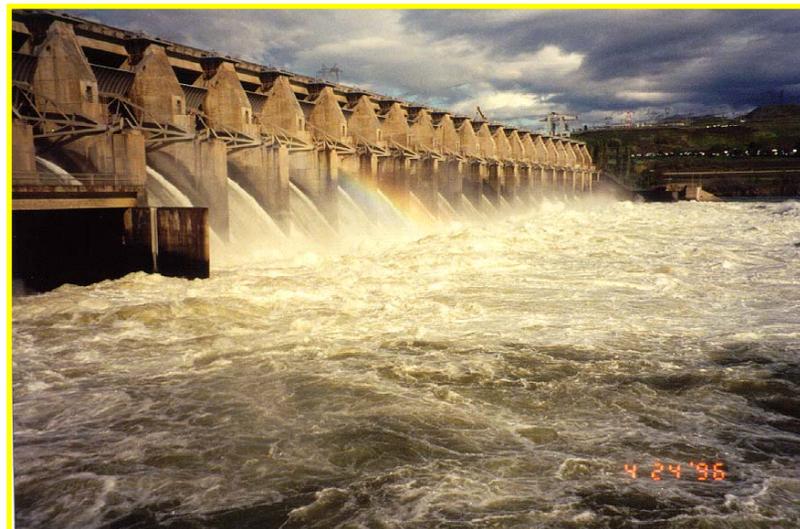


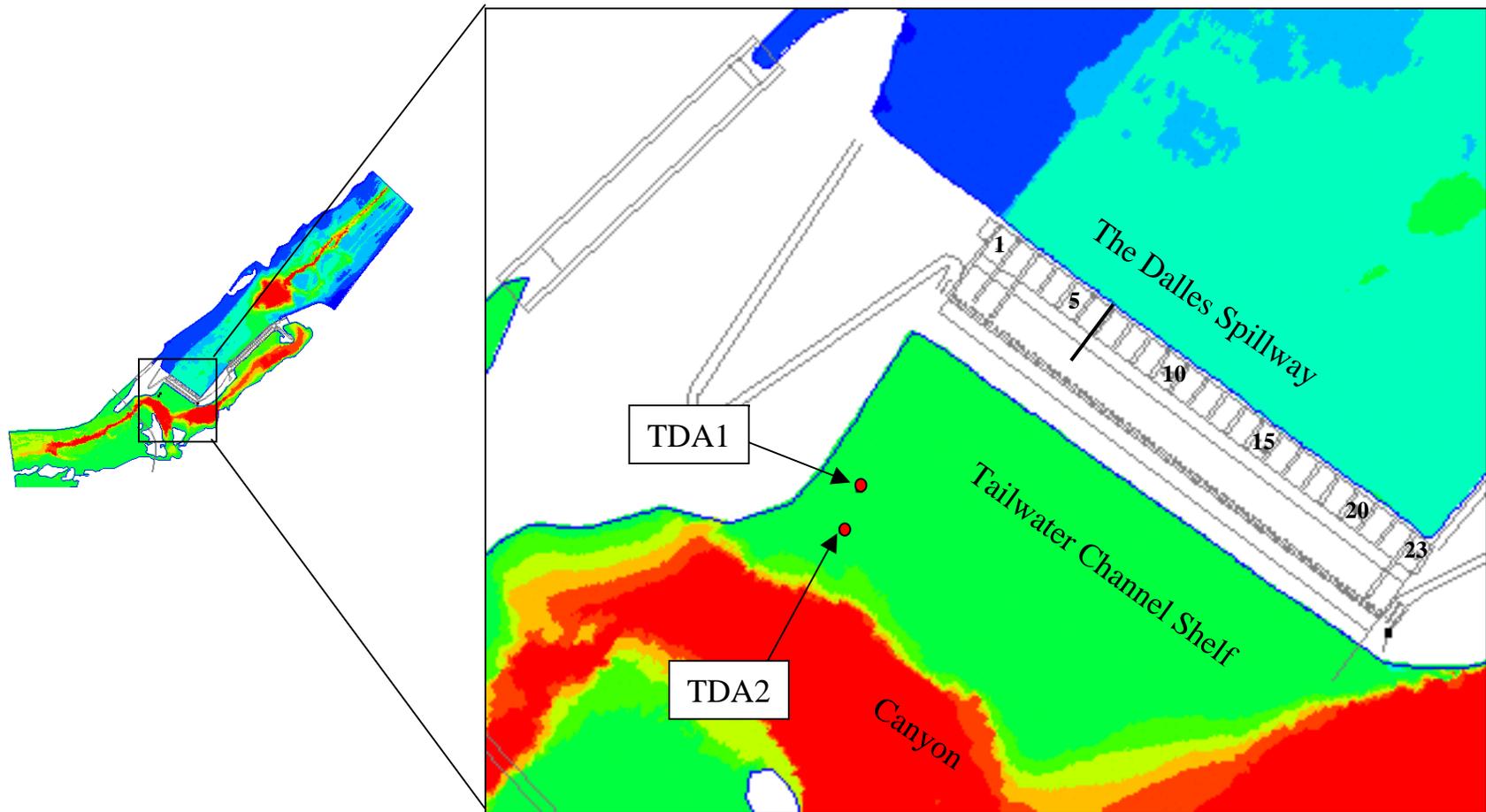
SYSTDG Case Study

- Bonneville Pool
- The Dalles Dam – upstream project
- Hypothetical Conditions
 - Transport and mixing
 - Environmental Influences
 - Background TDG levels
 - Time varying river flows and spill
- Actual 2004 Conditions
 - Wind induced degassing

The Dalles Dam

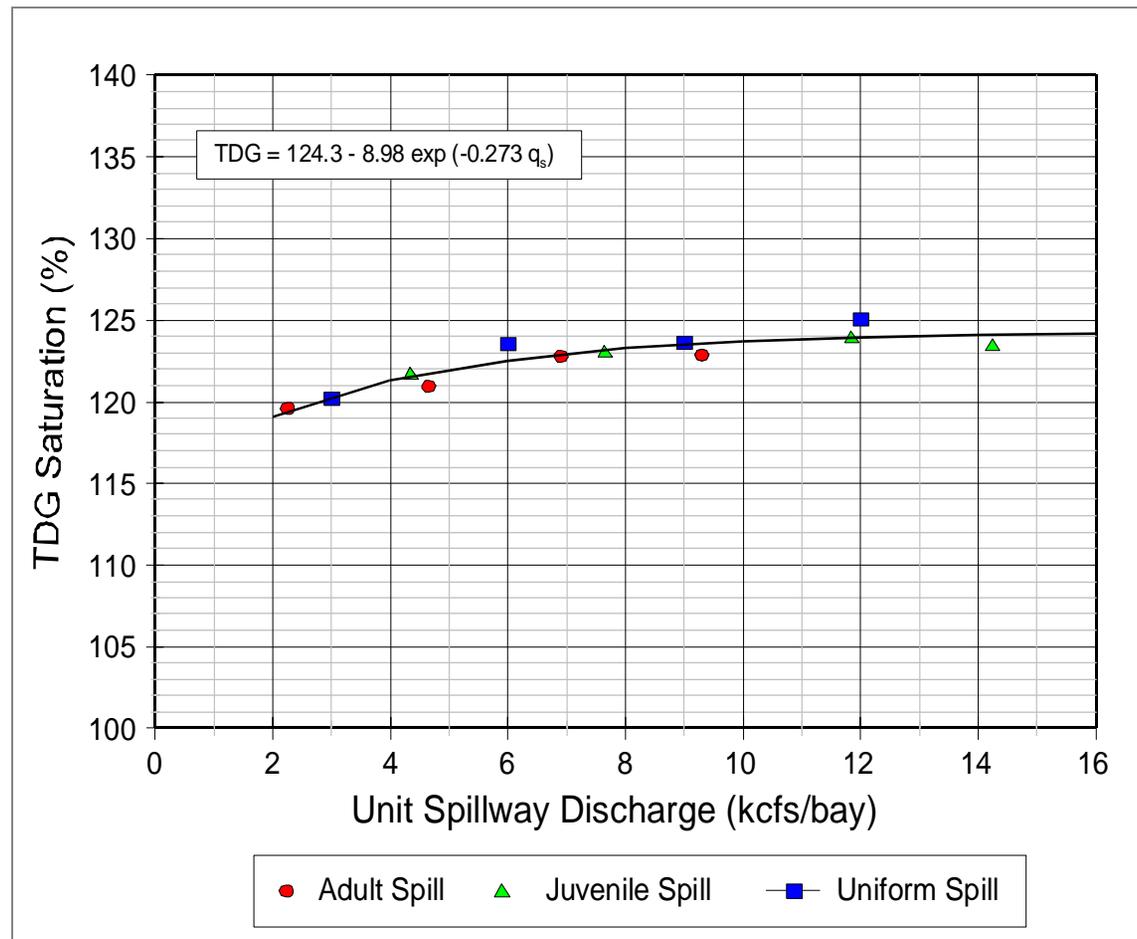


- High TDG Production
- Spill Pattern Peaked to North Side of Spillway
- No Spillway Flow Deflectors
- Training wall between bays 6&7
- Shallow Stilling Basin and Tailwater Channel
- Rapid Mixing of Project Releases
- Tailwater FMS in Mixed Water
- Powerhouse Capacity 375 kcfs
 - Hydraulic Head 78 ft
- Lake Celilo 24.1 Miles
 - Time of Travel 14 hrs

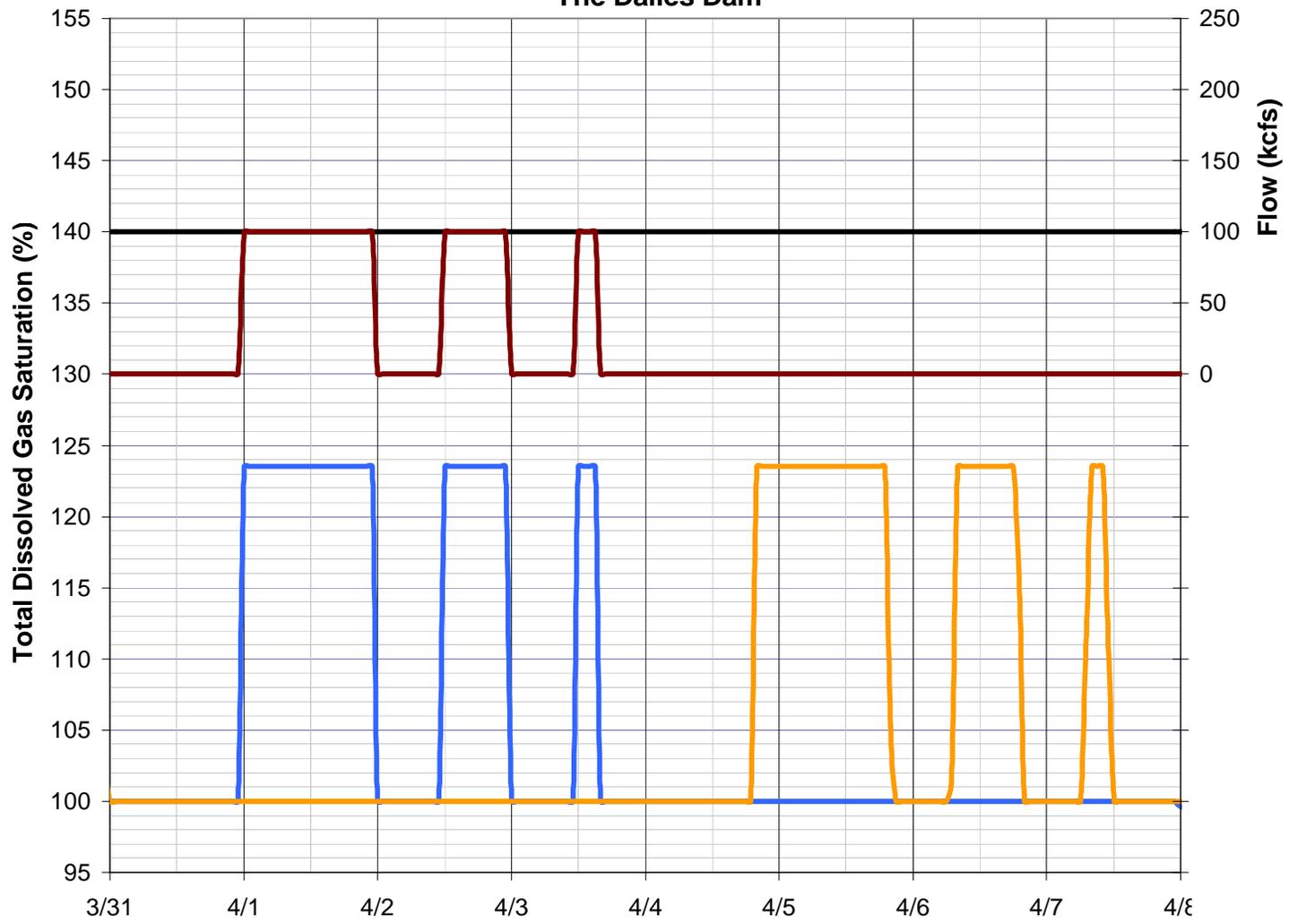


TDG Instrument Location in the Tailwater Channel at The Dalles Dam, April 14-June 7, 2000.

Total Dissolved Gas Exchange The Dalles Dam



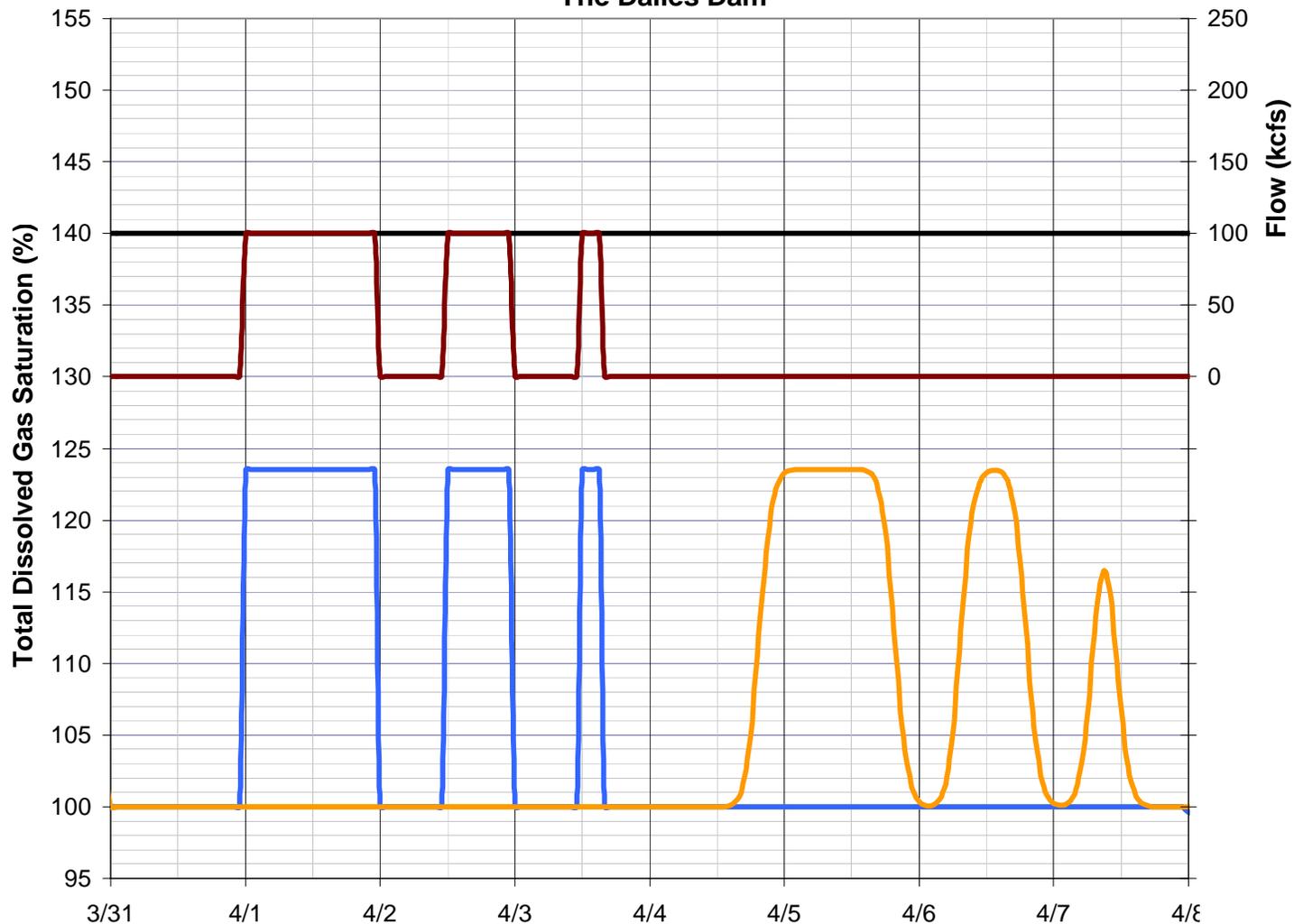
The Dalles Dam



TDA-OBS	FB CAL	TDDO-OBS	SP CAL	REL CAL	BON-OBS
BON-CAL		Qriver	Qspill	Wind	

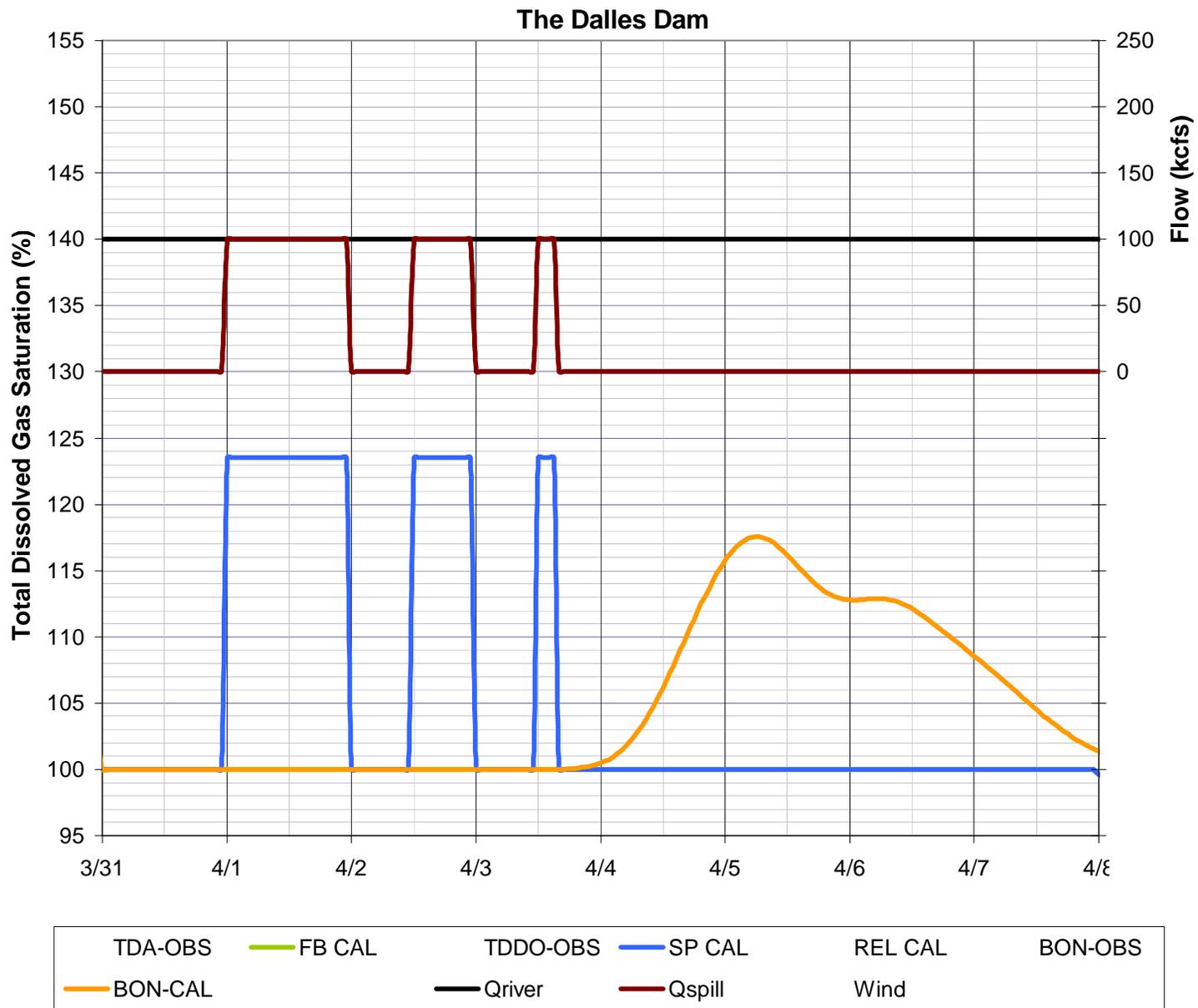
Plug Flow with no off-gassing
 The Dalles Operation, Qriver=100 kcfs, Spill 24, 12, 4 hr duration
 (Blue – TDG Spillway Flows, Gold – TDG Bonneville Forebay)

The Dalles Dam



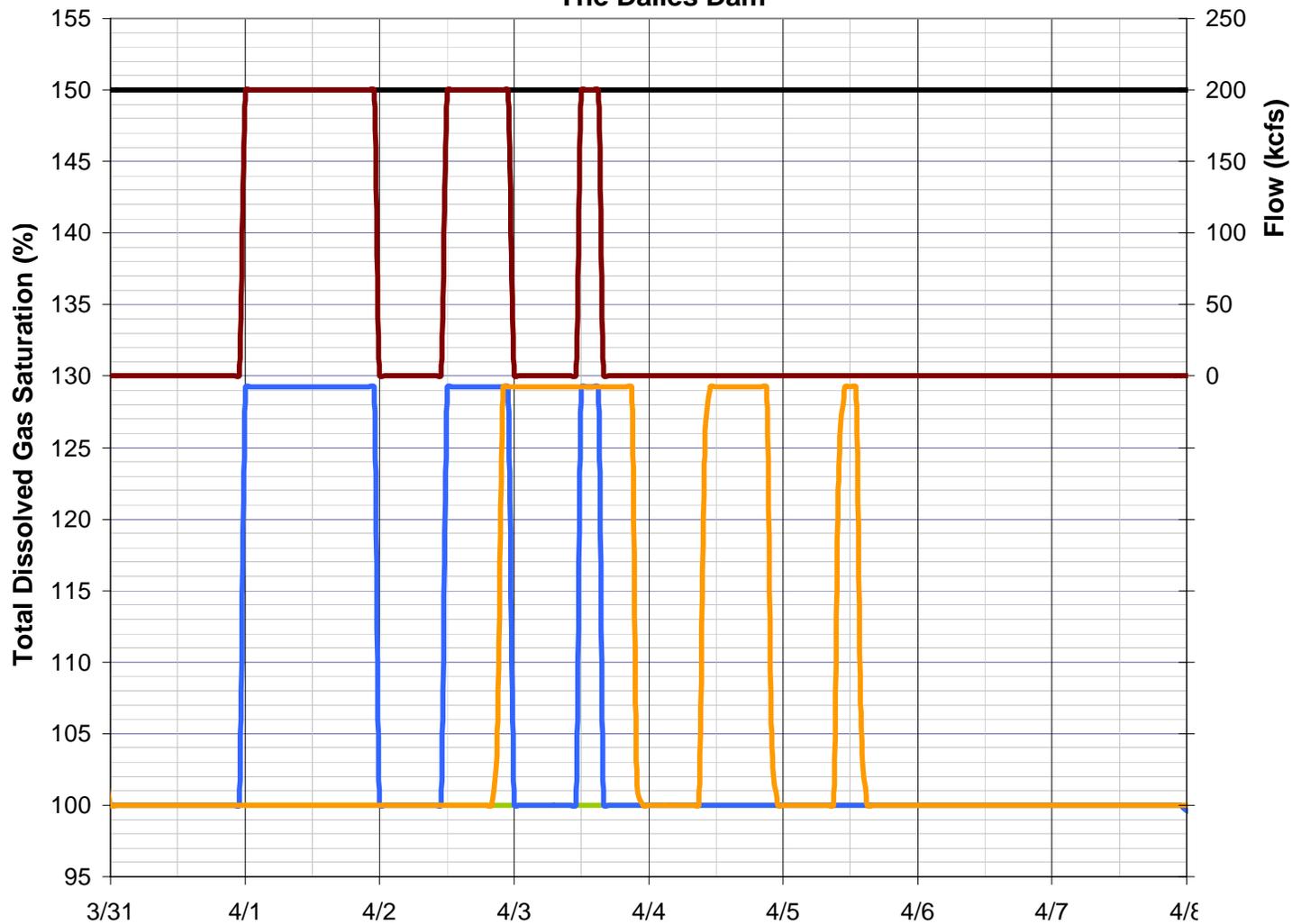
TDA-OBS	FB CAL	TDDO-OBS	SP CAL	REL CAL	BON-OBS
BON-CAL		Qriver	Qspill	Wind	

Small Dispersion Coefficient with no off-gassing
 The Dalles Operation, Qriver=100 kcfs, Spill 24, 12, 4 hr duration
 (Blue – TDG Spillway Flows, Gold – TDG Bonneville Forebay)

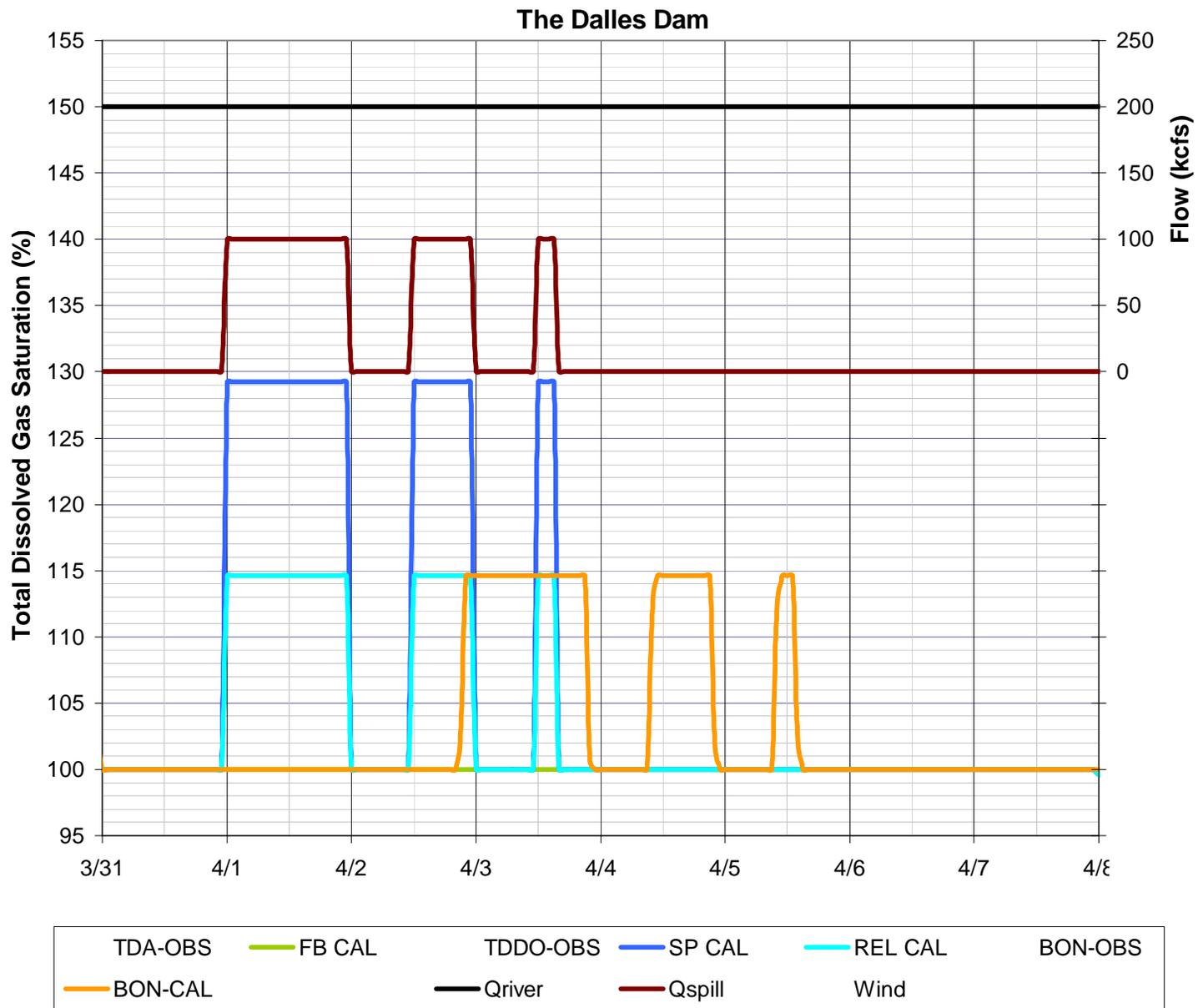


Large Dispersion Coefficient with no off-gassing
 The Dalles Operation, Qriver=100 kcfs, Spill 24, 12, 4 hr duration
 (Blue – TDG Spillway Flows, Gold – TDG Bonneville Forebay)

The Dalles Dam

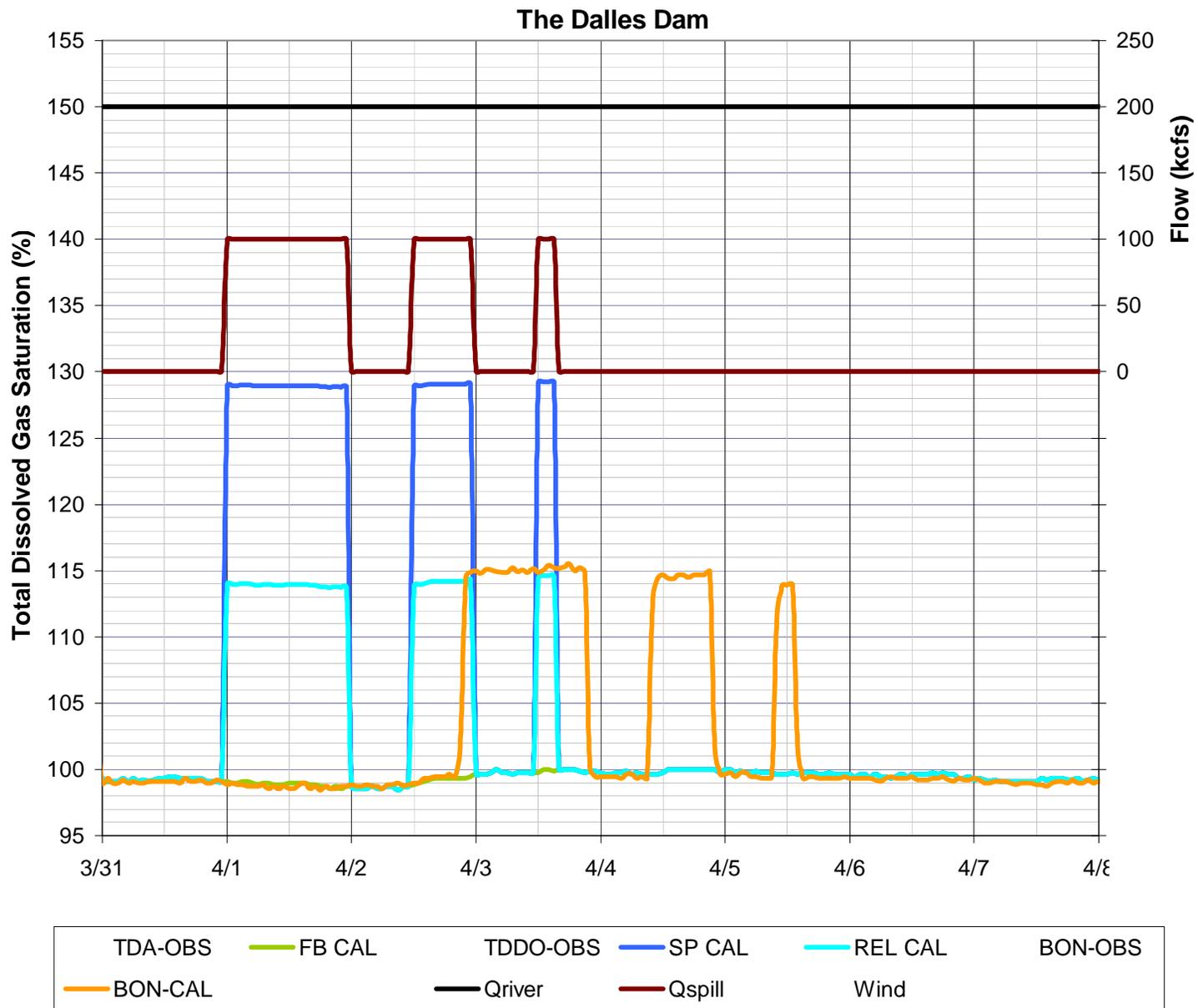


Plug Flow with no off-gassing
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration
 (Blue – TDG Spillway Flows, Gold – TDG Bonneville Forebay)

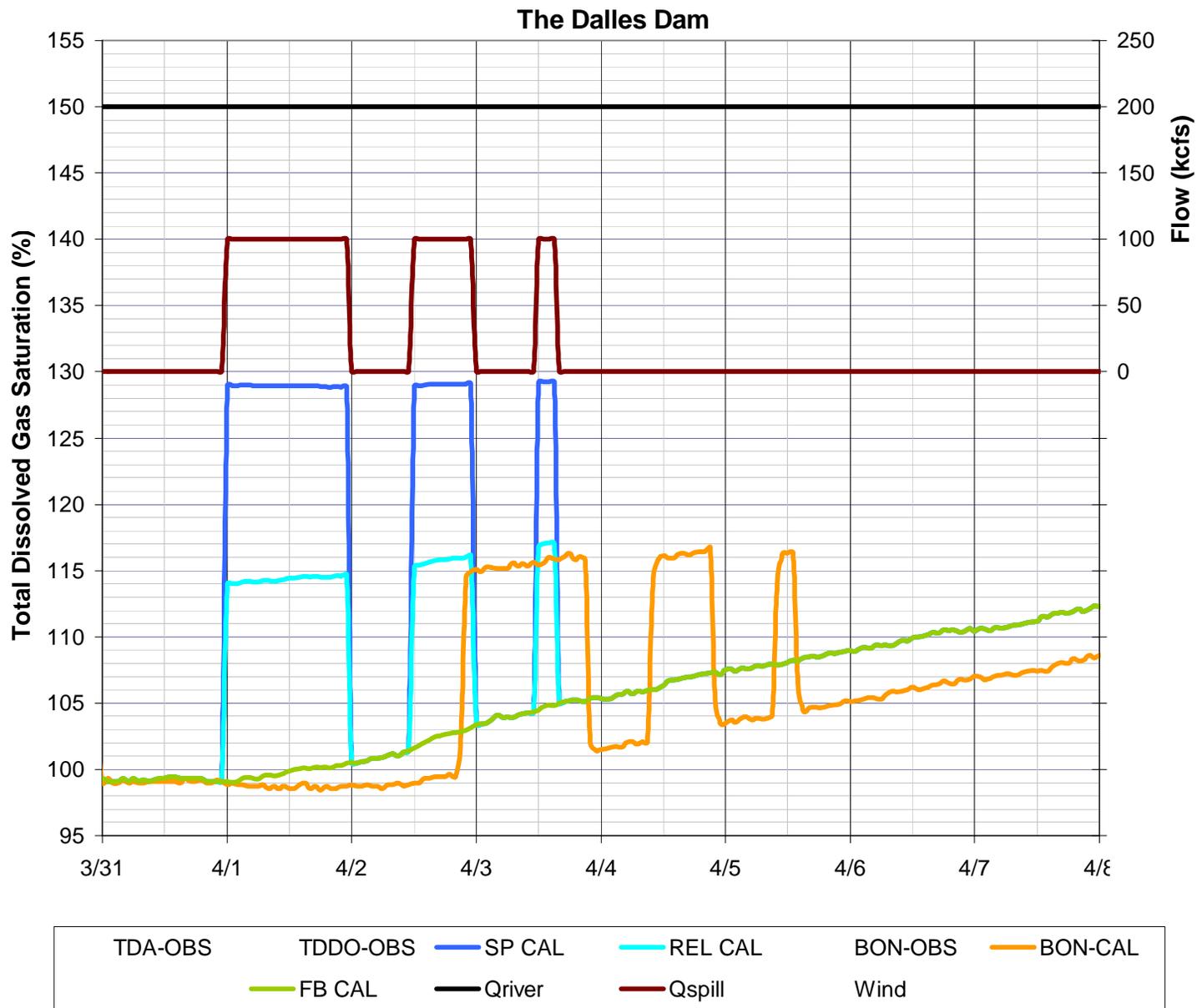


Plug Flow with no off-gassing

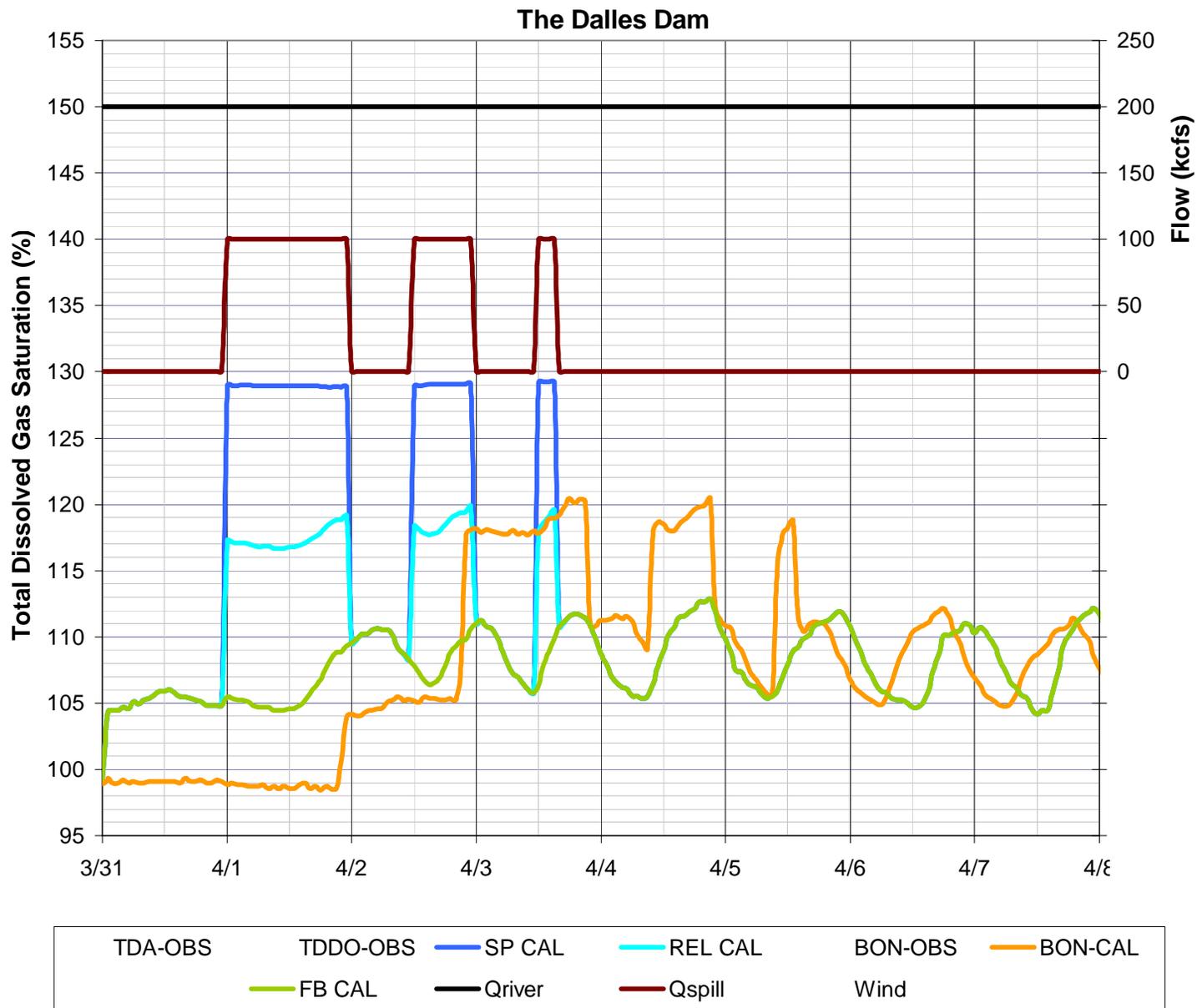
The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



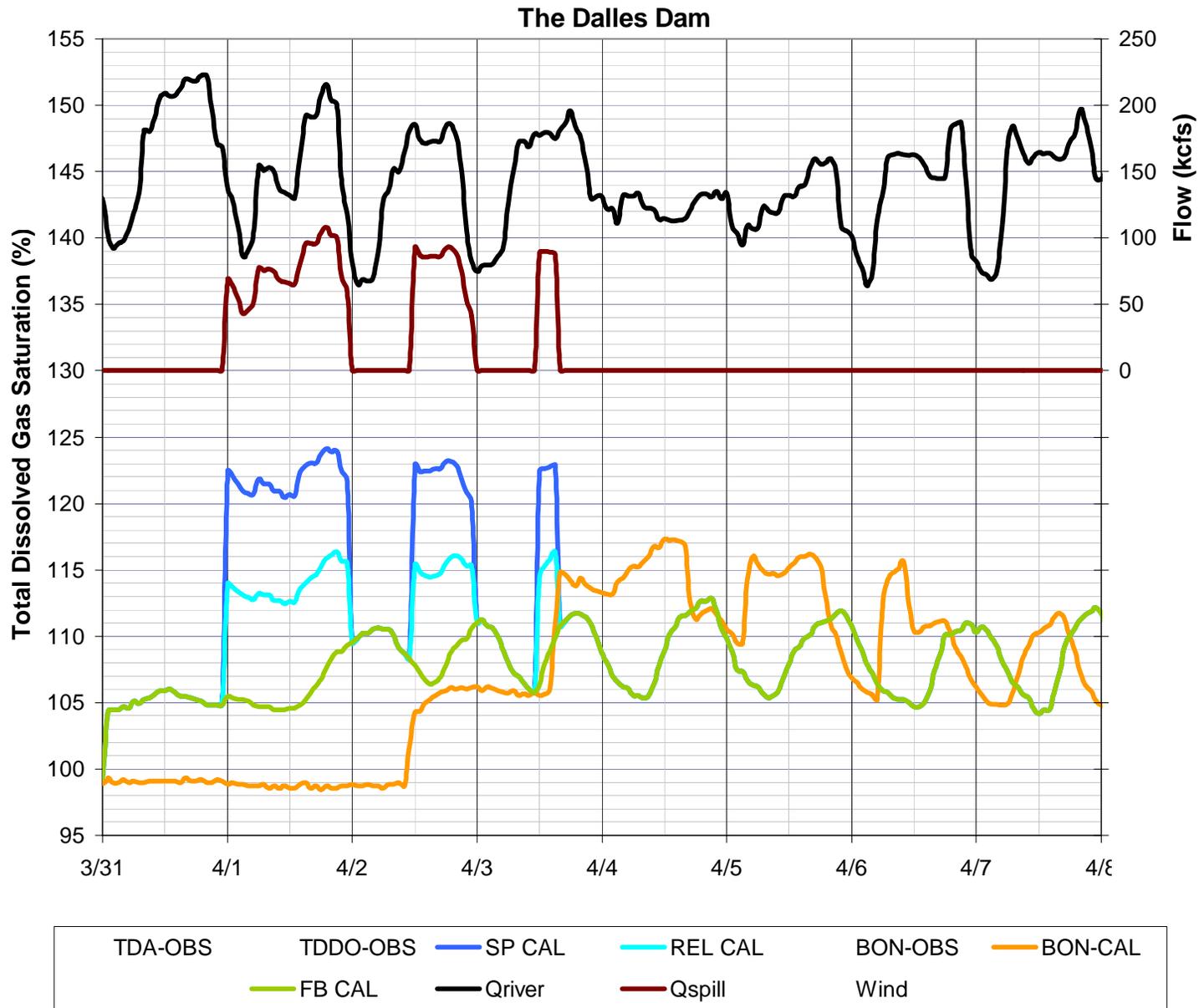
Plug Flow with no off-gassing, Variable Barometric Pressure
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



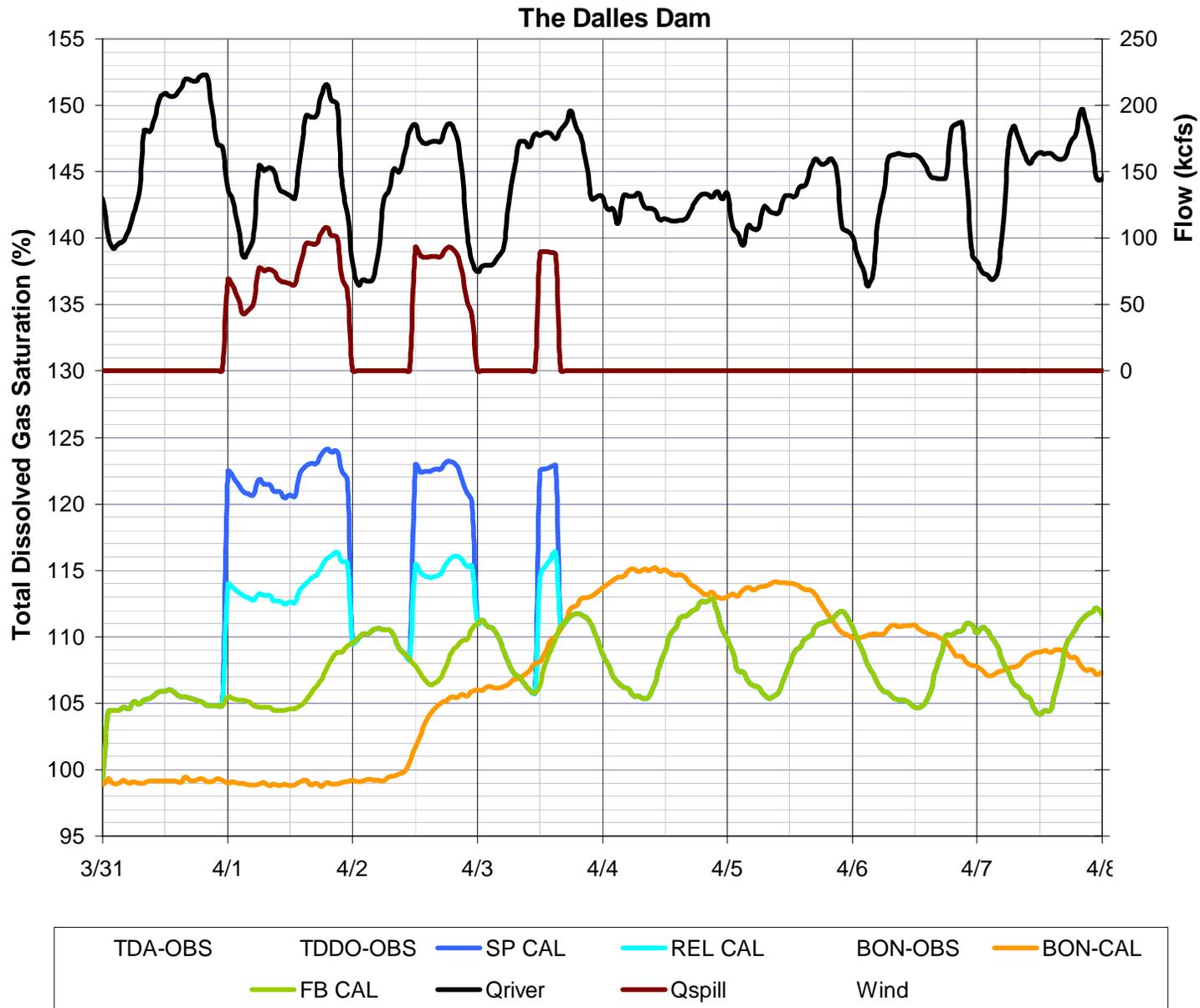
Plug Flow with no off-gassing, Variable Barometric Pressure and Background TDG (Green)
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



Plug Flow with no off-gassing, Variable Barometric Pressure and Background TDG (Green)
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)

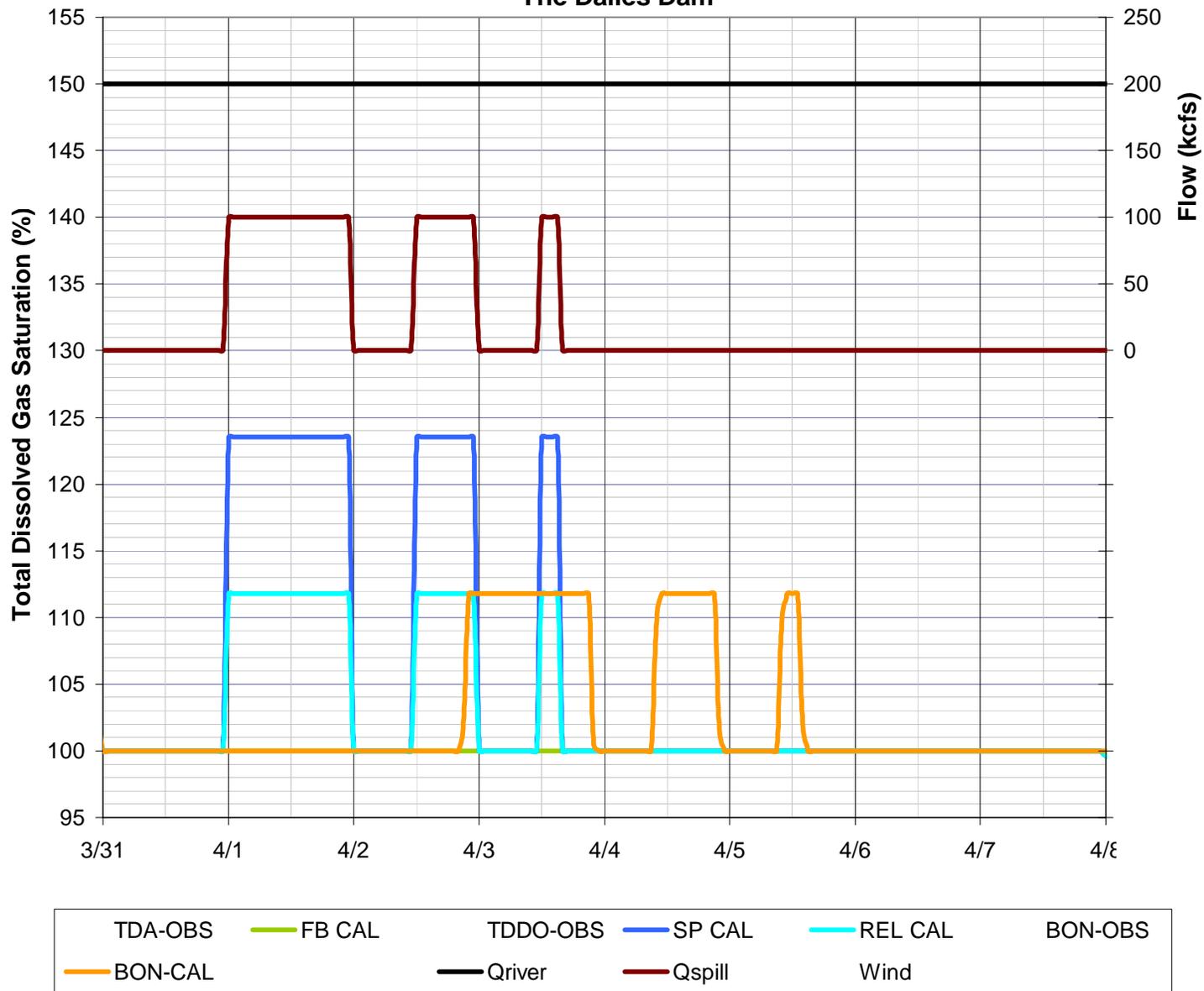


Plug Flow with no off-gassing, Variable Flow, Barometric Pressure, and Background TDG (Green)
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 50% of Qriver
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



Large Dispersion Coefficient with no off-gassing,
 Variable Flow, Barometric Pressure, and Background TDG (Green)
 The Dalles Operation, $Q_{river}=200$ kcfs, Spill 24, 12, 4 hr duration @ 50% of Q_{river}
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)

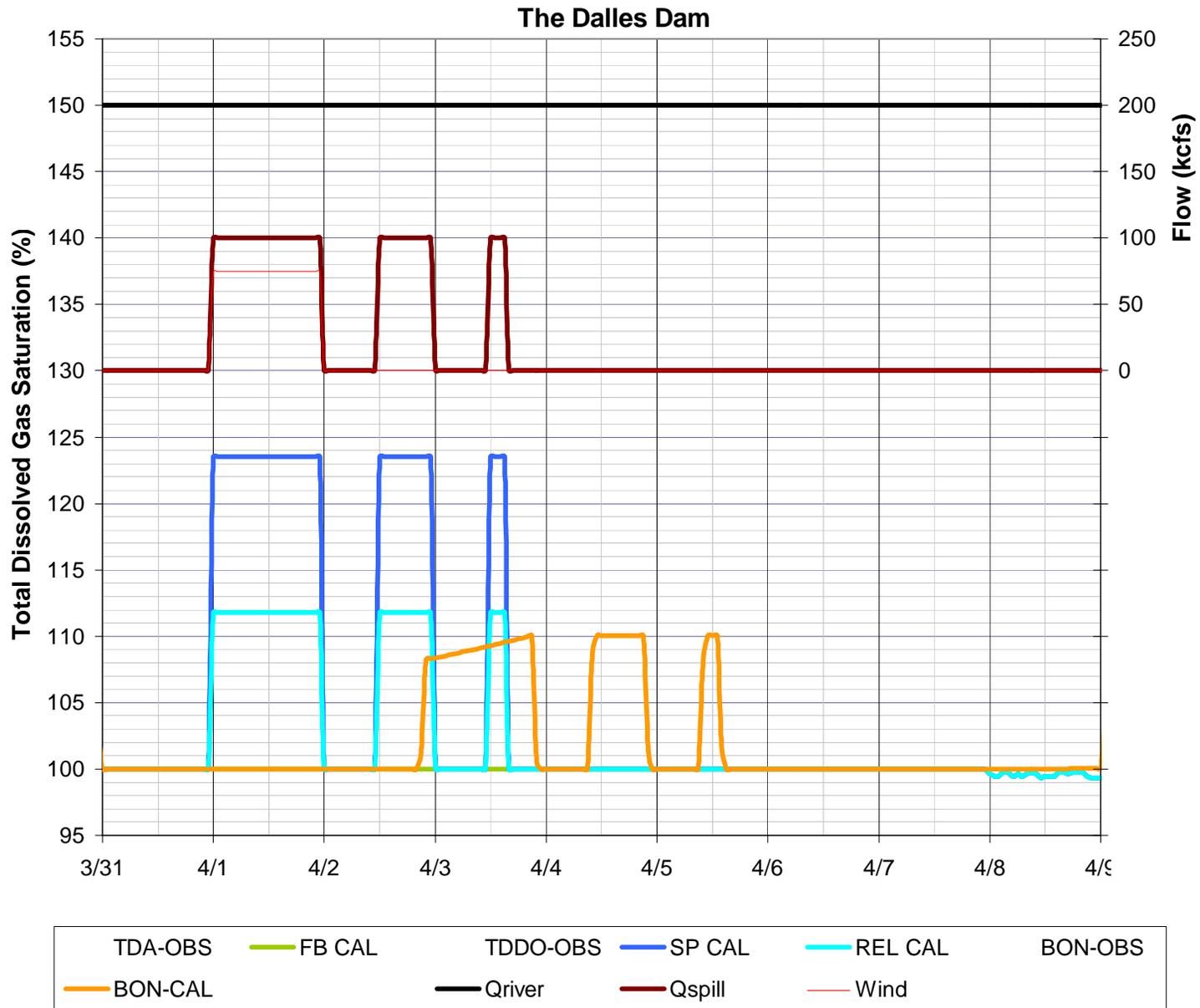
The Dalles Dam



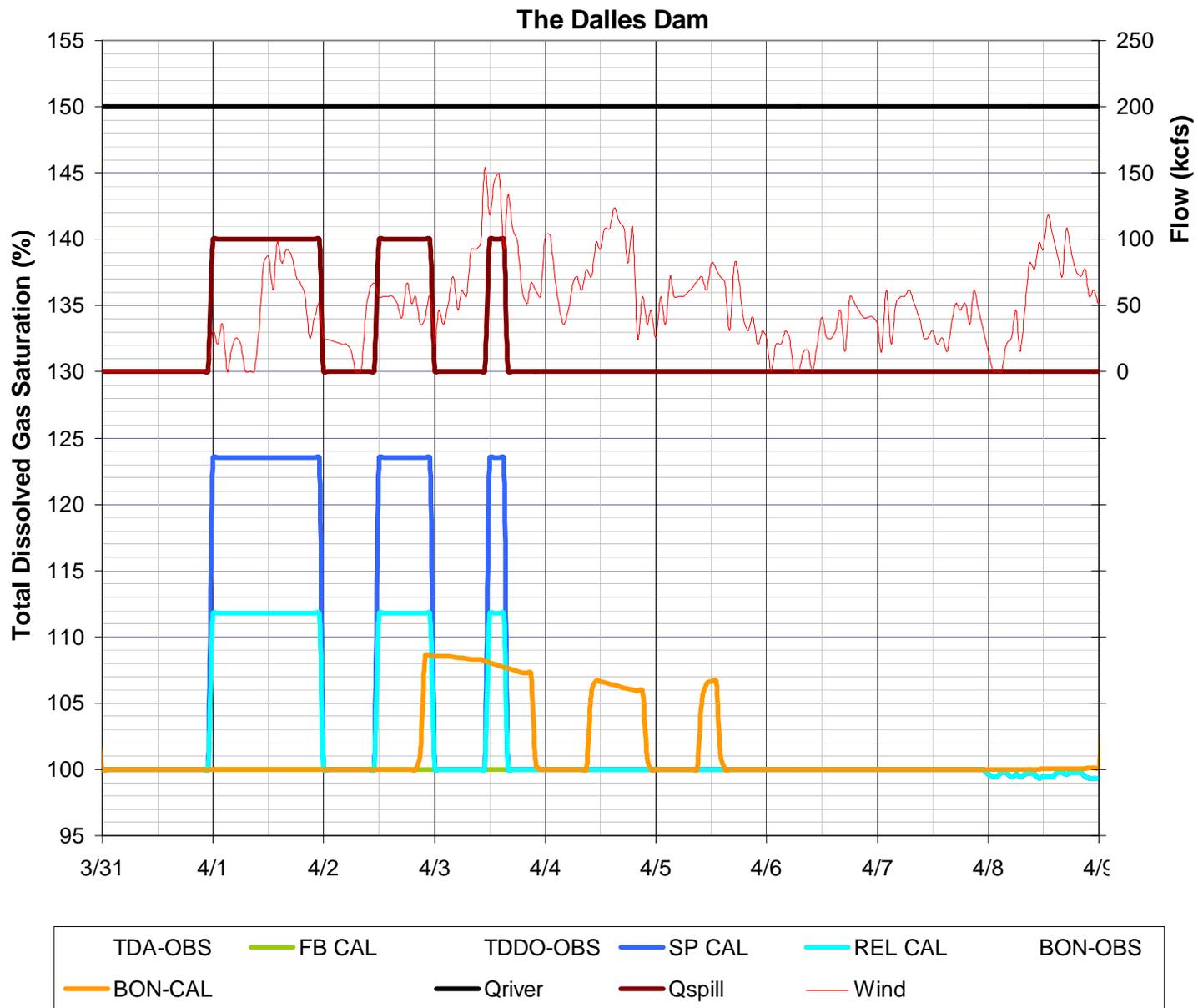
Plug Flow with no off-gassing

The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs

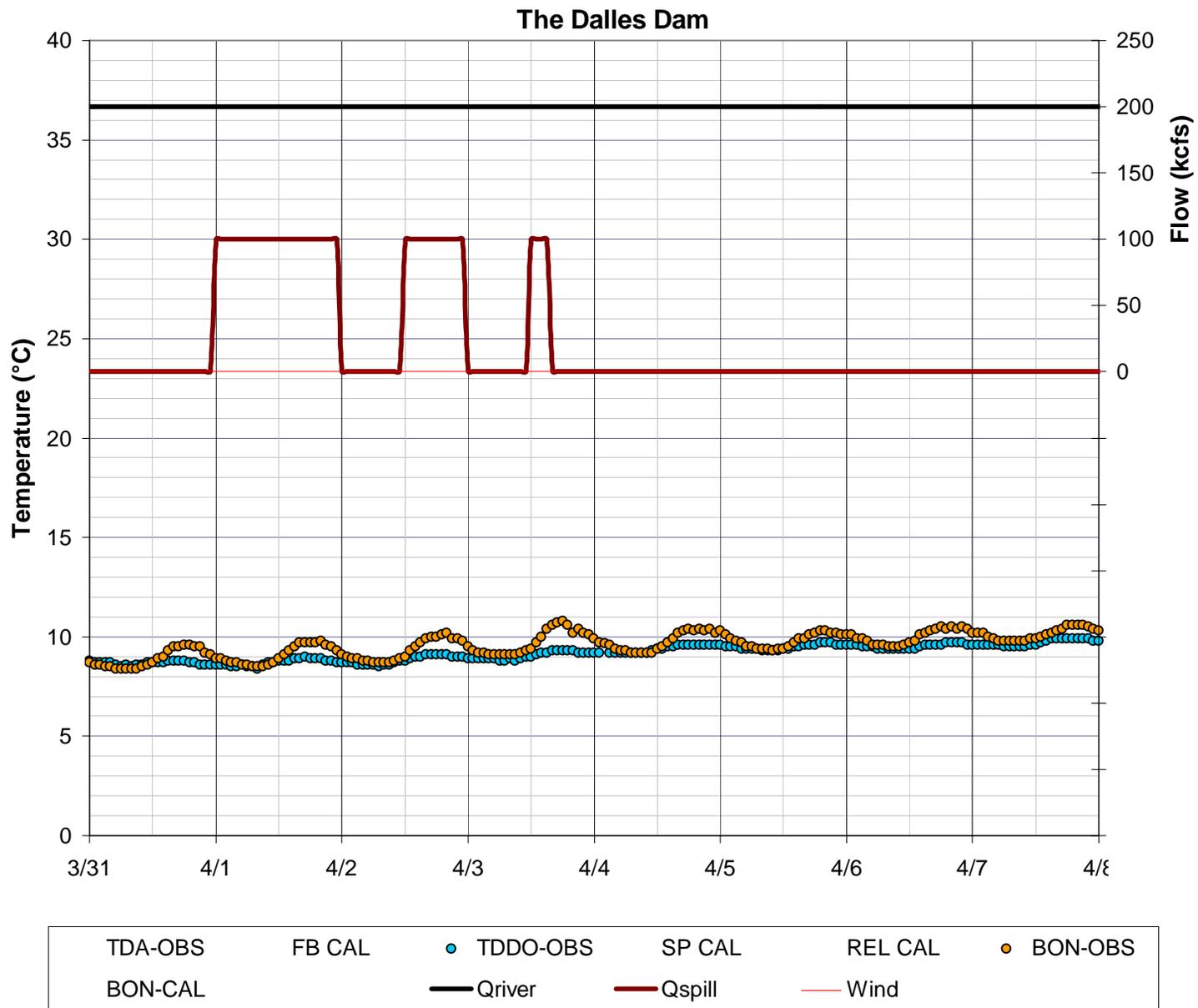
(Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



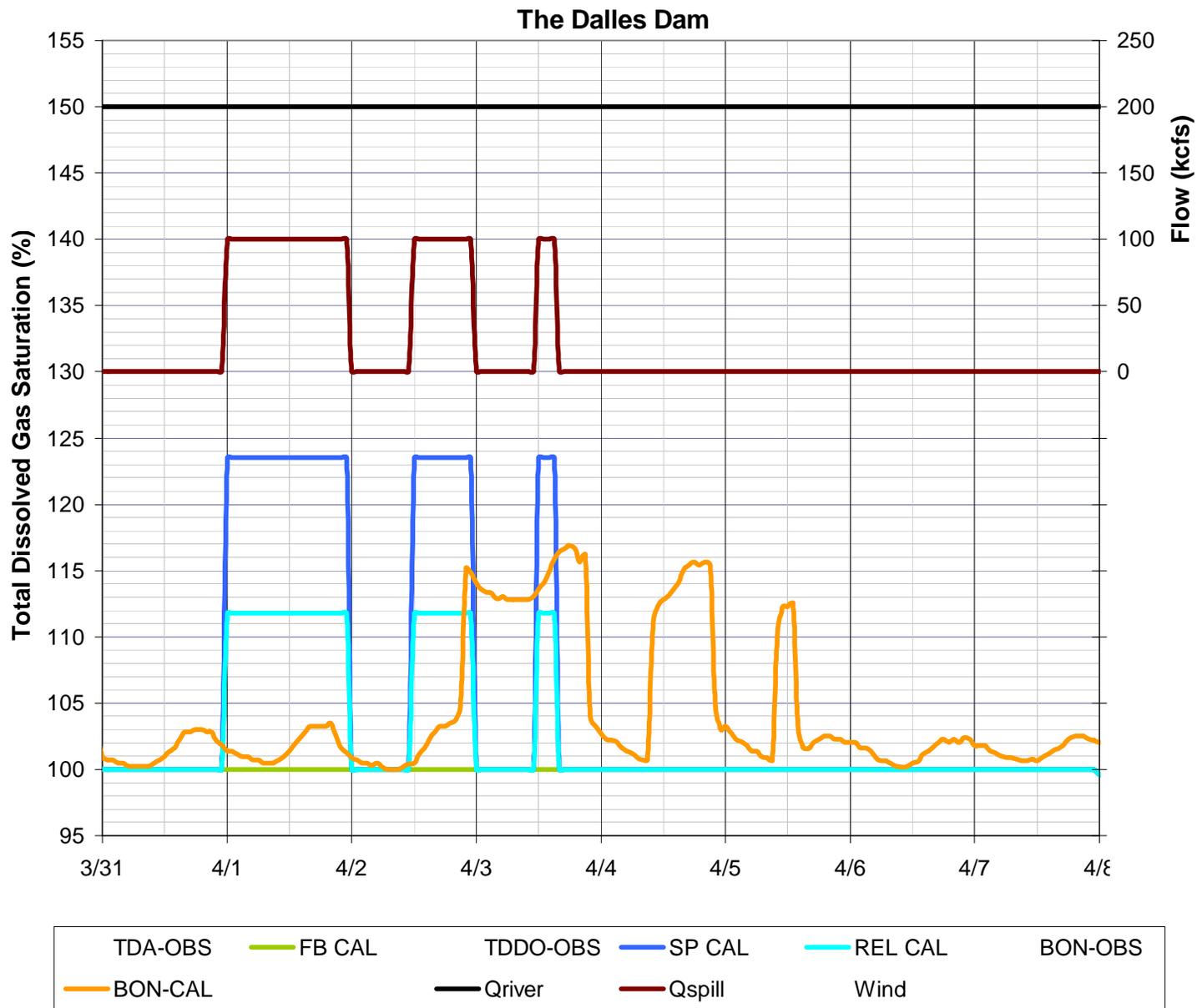
Plug Flow with wind induced off-gassing at water surface (wind blowing on 4/1 @ 7.5 mps)
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



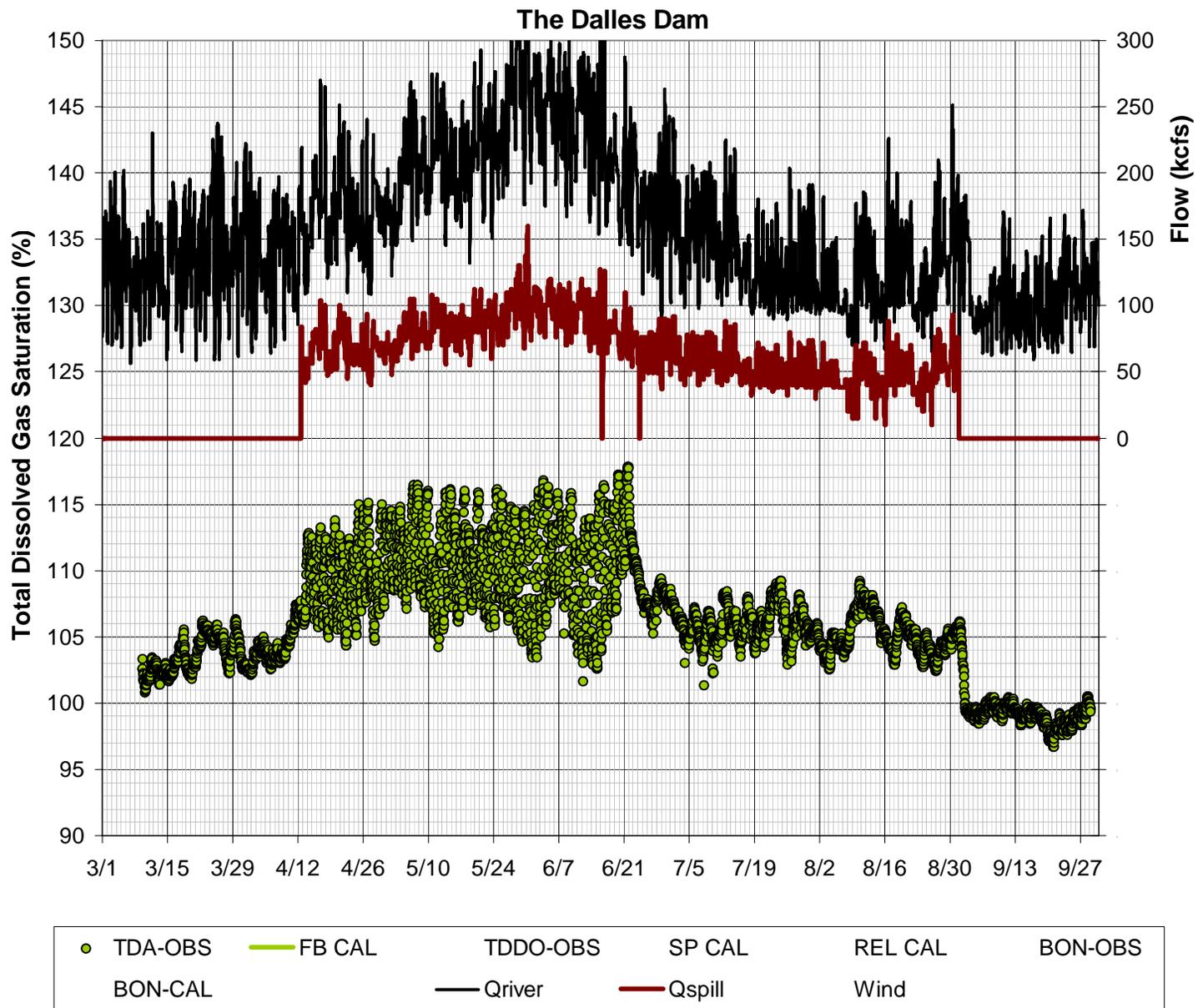
Plug Flow with wind induced off-gassing at water surface (variable wind)
 The Dalles Operation, $Q_{river}=200$ kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



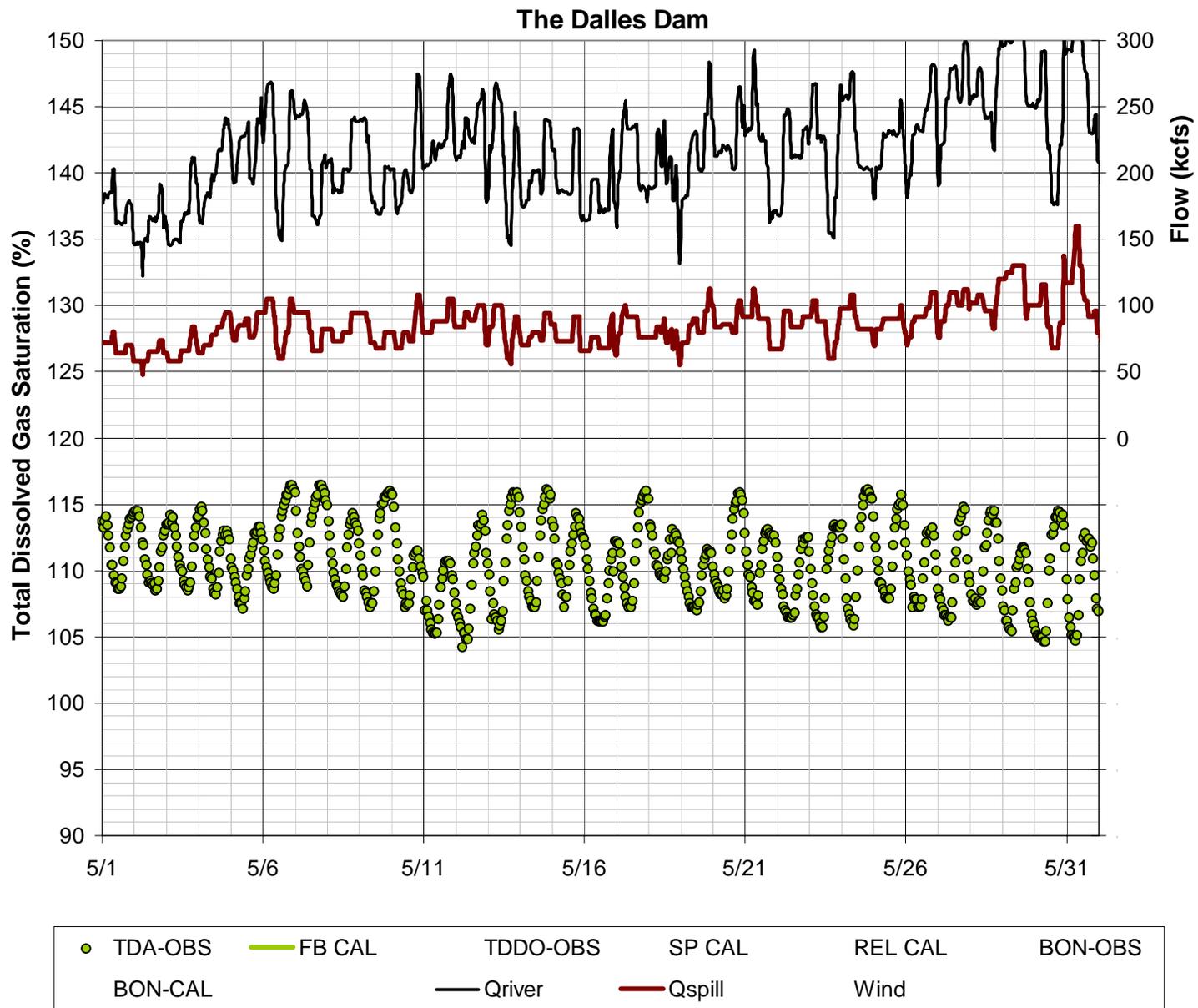
Water Temperature time history in Bonneville Pool
 (Gold – Bonneville Forebay, Blue- The Dalles Tailwater)



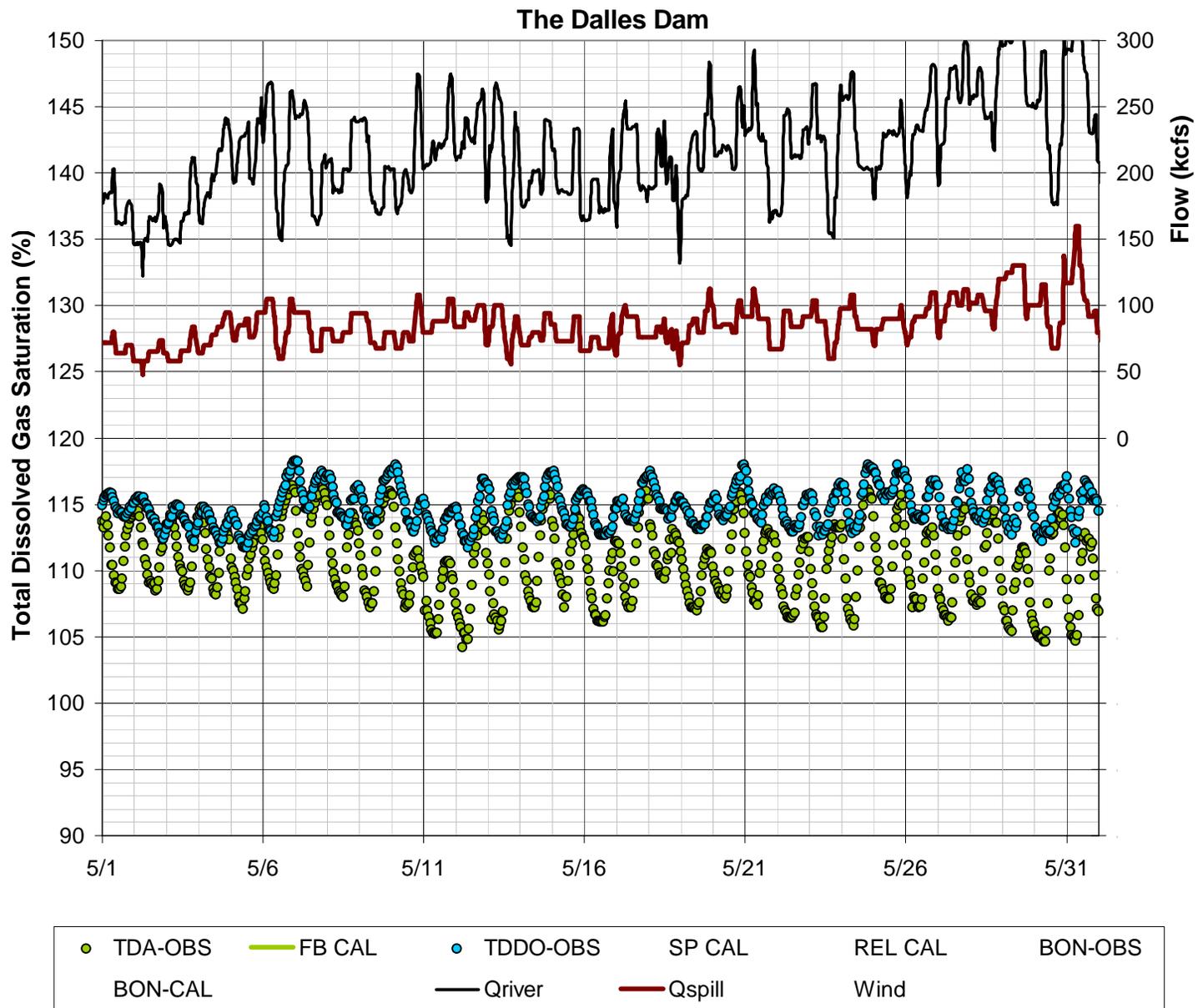
Plug Flow with no off-gassing with temperature induced pressure changes
 The Dalles Operation, Qriver=200 kcfs, Spill 24, 12, 4 hr duration @ 100 kcfs
 (Blue – TDG Spillway Flows, Light Blue- TDG Avg release, Gold – TDG Bonneville Forebay)



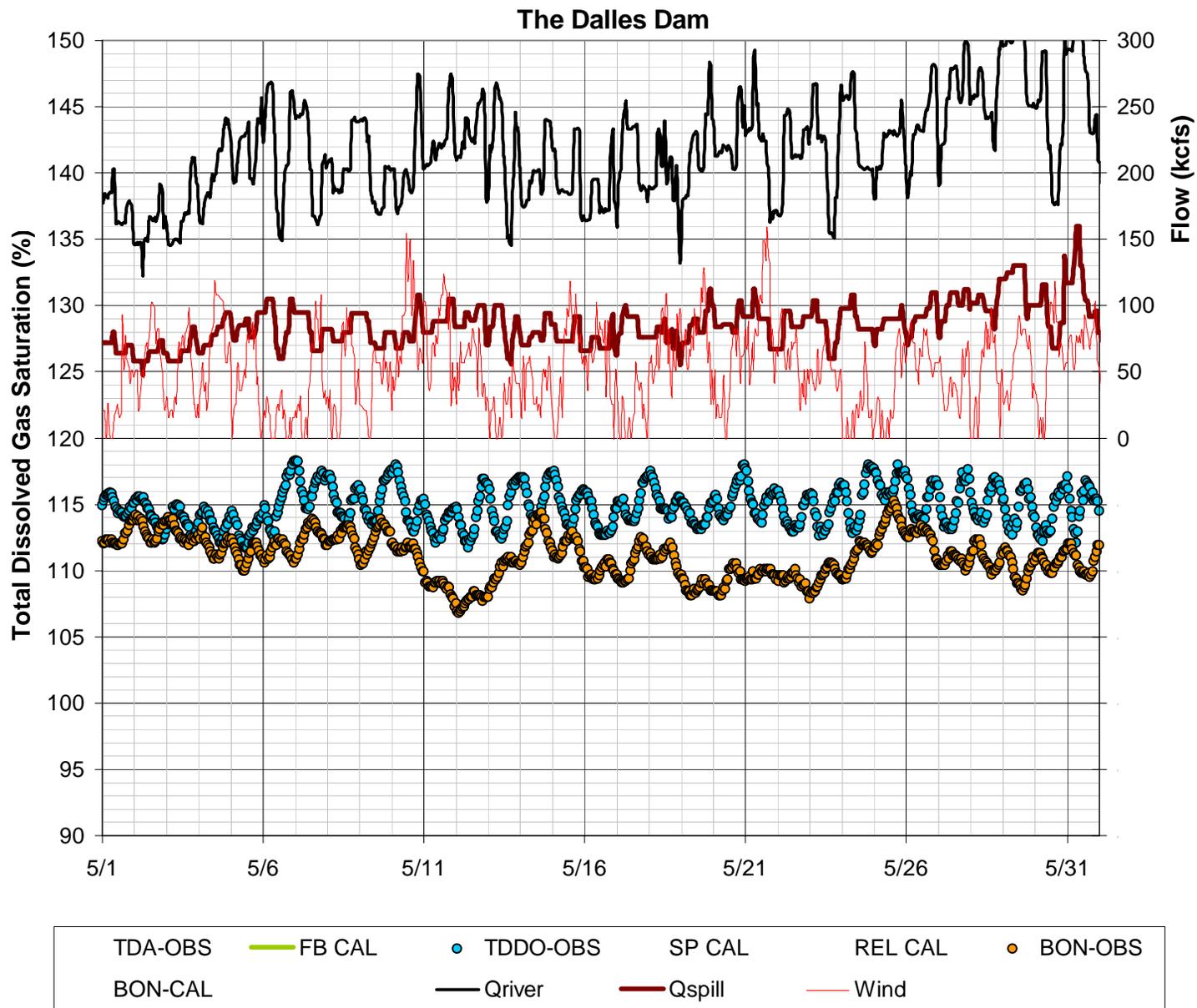
The Dalles Operations and Forebay TDG Saturation during 2004 Spill Season



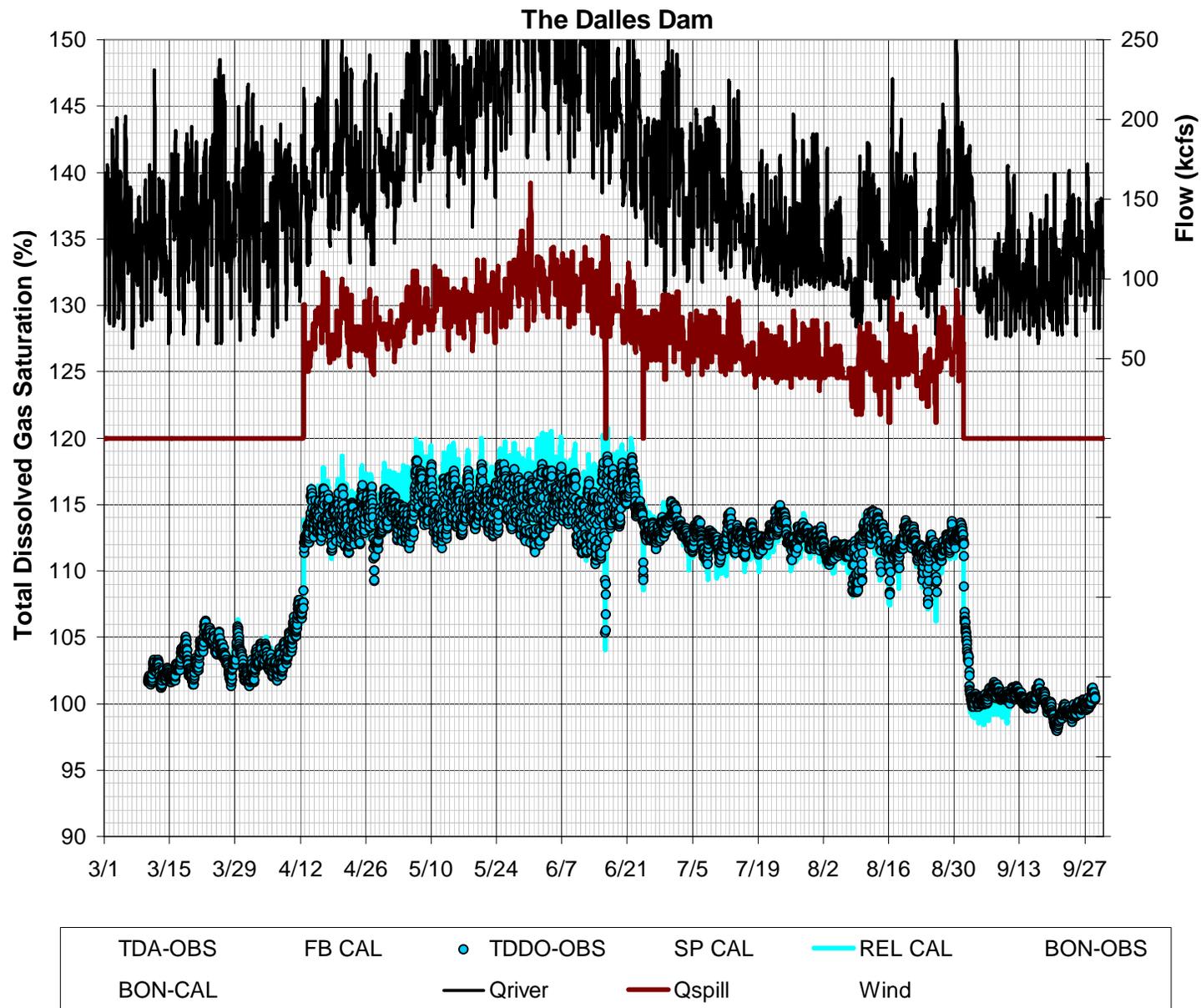
The Dalles Operations and Forebay TDG Saturation during 2004 Spill Season



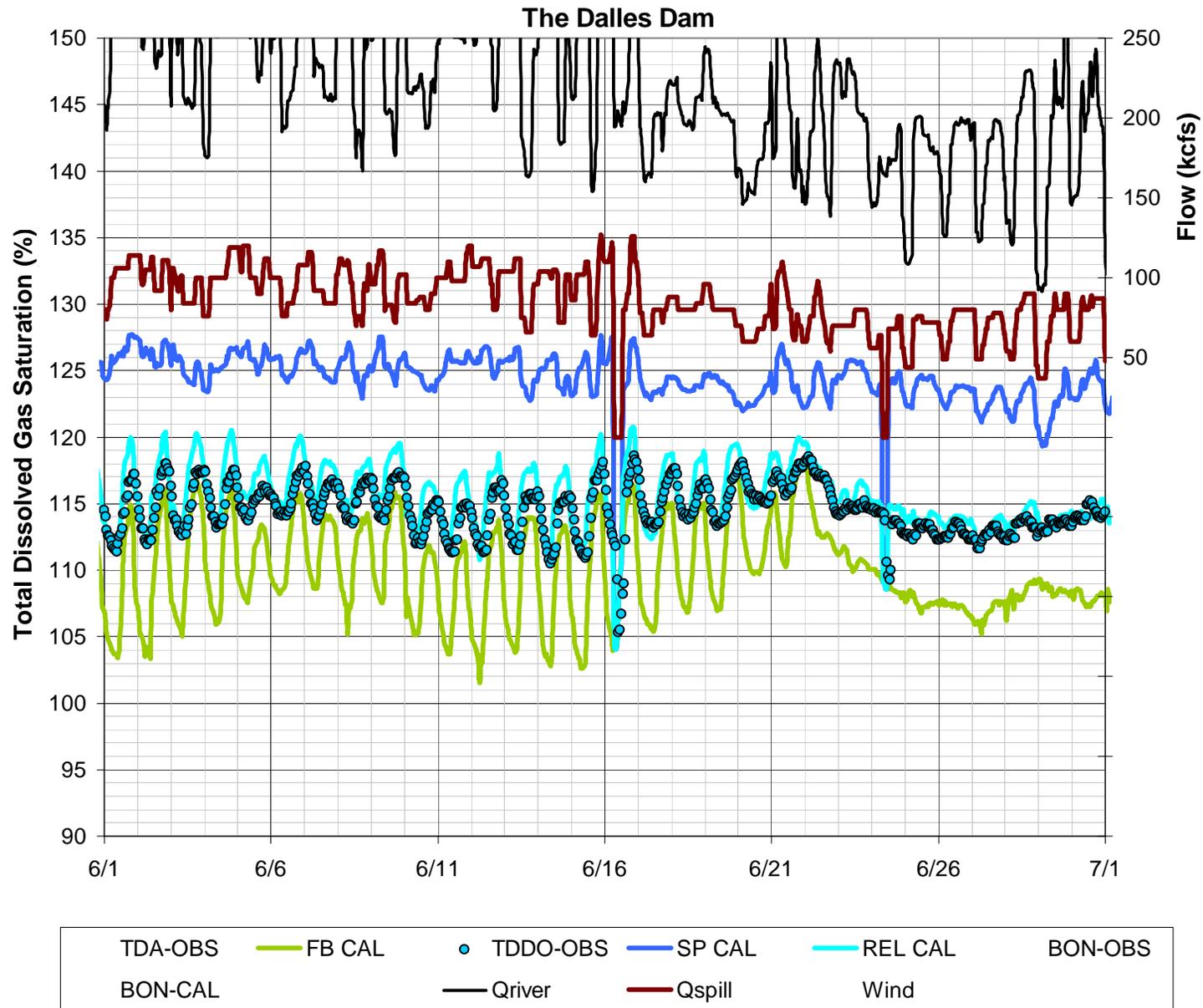
The Dalles Operations and Forebay TDG Saturation (Green) and Tailwater TDG Saturation (Blue) during 2004 Spill Season



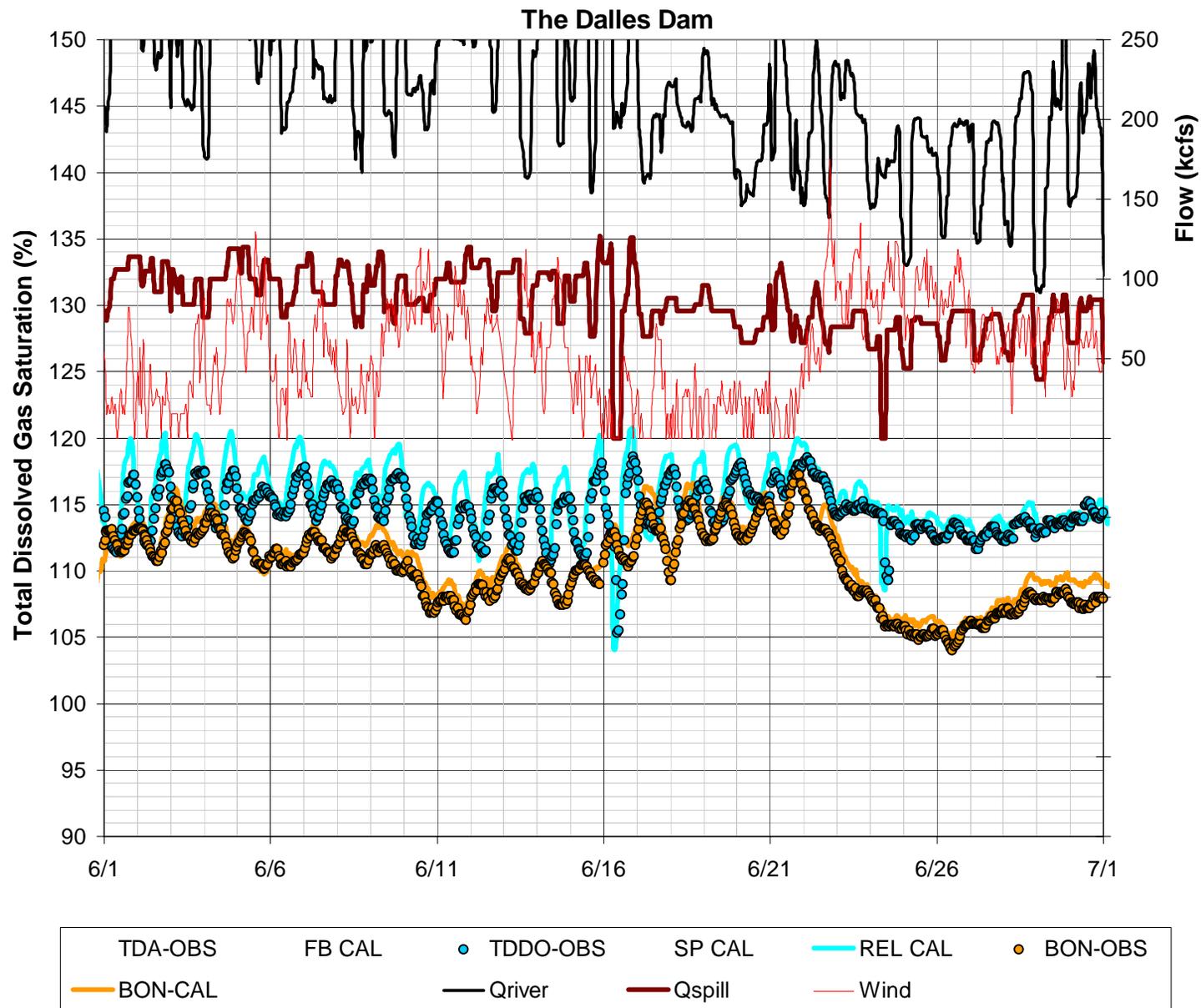
The Dalles Operations and Bonneville Forebay TDG Saturation (Gold) and Tailwater TDG Saturation (Blue) during 2004 Spill Season (Wind Speed at The Dalles Airport – Red)



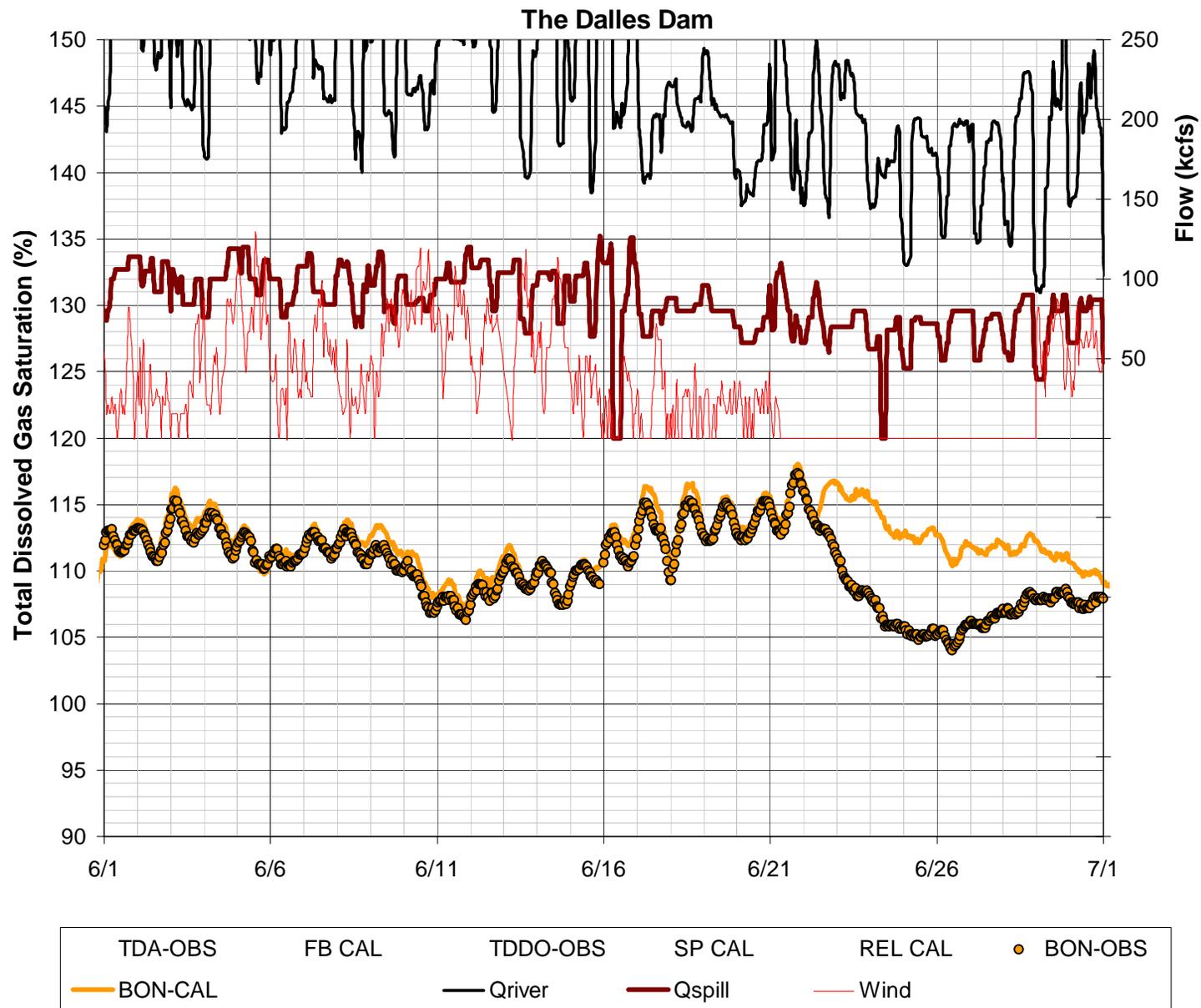
The Dalles Operations and Observed (Blue Circles) and Calculated (Blue line) Tailwater TDG Saturation during 2004 Spill Season



The Dalles Operations, Observed (Blue Circles) and Calculated (Light Blue Line) Tailwater TDG Saturation, Calculated TDG Saturation in Spillway Flow (dark blue line), and Observed Forebay TDG Saturation (Green Line) during 2004 Spill Season



The Dalles Operations, Observed (Blue Circles) and Calculated (Light Blue Line) Tailwater TDG Saturation, Observed (Gold Circles) and Calculated (Gold Line) TDG Saturation at Bonneville Forebay during 2004 Spill Season



The Dalles Operations, Observed (Blue Circles) and Calculated (Light Blue Line) Tailwater TDG Saturation, Observed (Gold Circles) and Calculated (Gold Line) TDG Saturation at Bonneville Forebay during 2004 Spill Season with No Wind on June 21-28

Observations

- Spill Directive at The Dalles Dam of 40 percent of river flow is not typically limited by TDG constraints
- TDG content in Spill $> 120\%$
- Tailwater FMS reflect mixture of spillway and powerhouse flows $< 120\%$
- Wind induced degassing moderates TDG levels transported to Bonneville Forebay $< 115\%$

STSTDG Case Study

- Bonneville Dam to Camas/Washougal
 - New Monitoring Proposal
 - CCIW to replace WRNO
 - Downstream TDG saturation at CWMW can limit spillway capacity
 - B2CC outfall

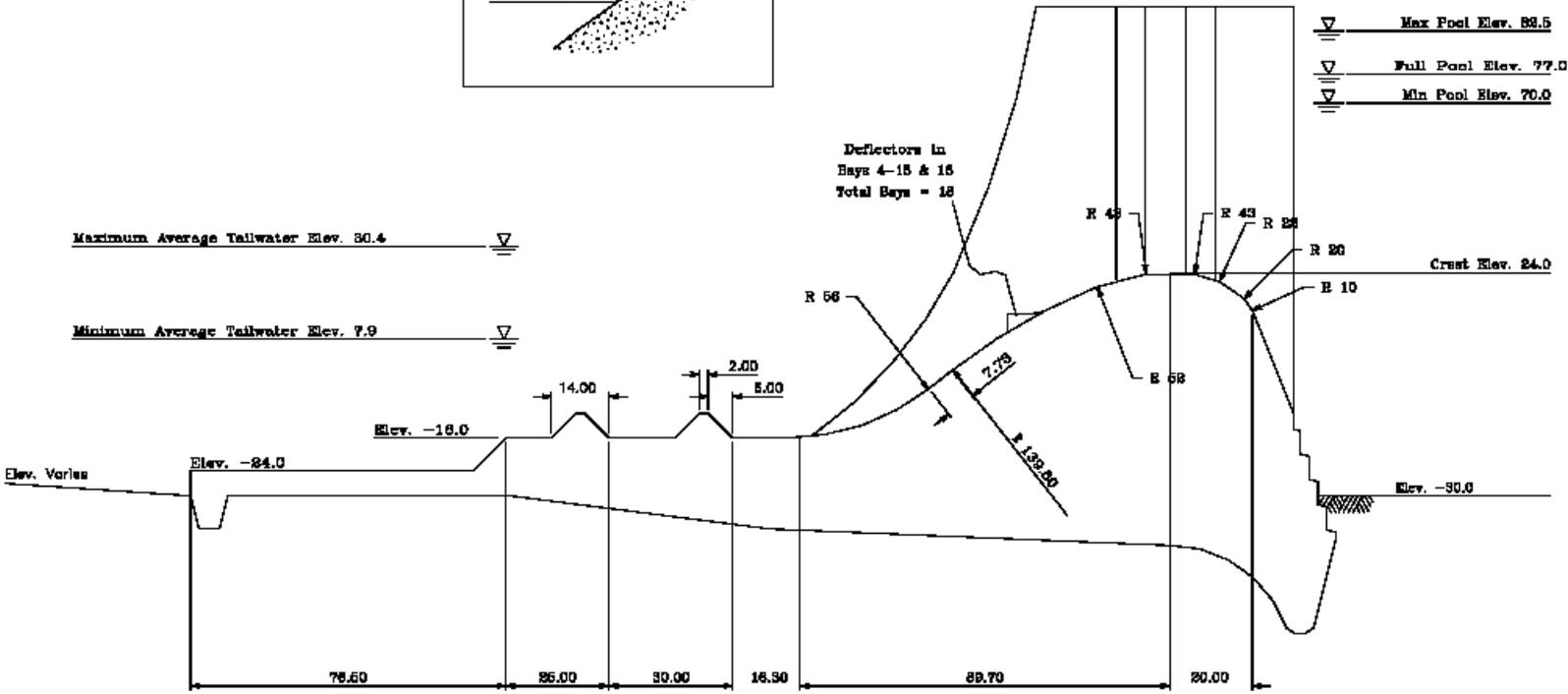
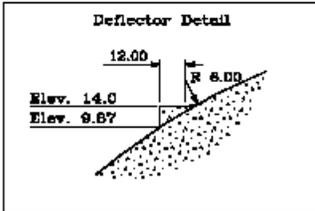
Bonneville Dam

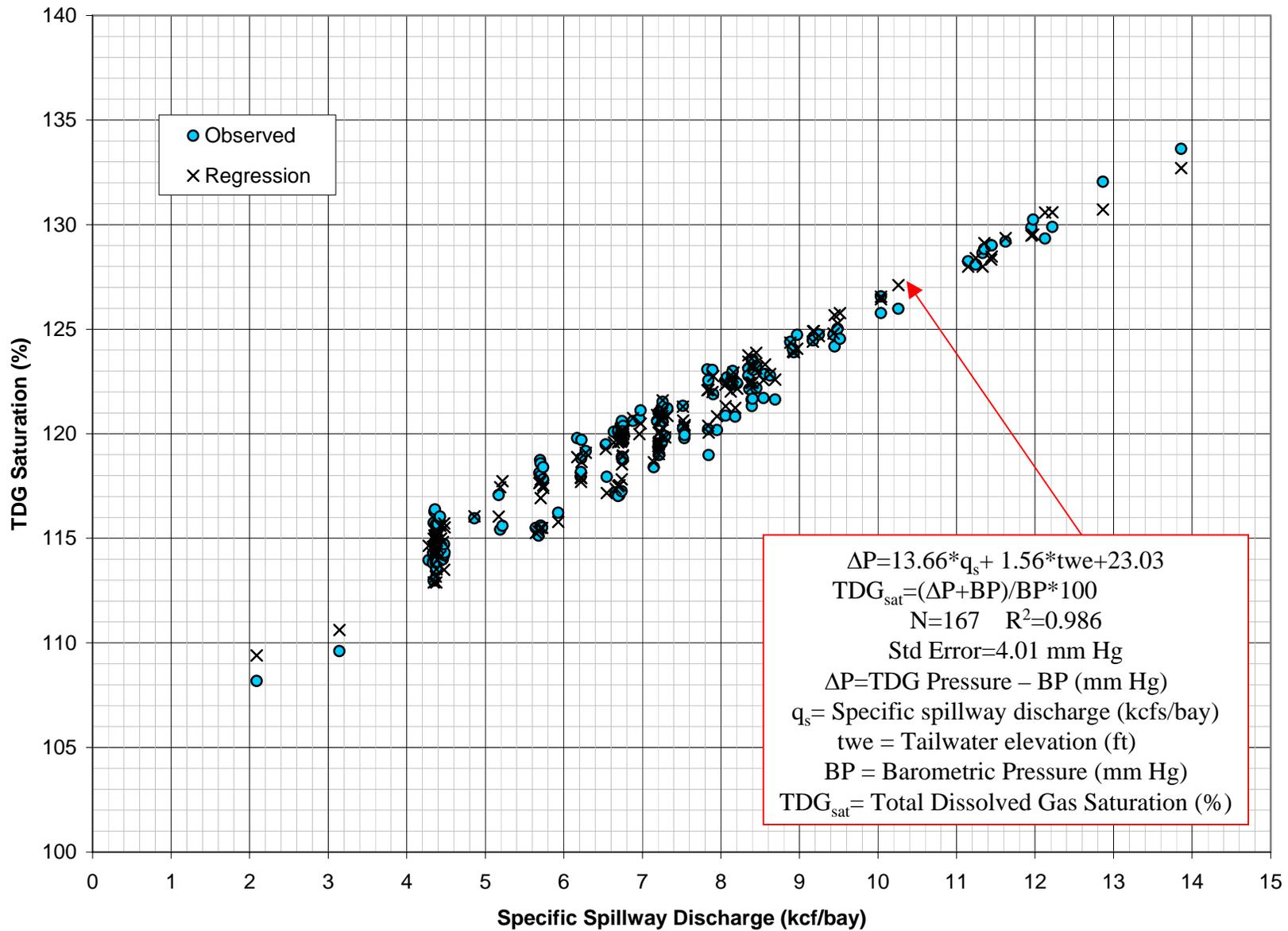


- Moderate TDG Production
- Flat Spill Pattern 18 Bays
- Spillway Flow Deflectors 14 @ 7 ft el.
- Wide range in Tailwater Elevation
- Deep Tailwater Channel
- Islands Partition Hydropower flows from Spillway
- Spill Management Directed by Camas/Washougel Gage
- Powerhouse Capacity 288 kcfs
 - Hydraulic Head 54 ft
- Bonneville Lake 45.4 miles
 - Time of Travel 33.4 hrs

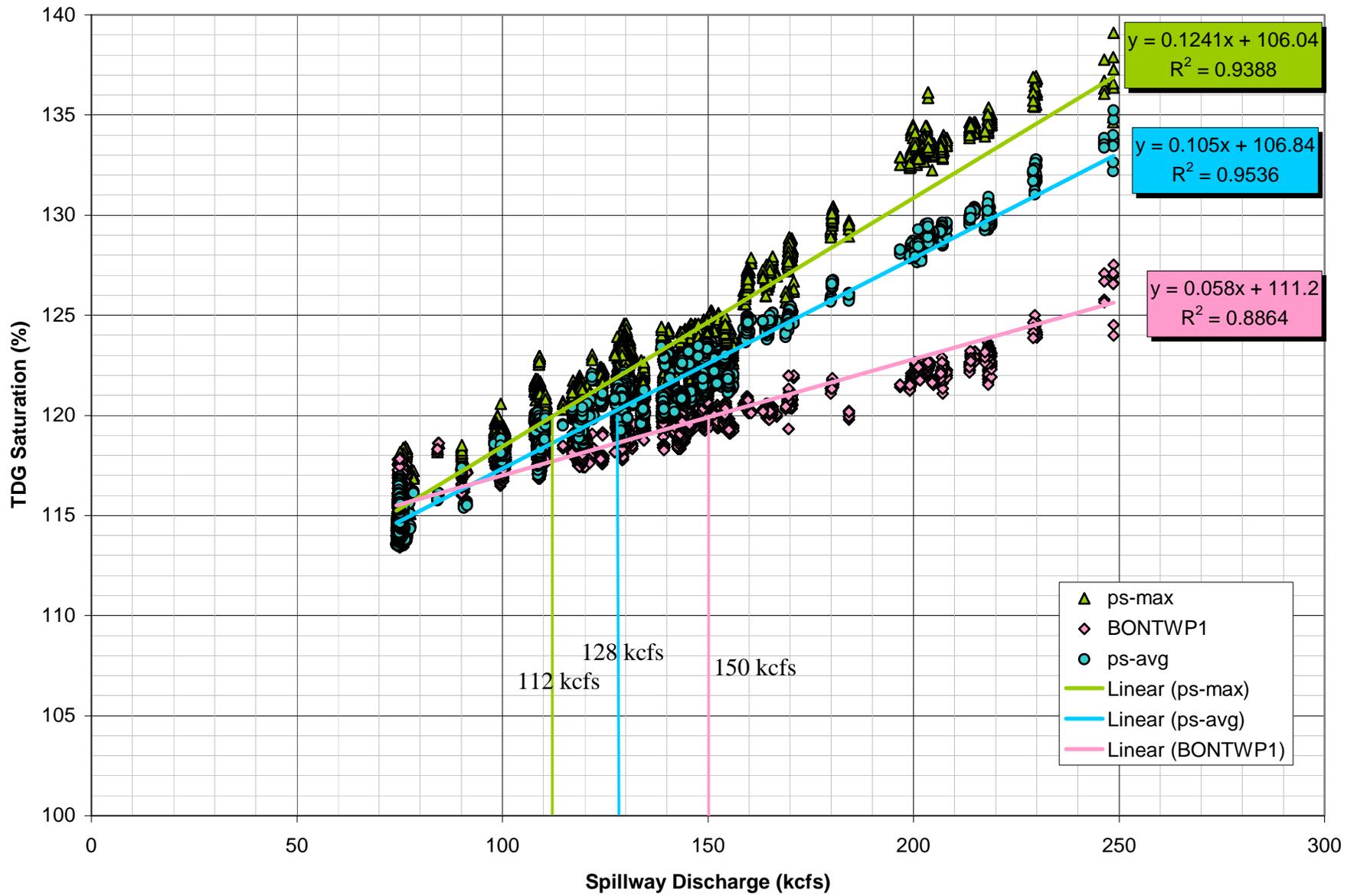


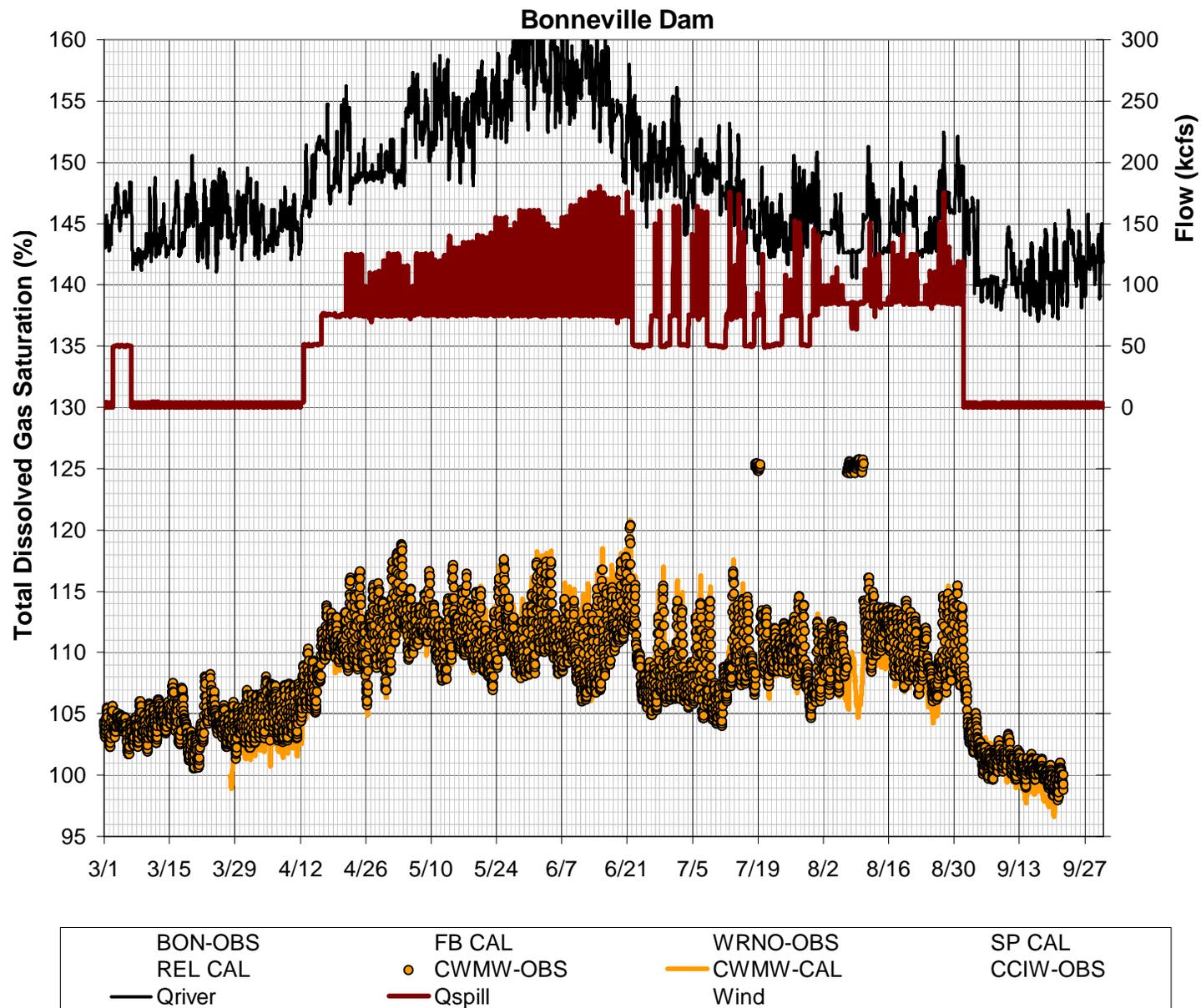
Figure 4-1. Aerial Photo of Bonneville Lock and Dam.





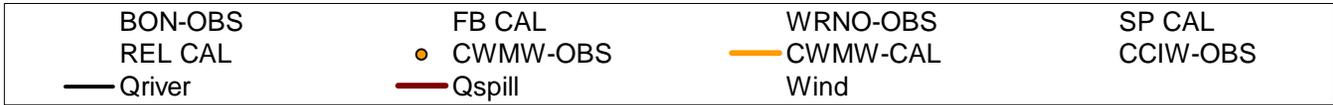
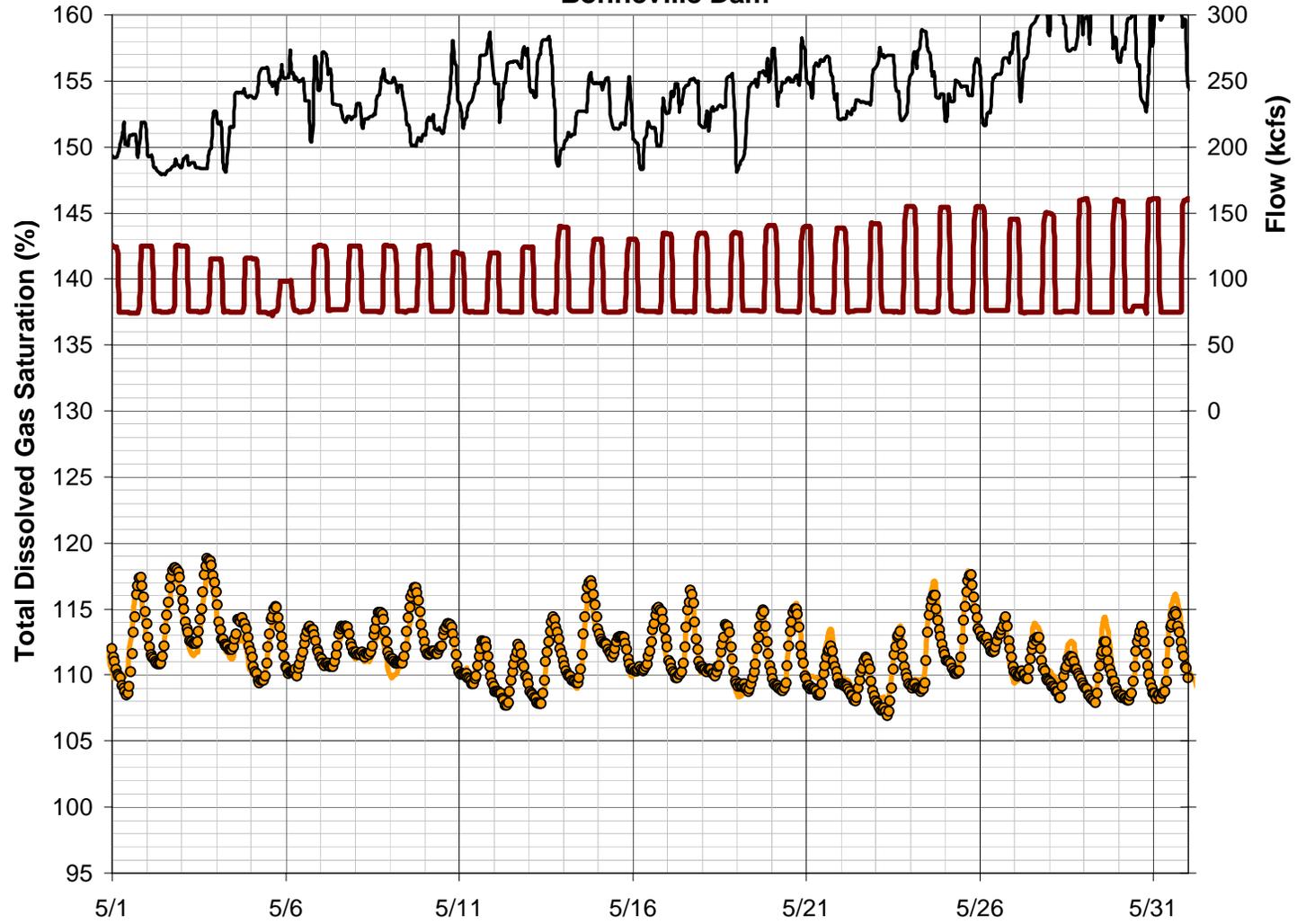
Observed and calculated average cross-sectional total dissolved gas saturation in the Bonneville spillway exit channel as a function of tailwater elevation and unit spillway discharge by event



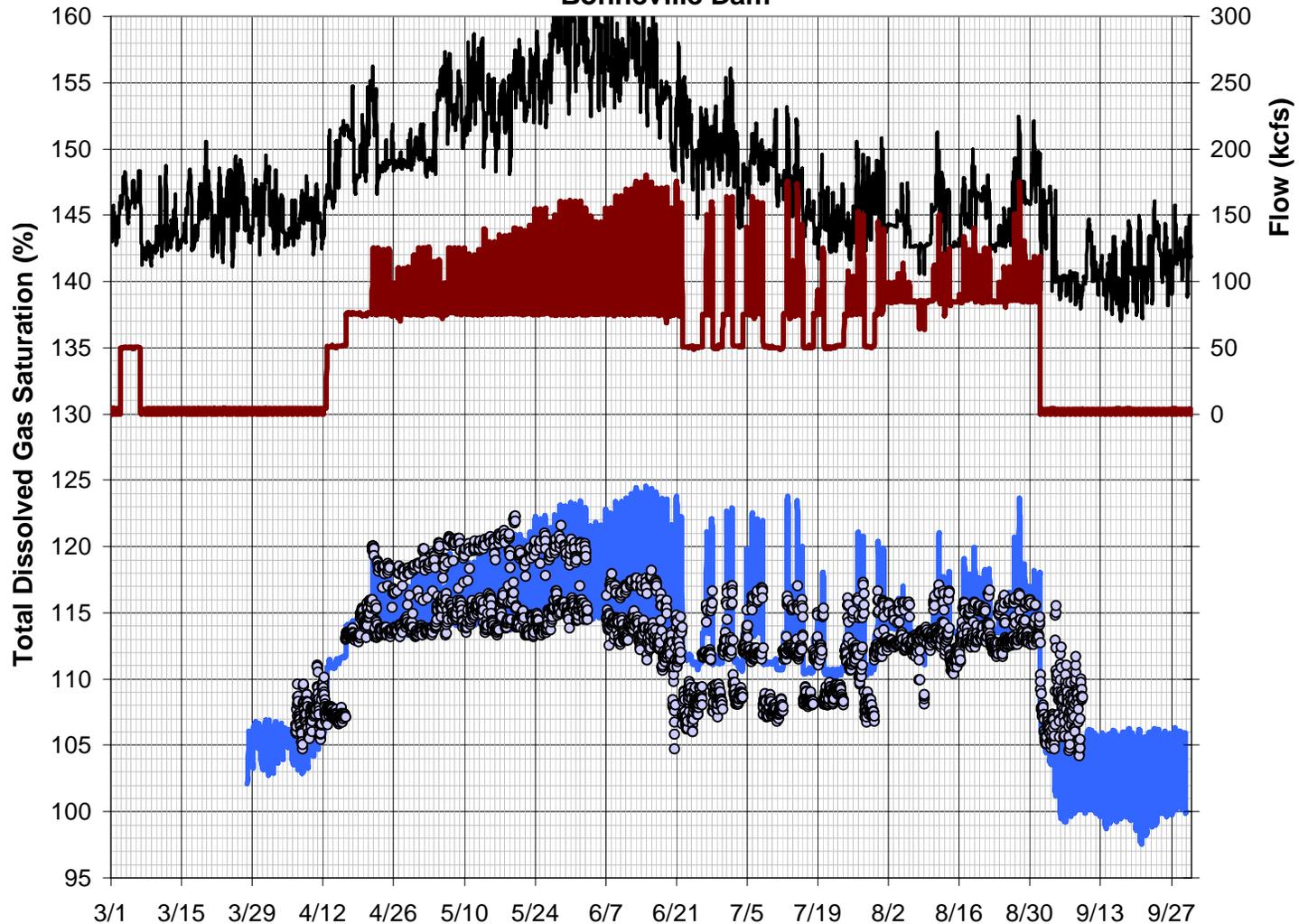


Observed and Calculated Total Dissolved Gas Pressures in the Columbia River at the Camas/Washougal fixed monitoring station downstream of Bonneville Dam, March-September 2004

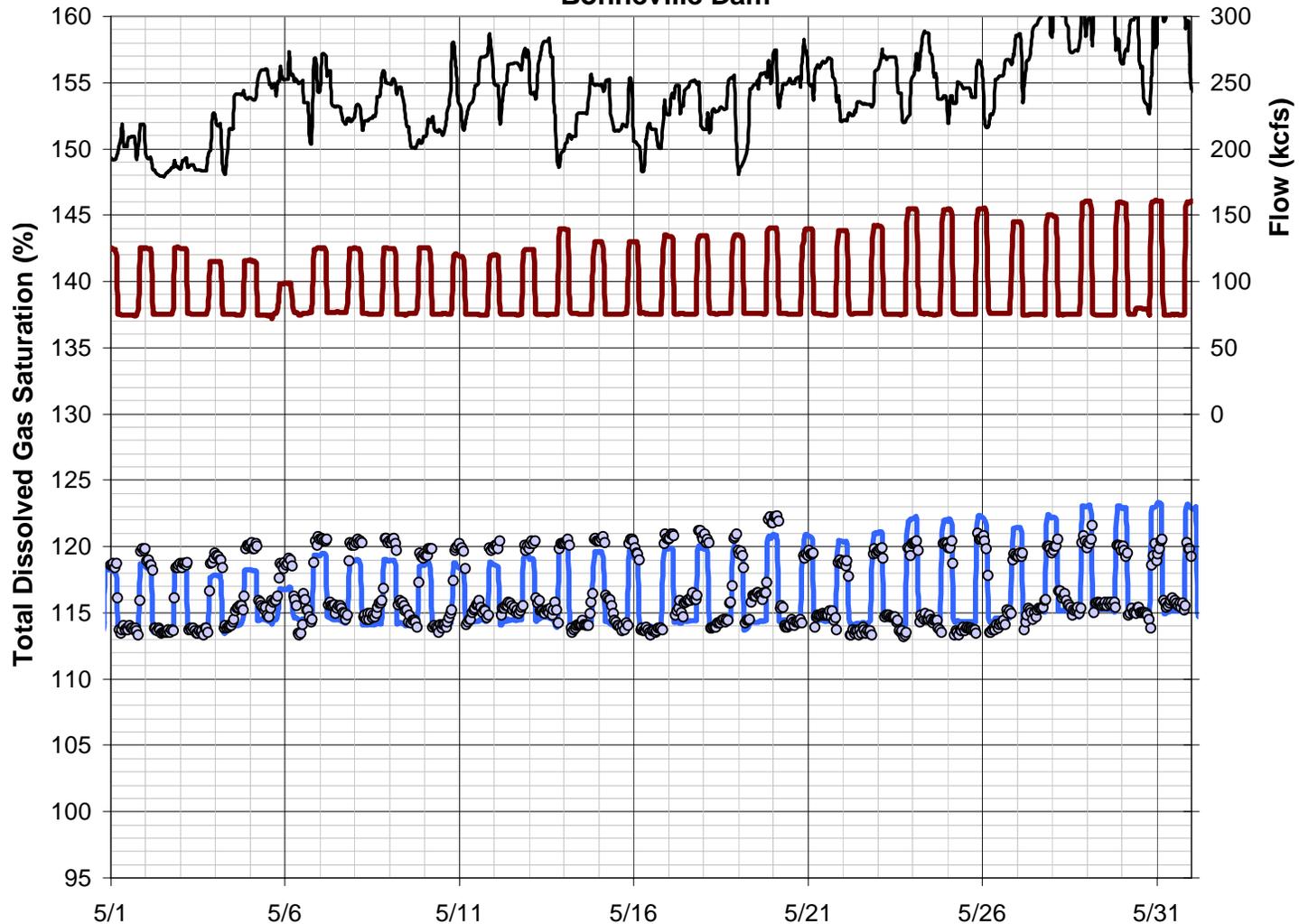
Bonneville Dam



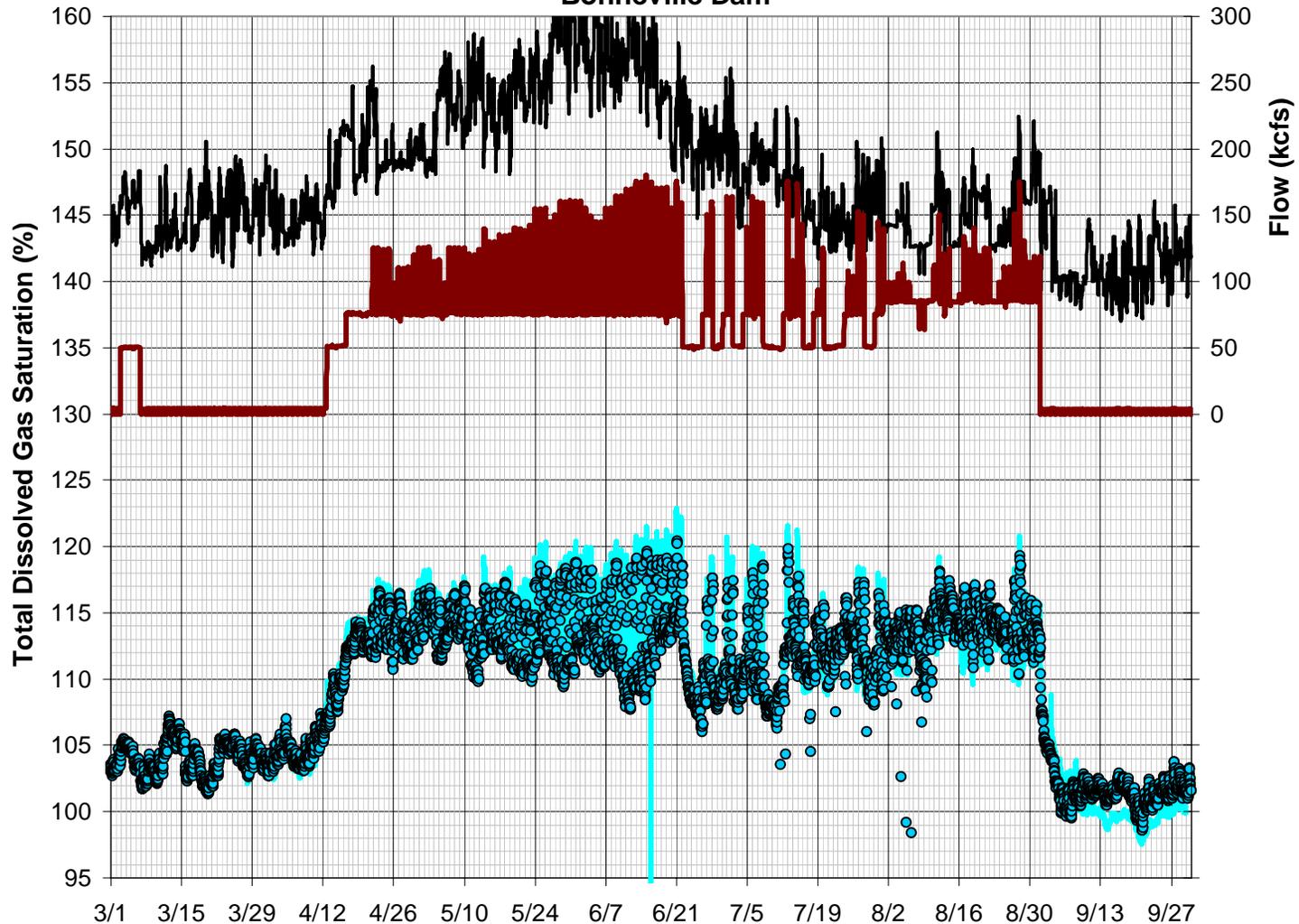
Bonneville Dam



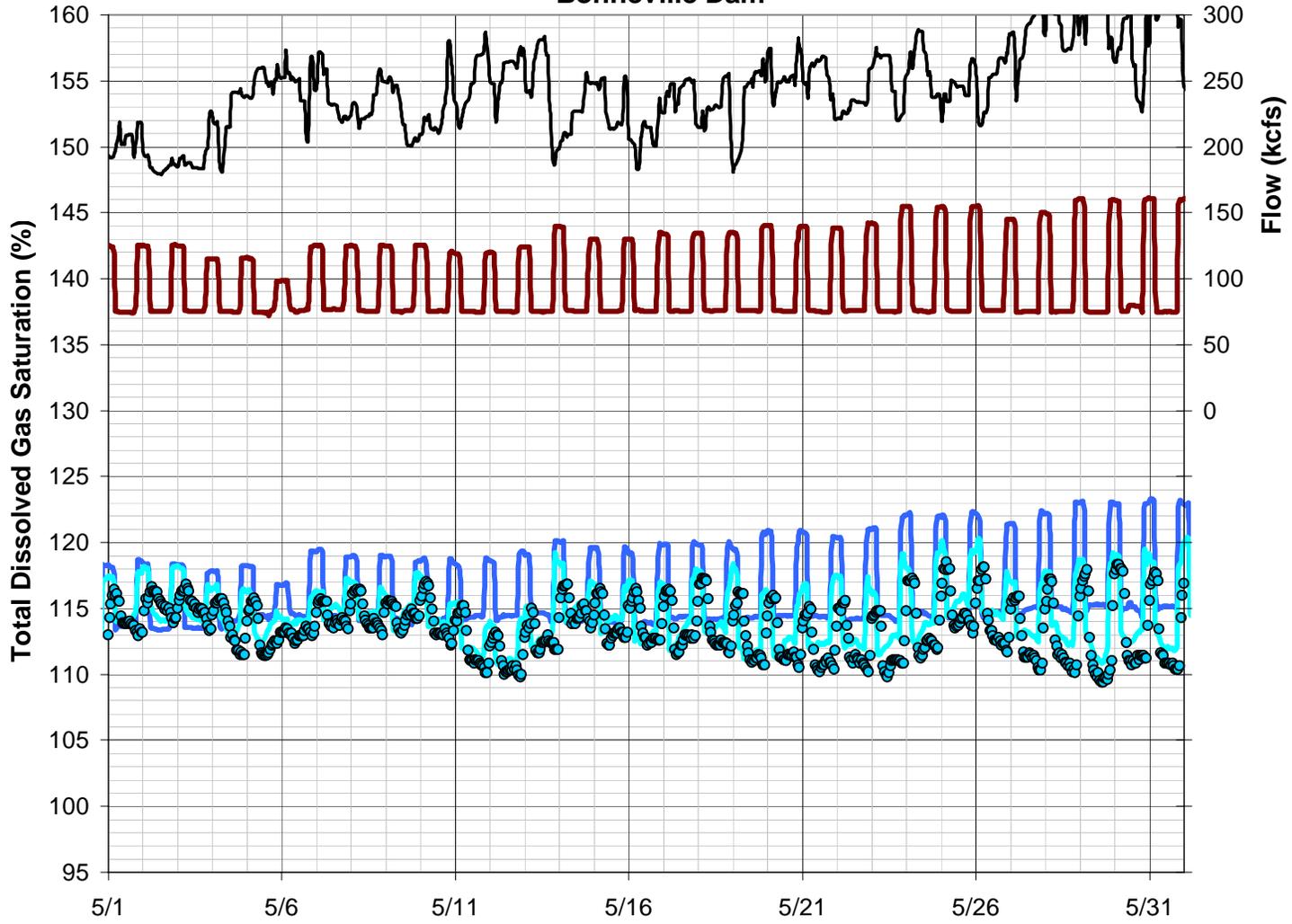
Bonneville Dam



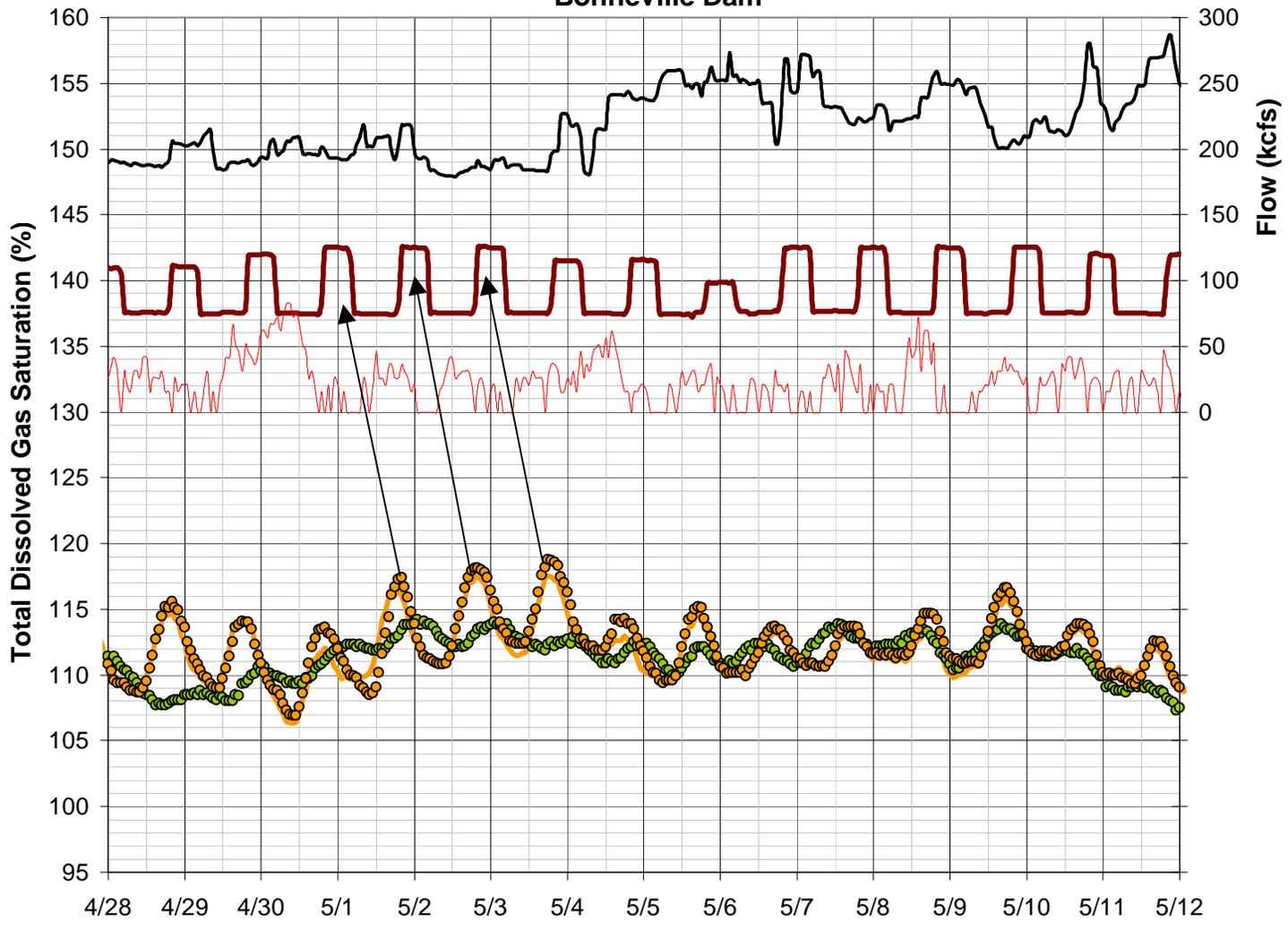
Bonneville Dam



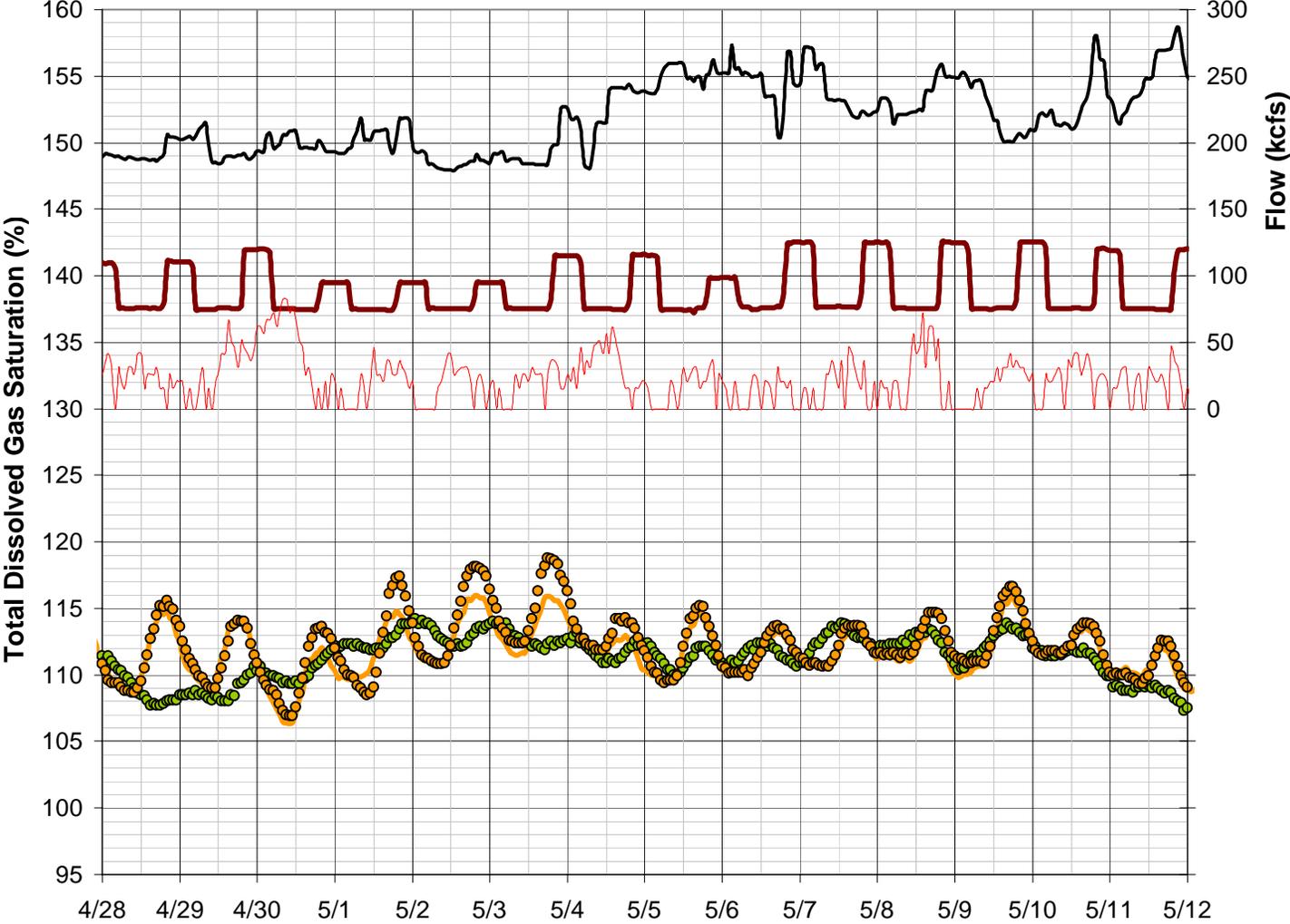
Bonneville Dam



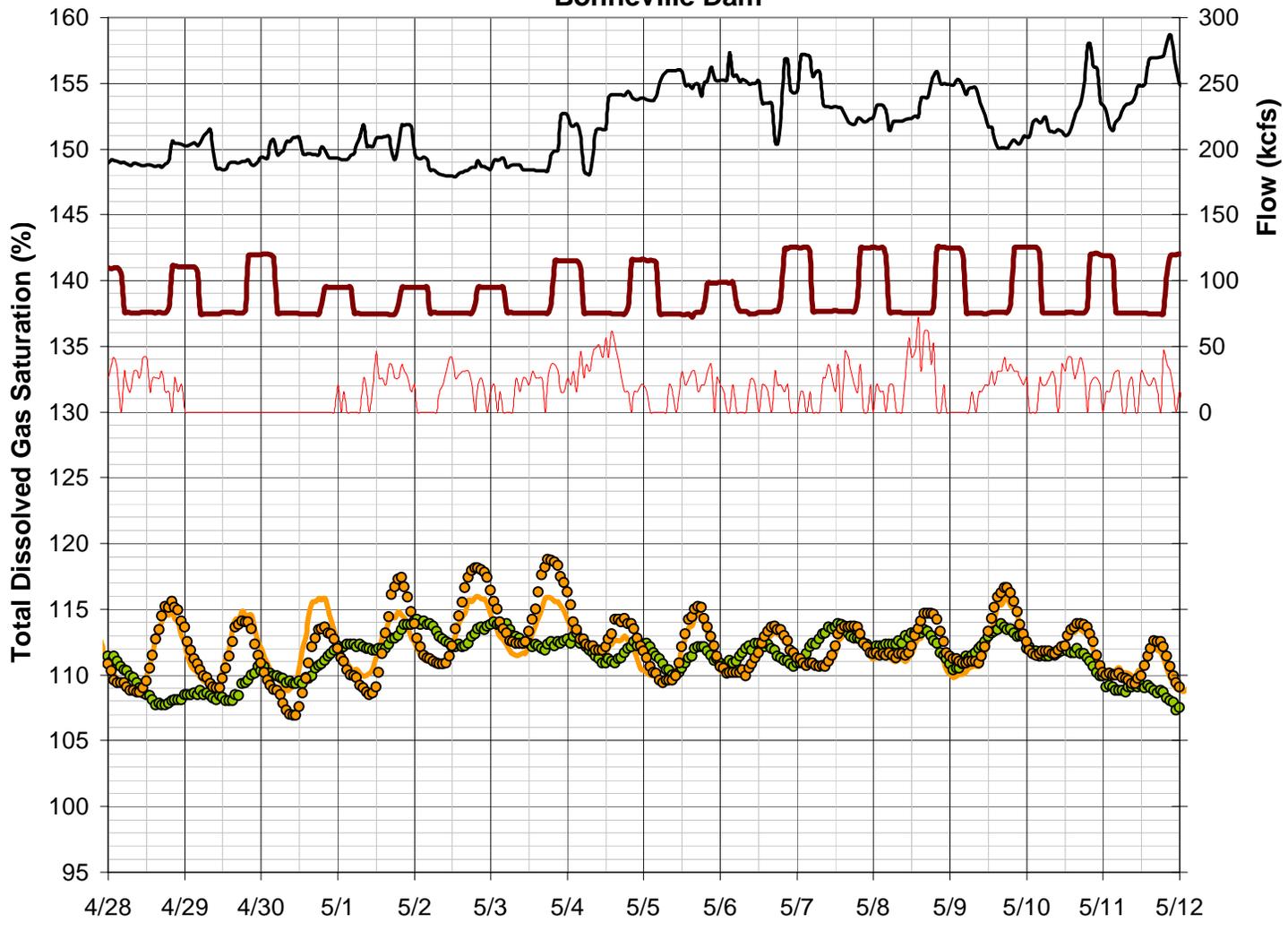
Bonneville Dam



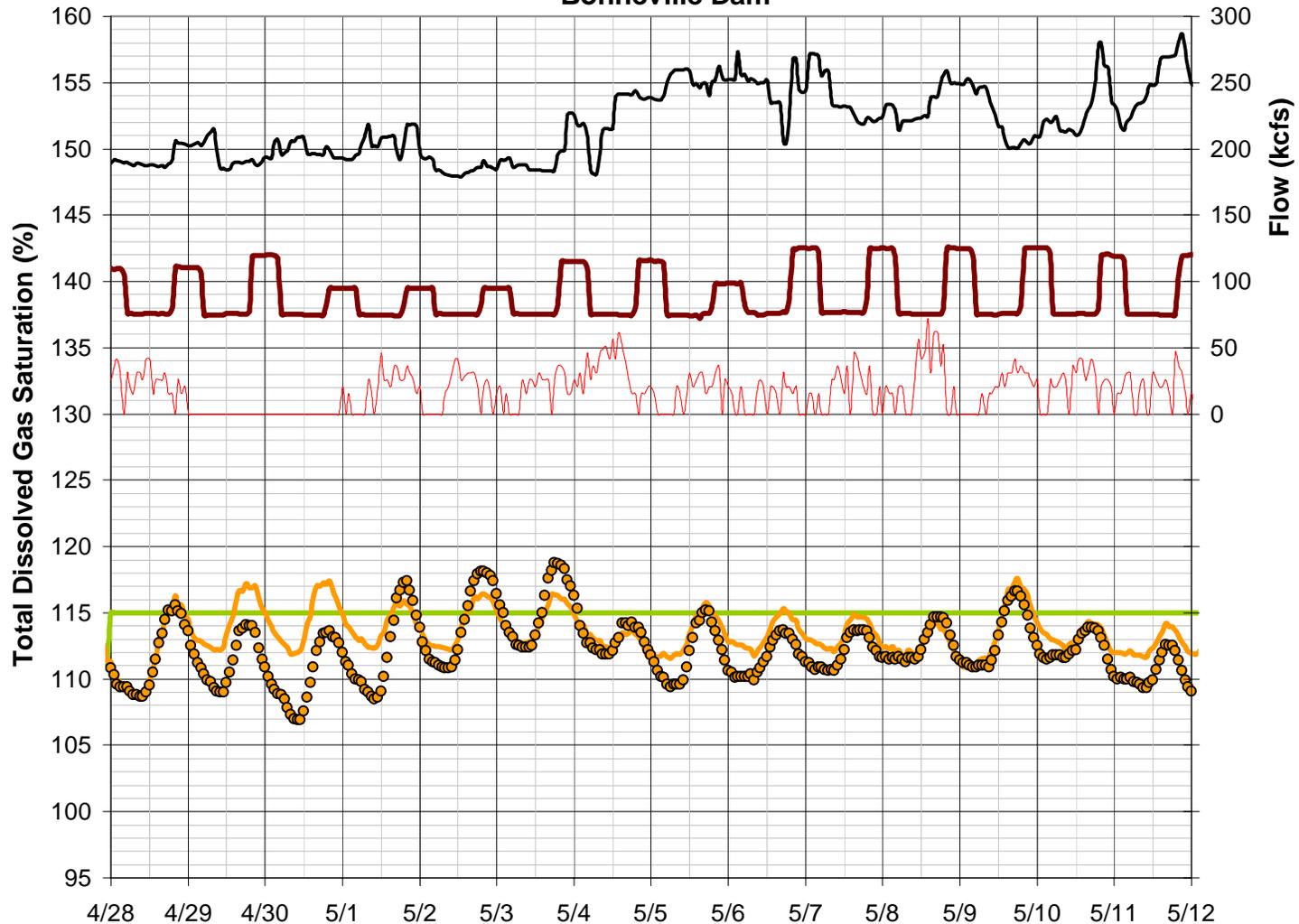
Bonneville Dam



Bonneville Dam

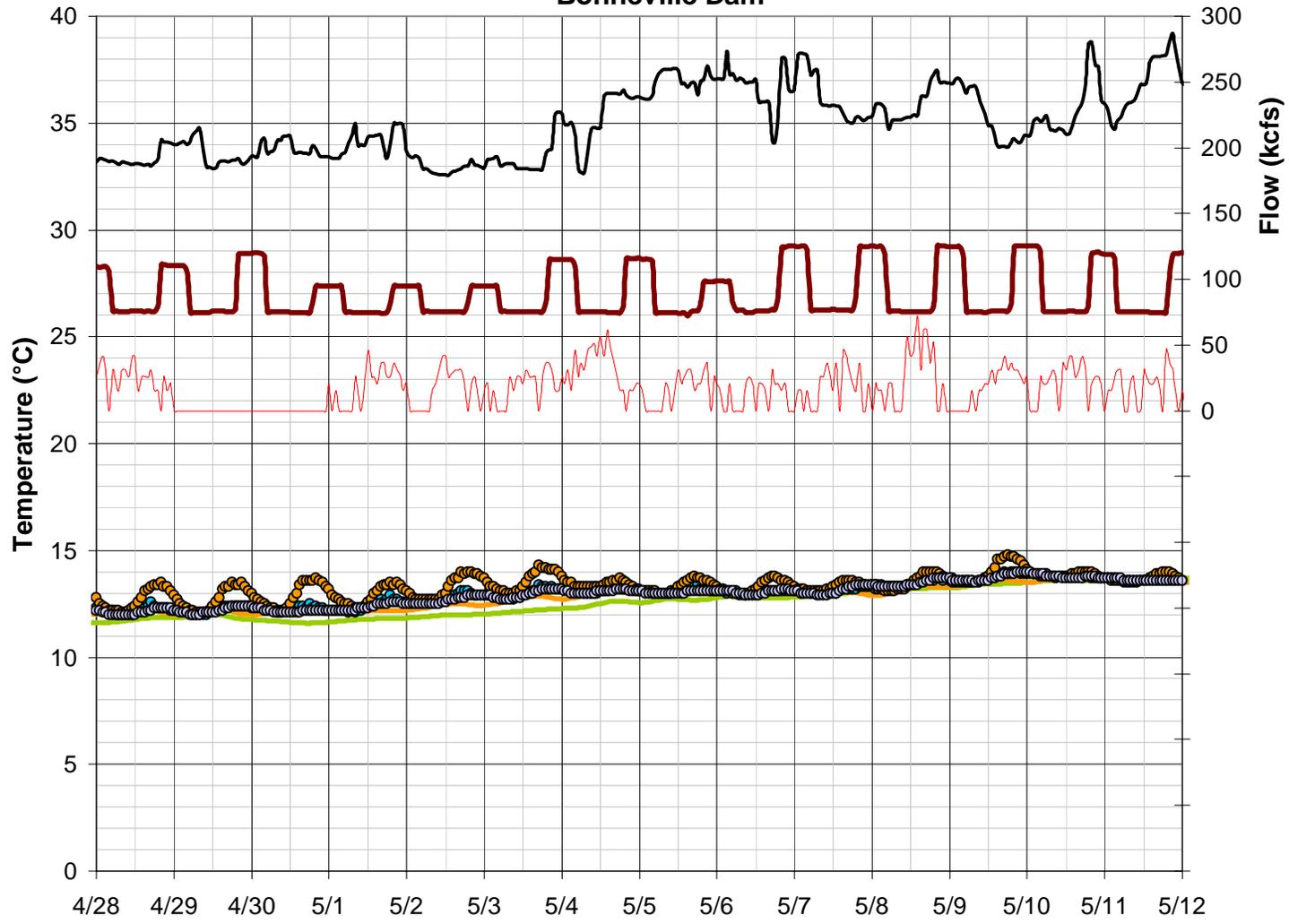


Bonneville Dam



BON-OBS	FB CAL	WRNO-OBS	SP CAL
REL CAL	CWMW-OBS	CWMW-CAL	CCIW-OBS
Qriver	Qspill	Wind	

Bonneville Dam



BON-OBS	FB CAL	WRNO-OBS	SP CAL
REL CAL	CWMW-OBS	CWMW-CAL	CCIW-OBS
Qriver	Qspill	Wind	

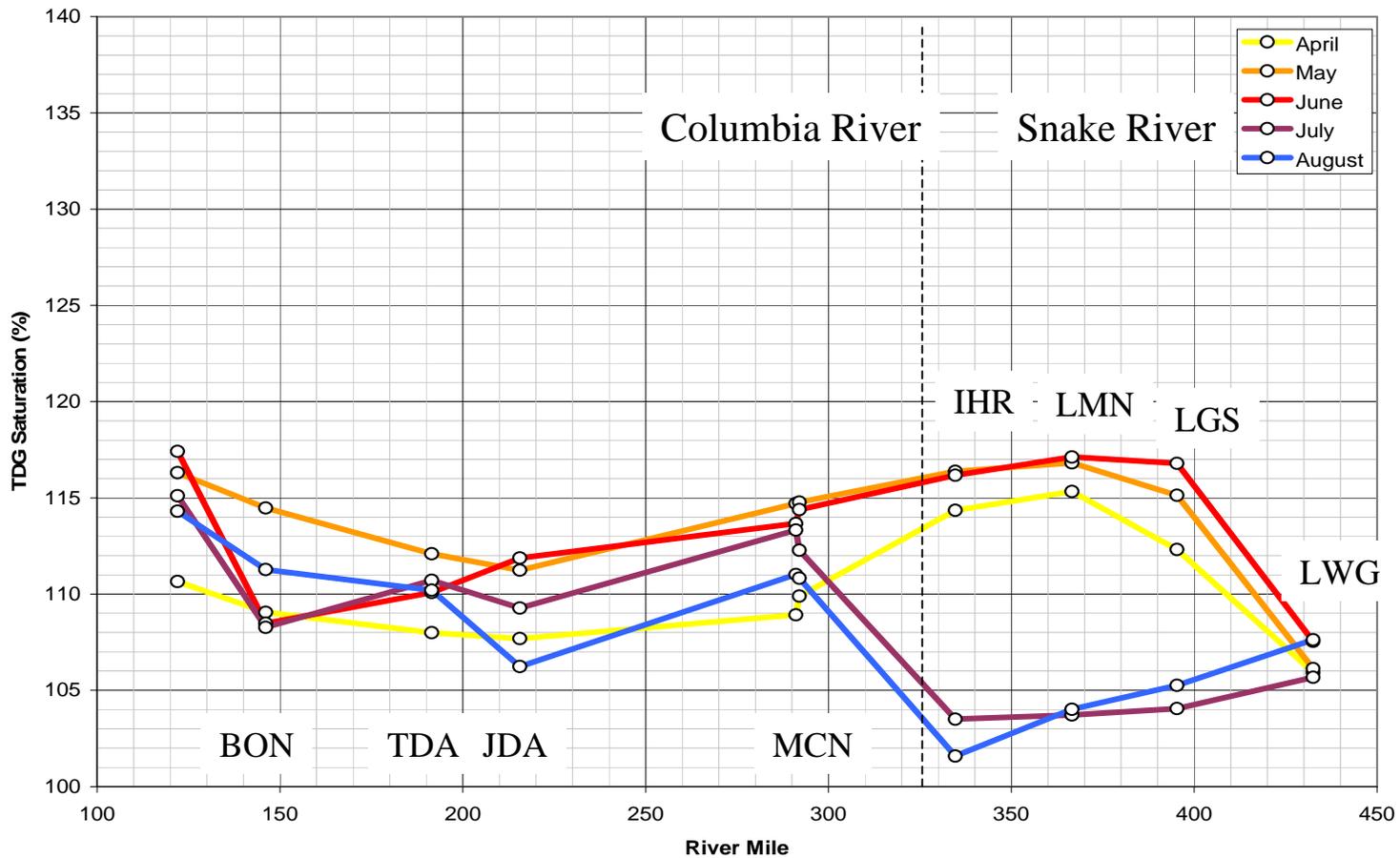
Conclusions

- TDG outcome at CWMW is well understood
 - Spill pattern and magnitude
 - Powerhouse TDG load
 - Environmental factors
 - Difficult to accurately forecast
- CCIW more closely reflects TDG content of spillway flows
 - Sampling bias at high discharges >120 kcfs

SYSTDG Case Study

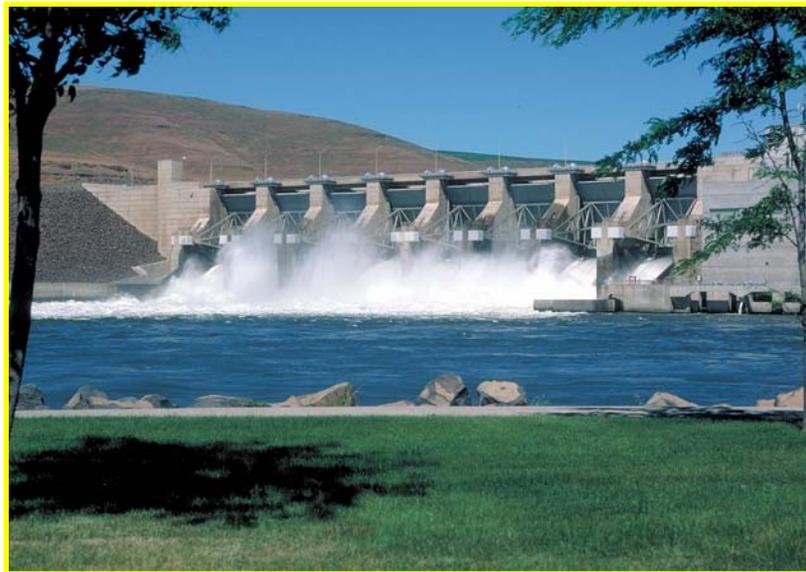
- Lower Monumental Pool
- Little Goose Dam – upstream project
 - Cumulative TDG levels on Snake River can constrain spill at downstream projects
 - Powerhouse entrainment source for high TDG load

Total Dissolved Gas Decision Support Workshop Project Characterization



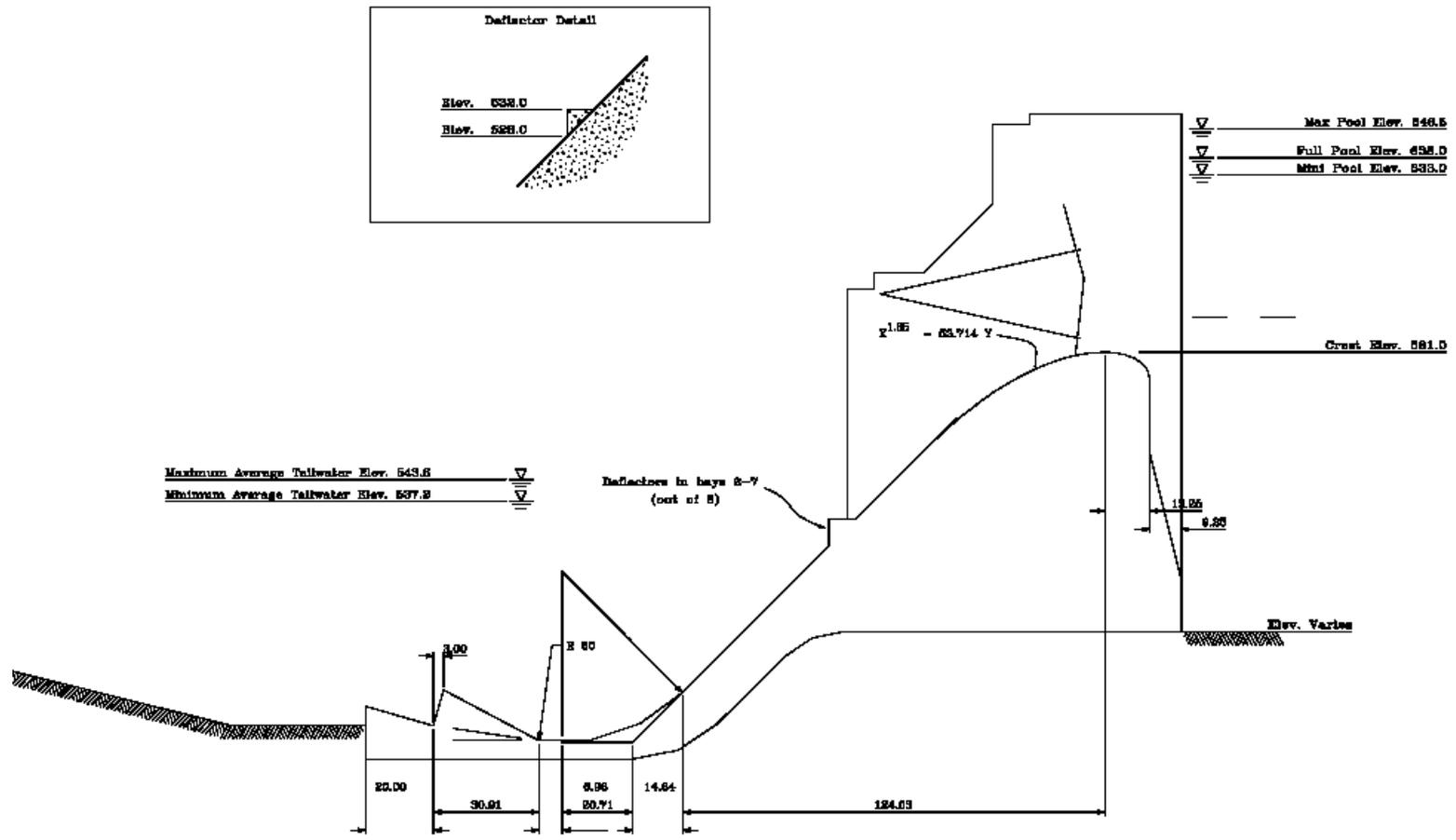
Monthly average forebay TDG saturations in 1999

Little Goose Dam



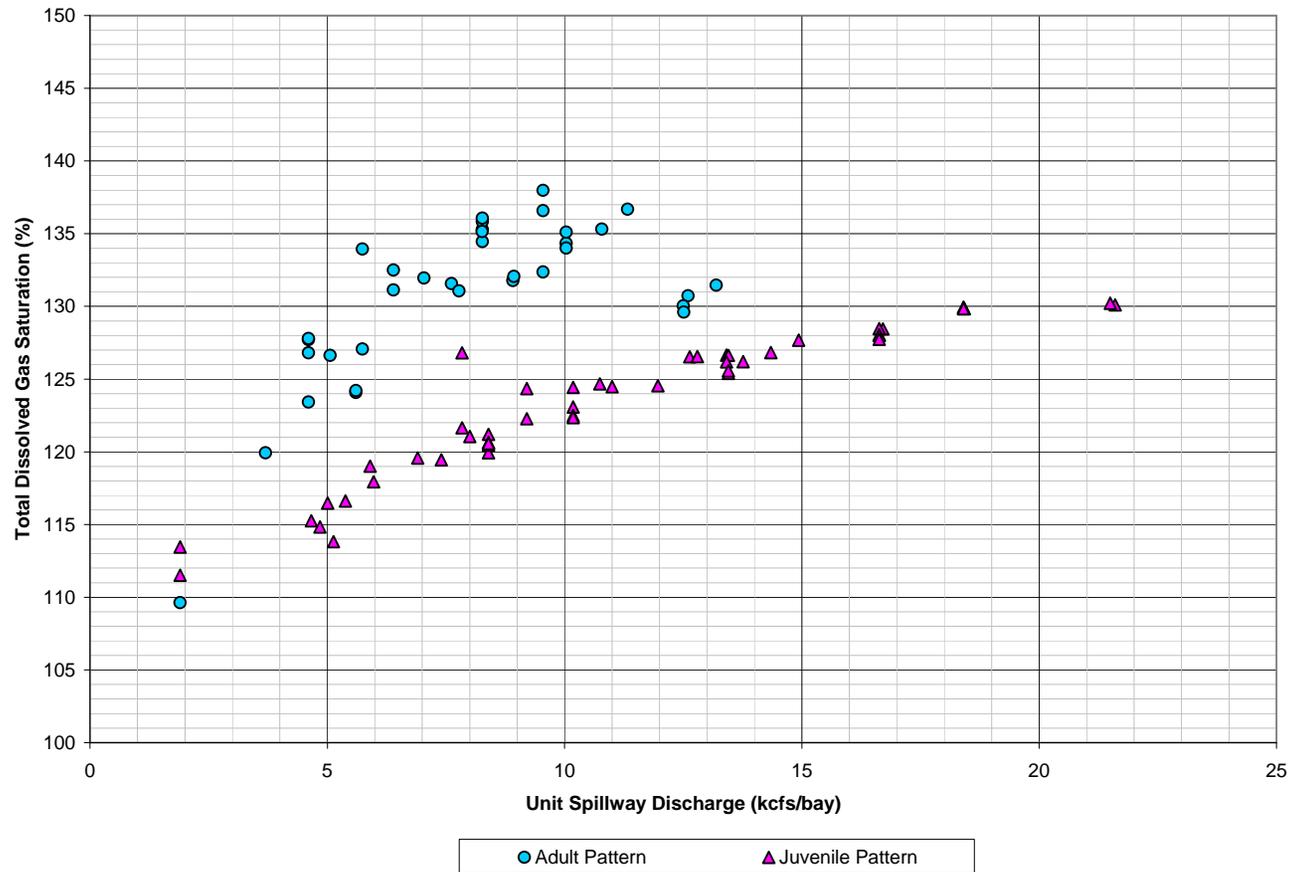
- Moderate TDG Production
- Uniform Spill Pattern Interior Bays Only
- Spillway Flow Deflectors on 6 of 8 Bays
- Strong Entrainment of Powerhouse Flows
- Roller Bucket Stilling Basin
- Tailwater FMS in Spillway Water
- Powerhouse Capacity 130 kcfs
 - Hydraulic Head 96
- Lake Bryan 37.2 miles
 - Time of Travel 80 hrs



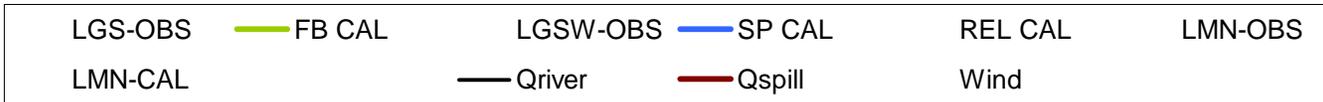
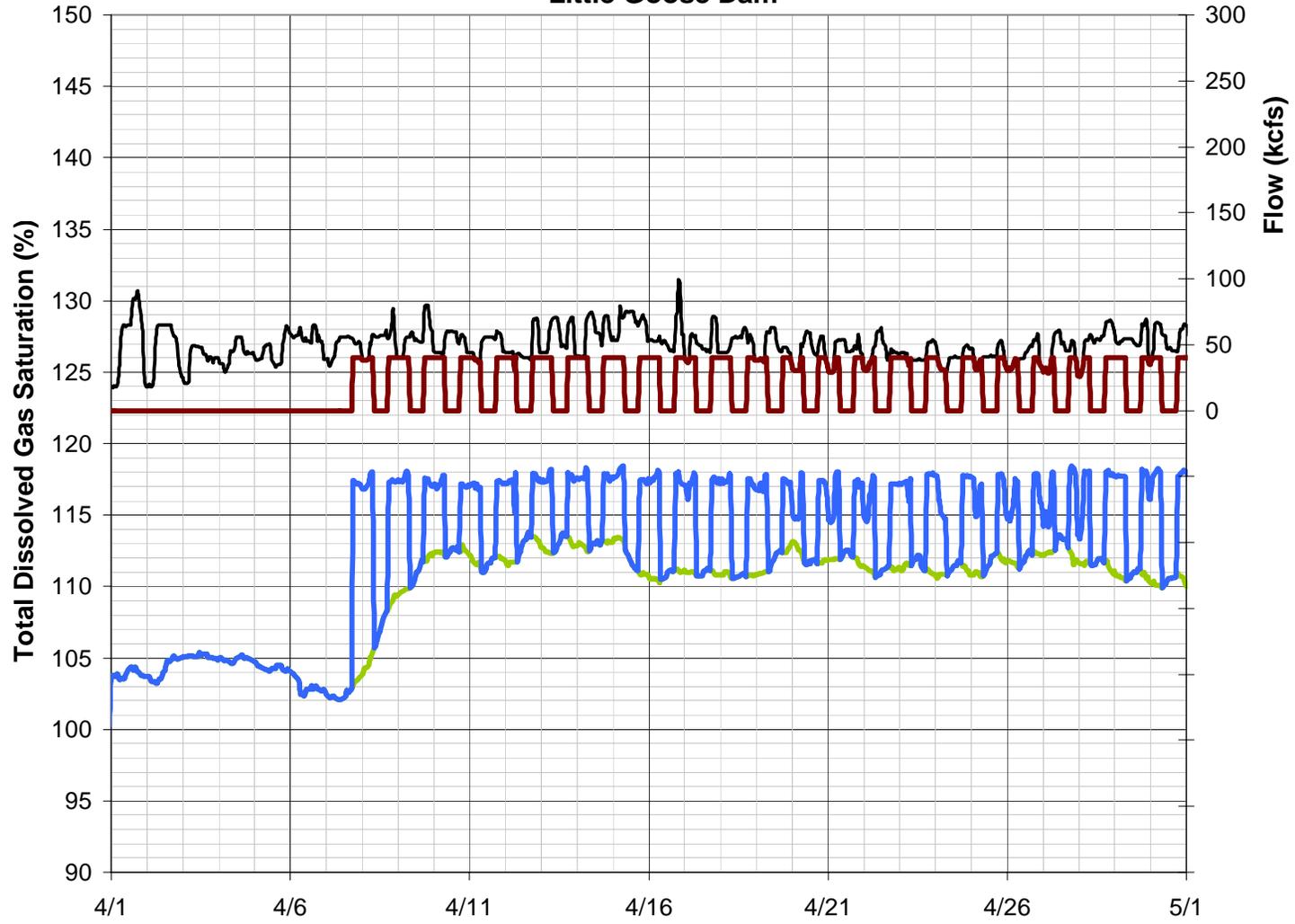


Little Goose Dam – Spillway
Elevation View

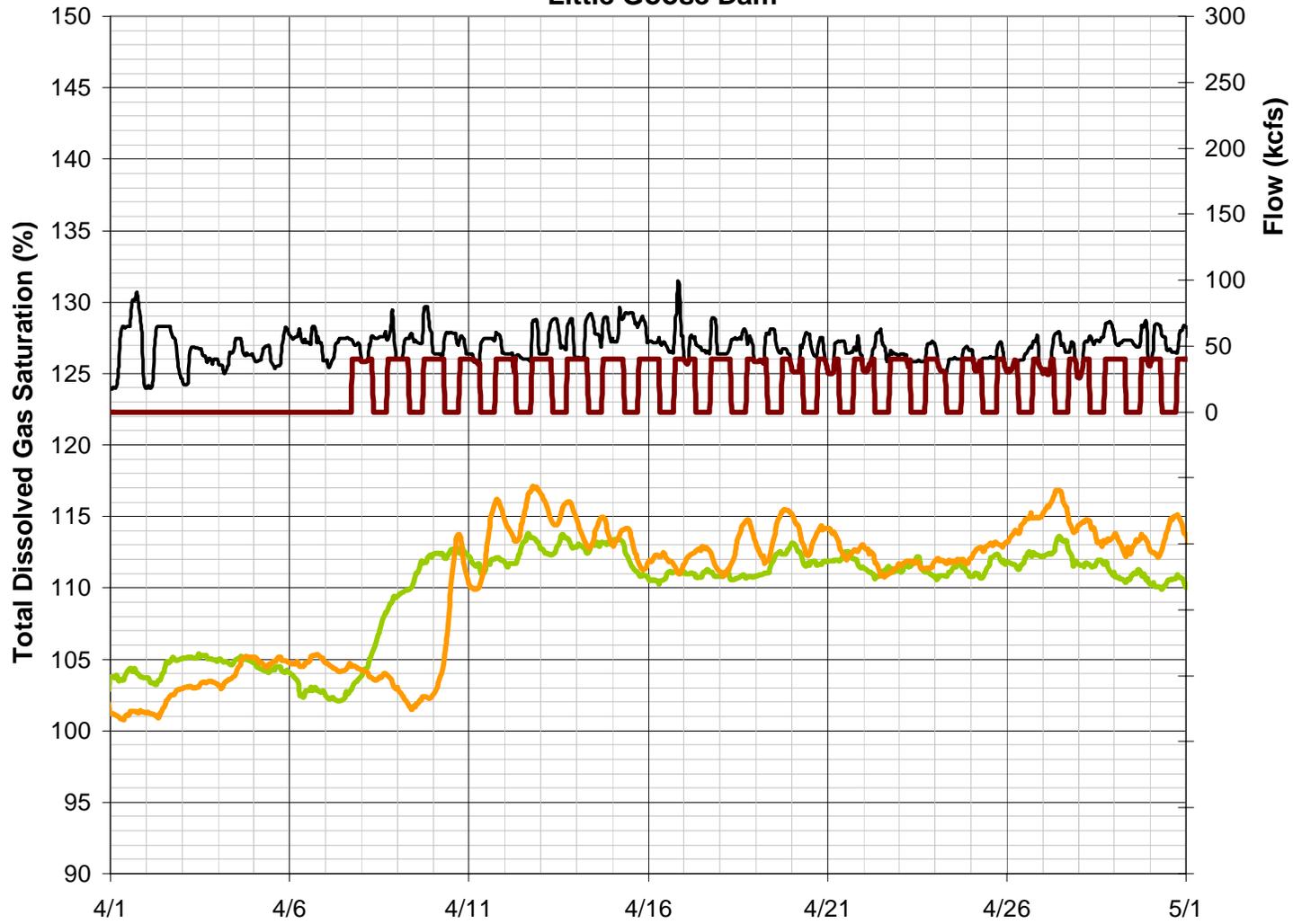
Total Dissolved Gas Exchange in the Columbia River Basin: Management Tools



Little Goose Dam



Little Goose Dam



Little Goose Dam



Conclusions

- Snake River spill is often constrained by forebay TDG criteria
- Lag time between spill decision and result of operation at next dam
- Requires accurate short term forecast to avoid these types of events