- Summary
 - TDG saturations greatly reduced with deflectors when compared to 1999 study
 - TDG saturations were greater for bulk spill pattern than for uniform spill pattern
 - Tailwater elevation impacted deflector performance and TDG reduction, with higher tailwater resulting in higher TDG saturations



Chief Joseph Dam, Spillway Flow Deflector

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- Spillway flow deflectors added to all 19 spill bays
- Deflector design
 - Elevation 776 ft
 - 12.5 foot length with toe curve
- Maximum design discharge 175 kcfs
 - Skimming flow targeted
- Tailwater Elevation Impacts
 - Skimming vs. Plunging flow



Chief Joseph Dam, Spillway Flow Deflector

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- **Study Objectives**

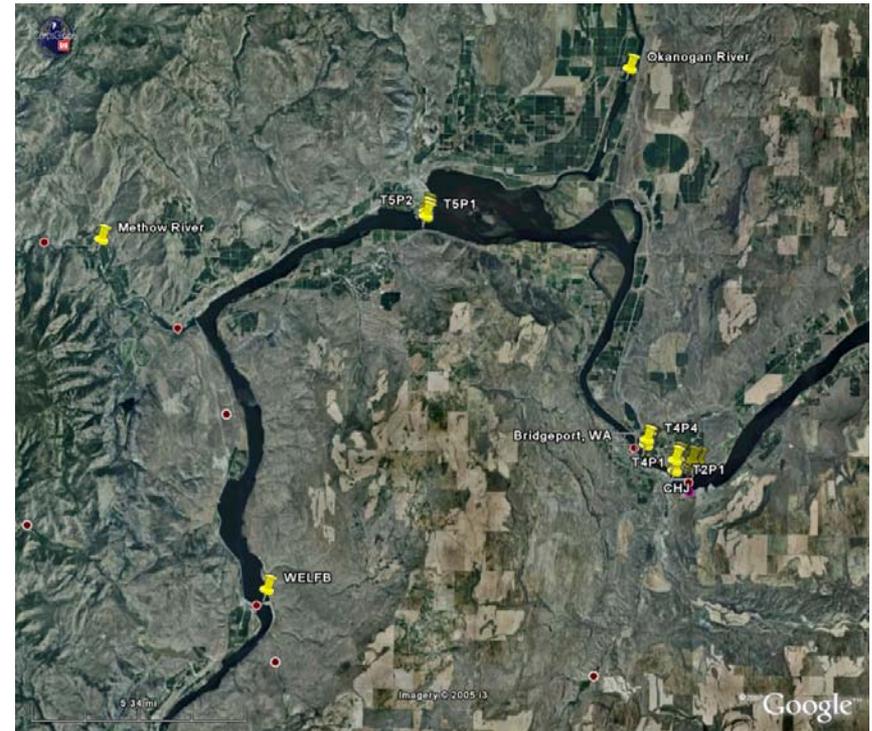
- Quantify TDG Exchange for range of flow conditions
 - Spill Discharge
 - Spill Pattern
 - Tailwater elevation
 - Powerhouse/Spillway Flows
- Spill Management Guidance
- Benefits of spillway flow deflectors
- Optimize Spillway Operations
- Fate of TDG Loading in Wells Pool
- Joint Operation of CHJ and GCL for TDG Abatement
- Fish Hatchery Impacts



Chief Joseph Dam, Spillway Flow Deflector

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- TDG exchange sampling
 - Automated fixed position sampling stations
 - 24 instruments
 - Sampling frequency 15 minutes
 - TDG pressure, depth, temperature, DO
 - Mobile Velocity/Water Quality sampling
 - ADCP – velocity field determination
 - DO/TDG correlation
 - TDG flux
 - Entrainment flow rates





Total Dissolved Gas fixed sampling array at Chief Joseph Dam



Total Dissolved Gas fixed sampling array downstream of Chief Joseph Dam at Brewster



Total Dissolved Gas fixed sampling station downstream of Chief Joseph Dam at Wells Dam

Chief Joseph Dam, Spillway Flow Deflector

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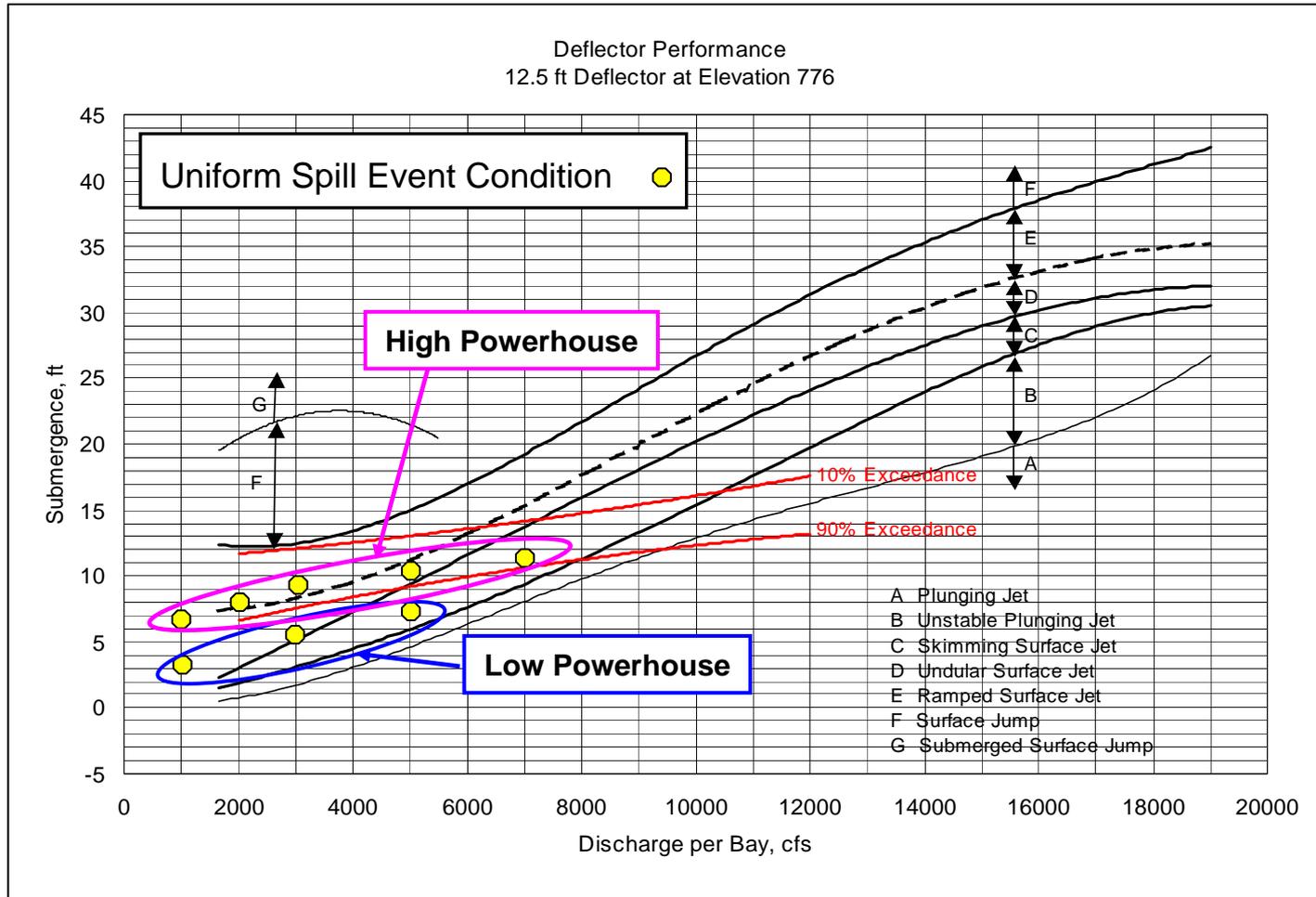
- TDG exchange Spill Events
 - Spillway Flows 18, 37, 58, 98, 142 kcfs
 - Duration of 3 hours
 - Deflector submergence
 - 3.6 to 11.1 ft
 - Deflector submergence in acceptable zone
 - Uniform and Bulk Spill Pattern
 - 19 Spill Bays
 - Bulking Pattern
 - Max spill in middle bays
 - Low and High Powerhouse Flow
 - 59 to 150 powerhouse flow
 - 77 to 226 kcfs total river flow

Chief Joseph Total Dissolved Gas Study Event Matrix, April 28-May 1, 2009 (12 Spill Events)			
Spill Flow (kcfs)	Powerhouse Flow (kcfs) and Spill Pattern		
	Uniform*	Uniform	Bulk
18	59	141	
37		150	150
58	59	145	145
98	62	95	106
142		82	84

*low powerhouse flow events.

Chief Joseph Dam, Spillway Flow Deflector

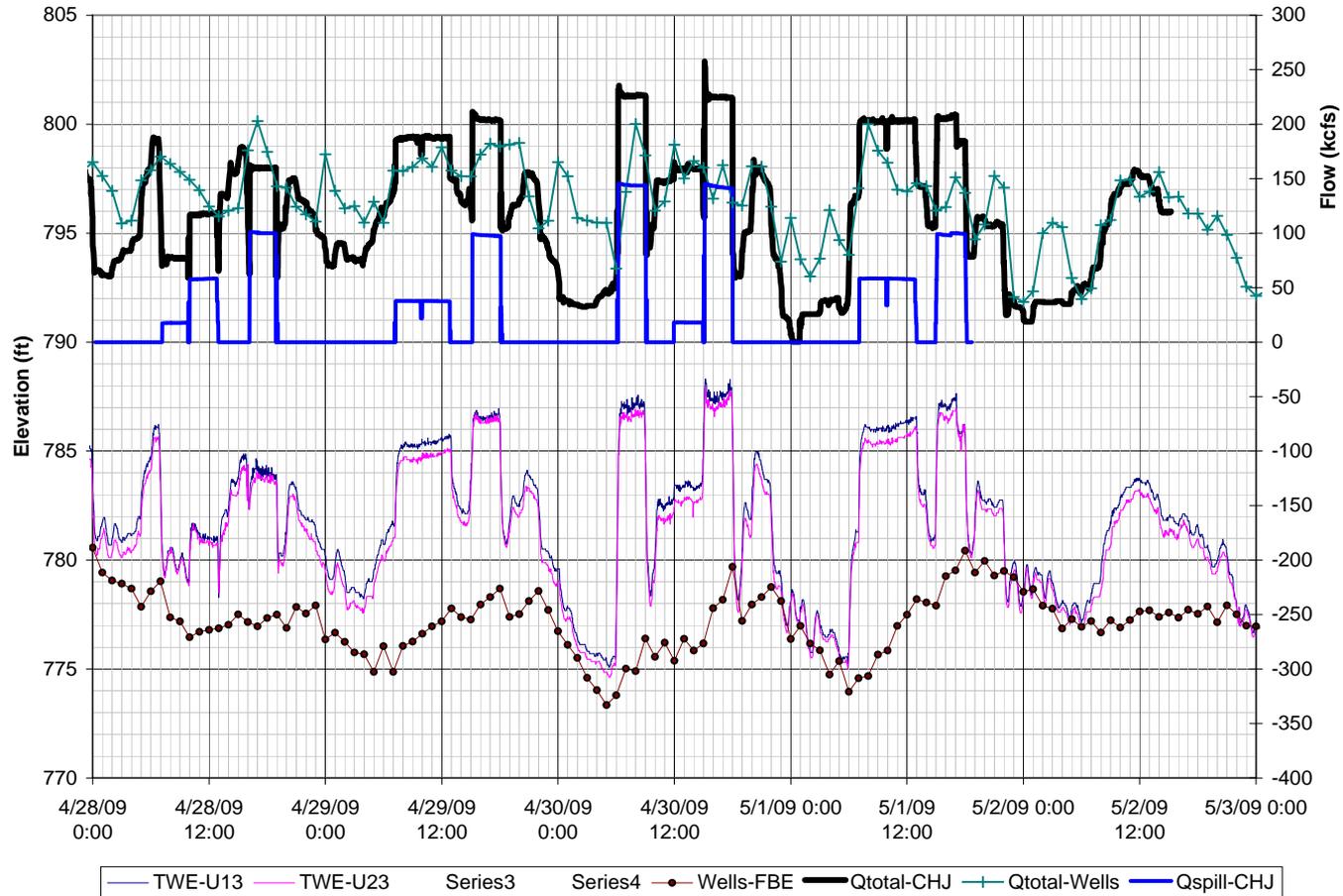
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Deflector Performance Curve and submergence of deflectors during Uniform Events with low powerhouse and high powerhouse flows

Chief Joseph Dam, Spillway Flow Deflector

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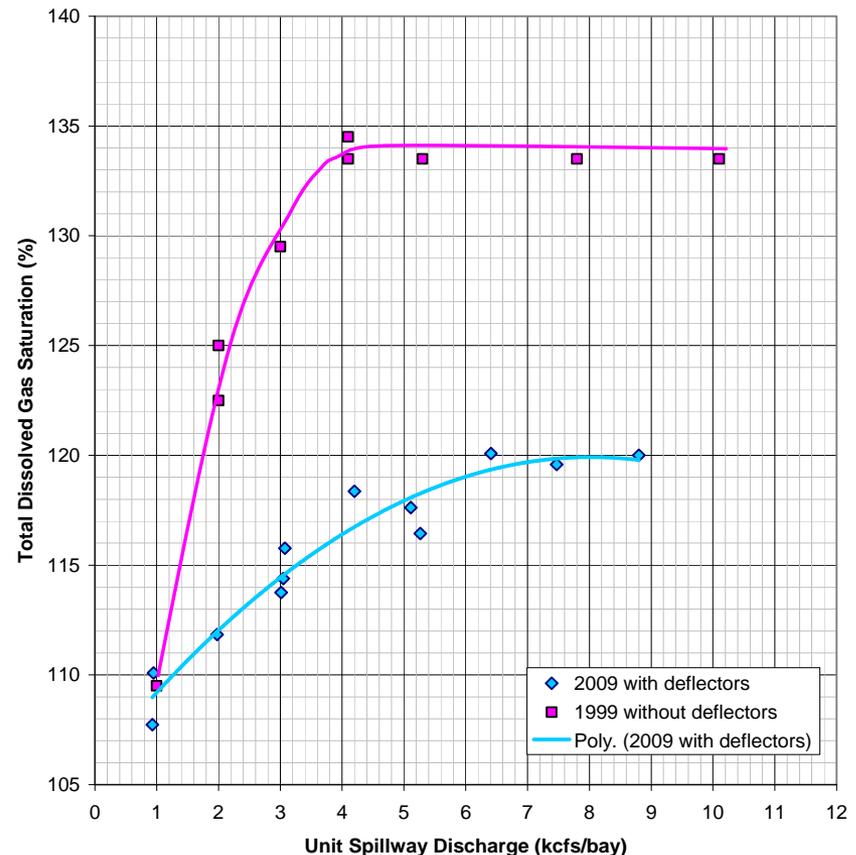


Chief Joseph Project Flow and Tailwater Elevation for April 28-May 2, 2009

Chief Joseph Dam, Spillway Flow Deflector

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- TDG exchange results
 - Deflectors produce reduction in TDG generation
 - TDG Reduction up to 16% saturation for comparable spill
 - Tripled spill capacity at 120% saturation
 - Abrupt TDG response to spill reduced with deflectors
 - TDG saturation approached 120 percent
 - Peak levels were a function of flow conditions and location
 - Highest TDG levels were observed in aerated flow locations (Transect T1)

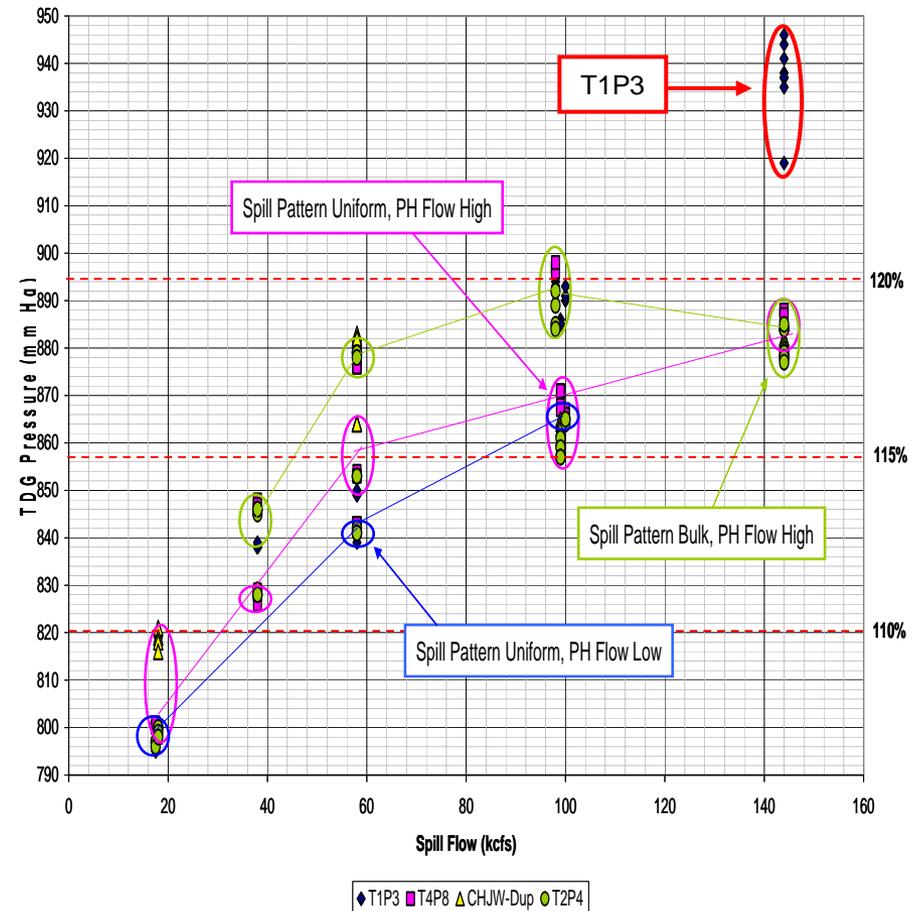


Chief Joseph Dam, Spillway Flow Deflector

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TDG Generation versus Spill Discharge

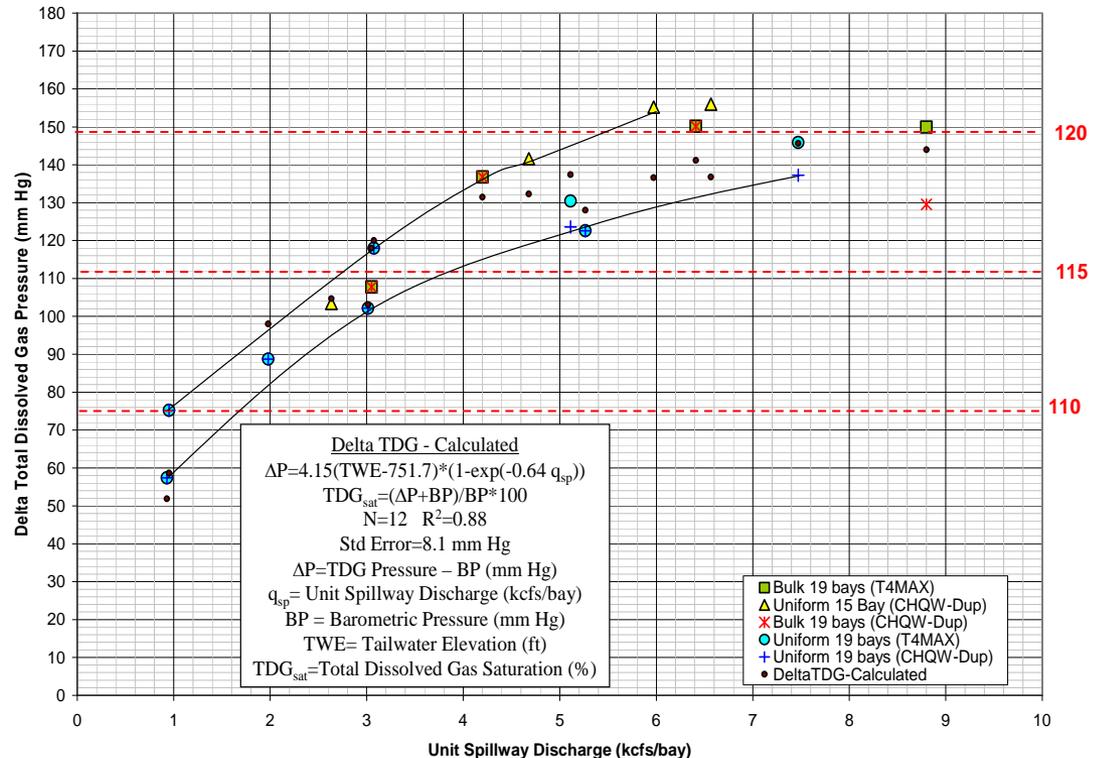
- TDG exchange function of
 - Spill magnitude
 - Exponential trend
 - Threshold TDG limits
 - Spill Pattern
 - Bulk pattern yielded higher TDG levels
 - Tailwater elevation
 - Higher tailwater conditions yielded higher TDG levels
 - Powerhouse/Spill Ratio
 - Entrainment
 - Mixing zone



Chief Joseph Dam, Spillway Flow Deflector

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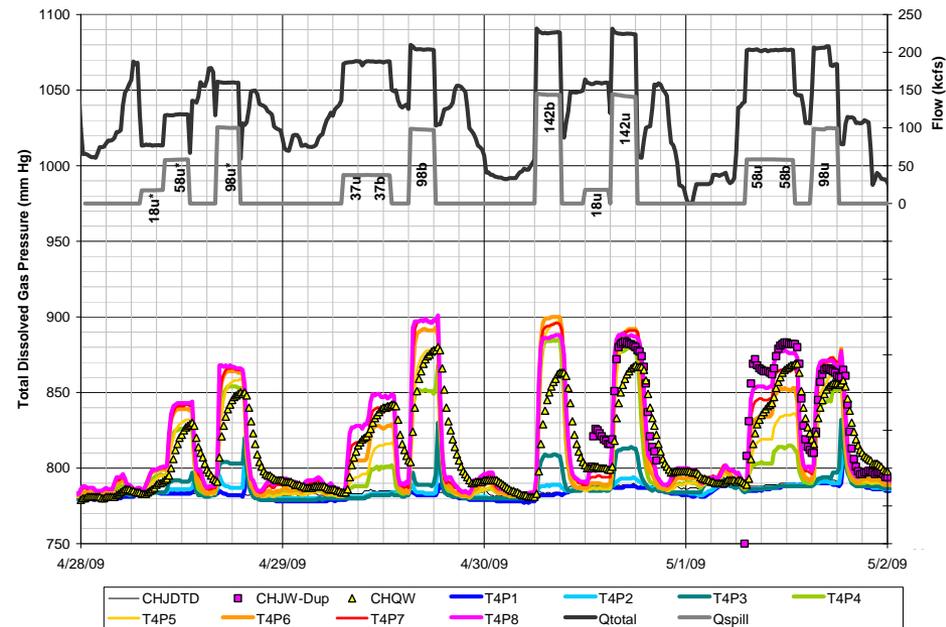
- Regression Model TDG saturation
 - Local atmospheric pressure (mm Hg)
 - Specific discharge (kcfs/bay)
 - Weighted for bulk pattern
 - Effective tailwater depth (ft)
 - Function of Q_{total}
 - Wells Pool Regulation
 - Limited number of events
N=12
 - Limited range of independent variables
- Upper and lower bound curves



Chief Joseph Dam, Spillway Flow Deflector

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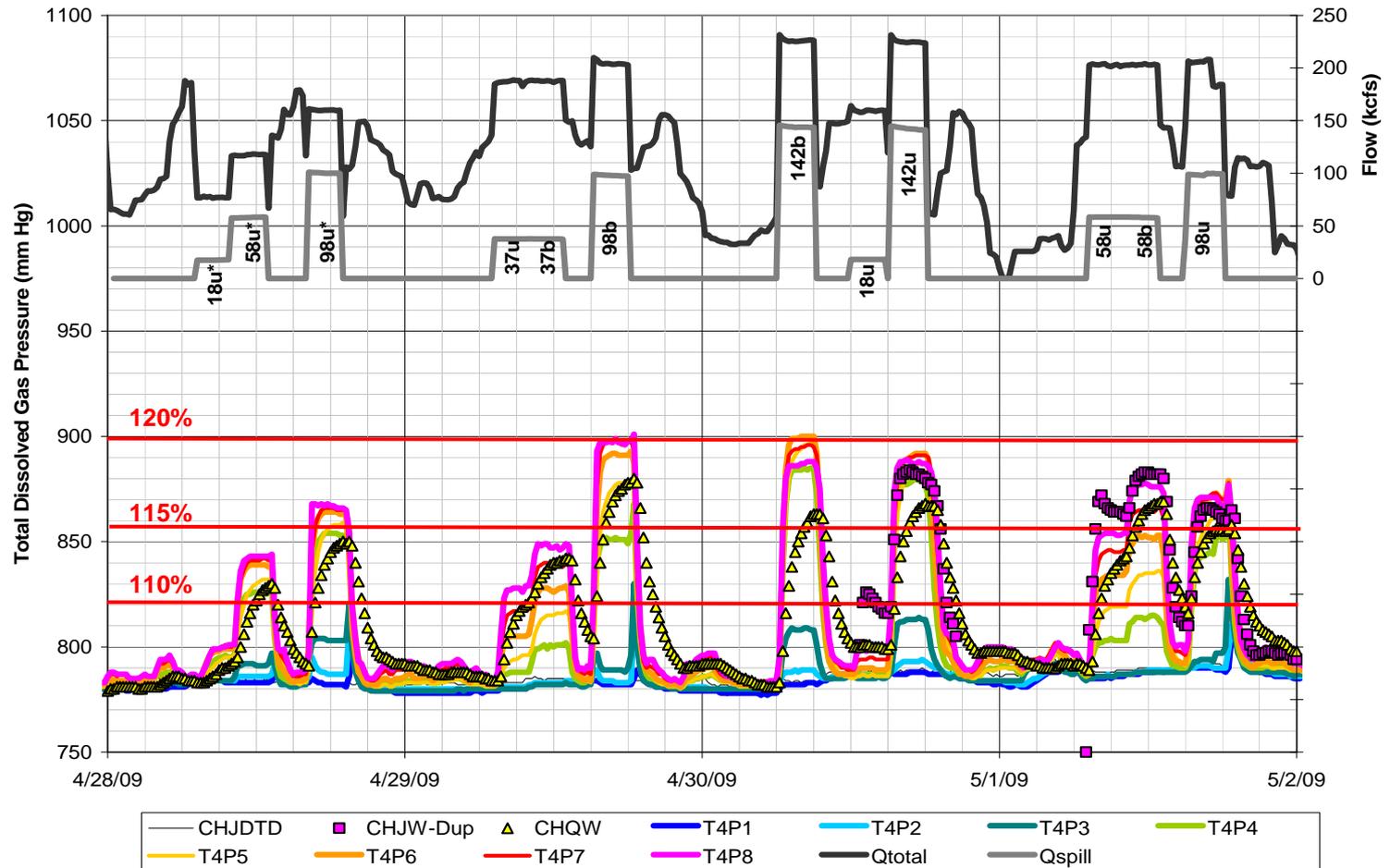
- Tailwater FMS unreliable during study
- Time to equilibrium at TW FMS 60-90 minutes
- Higher TDG for duplicate sensor at FMS
- Maximum cross sectional TDG levels not at FMS for spill discharge of 98 kcfs and greater



Total Dissolved Gas Saturation on Transect T4 during spillway operations at Chief Joseph Dam, April 28-May 1, 2009 (note: spill event discharge 18, 37, 58, 98, 142, pattern uniform and bulk)

Chief Joseph Dam, Spillway Flow Deflector

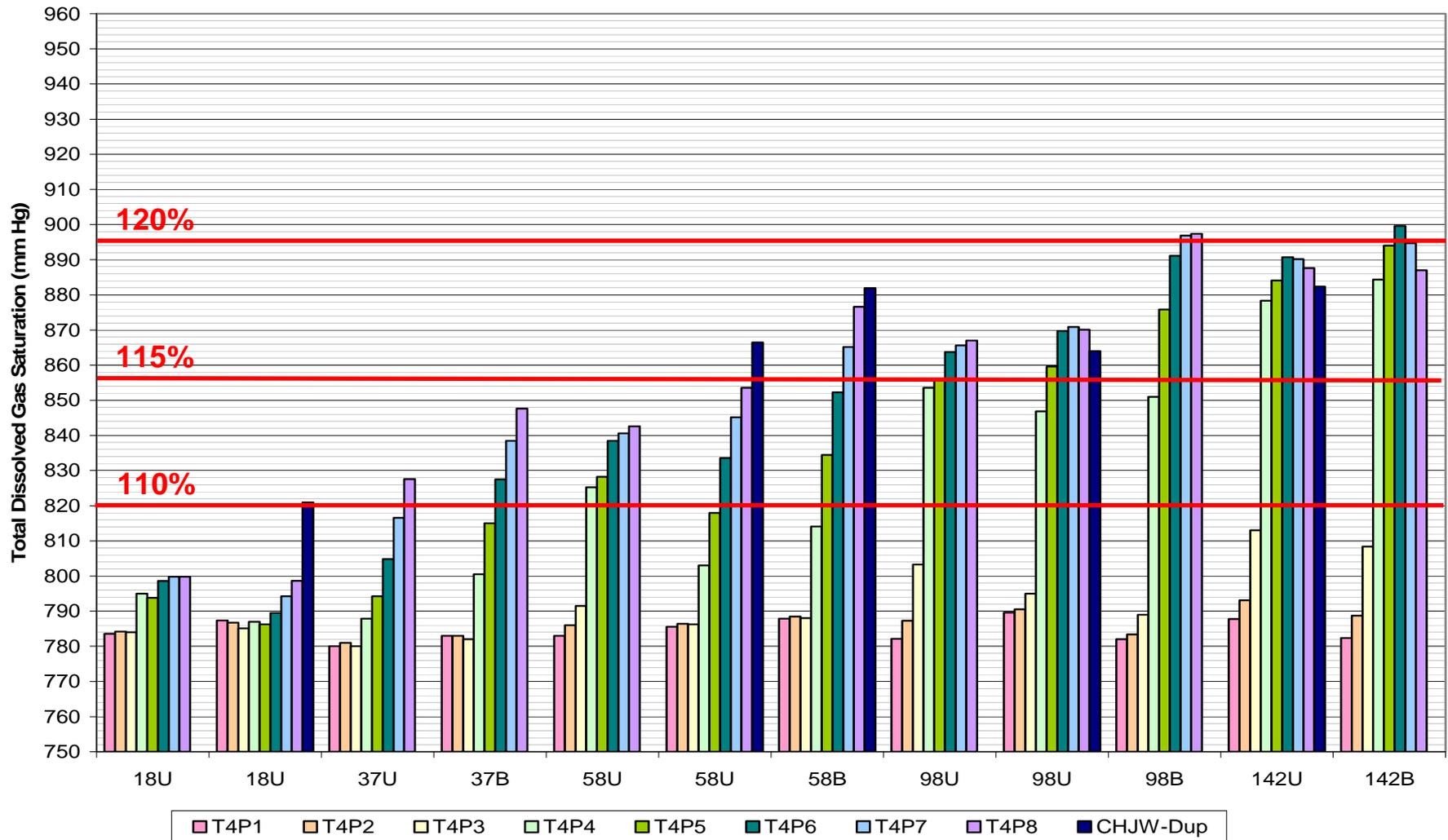
DRAFT Total Dissolved Gas Exchange Assessment



Total Dissolved Gas Saturation on Transect T4 during spillway operations at Chief Joseph Dam, April 28-May 1, 2009 (note: spill event discharge 18, 37, 58, 98, 142, pattern uniform and bulk)

Chief Joseph Dam, Spillway Flow Deflector

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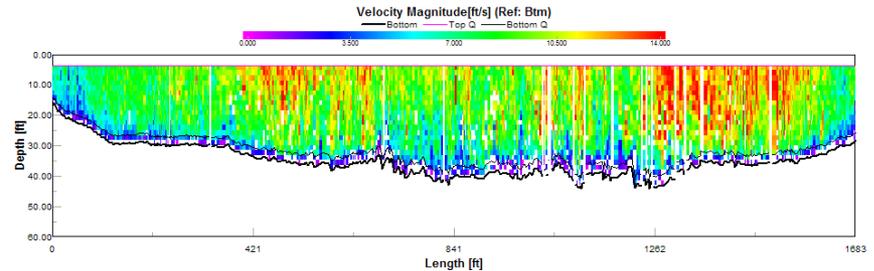
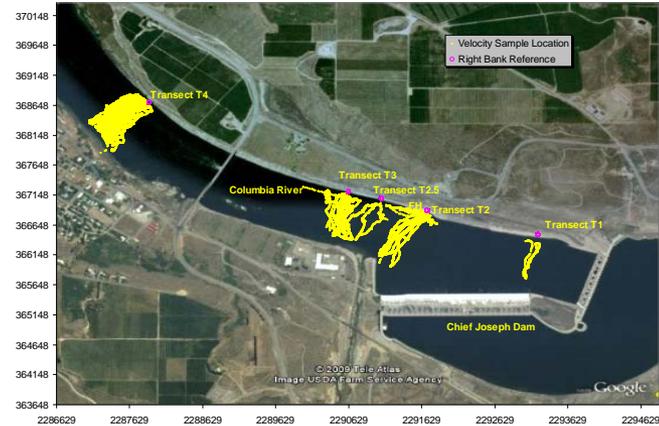


Total Dissolved Gas Saturation on Transect T4 during spillway operations at Chief Joseph Dam, April 28-May 1, 2009 (note: spill event discharge 18, 37, 58, 98, 142, pattern uniform and bulk)

Chief Joseph Dam, Spillway Flow Deflector

DRAFT Total Dissolved Gas Exchange Assessment

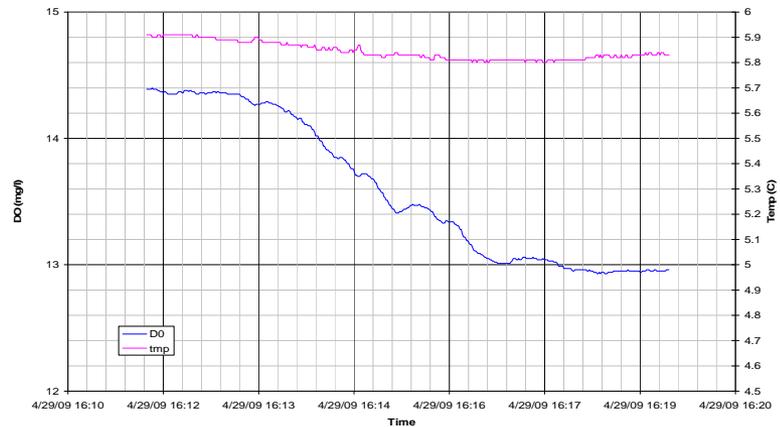
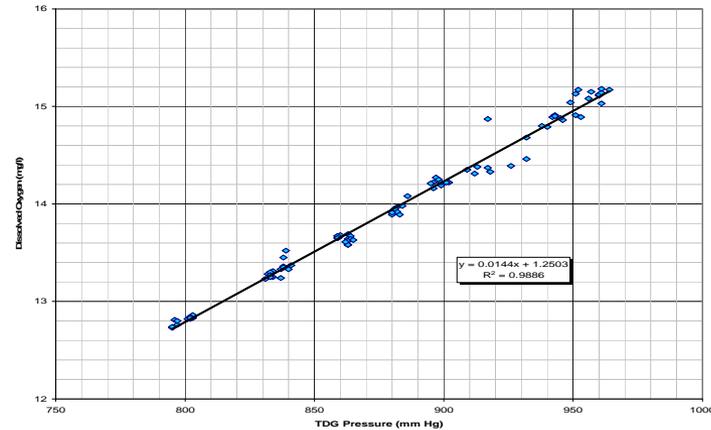
- Velocity field measurements
 - Acoustic Doppler Current Profiler (ADCP)
 - Mobile and Stationary Sampling
 - TDG Flux estimates
 - Influence of powerhouse entrainment on TDG exchange
 - Dam safety
 - Fish Hatchery



Chief Joseph Dam, Spillway Flow Deflector

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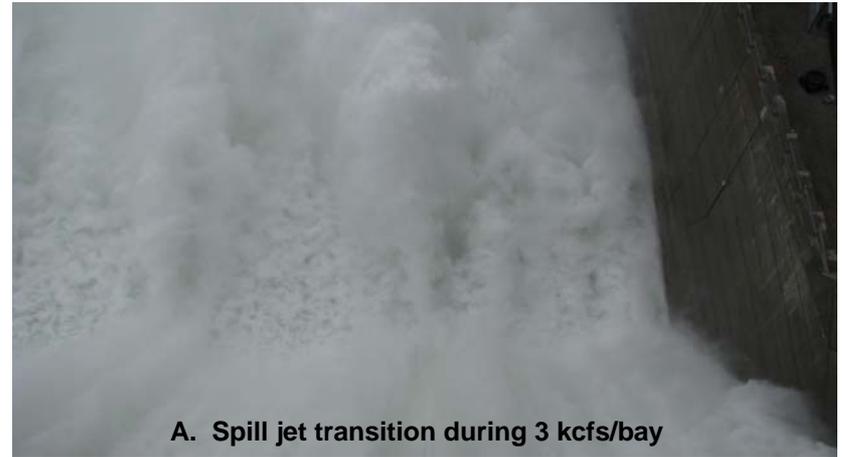
- Mobile Sampling
 - DO highly correlated with TDG at fixed sampling station
 - Temp and DO signature of spillway flows
 - Faster response of DO measure
 - Cross sectional distribution of DO and Temp
 - Integration with velocities yield flow weighted estimates of DO/TDG loading

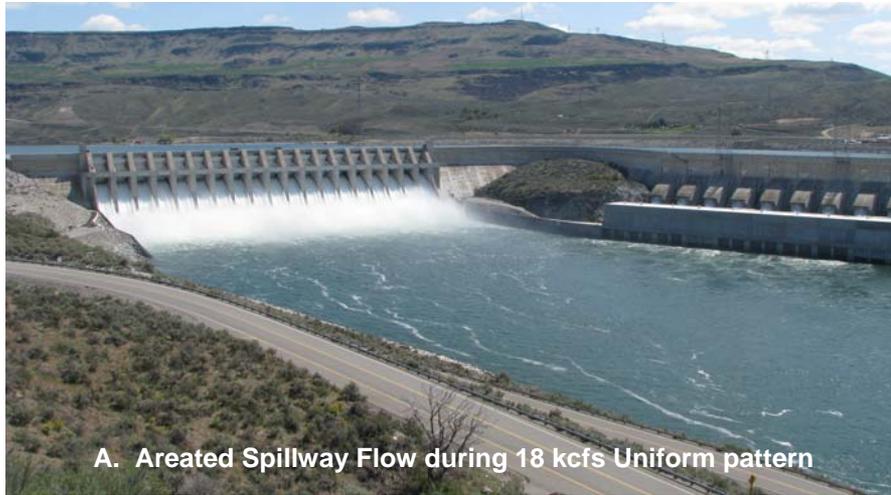


Chief Joseph Dam, Spillway Flow Deflector

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- Visual Observations
 - Redirection of spill jet from vertical to horizontal orientation when encountering the deflector for all flows
 - Prominent zone of highly aerated flow extends well downstream of stilling basin
 - Return flow into stilling basin more evident for bulk spill pattern

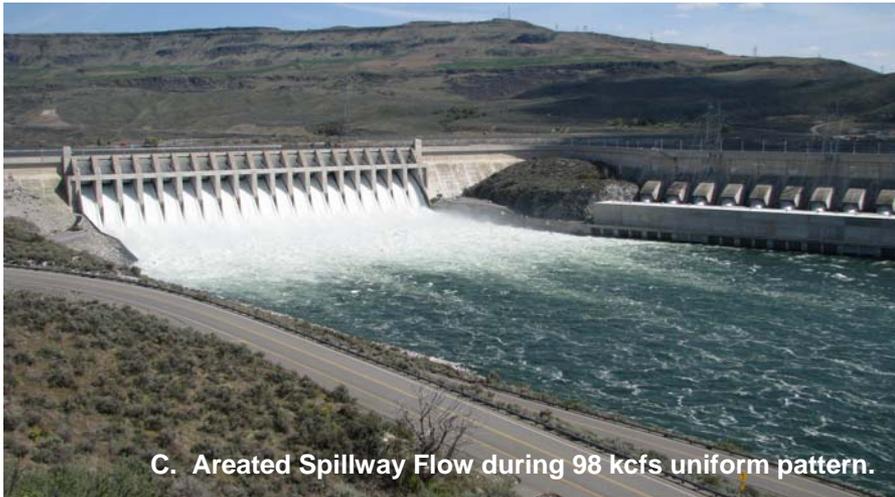




A. Areated Spillway Flow during 18 kcfs Uniform pattern



B. Areated Spillway Flow during 58 kcfs uniform pattern..



C. Areated Spillway Flow during 98 kcfs uniform pattern.



D. Areated Spillway Flow during 142 kcfs uniform pattern.

Chief Joseph Dam, Spillway Flow Deflector

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A. Bulking of spill and subsequent rooster tail trajectory.



B. Aerated Spillway Flow during 58 kcfs event.

Chief Joseph Dam, Spillway Flow Deflector

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Chief Joseph Dam 100 kcfs Uniform Spill Event, High Powerhouse Flow, May 1 2009