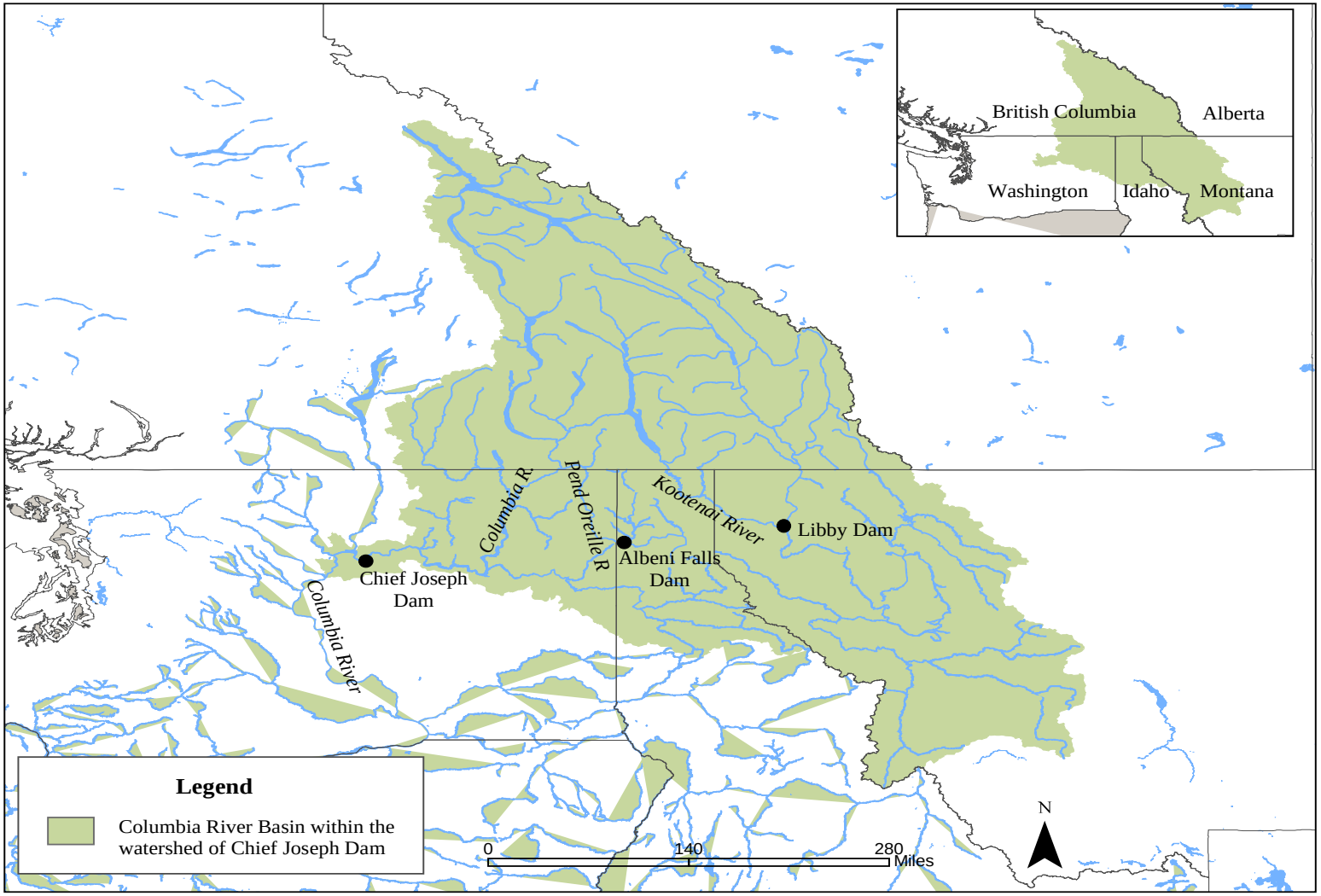
Total Dissolved Gas Monitoring 2011:
Chief Joseph Dam, Albeni Falls Dam, and Libby Dam

TDG Monitoring 2011

- Introduction
  - 5 monitoring sites
    - Libby tailwater
    - Chief Joseph forebay and tailwater
    - Albeni Falls forebay and tailwater
  - Seasonal sites (April 1 – September 30)
  - Sites calibrated every two weeks
    - COE data quality criteria
    - Laboratory calibrations
    - Field calibrations
    - Performance checks

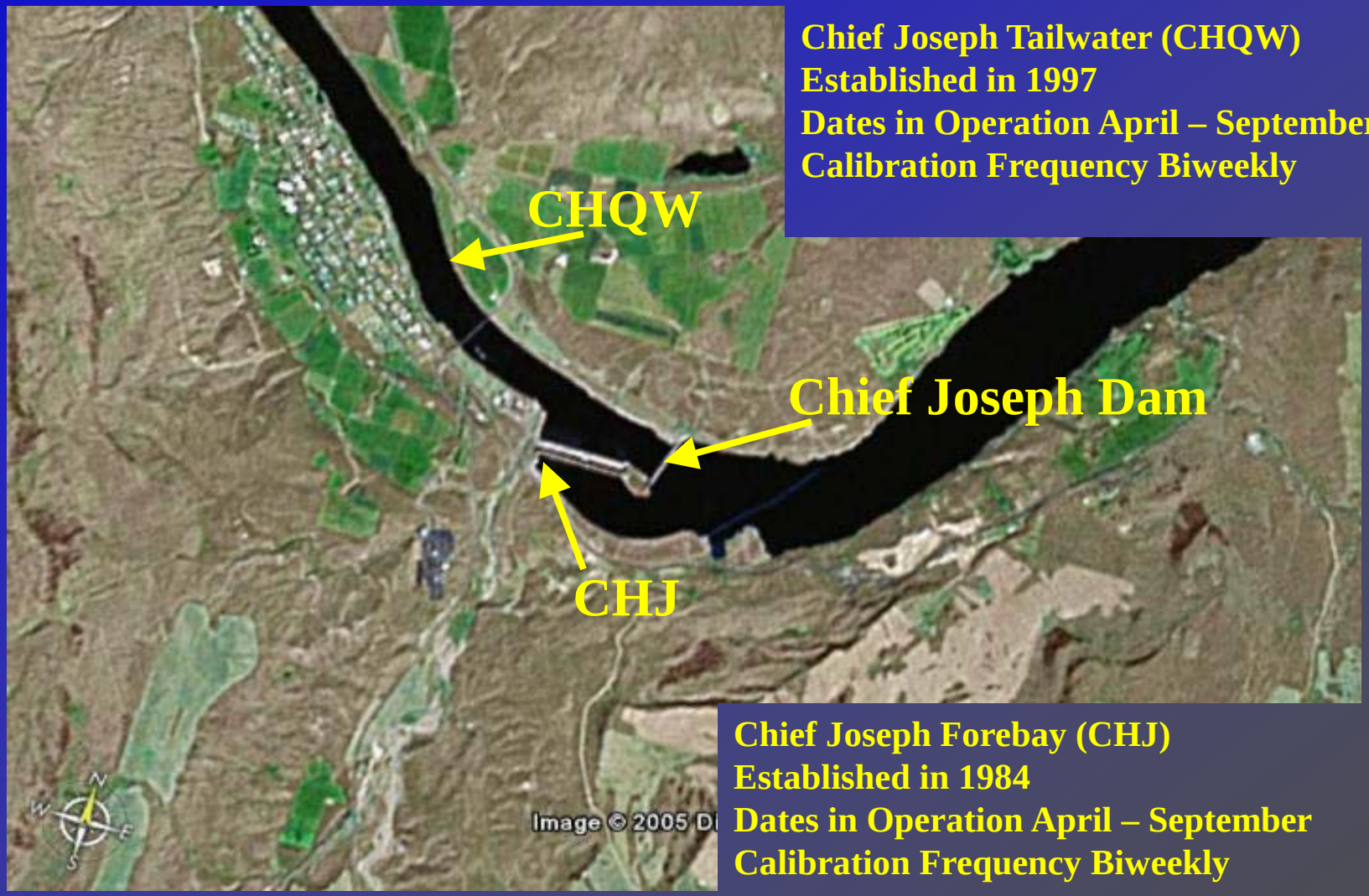


Location of the Seattle District's projects in the Upper Columbia River Basin.

TDG Monitoring 2011

- Chief Joseph
  - Equipment
    - Hydrolab MiniSonde 4a TDG sensor/Sutron barometer
    - Sutron 9210 XLite DCP, AC Power
    - Radio transmission and GOES station
- Albeni Falls
  - Equipment
    - Hydrolab MiniSonde 4a TDG sensor/Sutron barometer
    - Sutron 9210 XLite DCP, AC and Solar Power
    - Radio transmission station
- Libby
  - Equipment
    - Hydrolab MiniSonde 4a TDG sensor/Sutron barometer
    - Sutron 9210 XLite DCP, Solar Power
    - Radio transmission station

TDG Monitoring 2011



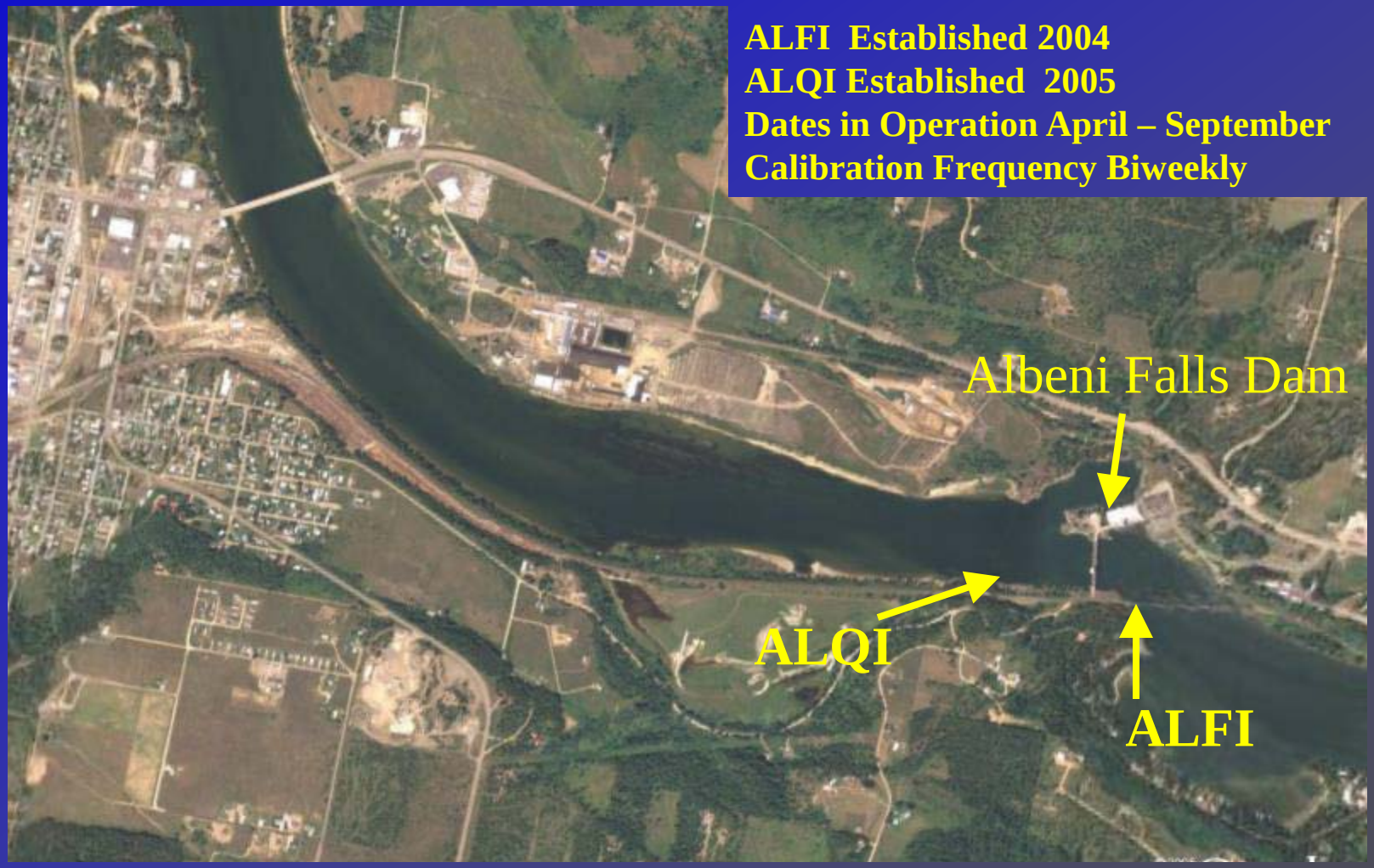
Chief Joseph Tailwater (CHQW)
Established in 1997
Dates in Operation April – September
Calibration Frequency Biweekly

Chief Joseph Forebay (CHJ)
Established in 1984
Dates in Operation April – September
Calibration Frequency Biweekly

Chief Joseph Total Dissolved Gas Monitoring System

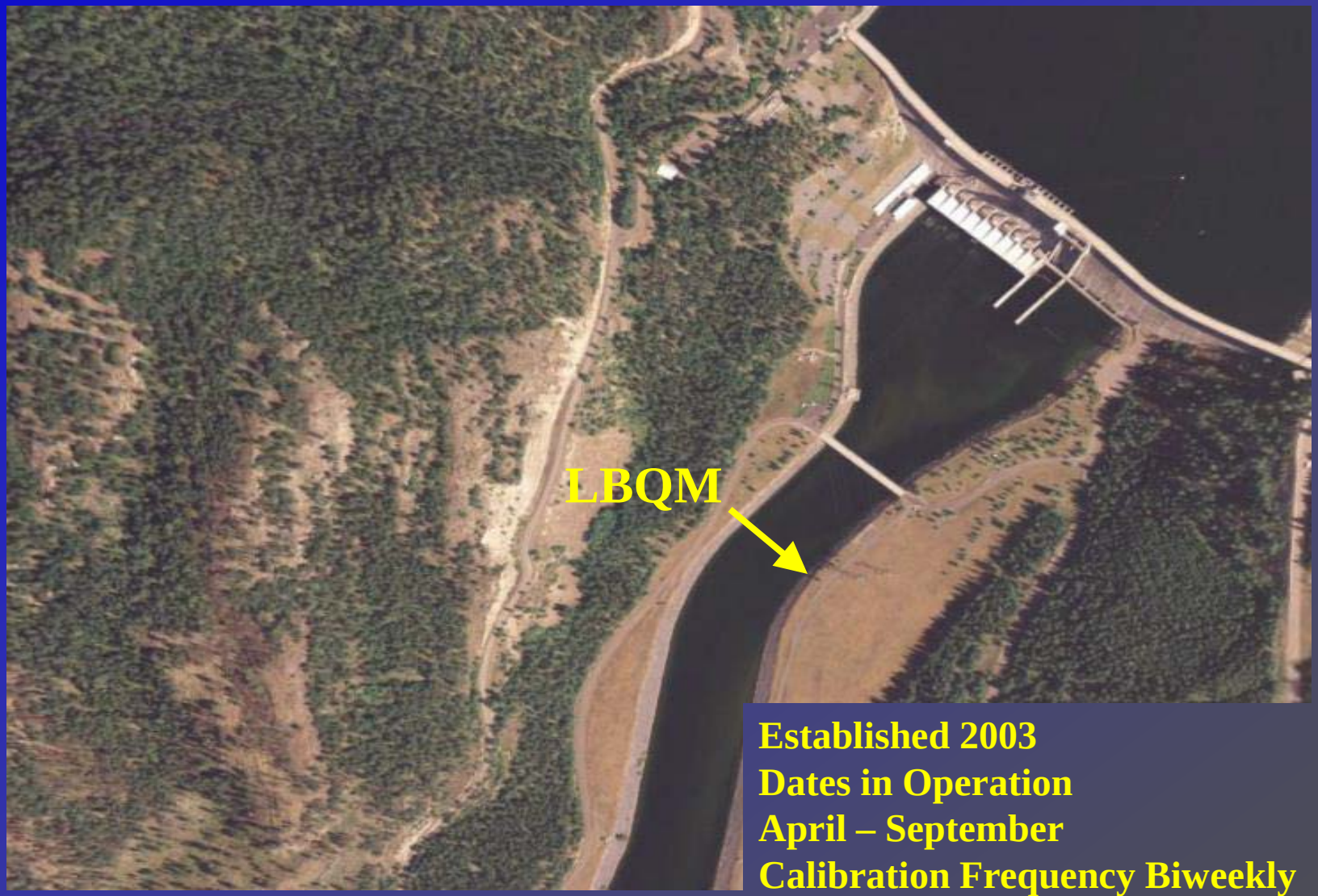
TDG Monitoring 2011

ALFI Established 2004
ALQI Established 2005
Dates in Operation April – September
Calibration Frequency Biweekly



Albeni Falls Total Dissolved Gas Monitoring System

TDG Monitoring 2011



Established 2003
Dates in Operation
April – September
Calibration Frequency Biweekly

Libby Dam Total Dissolved Gas Monitoring System

TDG Data Completeness 2011

Station Name	Station Abbreviation	Planned monitoring in hours	Number of missing hourly values	Number of hourly values not passing QA	Percentage of real-time TDG monitoring data received	Percentage of real-time TDG data received and passing quality assurance
Chief Joseph Forebay	CHJ	4392	80	0	98.2	98.2
Chief Joseph Tailwater	CHQW	4392	8	79	99.8	98.0
Albeni Falls Forebay	ALFI	4392	22	3	99.5	99.4
Albeni Falls Tailwater	ALQI	4392	25	0	99.4	99.4
Libby Tailwater	LBQM	4392	88	2	98.0	98.0

Temperature Data Completeness 2011

Station Name	Station Abbreviation	Planned monitoring in hours	Number of missing hourly values	Number of hourly values not passing QA	Percentage of real-time Temperature monitoring data received	Percentage of real-time Temperature data received and passing quality assurance
Chief Joseph Forebay	CHJ	4392	81	0	98.2	98.2
Chief Joseph Tailwater	CHQW	4392	6	0	99.9	99.9
Albeni Falls Forebay	ALFI	4392	18	2	99.6	99.5
Albeni Falls Tailwater	ALQI	4392	10	0	99.8	99.8
Libby Tailwater	LBQM	4392	88	0	98.0	98.0

TDG Monitoring 2011

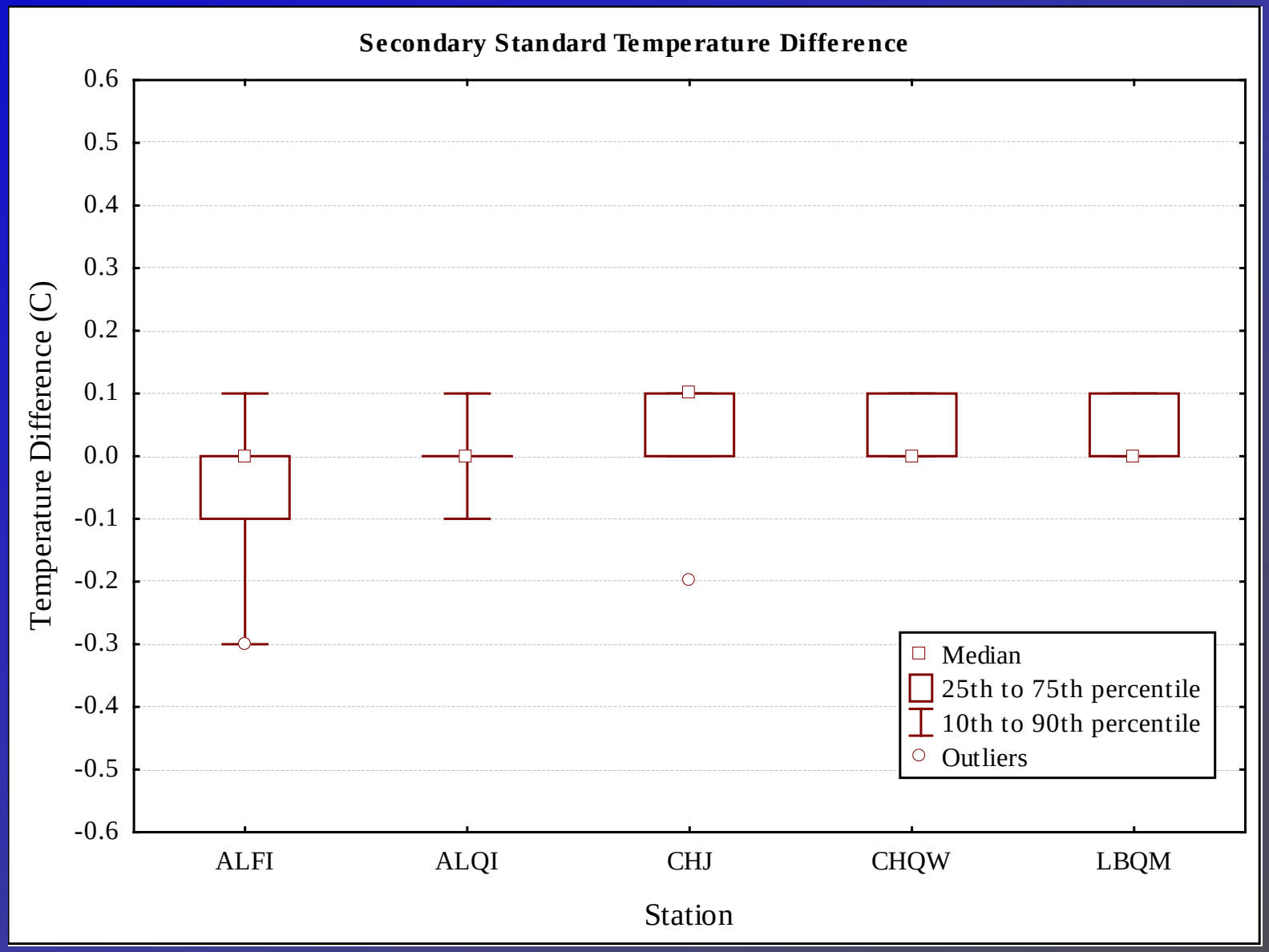
- Overview of 2011 TDG and Temperature Data
  - Data completeness
    - Chief Joseph Forebay (CHJ) and Tailwater (CHQW)
      - Barometer problems
      - DCP malfunctions and programming problems
      - TDG Probe Problems
    - Albeni Falls Forebay (ALFI) and Tailwater (ALQI)
      - DCP malfunctions and programming problems
    - Libby Tailwater (LBQM)
      - DCP malfunctions and programming problems

TDG and Temperature QA/QC 2011

	Temperature	Total Dissolved Gas Pressure (% Saturation)			
	°C	100%	113%	126%	140%
Num	69	69	65	69	69
min	-0.10	-0.34	-0.34	-0.34	-0.34
max	0.20	0.21	0.30	0.30	0.30
median	0.10	0.01	0.06	0.01	-0.03
avg	0.06	-0.01	0.04	0.03	-0.03
sd	0.07	0.12	0.11	0.11	0.11

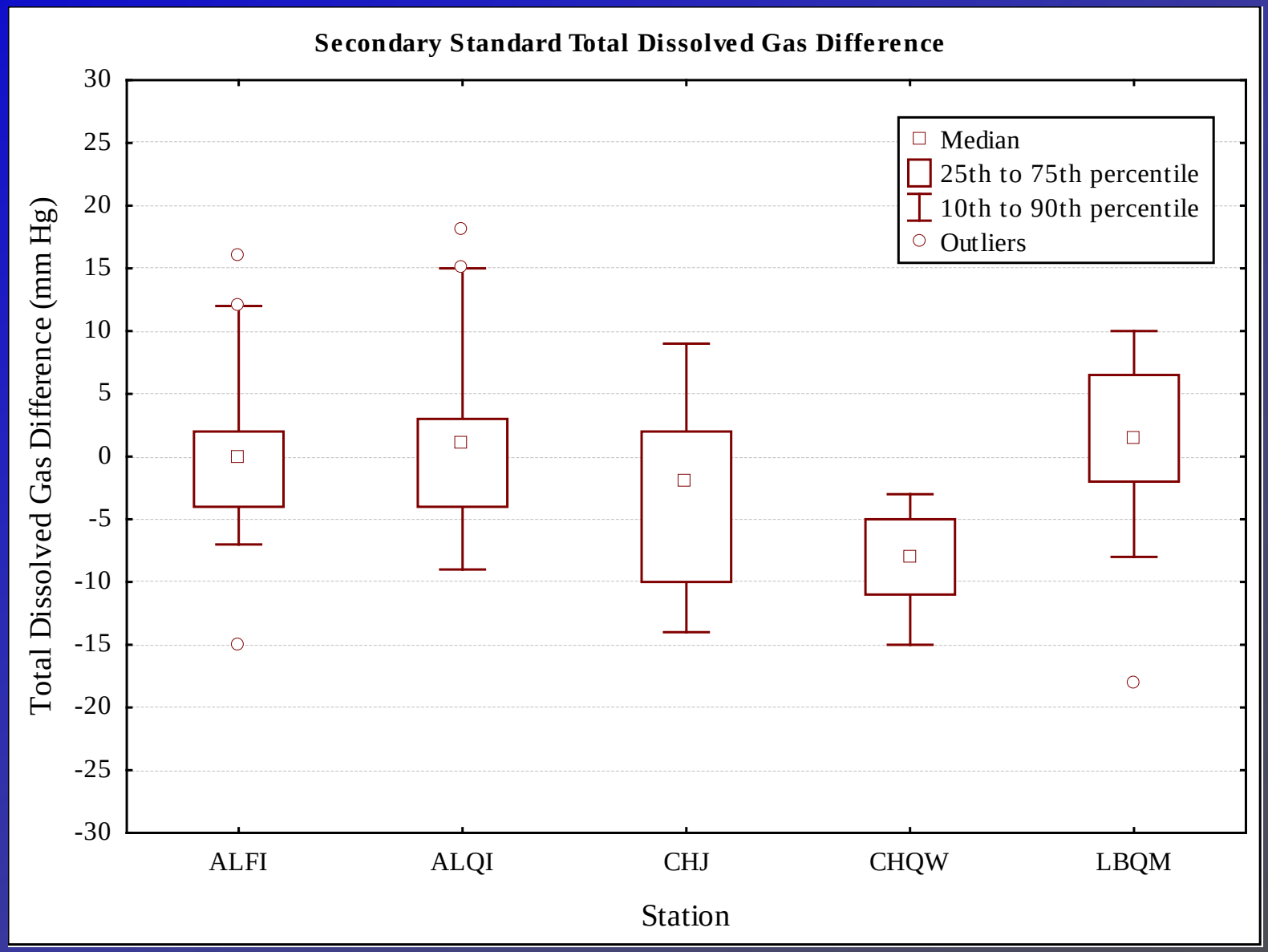
Difference between the primary standard and total dissolved gas instrument.

TDG and Temperature QA/QC 2011



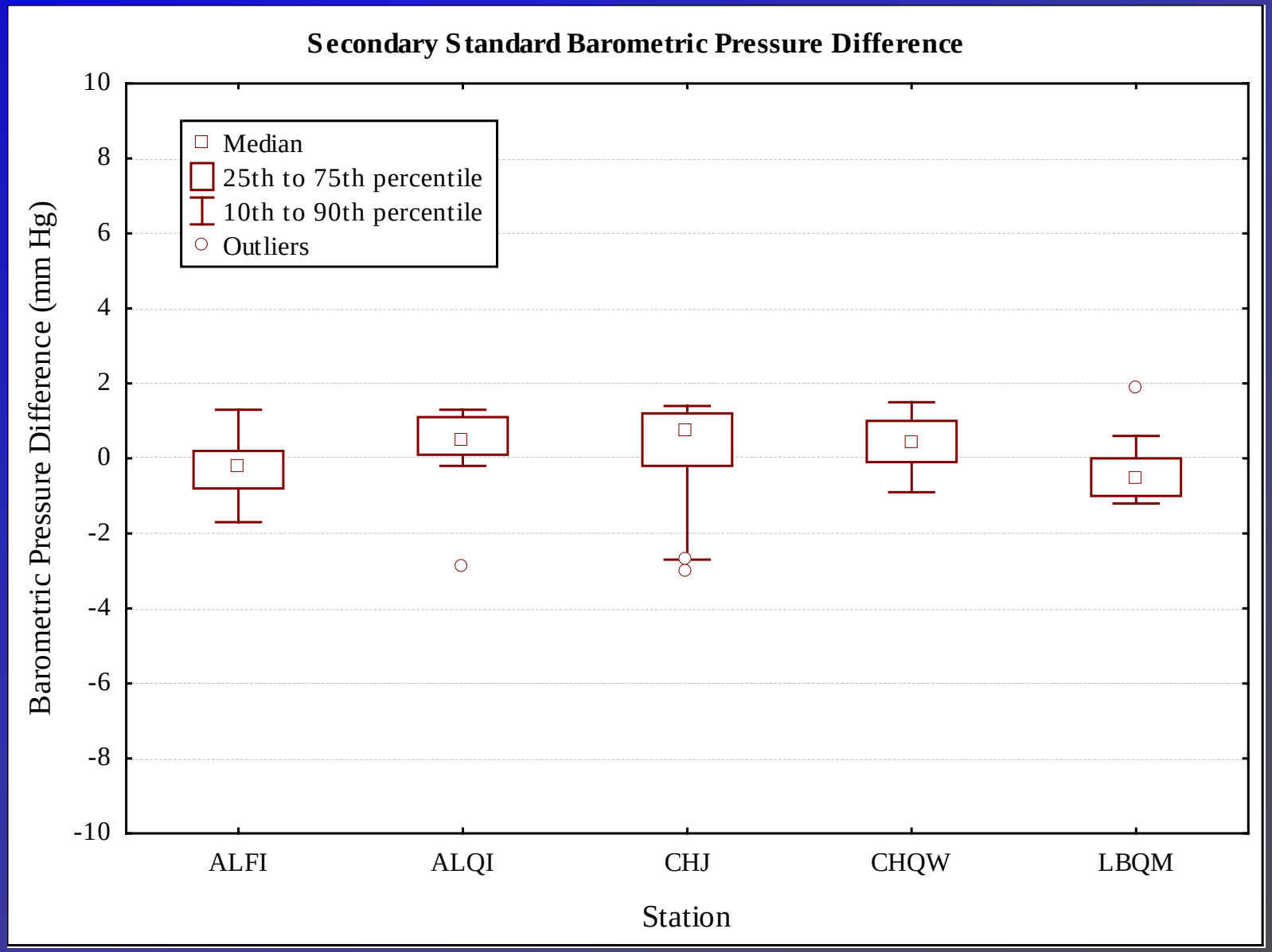
Difference between the secondary standard and the field thermometer

TDG and Temperature QA/QC 2011



Difference between the secondary standard and the TDG instrument

TDG and Temperature QA/QC 2011



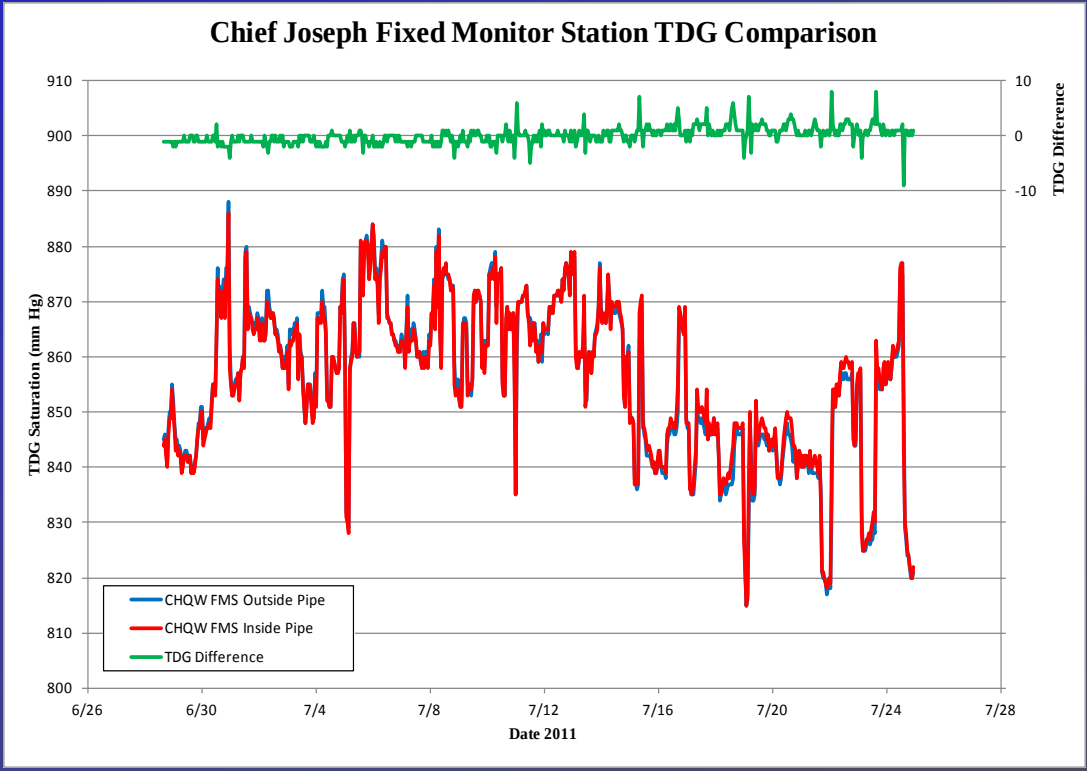
Difference between the secondary standard and the Barometer

TDG Monitoring 2011

- Overview of 2011 Data QA/QC
  - Laboratory calibration data were good and within 0.1 º C for temperature and 1% saturation for TDG
  - Field calibration data for temperature were good and generally within 0.2ºC of the secondary standard thermometer
  - Field calibration data for TDG were generally within 10 mm Hg of the secondary standard TDG instrument
  - Field calibration data for barometric pressure were generally within 2 mm Hg of the secondary standard

TDG Monitoring 2011

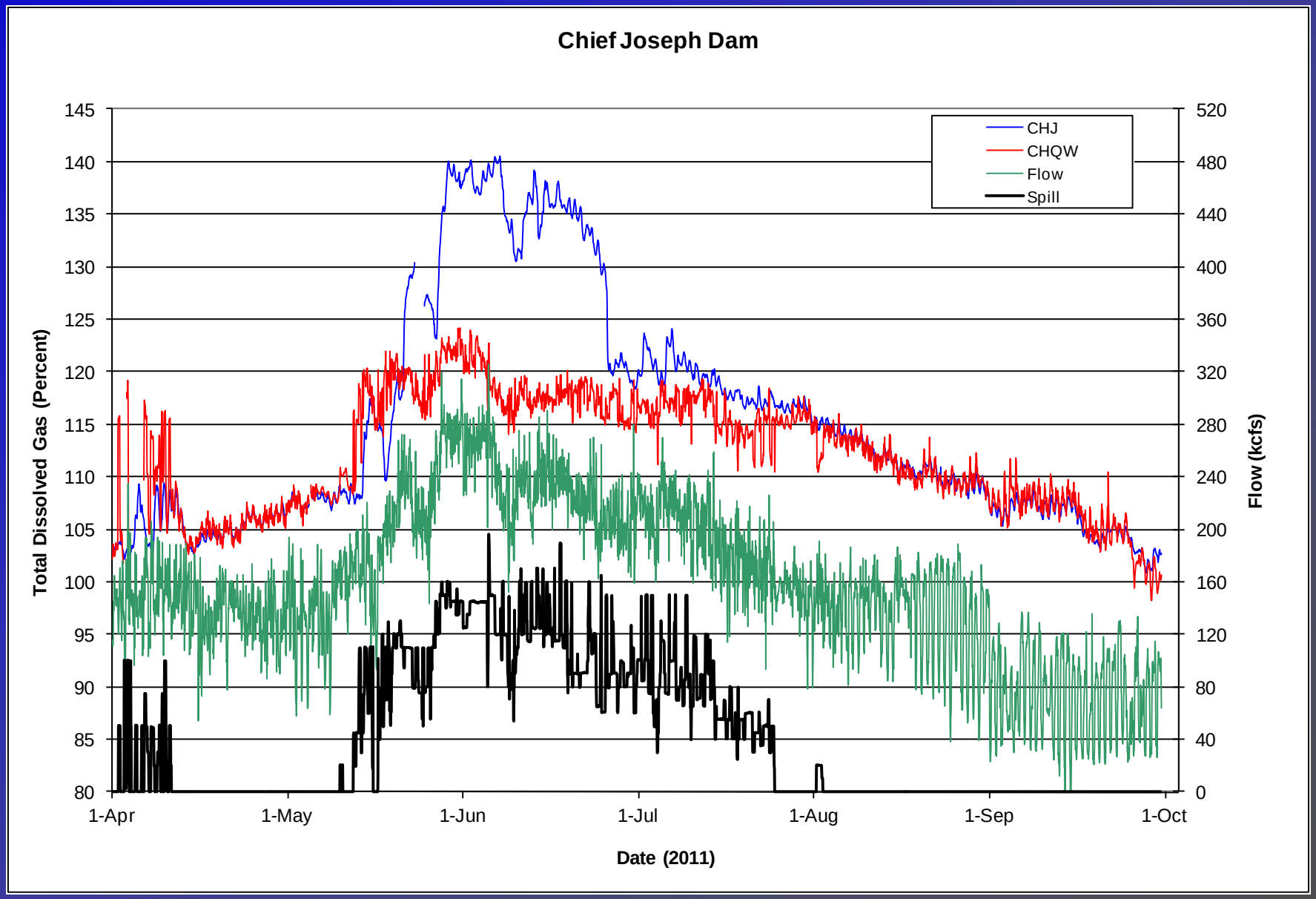
- Chief Joseph Tailwater FMS Station
  - Investigate TDG response at CHQW of probes placed inside conduit vs. outside conduit
  - FMS TDG probe deployed outside conduit since 2009 based on spill test data
    - Attenuated response
  - FMS probe deployed inside conduit on June 9 to protect from high flows and re-deployed outside conduit on June 28
  - TDG logger deployed to compare inside vs. outside conduit TDG (June 28-July 24)
  - Little difference seen between deployment methods



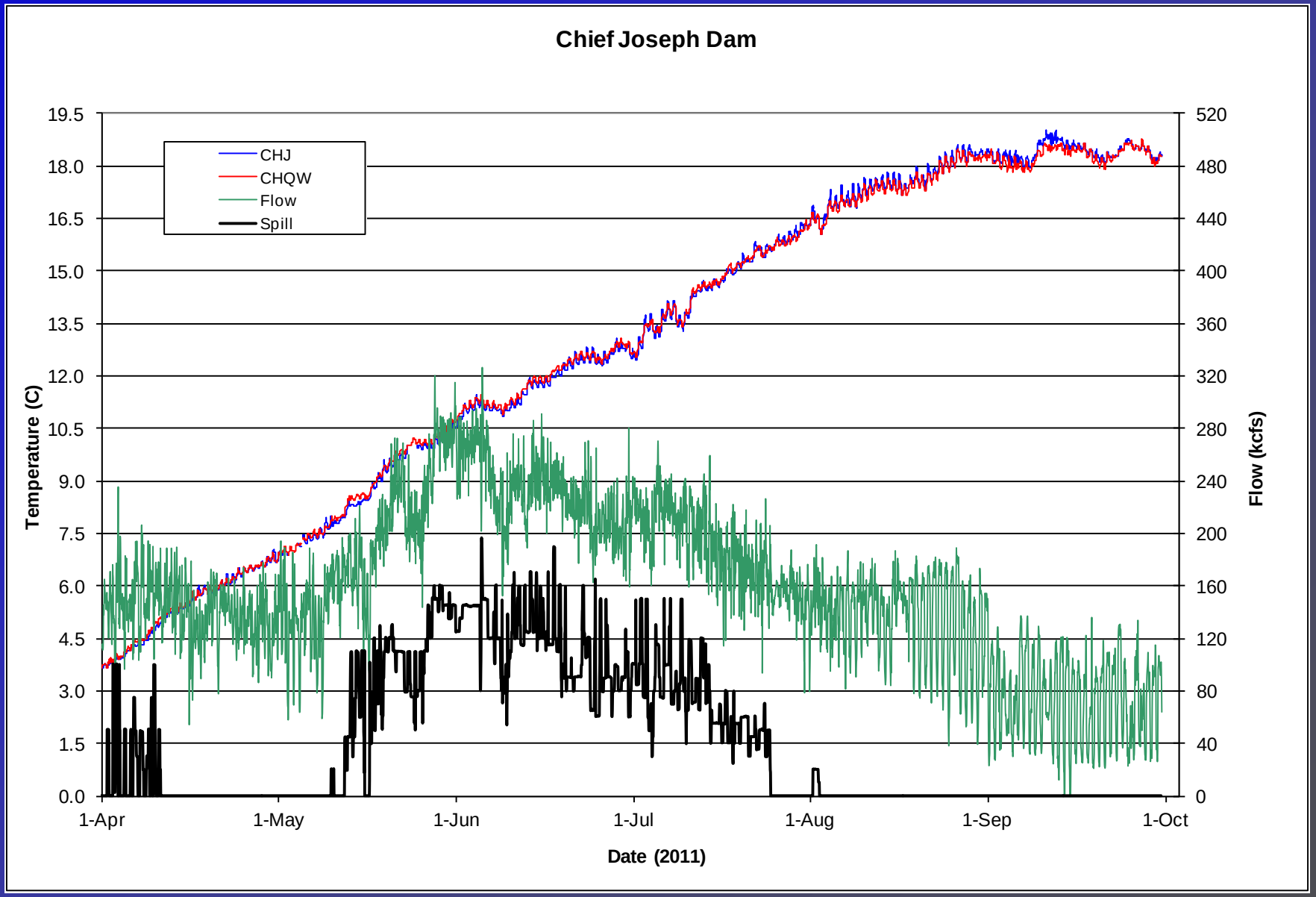
TDG Monitoring 2011

- 2011Spill Season Results for Chief Joseph Dam
  - TDG-Forebay (CHJ)
    - Forebay TDG levels a function of Grand Coulee tailwater TDG
    - Maximum forebay TDG about 140%
  - TDG-Tailwater (CHQW)
    - Station located in undiluted spillway flow, not mixed river
    - Maximum TDG about 124% during 145 kcfs spill over 17 of 19 bays and high tailwater condition
    - Greatest TDG reduction when spill over all 19 bays
    - TDG dependent on:
      - Tailwater elevation with higher tailwater resulting in higher TDG
      - Number of spillbays operational
  - Temperature-Forebay/Tailwater
    - Little difference between forebay and tailwater temperatures
    - Forebay temperatures exceeded 16ºC from about late July through Sept 30 and 18 ºC from about late August through Sept 30
    - Tailwater temperatures exceeded 18ºC from about late August through Sept 30

TDG Monitoring 2011



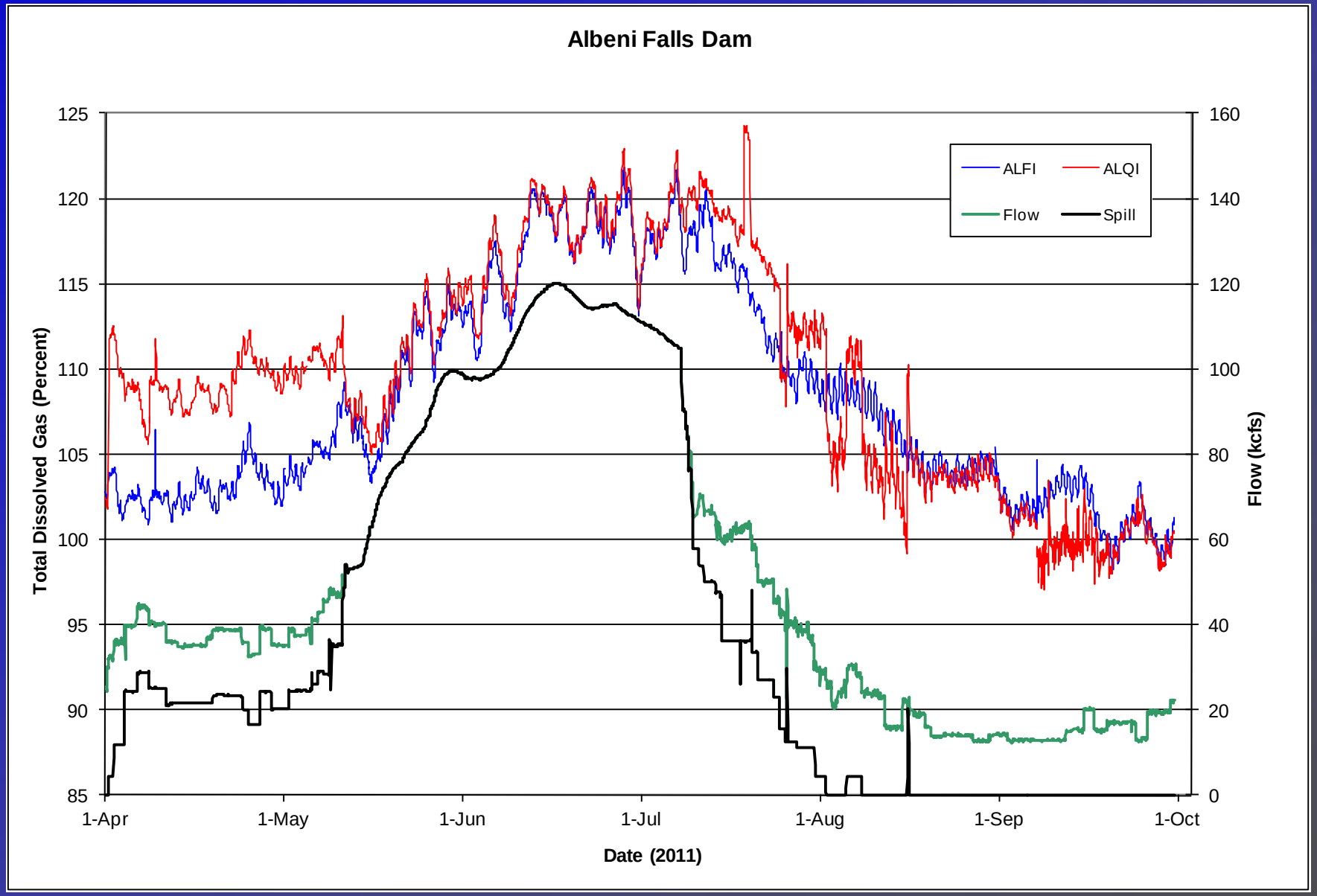
TDG Monitoring 2011



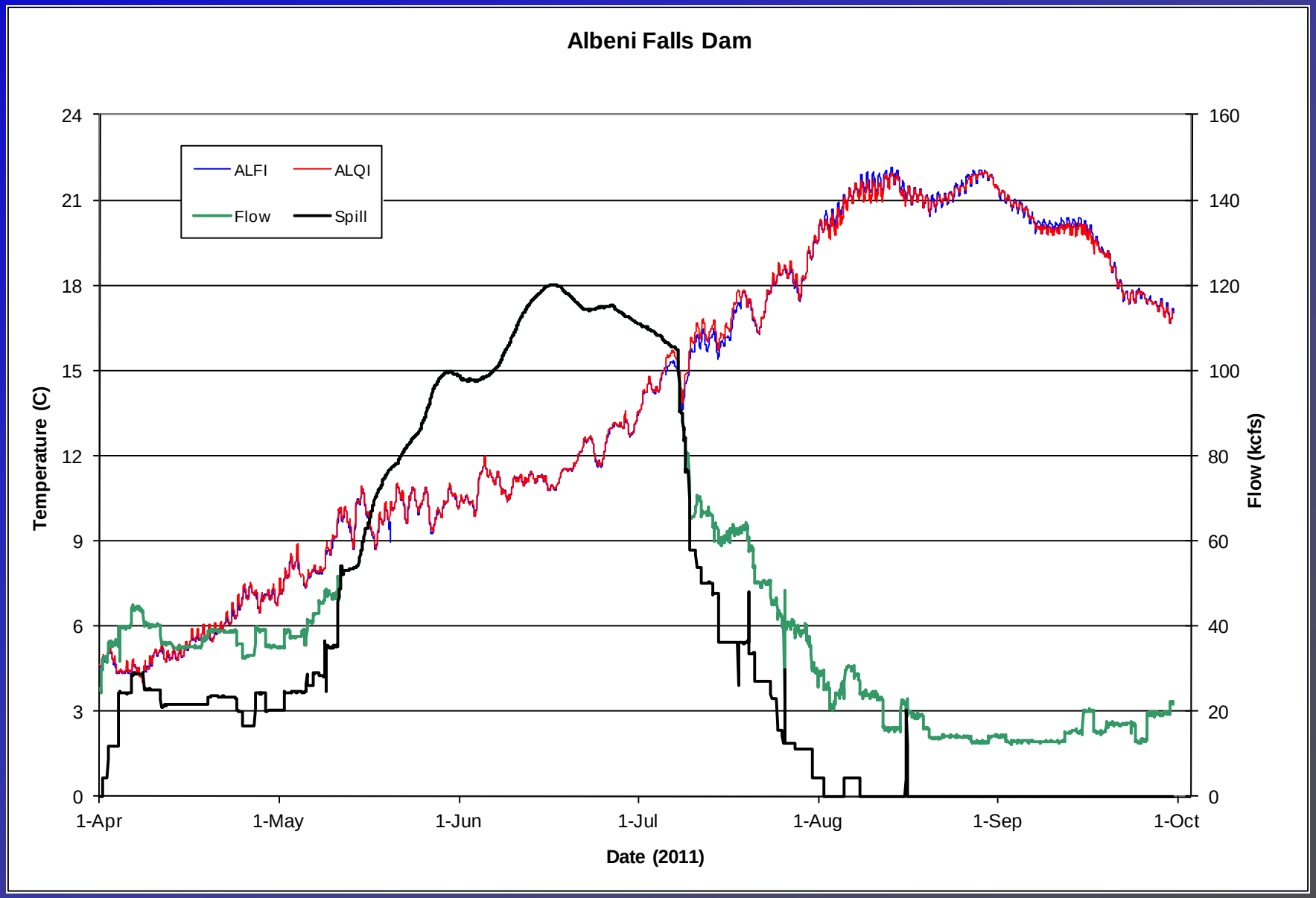
TDG Monitoring 2011

- 2011Spill Season Results for Albeni Falls Dam
  - TDG-Forebay (ALFI)
    - Forebay TDG a function of upstream TDG saturations
    - Highest TDG value was about 122%
  - TDG-Tailwater (ALQI)
    - Highest TDG value was about 124% during spill over 6 of 10 bays
    - Higher spill volumes did not produce higher TDG saturations
    - Free flow conditions did not increase downstream TDG
    - TDG saturations largely a function of forebay TDG, head, and number of spillbays used
  - Temperature-Forebay/Tailwater
    - Forebay and tailwater temperatures are similar, no stratification
    - Forebay and tailwater exceeded IDEQ daily average temperature standard (19ºC) from about early August through mid September
    - Forebay and tailwater exceeded I DEQ maximum daily temperature standard (22ºC) for a few days in August

TDG Monitoring 2011



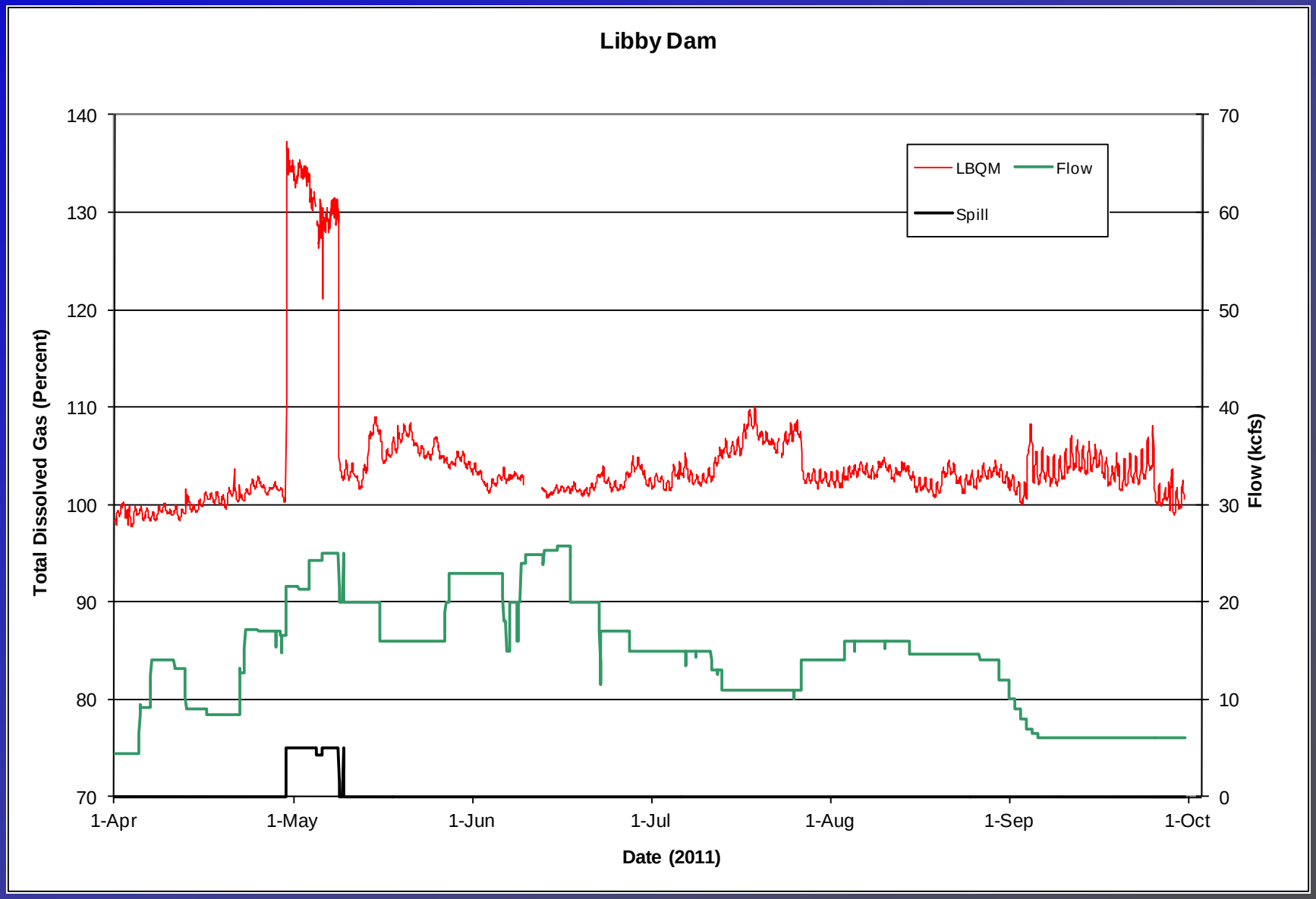
TDG Monitoring 2011



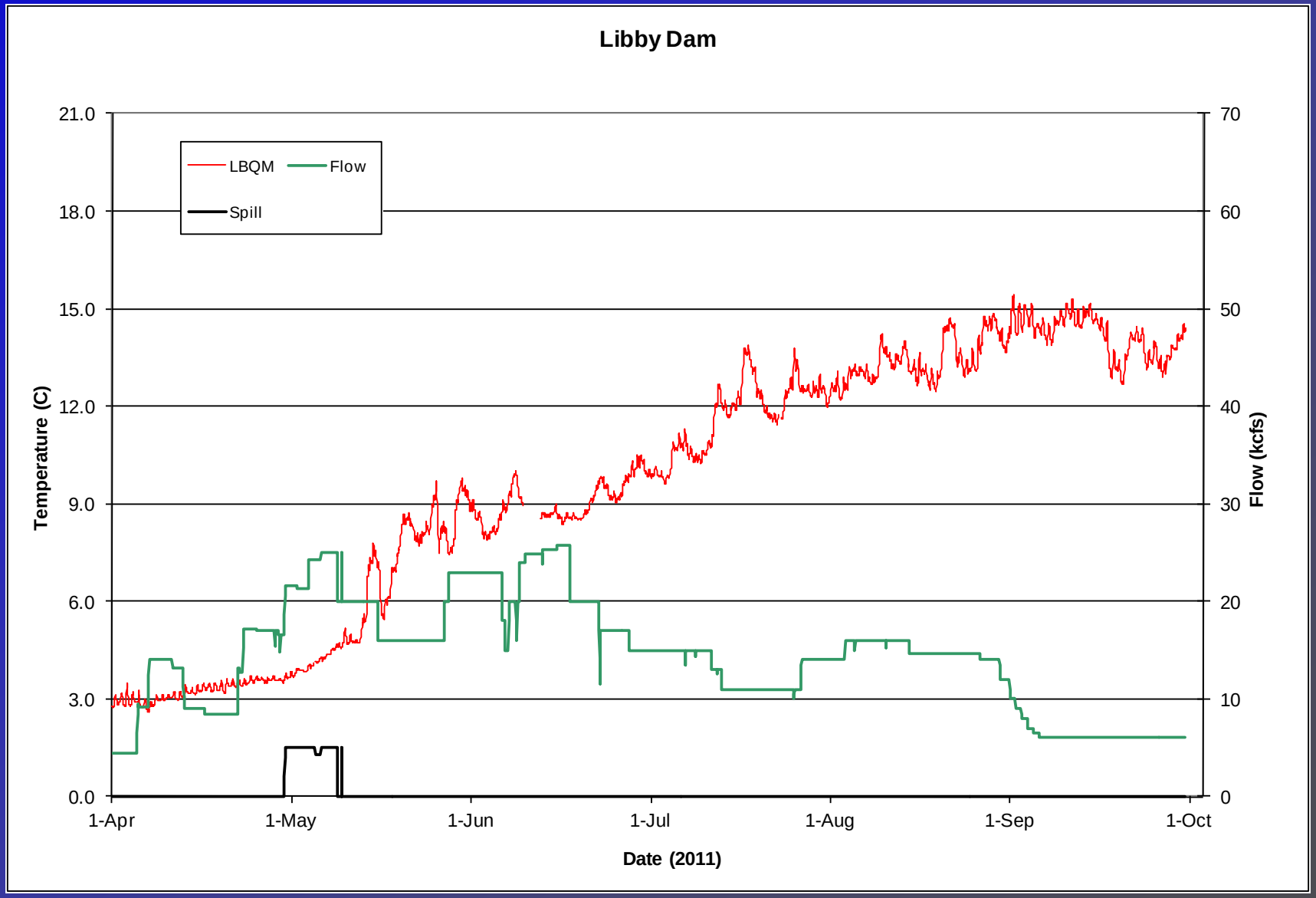
TDG Monitoring 2011

- 2011 Spill Season Results for Libby Dam
  - Sluiceway Spill during 2011
  - Max TDG of 137% during 5kcfs sluiceway spill
  - Temperature did not exceed 18ºC

TDG Monitoring 2011



TDG Monitoring 2011



TDG Exchange at Chief Joseph Dam

May – June 2011

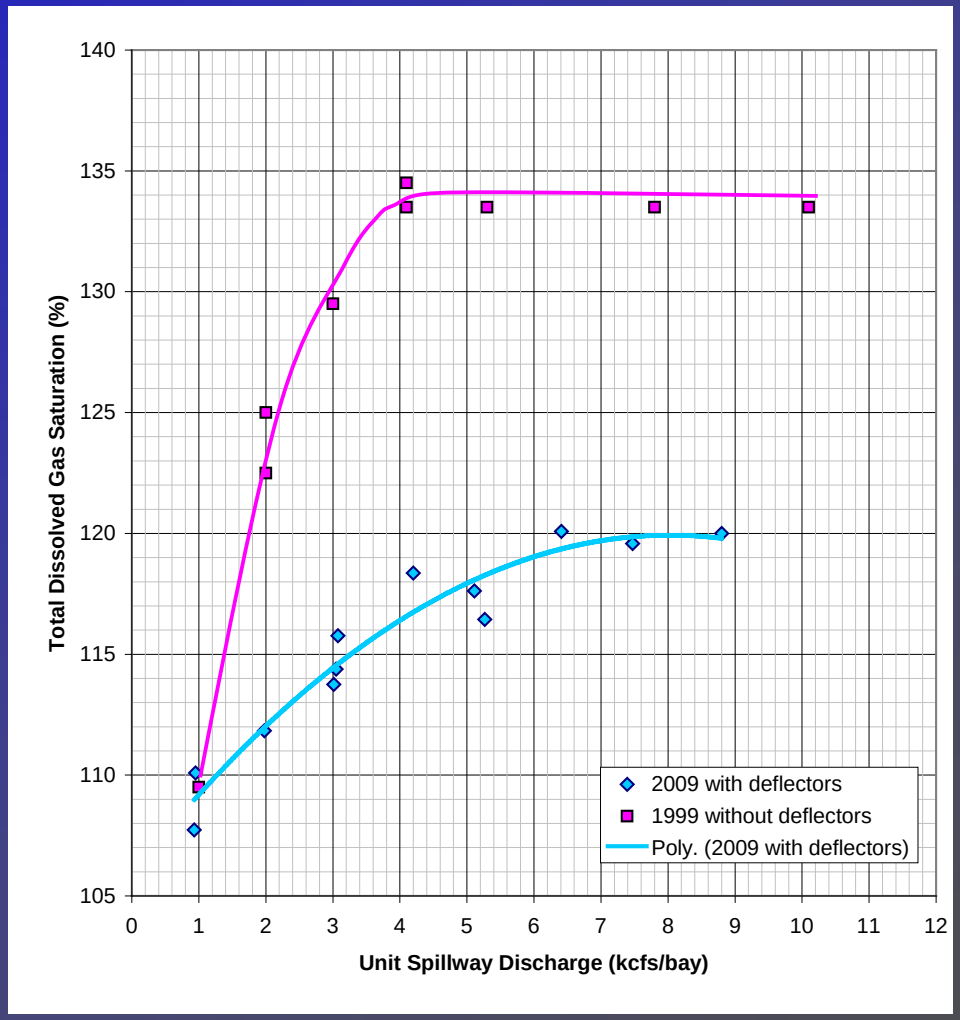
Scott English, Hydraulic Engineer
Northwestern Division - Water Management Division
Columbia River Basin Reservoir Control Center

Mike Schneider, Hydraulic Engineer
Engineering Research and Development Center

Kent Easthouse, Water Quality Specialist
Seattle District – Water Management

TDG Exchange at Chief Joseph Dam

- Background
  - TDG exchange in spillway flows at CHJ resets the TDG saturation
    - TDG exchange Independent from background conditions in aerated spillway flows
  - Spillway flow deflectors on all 19 bays completed for 2009 spill season
    - Results in prominent reduction in TDG exchange
  - Powerhouse release pass TDG content observed in forebay -unaltered
  - Average TDG content in CR can be estimated by flow weighting TDG observations from FMS

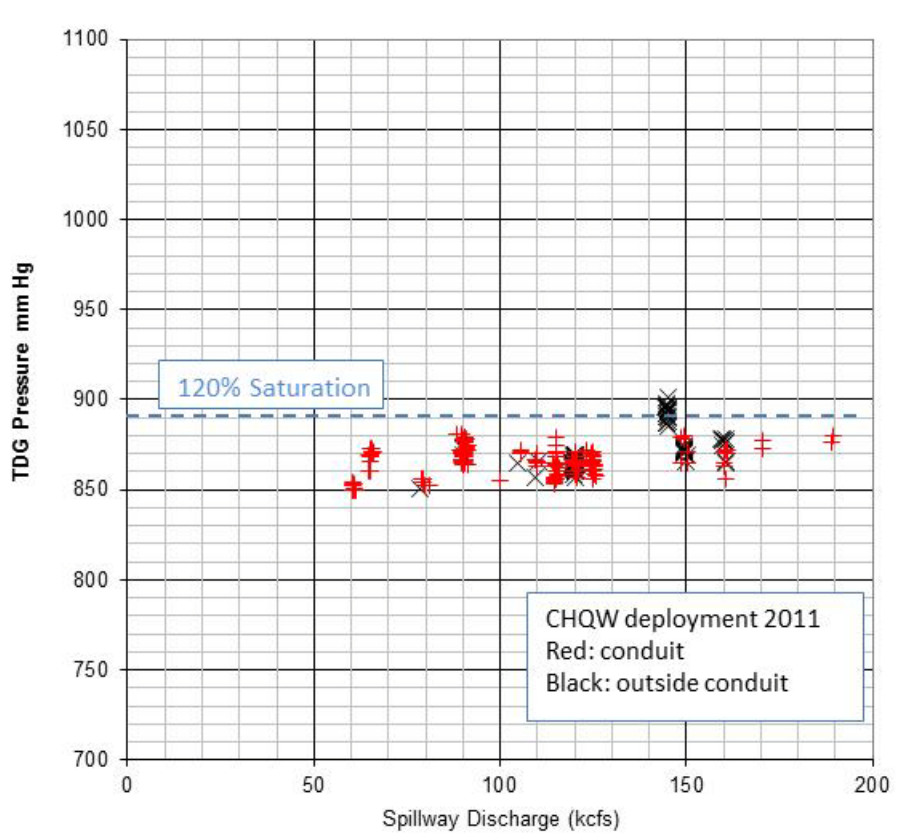


TDG Exchange at Chief Joseph Dam

- TDG Fixed Monitoring Stations
  - Tailwater station (CHQW) located 1.3 miles below spillway at right bank
  - Representative measure of spillway flows undiluted from powerhouse flows
  - Delayed and attenuated response was noted in 2009 for deployment in conduit
    - Attenuation (dampened) 1-2% saturation
  - Deployed outside of conduit since spring of 2009 until June 11, 2011
  - Swift currents in early June were forcing outside deployment of instrument into shallow waters above the compensation depth
  - Decision to deploy instrument in conduit to establish sufficient depth on June 11, 2011
  - Forebay Station (CHJ) located on west end of powerhouse at left bank

TDG Exchange at Chief Joseph Dam

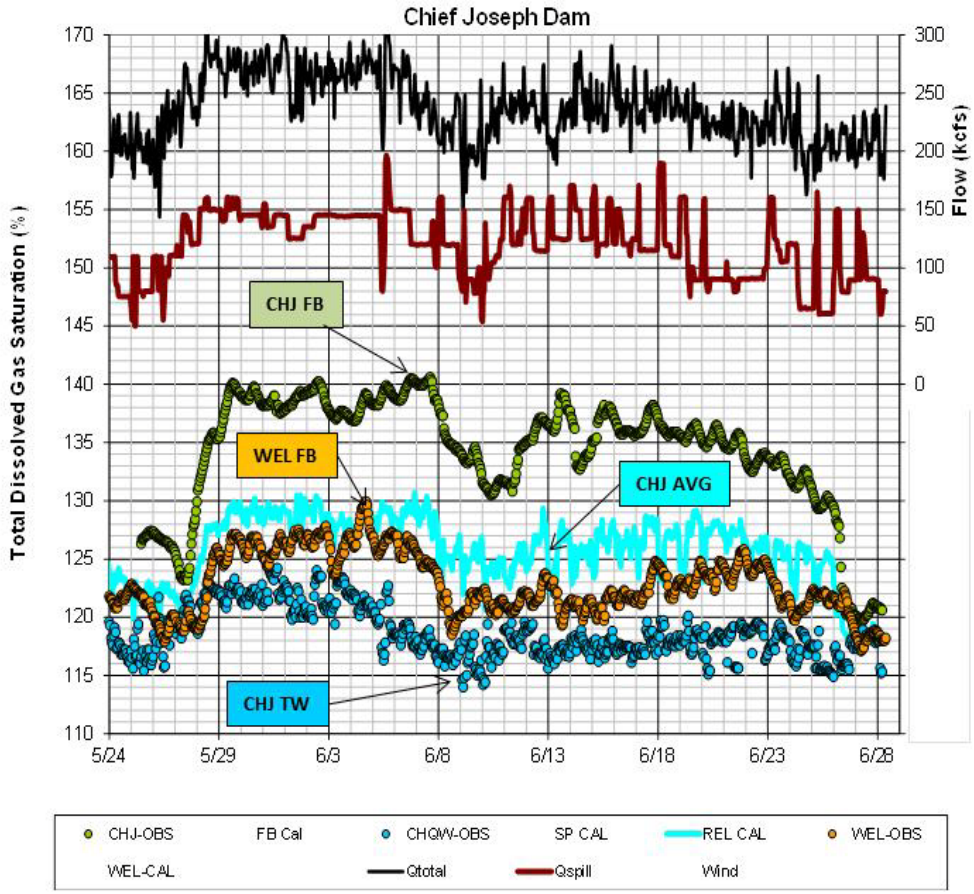
- TDG tailwater FMS CHQW
  - TDG response at CHQW to flow conditions since deployment change has been consistent
  - Other factors influencing TDG response at CHQW
    - Spill pattern
    - Tailwater elevation
    - Water temperature
    - Local atmospheric pressure



Tailwater Total Dissolved Gas pressure as a function of Spillway Discharge
(Uniform 19 bay spill pattern)

TDG Exchange at Chief Joseph Dam

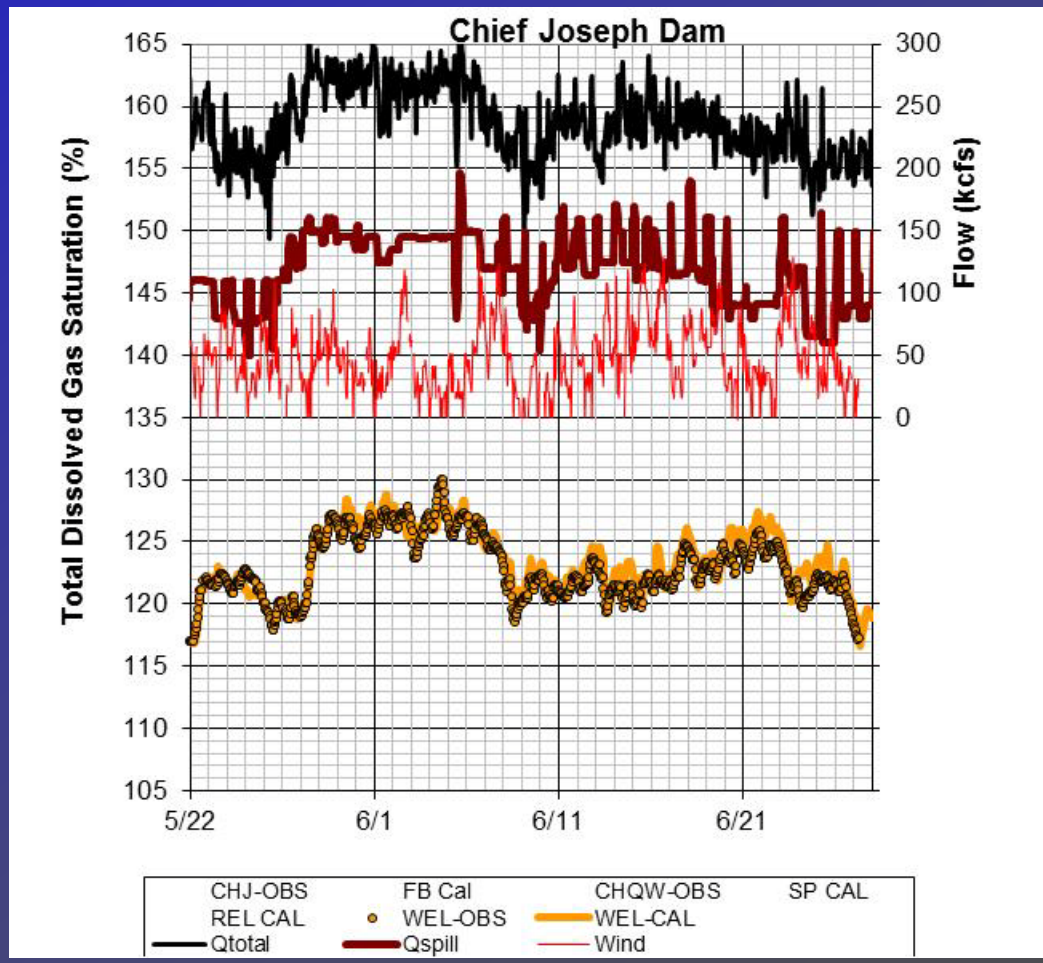
- TDG Management – (5/24-6/24)
  - High TDG levels in CR from upstream sources
    - TDG GCL tailwater 138.4%
  - TDG content in spill at CHJ resetting TDG pressures and reducing the TDG loading in CR
    - TDG CHJ forebay 135.3%
      - 3% lower than GCL tailwater
    - TDG CHQW tailwater 118.8%
      - 16.5% reduction in TDG saturation in spillway flows
    - TDG CHJ -flow weighted 126.8%
      - 8.5% reduction in TDG saturation in avg. river loading
    - TDG Wells forebay 123.2%
      - 3.6% saturation lower than CHJ flow weighted
      - Dilution from tribs
      - Reareation
      - Thermal Exchange



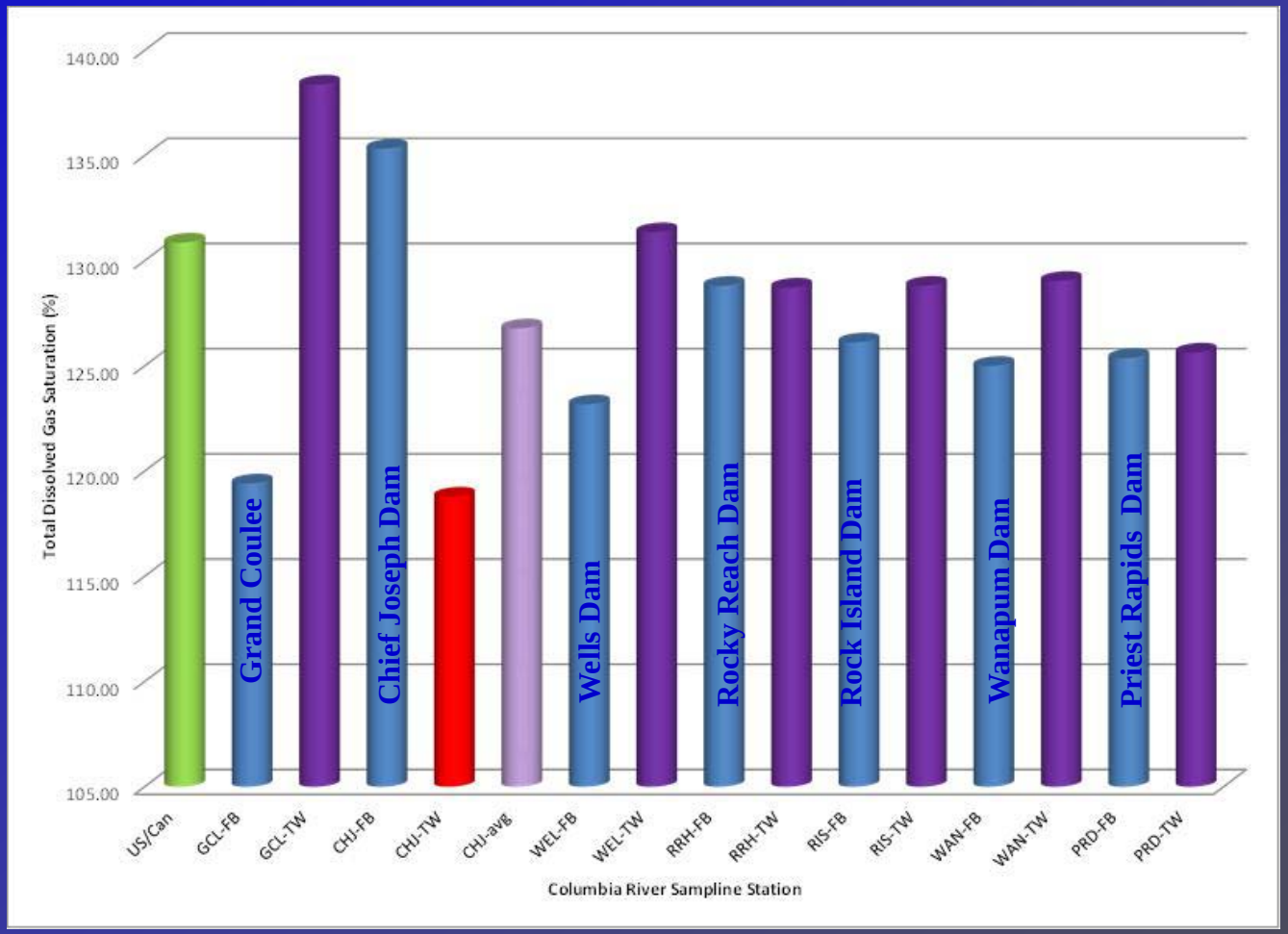
Chief Joseph Dam operations and total dissolved gas saturation, May 24-June 28, 2011

TDG Exchange at Chief Joseph Dam

- The net change in TDG loading in the CR at CHJ Dam can be estimated from conservation statement as follows:
- $TDG_{avg}=(TDG_{ph}Q_{ph}+TDG_{tw}Q_{sp})/(Q_{sp}+Q_{ph})$
  - Light blue line in figure on previous page.
- Attempts to meaningfully correlate CHJ spill or percent spill with Wells Forebay suffer from high correlations of CHJ forebay saturation with CHJ spill operations
  - Does not adequately identify upstream source of elevated TDG saturation
  - Does not take into account dilution, reaeration, thermal exchange
  - Daily average or 12 hour averages don't properly account for travel time of specific TDG events
- SYSTDG simulations using above estimate of average TDG pressures in CR below CHJ Dam are consistent with TDG pressures observed in forebay of Wells Dam.
  - Wel-CAL based on conservation equation above at CHJ
  - WEL-obs =Observed TDG saturation in forebay of Wells Dam



Average Total Dissolved Gas Saturation in the Columbia River, May 24-June 24, 2001



Legend

Forebay
Tailwater Mixed
Tailwater Spill
Tailwater Mixed est

TDG Exchange at Chief Joseph Dam

- TDG management
  - Activities to maintain safe and effective spillway operations at CHJ have been conducted
    - Surge Testing for high spillway discharges
    - Effective Spill patterns for reduction in TDG loading
    - Supplemental TDG monitoring to support TDG management activities