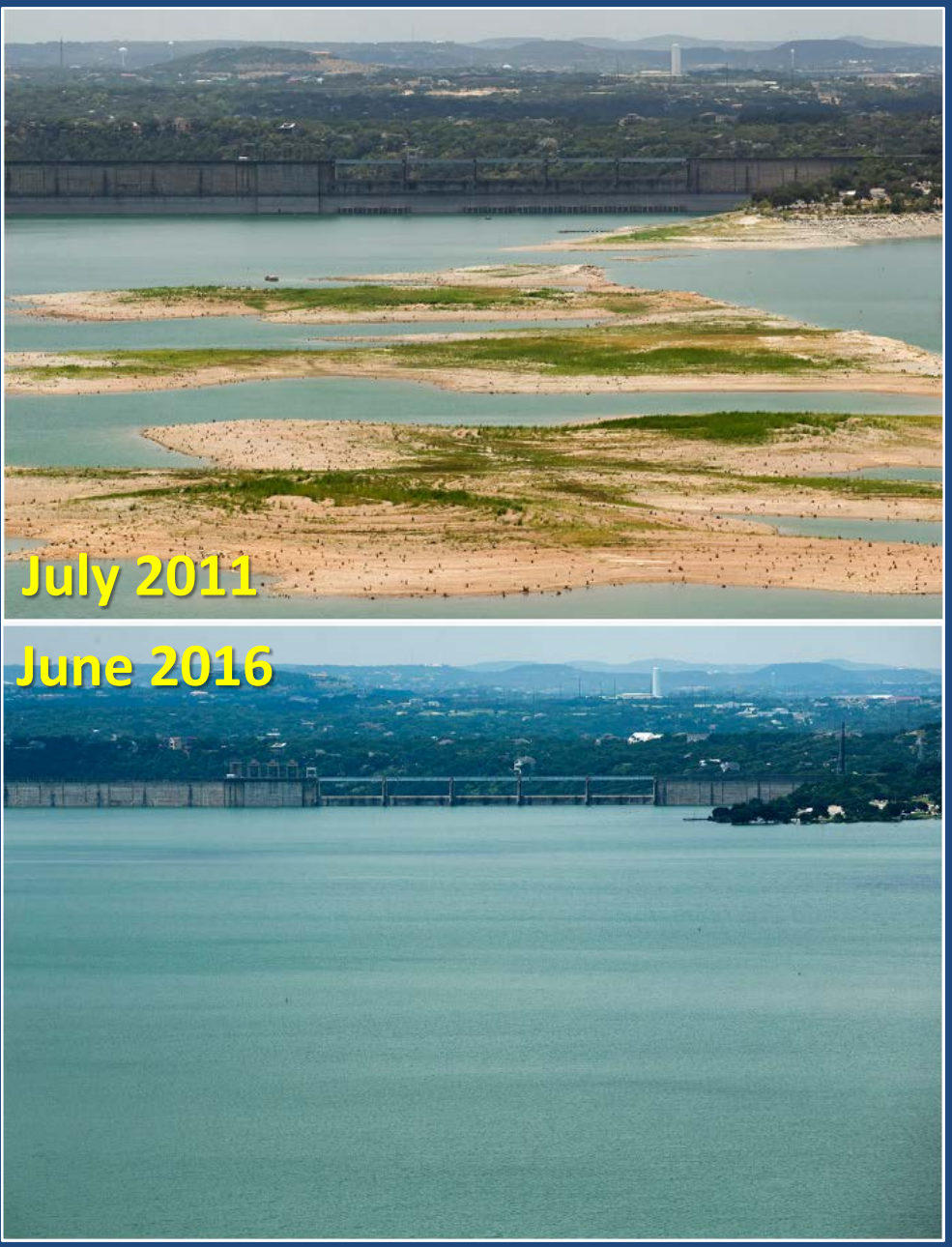

Lake Travis - drought impacts on reservoir level

Incorporating Drought Evaluations in the Integrated Report for Clean Water Act Sections 305(b) and 303(d)

Sarah Whitley

Texas Commission on Environmental Quality
Surface Water Quality Monitoring Team

Guidance Advisory Workgroup Meeting
August 24, 2018

Outline

- Revisit Drought Severity Index Scores (DSI)
- Incorporating drought evaluations
  - Methods tested and used for 2016 Integrated Report
- Drought in reservoirs
  - Discussion items
    - Onset of drought
    - Conclusion of drought
    - Data exclusion for drought period
    - Water quality data evaluation
- Drought in large rivers

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National Drought Mitigation Center

National Drought Mitigation Center (NDMC) based in the School of Natural Resources at the University of Nebraska-Lincoln (UNL).

NDMC partner entities include:

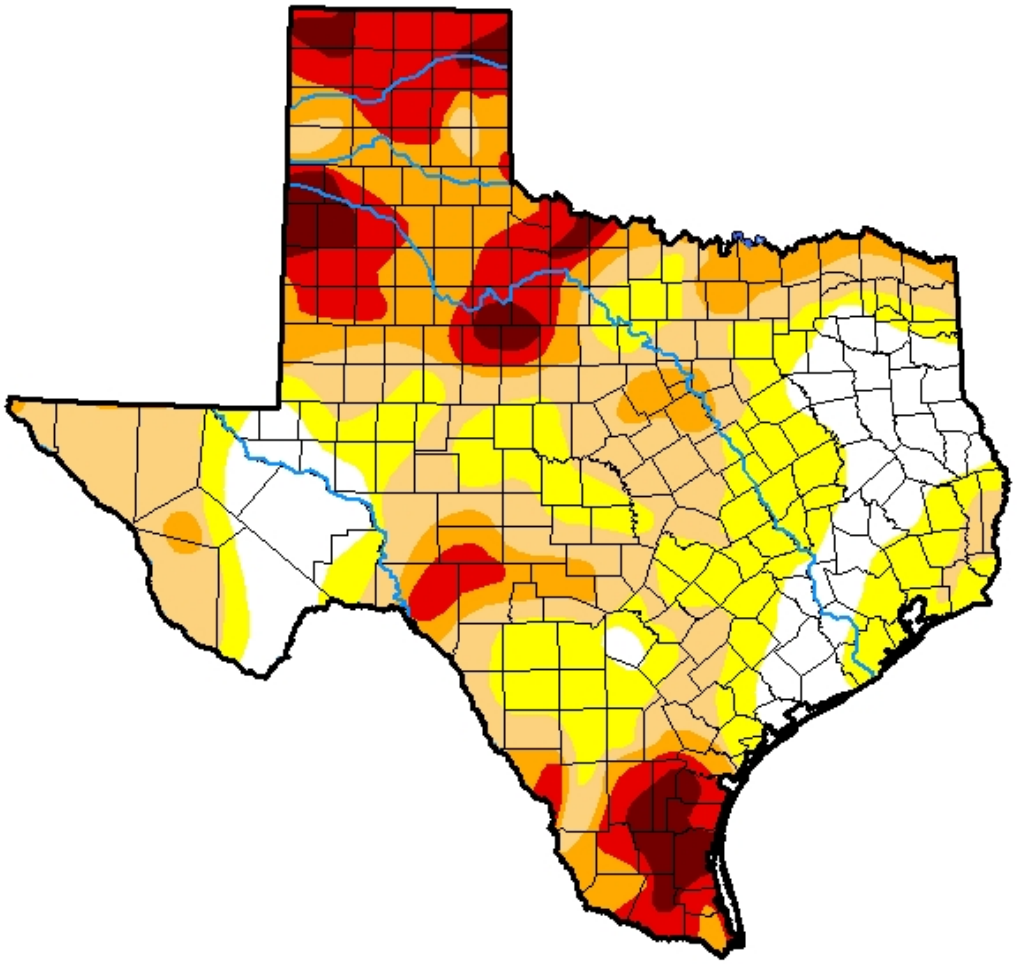
- National Integrated Drought Information System (NIDIS)
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Department of Agriculture (USDA)
- U.S. Geological Survey (USGS)
- National Climatic Data Center (NDMC)
- National Weather Service (NWS)

MISSION: The National Drought Mitigation Center (NDMC) helps people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management.

U.S. Drought Monitor Classification Scheme: Drought Severity Index

			Ranges				
Category	**Description**	**Possible Impacts**	**Palmer Drought Index**	**CPC Soil Moisture Model (Percentiles)**	**USGS Weekly Streamflow (Percentiles)**	**Standardized Precipitation Index (SPI)**	**Objective Short and Long-term Drought Indicator Blends (Percentiles)**
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

U.S. Drought Monitor
Texas



November 6, 2012
(Released Thursday, Nov. 8, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0	D1	D2	D3	D4
Current	15.44	24.65	26.35	16.57	12.30	4.68
Last Week *10-30-2012*	15.36	26.78	26.24	15.38	12.56	3.67
3 Months Ago *08-07-2012*	11.39	13.40	35.25	29.10	10.11	0.75
Start of Calendar Year *01-03-2012*	0.01	2.15	13.02	17.48	34.92	32.40
Start of Water Year *09-25-2012*	9.13	12.13	21.32	32.51	19.72	5.18
One Year Ago *11-08-2011*	0.00	0.00	1.92	7.77	24.49	65.82

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
David Miskus
NOAA/NWS/NCEP/CPC

USDA · National Drought Mitigation Center · NOAA

http://droughtmonitor.unl.edu/

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Incorporating Drought Evaluations

- Appendix E incorporated in the 2014 Guidance for Assessment

- Identifying candidate impairments to better characterize drought impacts using the 2014 IR

Exploratory Statistical Analysis

- Can we detect a quantifiable relationship between the DSI Scores and Surface Water Quality Monitoring Data?

Candidate Waterbodies

- Waterbody Selection
  - Adequate data for 305(b) Assessment
  - Segments listed as Category 5 for Dissolved Solids in the 2016 IR
  - Not previously listed for dissolved solids

- Diversion Lake
- Mackenzie Reservoir
- Bardwell Reservoir
- Elm Fork Trinity River below Lewisville Lake
- Nolan River
- White River Lake
- Frio River above Choke Canyon Reservoir
- Red Bluff Reservoir

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Candidate Waterbodies

- ANOVA
  - Meet assumption of equal variances
  - Significant result ($p < 0.05$)
  - Tukey's test successful


Mackenzie Reservoir

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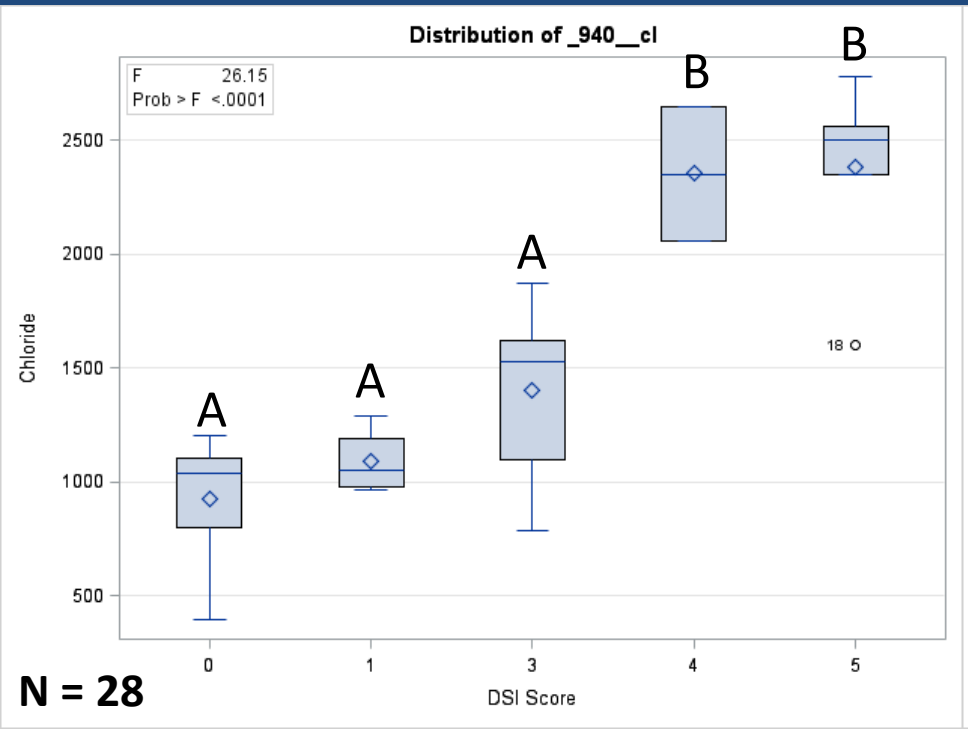
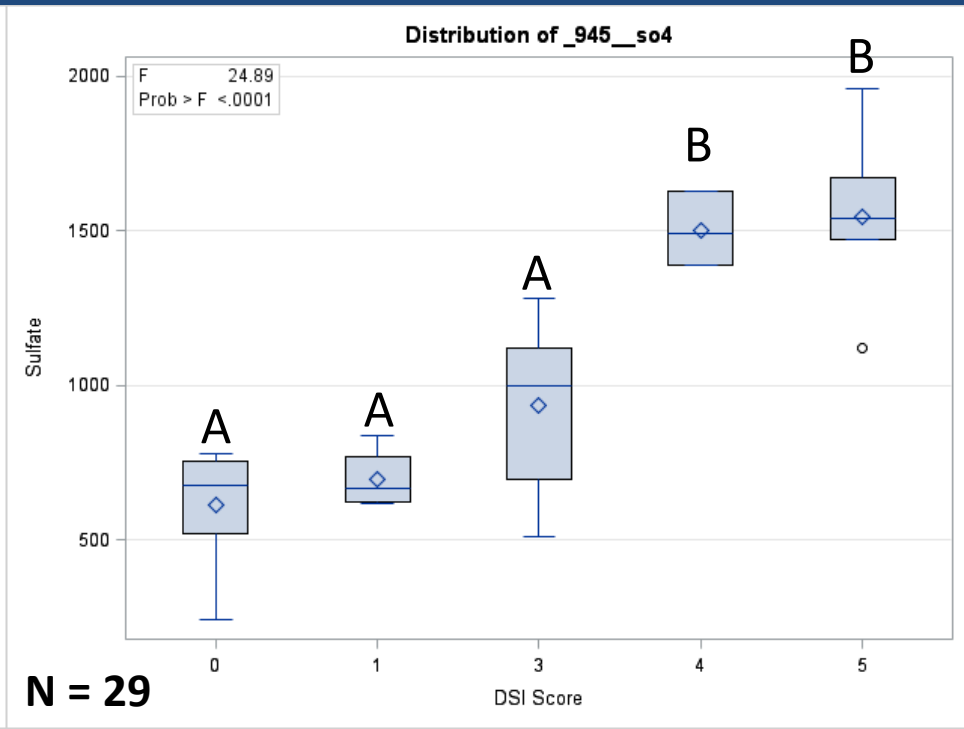
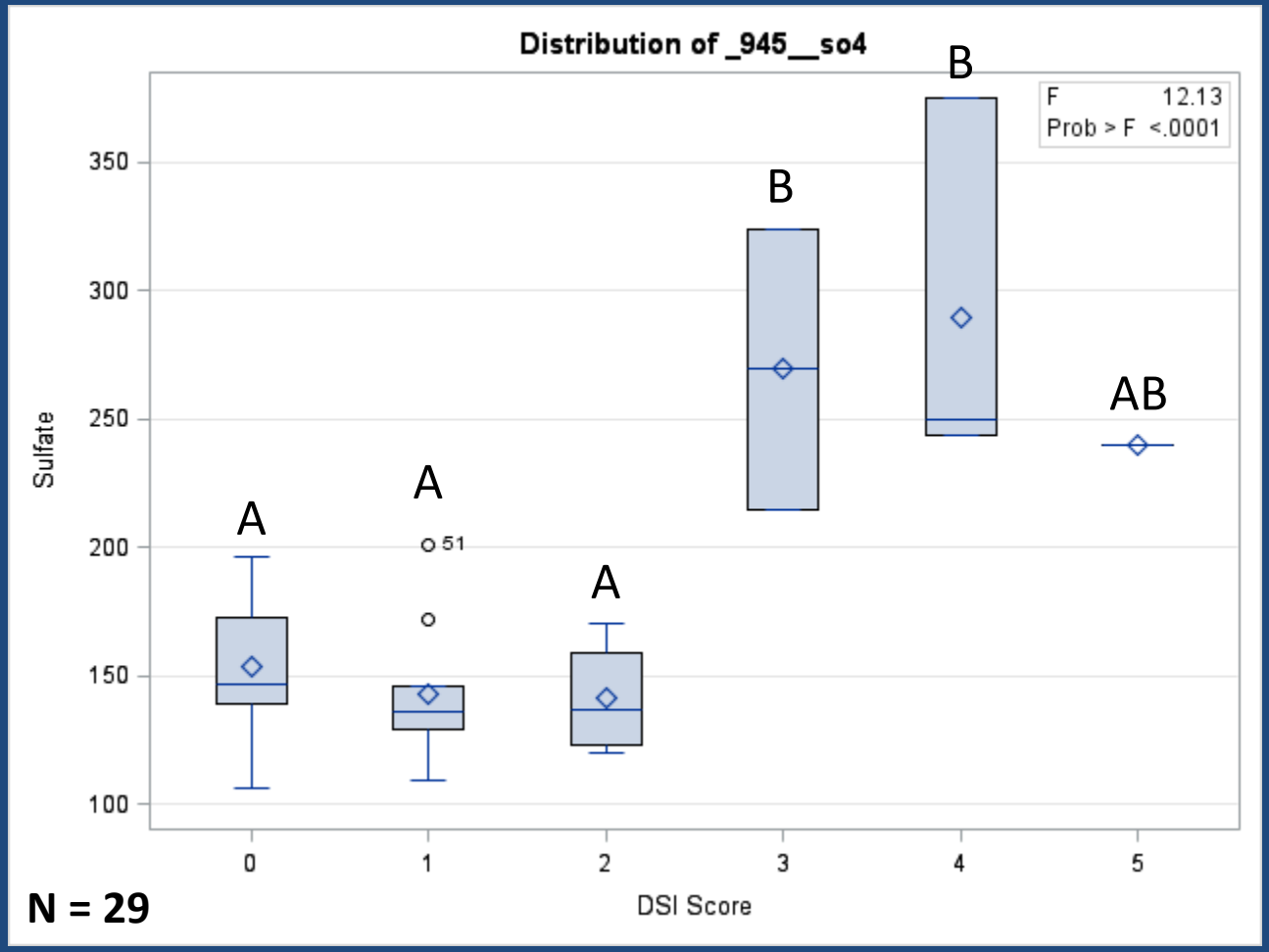
ANOVA Results: Diversion Lake

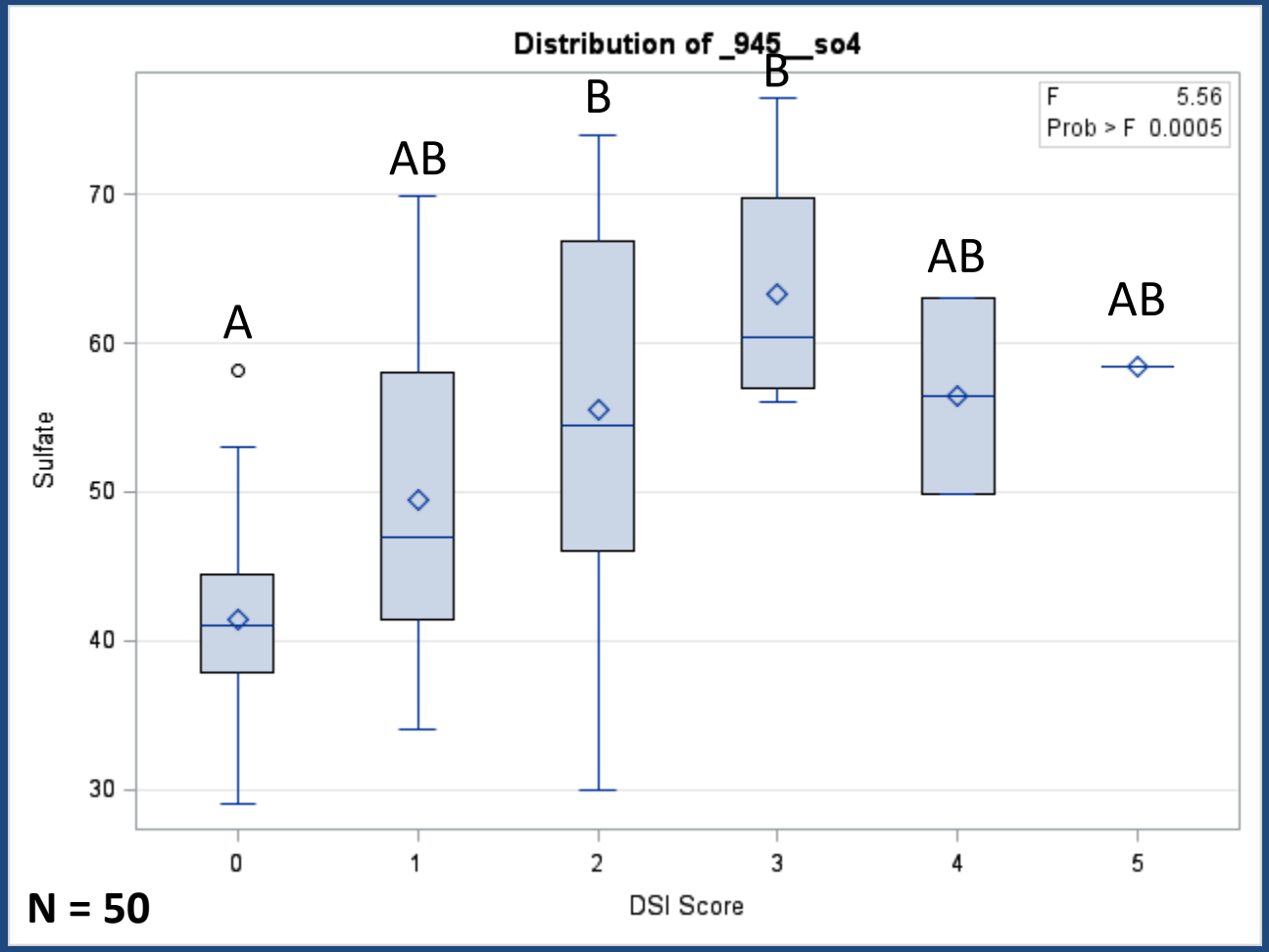




ANOVA Results: Mackenzie Reservoir



ANOVA Results: Bardwell Reservoir



Preliminary Drought Methods

- ANOVAs provided marginal results
  - Potential interpretation errors
  - Some water quality datasets are small
  - Few quantitative factors
- Focus efforts on reservoirs

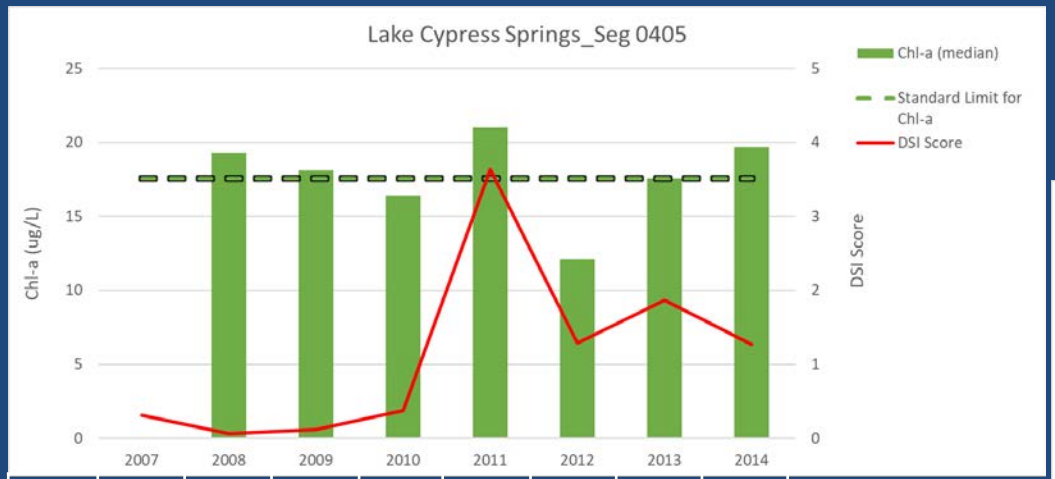
Reservoir Nutrients in 2016 IR

- Recently developed nutrient criteria using a line of evidence approach
- Applied ANOVAs to new nutrient impairments in reservoirs
  - DSI
  - Chlorophyll *a*
  - Reservoir level

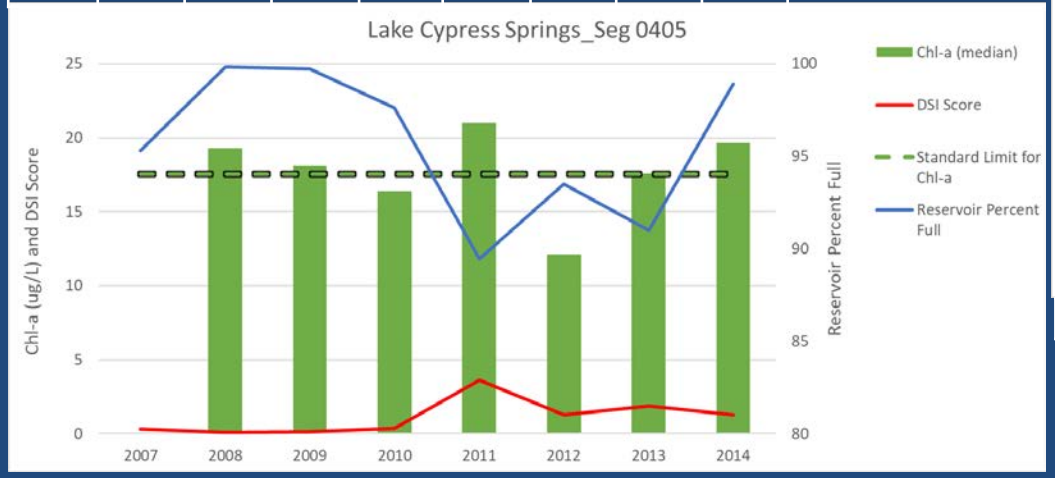
Candidate Waterbodies:

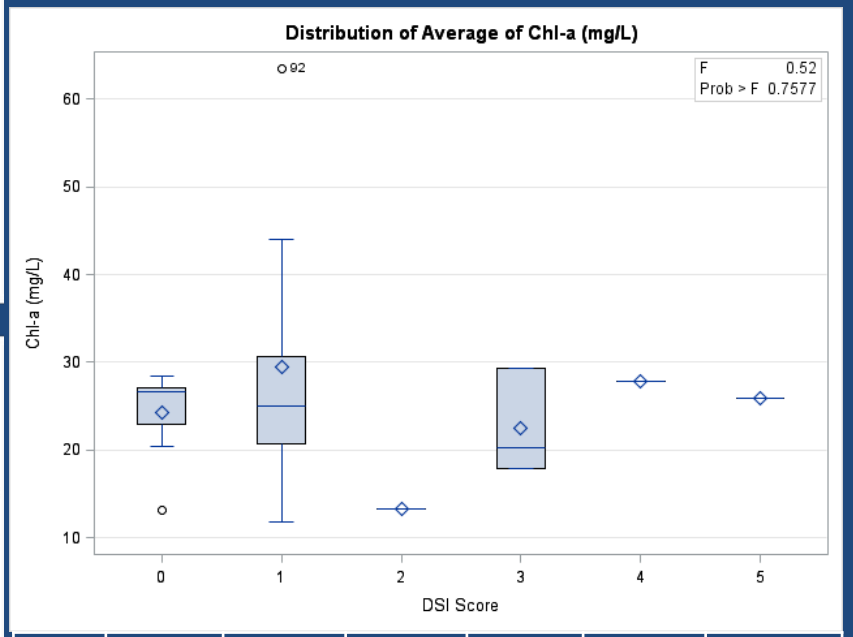
- Lake Cypress Springs
- Hubbard Creek Reservoir
- White River Lake
- Lake Coleman
- Choke Canyon Reservoir

Lake Cypress Springs



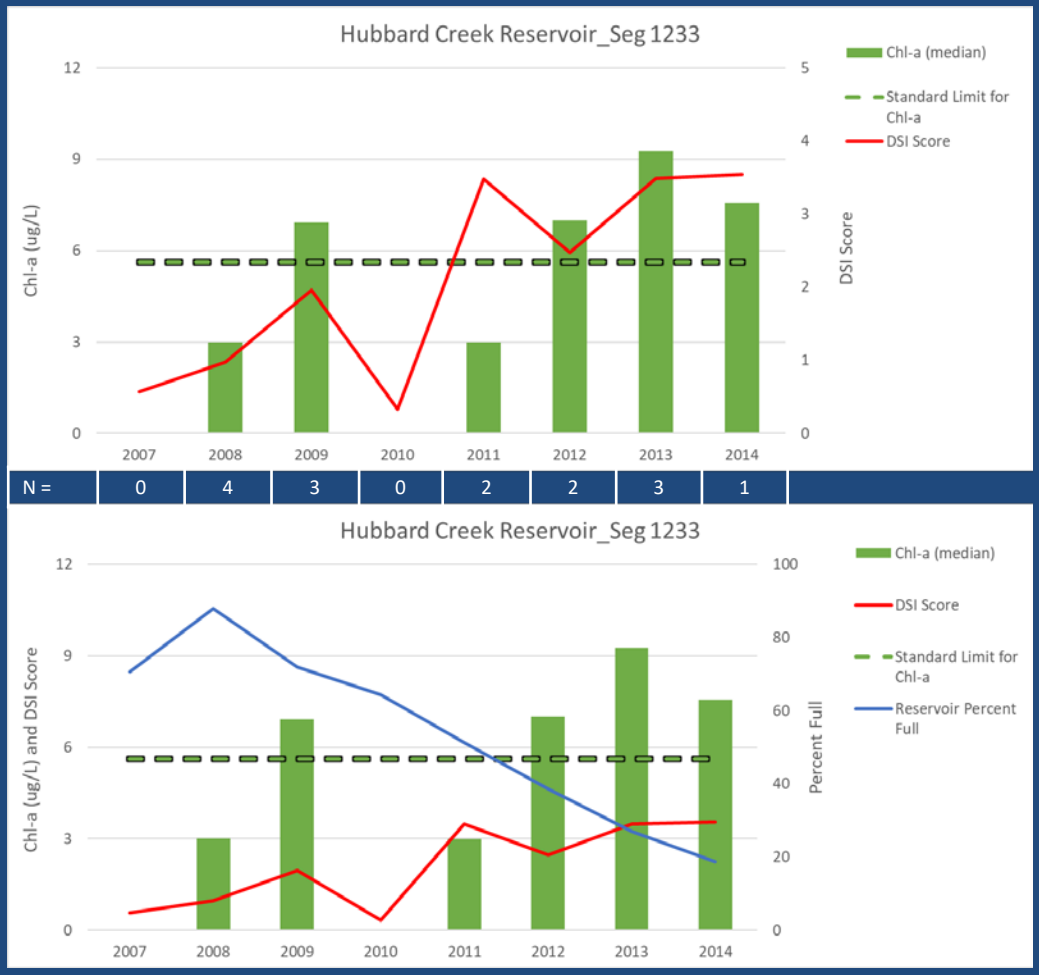
N =	0	4	3	3	4	3	4	3

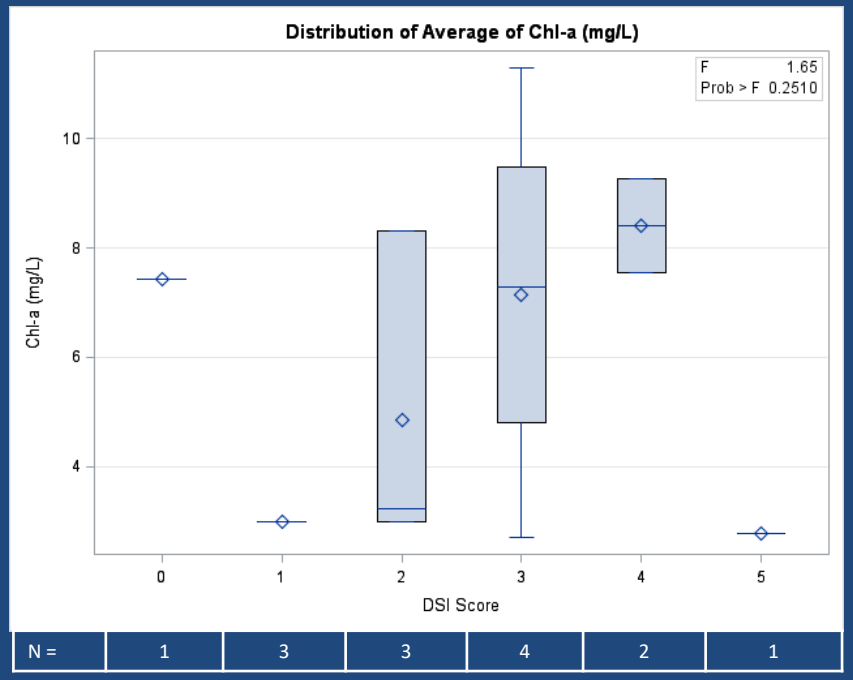




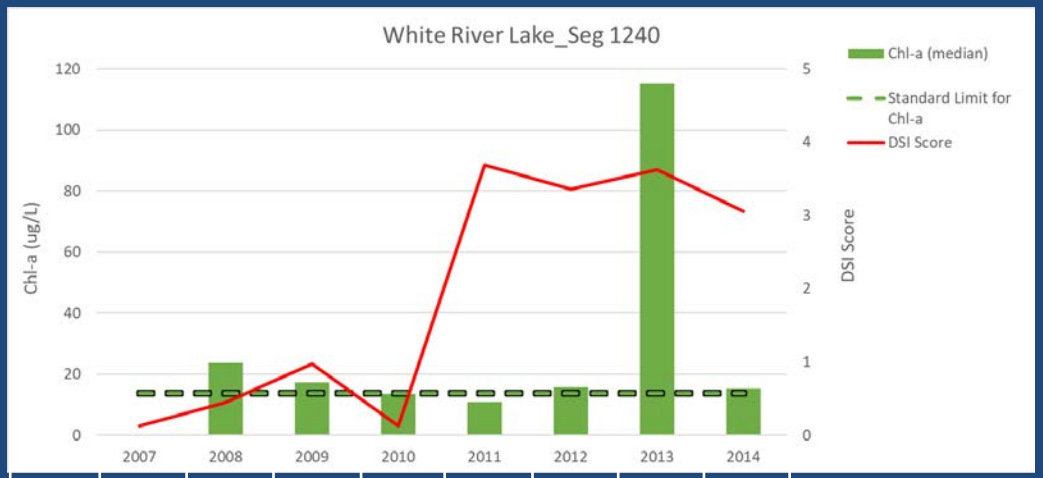
N =	8	9	1	3	1	1

Hubbard Creek Reservoir

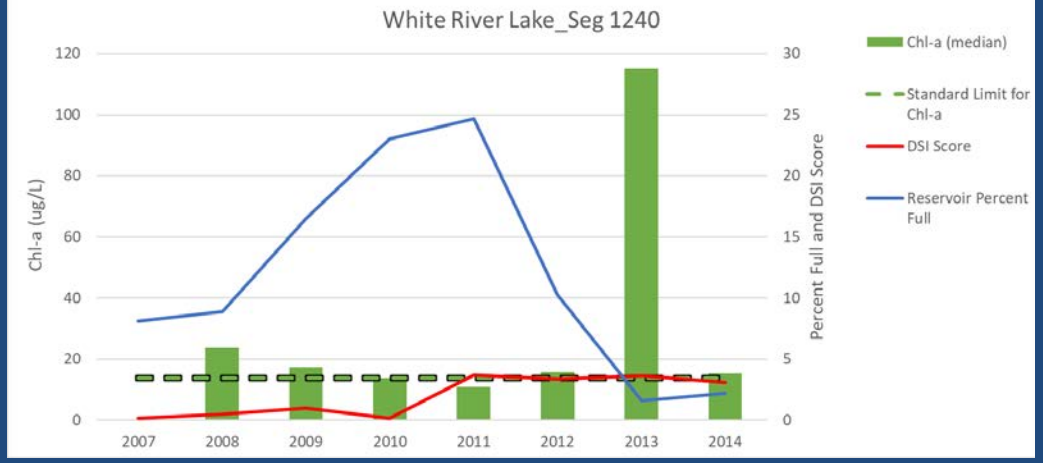


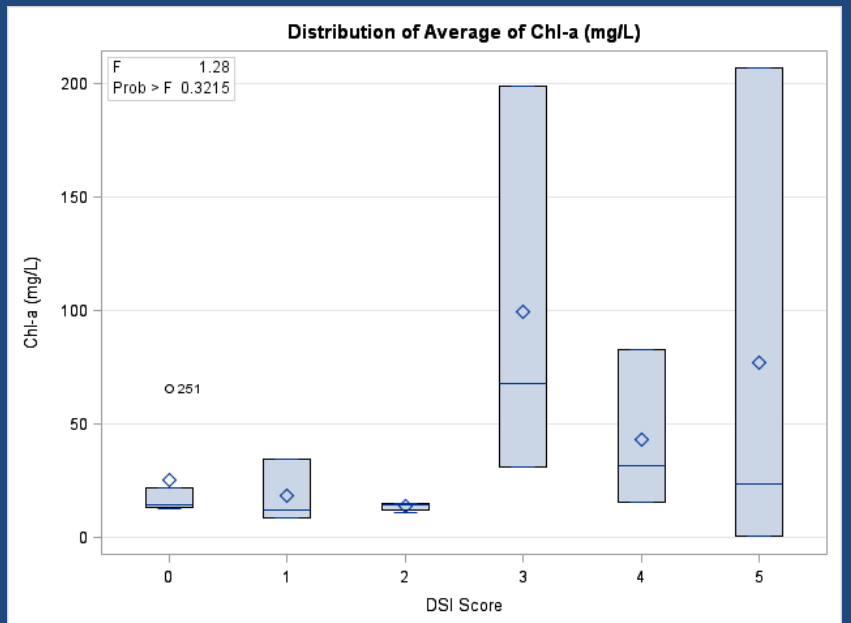


White River Lake



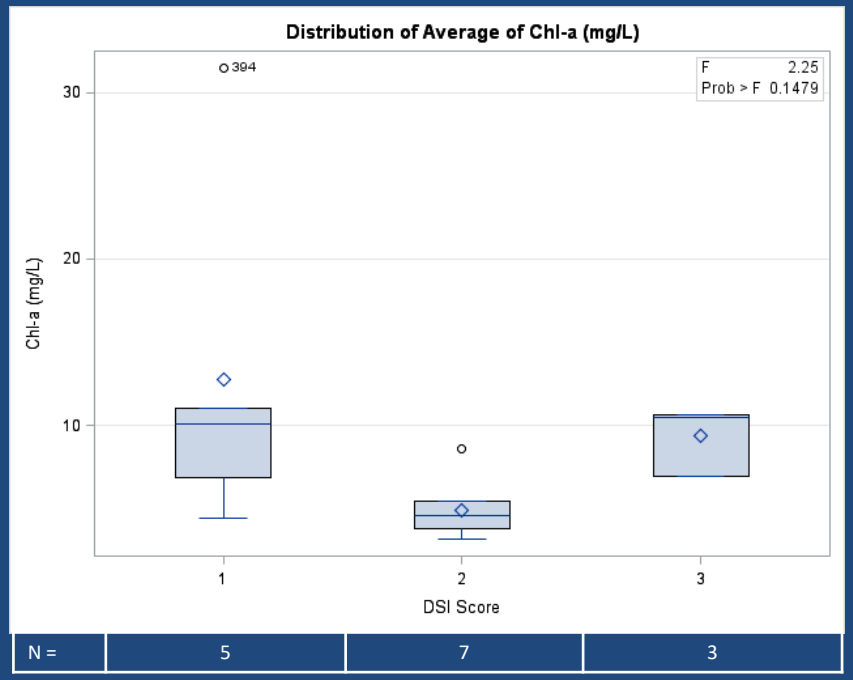
N =	0	4	2	2	4	3	4	3



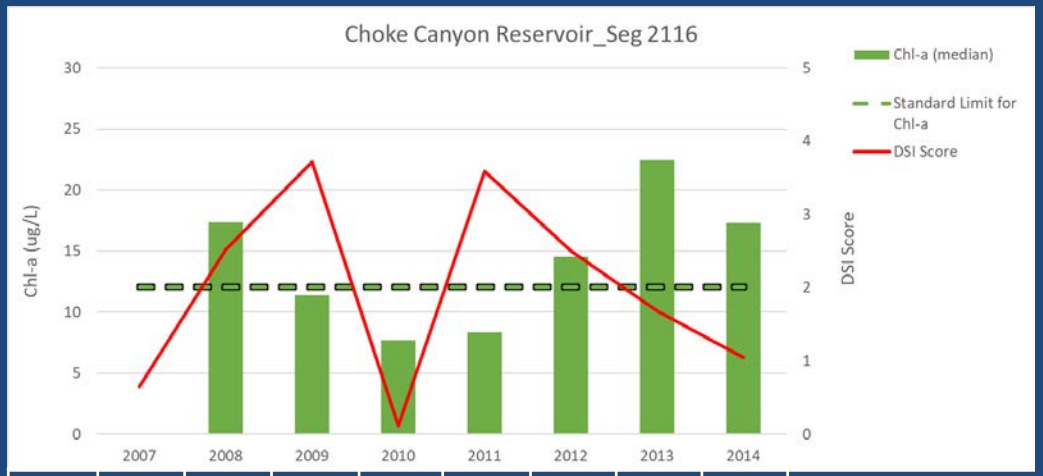


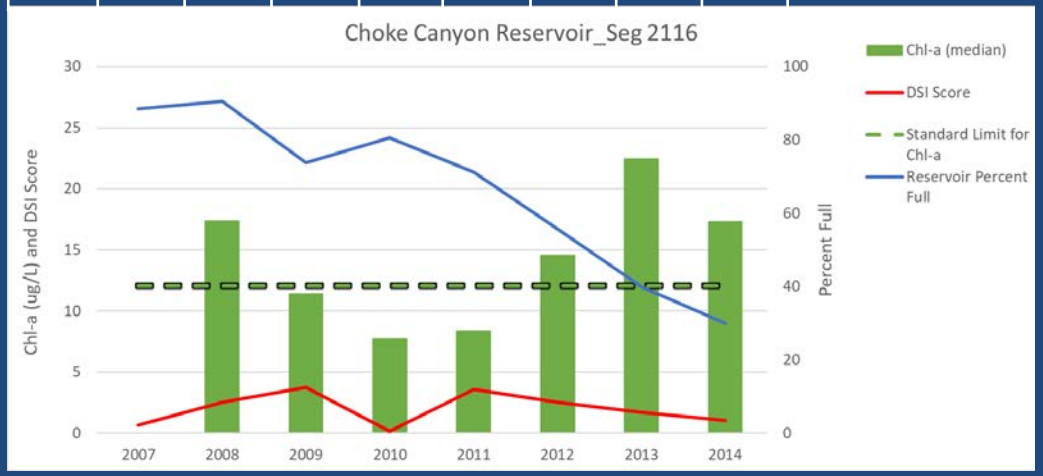
N =	5	3	4	3	3	3

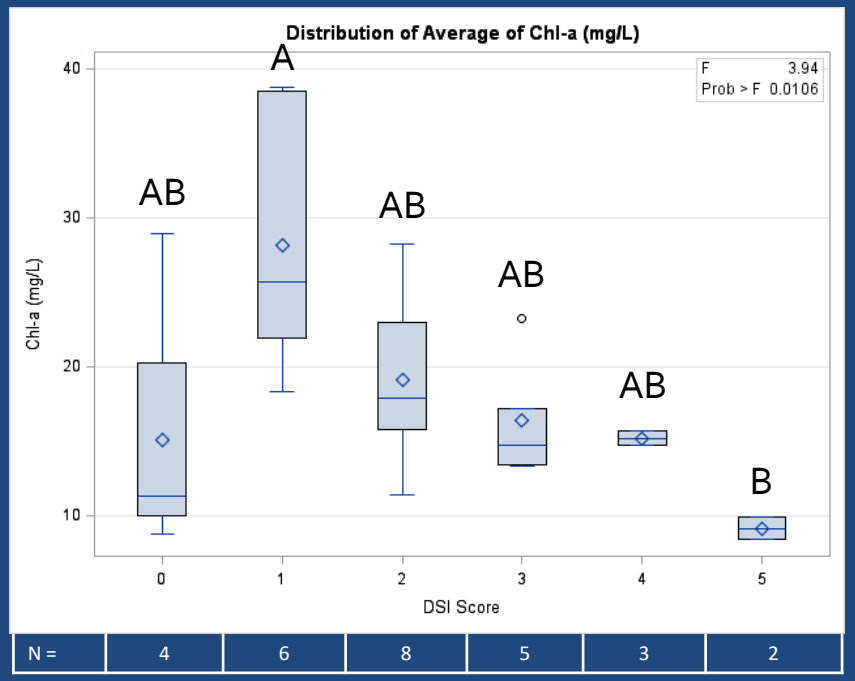
Lake Coleman



Choke Canyon Reservoir



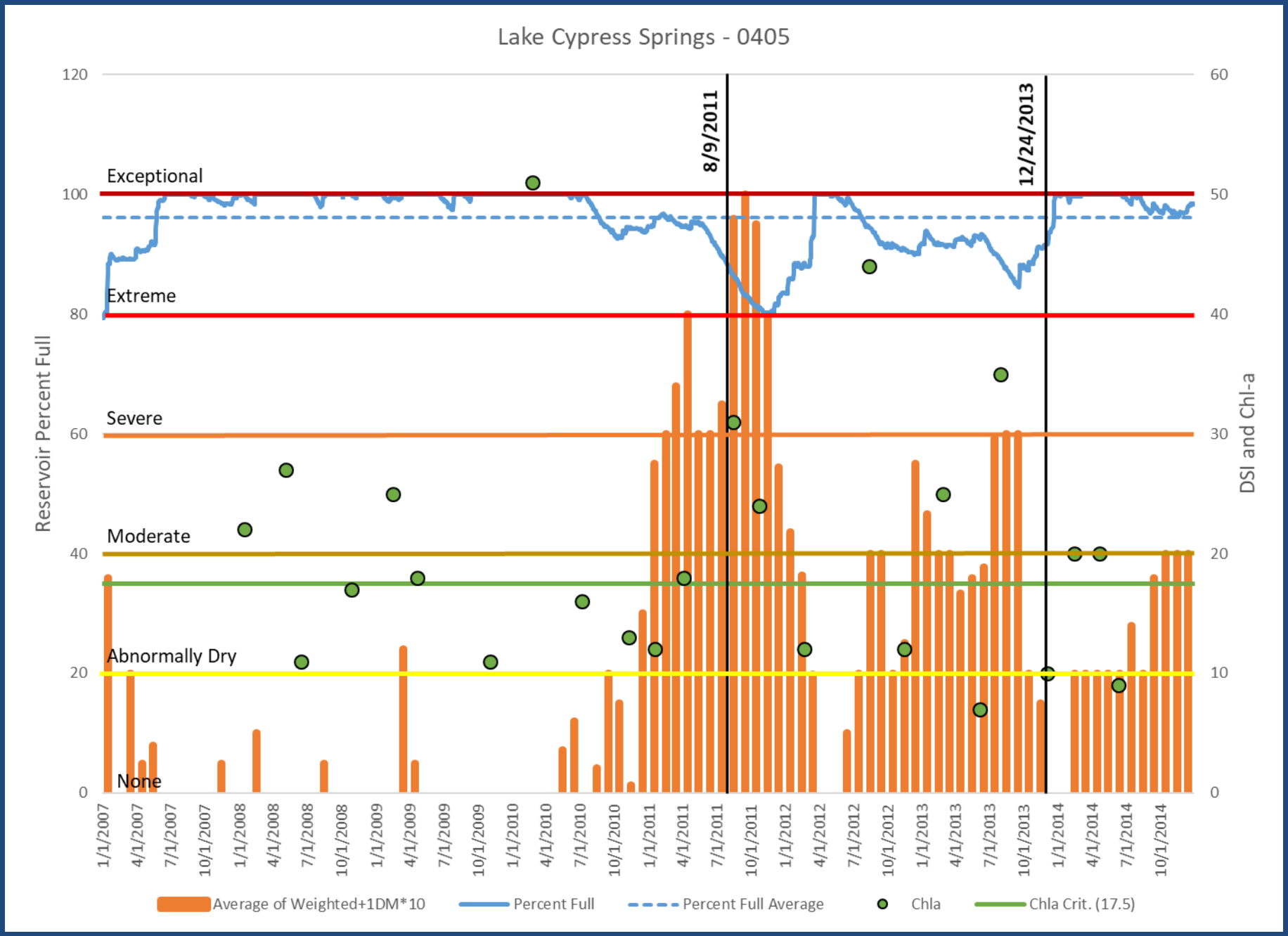


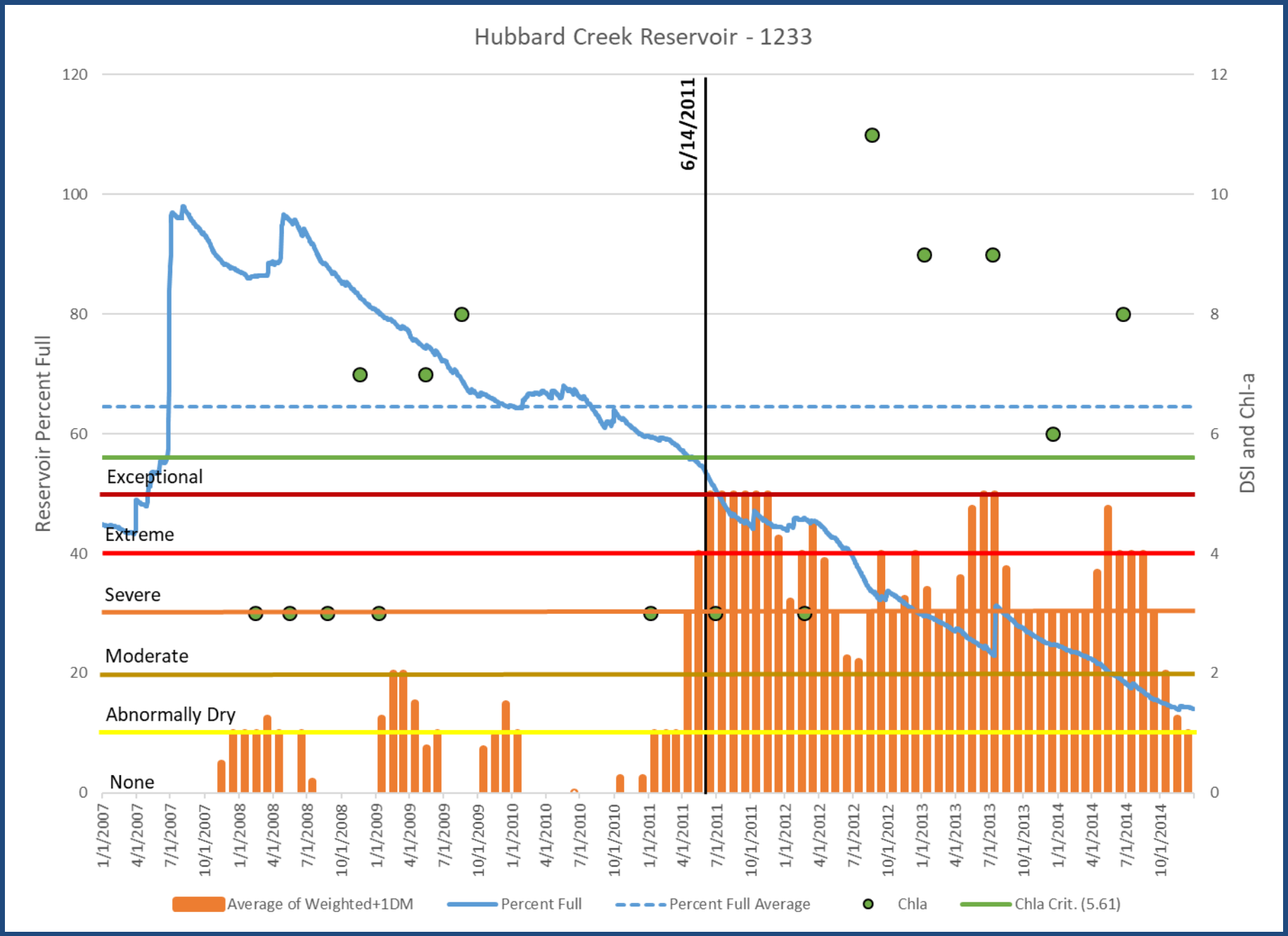


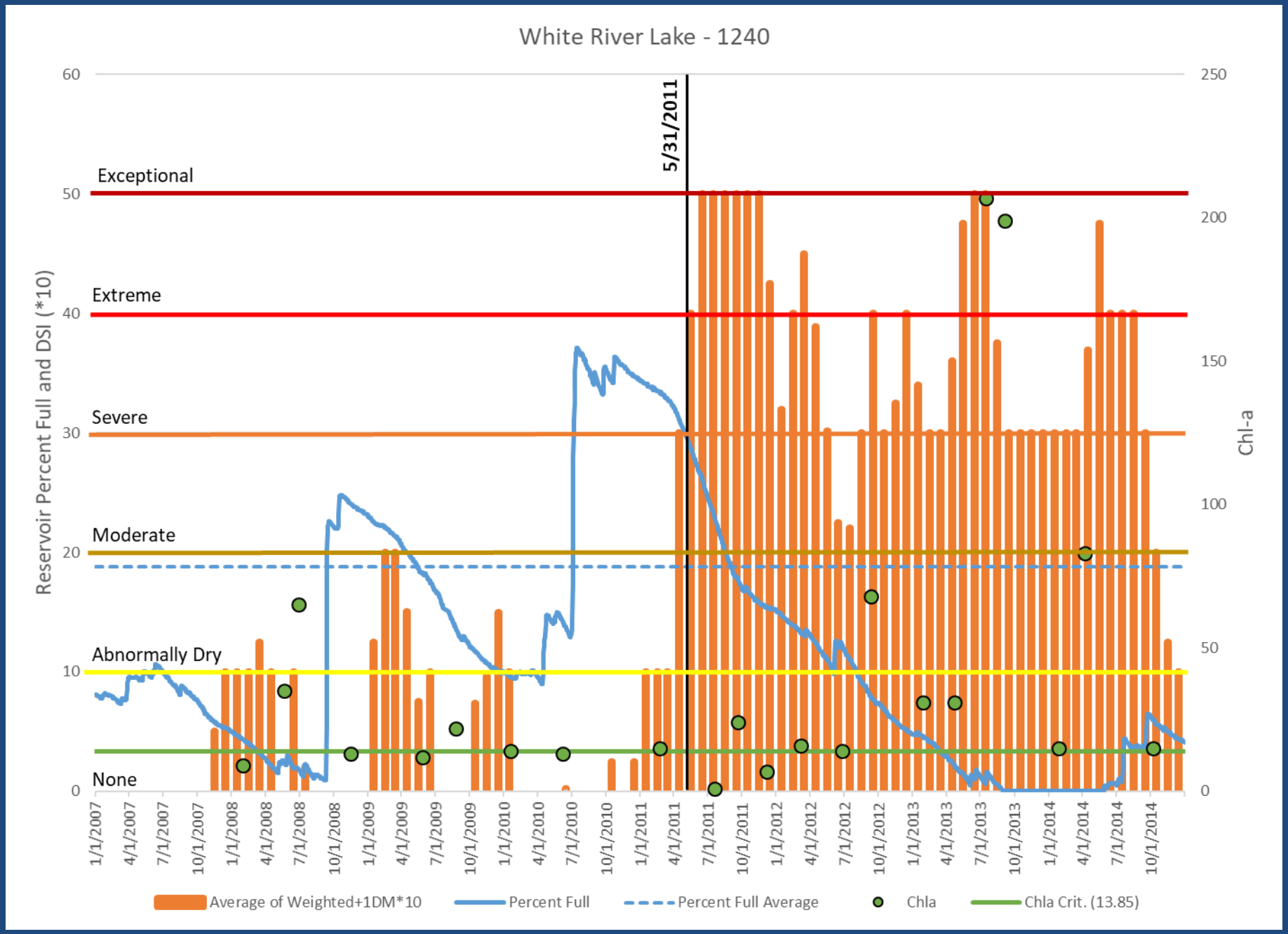
Method Used for 2016 Assessment

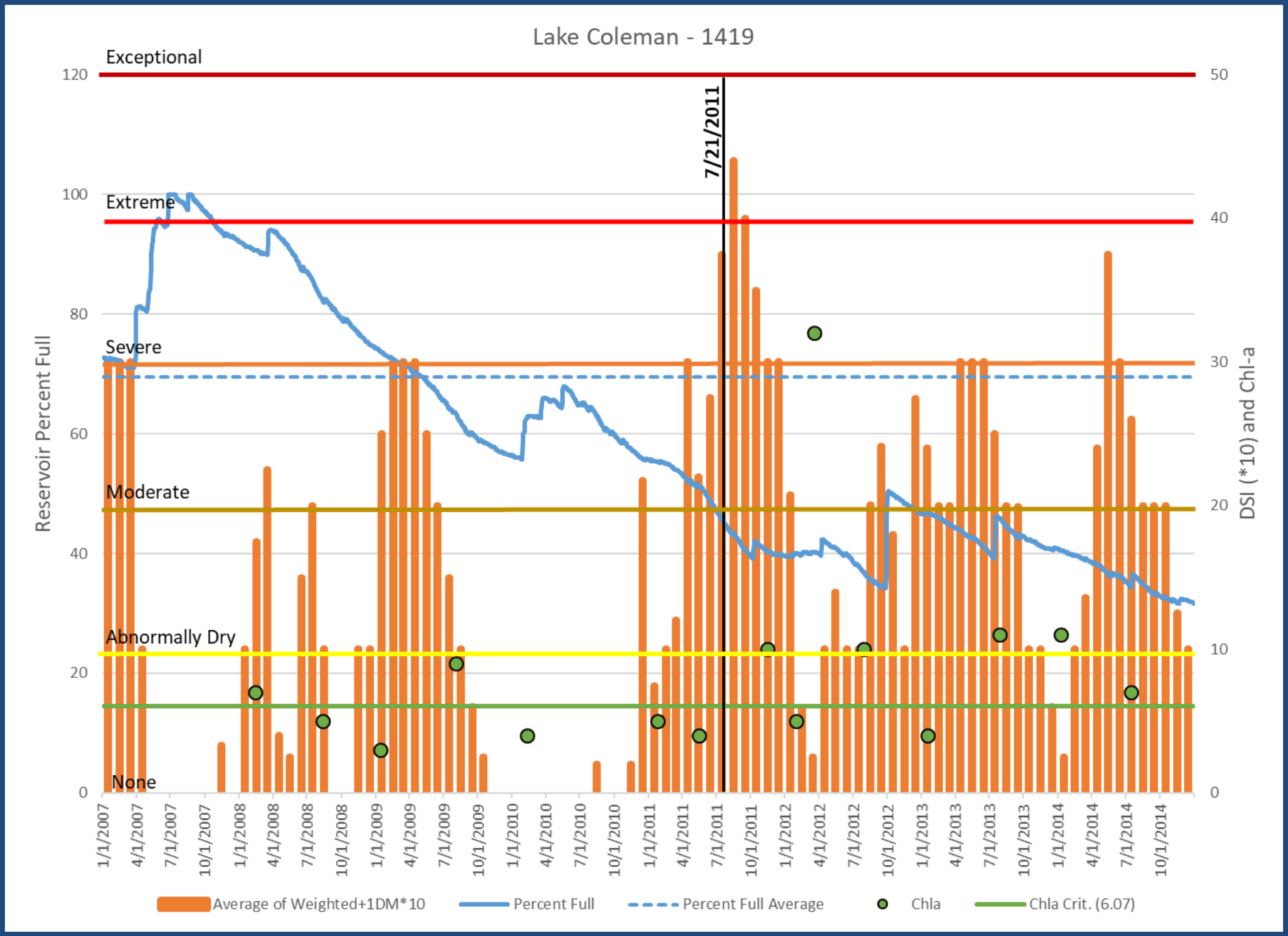
Reservoir Nutrients in 2016 IR

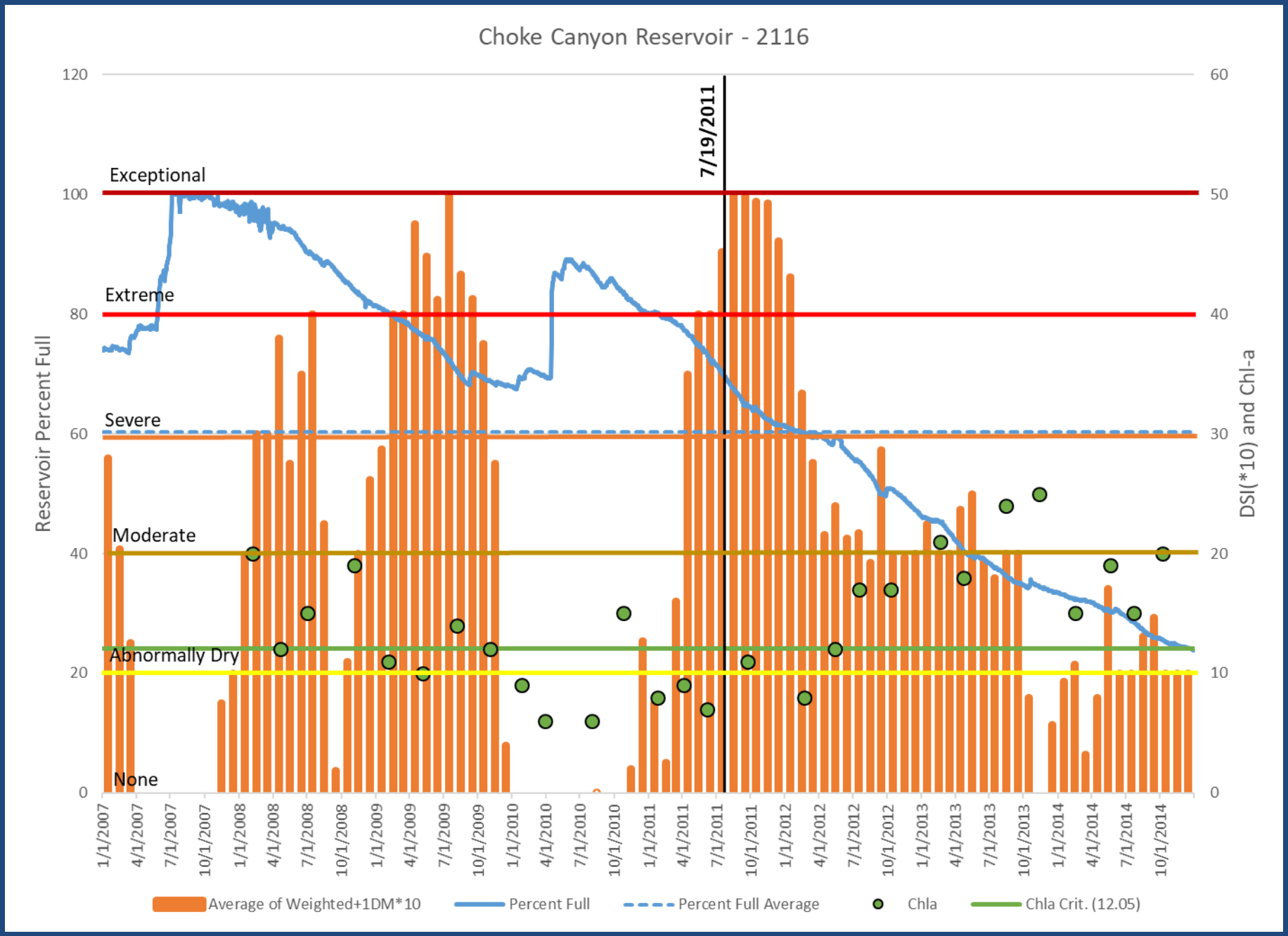
- ANOVAs and data graphs not telling the same story
- Modified graphs to better visualize trends
  - Chlorophyll *a*
  - DSI weighted average
  - Reservoir percent full
- Determined onset and conclusion of drought
- Removed all sample results within drought period and reassessed


Lake Cypress Springs - 0405
Reservoir Percent Full
DSI and Chl-a
120
100
80
60
40
20
0
60
50
40
30
20
10
0
8/9/2011
12/24/2013
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (17.5)


Hubbard Creek Reservoir - 1233
6/14/2011
Reservoir Percent Full
DSI and Chl-a
120
100
80
60
40
20
0
12
10
8
6
4
2
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM
Percent Full
Percent Full Average
Chla
Chla Crit. (5.61)


White River Lake - 1240
5/31/2011
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Reservoir Percent Full and DSI (*10)
Chl-a
60
50
40
30
20
10
0
250
200
150
100
50
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (13.85)


Lake Coleman - 1419
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
7/21/2011
Reservoir Percent Full
DSI (*10) and Chl-a
120
100
80
60
40
20
0
50
40
30
20
10
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (6.07)


Choke Canyon Reservoir - 2116
7/19/2011
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Reservoir Percent Full
DSI(*10) and Chl-a
120
100
80
60
40
20
0
60
50
40
30
20
10
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (12.05)

Reservoir Nutrients in 2016 IR

- Reviewed data and potential watershed impacts
- Results of drought evaluations on nutrient impairments (Category 3)
  - Hubbard Creek Reservoir – FS
  - Lake Coleman – FS
  - Choke Canyon Reservoir – insufficient data
- Resulted in two nutrient listings (Category 5)

Waterbodies:

- Lake Cypress Springs
- Hubbard Creek Reservoir
- White River Lake
- Lake Coleman
- Choke Canyon Reservoir

Factors that potentially complicate the relationship between the Drought Severity Index and Surface Water Quality

- Discharges
- Reservoir releases
- Spring flow
- Water extraction
- Land use
- Instantaneous grab sampling of WQ data
- Broad-scale intent of Drought Monitor map

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    - Water quality data evaluation
- Drought in large rivers

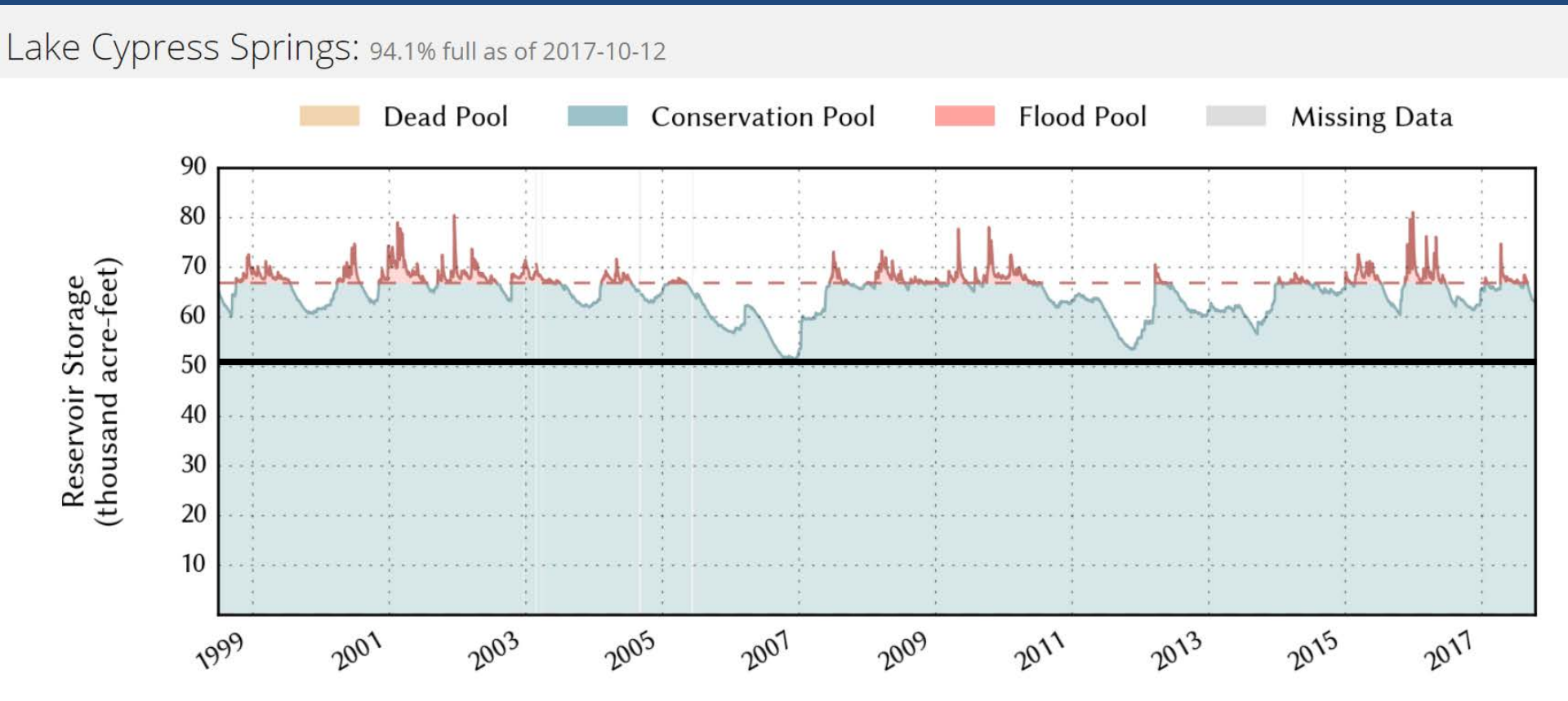
Drought in Reservoirs

- Method applied to nutrients in reservoirs in 2016
- Refinement to be applied for all parameters in 2018
- Discussion items
  - Onset
  - Conclusion
  - Data exclusion
  - Water quality evaluation

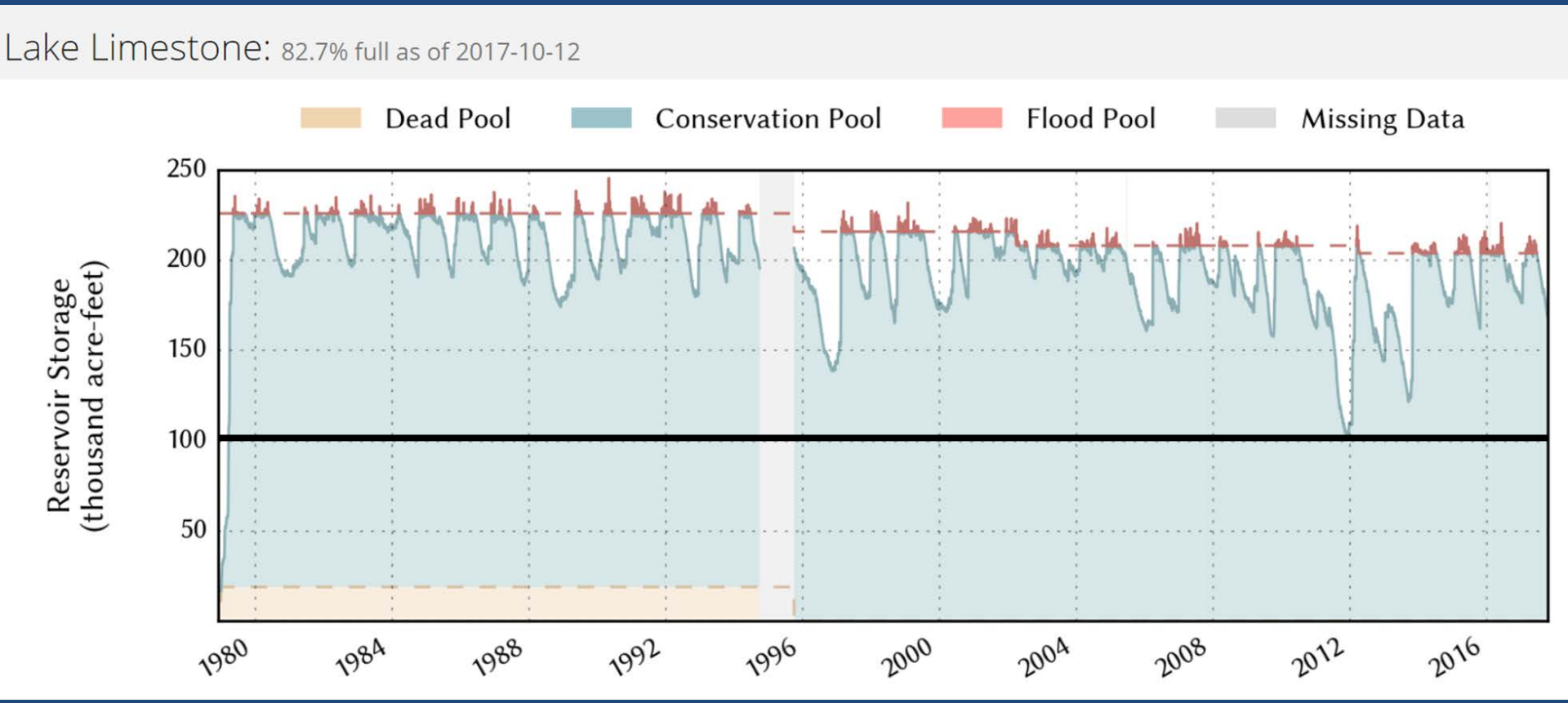
Drought Options: Onset

A. Reservoir percent full declines towards historic low

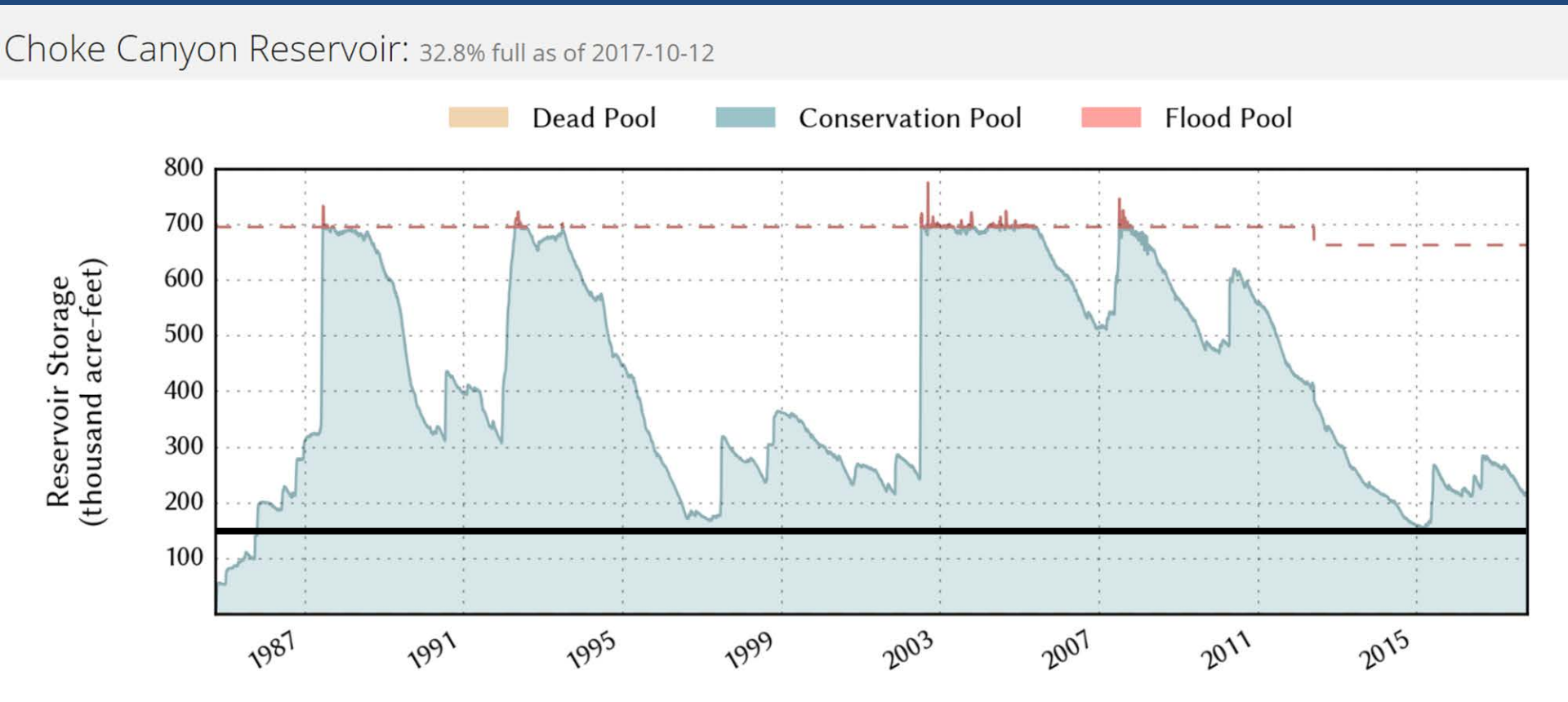
Historical Reservoir Levels



Historical Reservoir Levels

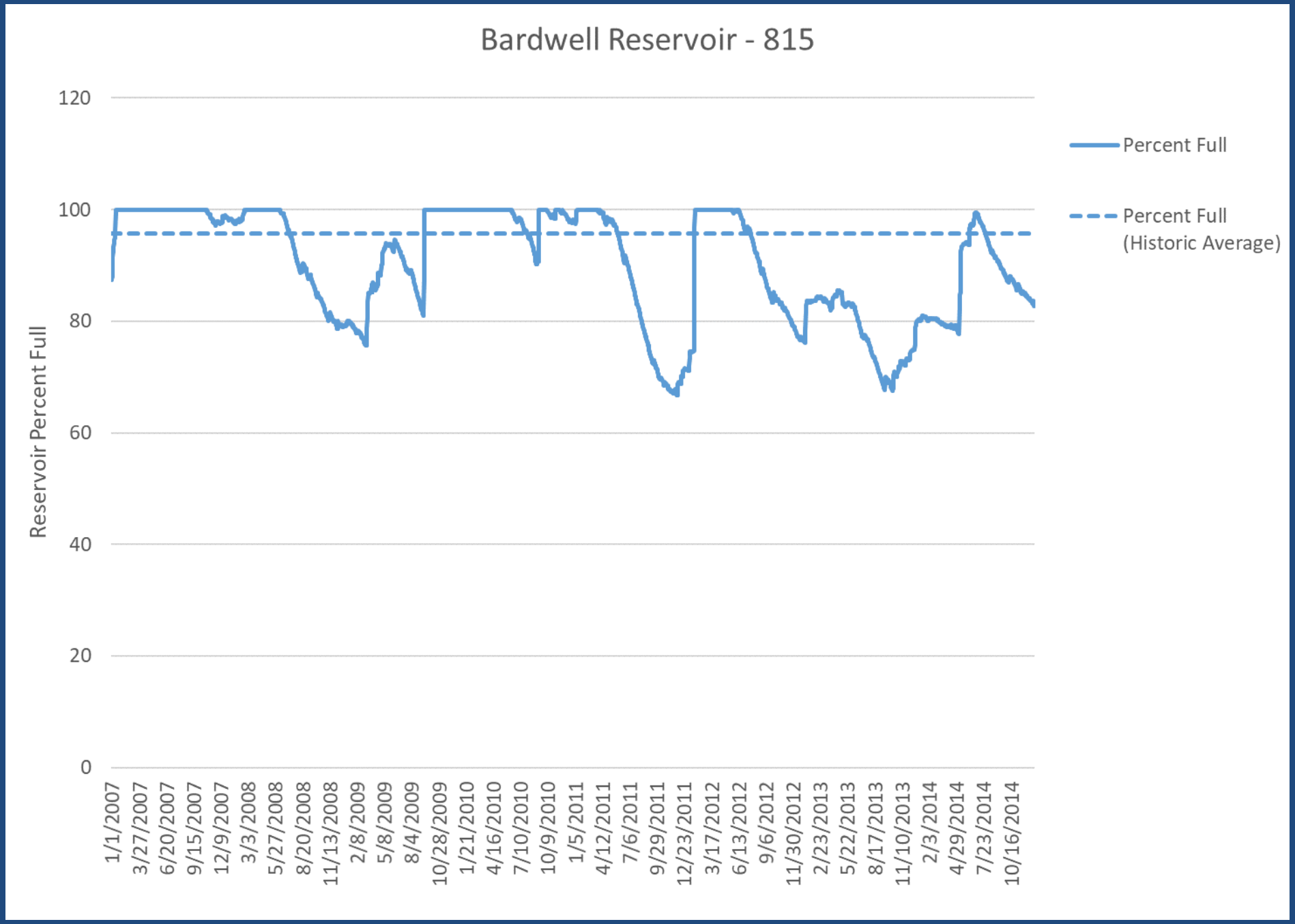


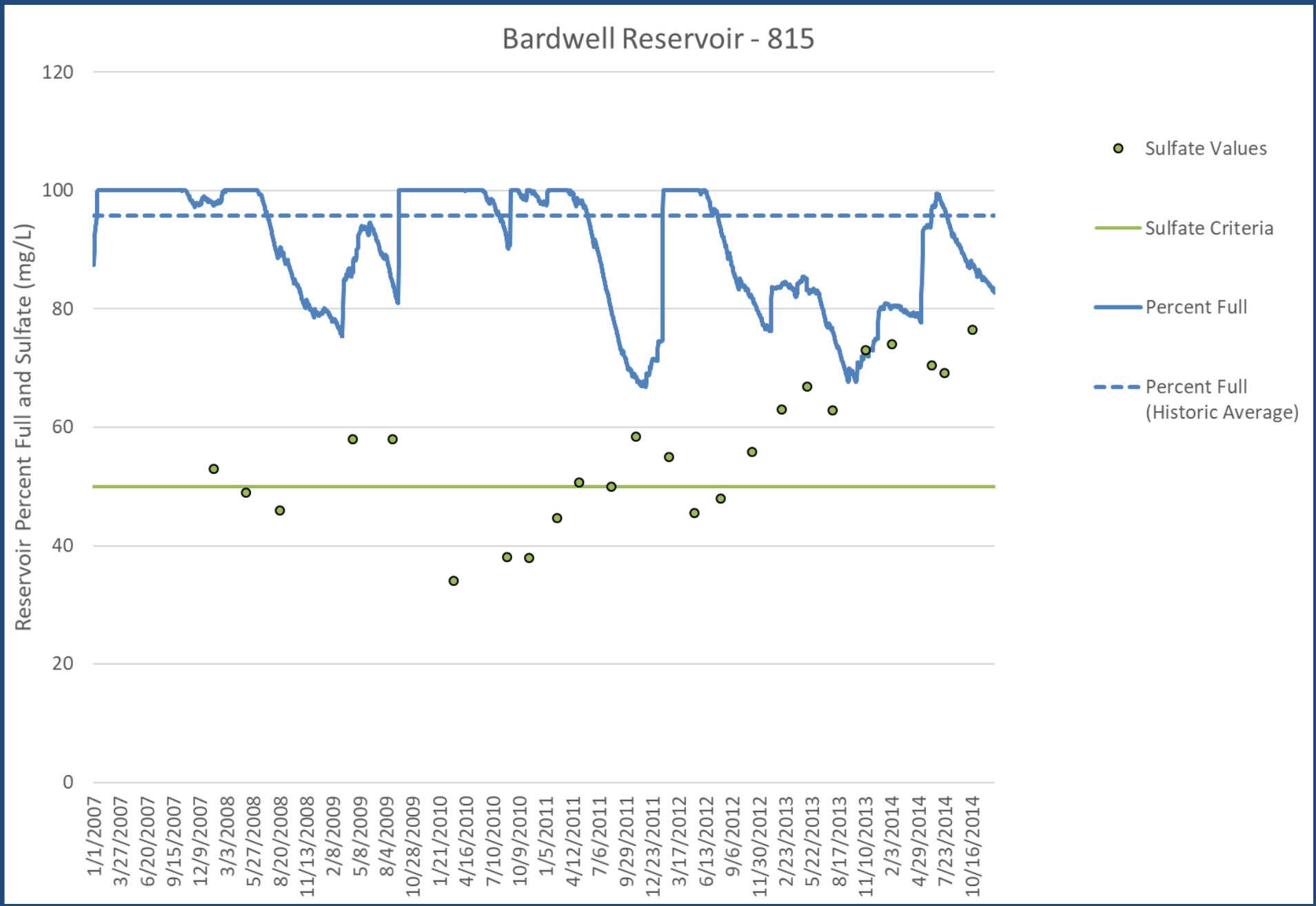
Historical Reservoir Levels

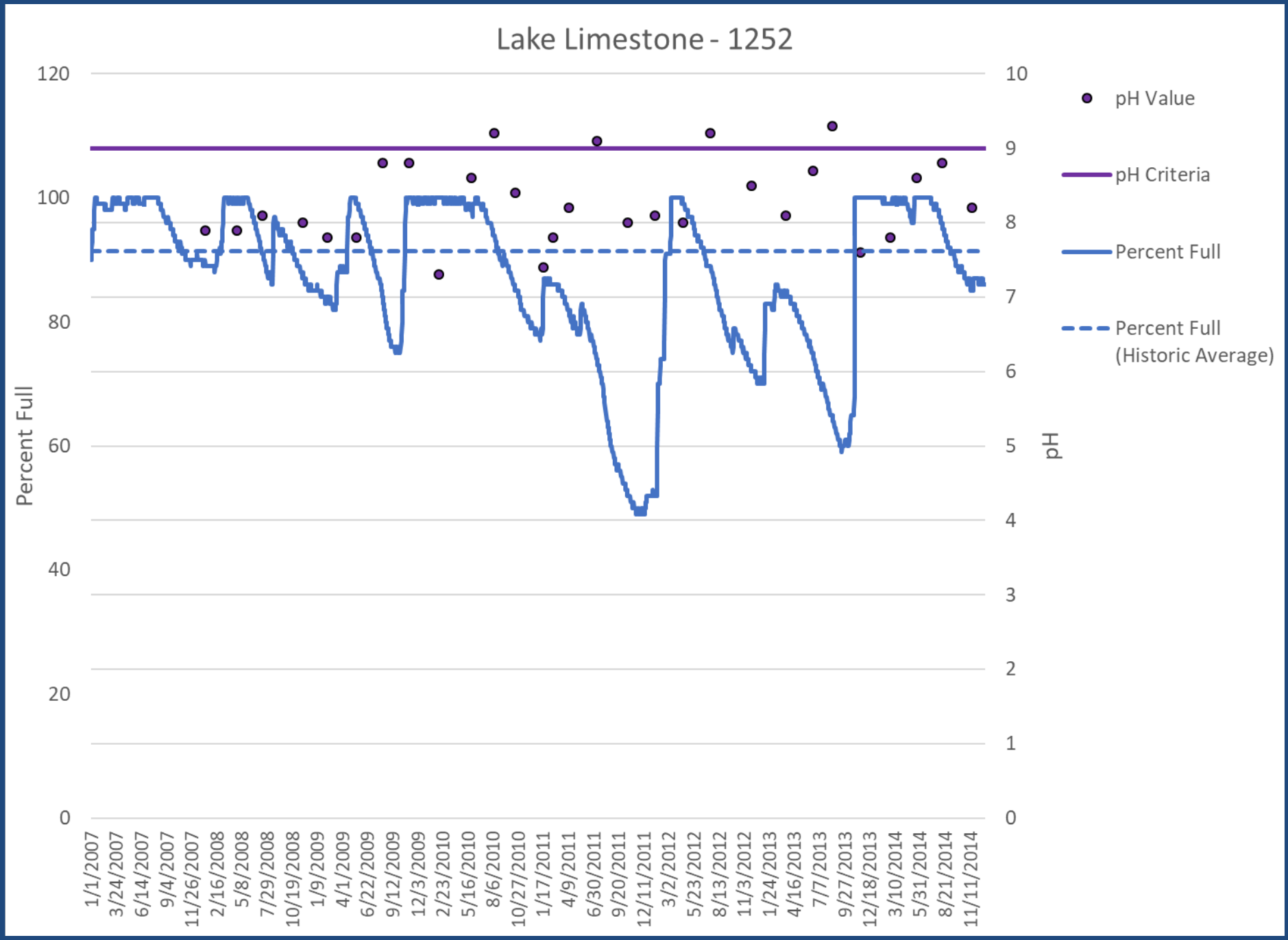


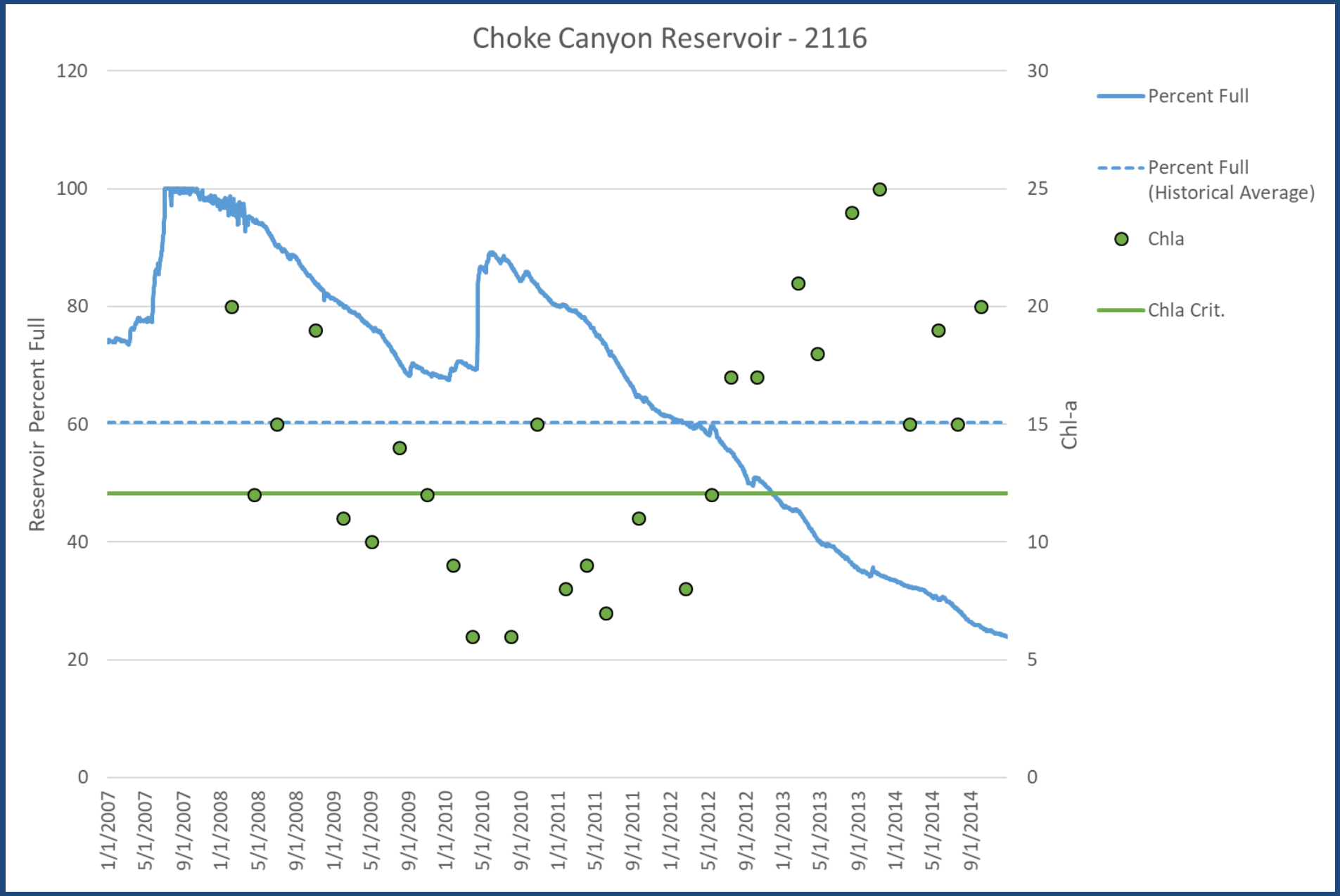
Drought Options: Onset

A. Reservoir percent full declines towards historic low
B. Reservoir percent full drops below historical average percent full


Bardwell Reservoir - 815
Reservoir Percent Full
120
100
80
60
40
20
0
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014
Percent Full
Percent Full (Historic Average)

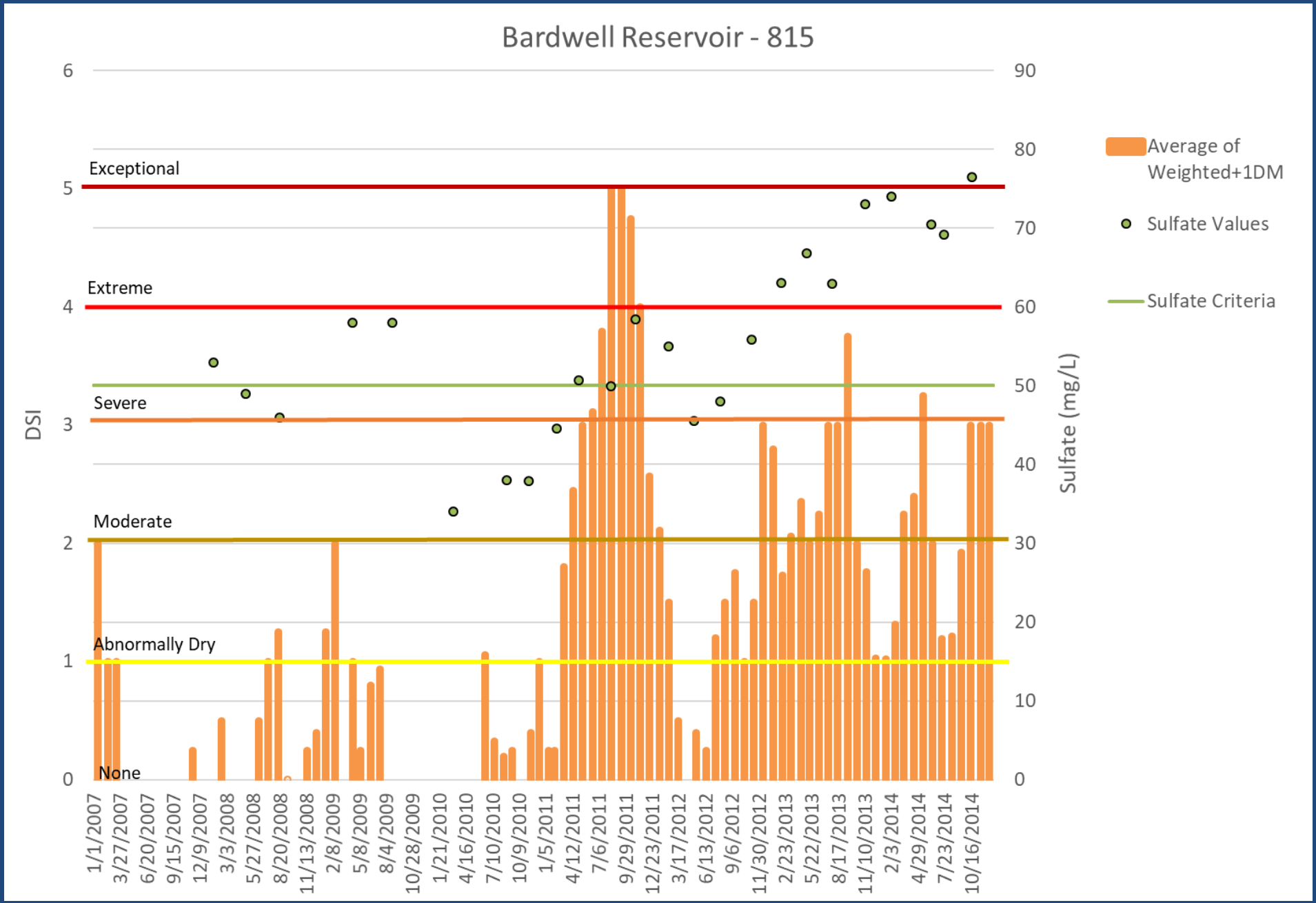

Bardwell Reservoir - 815
Reservoir Percent Full and Sulfate (mg/L)
120
100
80
60
40
20
0
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014
Sulfate Values
Sulfate Criteria
Percent Full
Percent Full (Historic Average)

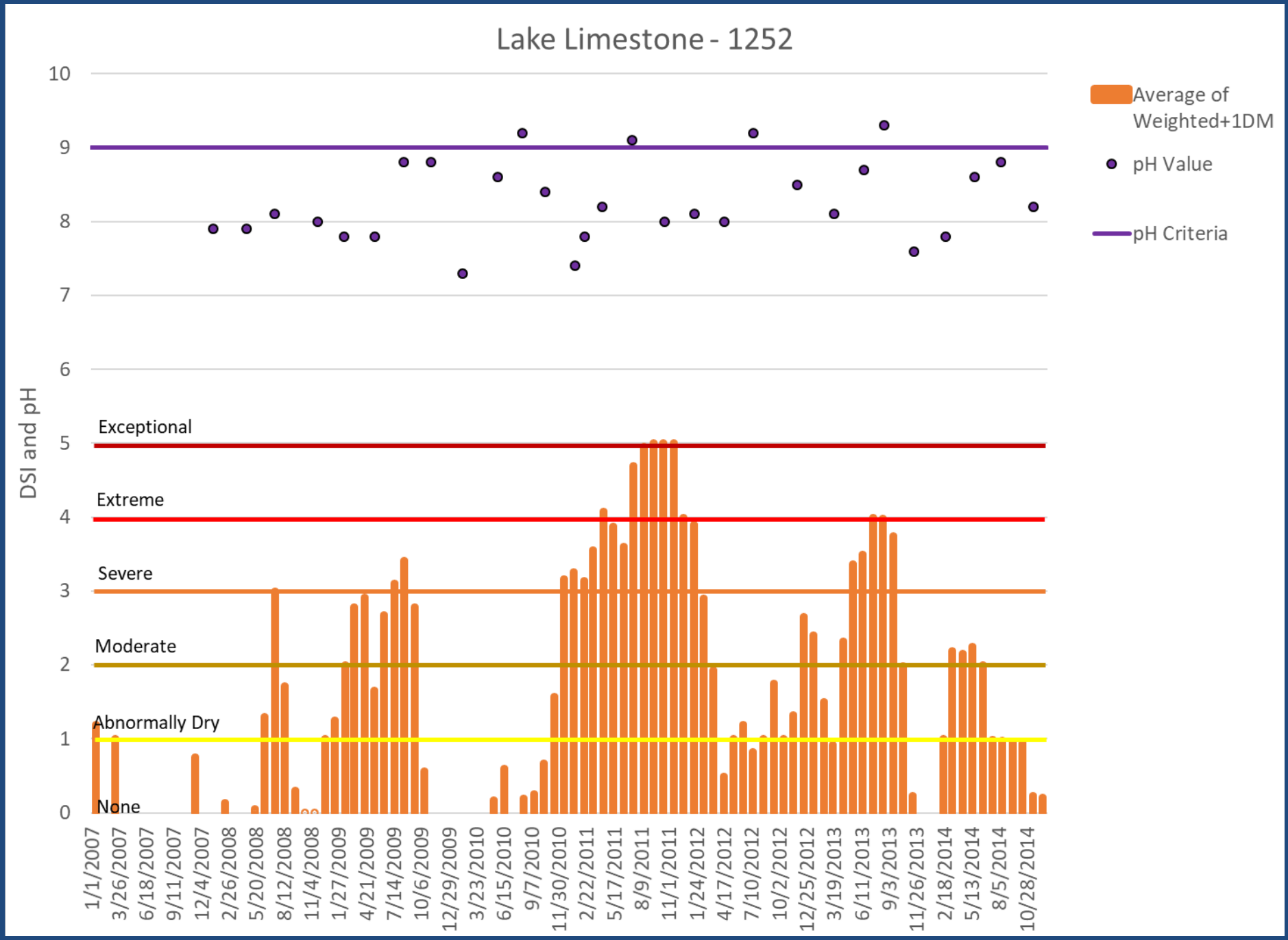

Lake Limestone - 1252
Percent Full
pH
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
pH Value
pH Criteria
Percent Full
Percent Full (Historic Average)
1/1/2007
3/24/2007
6/14/2007
9/4/2007
11/26/2007
2/16/2008
5/8/2008
7/29/2008
10/19/2008
1/9/2009
4/1/2009
6/22/2009
9/12/2009
12/3/2009
2/23/2010
5/16/2010
8/6/2010
10/27/2010
1/17/2011
4/9/2011
6/30/2011
9/20/2011
12/11/2011
3/2/2012
5/23/2012
8/13/2012
11/3/2012
1/24/2013
4/16/2013
7/7/2013
9/27/2013
12/18/2013
3/10/2014
5/31/2014
8/21/2014
11/11/2014

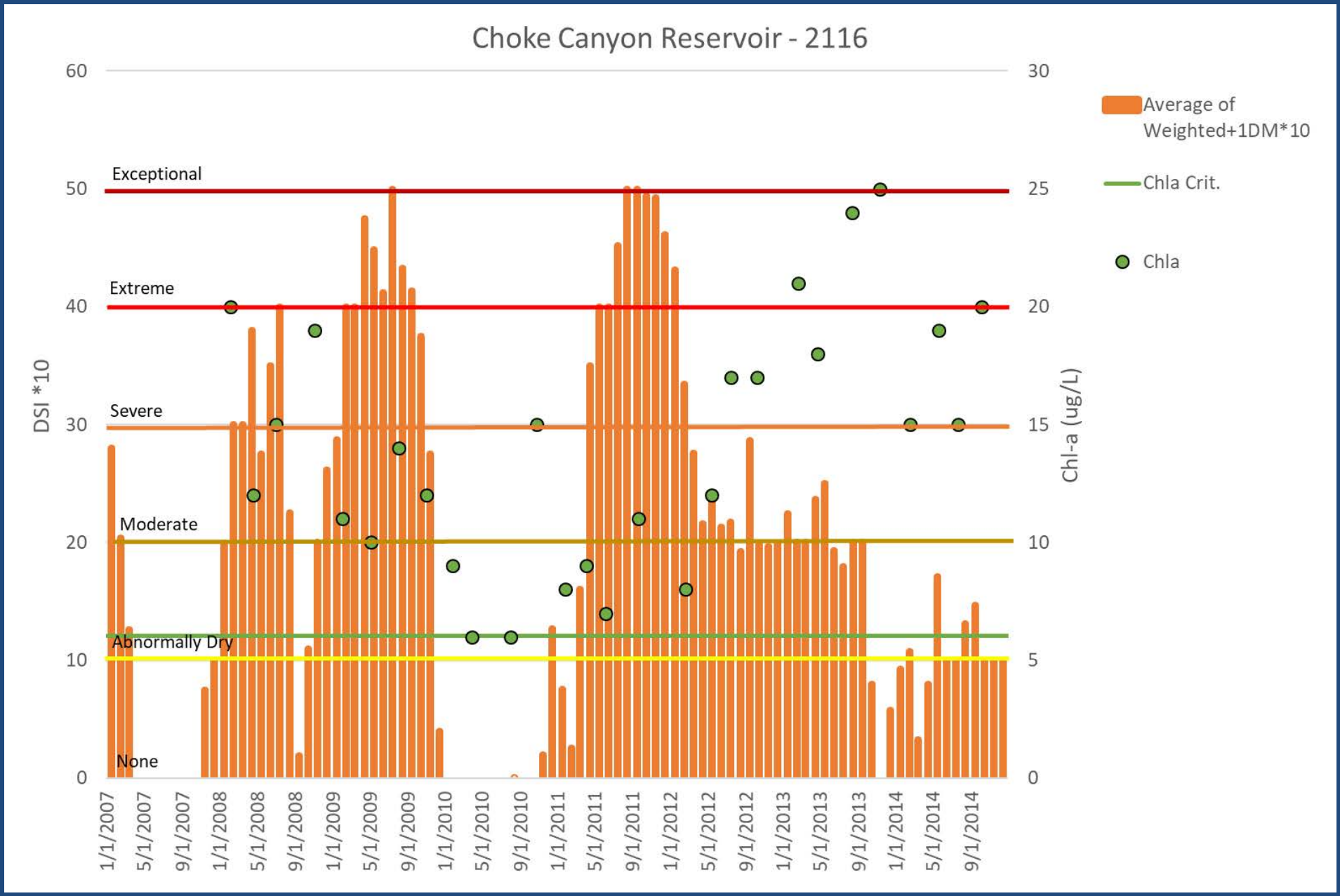

Choke Canyon Reservoir - 2116
Reservoir Percent Full
Chl-a
120
100
80
60
40
20
0
30
25
20
15
10
5
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
Percent Full
Percent Full (Historical Average)
Chla
Chla Crit.

Drought Options: Onset

A. Reservoir percent full declines towards historic low
B. Reservoir percent full drops below historical average percent full
C. Wt. DSI = 5 (exceptional)
   Wt. DSI = 4 (extreme)

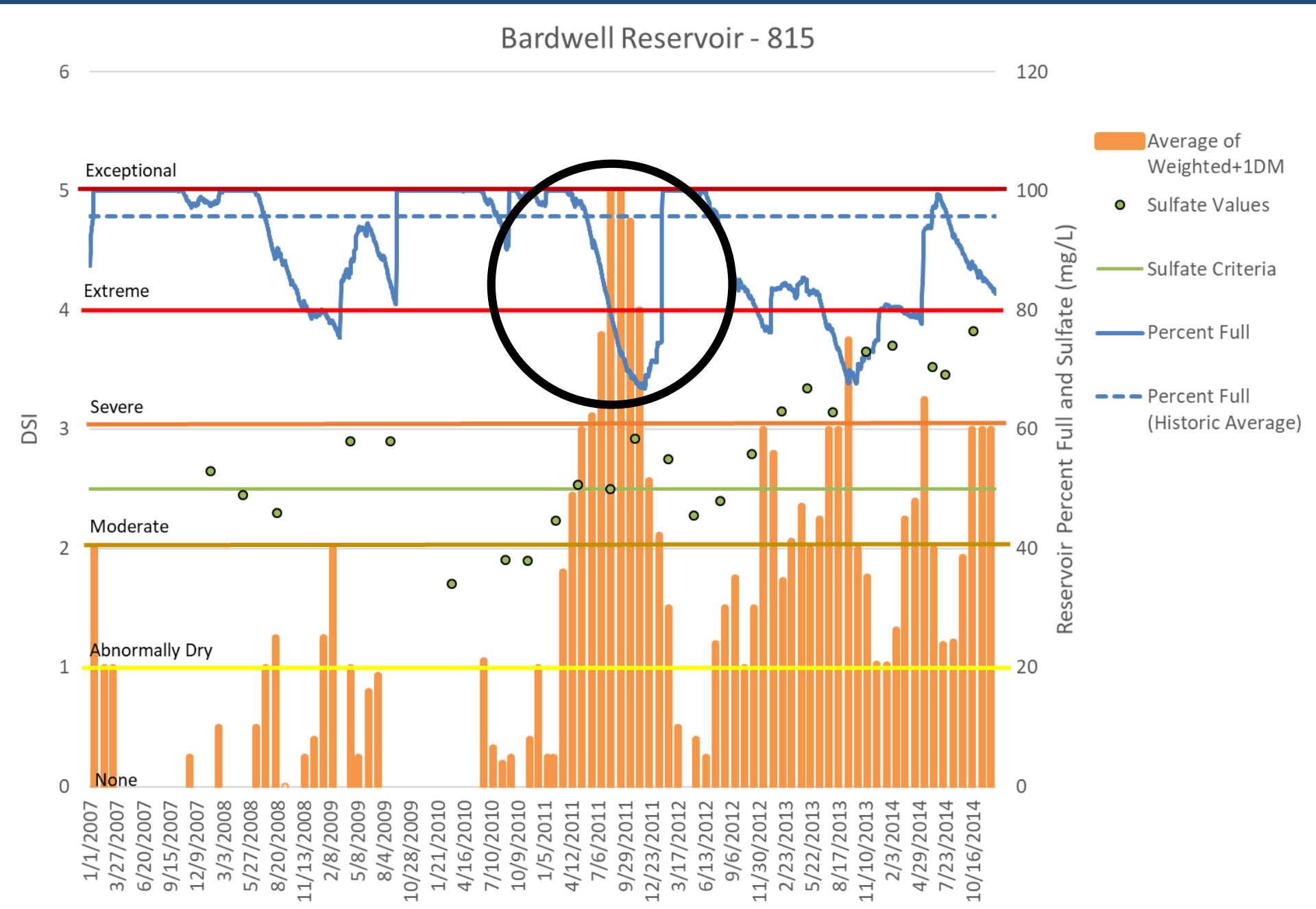

Bardwell Reservoir - 815
DSI
Sulfate (mg/L)
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Average of Weighted+1DM
Sulfate Values
Sulfate Criteria
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014

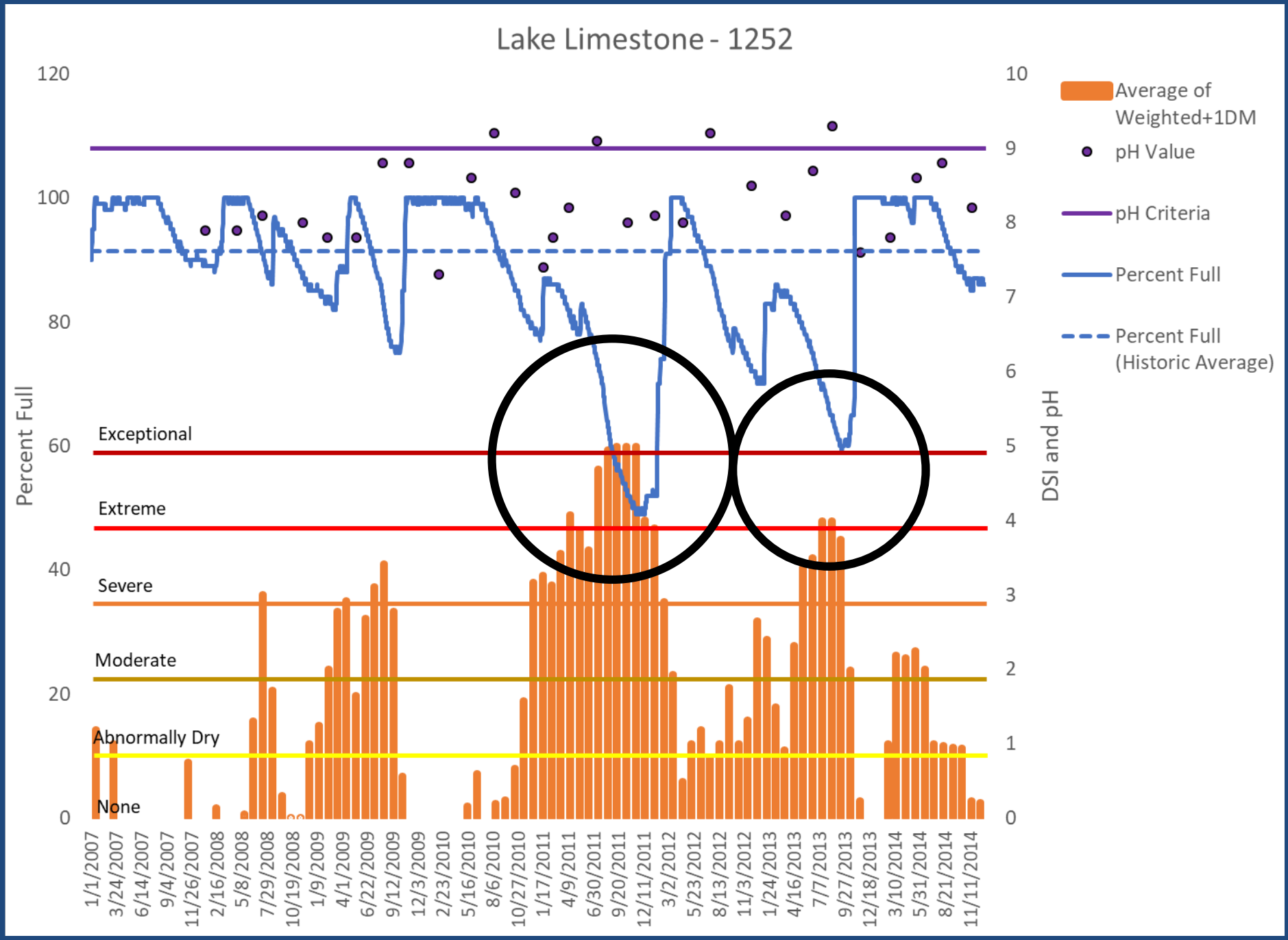

Lake Limestone - 1252
DSI and pH
10
9
8
7
6
5
4
3
2
1
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
1/1/2007
3/26/2007
6/18/2007
9/11/2007
12/4/2007
2/26/2008
5/20/2008
8/12/2008
11/4/2008
1/27/2009
4/21/2009
7/14/2009
10/6/2009
12/29/2009
3/23/2010
6/15/2010
9/7/2010
11/30/2010
2/22/2011
5/17/2011
8/9/2011
11/1/2011
1/24/2012
4/17/2012
7/10/2012
10/2/2012
12/25/2012
3/19/2013
6/11/2013
9/3/2013
11/26/2013
2/18/2014
5/13/2014
8/5/2014
10/28/2014
Average of Weighted+1DM
pH Value
pH Criteria

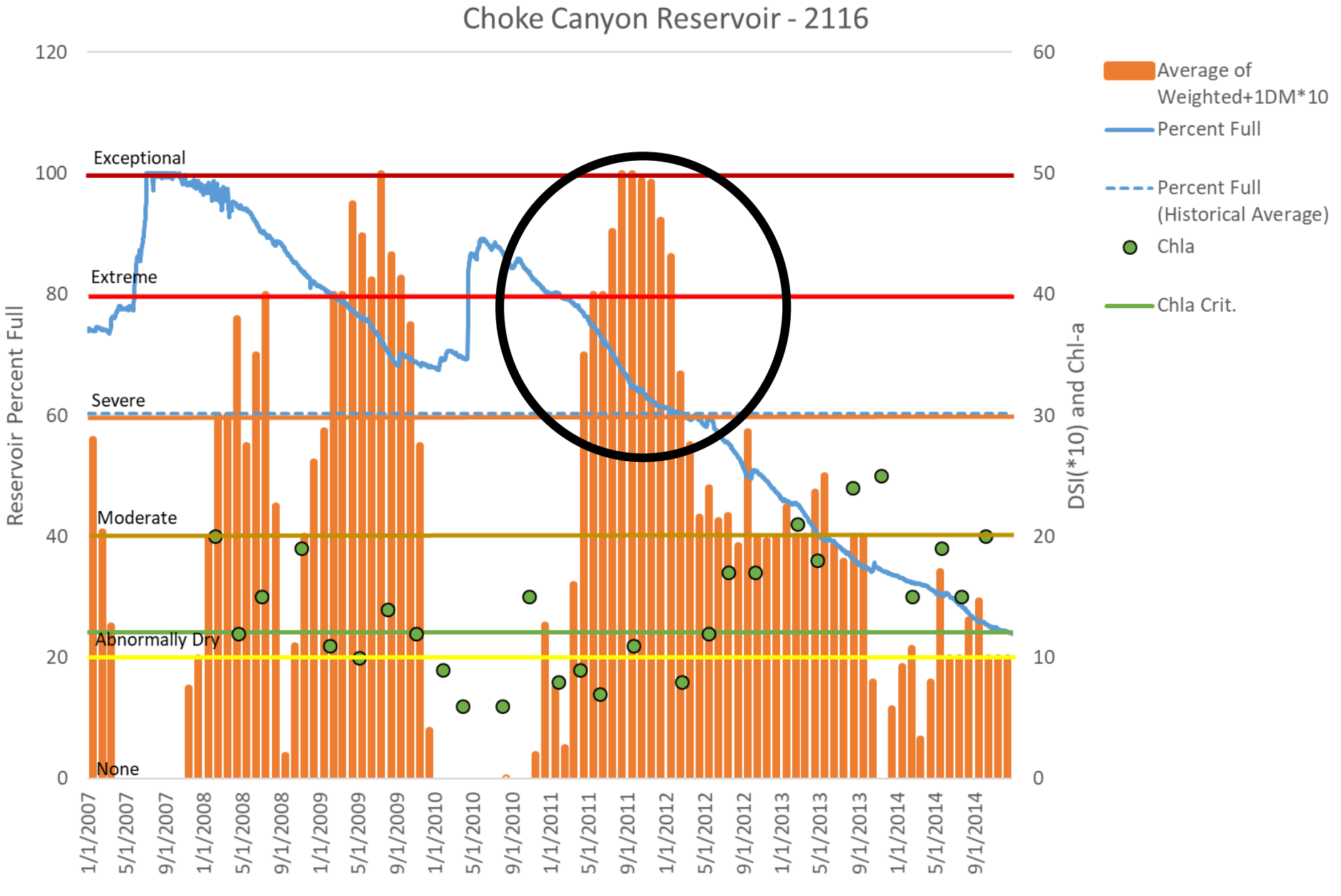

Choke Canyon Reservoir - 2116
60
50
40
30
20
10
0
30
25
20
15
10
5
0
DSI *10
Chl-a (ug/L)
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Average of Weighted+1DM*10
Chla Crit.
Chla
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014

Drought Options: Onset

A. Reservoir percent full declines towards historic low
B. Reservoir percent full drops below historical average percent full
C. Wt. DSI = 5 (exceptional)
   Wt. DSI = 4 (extreme)
D. A combination of the above
E. Other options and/or parameters?


Bardwell Reservoir - 815
DSI
Reservoir Percent Full and Sulfate (mg/L)
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Average of Weighted+1DM
Sulfate Values
Sulfate Criteria
Percent Full
Percent Full (Historic Average)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014


Lake Limestone - 1252
Percent Full
DSI and pH
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Average of Weighted+1DM
pH Value
pH Criteria
Percent Full
Percent Full (Historic Average)
1/1/2007
3/24/2007
6/14/2007
9/4/2007
11/26/2007
2/16/2008
5/8/2008
7/29/2008
10/19/2008
1/9/2009
4/1/2009
6/22/2009
9/12/2009
12/3/2009
2/23/2010
5/16/2010
8/6/2010
10/27/2010
1/17/2011
4/9/2011
6/30/2011
9/20/2011
12/11/2011
3/2/2012
5/23/2012
8/13/2012
11/3/2012
1/24/2013
4/16/2013
7/7/2013
9/27/2013
12/18/2013
3/10/2014
5/31/2014
8/21/2014
11/11/2014


Choke Canyon Reservoir - 2116
Reservoir Percent Full
DSI(*10) and Chl-a
120
100
80
60
40
20
0
60
50
40
30
20
10
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full (Historical Average)
Chla
Chla Crit.

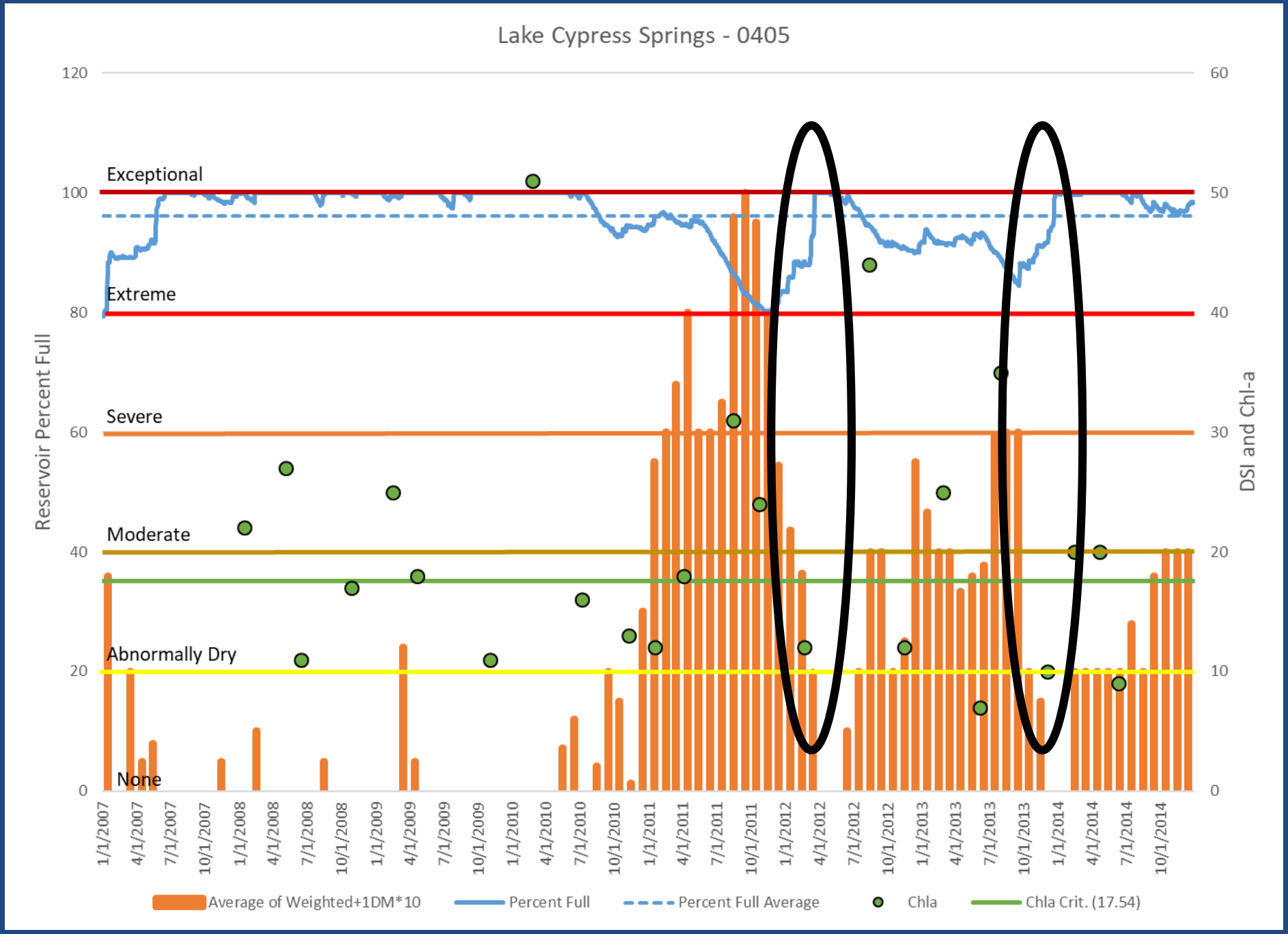
Drought Options: Conclusion

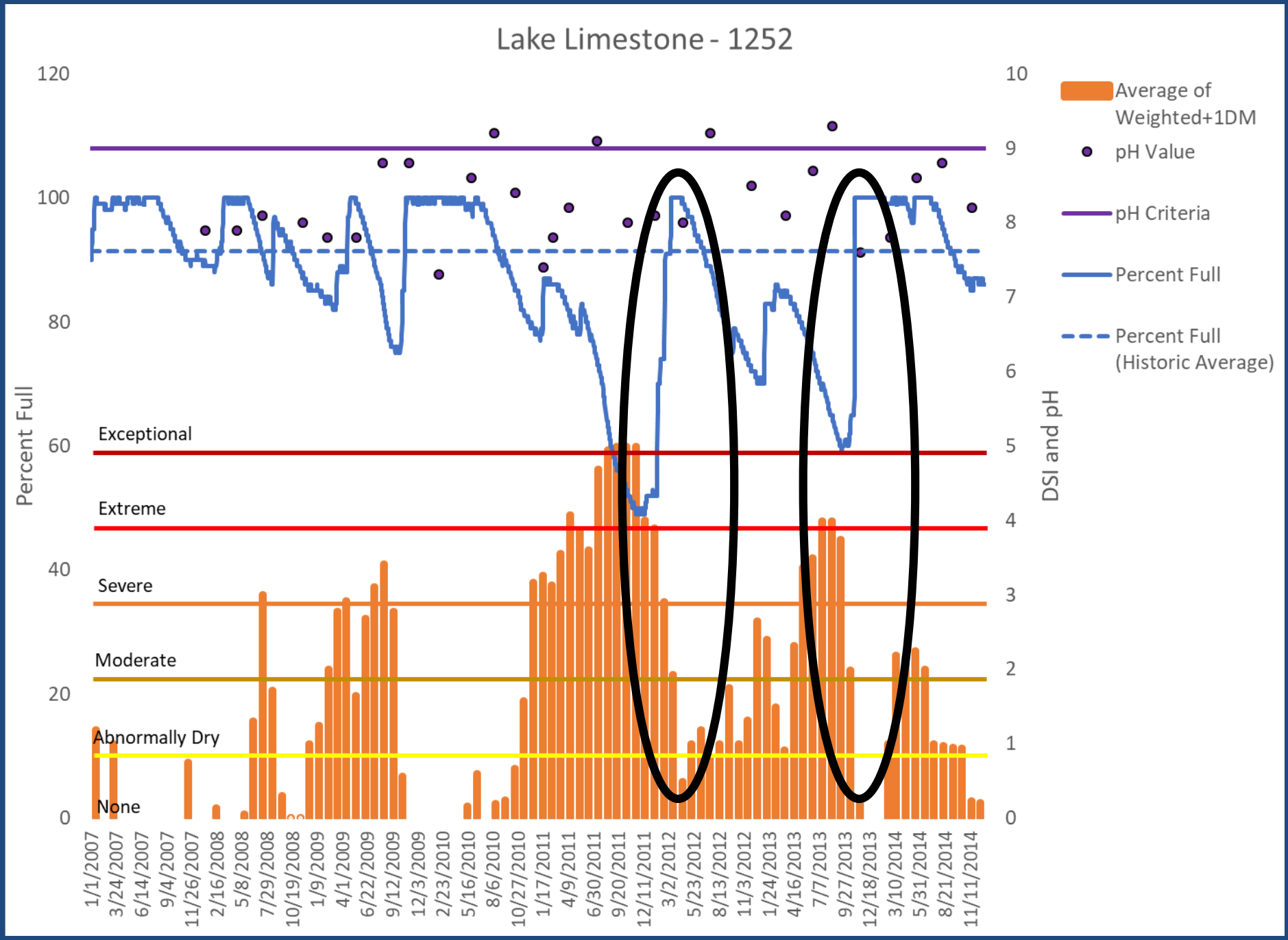
A. Reservoir percent full increases above historical average percent full

B. Wt. DSI ≤ 2 (moderate drought)
   Wt. DSI < 2 (more towards abnormally dry)
   Wt. DSI ≤ 1 (abnormally dry)

C. A combination of the above

D. Other options and/or parameters?


Lake Cypress Springs - 0405
Reservoir Percent Full
DSI and Chl-a
120
100
80
60
40
20
0
60
50
40
30
20
10
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (17.54)


Lake Limestone - 1252
Percent Full
DSI and pH
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Average of Weighted+1DM
pH Value
pH Criteria
Percent Full
Percent Full (Historic Average)
1/1/2007
3/24/2007
6/14/2007
9/4/2007
11/26/2007
2/16/2008
5/8/2008
7/29/2008
10/19/2008
1/9/2009
4/1/2009
6/22/2009
9/12/2009
12/3/2009
2/23/2010
5/16/2010
8/6/2010
10/27/2010
1/17/2011
4/9/2011
6/30/2011
9/20/2011
12/11/2011
3/2/2012
5/23/2012
8/13/2012
11/3/2012
1/24/2013
4/16/2013
7/7/2013
9/27/2013
12/18/2013
3/10/2014
5/31/2014
8/21/2014
11/11/2014

Drought Options: Data Exclusion

A. Exclude all sample results within drought period

Determination of Standards Attainment

§307.9 (b). Samples to determine standards attainment are collected at locations approved by the commission. Samples collected at non-approved locations may be accepted at the discretion of the commission. Samples to determine standards attainment in ambient water must be representative in terms of location, seasonal variations, and hydrologic conditions. Locations must be typical of significant areas of a water body. Temporal sampling must be sufficient to appropriately address seasonal variations of concern. Sample results that are used to assess standards attainment must not include samples that are collected during extreme hydrologic conditions such as high-flows and flooding immediately after heavy rains. Further guidance on representative sampling, both spatially, temporally, and hydrologically, can be found in the TCEQ Surface Water Quality Monitoring Procedures and the TCEQ Guidance for Assessing and Reporting Surface Water Quality in Texas as amended.

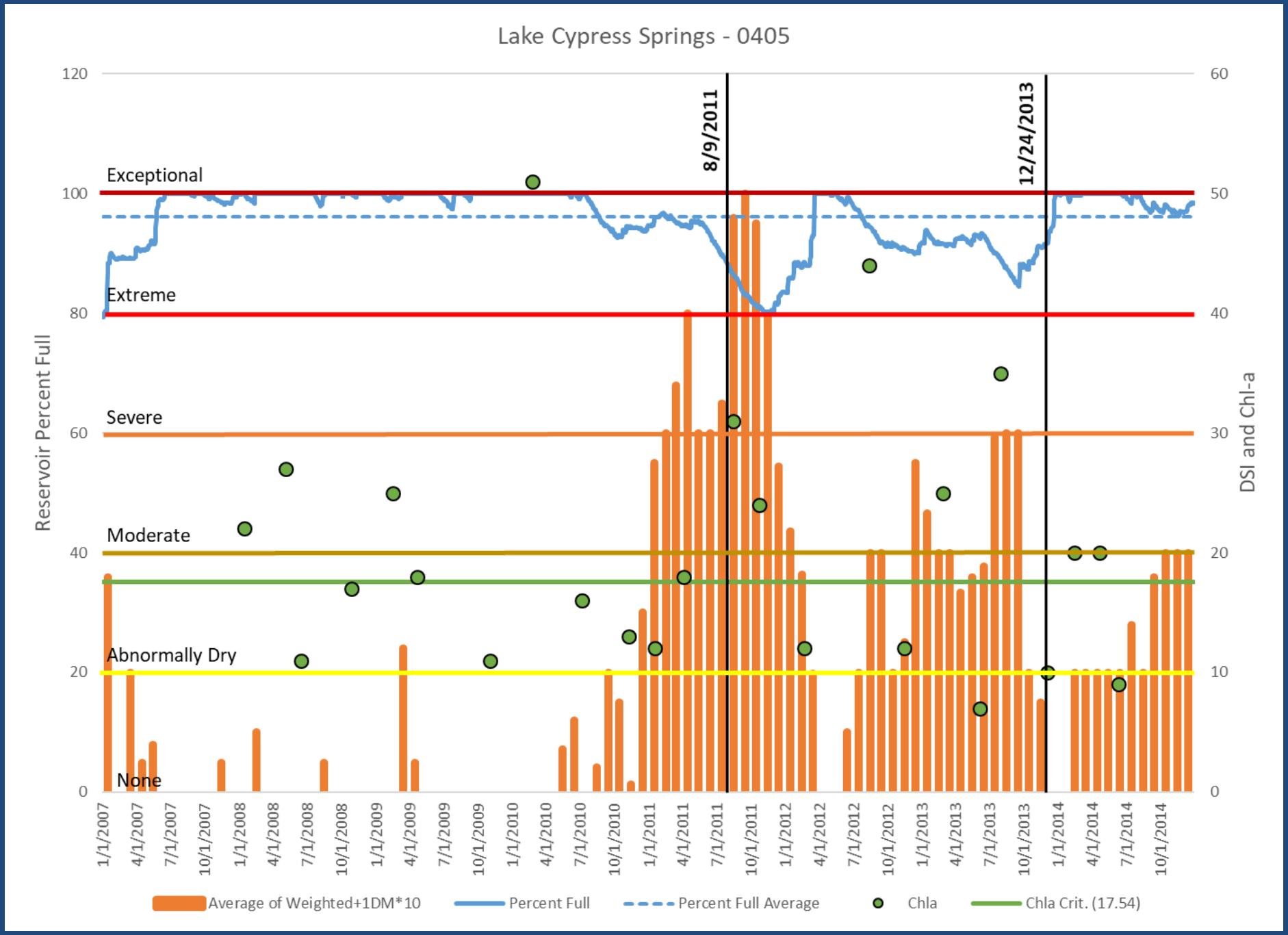
Drought Options: Data Exclusion

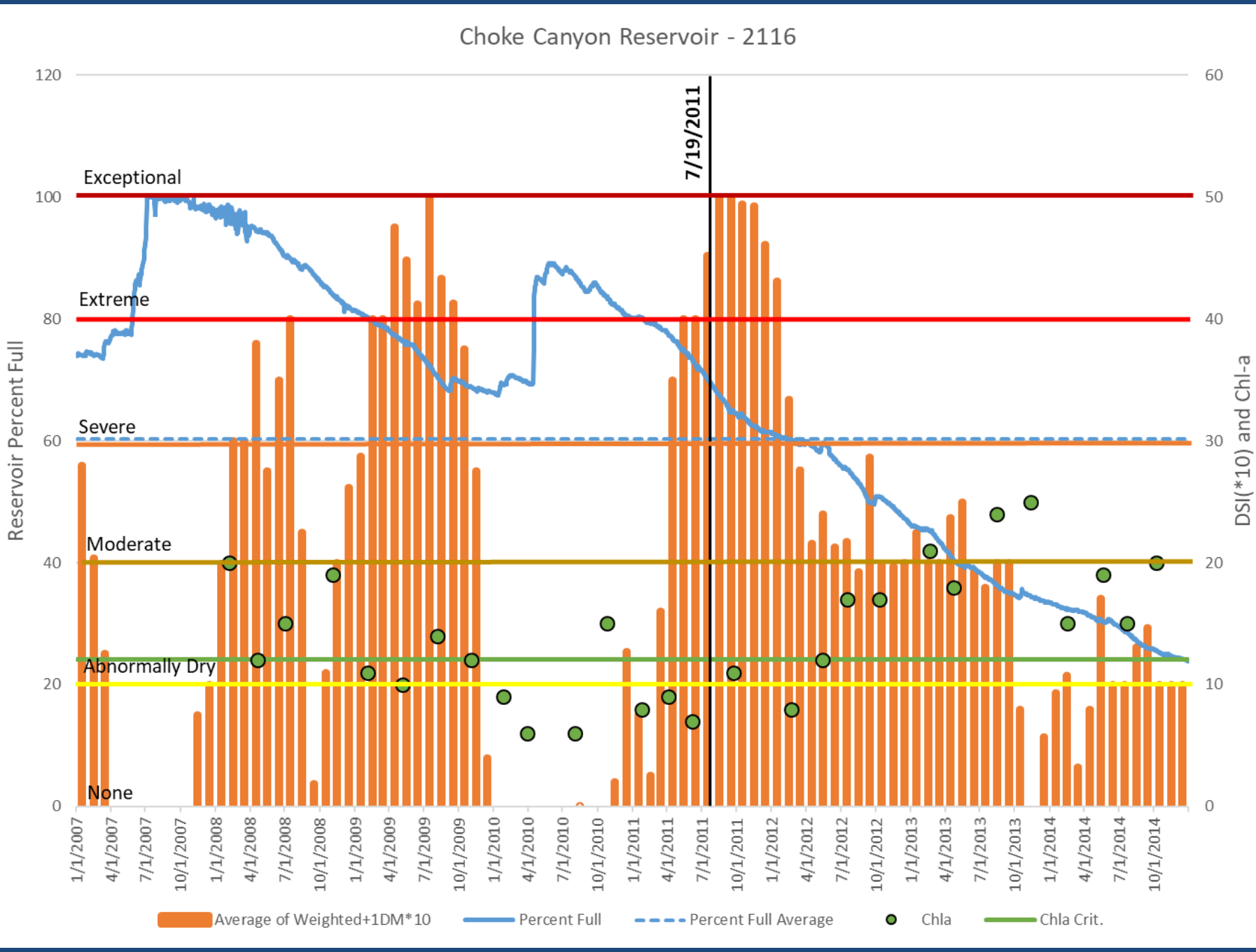
A. Exclude all sample results within drought period

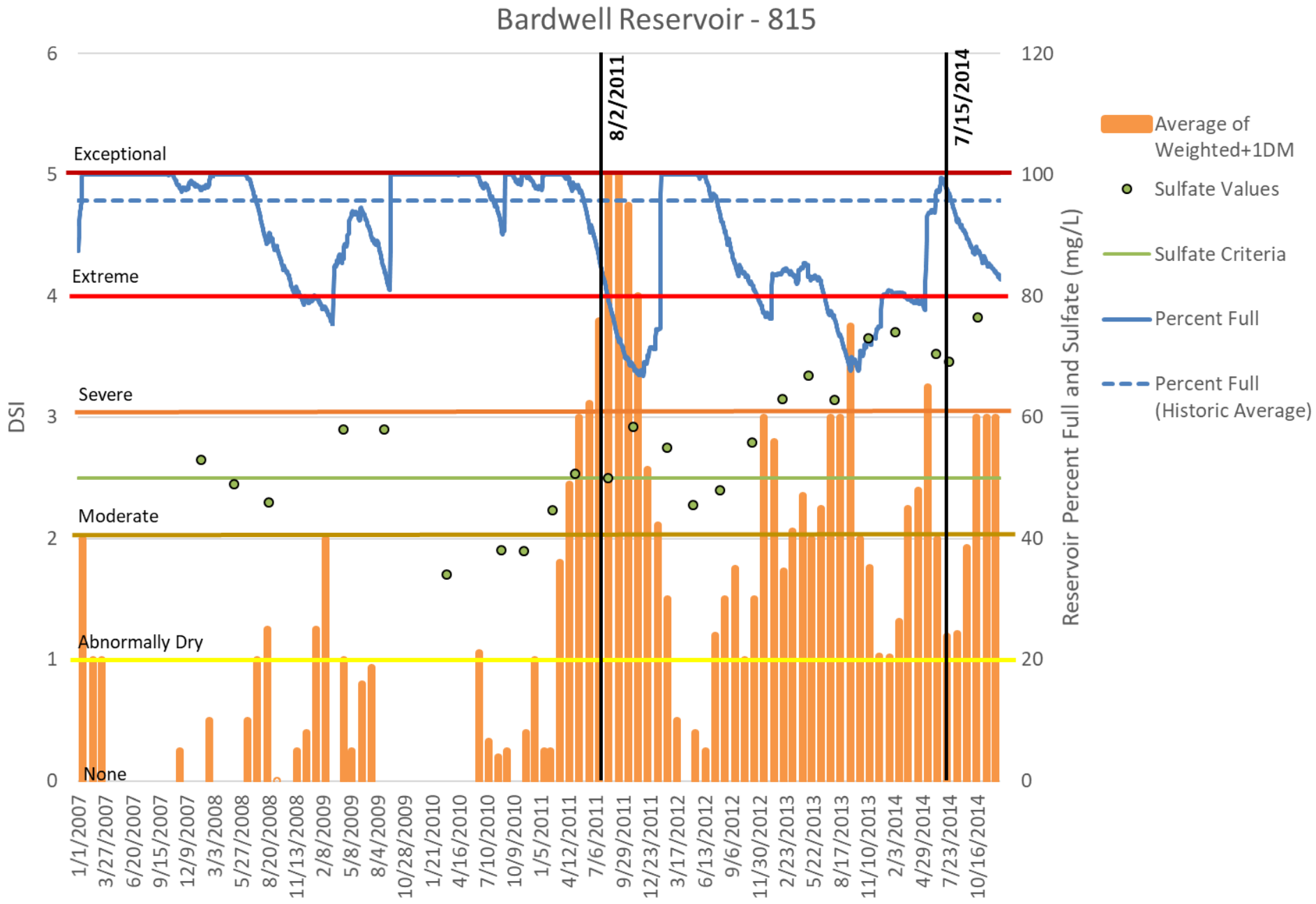
B. Exclude only exceedances within drought period

Reservoir Name	Segment ID	Summary outcome (no drought)	Summary outcome (all drought removed)	Summary outcome (drought exceedances removed)
Lake Cypress Springs	0405	not supporting	not supporting	fully supporting
Hubbard Creek Reservoir	1233	not supporting	fully supporting	fully supporting
White River Lake	1240	not supporting	not supporting	fully supporting
Lake Coleman	1419	not supporting	fully supporting	fully supporting
Choke Canyon Reservoir	2116	not supporting	insufficient data (TN)	insufficient data (TN)

Reservoir Name	sample count	sample count (all drought removed)	sample count (drought exceedances removed)	Criteria Chl-a	Chl-a median	Chl-a median (all drought removed)	Chl-a median (drought exceedances removed)
Lake Cypress Springs	24	15	19	17.54	18	17.9	16.4
Hubbard Creek Reservoir	15	8	10	5.61	5.89	5.08	3.0
White River Lake	22	10	12	13.85	15.5	14.15	13.3
Lake Coleman	15	8	10	6.07	6.85	4.8	4.53
Choke Canyon Reservoir	28	15	17	12.05	14.55	10.8	10.8

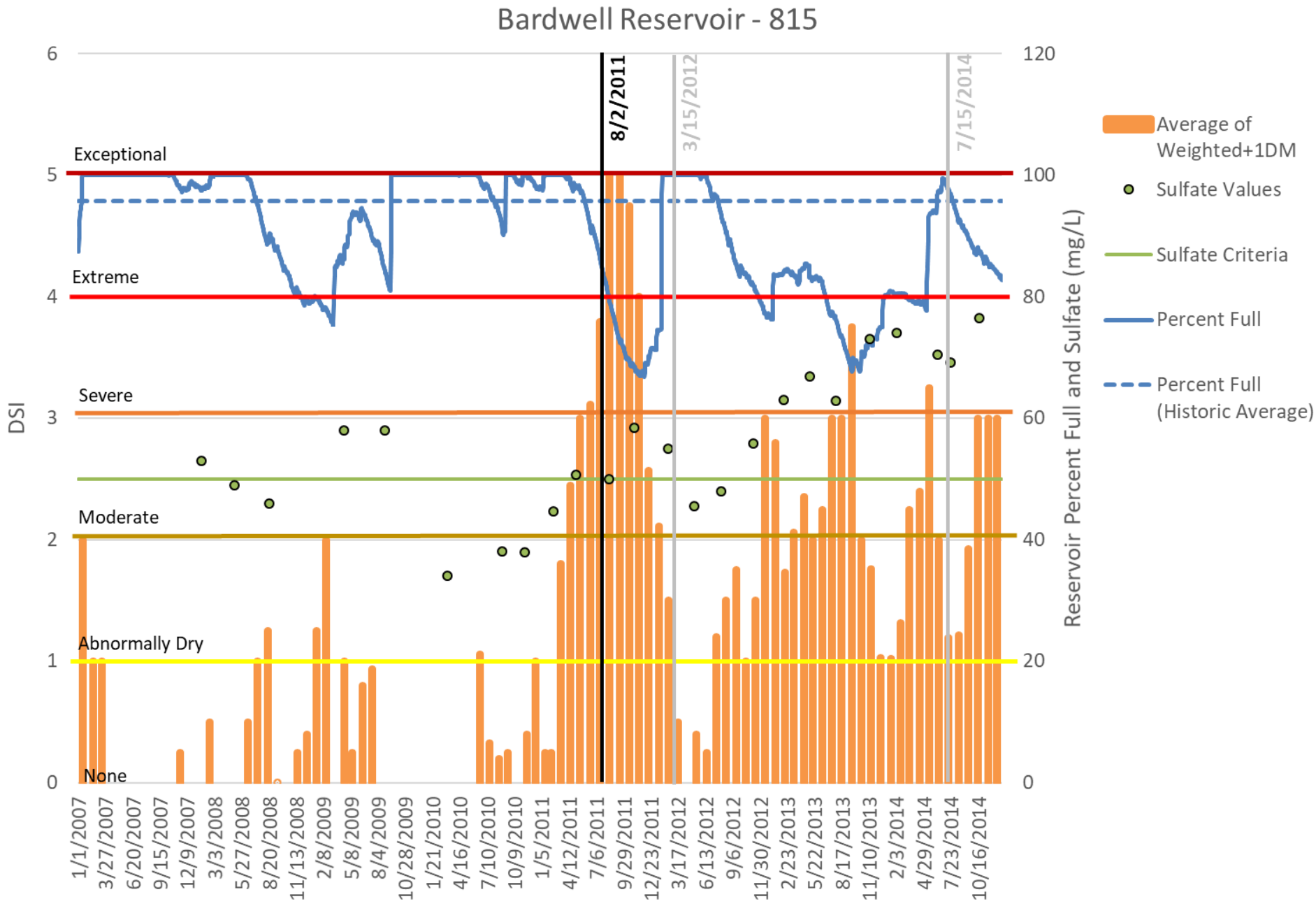

Lake Cypress Springs - 0405
Reservoir Percent Full
DSI and Chl-a
8/9/2011
12/24/2013
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
120
100
80
60
40
20
0
60
50
40
30
20
10
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit. (17.54)


Choke Canyon Reservoir - 2116
7/19/2011
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
Reservoir Percent Full
DSI(*10) and Chl-a
120
100
80
60
40
20
0
60
50
40
30
20
10
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
Average of Weighted+1DM*10
Percent Full
Percent Full Average
Chla
Chla Crit.


Bardwell Reservoir - 815
DSI
Reservoir Percent Full and Sulfate (mg/L)
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
8/2/2011
7/15/2014
Average of Weighted+1DM
Sulfate Values
Sulfate Criteria
Percent Full
Percent Full (Historic Average)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014

Drought Options: Water Quality Data

- How should we evaluate if and what water quality data should be excluded?
  - Overall data trends
  - Additional information and best professional judgement
  - Do not take water quality data into consideration
  - Other options?


Bardwell Reservoir - 815
DSI
Reservoir Percent Full and Sulfate (mg/L)
Exceptional
Extreme
Severe
Moderate
Abnormally Dry
None
8/2/2011
3/15/2012
7/15/2014
Average of Weighted+1DM
Sulfate Values
Sulfate Criteria
Percent Full
Percent Full (Historic Average)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
1/1/2007
3/27/2007
6/20/2007
9/15/2007
12/9/2007
3/3/2008
5/27/2008
8/20/2008
11/13/2008
2/8/2009
5/8/2009
8/4/2009
10/28/2009
1/21/2010
4/16/2010
7/10/2010
10/9/2010
1/5/2011
4/12/2011
7/6/2011
9/29/2011
12/23/2011
3/17/2012
6/13/2012
9/6/2012
11/30/2012
2/23/2013
5/22/2013
8/17/2013
11/10/2013
2/3/2014
4/29/2014
7/23/2014
10/16/2014

Outline

- Revisit Drought Severity Index Scores (DSI)
- Incorporating drought evaluations
  - Methods tested and used for 2016 Integrated Report
- Drought in reservoirs
  - Discussion items
    - Onset of drought
    - Conclusion of drought
    - Data exclusion for drought period
    - Water quality data evaluation
- Drought in large rivers

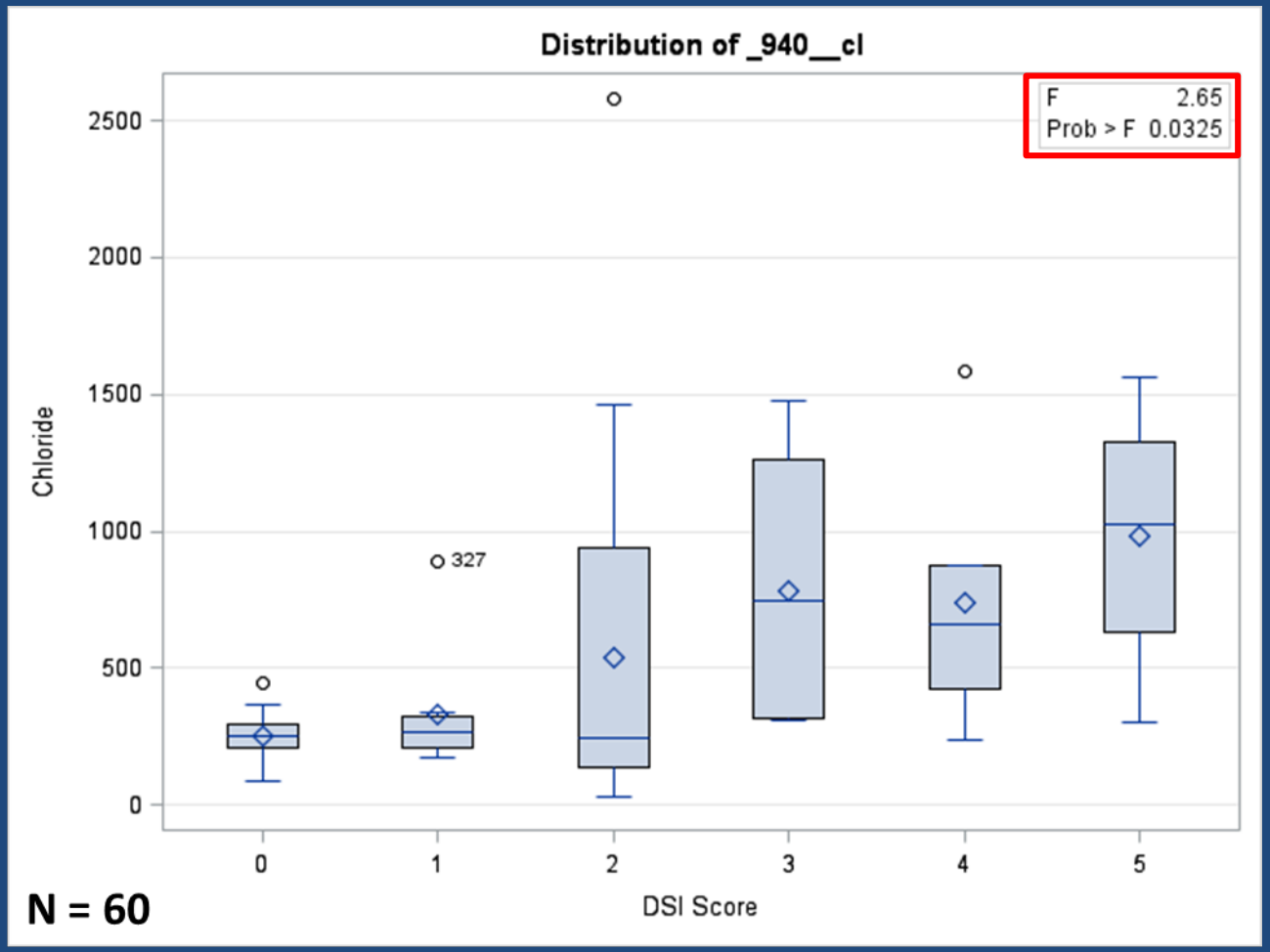
Drought in Rivers

- Small rivers and streams are already evaluated during low-flow conditions or are dry during drought conditions
- What methods should be used to evaluate drought in large rivers?
  - Statistics
    - Naturally small sample size due to monitoring schedule
    - Lower sample size when exceedances are removed
    - Values have wide range (focus is on impairments)
  - Graph visualizations
    - Flow variations

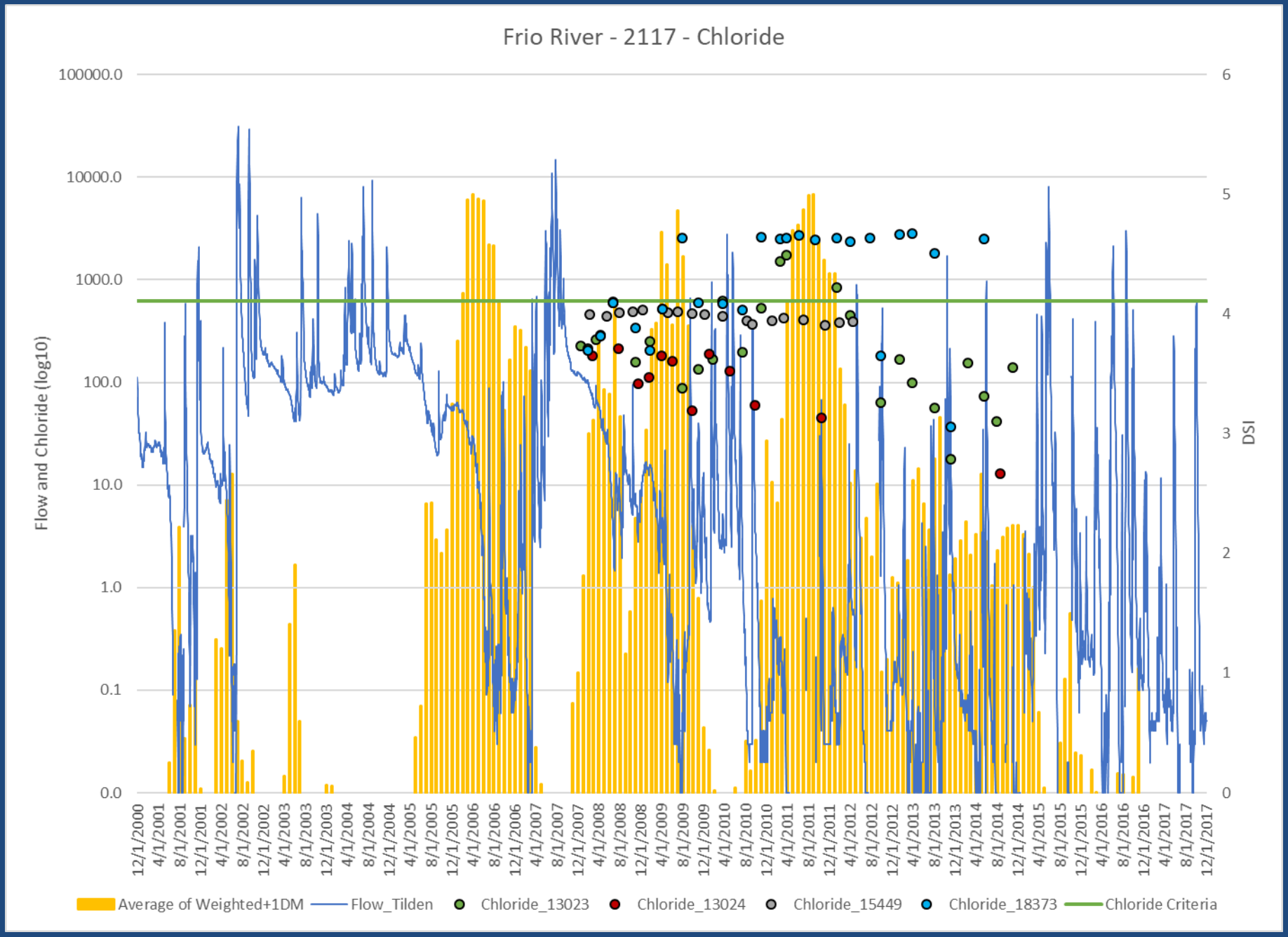
Drought in Rivers

- Factors to consider
  - Water quality
  - DSI
  - Flow
  - Other parameters?
- Examples of preliminary ANOVAs and graphs for new impairments in 2016 IR

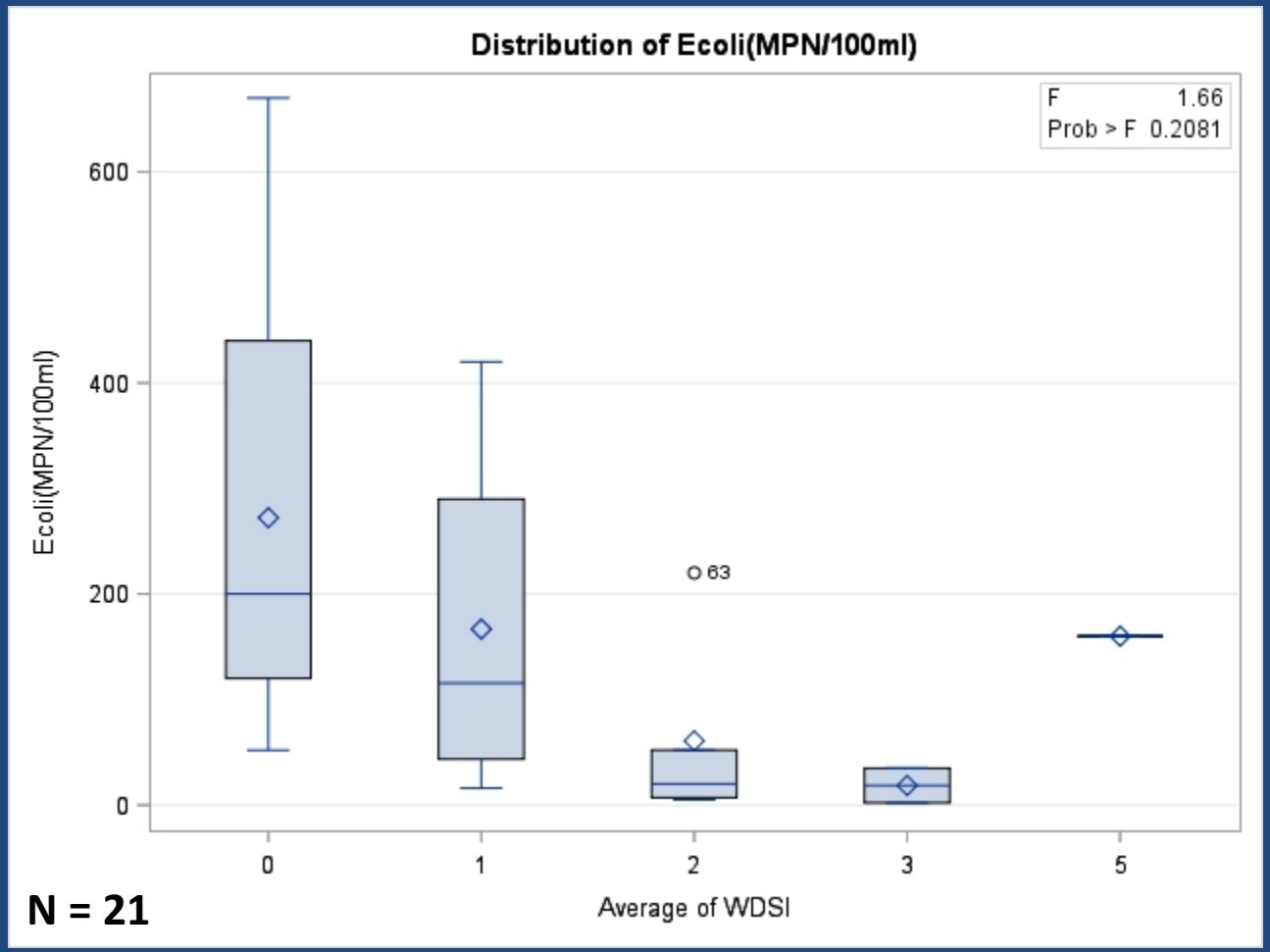
Frio River - Chloride

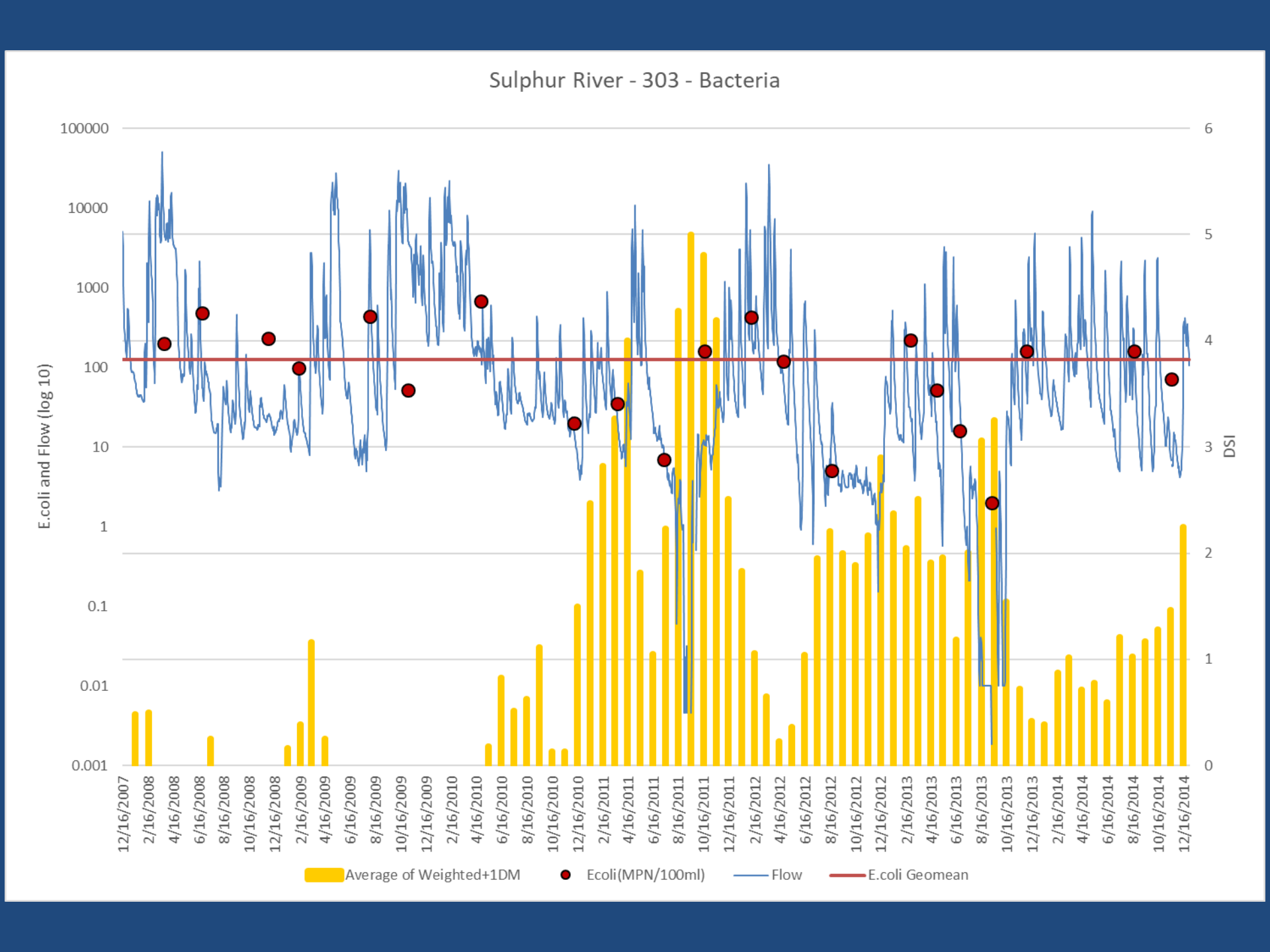


ANOVA significant; Tukey's did not show individual significance

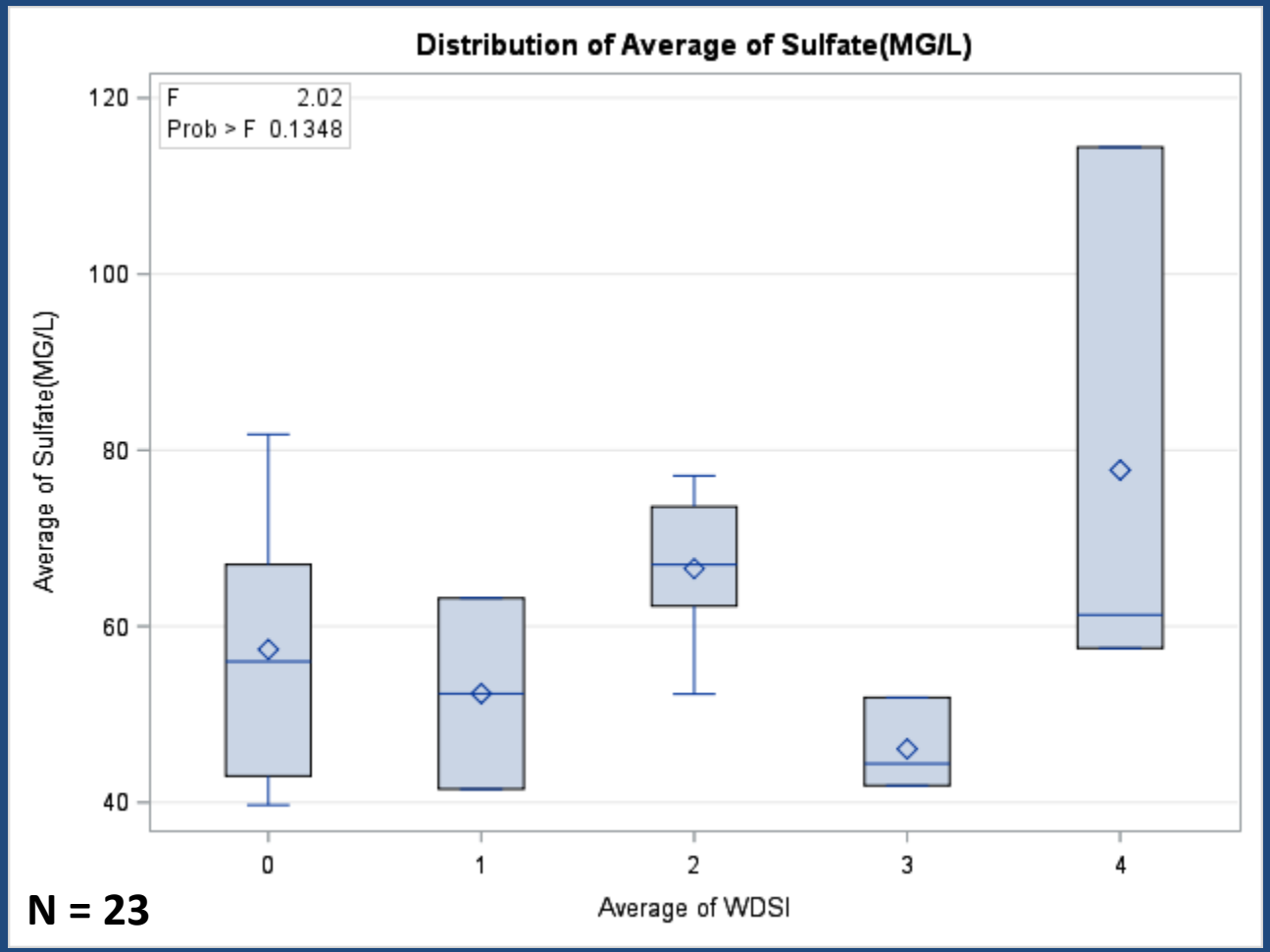

Frio River - 2117 - Chloride
Flow and Chloride (log10)
DSI
100000.0
10000.0
1000.0
100.0
10.0
1.0
0.1
0.0
6
5
4
3
2
1
0
12/1/2000
4/1/2001
8/1/2001
12/1/2001
4/1/2002
8/1/2002
12/1/2002
4/1/2003
8/1/2003
12/1/2003
4/1/2004
8/1/2004
12/1/2004
4/1/2005
8/1/2005
12/1/2005
4/1/2006
8/1/2006
12/1/2006
4/1/2007
8/1/2007
12/1/2007
4/1/2008
8/1/2008
12/1/2008
4/1/2009
8/1/2009
12/1/2009
4/1/2010
8/1/2010
12/1/2010
4/1/2011
8/1/2011
12/1/2011
4/1/2012
8/1/2012
12/1/2012
4/1/2013
8/1/2013
12/1/2013
4/1/2014
8/1/2014
12/1/2014
4/1/2015
8/1/2015
12/1/2015
4/1/2016
8/1/2016
12/1/2016
4/1/2017
8/1/2017
12/1/2017
Average of Weighted+1DM
Flow_Tilden
Chloride_13023
Chloride_13024
Chloride_15449
Chloride_18373
Chloride Criteria

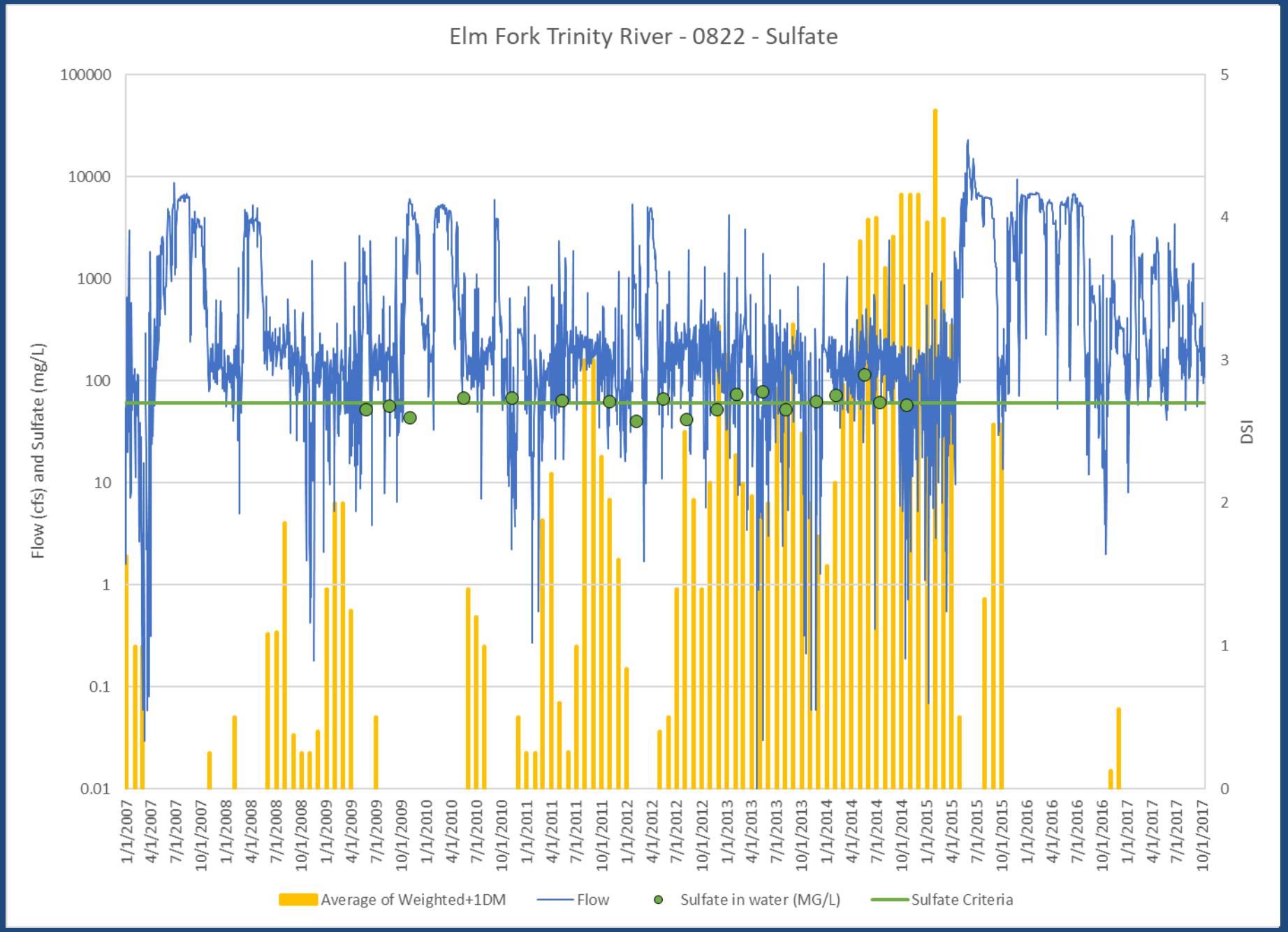
Sulphur River - Bacteria



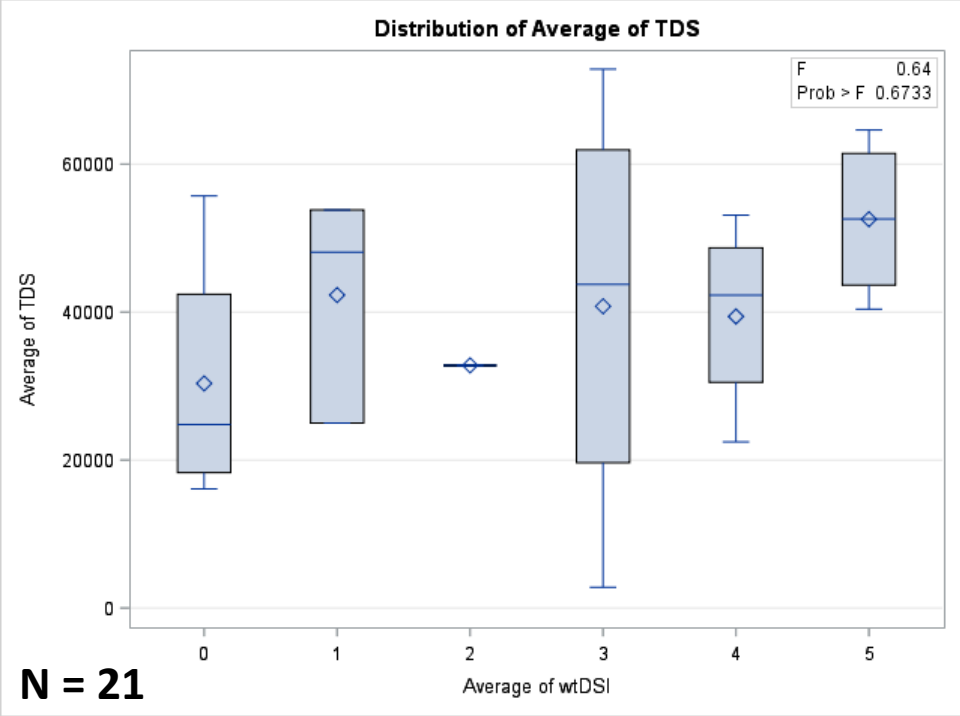

Sulphur River - 303 - Bacteria
E.coli and Flow (log 10)
DSI
100000
10000
1000
100
10
1
0.1
0.01
0.001
6
5
4
3
2
1
0
12/16/2007
2/16/2008
4/16/2008
6/16/2008
8/16/2008
10/16/2008
12/16/2008
2/16/2009
4/16/2009
6/16/2009
8/16/2009
10/16/2009
12/16/2009
2/16/2010
4/16/2010
6/16/2010
8/16/2010
10/16/2010
12/16/2010
2/16/2011
4/16/2011
6/16/2011
8/16/2011
10/16/2011
12/16/2011
2/16/2012
4/16/2012
6/16/2012
8/16/2012
10/16/2012
12/16/2012
2/16/2013
4/16/2013
6/16/2013
8/16/2013
10/16/2013
12/16/2013
2/16/2014
4/16/2014
6/16/2014
8/16/2014
10/16/2014
12/16/2014
Average of Weighted+1DM
Ecoli(MPN/100ml)
Flow
E.coli Geomean

Elm Fork Trinity River - Sulfate

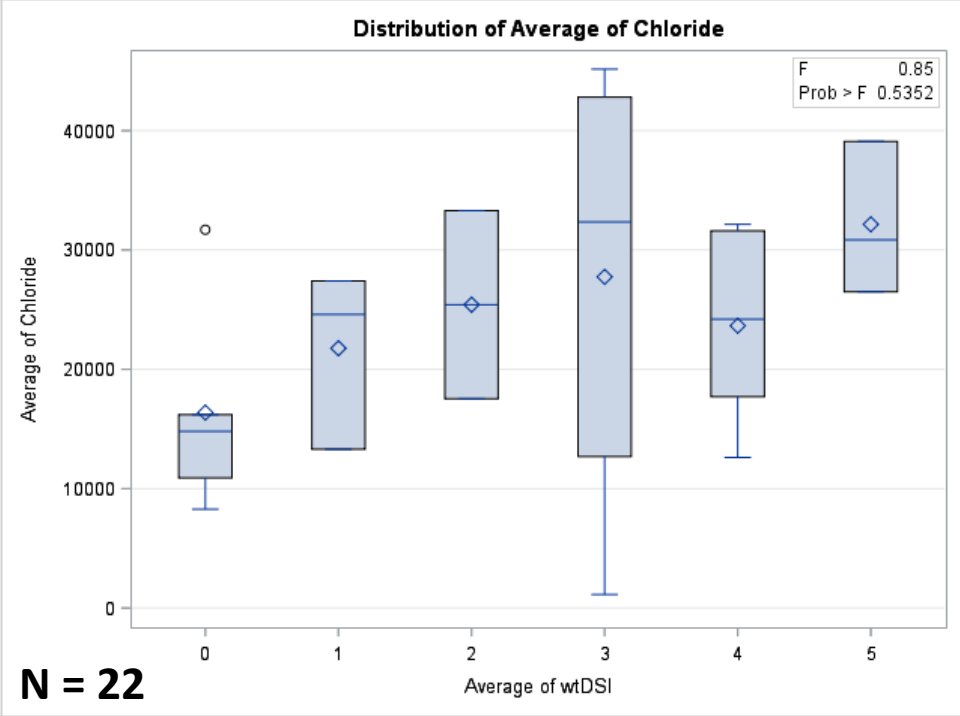



Elm Fork Trinity River - 0822 - Sulfate
Flow (cfs) and Sulfate (mg/L)
DSI
100000
10000
1000
100
10
1
0.1
0.01
5
4
3
2
1
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015
4/1/2015
7/1/2015
10/1/2015
1/1/2016
4/1/2016
7/1/2016
10/1/2016
1/1/2017
4/1/2017
7/1/2017
10/1/2017
Average of Weighted+1DM
Flow
Sulfate in water (MG/L)
Sulfate Criteria

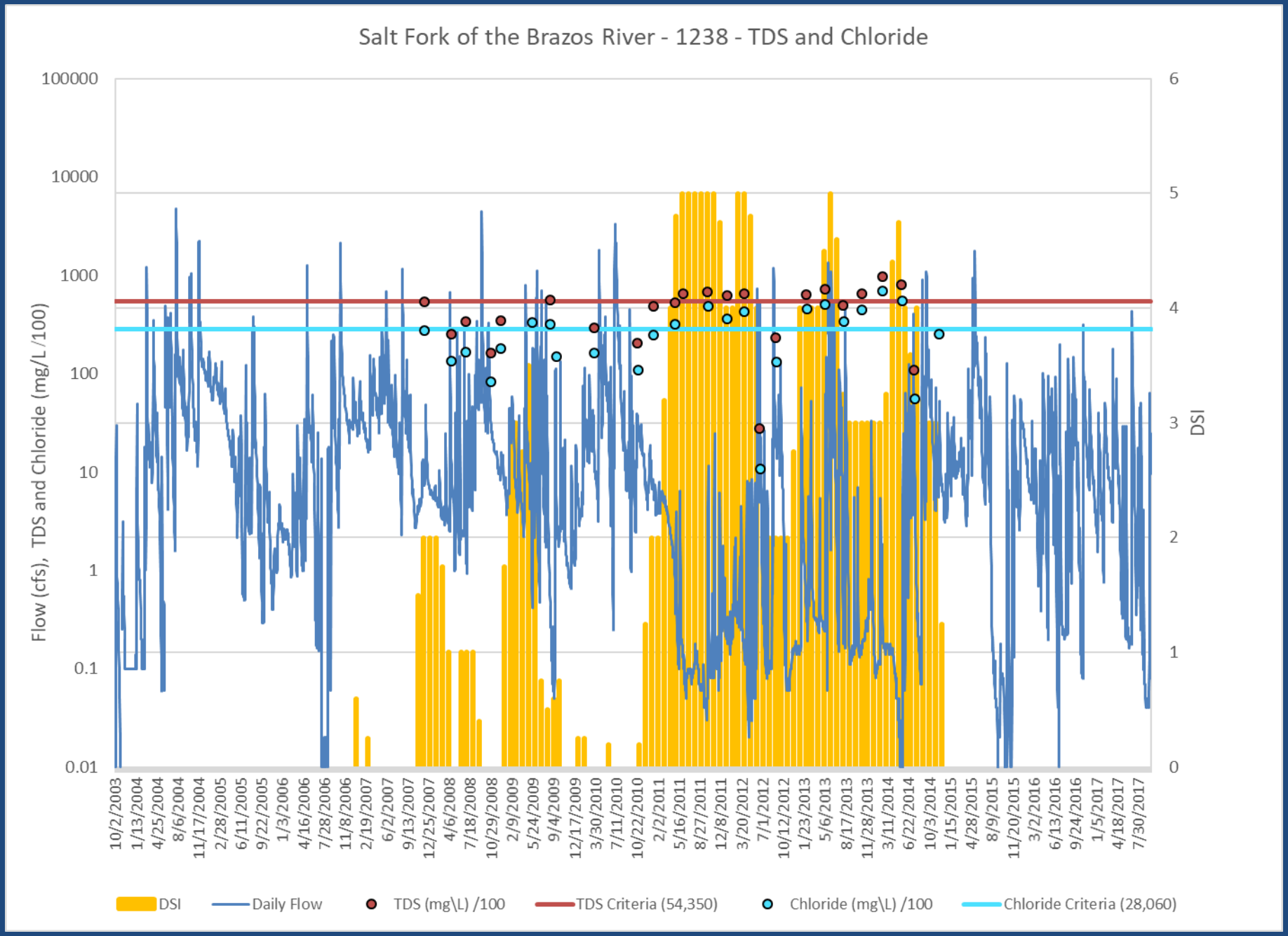
Salt Fork Brazos River – TDS and Chloride



N = 21



N = 22

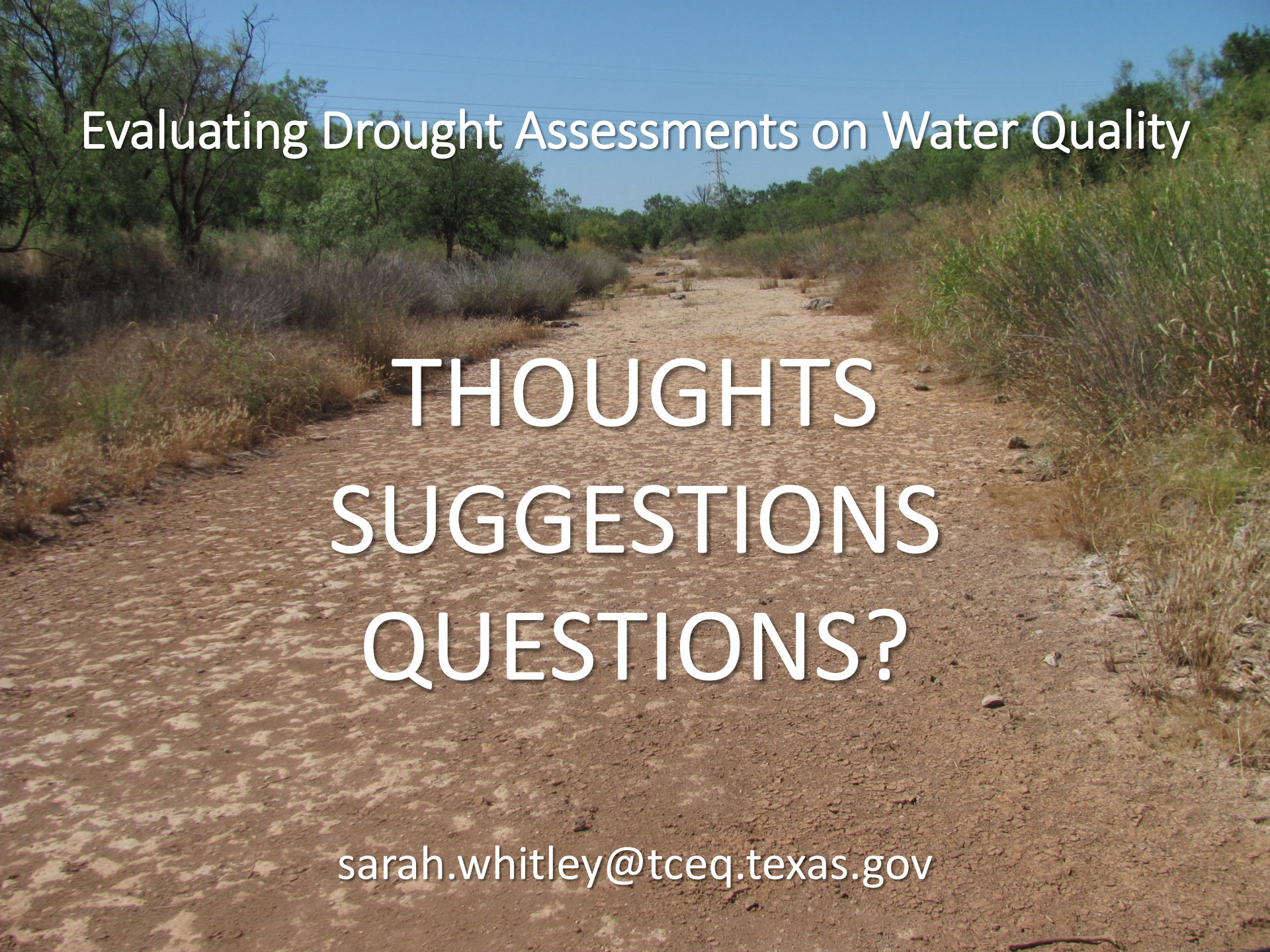

Salt Fork of the Brazos River - 1238 - TDS and Chloride
Flow (cfs), TDS and Chloride (mg/L /100)
DSI
100000
10000
1000
100
10
1
0.1
0.01
6
5
4
3
2
1
0
10/2/2003
1/13/2004
4/25/2004
8/6/2004
11/17/2004
2/28/2005
6/11/2005
9/22/2005
1/3/2006
4/16/2006
7/28/2006
11/8/2006
2/19/2007
6/2/2007
9/13/2007
12/25/2007
4/6/2008
7/18/2008
10/29/2008
2/9/2009
5/24/2009
9/4/2009
12/17/2009
3/30/2010
7/11/2010
10/22/2010
2/2/2011
5/16/2011
8/27/2011
12/8/2011
3/20/2012
7/1/2012
10/12/2012
1/23/2013
5/6/2013
8/17/2013
11/28/2013
3/11/2014
6/22/2014
10/3/2014
1/15/2015
4/28/2015
8/9/2015
11/20/2015
3/2/2016
6/13/2016
9/24/2016
1/5/2017
4/18/2017
7/30/2017
DSI
Daily Flow
TDS (mg\L) /100
TDS Criteria (54,350)
Chloride (mg\L) /100
Chloride Criteria (28,060)

Drought in Rivers

- How should we evaluate if and what water quality data should be excluded?
  - Overall data trends
  - Additional information and best professional judgement
  - Consider gaging stations and associated flows
  - Do not take water quality data into consideration
  - Other options?

Drought Methods

- Methods continue to be developed
  - Is there a better method that we have not explored?
  - Can the same or similar method be applied to rivers as we used for reservoirs?
  - Can one method be applied to all water quality parameters for the same waterbody type?
    - Dissolved Solids
    - Bacteria
    - pH


Evaluating Drought Assessments on Water Quality
THOUGHTS
SUGGESTIONS
QUESTIONS?
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