Bonneville Dam TDG Production, Fate, and Transport

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Bonneville Dam TDG Production, Fate and Transport

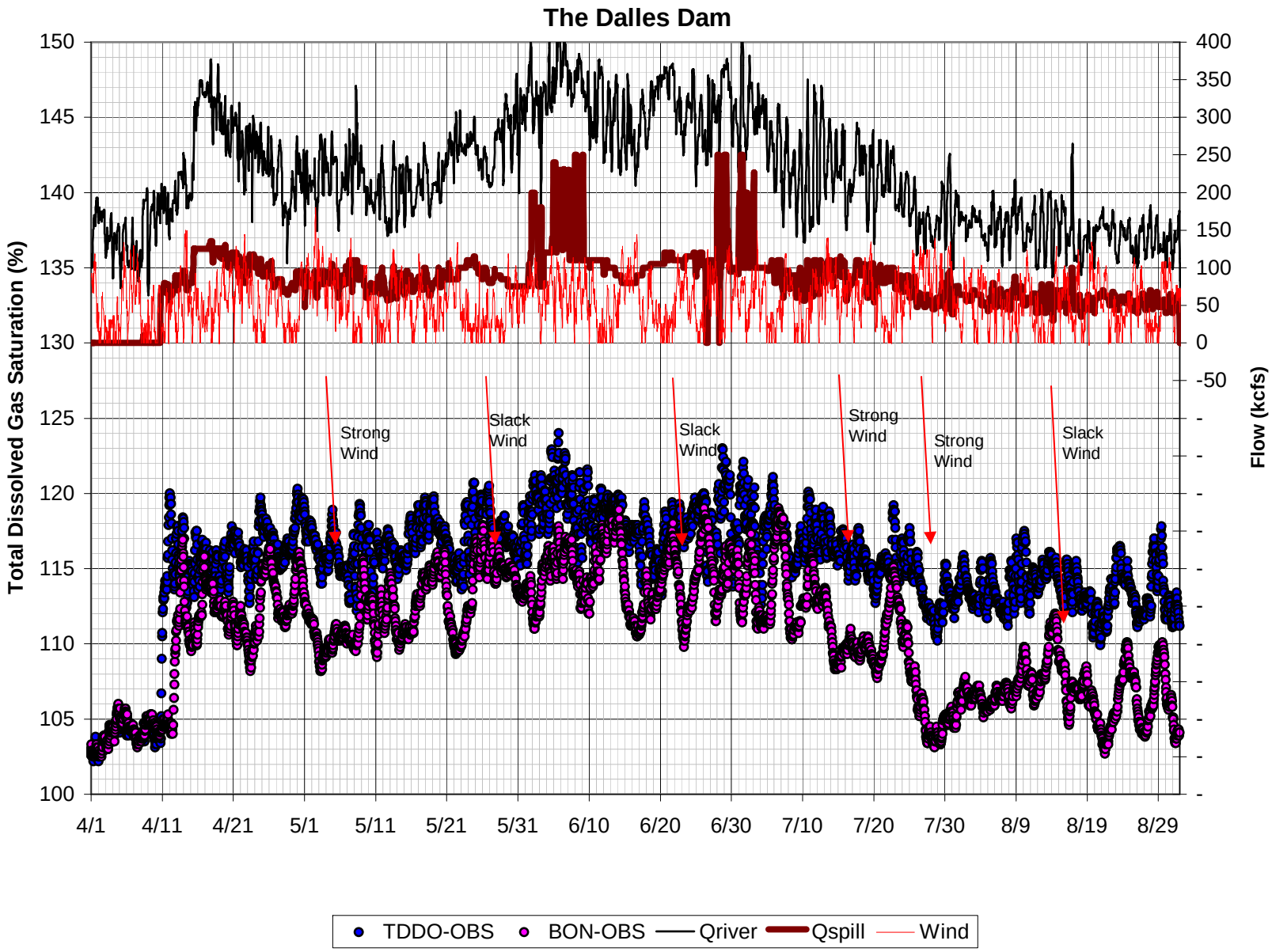
- Background
  - Elevated levels of total dissolved gas saturation are created when highly aerated flow conditions are produced in project flows
  - Change in TDG loading in the Columbia River at Bonneville Dam is chiefly attributed to spillway flows
  - Operation of Bonneville spillway and spillway structure have changed significantly over time
  - Addition of spillway flow deflectors on bays 1-3, 16-18 in 2002 coupled with the flat spill pattern resulted in a significant reduction in TDG exchange at Bonneville Dam

Bonneville Dam TDG Production, Fate and Transport

- TDG characterization at Bonneville Dam
  - TDG forebay
  - TDG exchange in project flows
    - Spillway
    - B2CC outfall
  - TDG fate and transport
  - TDG monitoring
  - TDG management

Bonneville Dam TDG Production, Fate and Transport

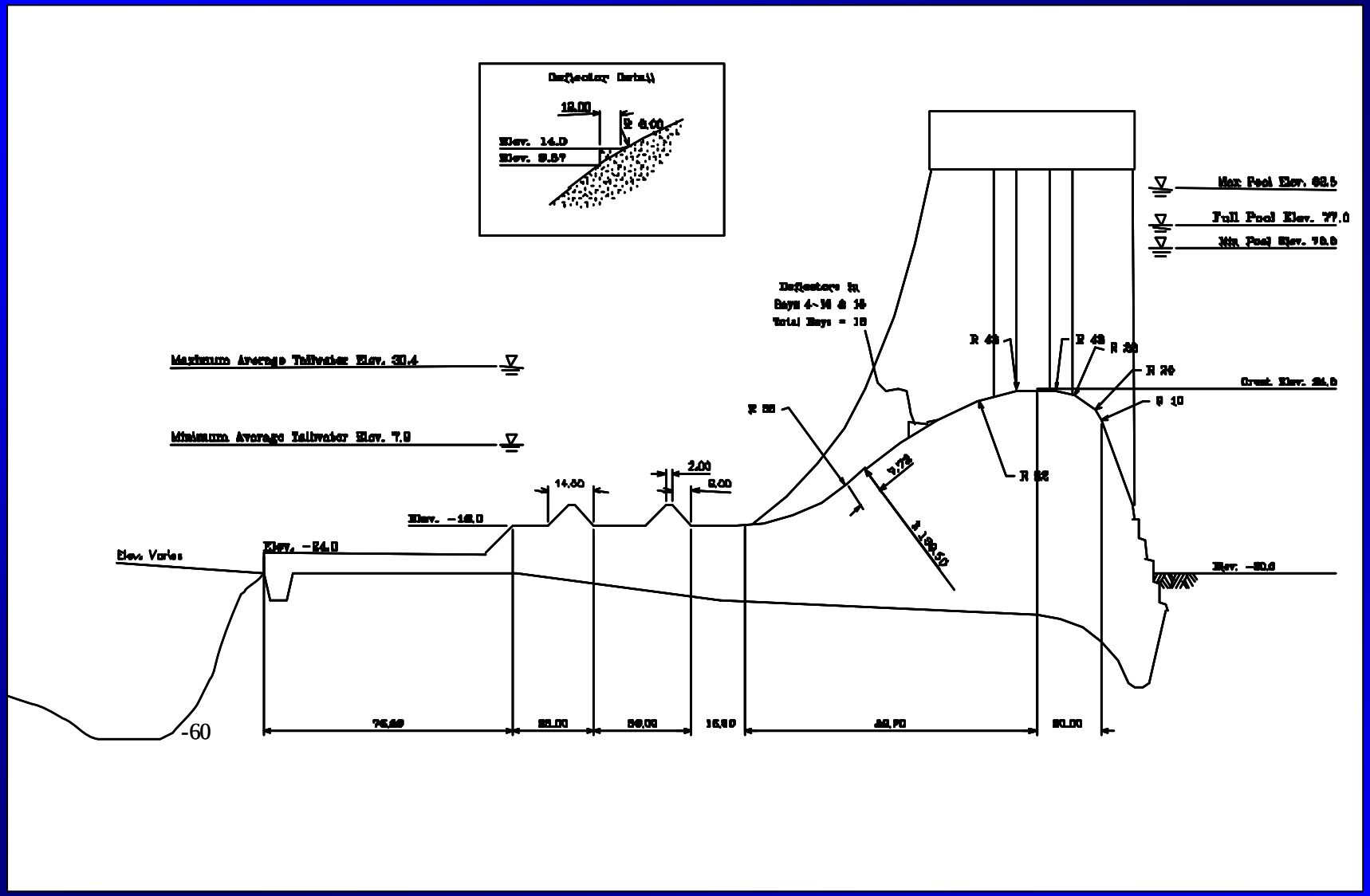
- Bonneville forebay TDG saturation
  - Function of TDG production at upstream projects
  - Moderated by degassing related to wind/wave events
  - Time of travel from upstream sources
  - Average TDG saturation ~111%
  - >115 for short durations during voluntary spill



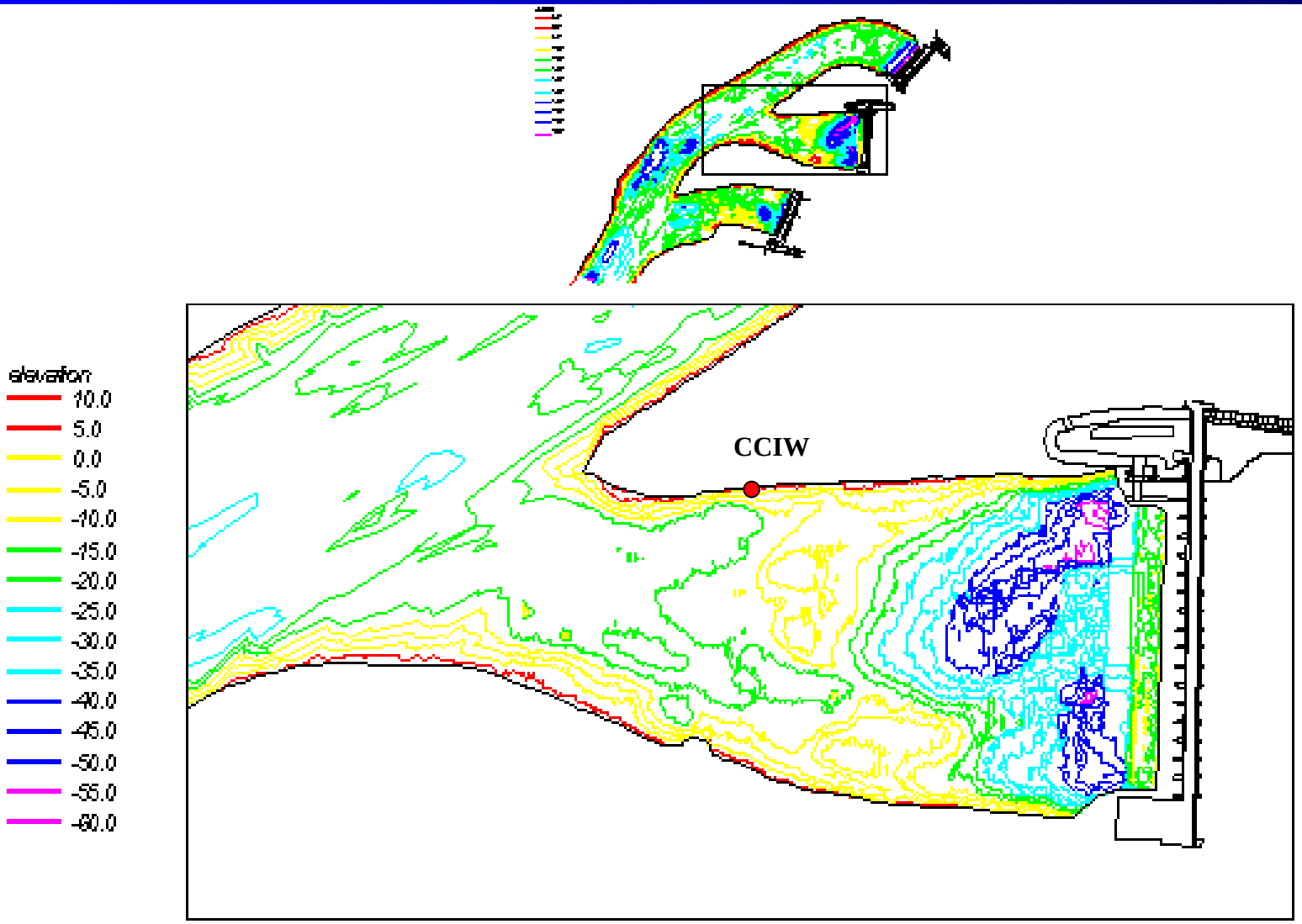
Hourly summary of The Dalles Dam operation, total dissolved gas saturation at The Dalles Tailwater FMS (TDDO) and Bonneville forebay (BON), and wind speed at The Dalles Airport, April-August, 2002.
(note: wind speed in mps x 10 on flow axis)

Bonneville Dam TDG Production, Fate and Transport

- Site Description
  - Structure
    - Spillway channel bounded by Bradford/Cascade Islands
    - Spillway crest el. 24 ft
    - Deflectors el. 14 ft on bays 4-15
    - Deflector el. 7 ft on bays 1-3, 16-18
    - Stilling basin elevation –16 ft/ -24 ft
  - Tailwater Channel
    - Deep channel below stilling basin
    - Spillway exit channel shallows/narrows
    - Free flowing river causes wide range in tailwater stage



Profile View of Bonneville Spillway, Stilling Basin, and Tailwater Channel.



Spillway Channel Bathymetry below Bonneville Dam

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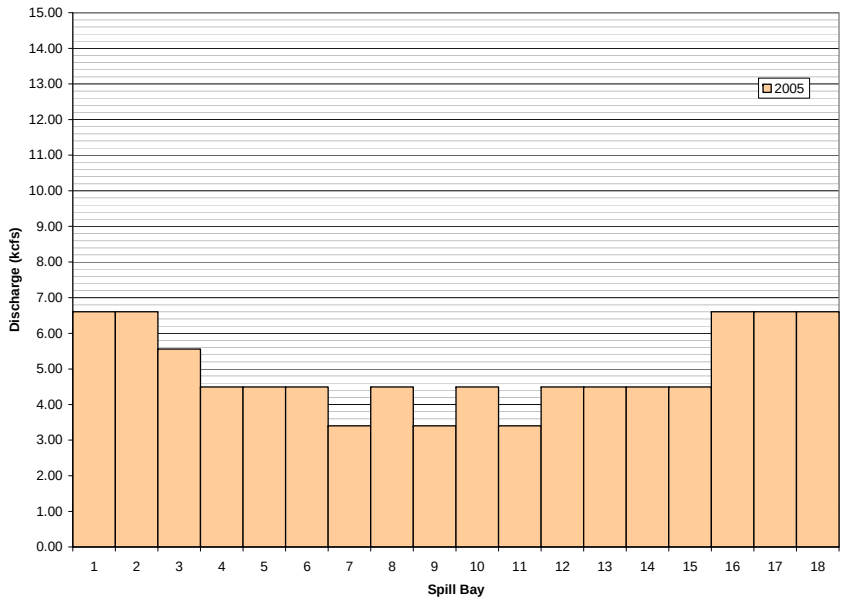
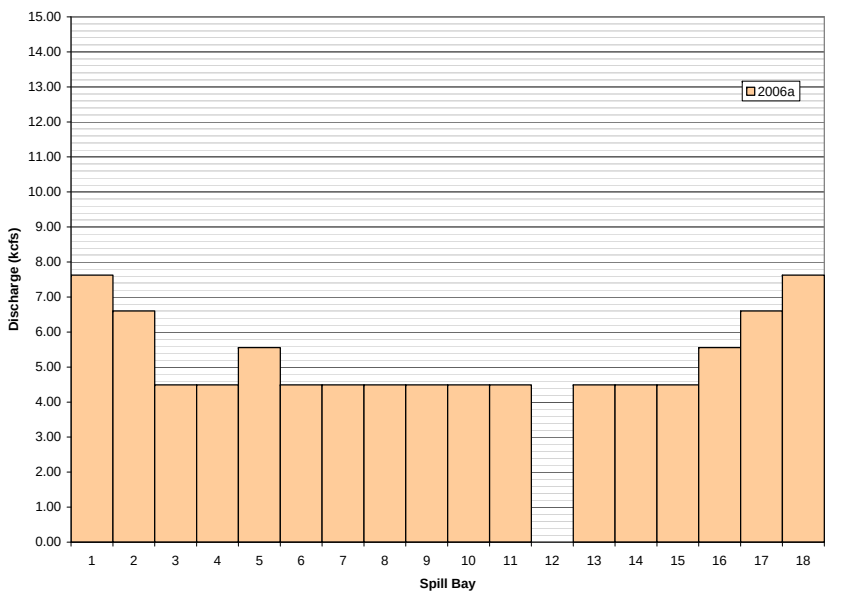
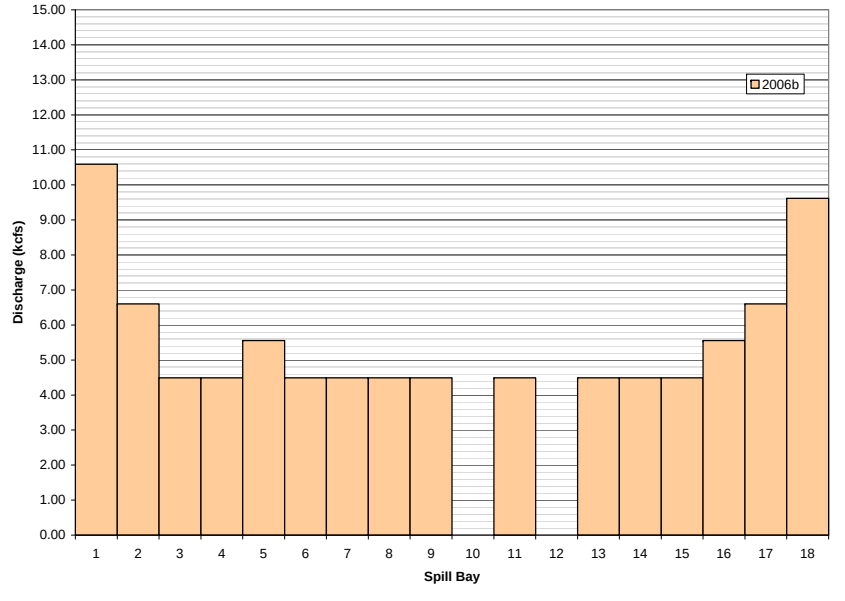
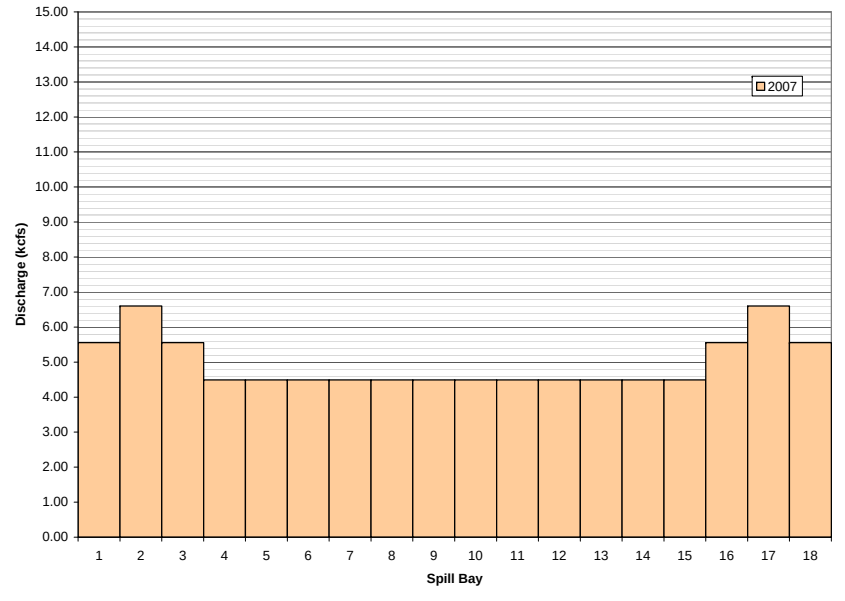
- Spillway
  - Operational constraints/considerations
    - 2 ft gate opening
    - Maintain velocities near shore area ~ 4 fps
    - Avoid areas of recirculation/low flow
  - Spill policy
    - Spring 100 kcfs
    - Summer 75/85 kcfs minimum with spill to TDGD capacity at night
- B2CC outfall
  - Plunge pool
  - Flow entrainment
- Powerhouse
  - Minimum powerhouse flow
  - Turbine Passage does not change the TDG properties
    - Exception when air is introduced during rough settings





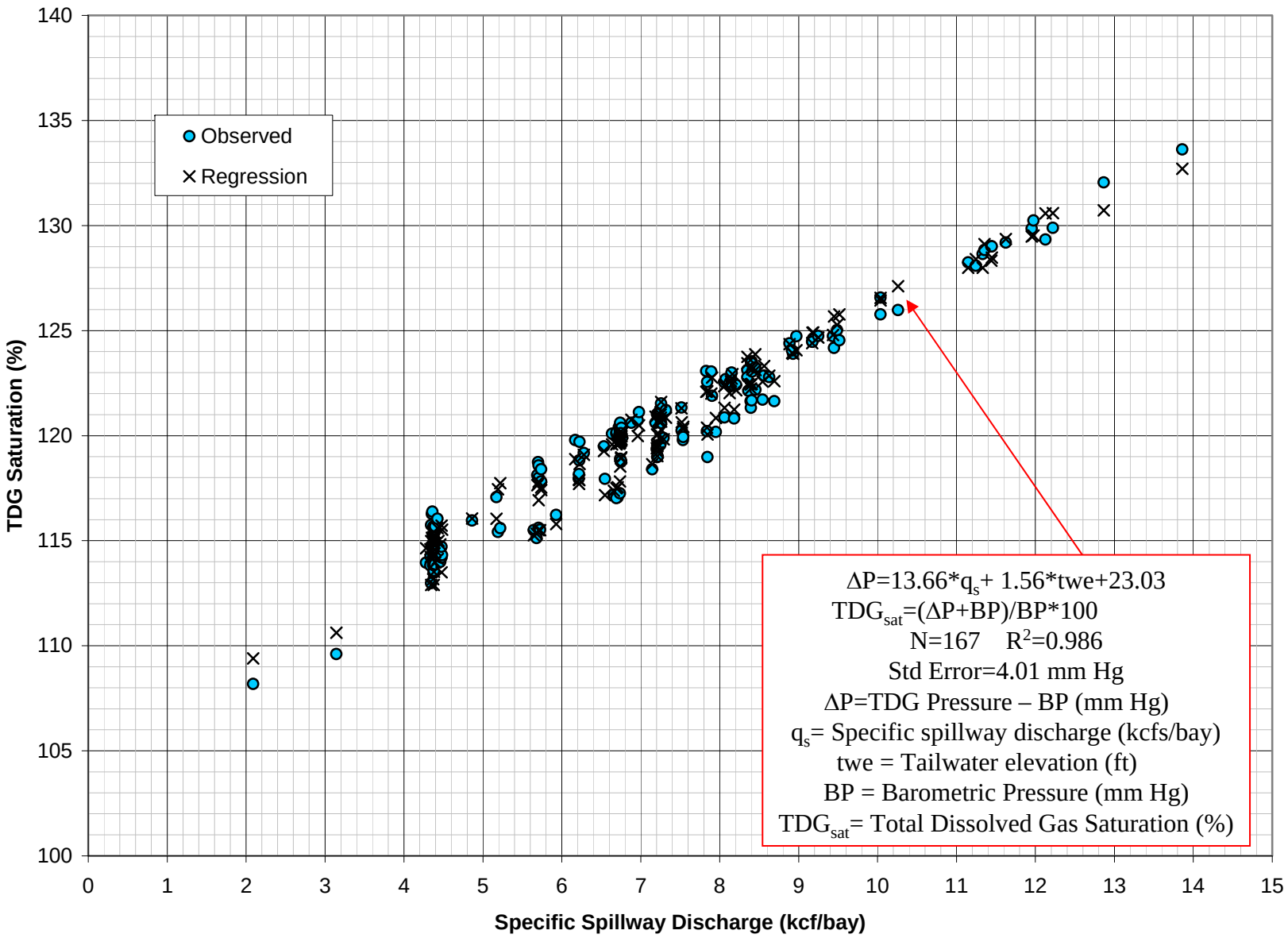




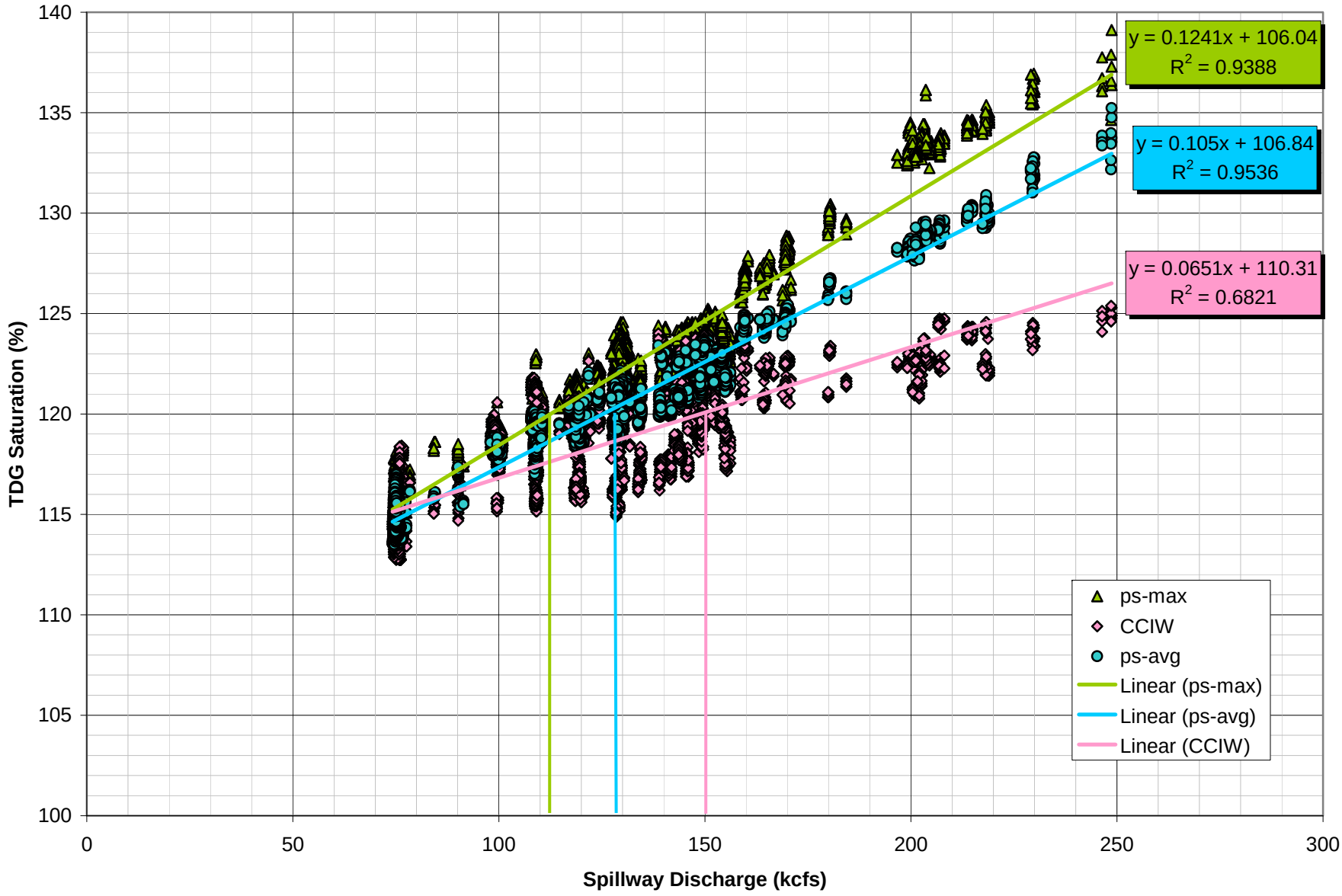
Bonneville Dam spill patterns for 2005, 2006, and 2007 for 83 kcfs.

Bonneville Dam TDG Production, Fate and Transport

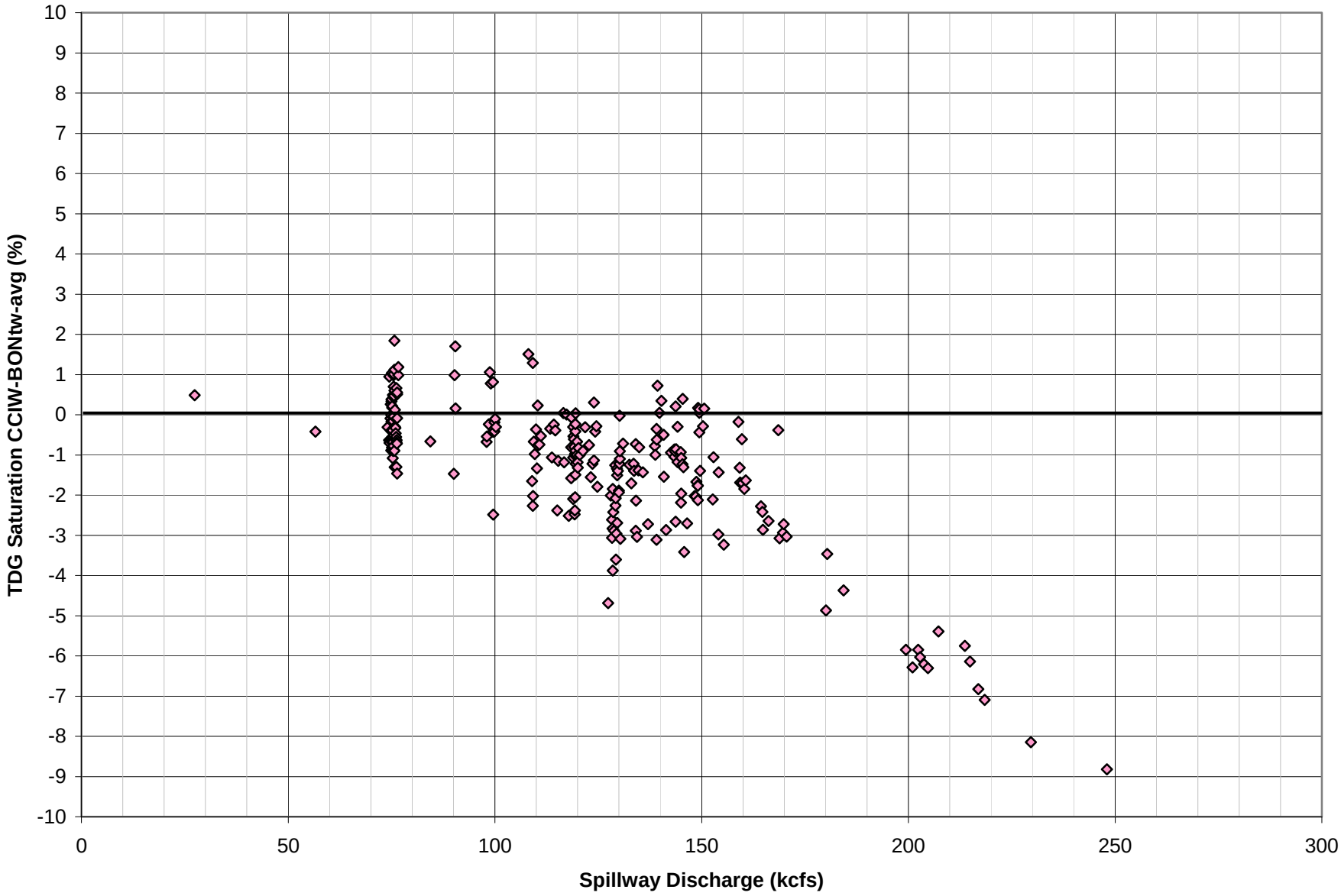
- Bonneville spillway exit channel TDG exchange
  - TDG exchange directly related to spillway discharge
    - Average TDG saturation reach 120% from 100 to 145 kcfs
    - Specific spillway discharge q_s kcfs/bay (1 kcfs/bay~2% saturation)
    - Bulk pattern will generate higher TDG levels than flat pattern
  - Tailwater depth of flow is a secondary causal parameter
    - 10 ft rise will cause 2 % increase in TDG saturation
  - Spillway channel TDG independent of forebay conditions
    - Short periods of reduction in TDG during spill
  - TDG can vary across spillway exit channel
    - Peak TDG in center of channel for Qsp>120 kcfs
    - Peak TDG near shore during bulk 2006 patterns Qsp<100 kcfs
    - Limited spill capacity in 2006 for new bulk pattern for flows Qsp<100 kcfs



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



Total Dissolved Gas Saturation in the Bonneville spillway exit channel as a function of spillway discharge, April- July, 2002
(ps-max=maximum cross sectional, ps-avg=average cross sectional, CCIW-Cascade Island station)



TDG Saturation difference between CCIW and average cross sectional conditions near the exit of Bonneville spillway channel, 2002.

Bonneville Dam TDG Production, Fate and Transport

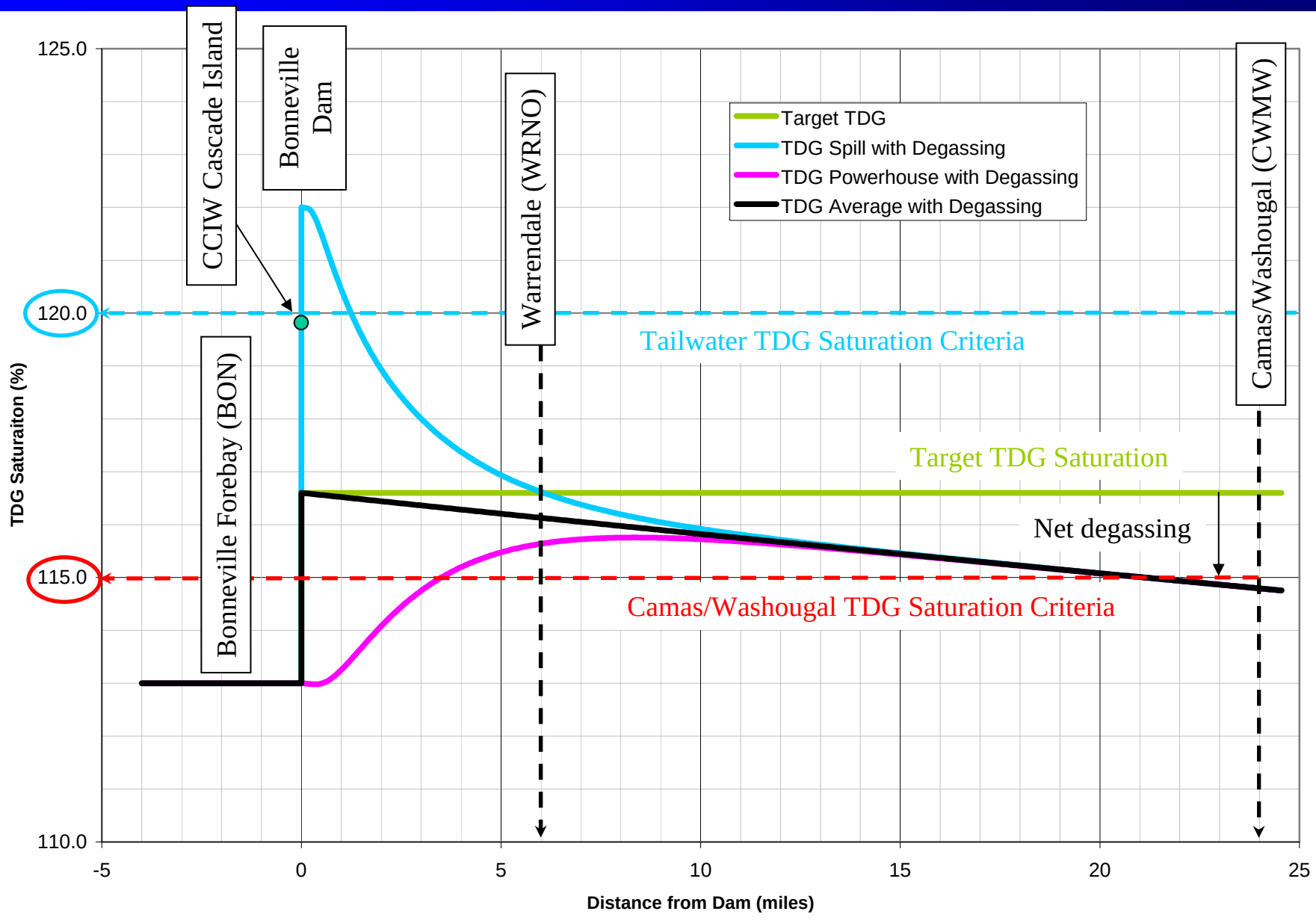
- Columbia River below Bonneville Dam (CWMW)
  - Highly correlated with TDG loading released from Bonneville Dam
  - Mixing zone development (complete in first 6 miles at WRNO)
  - Net reduction in average TDG saturation released from BON (2-3 percent saturation on average)
    - Degassing at air/water interface
    - Thermally induced pressure response (1-2 C)
    - Chemical/Biological processes (1 mg/l cycle)
  - Travel time ranging from 14-20 hours
  - Peak nighttime percent spill in phase with peak daily heating cycle at CWMW

Bonneville Dam TDG Production, Fate and Transport

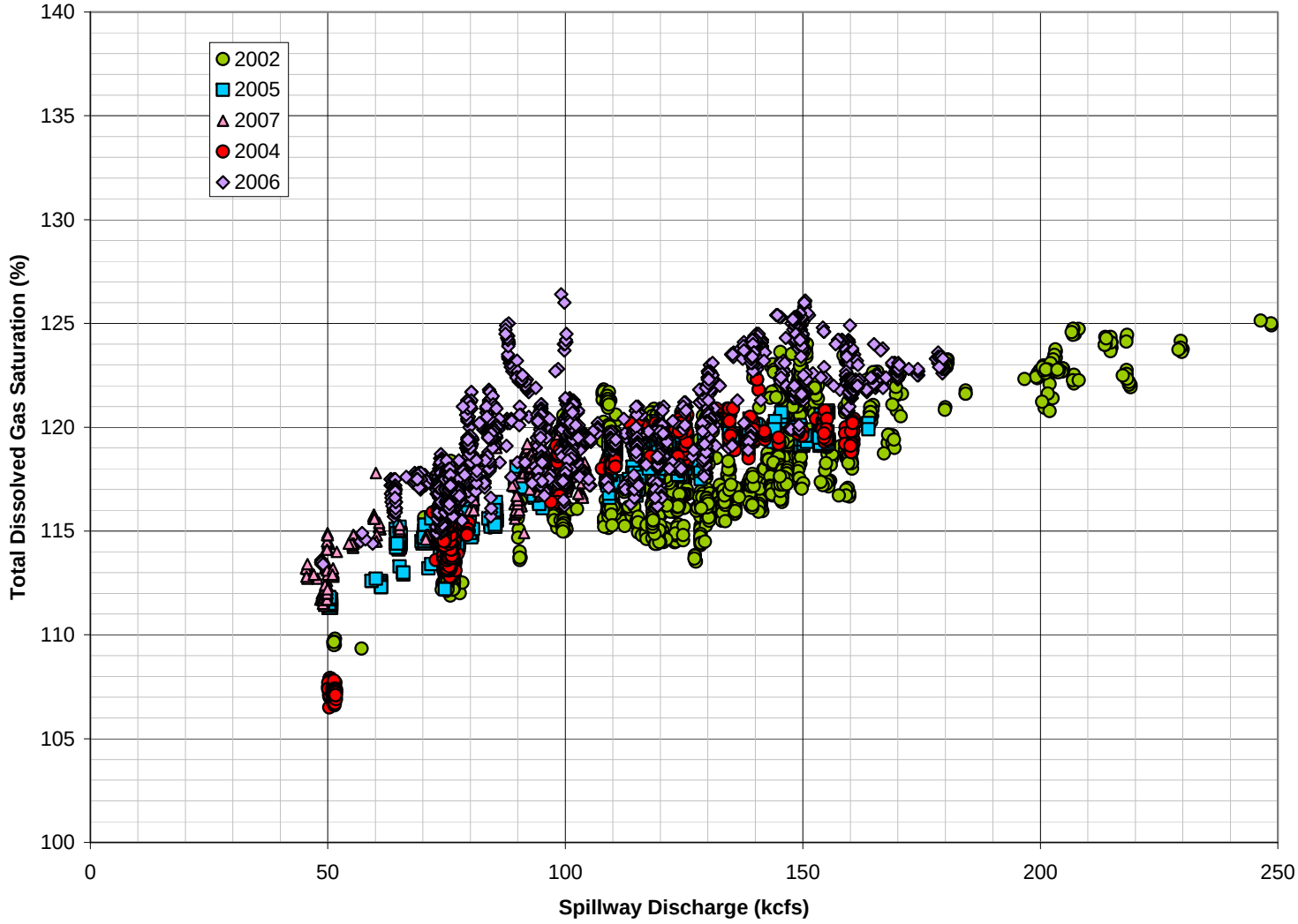
- TDG Monitoring - reliable and accurate
  - Habitat assessment
  - Water quality compliance / TMDL
  - TDG management
  - Project WQ impacts / Gas abatement progress
  - Bonneville Dam fixed monitoring stations
    - BON forebay spillway approach channel
    - CCIW tailwater spillway exit channel
    - WRNO auxiliary station/active during winter
    - CWMW downstream mixed river station 115%

Bonneville Dam TDG Production, Fate and Transport

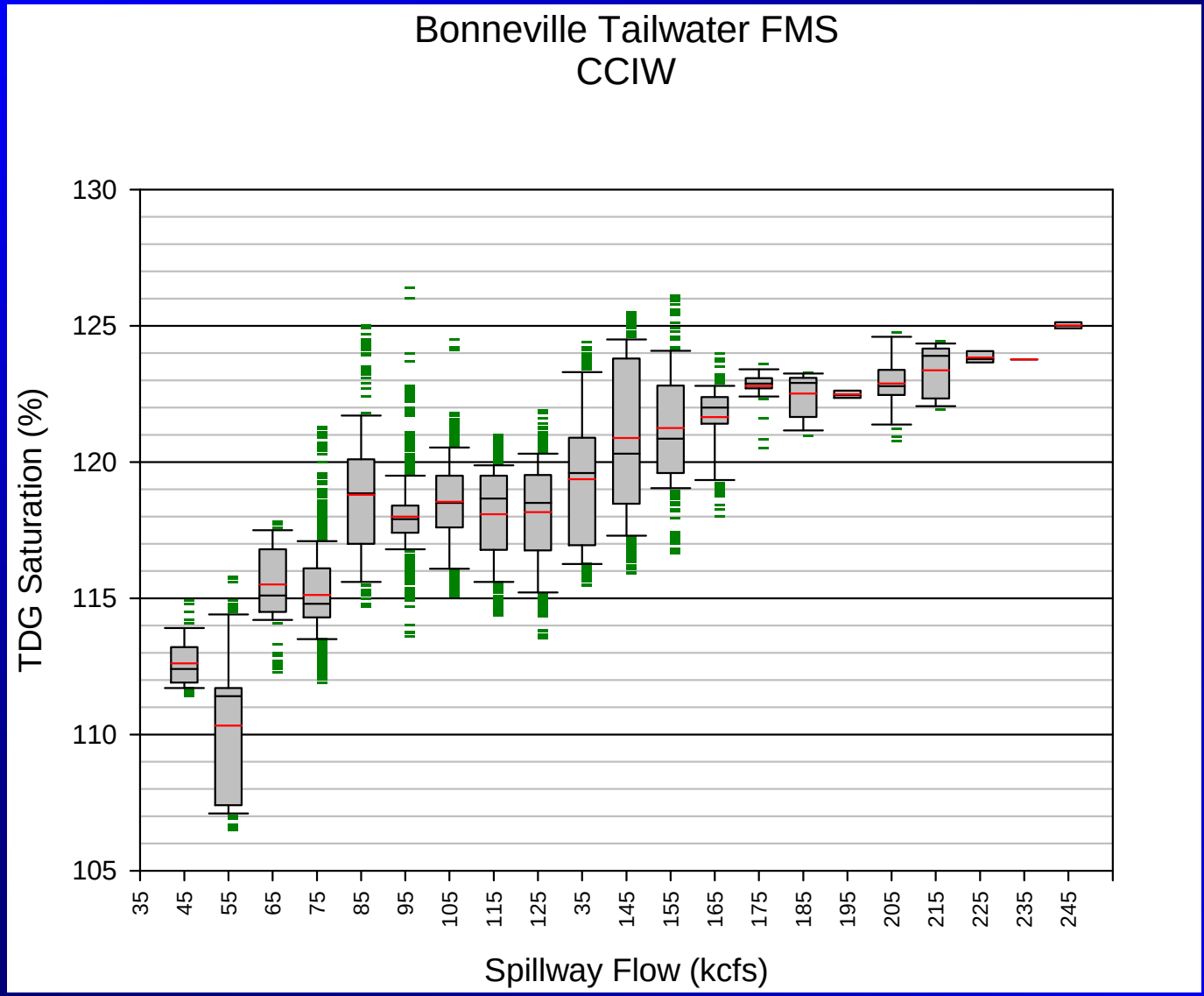
- TDG Management - What is the spillway capacity at Bonneville Dam as limited by TDG criteria?
  - Powerhouse releases >50% river and are a prominent contribution of TDG loading
  - B2CC – low tailwater/background conditions adds 2-3 percent to CR
  - CCIW TDG cap has ranged from 80 to 170 kcfs
    - Sensitive to spill pattern/magnitude
    - Limiting criteria during night time spill to TDG capacity during summer
  - Camas/Washougal often lower cap when forebay TDG levels are elevated
  - Sensitive habitat (WRNO)
    - Ives/Hamilton Island redds 105% depth compensated
    - Stage and TDG saturation important for managing this habitat
  - Spill capacity will be related to WQ definition of TDG criteria
    - 12 highest daily observations – moving 12 hr average



Total Dissolved Gas Exchange and Transport at Bonneville Dam and in the Columbia River.

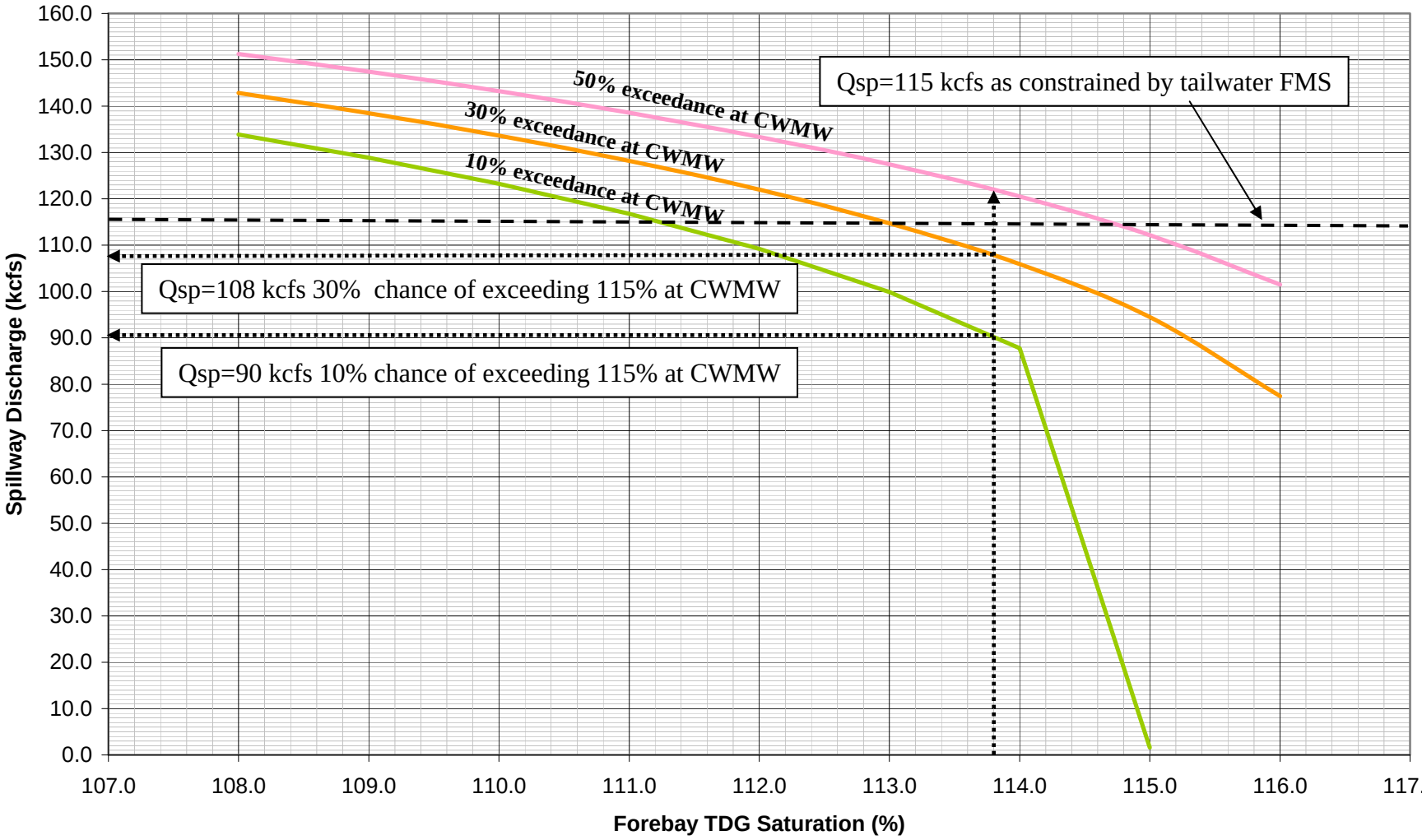


Total Dissolved Gas Saturation at Bonneville spillway exit channel fixed monitoring station CCIW as a function of spillway discharge, 2002, 2004-2007

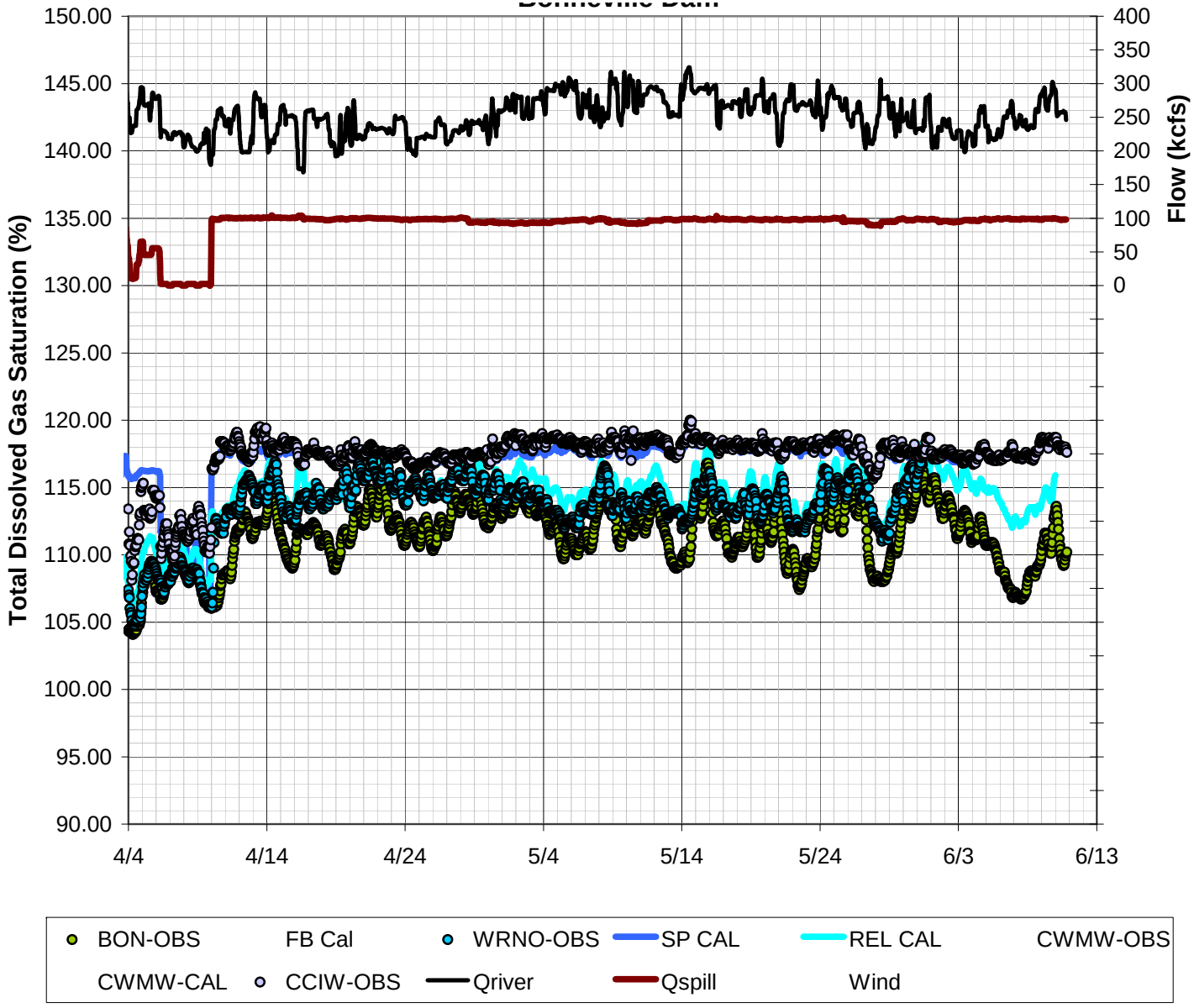


TDG Saturation response in Bonneville spillway exit channel (CCIW) as a function of spillway discharge, 2002, 2004-2007

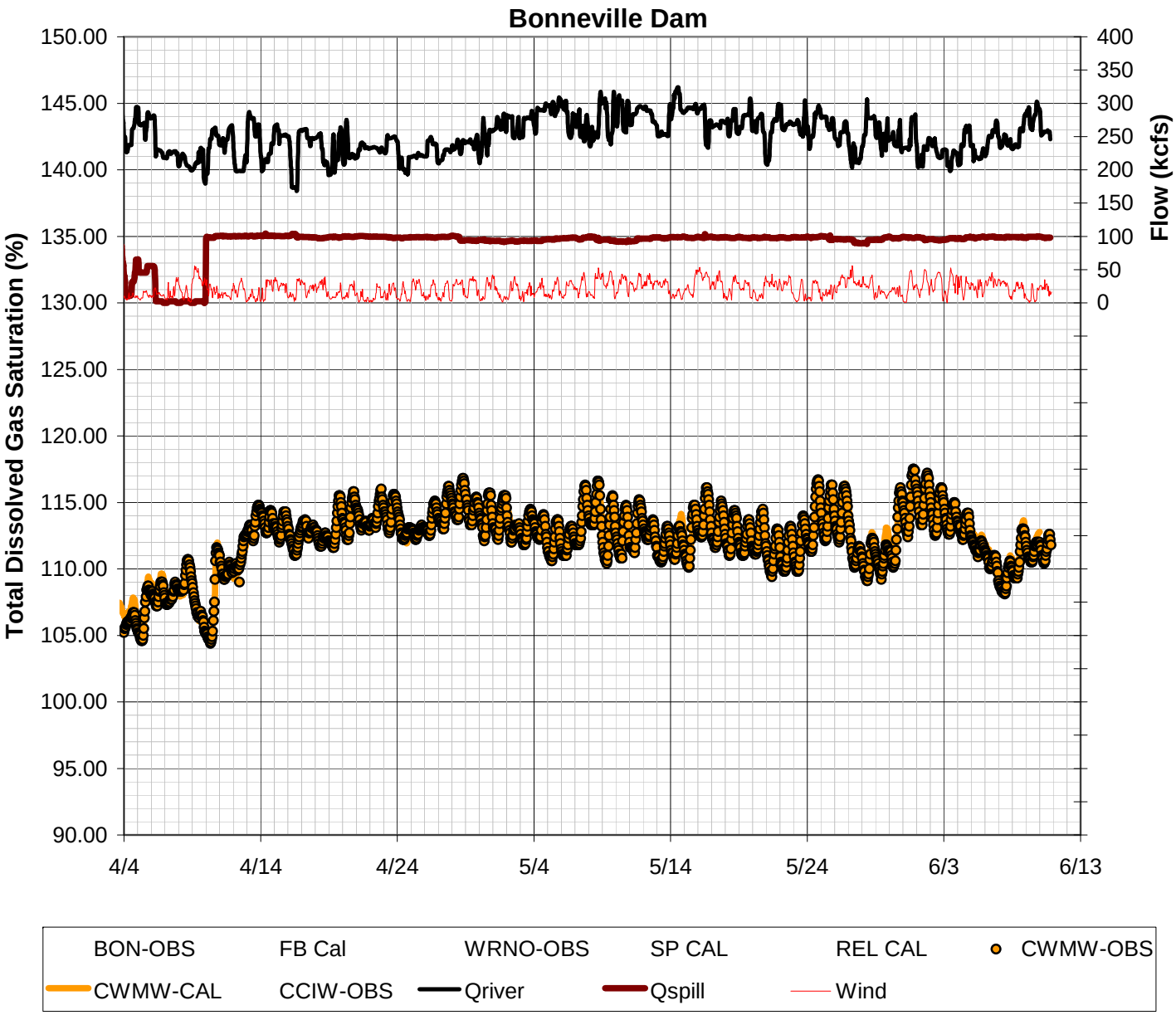
Bonneville spillway capacity as limited at the tailwater (CCIW) and downstream forebay (CWMW) FMS for a total river flow 275 kcfs



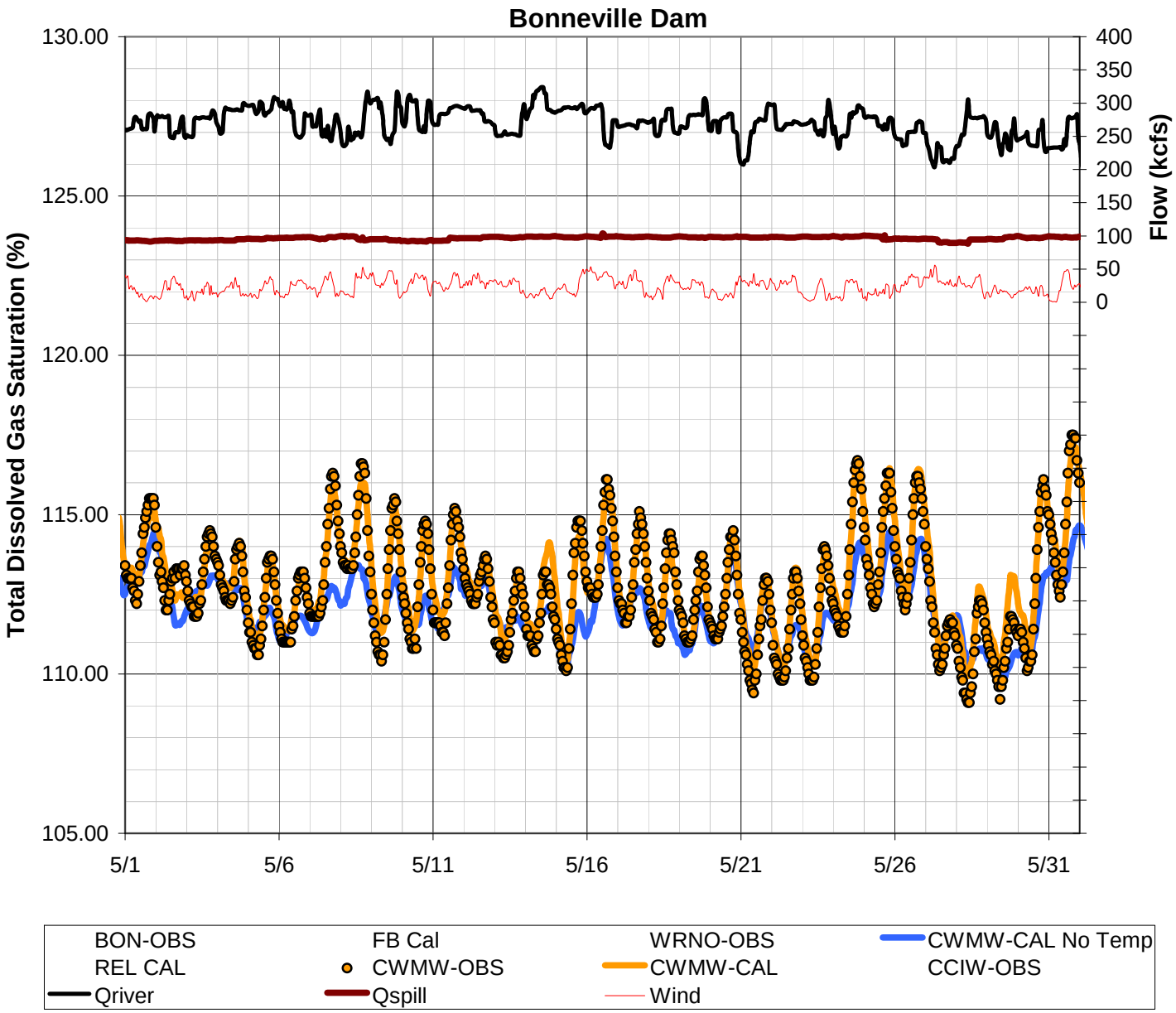
Bonneville spill capacity determination limited by TDG criteria for a river flow of 275 kcfs



Bonneville Dam Operations and TDG Saturation at BON, CCIW and WRNO, (observed and calculated) 2007



Bonneville Dam Operations and TDG Saturation at CWMW, (observed and calculated) 2007



Influence of heat exchange on TDG saturation at Camas/Washougal in the Columbia River below Bonneville Dam, 2007 (CWMW-Cal no heat exchange, CWMW-Cal with heat exchange)