Narrative Nutrient Criteria Development for Arizona Reservoirs

AIS Meeting 2/16/2018

Susan Fitch, Hydrogeologist III/Reservoir Ecologist

ADEQ

High Level Overview

- 2002/2003 began project and hired Malcolm Pirnie (MP) for statistical analysis and modeling
- 2005 Data analysis report/addendum and proposed targets
- 2008/2009 Draft IP; "Matrix of Endpoints" and narrative language promulgated in 2009 in AZ WQS (Region 9 review)
- 2009/2010 EPA Headquarters/peer review (Tetra Tech and Dr. Wurtsbaugh)
- 2010 EPA review* resulted in the need to refine criteria
- 2012 Dr. David Walker (University of Arizona) hired to refine criteria

* Next page

Phase I Peer Review

- Data Issues
  - Questioned TN and TP data/values.. seemed high
  - Questioned relationship of TN and TP to Chlrorophyll-a data/values
- Cold water criteria not protective of salmonids; define “warm”, vs. “cool”, vs “cold” fishery
- Classification scheme
  - Lack of direct consideration of stratified vs mixed
  - Lack of consideration of dissolved oxygen under stratified conditions
- Questioned protectiveness of Chlorophyll-a ranges
- Use of ranges in “matrix of endpoints”; implementation?
- DO criteria only applies in top 1 m; address DO gradient/hypoxia

Summary of Phase II Project Approach

- Use expanded/updated database (1990 – 2012) of 68 reservoirs
- Create elevation categories; define "cold" vs "cool" fisheries
- Incorporate DO gradient (hypoxia) analysis
- Refine reservoir classes by size, depth and stratification
- Rerun key statistics
  - Confirm and/or refine nutrient : chlorophyll relationship
  - Add dissolved organic carbon (DOC) and total suspended solids (TSS)
- Establish protective chlorophyll-a endpoints that relate to risk of cyanobacteria blooms
- Replace ranges with bright-line numeric endpoints, while retaining the "matrix of endpoints" and "weight-of-evidence" approach

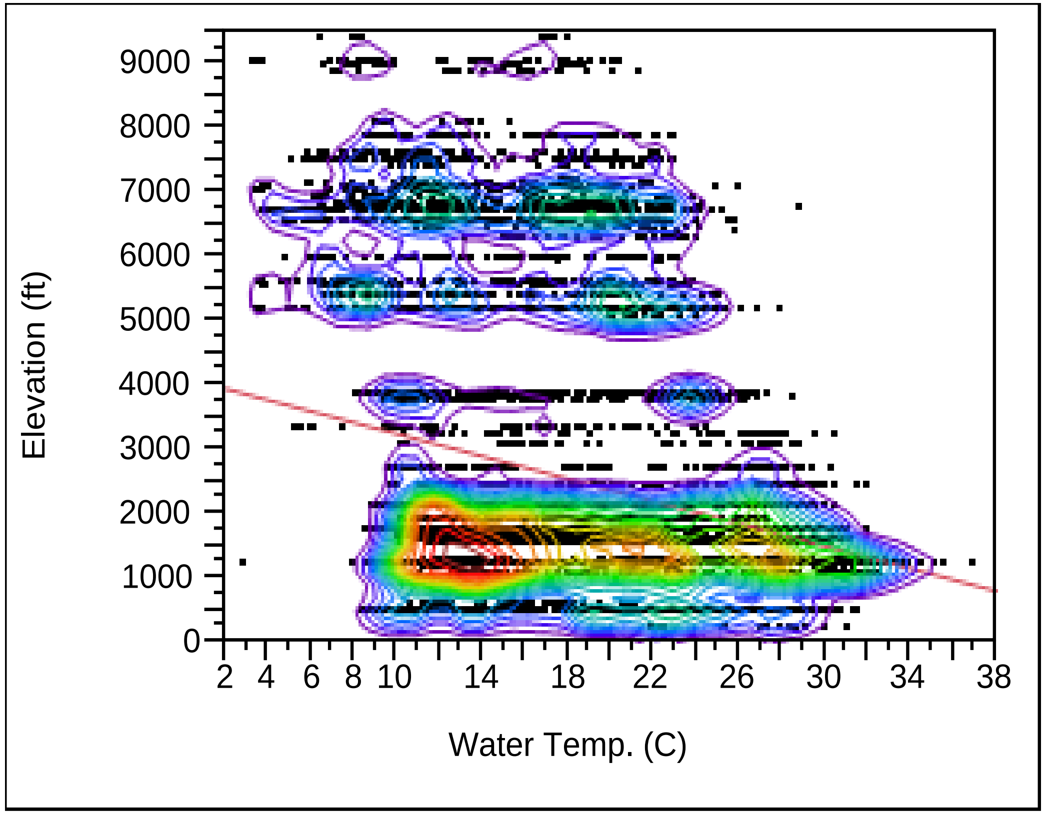
Determination of Elevation Categories

Bivariate Fit of Elevation (ft) By Water Temp. (C)

Cold

Cool

Warm



Quantiles for all 66 Reservoirs

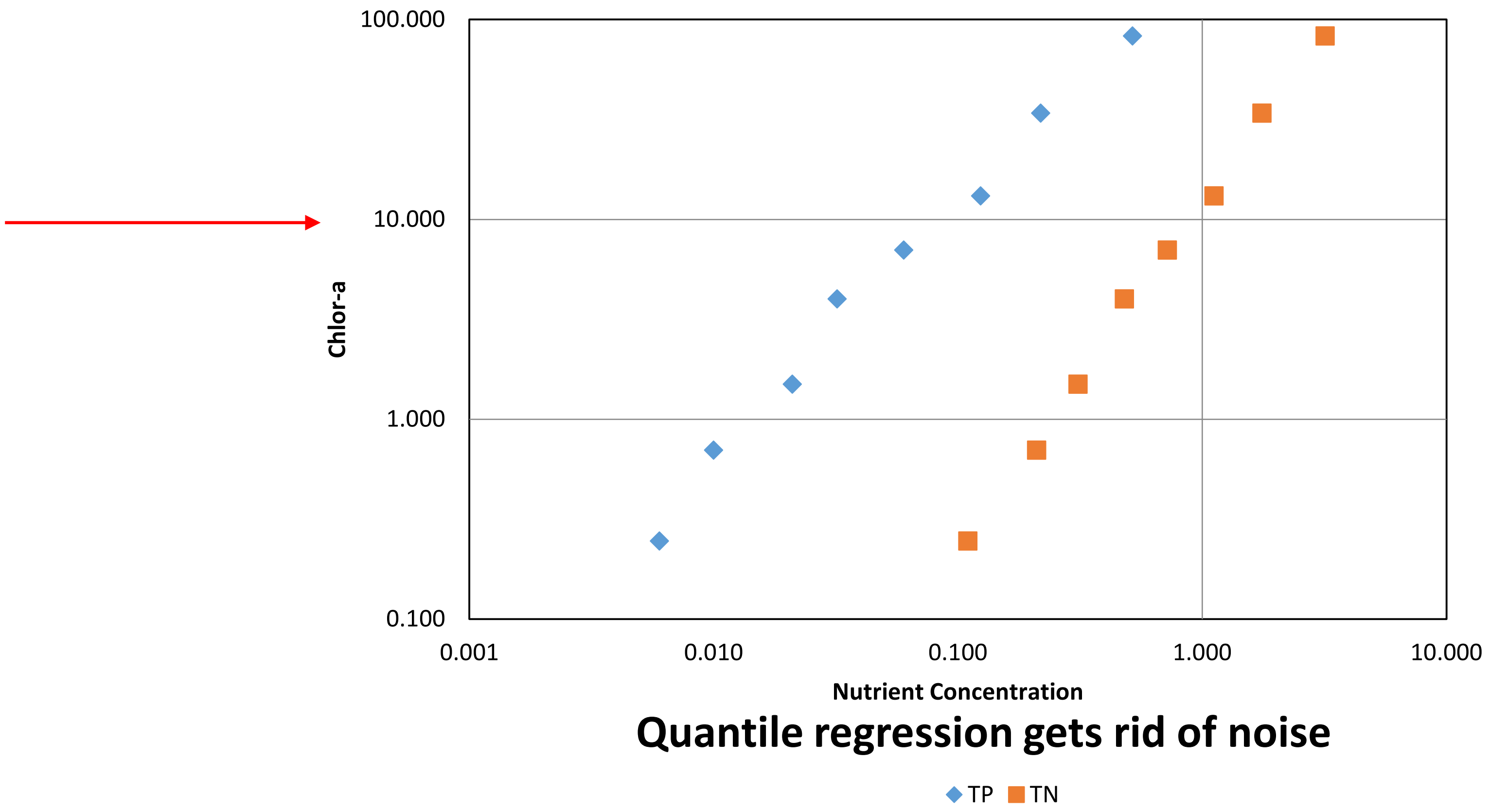
Stat %	NO2+NO3	TKN	TN	TP	CHLOR	DOC
0.0	0.005	0.010	0.015	0.004	0.060	1.500
2.5	0.010	0.100	0.110	0.006	0.246	1.500
5.0	0.010	0.200	0.210	0.010	0.700	2.915
10.0	0.010	0.300	0.310	0.021	1.500	5.060
25.0	0.030	0.450	0.480	0.032	4.000	6.185
50.0	0.090	0.630	0.720	0.060	7.028	8.300
75.0	0.200	0.920	1.120	0.124	13.100	12.250
90.0	0.370	1.390	1.760	0.218	34.080	15.300
97.5	0.738	2.451	3.189	0.518	82.800	22.955
99.5	3.875	4.230	8.105	5.029	95.628	36.637
100.0	7.380	15.100	22.480	19.000	127.000	38.400

25th to 50th percentiles used as benchmark for protection of most sensitive designated uses (cold water fishery); 25th as basis for TSI

50th – 75th percentiles could be basis for a **range** of expectation from DWS to FBC to A&W designated uses

TN and TP with Chlorophyll-a (all 66 ‘lakes’)

Log-log Quantiles 2.5 - 97.5



Recursive Partitioning (CART) based on Chlorophyll-a

in order of significance

- **Catagorical + Nutrients**
  - Overall: Dominant geology, TSS/Secchi, TP
  - < 4500: Dominant geology, W:L, % Ag
  - 4500-8000: TP, Dominant geology, size/depth
  - > 8000: Avg surface temp, % range

- **Nutrients Only**
  - Overall: TP, DOC, TN
  - < 4500: TN, TP
  - 4500-8000: TP, TOC, TN
  - > 8000: TKN

Principal Components Analysis (PCA)

Covariance Matrix (log transformed data) R values

- **Overall (P)**
  - **TP w/Chlor-a: 0.58**
  - TP w/TOC: 0.41
  - TP w/DOC: 0.39
  - **Ortho-P* w/Chlor-a: 0.63**

- **< 4500 ft (P)**
  - **TP w/Chlor-a: 1.1**
  - TP w/TOC: 0.31
  - TP w/DOC: 0.36
  - **Ortho-P* w/Chlor-a: 1.4**

- **4500-8000 ft (Co-limitation?)**
  - TP w/Chlor-a: 0.09
  - TP w/TOC or DOC: 0.26
  - **TN w/Chlor-a: 0.44**
  - **Ortho-P* w/Chlor-a: -0.48**
  - **Ortho-P w/TKN: 0.82**

- **>8000 ft (needs further investigaton)**
  - TP w/TKN :   -0.37
  - TP w/NO2+NO3: -0.45
  - DOC w/Chlor-a: 0.12 (best of any parameter with Chlor-a)
  - TKN w/Chlor-a: -0.12
  - Too little Ortho-P data

* Ortho-P has not been consistently collected

Best Fit Regressions: TP, TN, Chlor-a & Secchi

Least Squares (R^2) vs **Orthogonal (R)**

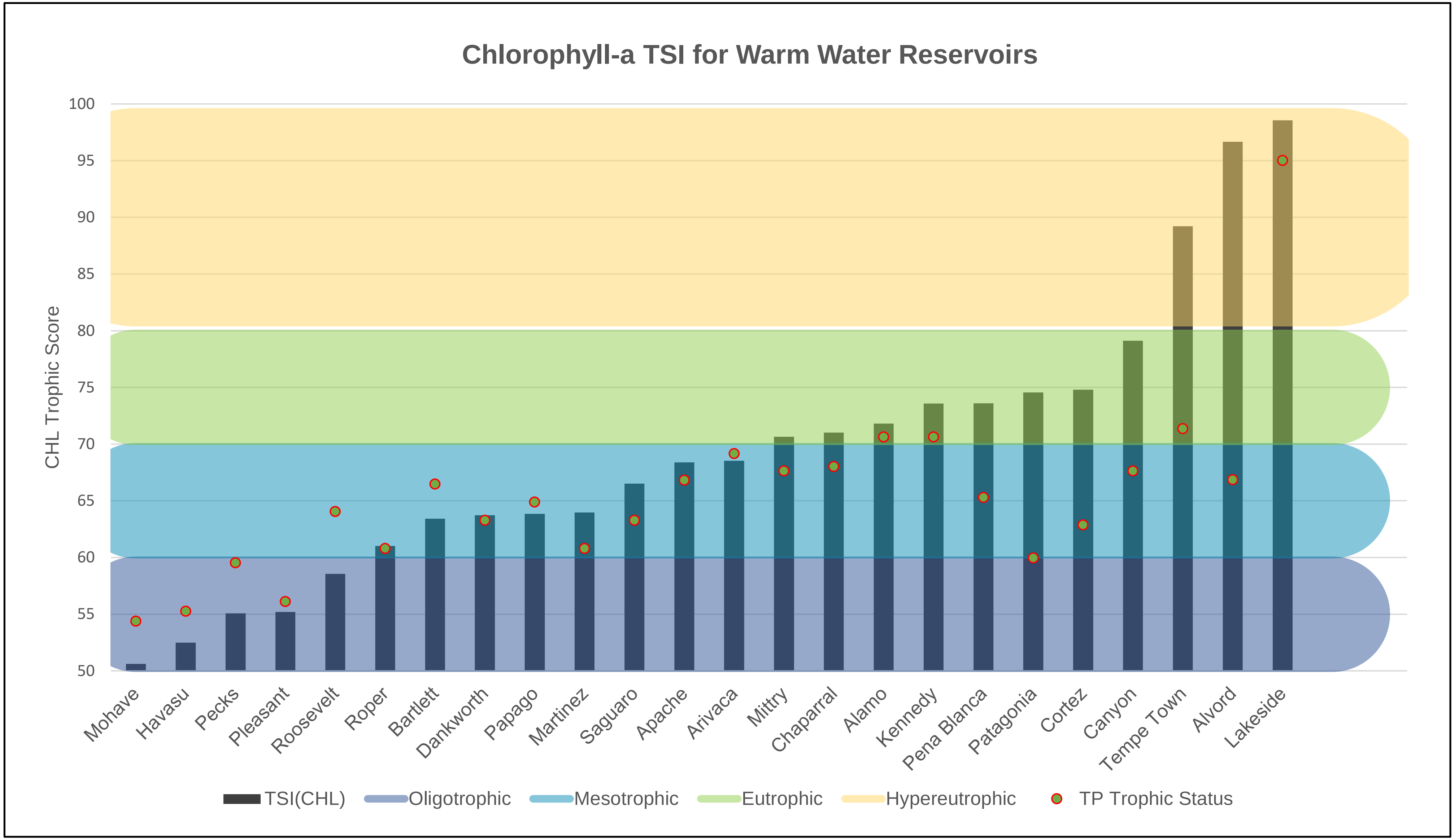
- < 4500 ft
  - 25th Chlor w/25th secchi: R^2 = 0.2; **R = -0.42**
  - 25th Chlor w/25th TP: R^2 = 0.55; **R = 0.75**
  - 50th Chlor w/50th secchi: R^2 = 0.3; **R = -0.55**
  - 50th Chlor w/50th TP: R^2 = 0.66; **R = 0.8**
  - 75th Chlor w75th secchi: R^2 = 0.35; **R = -0.6**
  - 75th Chlor w/75th TP: R^2 = 0.8; **R = 0.9**
- 4500 – 8000 ft
  - 25th Chlor w/25th secchi: R^2 = 0.01; R = -0.11
  - 25th Chlor w/25th TN: R^2 = 0.18; **R = 0.43**
  - 50th Chlor w/50th secchi: R^2 = 0.02; R = -0.15
  - 50th Chlor w/50th TN: R^2 = 0.17; **R = 0.41**
  - 75th Chlor w/75th secchi: R^2 = 0.05; R = -0.21
  - 75th Chlor w/75th TN: R^2 = 0.10; **R = 0.30**
- > 8000 ft
  - Need more data

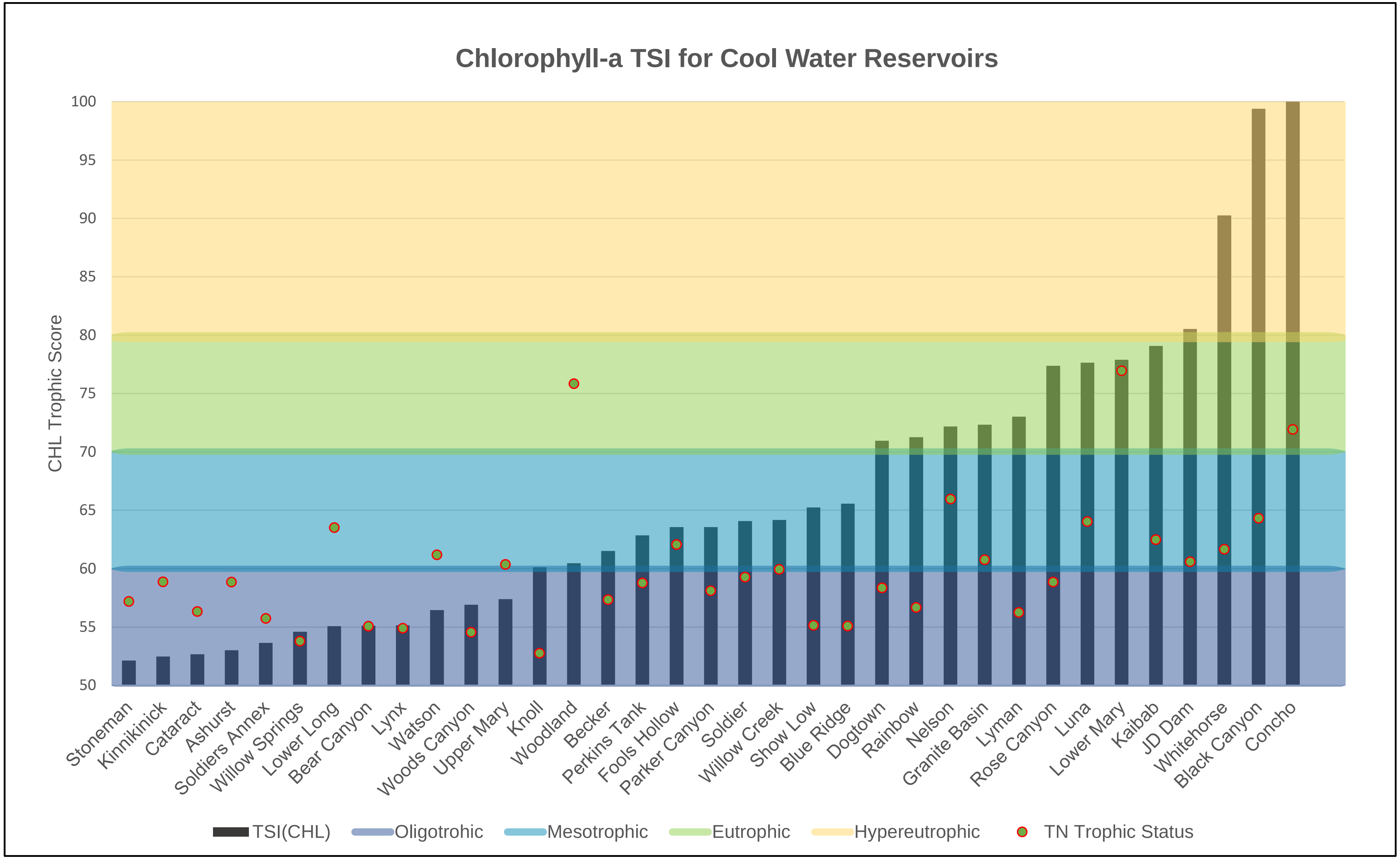
- Lower elevation shows clear trend of decreasing Secchi in relationship to increasing chlorophyll and increasing TP

- Middle elevation shows situation more muddled
  - influence of TN
  - co-limitation
  - impacts of TSS and TOC

AZ Trophic State Index (TSI)

- New method includes TN, TP, secchi and TSS in relation to chlorophyll-a
- Scale of TSI scores based on 50^{th} quantiles
- There is not a consistent relationship across reservoirs, but relationships appear for individual reservoir TN, TP, TSS or Secchi and Chlorophyll-a
- So, the Chlorophyll-a trophic score will set the baseline for comparison and tracking trends over time


Chlorophyll-a TSI for Warm Water Reservoirs
CHL Trophic Score
100
95
90
85
80
75
70
65
60
55
50
Mohave
Havasu
Pecks
Pleasant
Roosevelt
Roper
Bartlett
Dankworth
Papago
Martinez
Saguaro
Apache
Arivaca
Mittry
Chaparral
Alamo
Kennedy
Pena Blanca
Patagonia
Cortez
Canyon
Tempe Town
Alvord
Lakeside
TSI(CHL)
Oligotrophic
Mesotrophic
Eutrophic
Hypereutrophic
TP Trophic Status



Chlorophyll-a TSI for Cool Water Reservoirs
CHL Trophic Score
100
95
90
85
80
75
70
65
60
55
50
Stoneman
Kinnikinick
Cataract
Ashurst
Soldiers Annex
Willow Springs
Lower Long
Bear Canyon
Lynx
Watson
Woods Canyon
Upper Mary
Knoll
Woodland
Becker
Perkins Tank
Fools Hollow
Parker Canyon
Soldier
Willow Creek
Show Low
Blue Ridge
Dogtown
Rainbow
Nelson
Granite Basin
Lyman
Rose Canyon
Luna
Lower Mary
Kaibab
JD Dam
Whitehorse
Black Canyon
Concho
TSI(CHL)
Oligotrohic
Mesotrophic
Eutrophic
Hypereutrophic
TN Trophic Status

Design of the Matrix of Endpoints

- Numeric nutrient criteria will be guided by
  - Quantile relationships per elevation
  - Tiered designated use priority/protection based on most critical use
  - Impact of inorganic and organic particulate matter (spatial and temporal “dystrophy”)
  - Presence of potentially toxic cyanobacteria

- Proposed categorical refinements:
  - 3 elevational categories
  - Stratified vs non-stratified (deep vs. shallow) w/ % hypoxia goals
  - Large reservoirs/reservoir in series tracked separately but all subject to same designated use protection
  - Replacement of igneous and sedimentary categories with incorporation of TSS and organic matter - influence of clay and silt with associated bound nutrients
  - Seasonal application of criteria to intermittent waterbodies – greater than 1 m mean depth
  - Option of site-specific criteria if justified
  - Urban category is still based on constraints of setting and need for active management
  - Effluent dependent waterbodies have been eliminated from the matrix – addressed through AZPDES permit

The 2017 Proposed Matrix of Endpoints

Table 1. 2017 Proposed Matrix of Endpoints (Thresholds) for Evaluation of the Narrative Nutrient Standard, R18-11-108(A-D)

ARIZONA LAKES AND RESERVOIRS NARRATIVE NUTRIENT STANDARD: MATRIX for IMPLEMENTATION			RESPONSE VARIABLES				CAUSAL VARIABLES					RELATED VARIABLES			
			Chlor-a	Cyanobact[5]	Cyanobact[5]	DO % water column > 3 mg/L	Derivation	TN	TP	TSS	DOC	Secchi[6]	DO top m	pH	NH3
Elevation	Designated Use*	Lake Category	ug/L	#/ml	percent	Oligo/Meso/Eutro	Quartile of 50^{th} Quantile	mg/L	ug/L	mg/L	mg/L	m	mg/L	SU	mg/L
> 8000	A&Wcold		< 4		< 50	60%/50%/40%	25^{th} (of the mean)	< 0.7	< 28	< 3	< 6	> 2.2	7	6.5 to 9	See tal
> 4500	A&Wcool		< 12		< 50	50%/40%/30%	50^{h} - 90^{th}	< 1.4	< 50	< 10	< 10	> 1.4	6	6.5 to 9	See tal
< 4500	A&Wwarm		< 15		< 50	50%/40%/30%	50^{th} - 90^{th}	< 1.4	< 45	< 8	< 8	> 1.5	5	6.5 to 9	See tal
< 4500	DWSwarm		< 10	<20,000		60%/50%/40%	50^{th} - 75^{th}	< 1.2	< 35	< 6	< 6	> 1.8	6	6.5 to 9	
> 4500	DWScool		< 10	<20,000		50%/40%/30%	50^{th} - 75^{th}	< 1.2	< 50	< 8	< 8	> 1.4	6	6.5 to 9	
any	FBC	Deep[1]	< 10	<20,000		60%/50%/40%	50^{th} - 75^{th}	< 1.2	< 35	< 6	< 6	> 1.8	6	6.5 to 9	
any	FBC	Moderate[2]	< 12	<20,000		50%/40%/30%	50^{th} - 75^{th}	< 1.4	< 50	< 10	< 10	> 1.4	6	6.5 to 9	
any	FBC	Shallow[3]	< 10	<20,000		50%/40%/30%	50^{th} - 75^{th}	< 1.2	< 35	< 8	< 8	> 1.4	6	6.5 to 9	
any	PBC	Urban[4]	< 20		< 50	50%/40%/30%	75^{th} - 90^{th}	< 1.5	< 60	< 10	< 10	> 0.7	5	6.5 to 9	

*A&Wcold most restrictive, then DWSwarm, FBCdeep and FBCshallow, then DWScool, FBCmoderate, and A&Wcool , then A&Wwarm and Urban/PBC

[1]Lake stratifies; > 15 m mean depth

[2]Lake stratifies; 3 - 15 m mean depth

[3]Lake does not stratify; < 3m mean depth

[4]Lake in urban setting with "put and take" fishery (seasonal, based on temperature and pH)

[5]Genera with potential for toxin production listed in R18-11-108.03

[6]Secchi targets set in reverse (75^{th} down to 25^{th} quartile of 50^{th} quantile)

[7]pH –dependent (Table 11 in R18-11 Appendix A) or pH and temperature-dependent (Table 12 in R-18-11 Appendix A)

Summary

- Phase II corroborates the earlier finding that nutrient levels are relatively high for corresponding chlor-a (vs. temperate lake systems)
- There appears to be significant spatial and temporal impacts of suspended sediment and organic matter limiting nutrient availability
- Choice of three elevation/temperature categories to better address nature of AZ dynamics and fisheries type
- Separate AZ Game and Fish (AGFD) “put and take” salmonid fisheries(cool) from high elevation or native salmonid fisheries (cold)
- Cold water designated use may be formally designated by AGFD
- Establishing limits on allowable percent hypoxia
- Chlorophyll-a endpoints have been revised to protect against cyanobacteria blooms
- Algae ID data collected since 2003; early warning for HAB testing
- Use of bright-line nutrient criteria for AZPDES permits