TDG Characterization of the Lower Columbia River

Water Quality Team
Portland Oregon, December 9, 2005

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TDG Characterization of the Lower Columbia River

- Compilation of TDG data
  - Bonneville Dam to Wauna Mill (RM 42-146)
  - Parameters
    - TDG, Temp, DO
    - Flows (Bonneville and tributaries)
    - Stage
    - Channel configuration
  - Date Sources - COE
    - Fixed monitoring stations
      - BON, CCIW, WRNO, SKAW, CWMW, KLAW, WANO
      - 1990-2005 hourly frequency
    - Research Studies
      - DGAS program – 3 pool studies
      - Evaluation of CWMW station
      - 2002 TDG production in Spill post-deflector
      - 1999 TDG production in Spill
      - 2005 KLAW & WANO (2 weeks)

TDG Characterization of the Lower Columbia River

- TDG properties and processes
  - Bonneville TDG loading
    - Spill
    - B2CC
    - Powerhouse releases
    - Auxiliary flows
  - Mixing Zone
    - Extends through the Ives/Pierce Islands reach
  - Well mixed open river
    - Exchange air/water (degassing)
      - » Wind induced
    - Temperature
    - Biological productivity
    - Tributary inputs

TDG Characterization of the Lower Columbia River

- Bonneville Operations
  - Historical perspective
    - 1938 2 units online producing power
    - 1943 completion of 1st Powerhouse (136 kcfs capacity)
    - 1957 The Dalles Dam completed
    - 1976 “flip lips” on 13 of 18 spill bay
    - 1982 completion of 2nd Powerhouse (152 kcfs capacity)
    - 1984 Revelstroke Dam completed
    - 1995 spill for fish passage policy adopted
    - 2002 redesigned “flip lips” added to bays 1-3, 16-18
    - 2004 Bonneville 2nd powerhouse corner collected operational

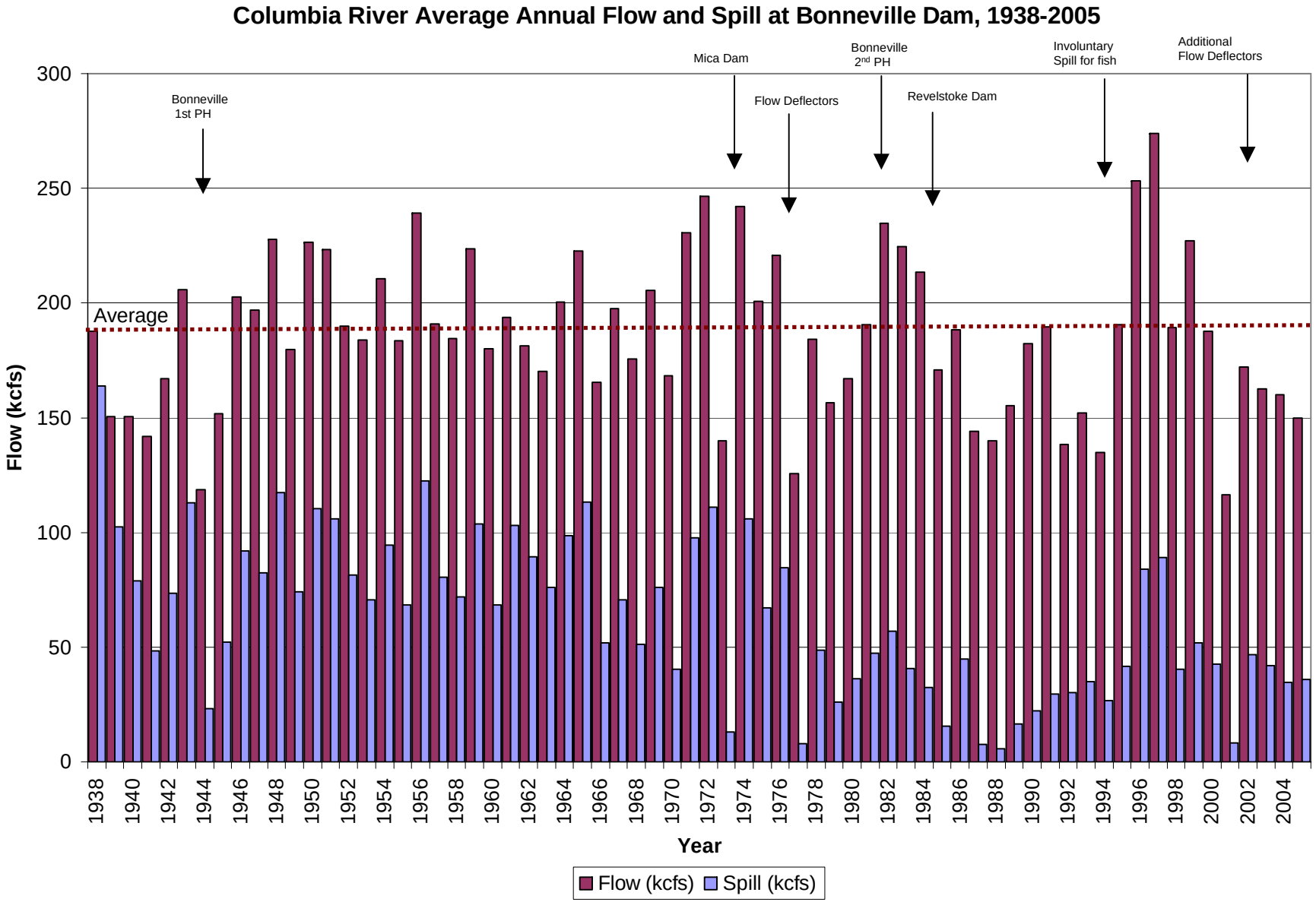
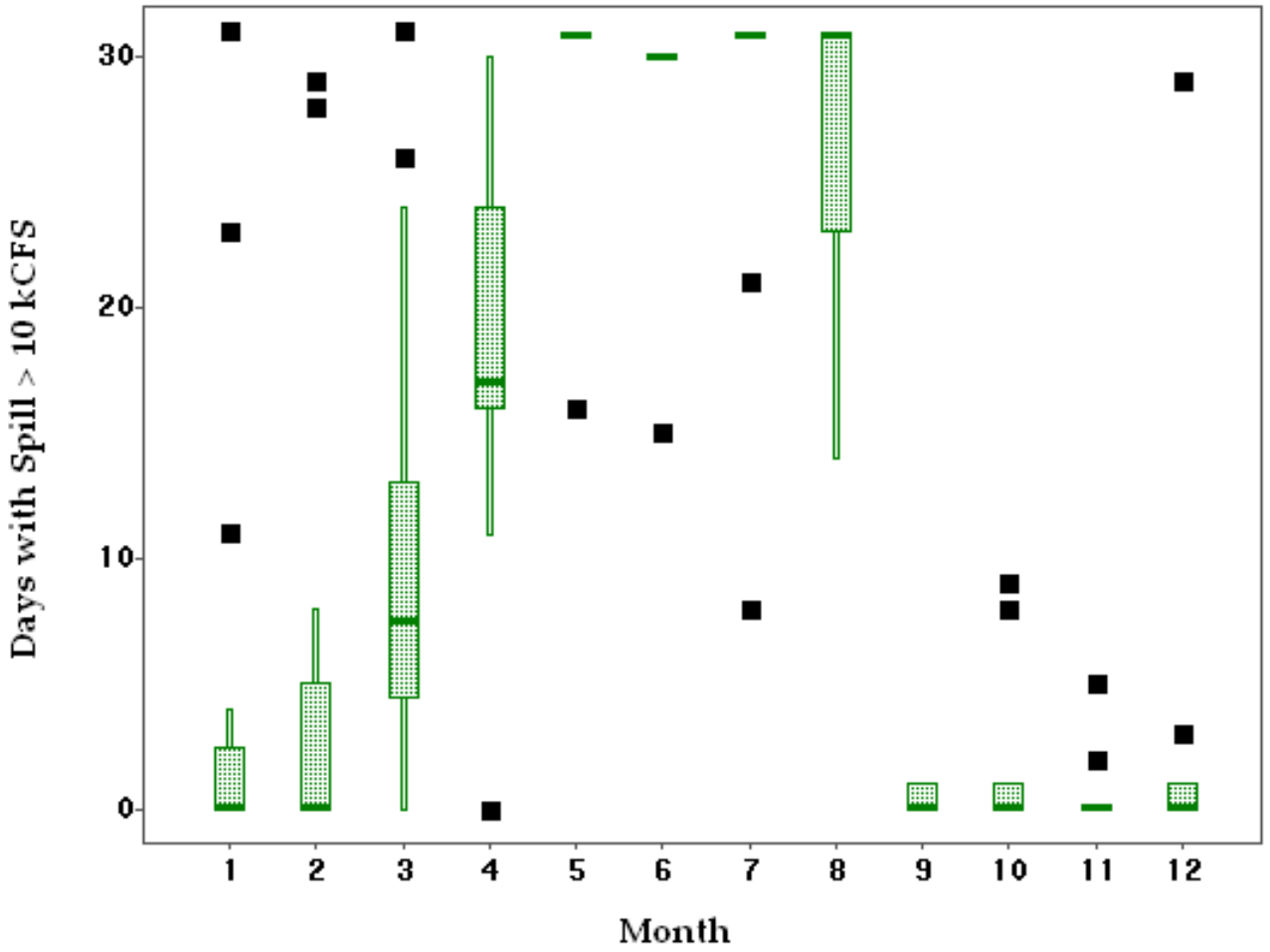


Figure xx Average annual Columbia River Flow and spill at Bonneville Dam 1938-2005

TDG Characterization of the Lower Columbia River

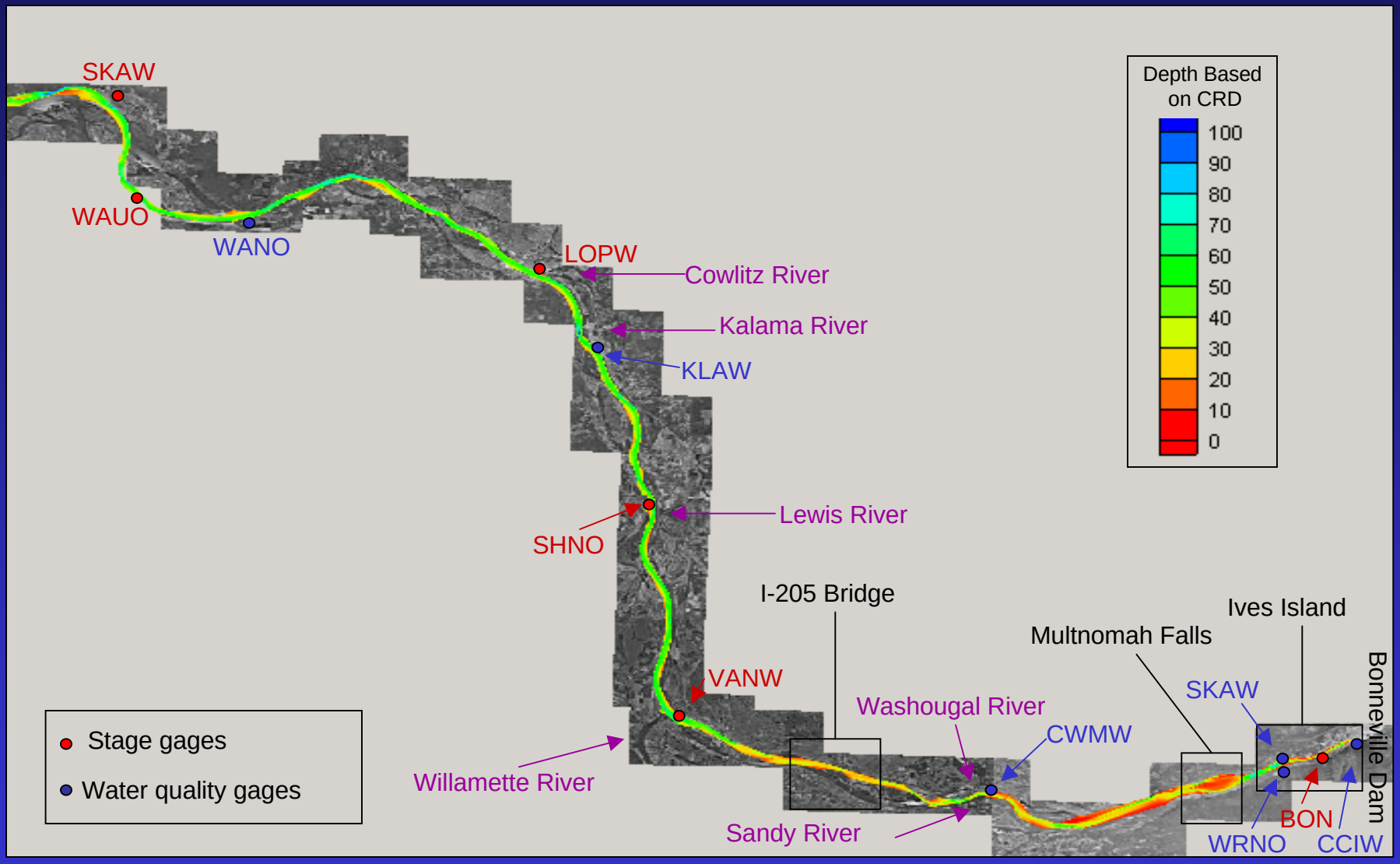
- Seasonal Bonneville Operations
  - Involuntary spill April-August
    - TDG capacity 115%/120%/125% at tailwater station and Camas/Washougal
  - Spring Creek Spill in March
  - B2CC operation only with spill
  - Involuntary spill December-July



Monthly summary of days with spill greater than 10 kcfs at Bonneville Dam from 1990-2005

TDG Characterization of the Lower Columbia River

- Tributary Flows
  - Willamette, Cowlitz, Lewis, Kalama, Sandy, Washougal
  - Flow Contribution
    - 20-22 percent during the summer
    - 35-41 percent during the winter
  - TDG Contribution
    - Willamette Falls (as high as 120%)
    - Little TDG data
    - 4 percent reduction in CR TDG pressure for the following
      - TDG_{BON}=120%
      - TDG_{trib}=100%
      - Q_{trib}/Q_{cr}=0.20



The Columbia River Tidal Pool Reach below Bonneville Dam

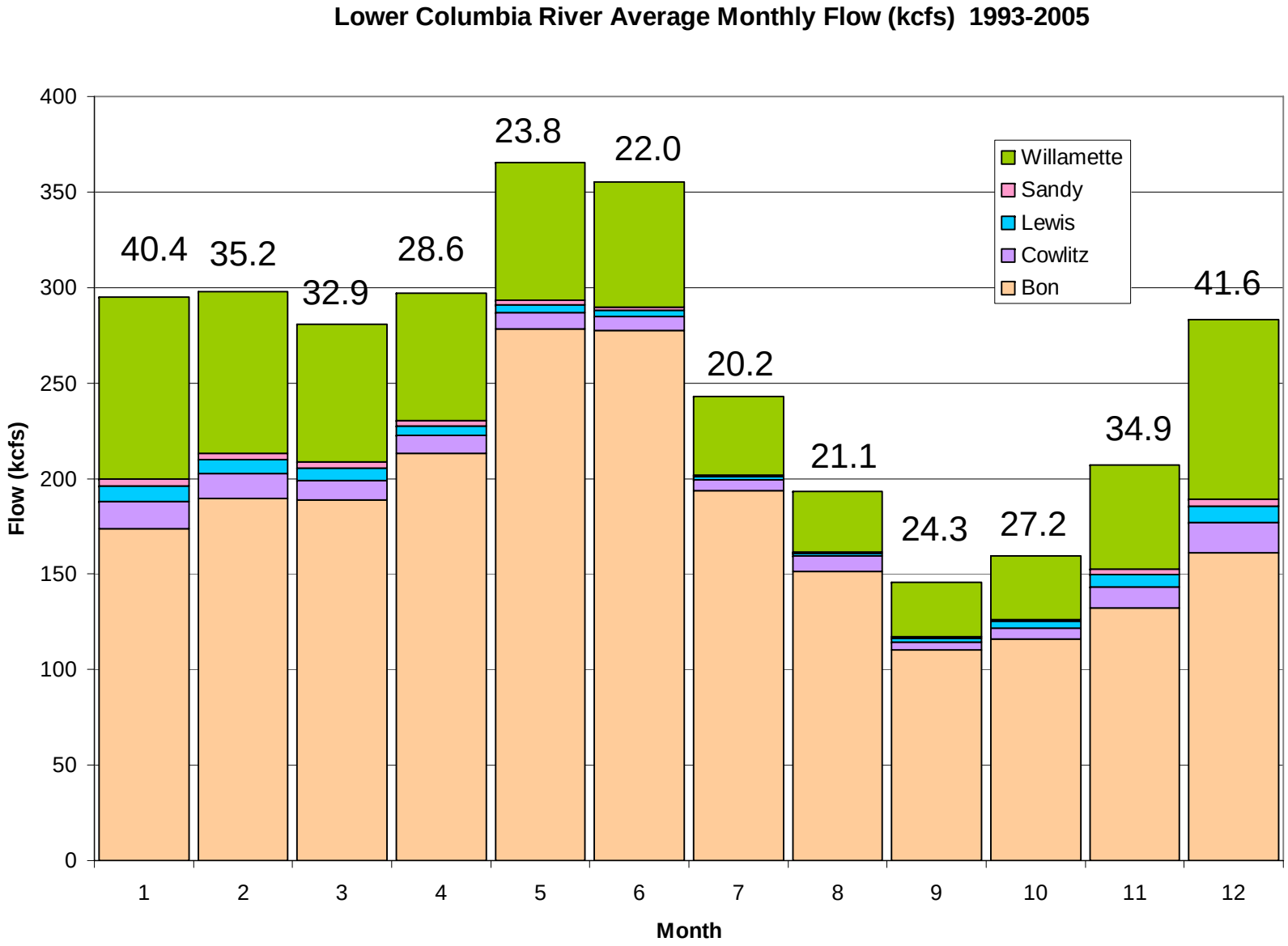


Figure xx Lower Columbia River Average Monthly Flow Composition, 1993-2005
(Percent contribution from tributaries noted on this figure)

TDG Characterization of the Lower Columbia River

- Columbia River Stage
  - Bonneville Tailwater function of total river flow
    - 15 kcfs change ~ 1 ft stage change
    - Ives Island area responds similarly
    - Wide range of tailwater elevations (8-36 ft)
    - Habitat Influences
      - Stranding
      - Depth Compensation for TDG exposure
      - Water and Temperature exchange
    - TDG exchange
      - Deflector submergence
      - Available aerated depth
  - Tidal influence on river stage increases with decreasing flow and distance from Bonneville Dam

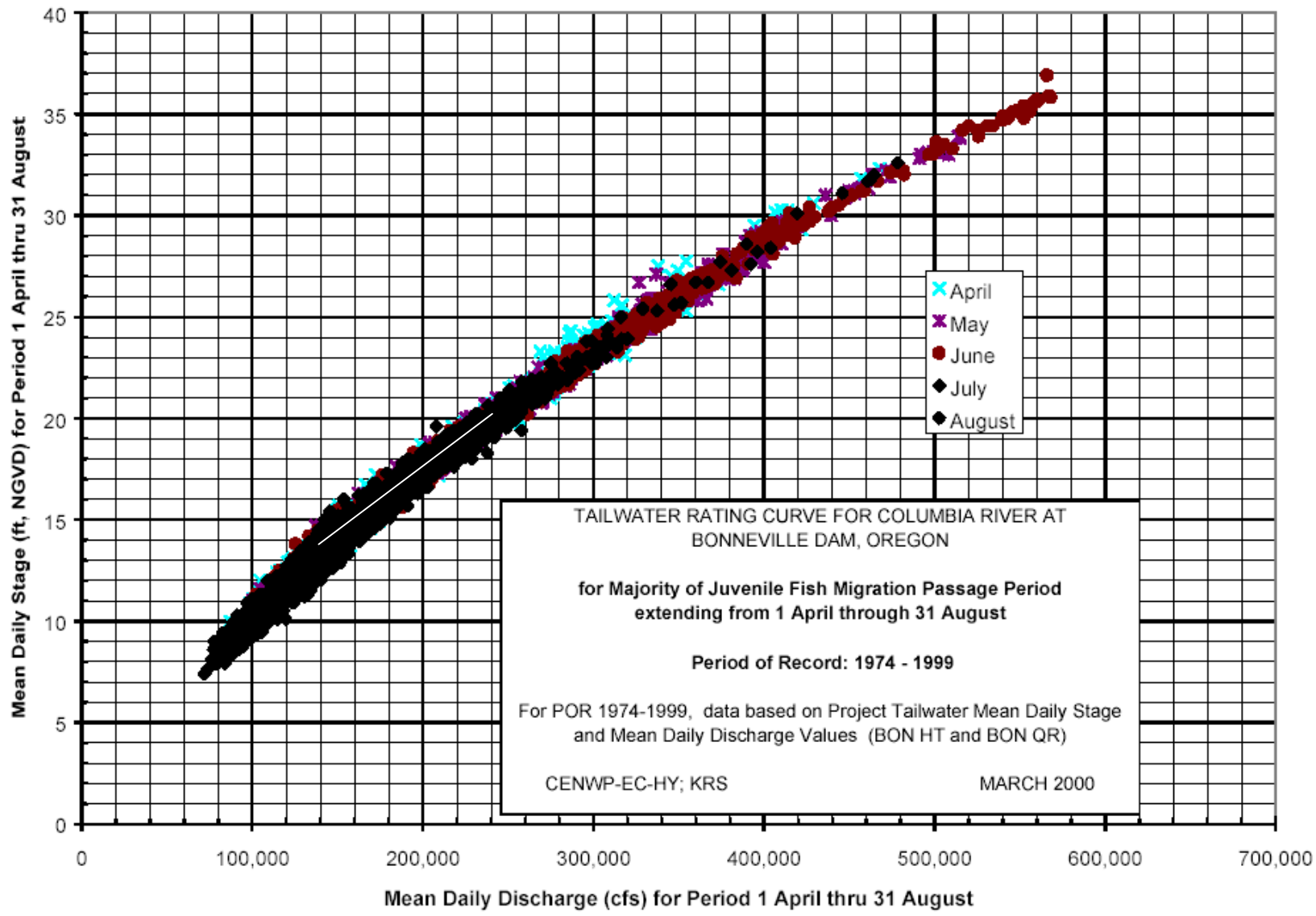
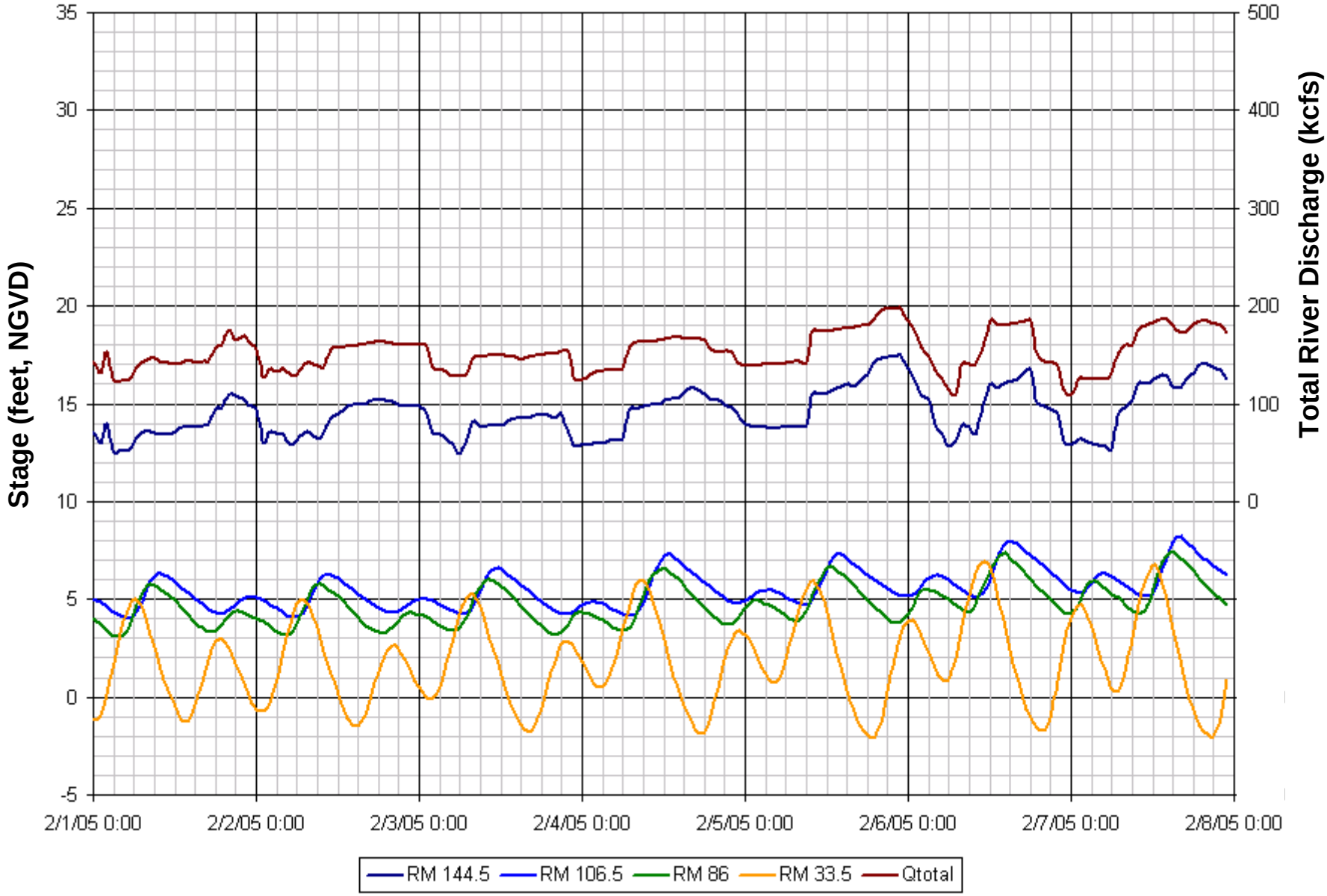
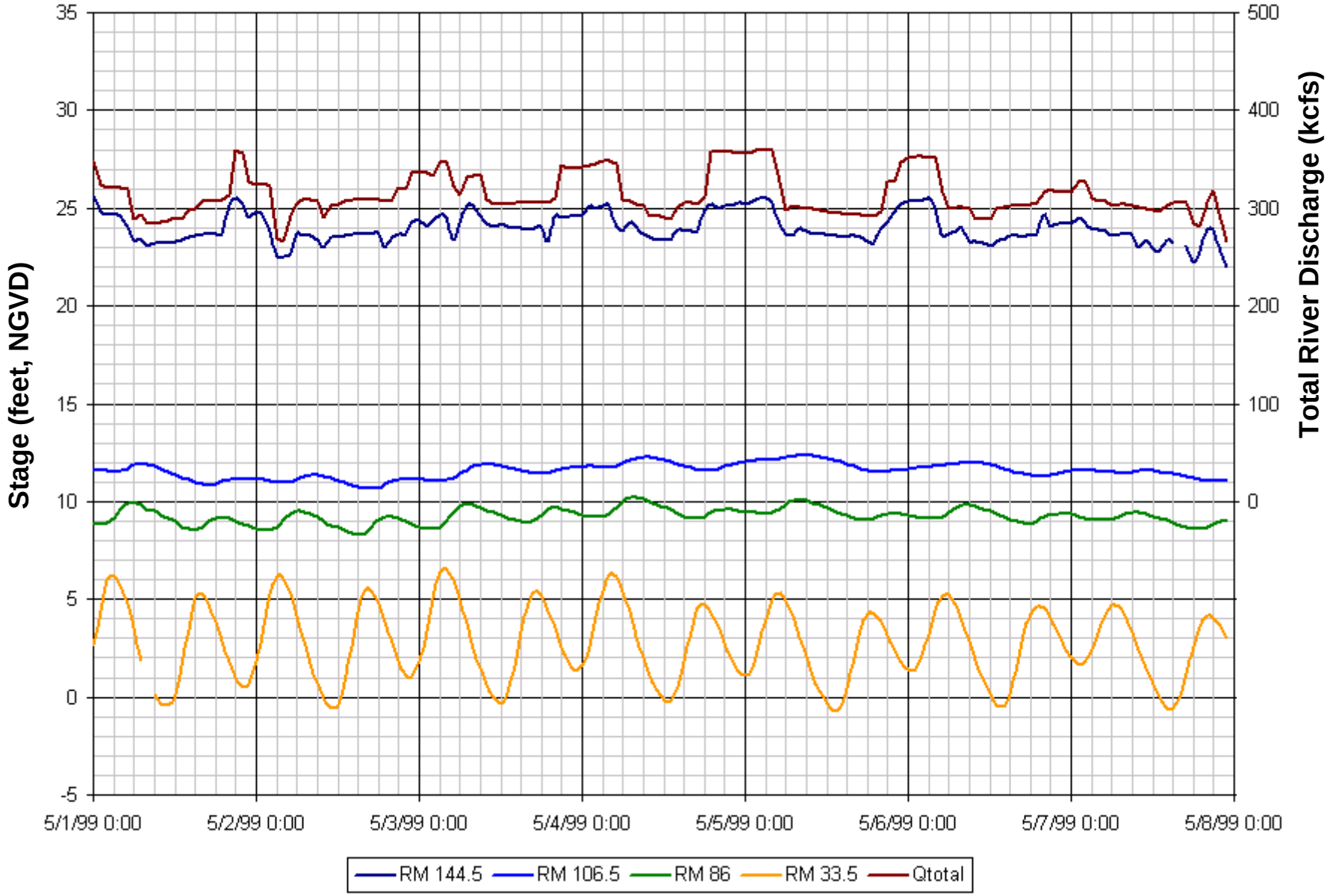


Figure 4.8. Tailwater Stage Duration Curve for Columbia River at Bonneville Dam, Oregon 1 April through 31 August



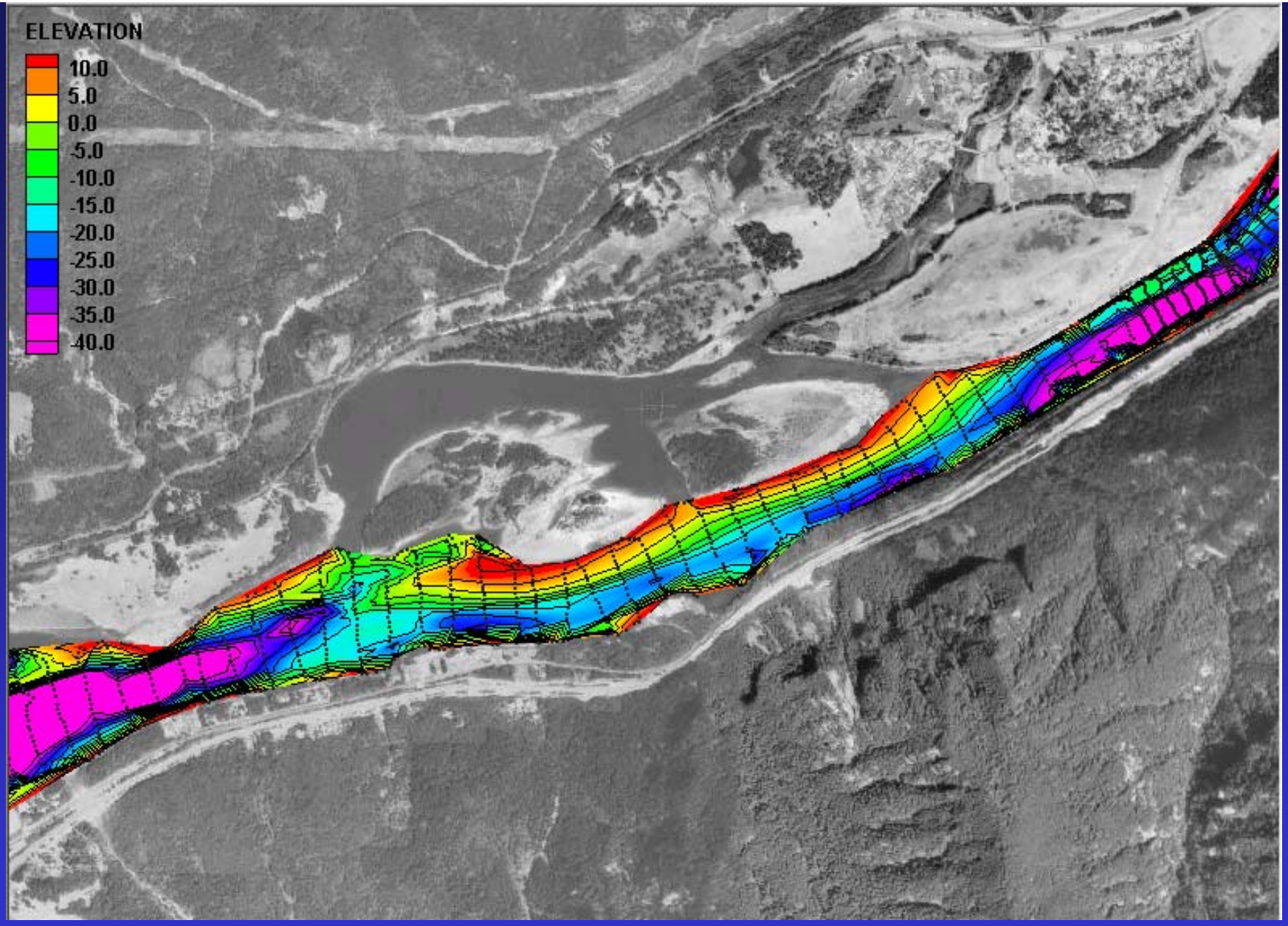
Stage @ ~153 kcfs (weekly avg)



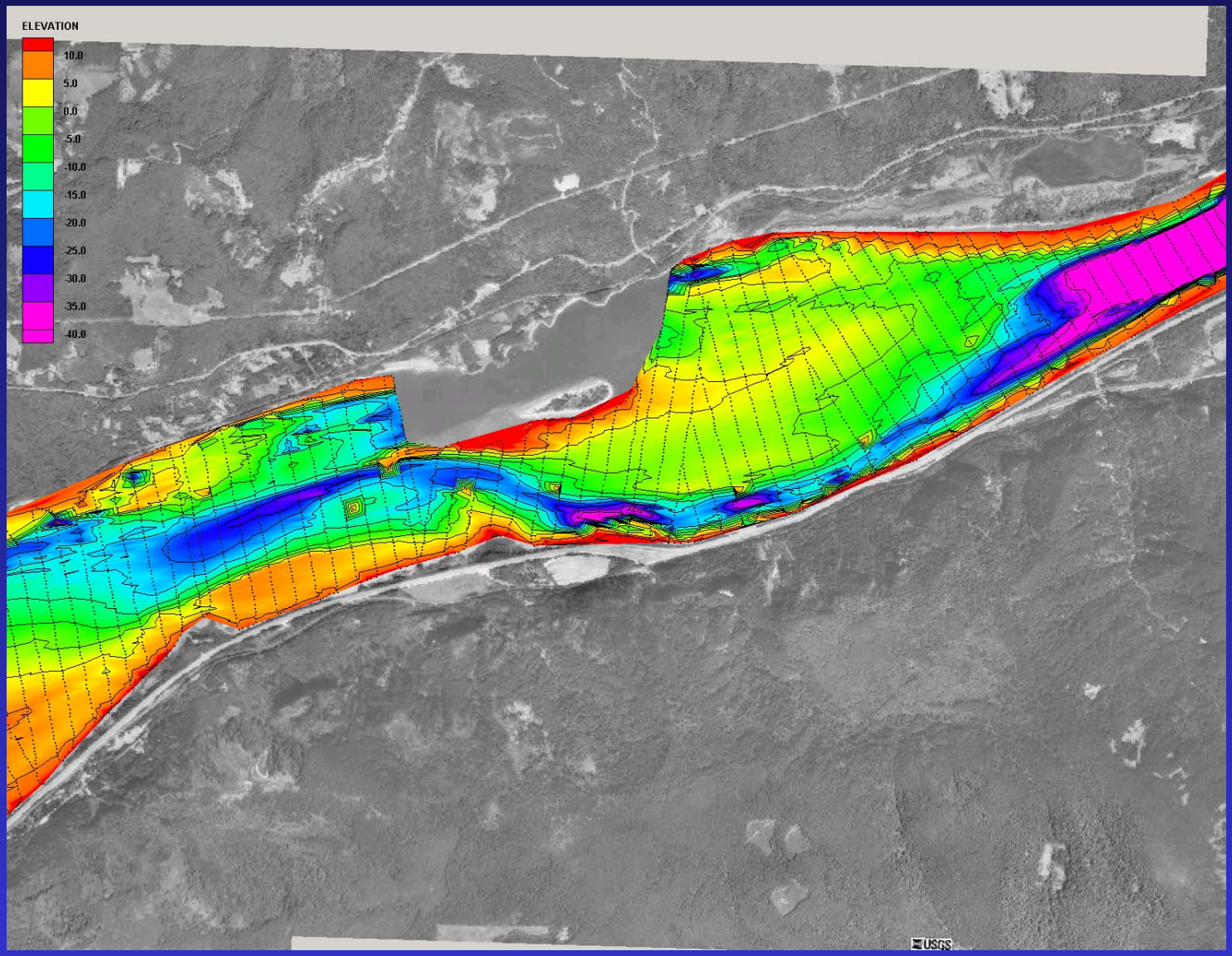
Stage @ ~313 kcfs (weekly avg)

TDG Characterization of the Lower Columbia River

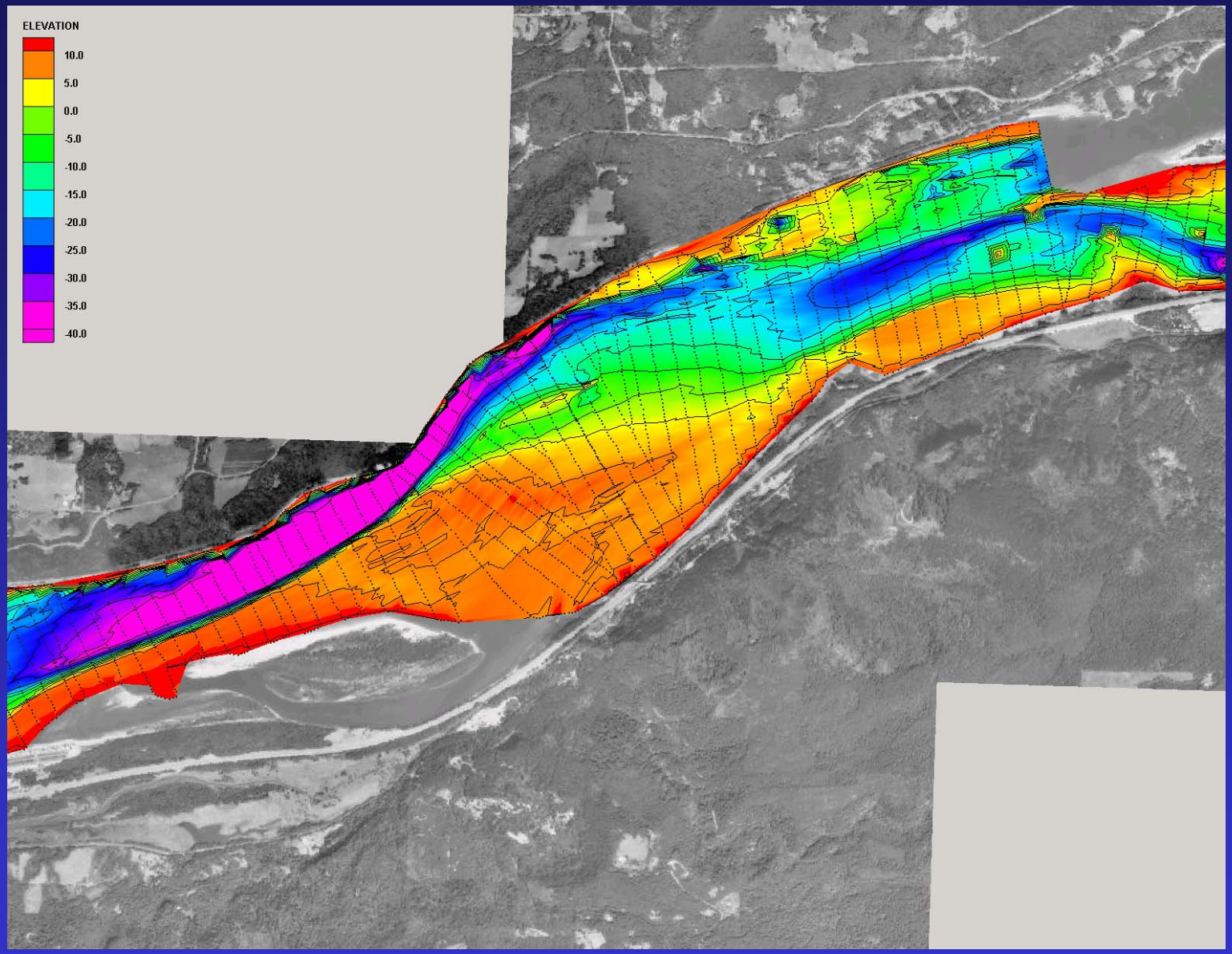
- Columbia River Channel
  - Channel in the Gorge (rm 122-146)
    - Shallow and wide
    - Narrow and deep
    - Average depth 24-34 ft at low flow
    - Channel Width ranges from 900-6200 ft



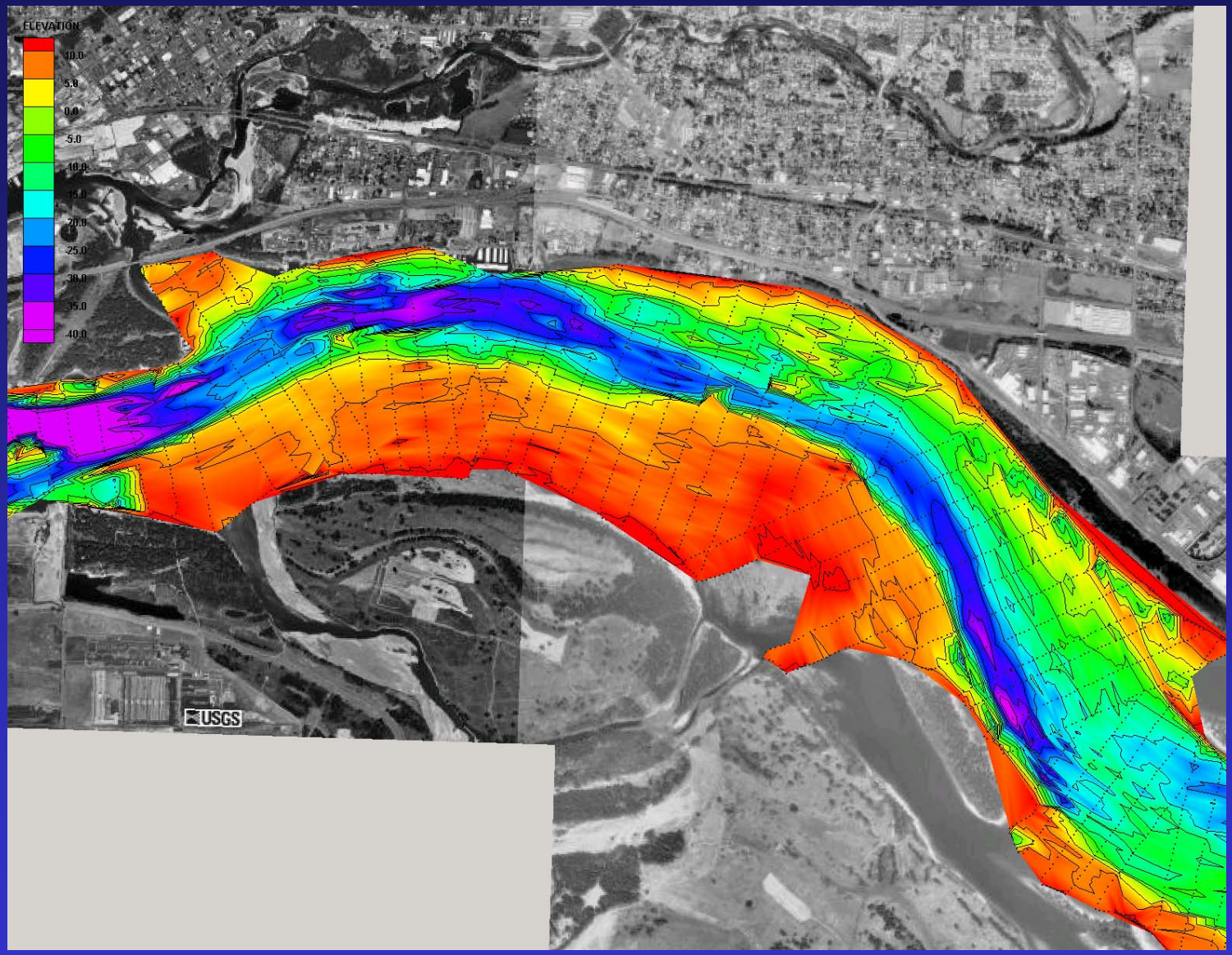
Ives Island rm 142



Multinomah Falls rm 135



Sand Island rm 130



Camas/Washougal rm 122

TDG Characterization of the Lower Columbia River

- TDG Saturation
  - Bonneville Dam Spillway
    - 2002 Spillway flow deflectors at El. 7 added bays 1-3, 16-18
    - Flow deflectors at Bays 4-15 at El. 14 ft
    - TDG function of specific spillway discharge and tailwater channel depth
    - Non-uniform TDG pressures exiting spillway channel at spill > 120 kcfs
    - Spillway capacity as limited by tailwater fixed monitoring station CCIW is 150-160 kcfs
    - Spill capacity can be limited by the 115% criteria measured at the CWMW fixed monitoring station

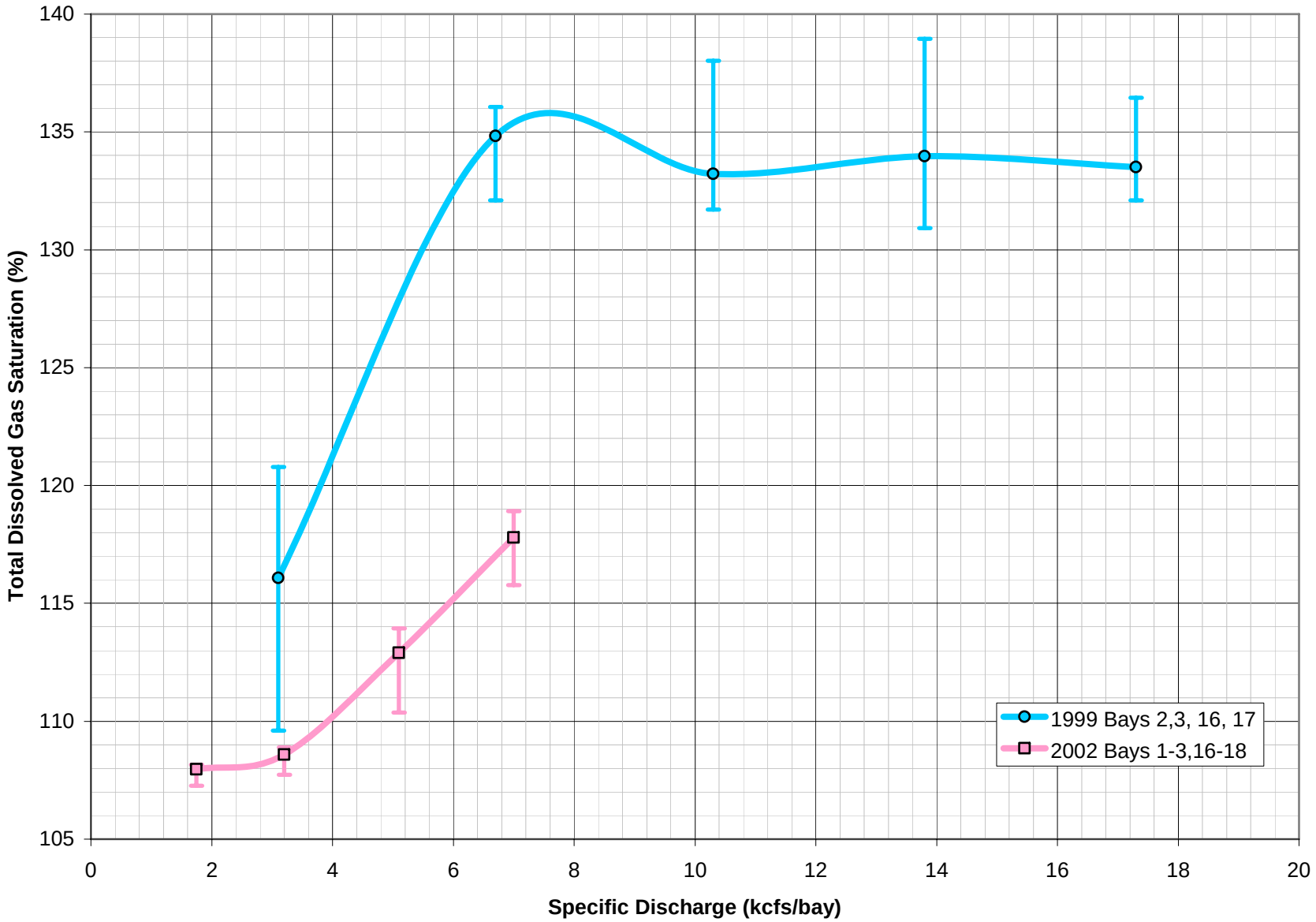
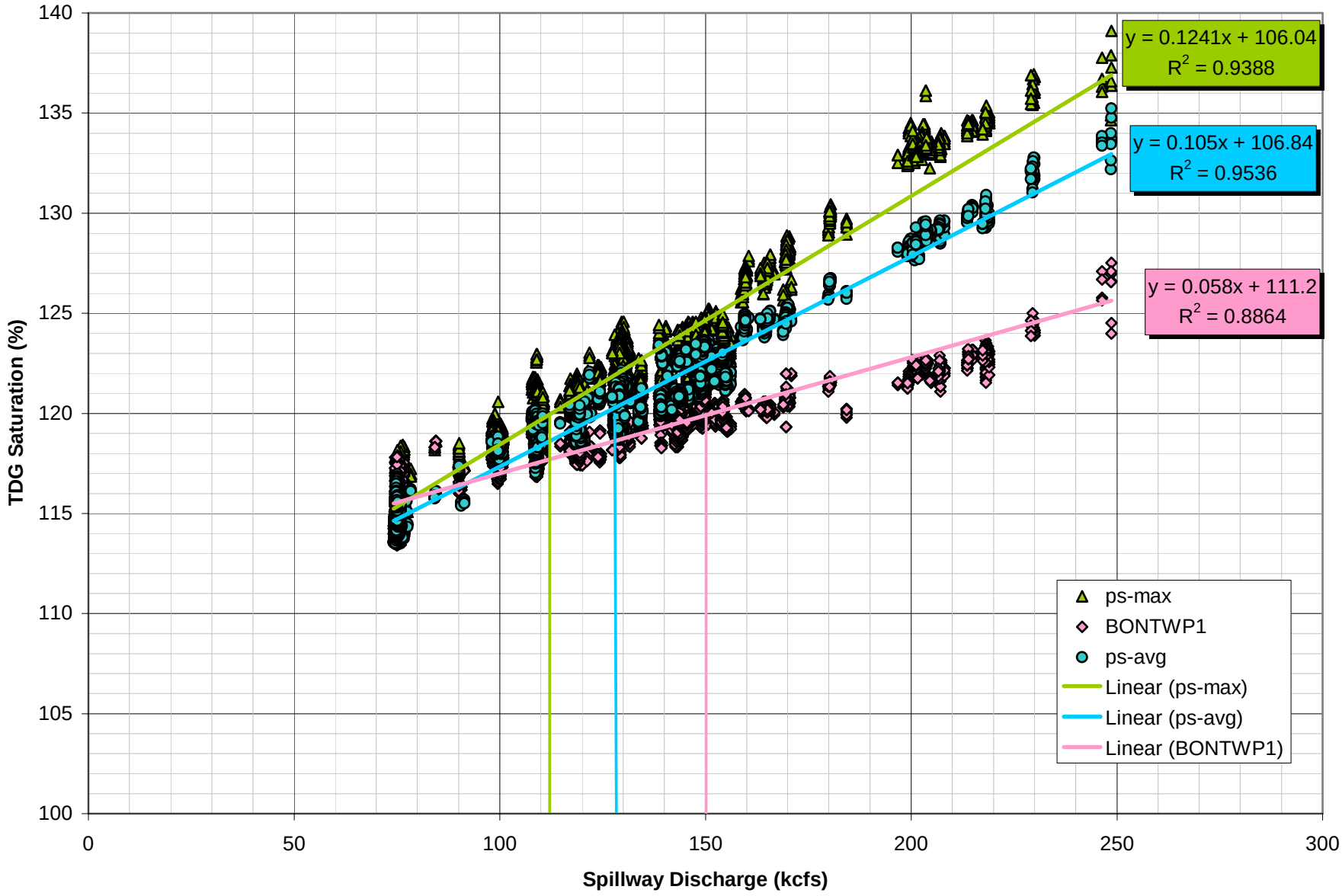
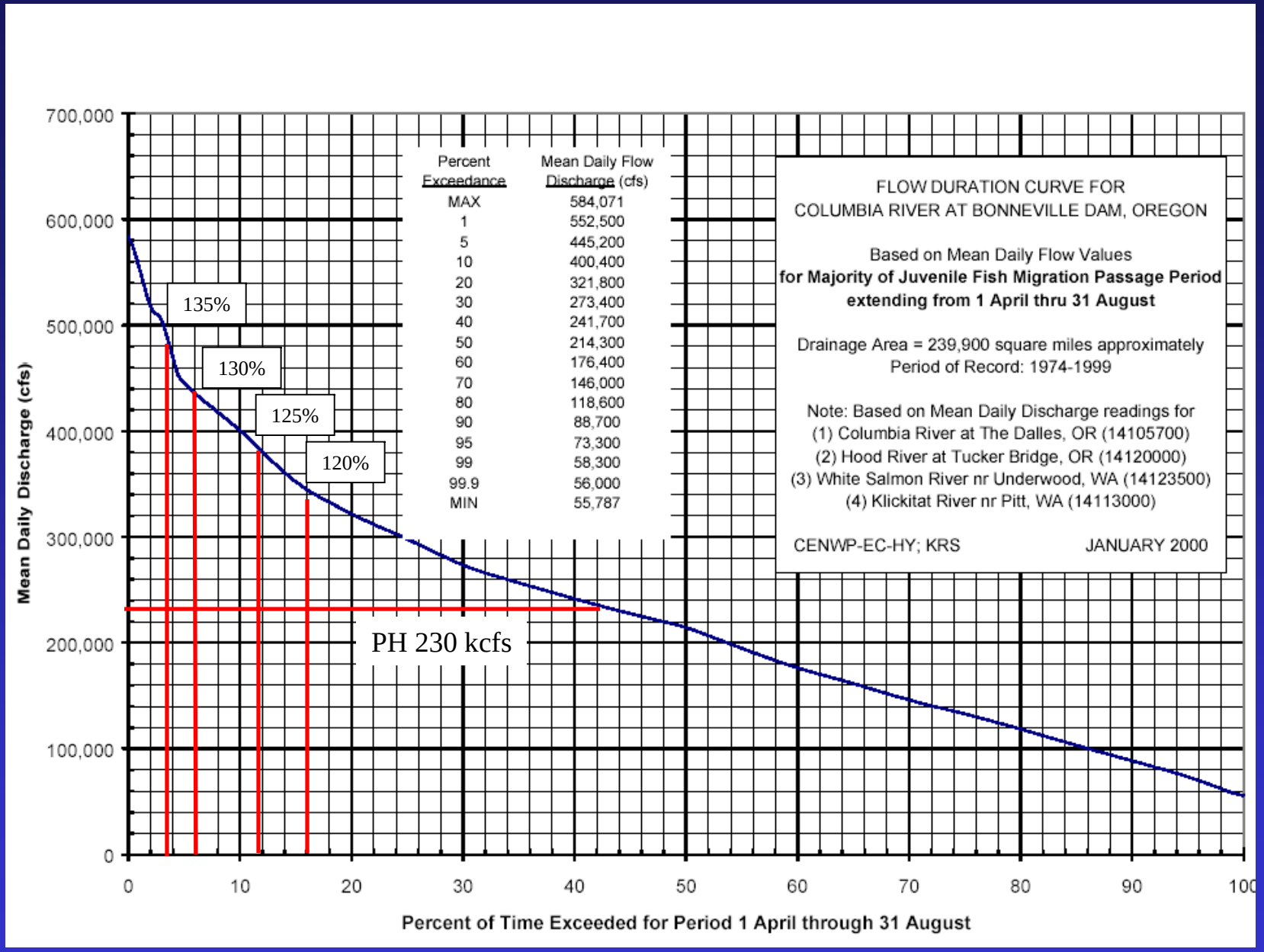


Figure 28. Total dissolved gas saturation as a function of specific spill discharge in the Bonneville spillway exit channel. (1999 – No deflectors, 2002 - El. 7 ft deflectors)



Total Dissolved Gas Saturation in the Bonneville spillway exit channel as a function of spillway discharge, April 10-June 5, 2002 (ps-max maximum cross sectional, ps-avg average cross sectional, BONTWP1-Bradford Island station)



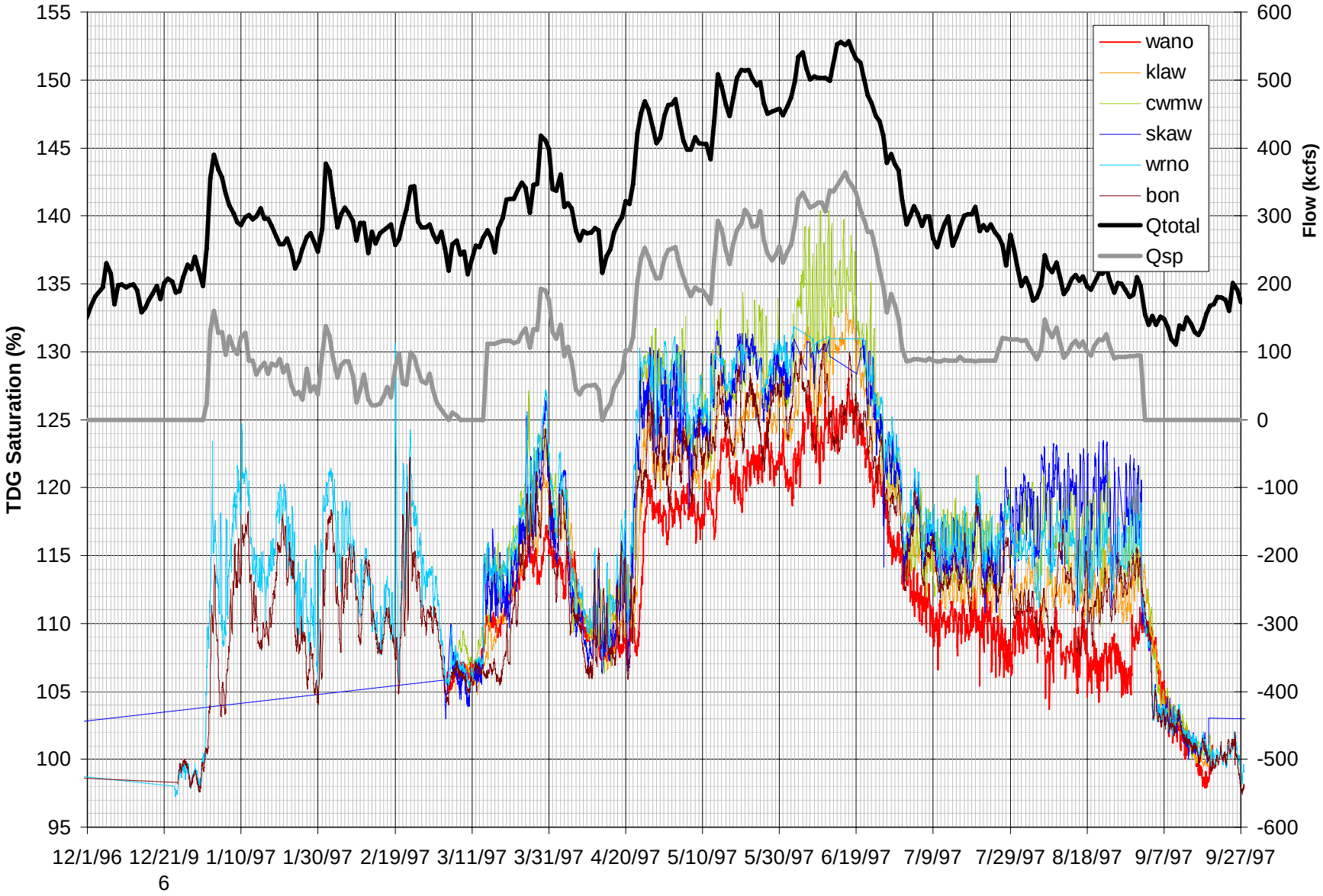
Flow duration for Columbia River at Bonneville Dam, Oregon 1 April through 31 August

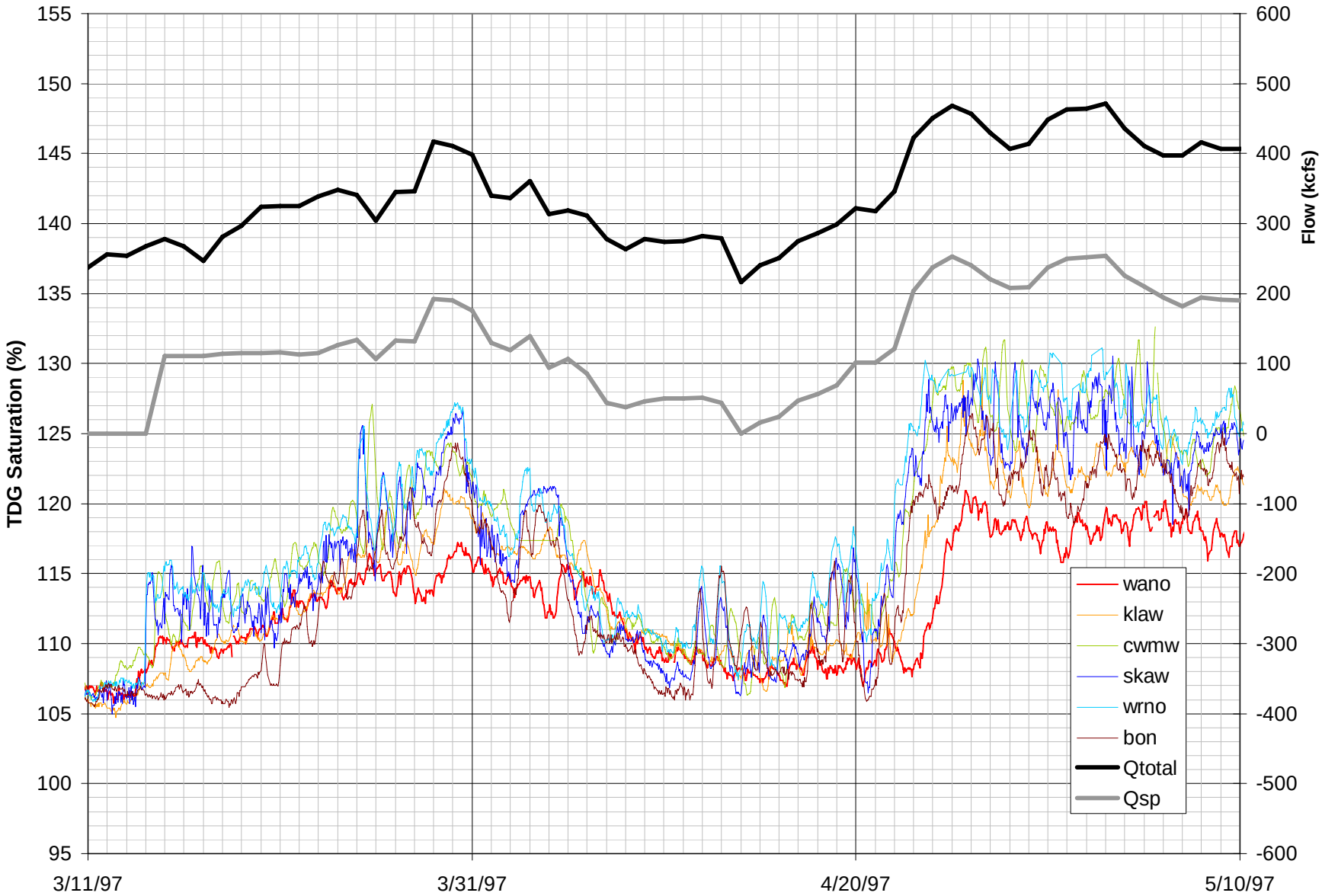
TDG Characterization of the Lower Columbia River

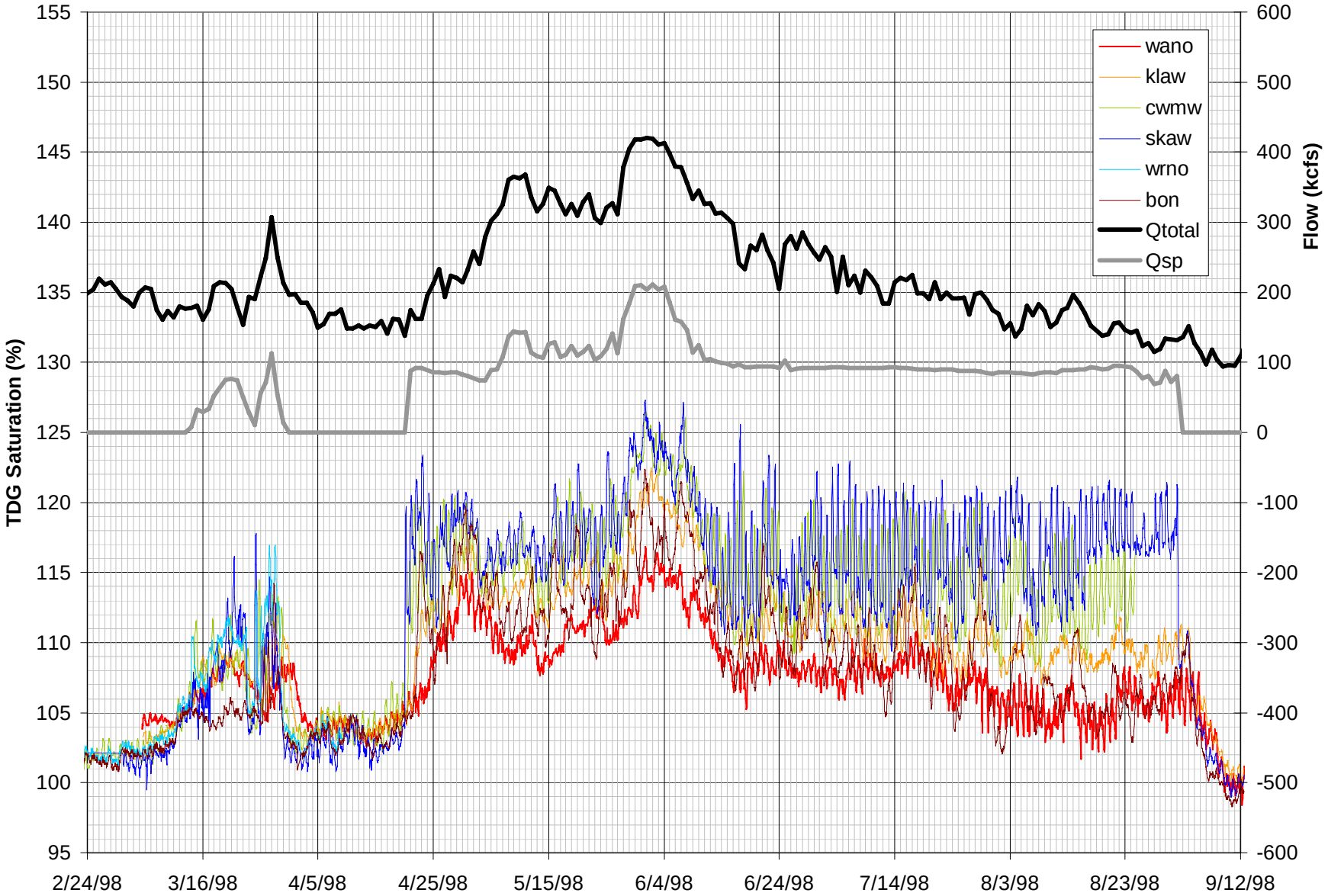
- TDG Saturation
  - Voluntary spill
    - TDG levels range from 110-120 %
  - Forced spill
    - TDG levels range from 120-130%
  - TDG Decreases with distance from Bonneville
    - Lose from 2-3% by CWMW rm 122
    - Rate of loss is a function of magnitude of TDG at Bonneville
      - First order exchange
    - Wind events can increase degassing
    - Temperature induced TDG variation
    - Biological Productivity DO induced TDG variation

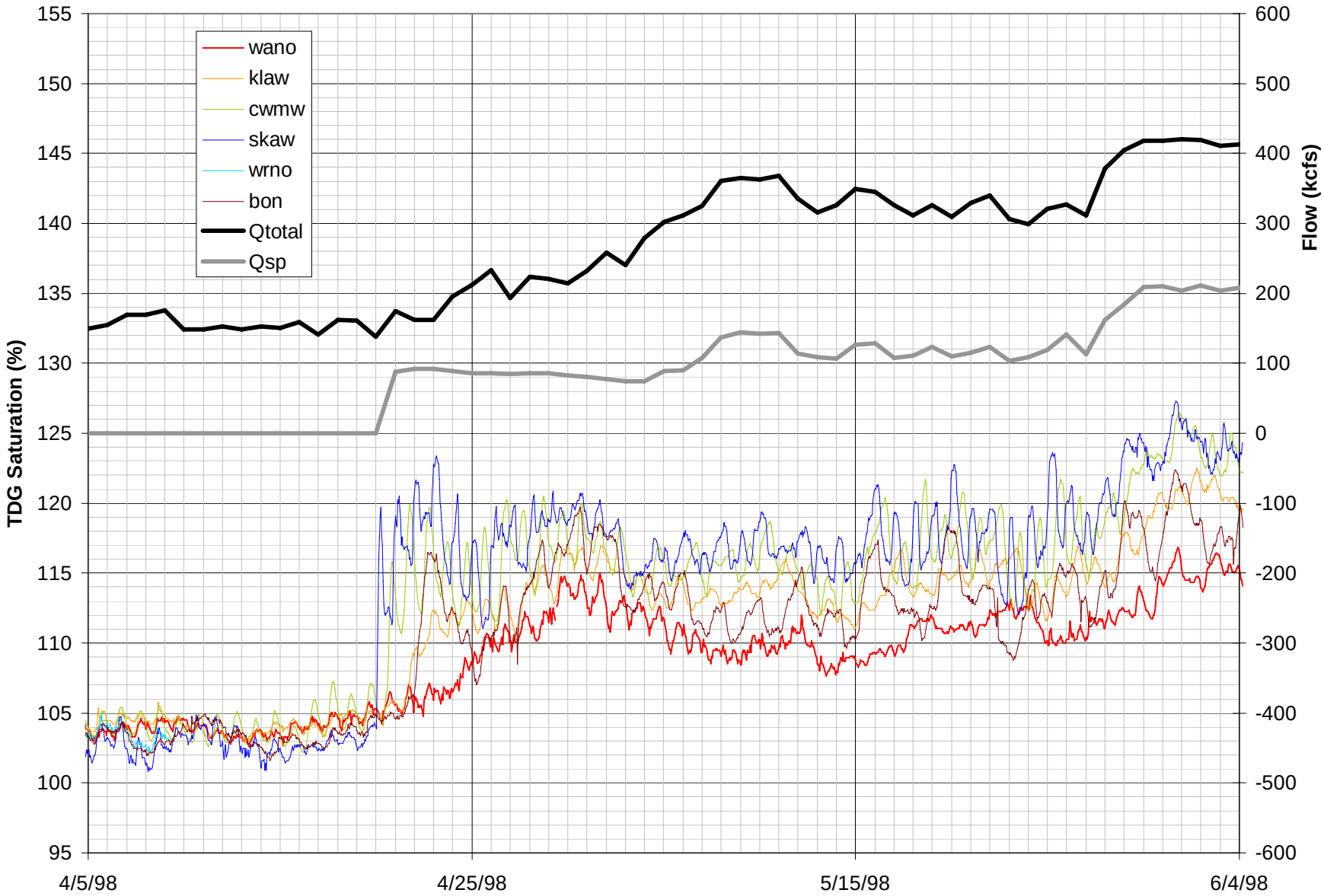
TDG Characterization of the Lower Columbia River

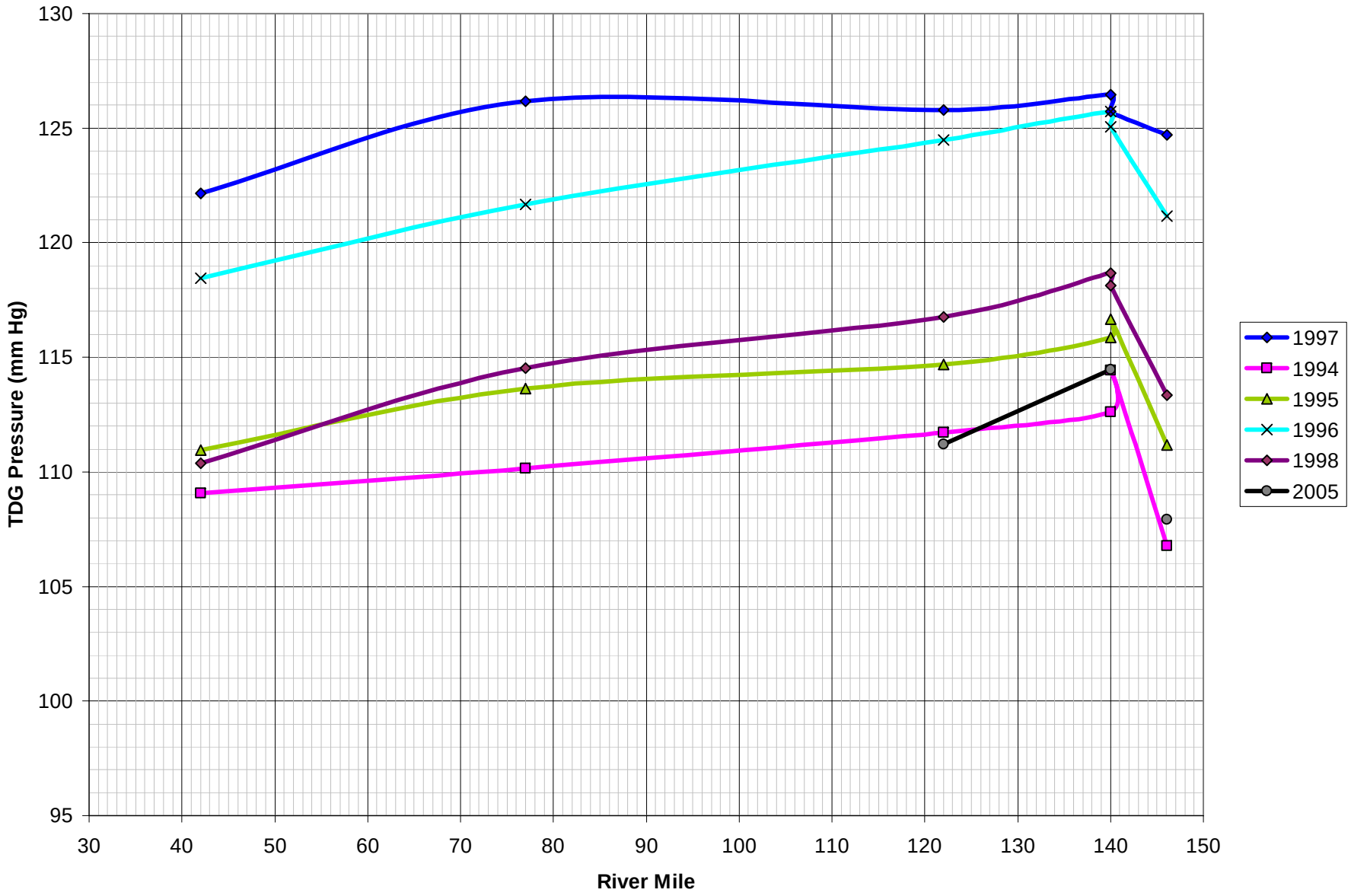
- TDG Saturation
  - Lateral TDG variation outside mixing zone is small
  - Temporal and spatial TDG variability is greatest just below the dam
  - Day / Night Spill policy generates fronts of elevated TDG saturation that propagate downstream
  - TDG content of powerhouse release mimic forebay TDG levels


TDG Saturation (%)
Flow (kcfs)
155
150
145
140
135
130
125
120
115
110
105
100
95
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
12/1/96
12/21/96
1/10/97
1/30/97
2/19/97
3/11/97
3/31/97
4/20/97
5/10/97
5/30/97
6/19/97
7/9/97
7/29/97
8/18/97
9/7/97
9/27/97
wano
klaw
cwmw
skaw
wrno
bon
Qtotal
Qsp

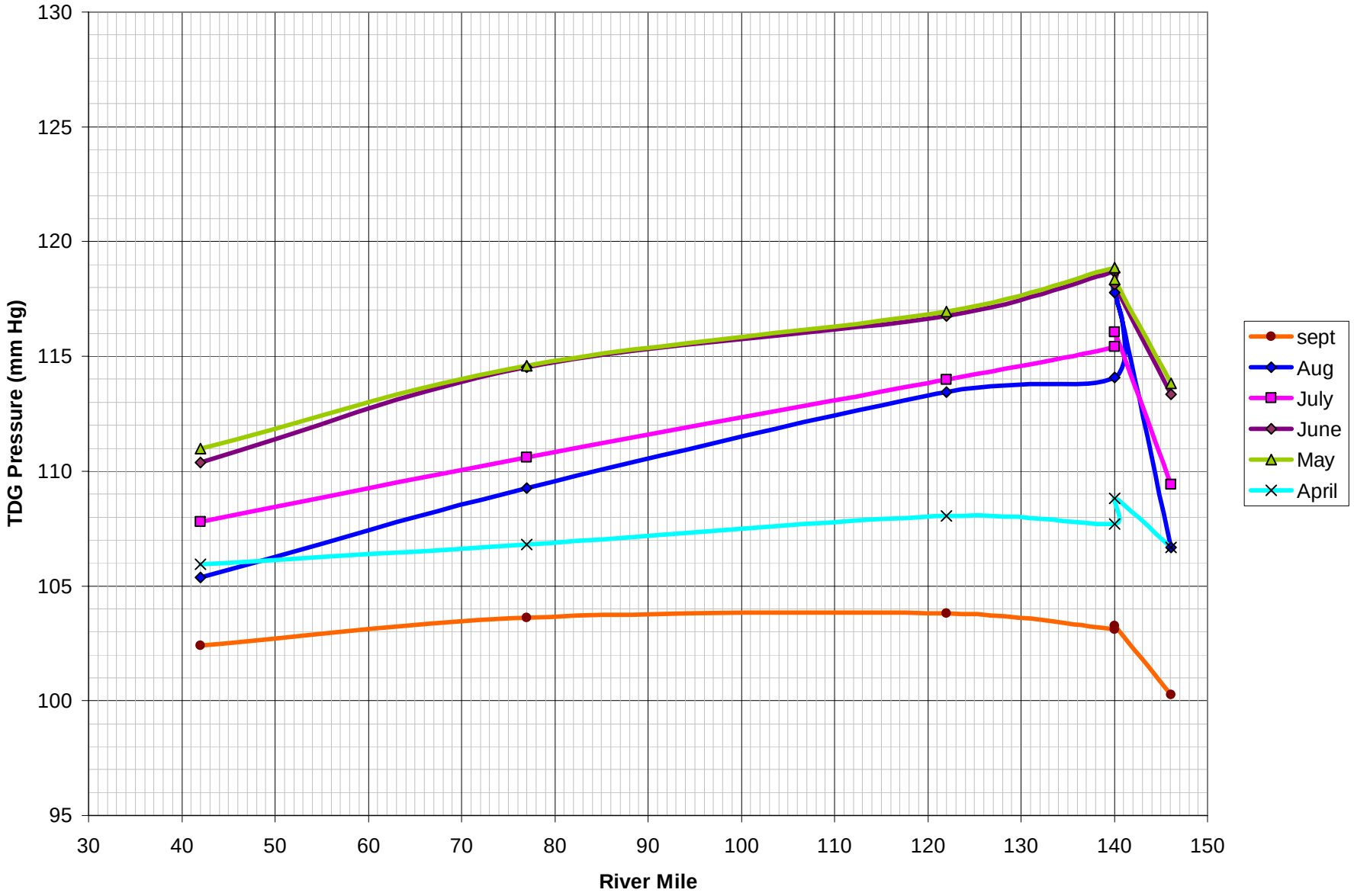

TDG Saturation (%)
Flow (kcfs)
155
150
145
140
135
130
125
120
115
110
105
100
95
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
3/11/97
3/31/97
4/20/97
5/10/97
wano
klaw
cwmw
skaw
wrno
bon
Qtotal
Qsp


TDG Saturation (%)
Flow (kcfs)
155
150
145
140
135
130
125
120
115
110
105
100
95
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
2/24/98
3/16/98
4/5/98
4/25/98
5/15/98
6/4/98
6/24/98
7/14/98
8/3/98
8/23/98
9/12/98
wano
klaw
cwmw
skaw
wrno
bon
Qtotal
Qsp

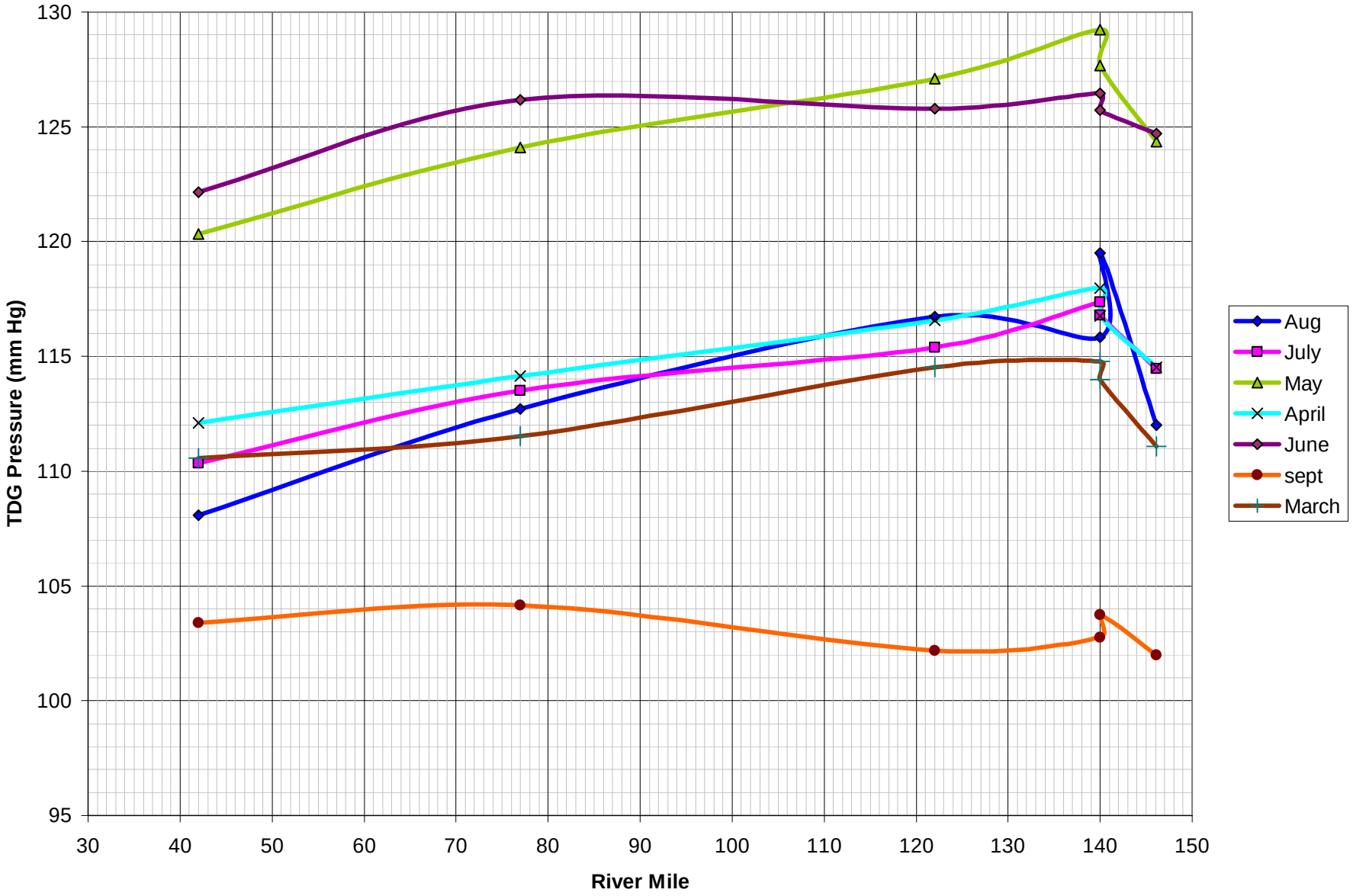

wano
klaw
cwmw
skaw
wrno
bon
Qtotal
Qsp
TDG Saturation (%)
Flow (kcfs)
155
150
145
140
135
130
125
120
115
110
105
100
95
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
4/5/98
4/25/98
5/15/98
6/4/98



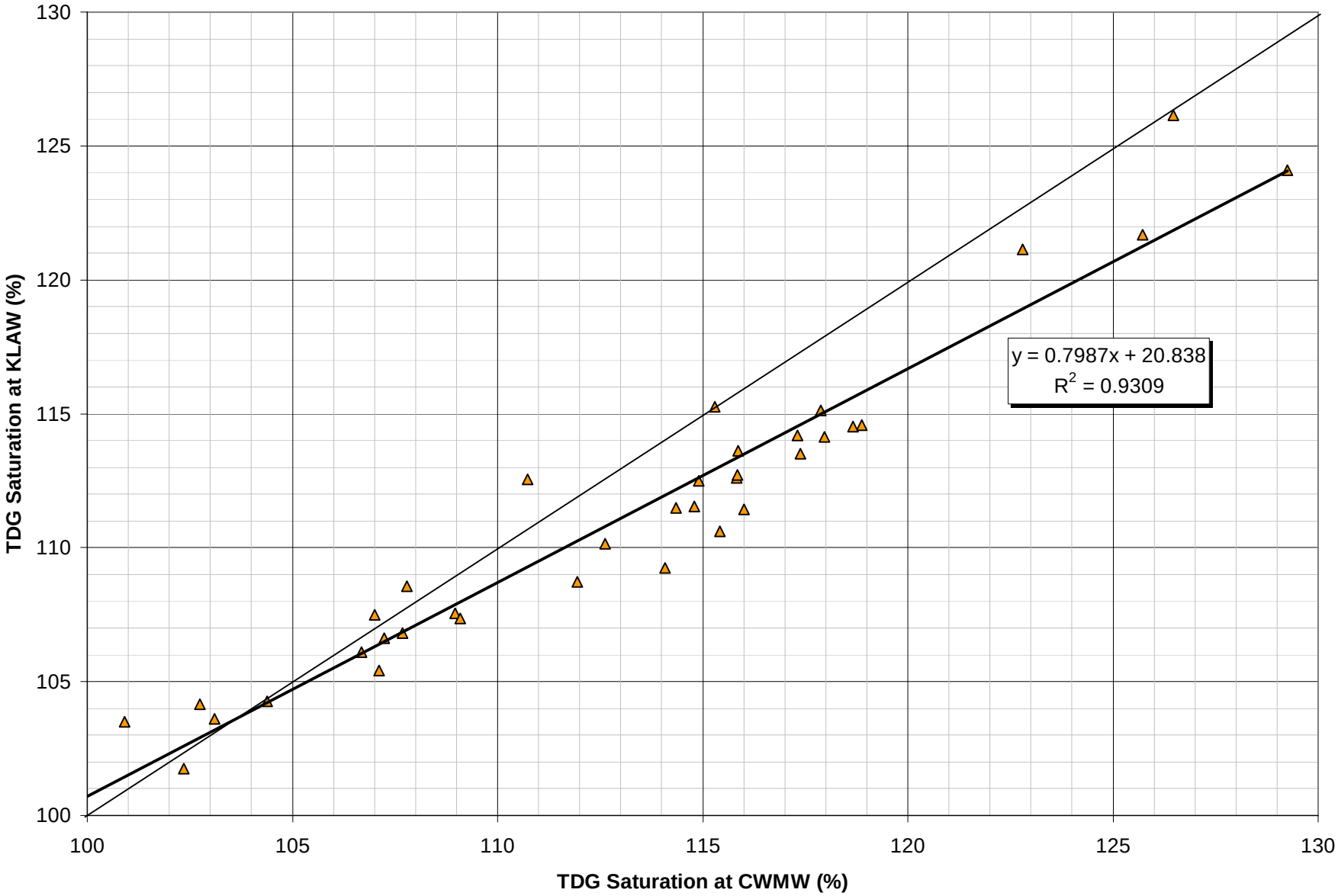
Columbia River Mile 42-145 Monthly Average TDG Saturation for June 1994-2005



Columbia River Mile 42-145 average monthly TDG saturation for 1998



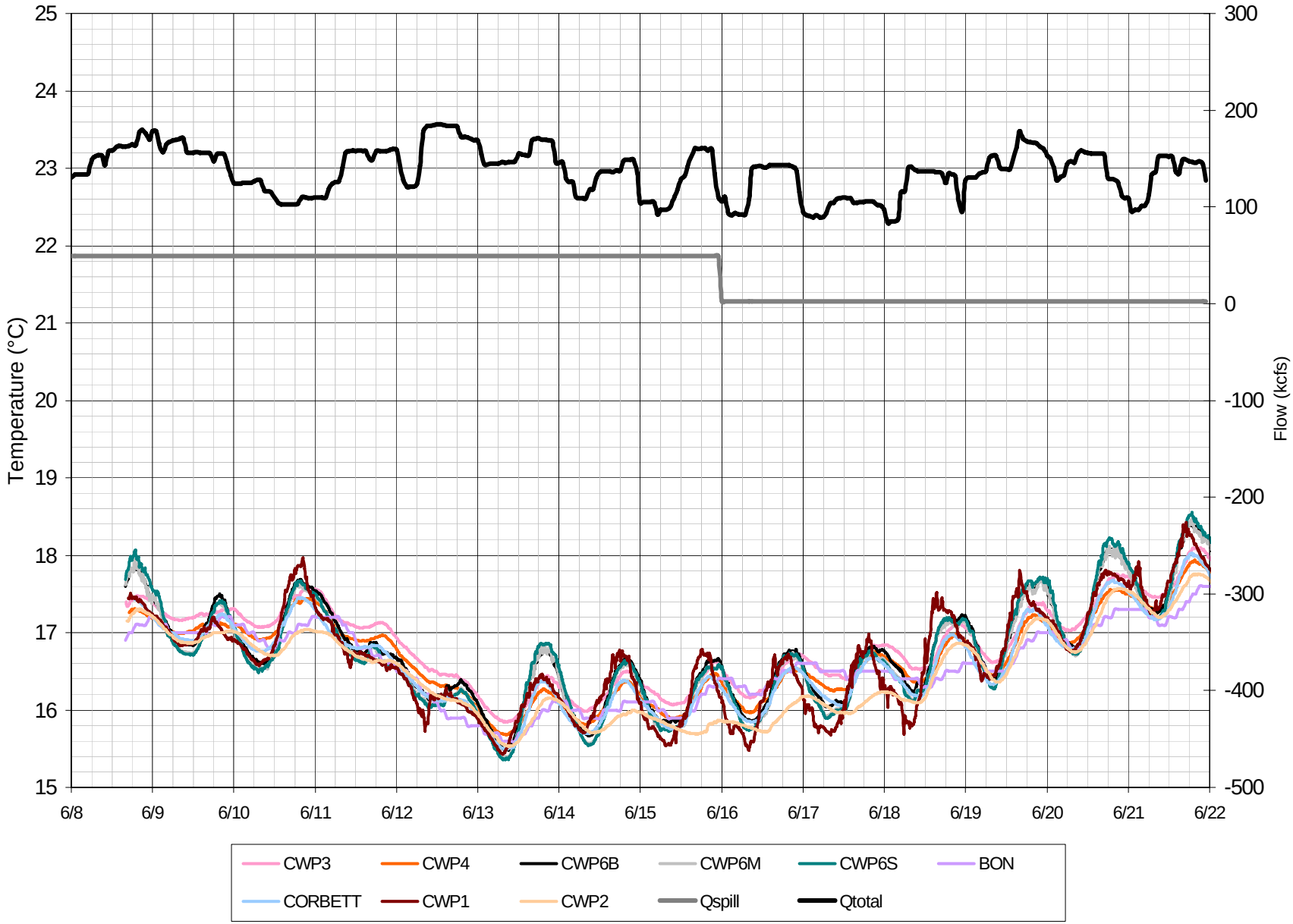
Columbia River Mile 42-145 average monthly TDG saturation for 1997

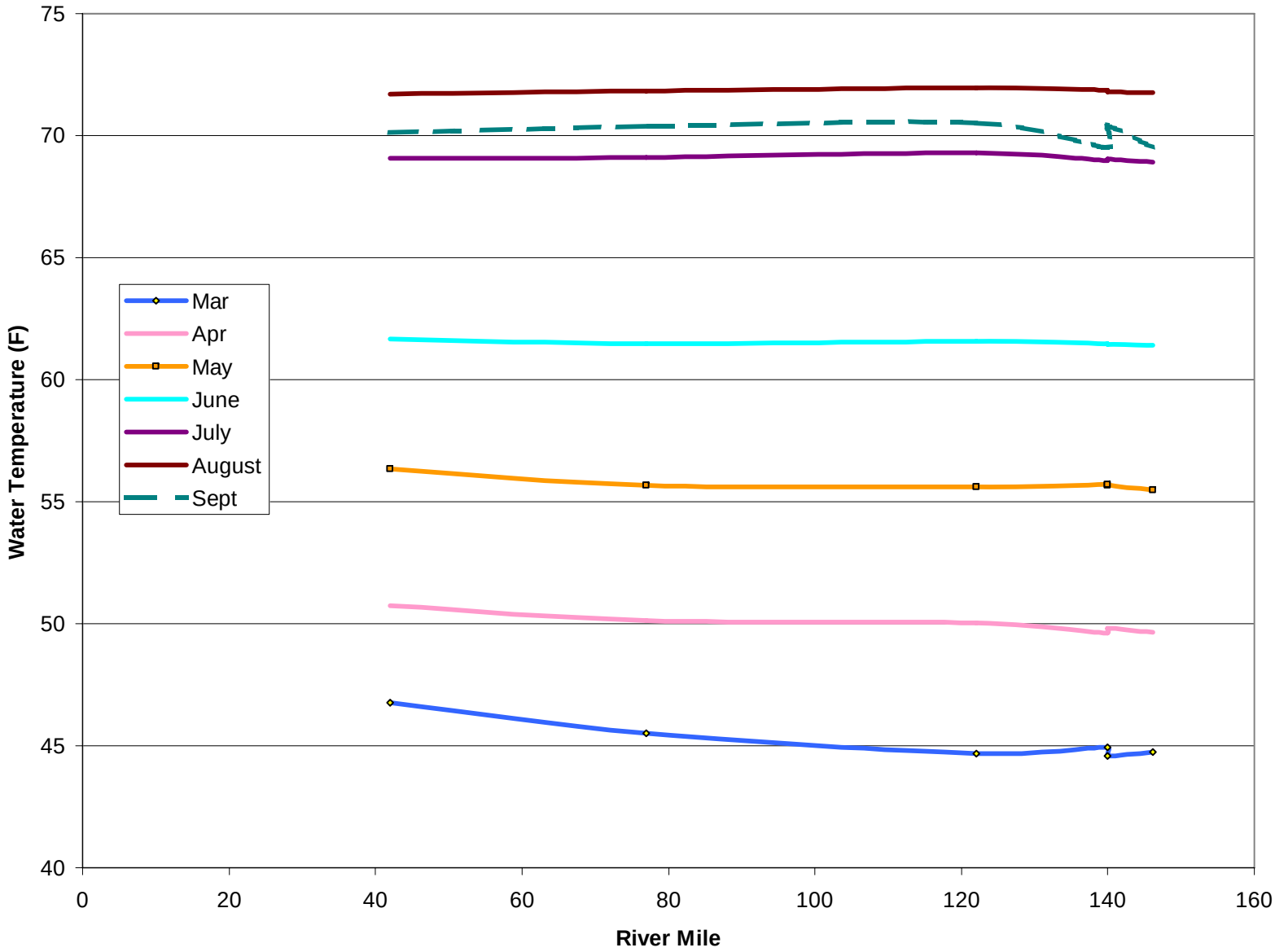


Monthly Average TDG Saturation at CWMW vs KLAW

TDG Characterization of the Lower Columbia River

- Water Temperature
  - Gas Laws
    - 1 C change in Temperature can cause a 2-3% change in TDG pressure
  - Temperature of CR does respond to daily thermal inputs
    - Daily temperature range can be 2-3 C
  - Water Temperature change is small from Bonneville to Wauna Mill (monthly trends)
  - Tributary temperatures were not reviewed

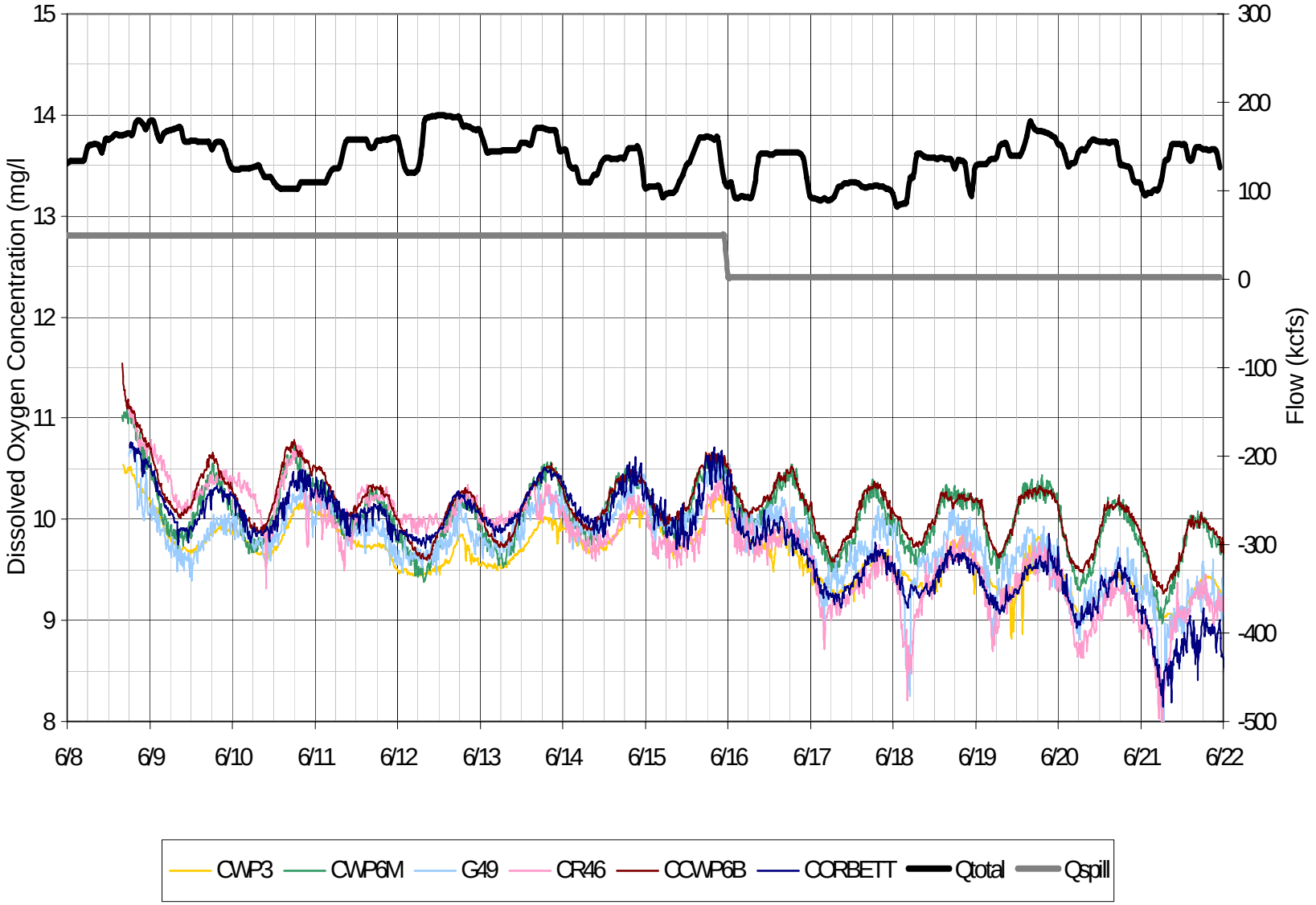

Temperature (°C)
Flow (kcfs)
25
24
23
22
21
20
19
18
17
16
15
300
200
100
0
-100
-200
-300
-400
-500
6/8
6/9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
6/18
6/19
6/20
6/21
6/22
CWP3
CWP4
CWP6B
CWP6M
CWP6S
BON
CORBETT
CWP1
CWP2
Qspill
Qtotal



Columbia River Mile 42-145 monthly average temperatures from March-September 2005

TDG Characterization of the Lower Columbia River

- Dissolved Oxygen
  - Gas Laws
    - 1 mg/l change in DO can cause a 2% change in TDG pressure
  - Typical daily DO variation is from 0.4-0.8 mg/l
  - DO content in spill is under represented compared to atmospheric ratios


Dissolved Oxygen Concentration (mg/l
Flow (kcfs)
15
14
13
12
11
10
9
8
300
200
100
0
-100
-200
-300
-400
-500
6/8
6/9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
6/18
6/19
6/20
6/21
6/22
CWP3
CWP6M
G49
CR46
CCWP6B
CORBETT
Qtotal
Qspill

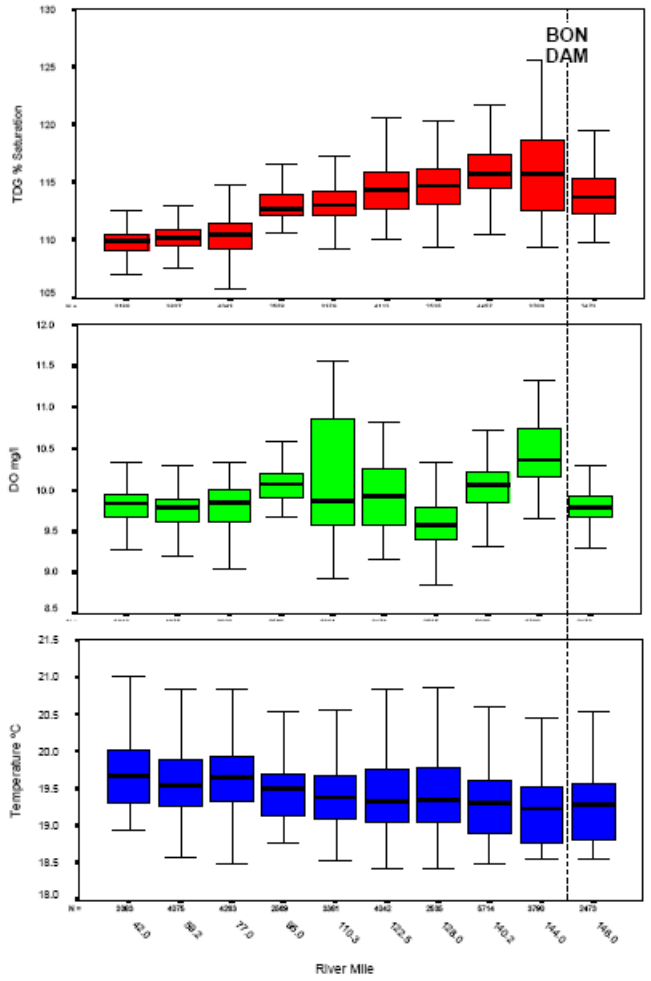
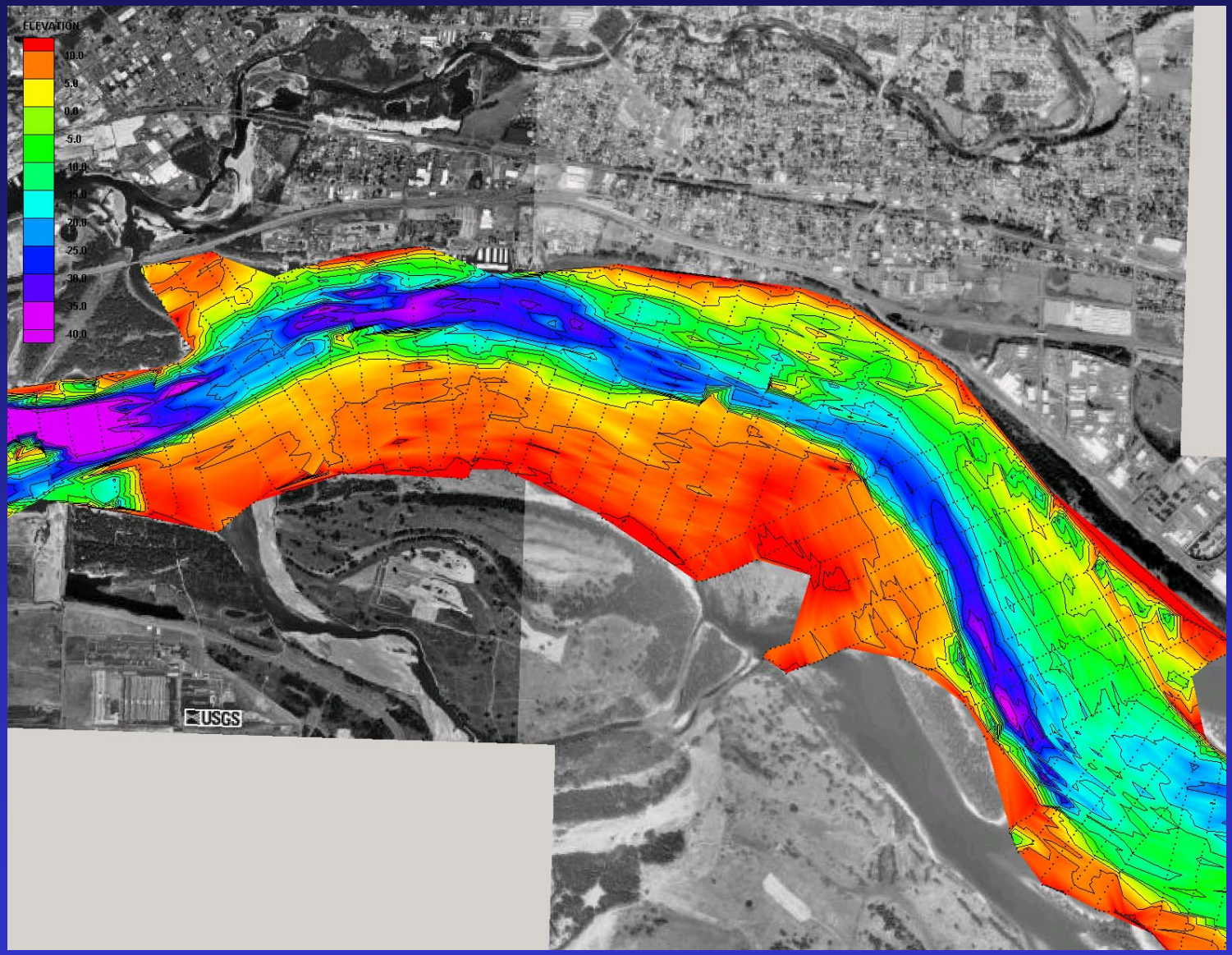


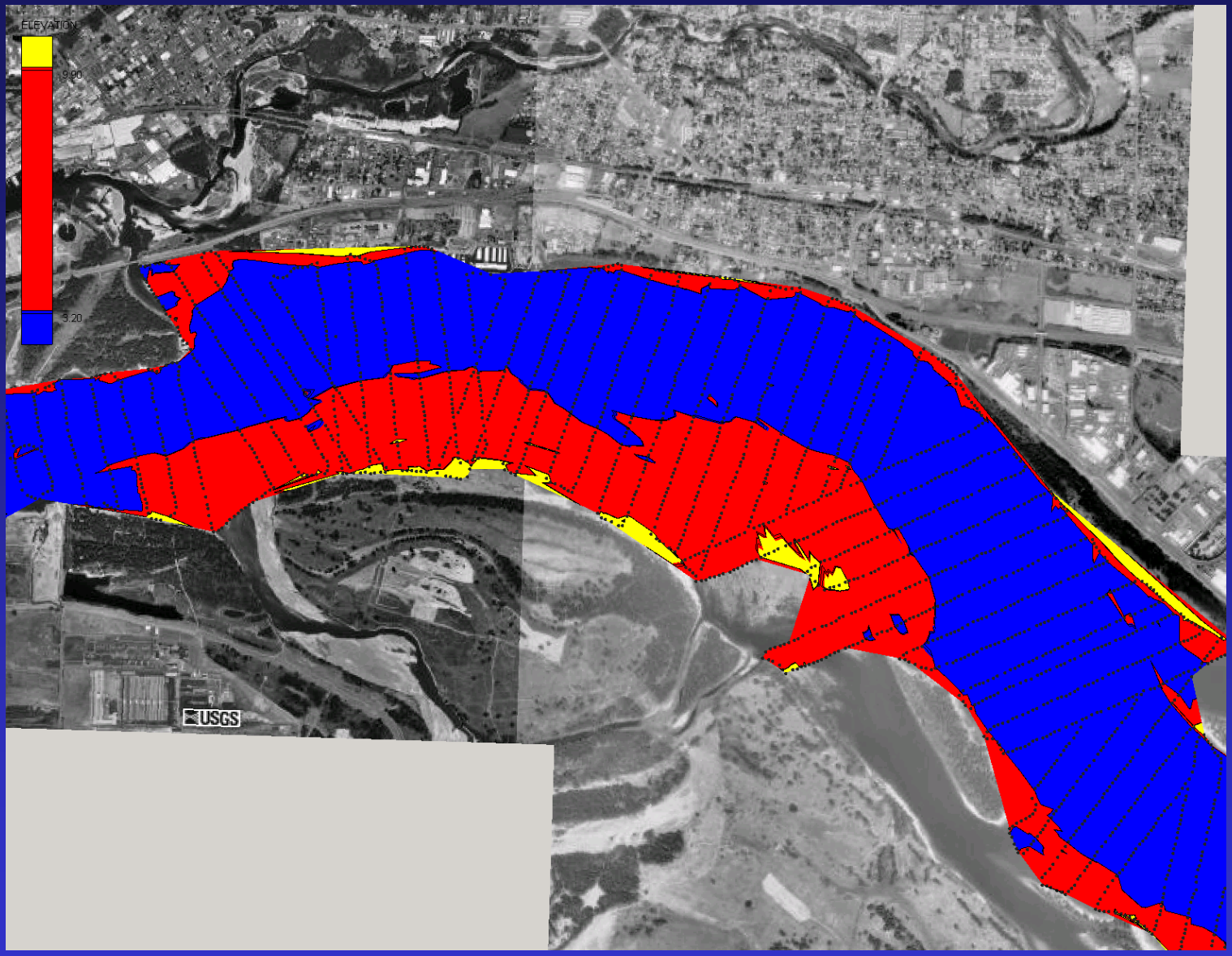
Figure F4-26. Tidal Pool (14 - 30 JULY 97)

TDG Characterization of the Lower Columbia River

- TDG Habitat
  - Depth Compensation
    - TDG pressure = Total Pressure=P_{atm}+$P_{hydrostatic}$
    - Substrate below compensation depth is protected
  - Shallow habitat is at greater risk
    - Compare percent habitat exposed to supersaturated conditions
      - 115 % saturation = 5 ft of depth
      - CR near CWMW 21% river is above depth of compensation
      - CR upstream Bon 8% river isl above depth of compensation
  - TDG Hazard Delineation
    - Channel configuration
    - River stage
    - TDG pressure
    - Map of substrate dewatered, above depth of compensation, below depth of compensation



Camas/Washougal rm 122



TDG hazard map for TDG=115% near Camas/Washougal Blue-below CD Yellow-dewatered Red-above CD

TDG Characterization of the Lower Columbia River

- Conclusions
- Recommendations
  - Develop better understanding of TDG management in critical habitat areas
    - Powerhouse 2 versus 1 operation
    - Spill pattern modification to generate less TDG
    - Water stage, Bathymetry, TDG interaction