



A Systems Approach to Watershed & Lake Management

Ann, Lucy, Susan, Mitchell and Red Rock

Board of Managers Workshop

May 20, 2026

Introduction

A Systems Approach to Watershed & Lake Management



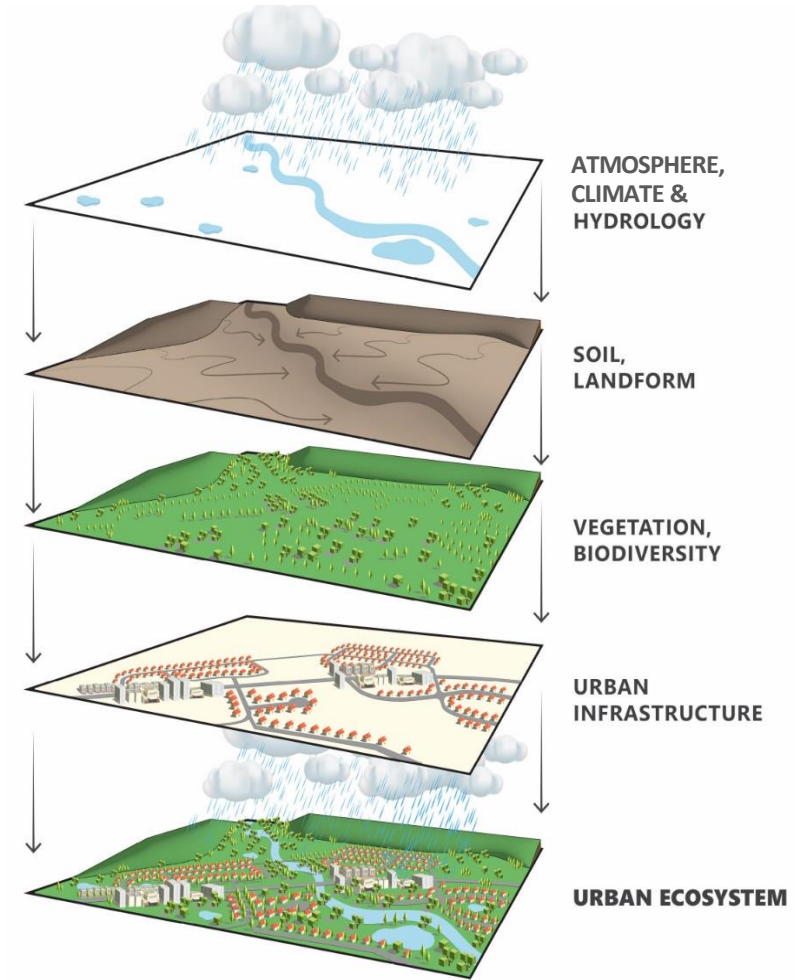
A Systems Approach for Lake & Watershed Management



Lake & watershed characteristics



Balancing goals



Layered systems

The Big Picture: 10-year Plan Update

10-year Management Plan (2028-2038)

Assesses land & water resources

Identifies watershed issues

Sets goals & strategies for the next 10 years

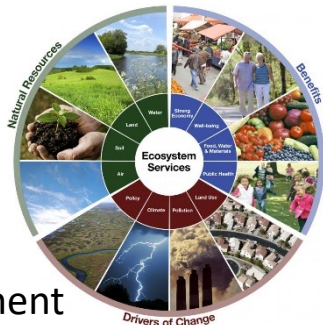
Identifies process for project prioritization

Ecosystem Health Action Plan (EHAP)

- Inform, through an ecosystem lens, development of the 10-year plan update

- Identified 70+ strategies

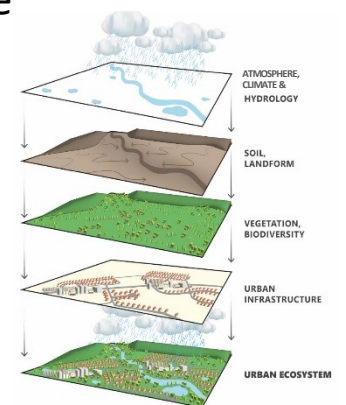
- Regulation
- Climate resiliency
- Land protection & regeneration
- Surface water management
- Education & outreach
- Partnerships
- Data collection



Systems Approach to Watershed & Lake Management

- Perform lake & watershed diagnostic studies to inform development of the 10-year plan update

- Five lakes as case studies:
 - **Ann**
 - **Lucy**
 - **Susan**
 - **Mitchell**
 - **Red Rock**



Suburban Watersheds

Watershed Features

- Lakes
- Ponds
- Wetlands
- Uplands
- Streams and floodplains

Watershed Functions

- Nutrient Cycling
 - Nitrogen and Phosphorus
- Flood Storage
- Biodiversity
- Recreation



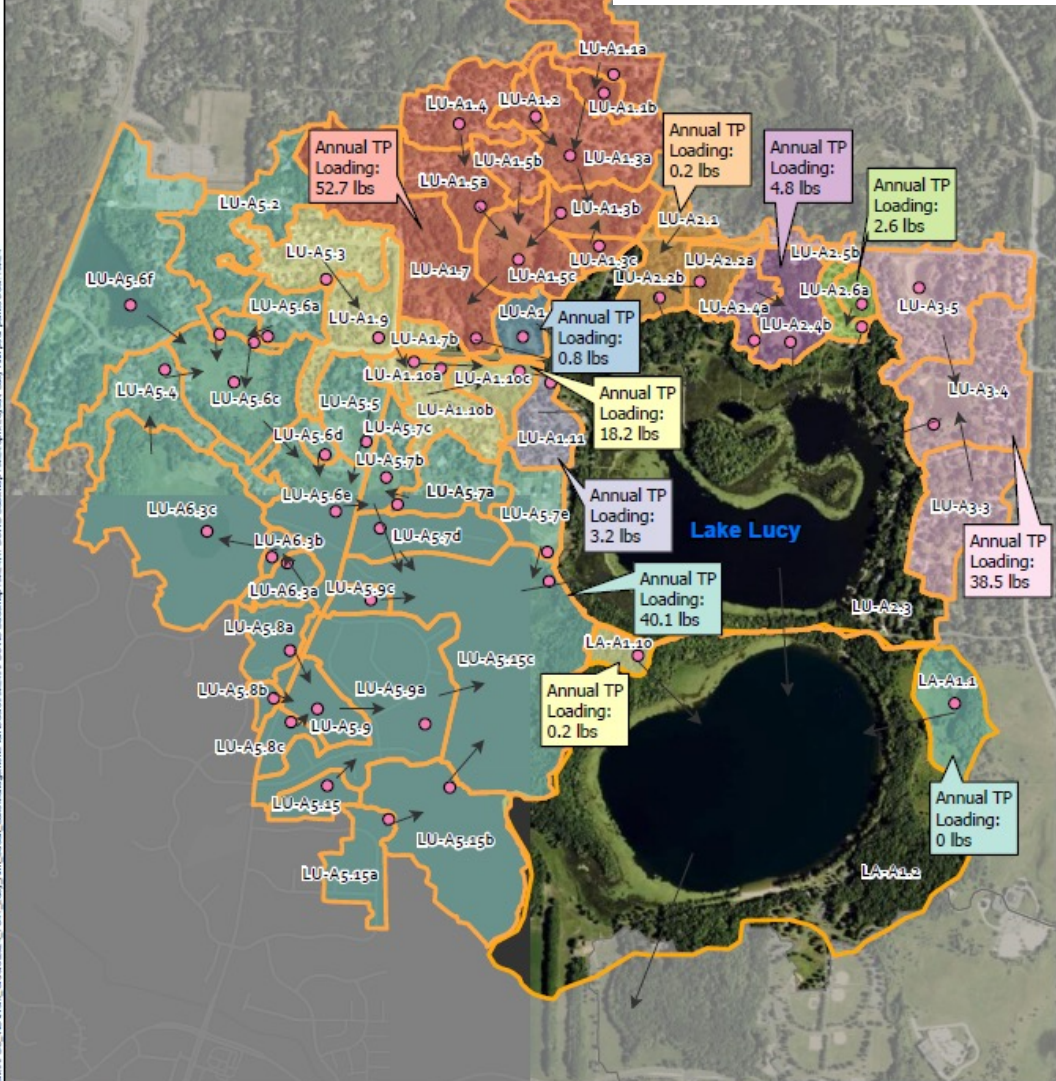
Lake and Watershed Stressors



Impervious surfaces/loss of green space/soil health and compaction

- Excess nutrients (nitrogen and phosphorus)
- Toxic contaminants (chloride)
- Unnatural hydrology and flooding
- Pipe and ditch conveyance

Watershed Nutrient Cycles



→ Flow direction
 Lake Outlines
 P8 Devices
 Lucy & Ann SWS
 Lucy Pour Points
 LU-A5.15c
 LU-A1.10c

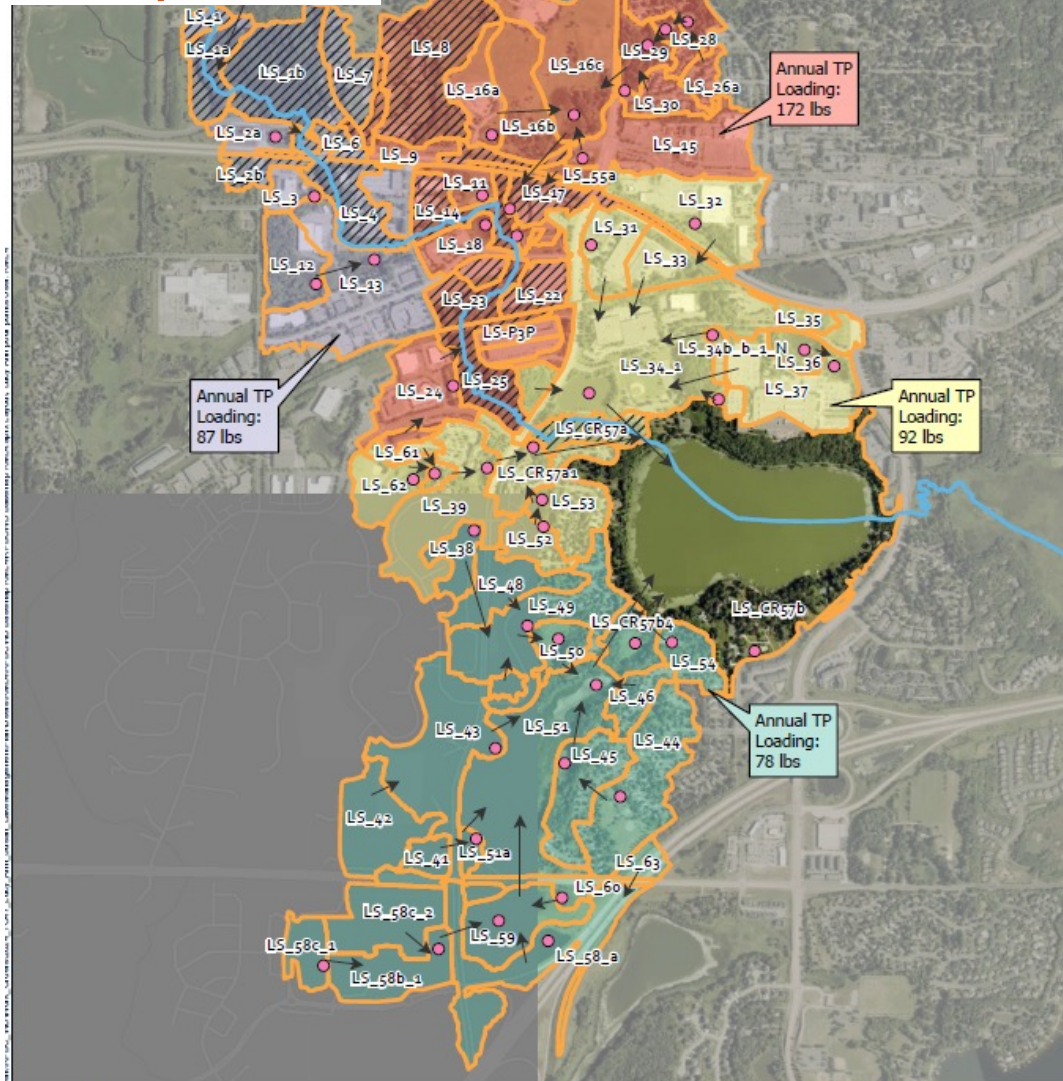
LU-A1.11
 LU-A1.7
 LU-A1.8
 LU-A2.2b
 LU-A2.4b
 LU-A2.6a
 LU-A3.4

Ann Pour Points
 LA-A1.1
 LA-A1.10

0 500 1,000
 Feet

RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

Lucy and Ann Pour Points RPBCWD
 FIGURE #



→ Flow direction
 Lake Outline
 P8 Devices
 Susan SWS
 Riley Creek
 Direct drainage

CR1
 CR2
 CR3
 2.12p

Susan Pour Points

0 500 1,000 2,000
 Feet

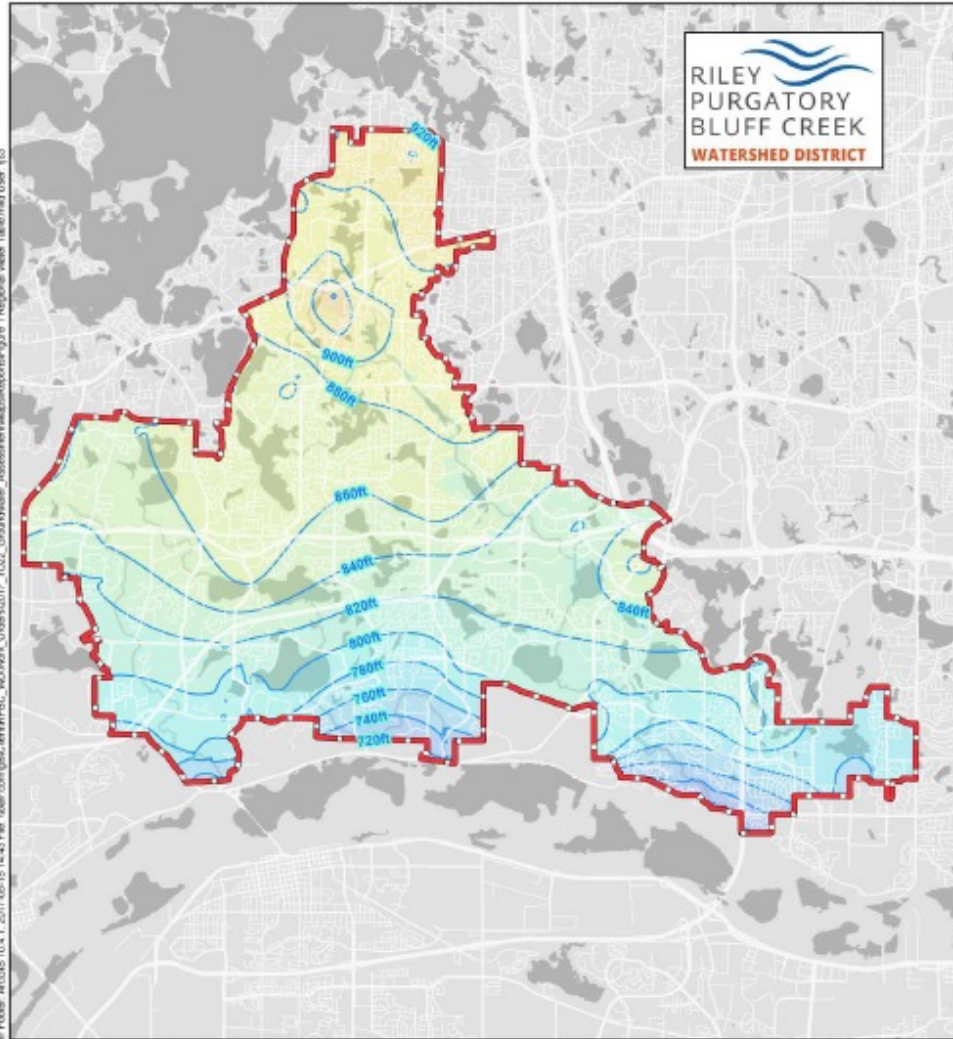
RILEY PURGATORY BLUFF CREEK WATERSHED DISTRICT

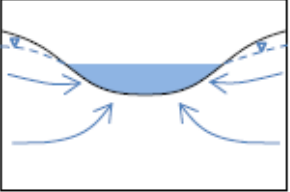
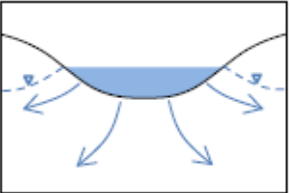
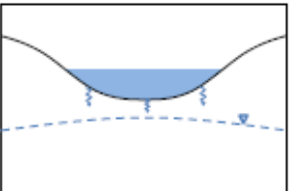
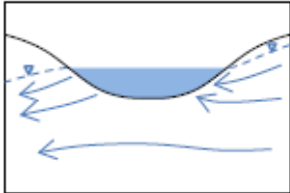
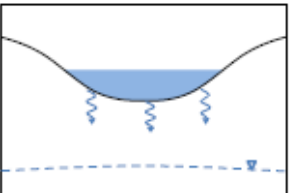
Lake Susan Pour Points RPBCWD
 FIGURE #

Current Conditions – Hydrology

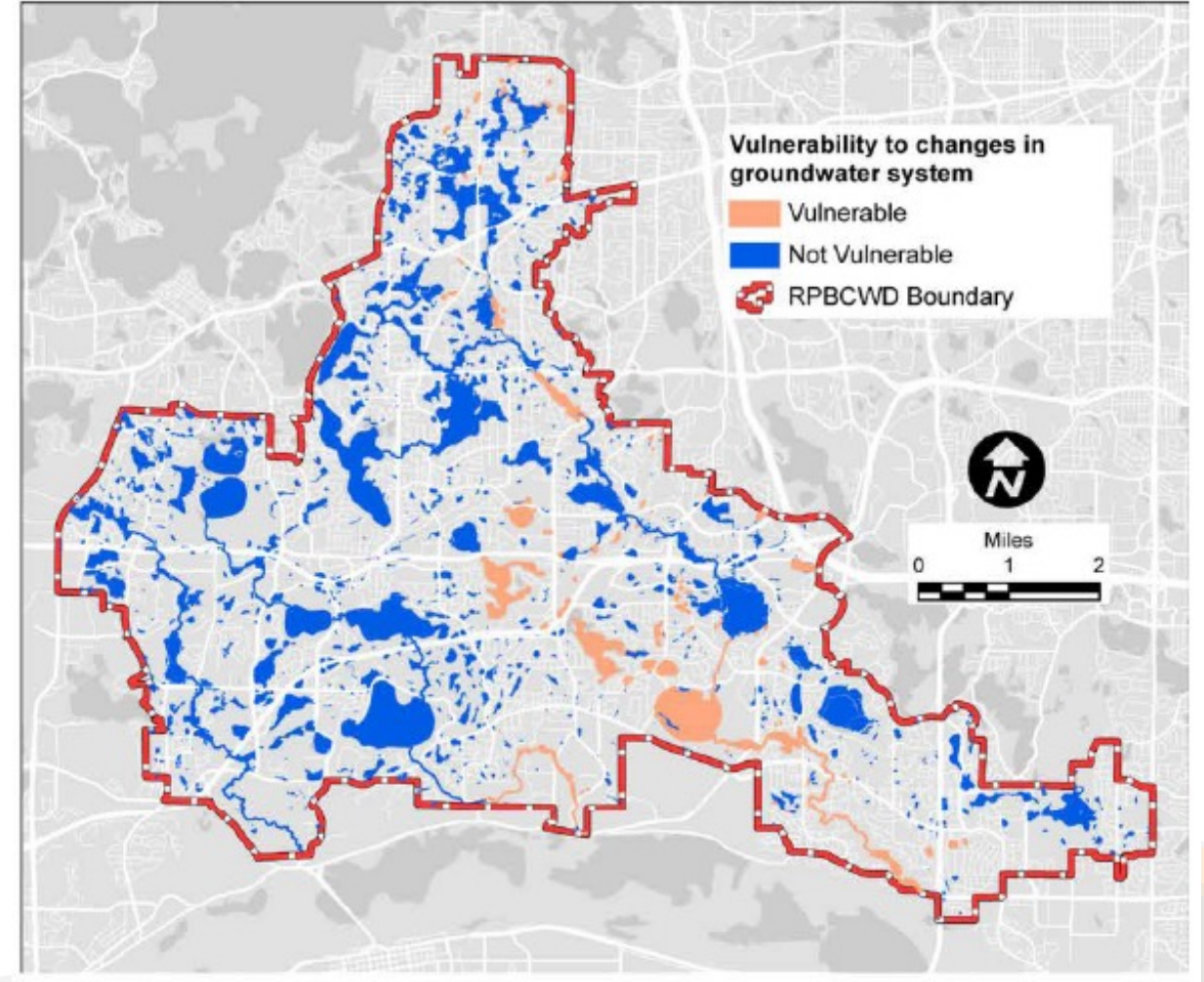
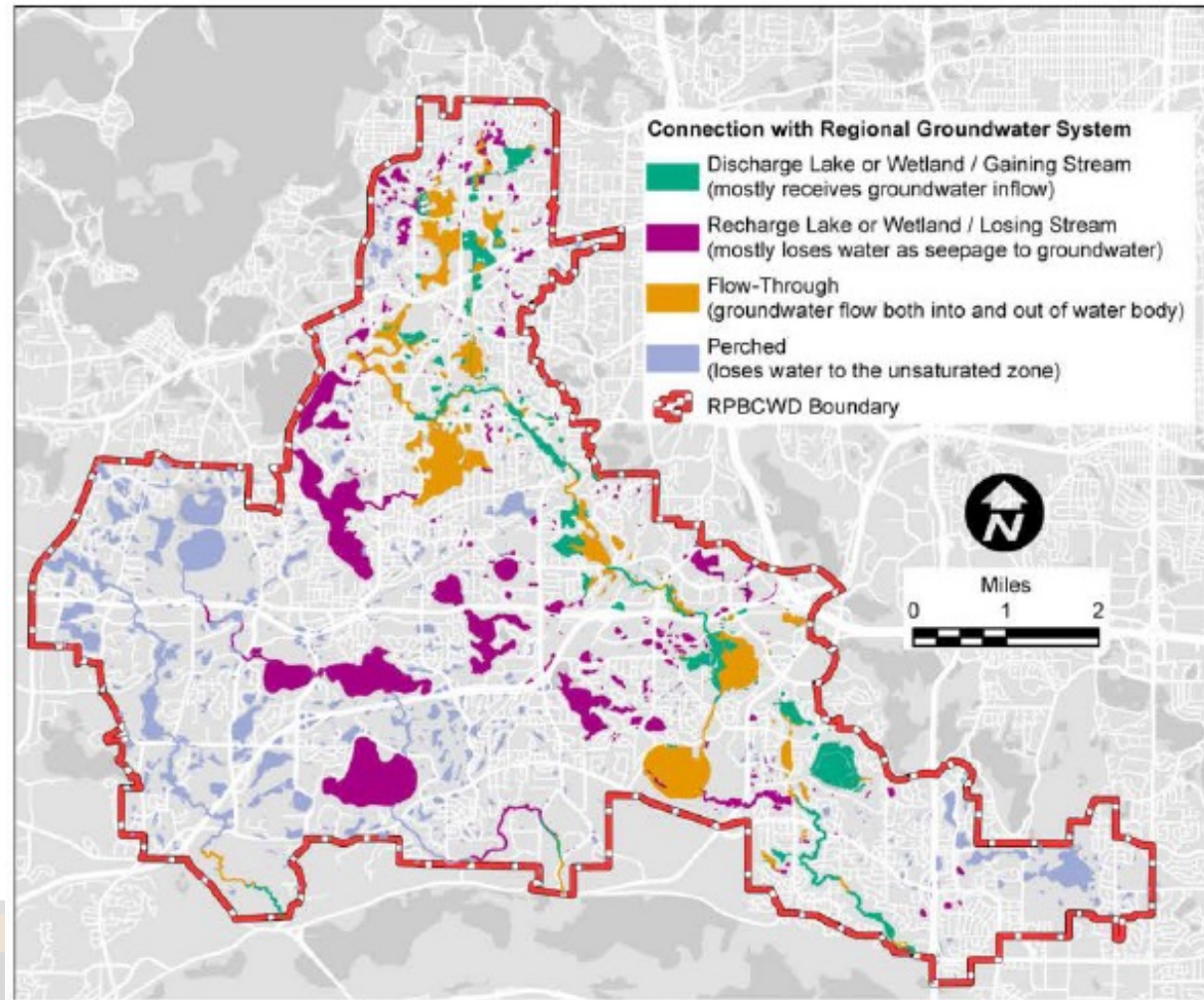


RPBCWD Regional Groundwater Study

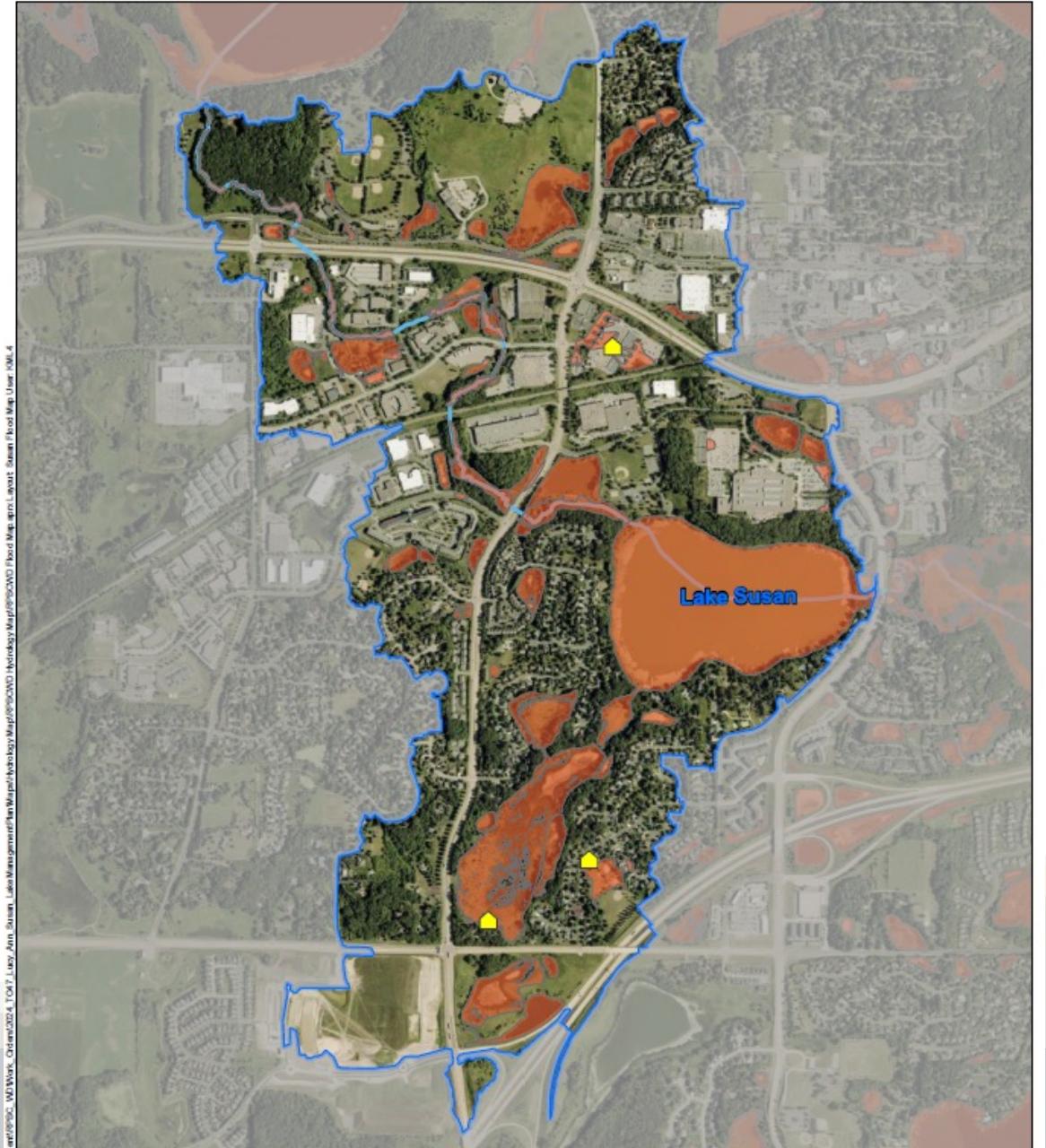
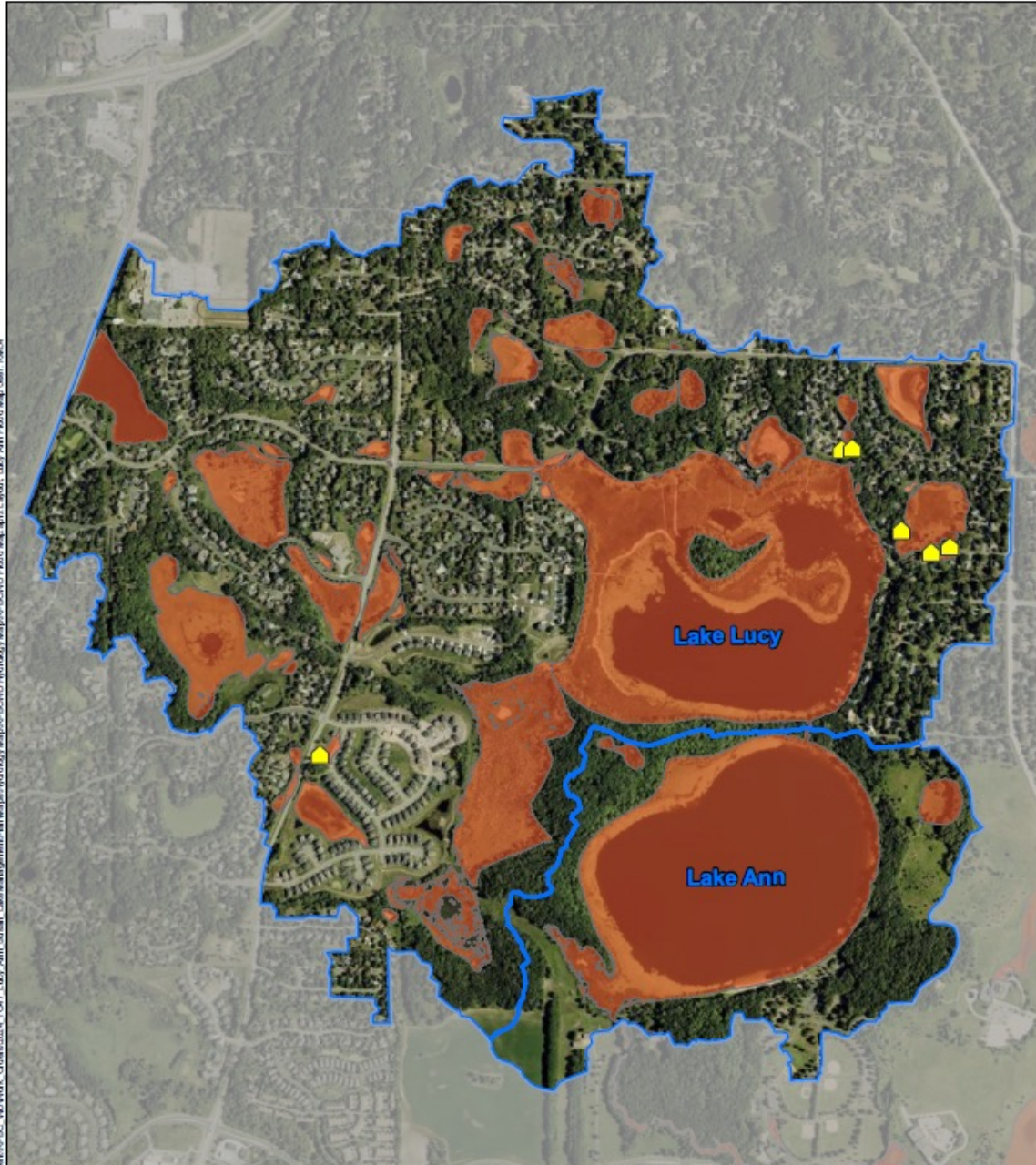


Type	Description		Qualifiers
Discharge lake/wetland	Mostly receives groundwater inflow		Connected to groundwater, surface water elevation below regional groundwater table
Recharge lake/wetland or Indeterminate	Connected to groundwater. Mostly loses water as seepage to groundwater		Groundwater connection is indeterminate, regional groundwater table lower than surface water elevation. Uncertainty in regional groundwater table makes it difficult to distinguish between features that are connected and those that are disconnected to groundwater.
	Disconnected to groundwater. Water table slightly below lake bottom. Fluctuations in the water table can affect the flow dynamics out of lake.		
Flow-through lake/wetland	Groundwater flow both into and out of lake/ wetland		Connected to groundwater, surface water elevation above or equal to regional groundwater table
Perched lake/wetland with deep water table	Water table deep below feature. Loss of water into the unsaturated zone. Change in water table has no effect on feature		Disconnected from groundwater

Groundwater Vulnerability

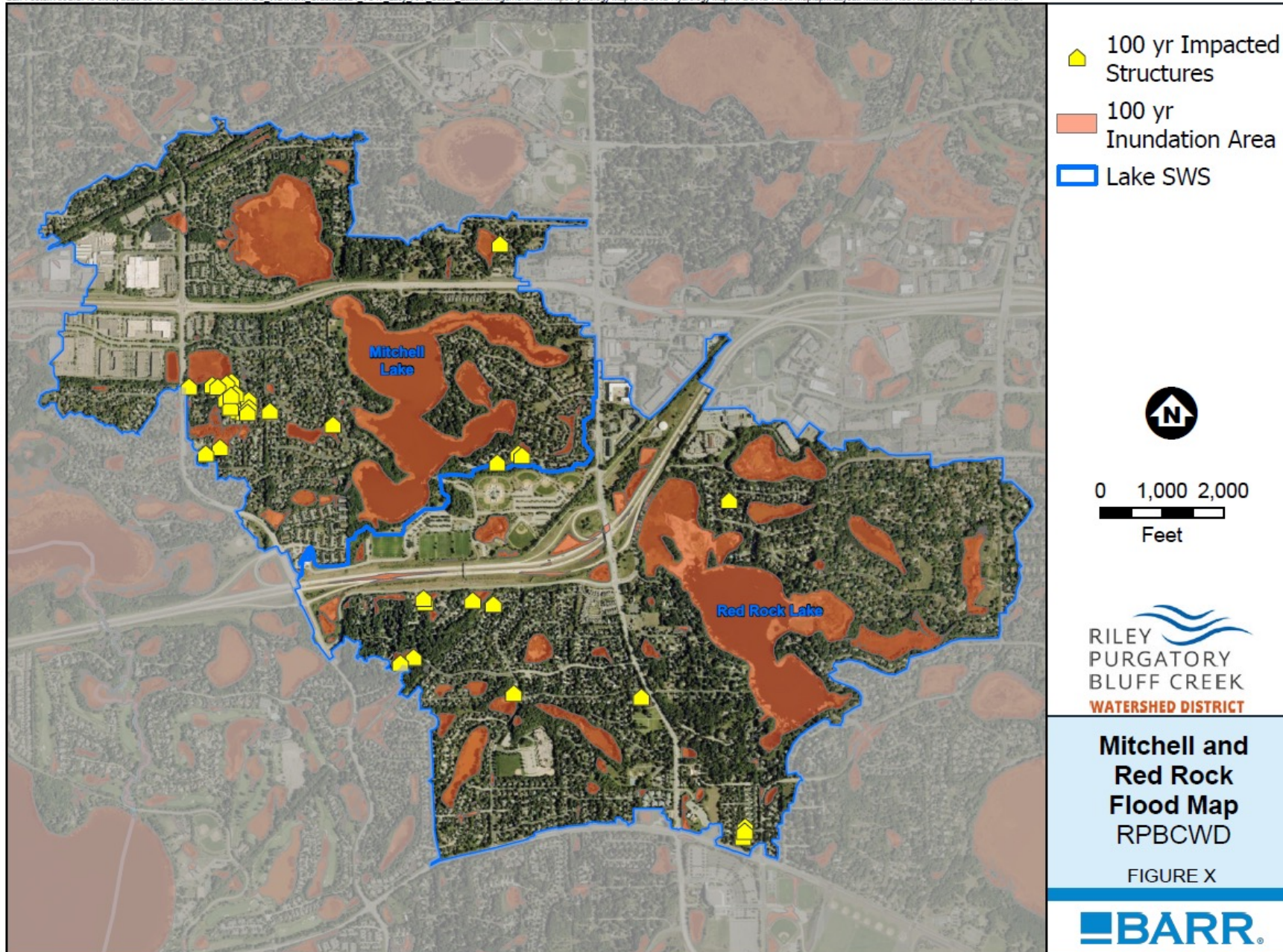


100 Flood Inundation and At-risk Structures



100 Flood Inundation and At-risk Structures

Barr Footer: ArcGISPro 3.6.3, 2026-05-19 19:24 File: I:\Client\RPBC_WDI\Work_Orders\2024_TO47_Lucy_Ann_Susan_LakeManagementPlan\Maps\Hydrology Map\RPBCWD_Hydrology Map\RPBCWD Flood Map.aprx Layout: Mitchell Red Rock Flood Map User: KML4



Hydrology Summary

- **Lake Lucy and Lake Ann**

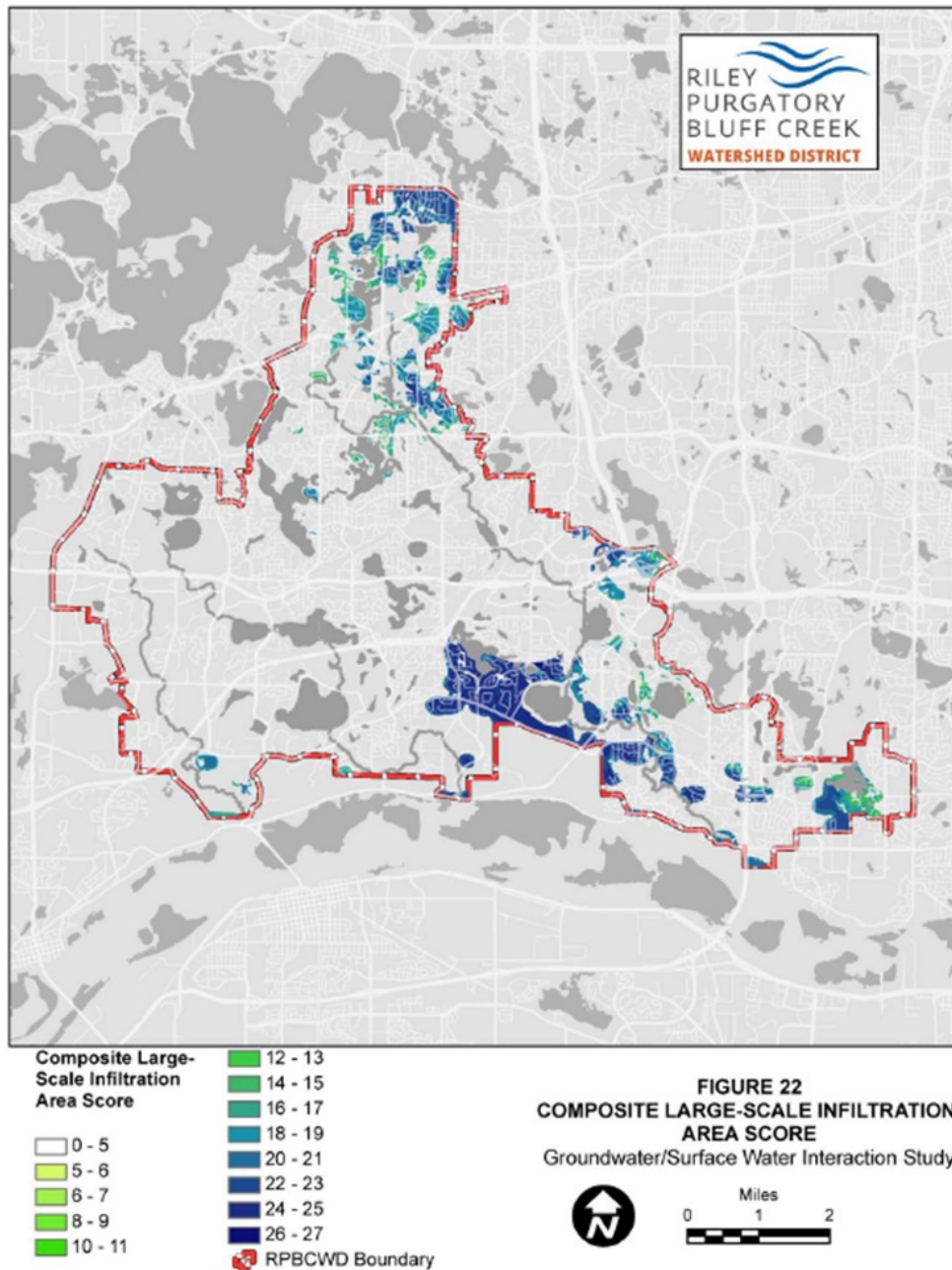
- Perched lakes that are not overly vulnerable to groundwater changes
- Primarily driven by surface water
- Groundwater chloride and nutrients are low risk to the lakes
- Infiltration not likely to reach the lakes; low infiltration potential in watershed

- **Lake Susan**

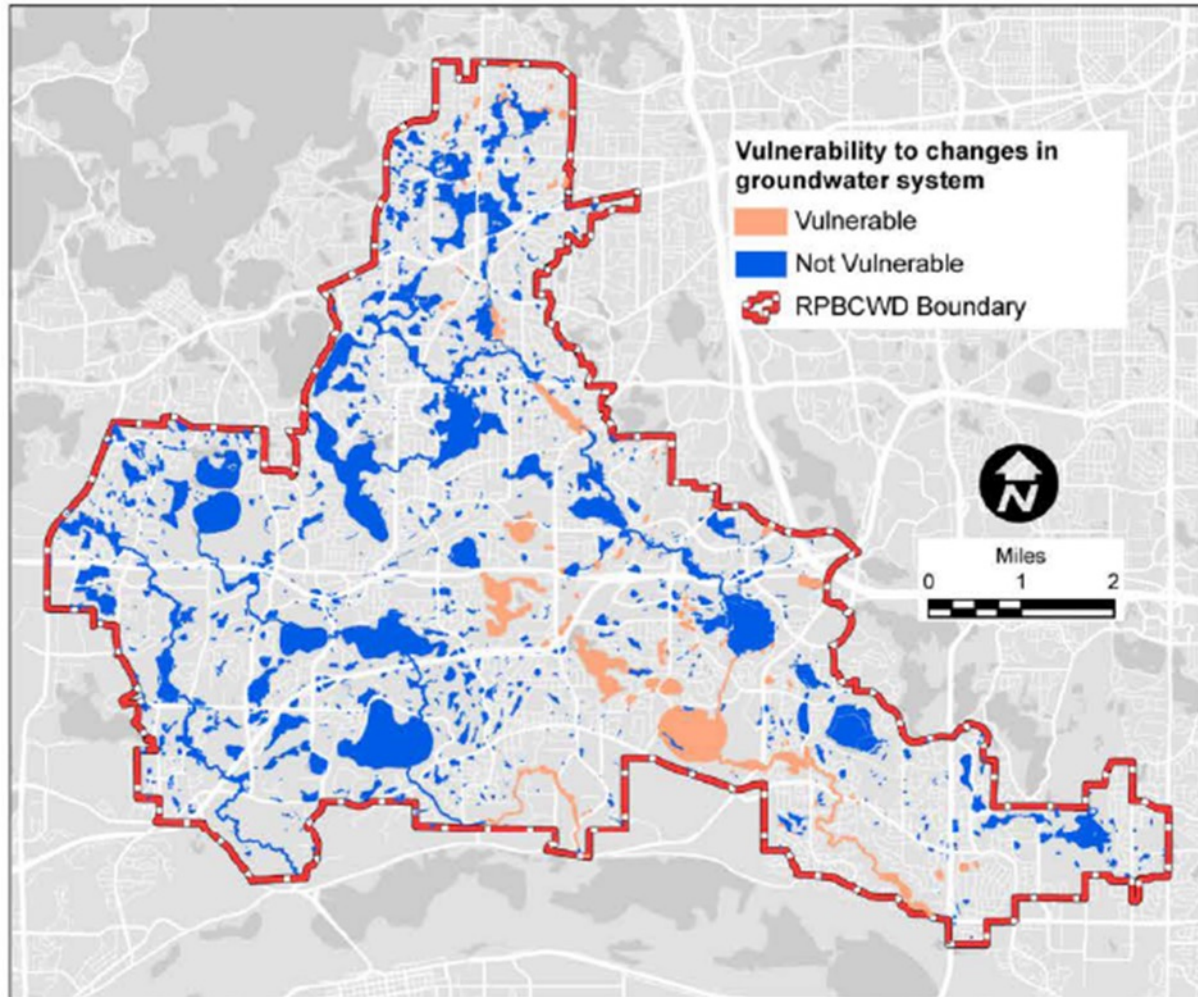
- Recharge lake but not vulnerable to changes in groundwater table
- Chloride likely driven by surface water runoff

- **Lake Mitchell and Red Rock Lake**

- Both lakes are recharge lakes with relatively high vulnerability to changes in groundwater
- High infiltration potential in Red Rock watershed



Groundwater Recommendations



- Establish thresholds/target hydrographs for lakes and wetlands identified as vulnerable to changes in the groundwater system.
- Re-establish a monitoring well network within the District and monitoring program.
 - areas identified as areas of projected future drawdown
 - areas near surface waters classified as vulnerable to changes in the groundwater

Eutrophication

An aerial photograph of a suburban landscape. In the foreground, a large, dark blue lake is visible, surrounded by green trees and a few buildings. To the left, a golf course with several green fairways and a clubhouse is situated. A multi-lane highway runs diagonally across the middle ground. The background shows a dense residential area with many houses and trees, extending to a hazy horizon under a clear blue sky.

Relationship between **Total Phosphorus** and **Transparency**

Algal growth (water clarity)



Oligotrophic

Mesotrophic

Eutrophic

Hyper-Eutrophic

3

5

7

10

15

20

25

30

40

50

60

80

100

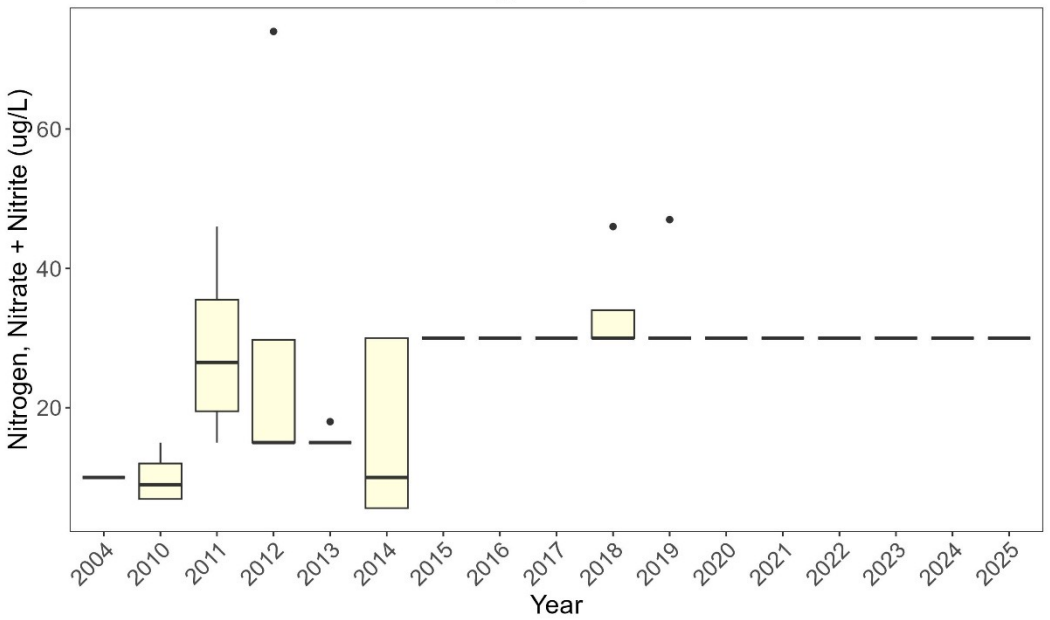
150

Total Phosphorus ($\mu\text{g/L}$)

Nitrogen

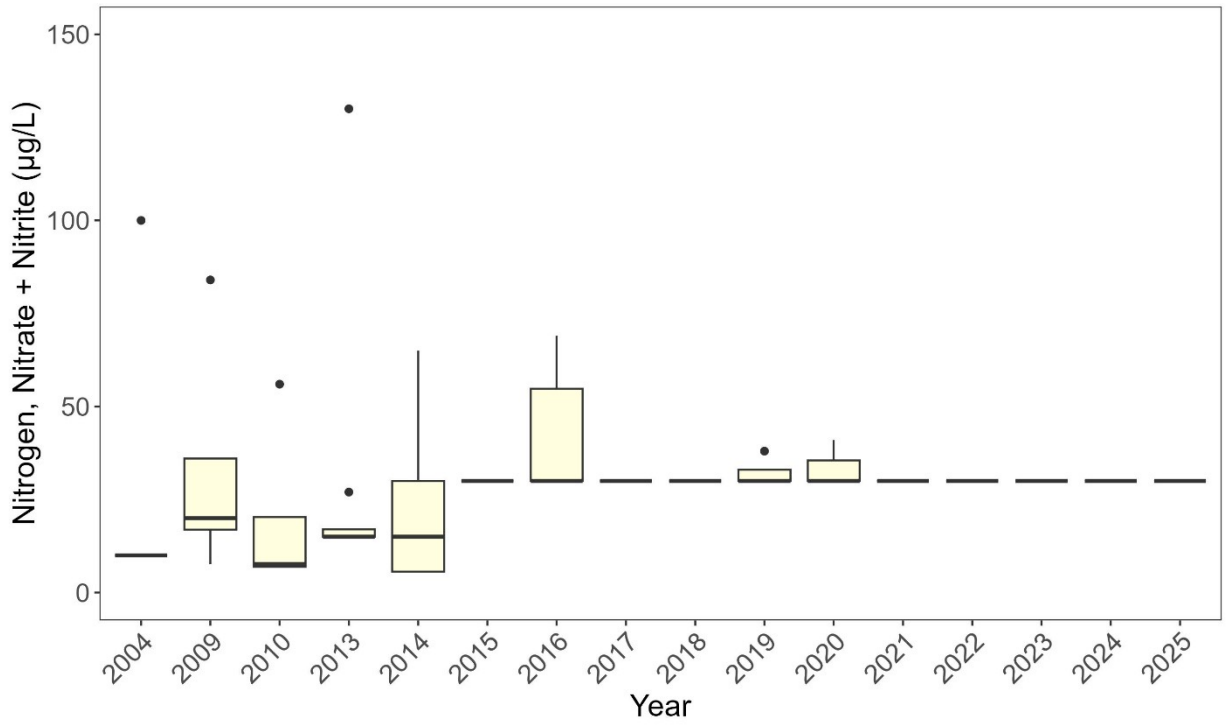
Nitrogen Species	Chemical Formula	Bioavailability	Role in Lake Algae Blooms
Ammonium	NH ₄ ⁺	Highest	Fuel source. Algae absorb it instantly without expending energy, triggering rapid bloom growth.
Dissolved Organic Nitrogen	DON	High	Selectively fuels non-fixing, toxic species like <i>Microcystis</i> . Enters lakes via modern fertilizers.
Nitrate/Nitrite	NO ₃ ⁻ /NO ₂ ⁻	Moderate	Promotes large-scale biomass. Mobile in soil, causing massive agricultural runoff that feeds blooms.
Total Kjeldahl Nitrogen	TKN (Ammonium + Organic N)	High	Measures the total pool of nitrogen immediately available plus nitrogen locked in organic matter that will eventually decay and feed future blooms.
Particulate Organic Nitrogen	PON	Low (requires decomposition)	Represents the bloom itself. This is the nitrogen locked inside living or dead algae tissue.
Total Nitrogen	TN (nitrate/nitrite+TKN)	Variable	Represents all bound organic nitrogen; slowly breaks down into usable fuel.

Lake Lucy Surface Nitrate + Nitrite
June through Sept, 2004-2025

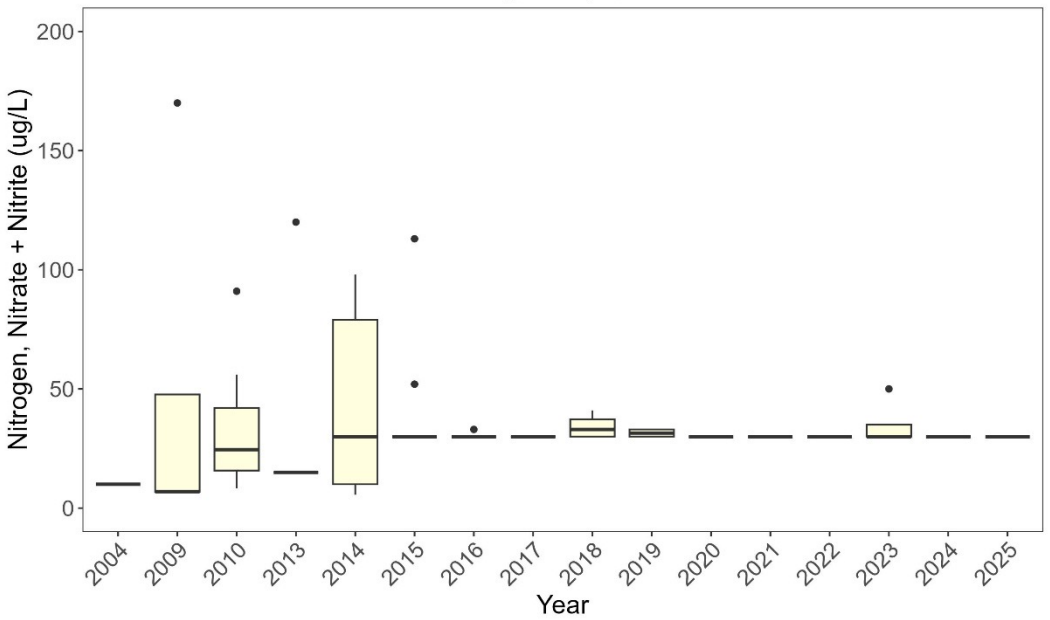


Nitrate/Nitrite Concentrations

Lake Susan Surface Nitrate + Nitrite
June through Sept, 2004-2025



Lake Ann Surface Nitrate + Nitrite
June through Sept, 2004-2025



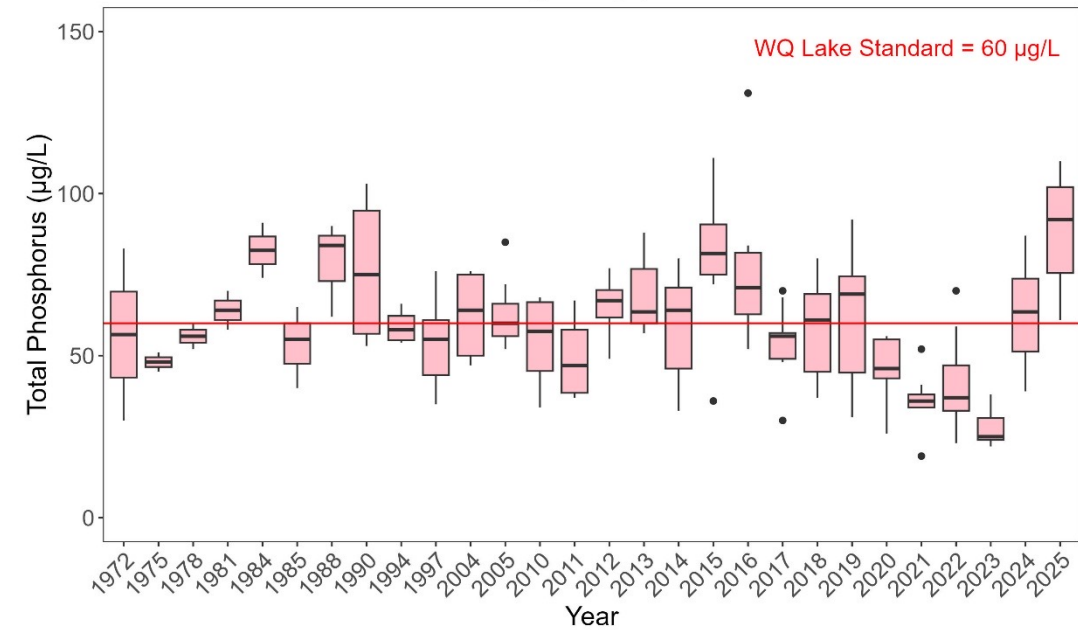
NCHF Reference Lakes: 600 to 1,200 ug/L TKN; <10 NO3/NO2

Lake Susan

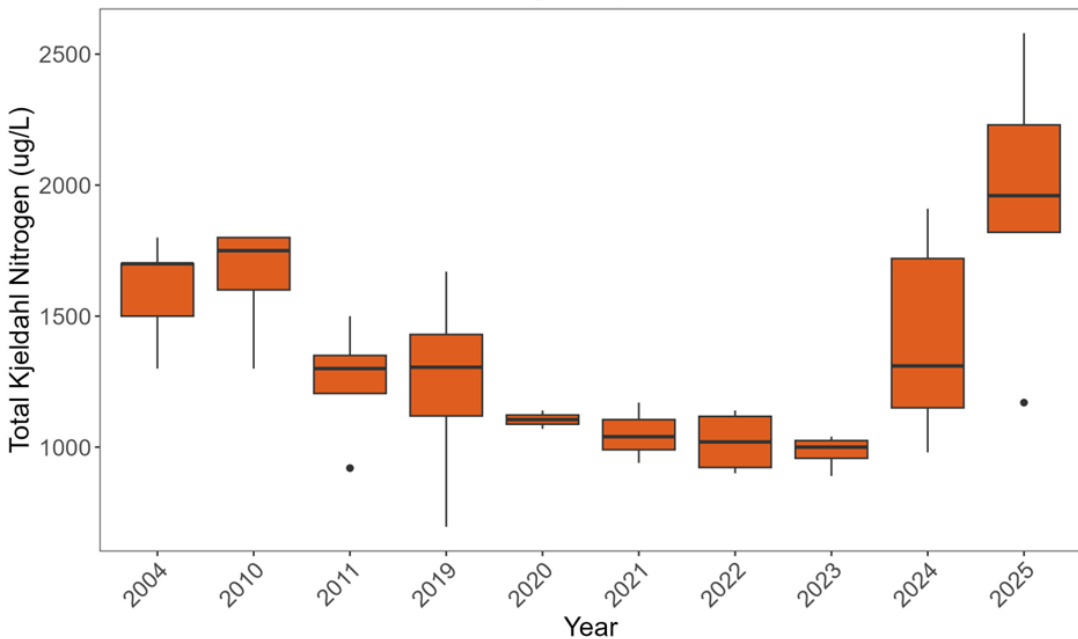
Lake Characteristic	Lake Susan
Surface Area (acres)	88
Average Depth (ft)	10
Maximum Depth (ft)	17
Littoral Area (ac)	83
Watershed Area (ac)	2,553
Direct Watershed Area (ac)	1,231
Invasive Species	Curly-leaf Pondweed Eurasian Watermilfoil Common Carp Brittle Naiad



Lake Lucy Surface Total Phosphorus
June through Sept, 1972-2025

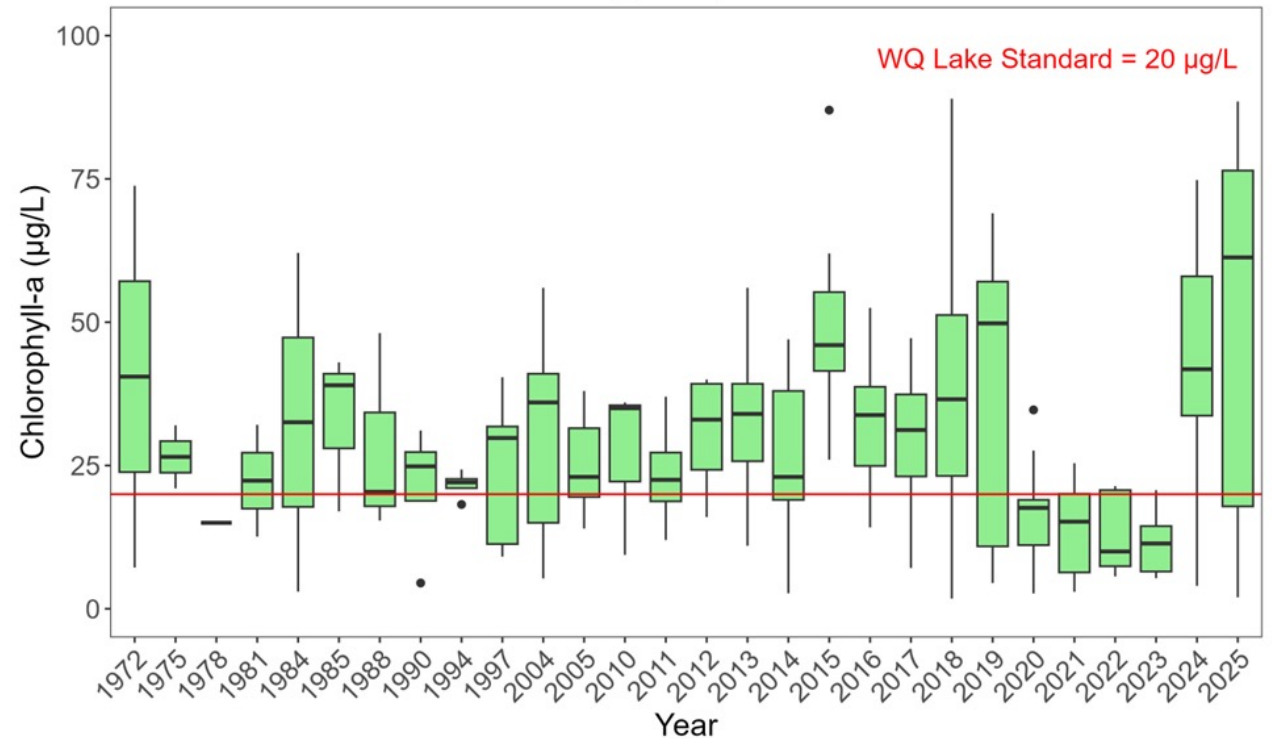


Lake Lucy Surface TKN
June through Sept, 2004-2025



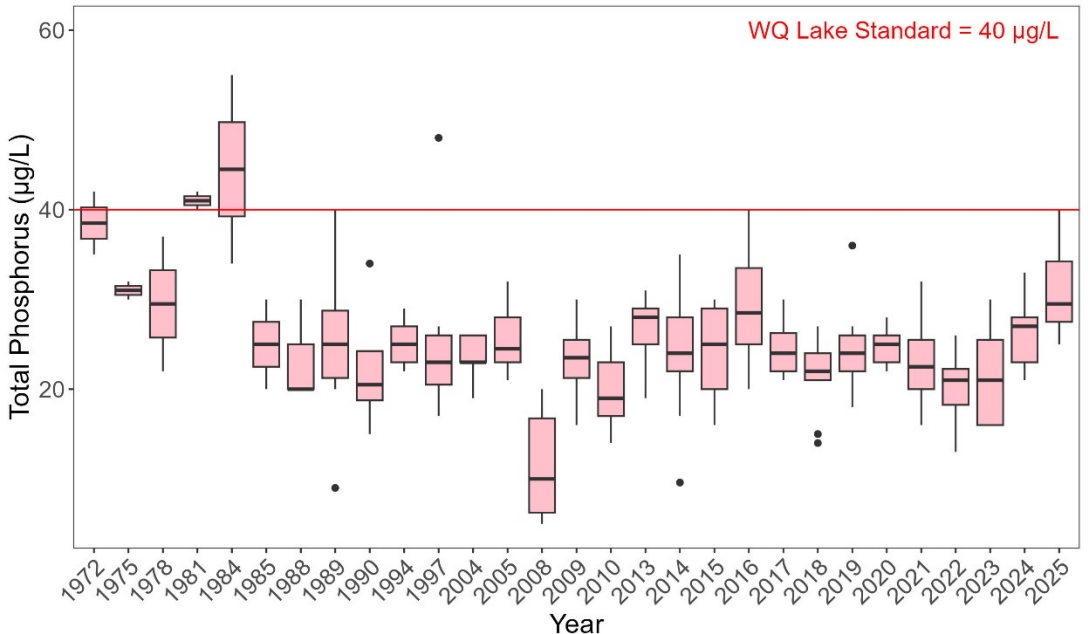
Lake Lucy Nutrients and Algae

Lake Lucy Surface Chlorophyll-a
June through Sept, 1972-2025

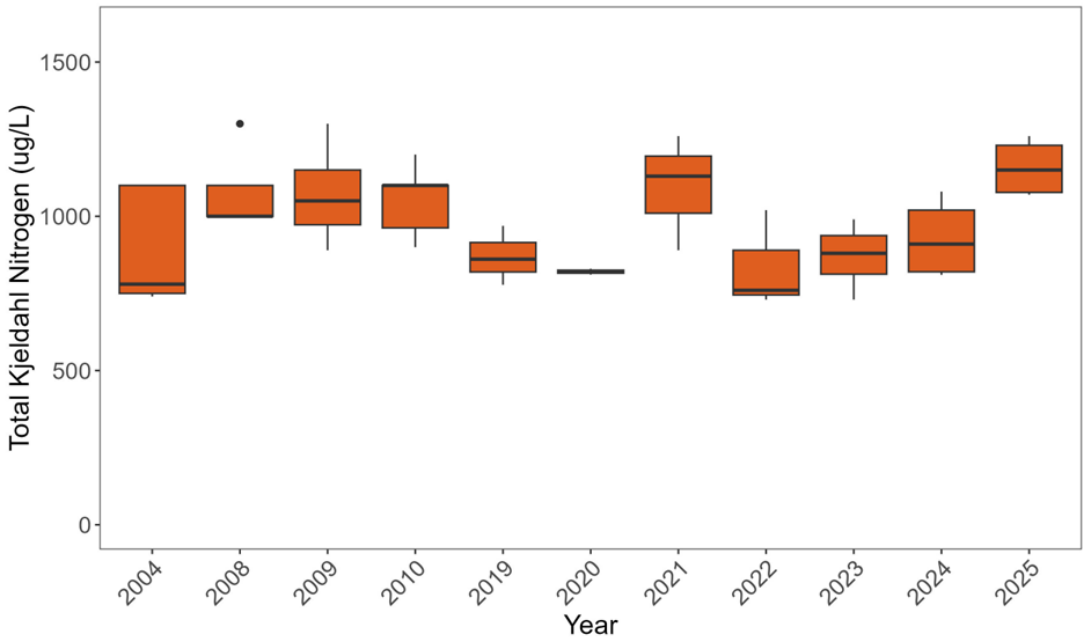


NCHF Reference Lakes: 600 to 1,200 µg/L TKN; <10 NO₃/NO₂

Lake Ann Surface Total Phosphorus
June through Sept, 1972-2025

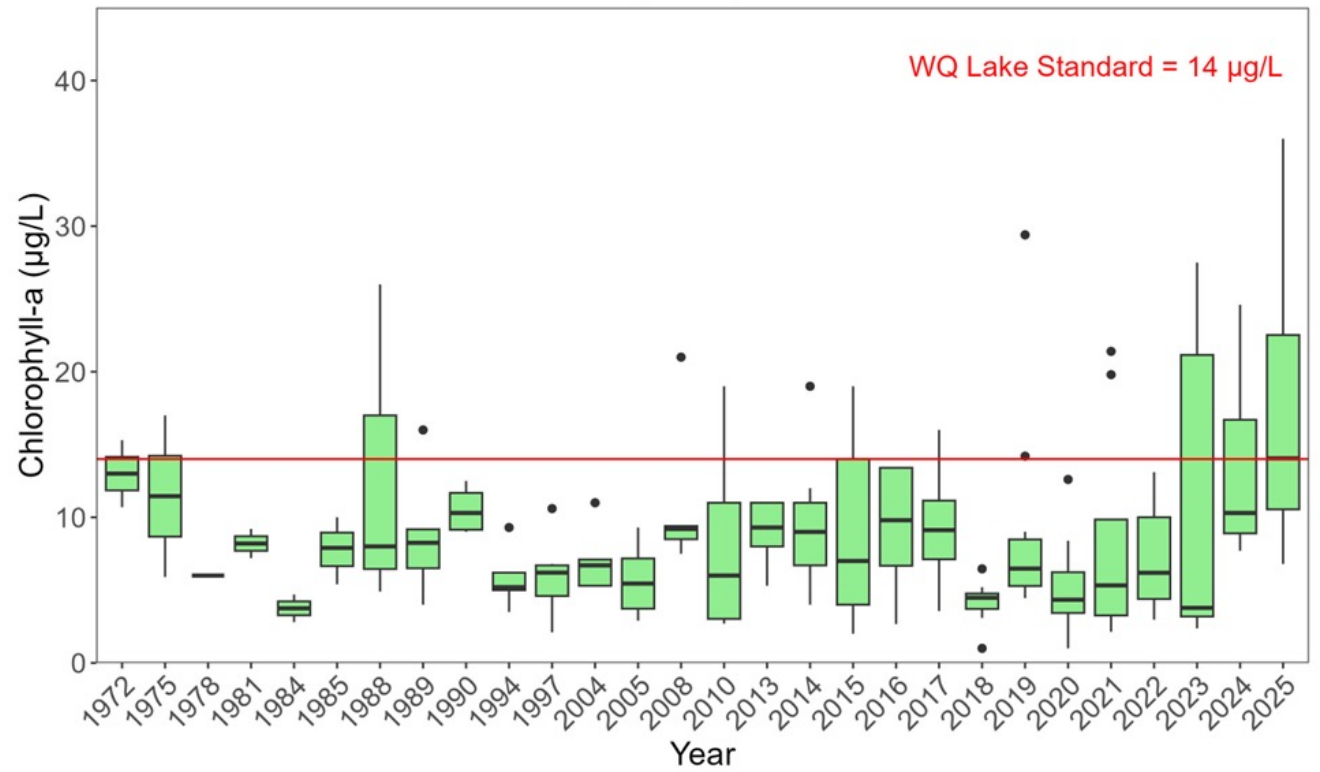


Lake Ann Surface TKN
June through Sept, 2004-2025



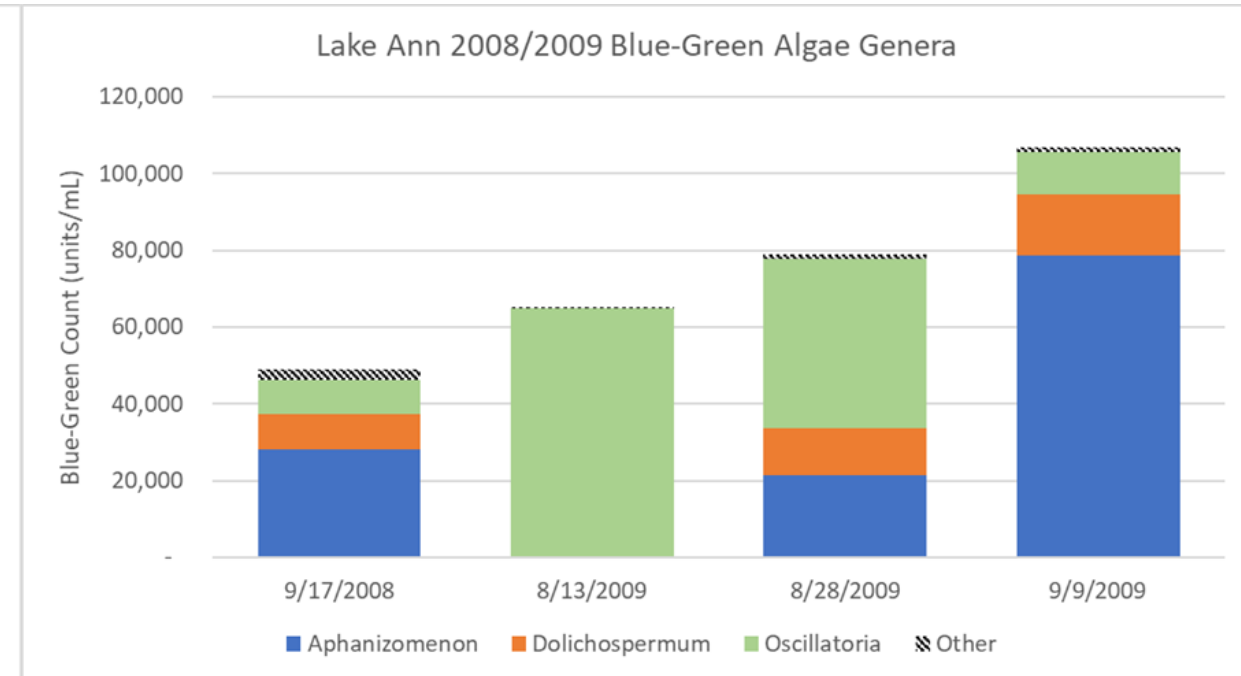
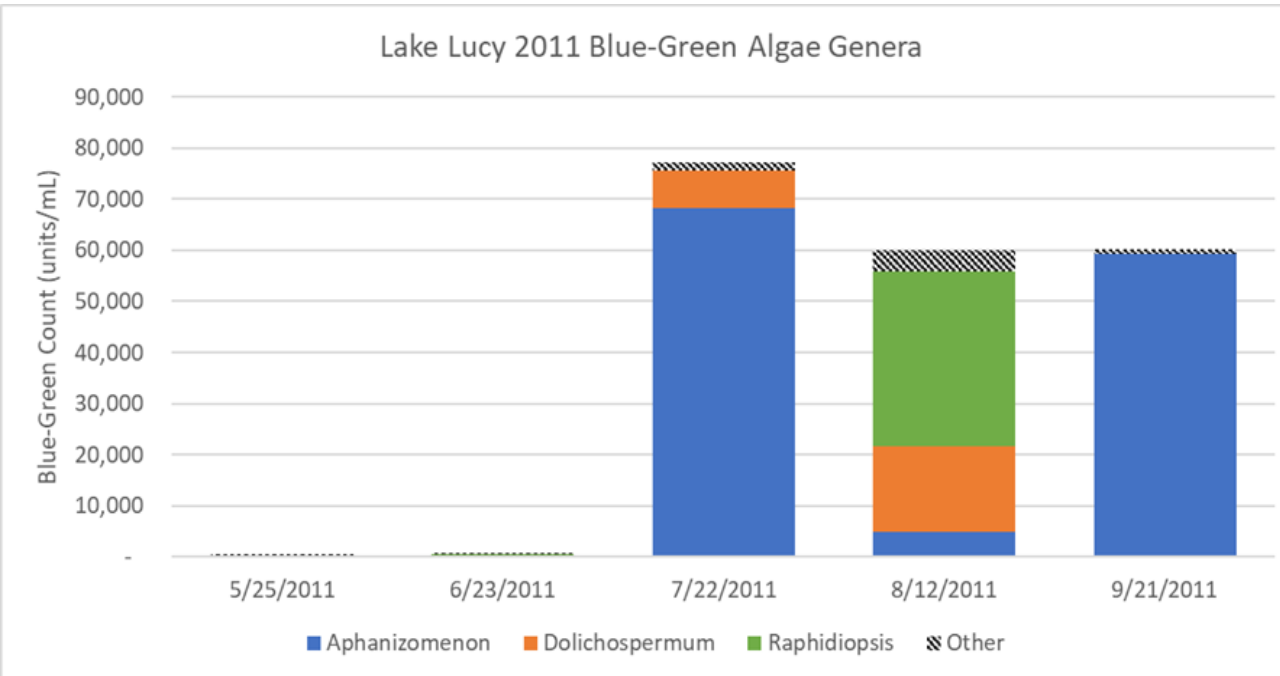
Lake Ann Nutrients and Algae

Lake Ann Surface Chlorophyll-a
June through Sept, 1972-2025



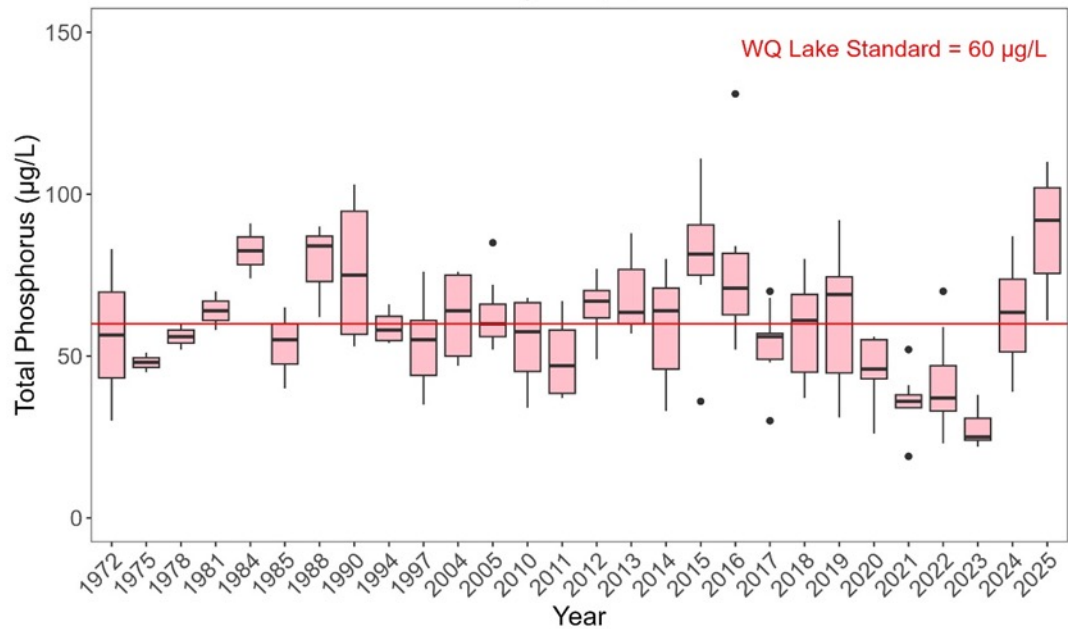
NCHF Reference Lakes: 600 to 1,200 ug/L TKN; <10 NO3/NO2

Lake Ann and Lake Lucy Cyanobacteria

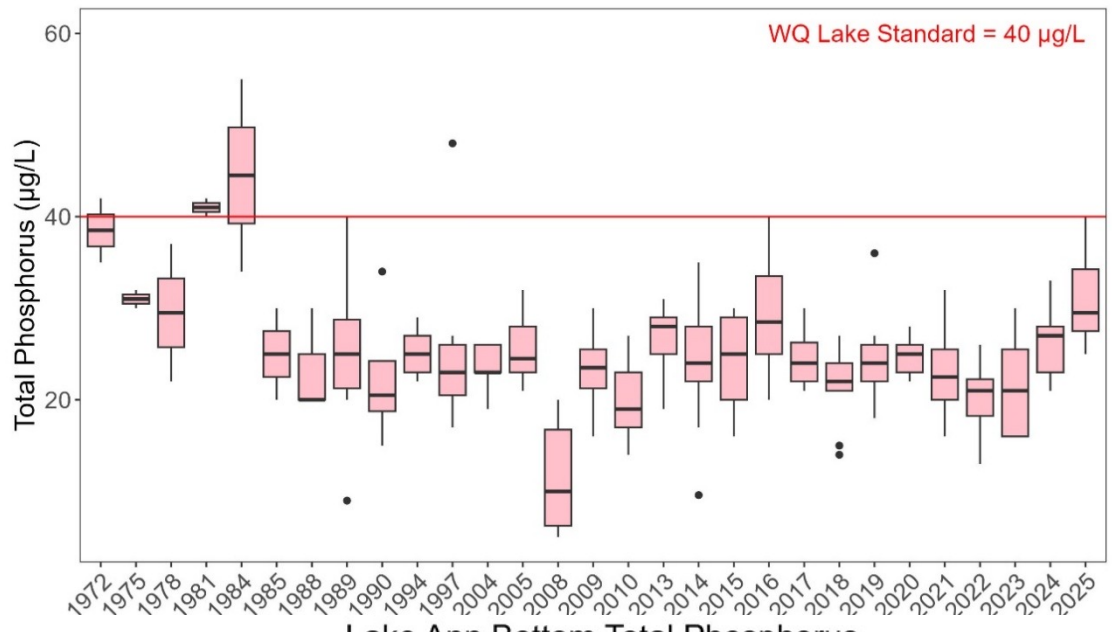


Cyanobacteria Species	Hepatotoxins		Neurotoxins	
	Cylindrospermopsin	Microcystins	Anatoxin-a	Saxitoxins
<i>Aphanizomenon flos-aquae</i> *	X			X
<i>Dolichospermum flos-aquae</i> *		X	X	
<i>Dolichospermum circinale</i> *		X	X	X
<i>Dolichospermum planctonicum</i> *			X	
<i>Raphidiopsis raciborskii</i> *	X	X	X	X

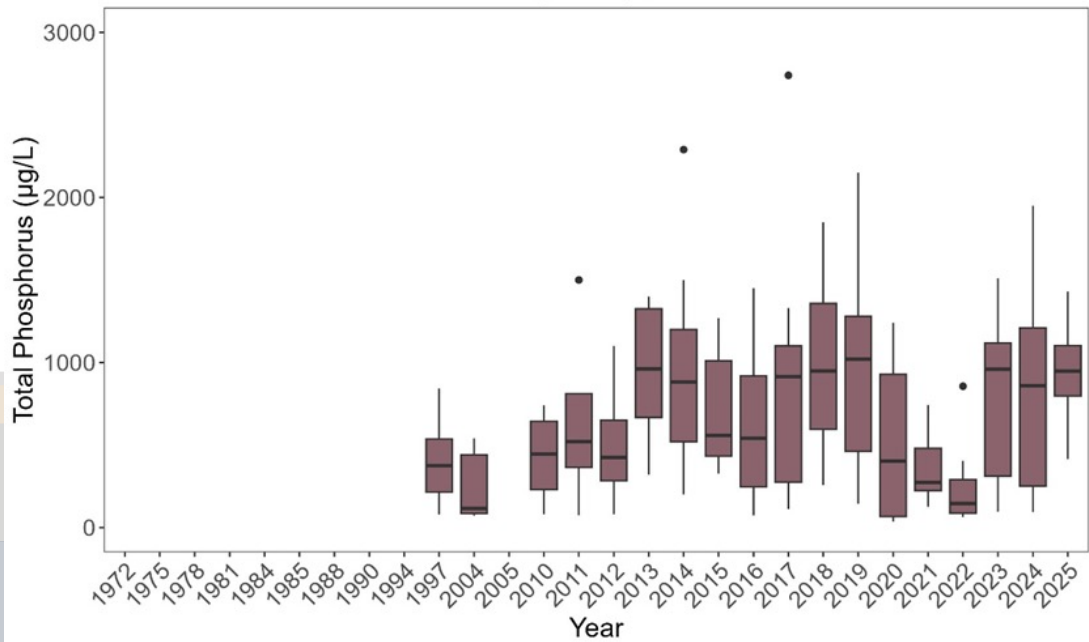
Lake Lucy Surface Total Phosphorus
June through Sept, 1972-2025



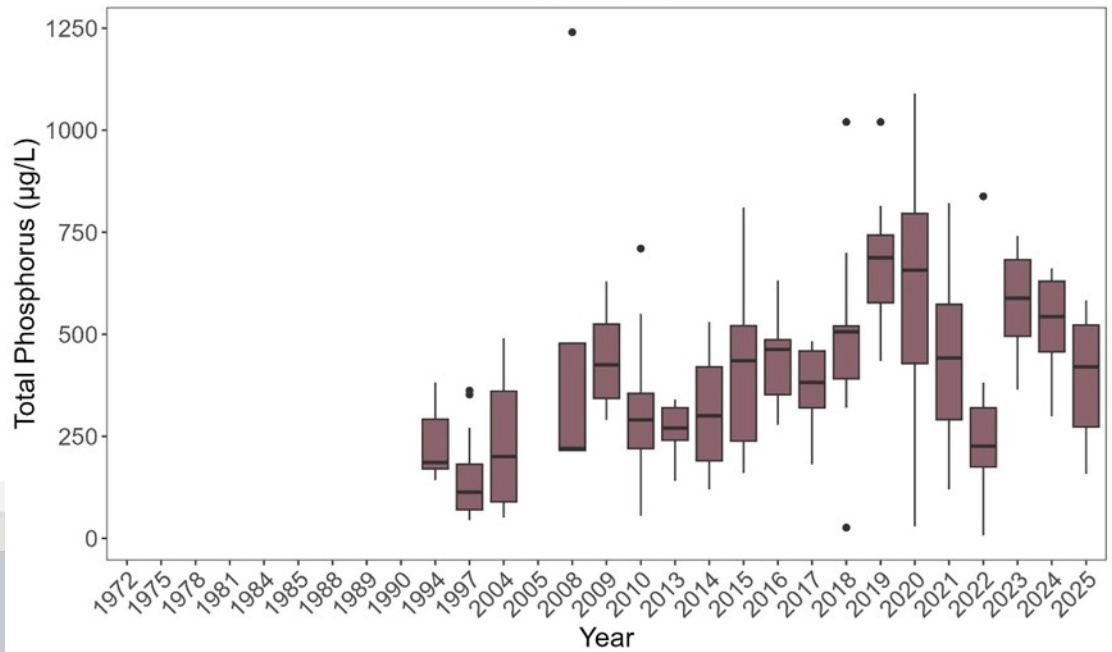
Lake Ann Surface Total Phosphorus
June through Sept, 1972-2025



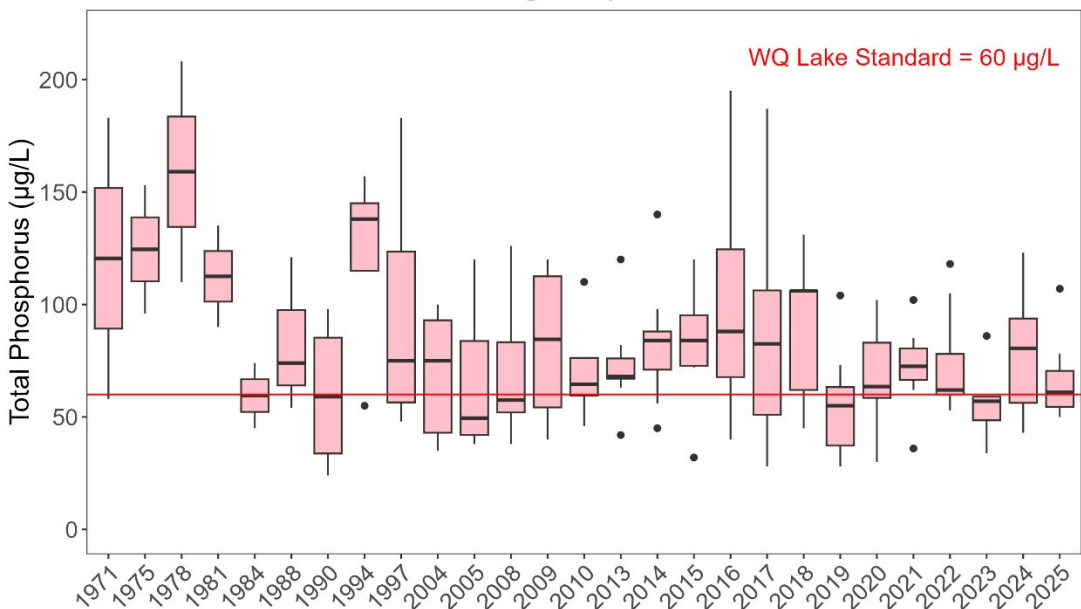
Lake Lucy Bottom Total Phosphorus
June through Sept, 1972-2025



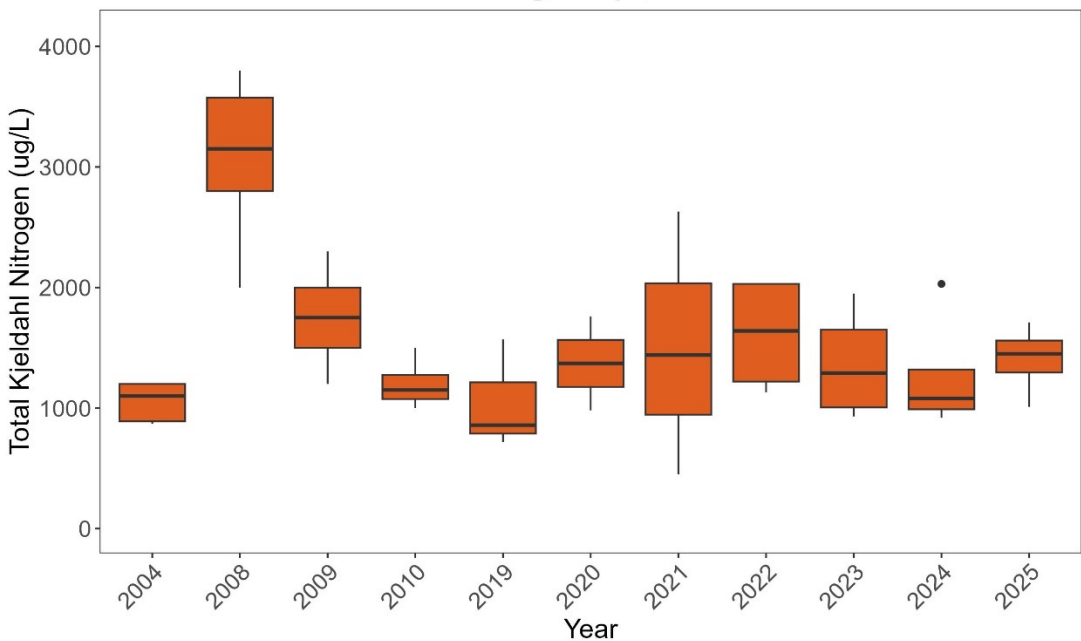
Lake Ann Bottom Total Phosphorus
June through Sept, 1972-2025



Lake Susan Surface Total Phosphorus
June through Sept, 1971-2025

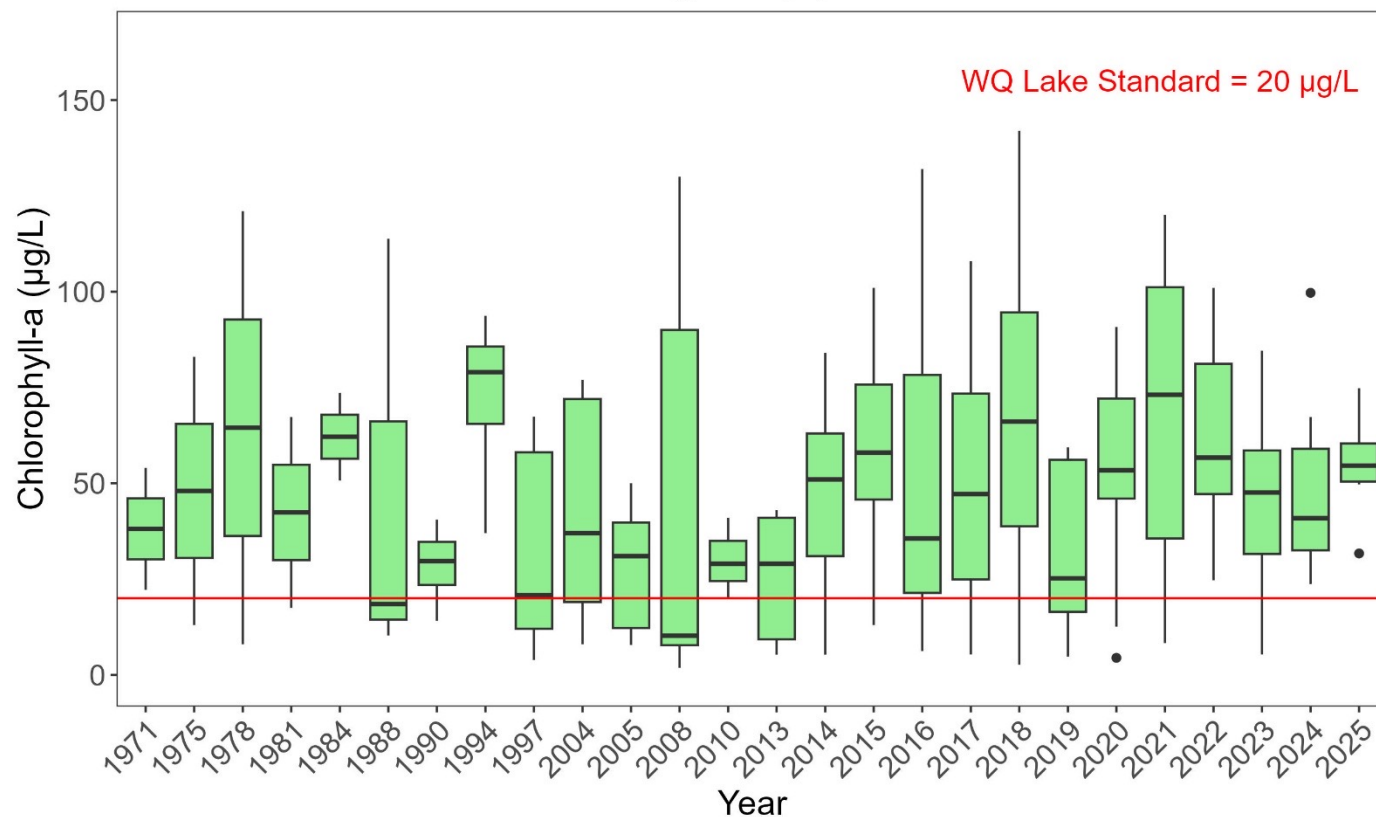


Lake Susan Surface TKN
June through Sept, 2004-2025



Lake Susan Nutrients and Algae

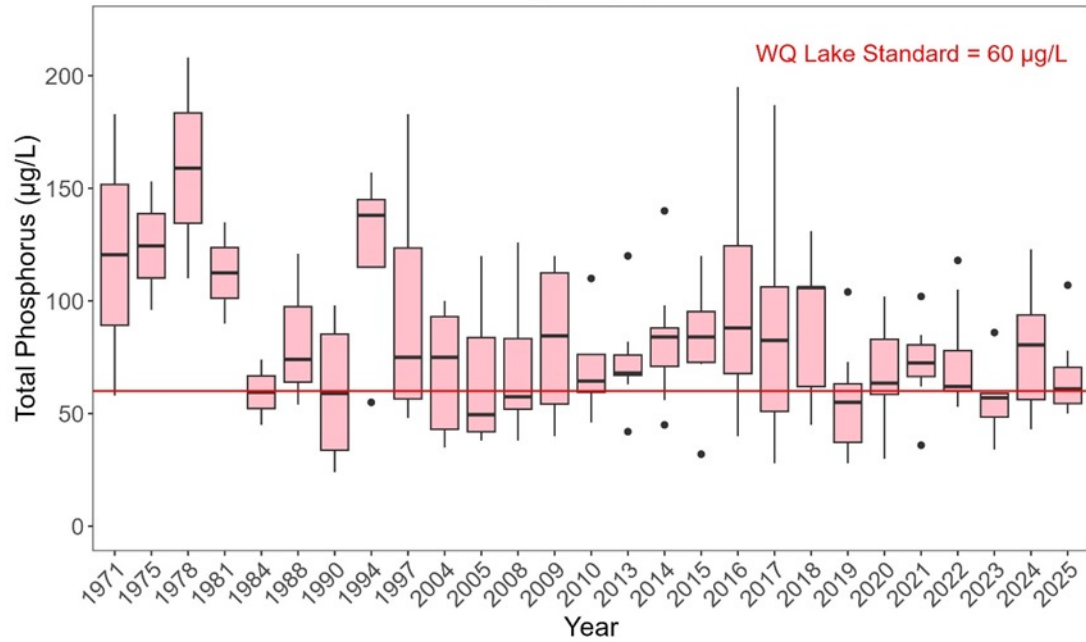
Lake Susan Surface Chlorophyll-a
June through Sept, 1971-2025



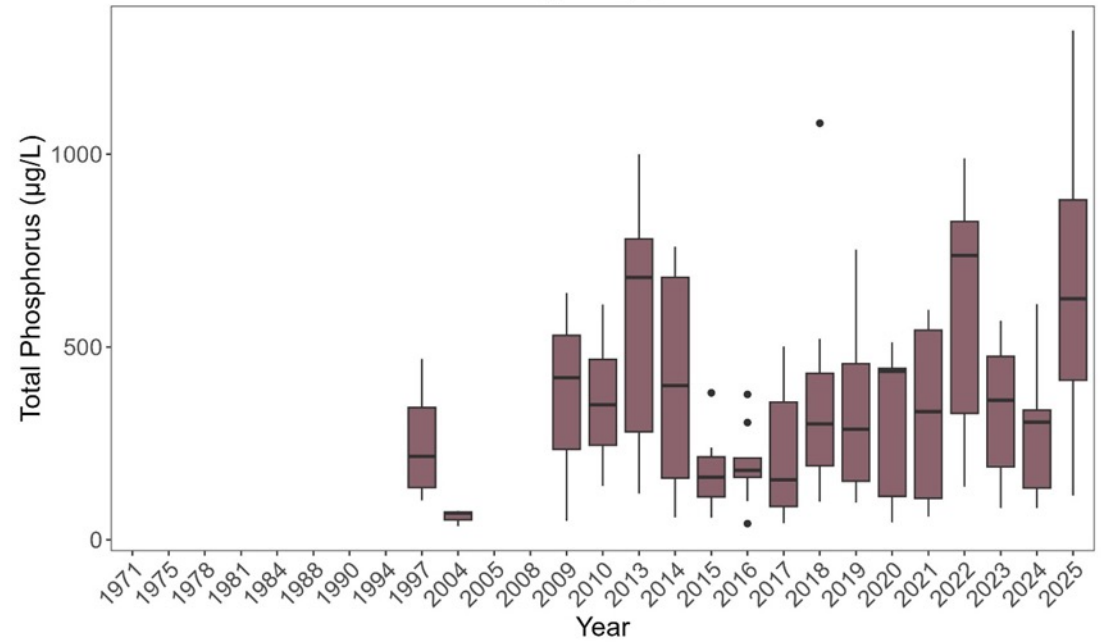
NCHF Reference Lakes: 600 to 1,200 µg/L TKN; <10 NO₃/NO₂

Surface and Bottom Total Phosphorus

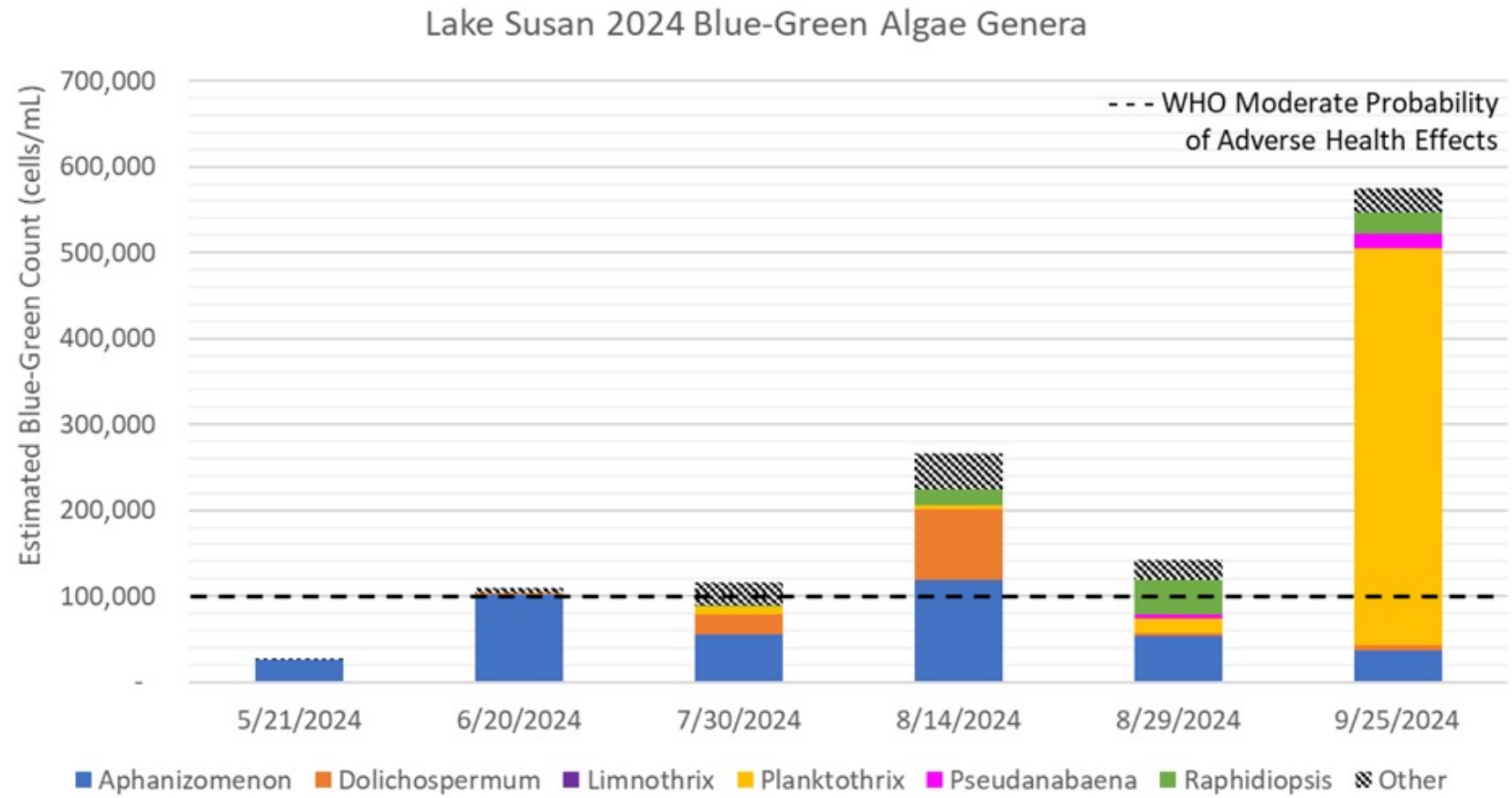
Lake Susan Surface Total Phosphorus
June through Sept, 1971-2025



Lake Susan Bottom Total Phosphorus
June through Sept, 1971-2025



Lake Susan Cyanobacteria



Cyanobacteria Species	Hepatotoxins		Neurotoxins	
	Cylindrospermopsin	Microcystins	Anatoxin-a	Saxitoxins
<i>Aphanizomenon flos-aquae</i>*	X			X
<i>Aphanocapsa sp.</i>		X		
<i>Dolichospermum flos-aquae</i>*		X	X	
<i>Limnothrix redekei</i>		X		
<i>Merismopedia tenuissima</i>		X		
<i>Microcystis sp.</i>*		X	X	
<i>Planktothrix agardhii</i>*		X	X	X
<i>Pseudanabaena limnetica</i>	X	X		
<i>Pseudanabaena mucicola</i>		X		
<i>Raphidiopsis raciborskii</i>*	X	X	X	X

Eutrophication Goals

Goal 1. Meet summer average state water quality standards for the lakes

Goal 2. Minimize cyanobacteria blooms below WHO thresholds throughout the growing season

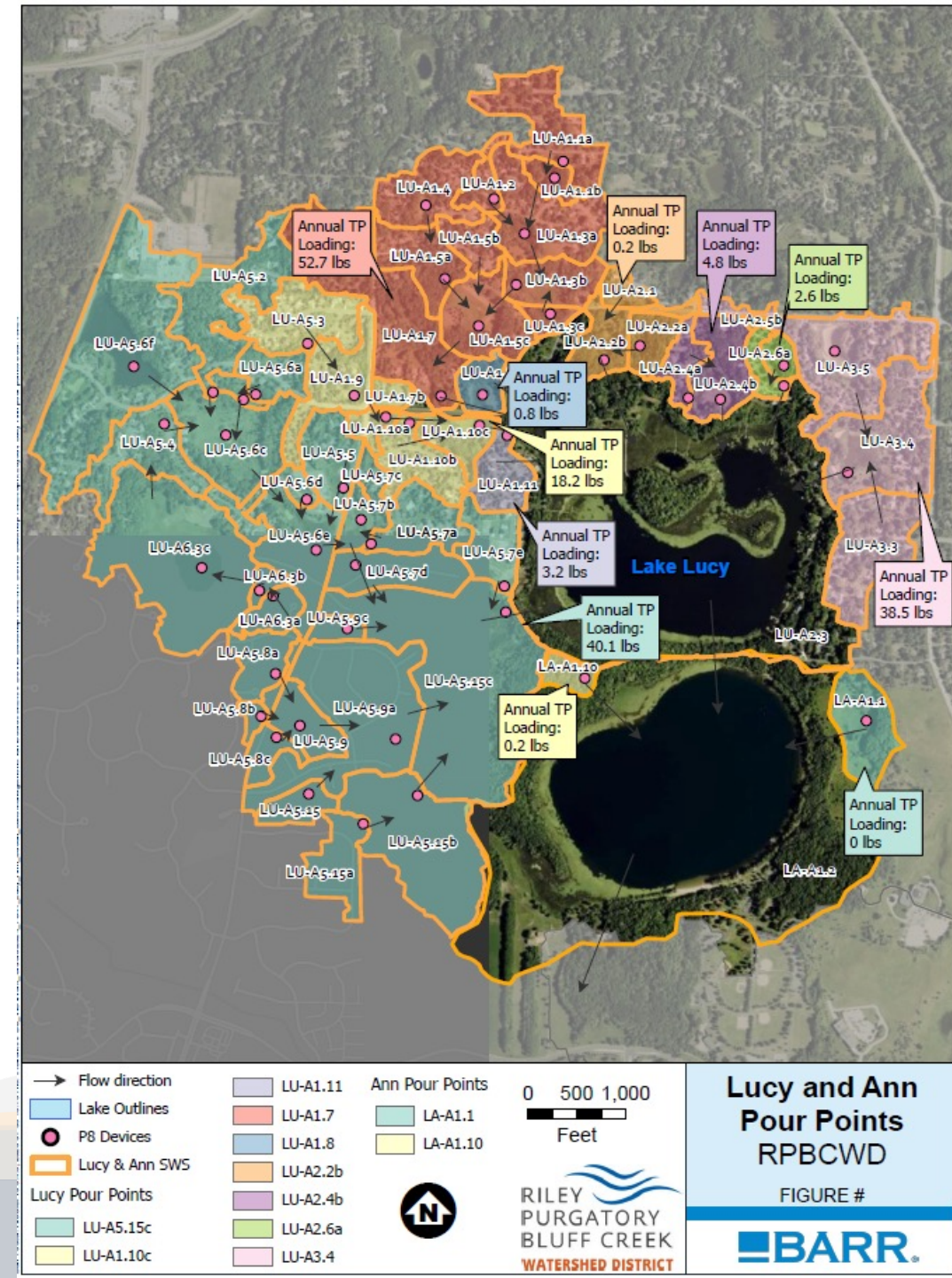
Eutrophication Parameter	Shallow Lakes¹	Deep Lakes
Total Phosphorus (summer average, $\mu\text{g/L}$)	≤ 60	≤ 40
Chlorophyll-a (summer average, $\mu\text{g/L}$)	≤ 20	≤ 14
Secchi Disk transparency (summer average, meters)	≥ 1.0	≥ 1.4

Barr Lake Response Model

- Water Balance (wet and dry year)
- Temperature and Dissolved Oxygen
- Nitrogen and Phosphorus
- Sediment phosphorus release
- Inorganic and organic sources
- Phytoplankton
- Chlorophytes and cyanobacteria

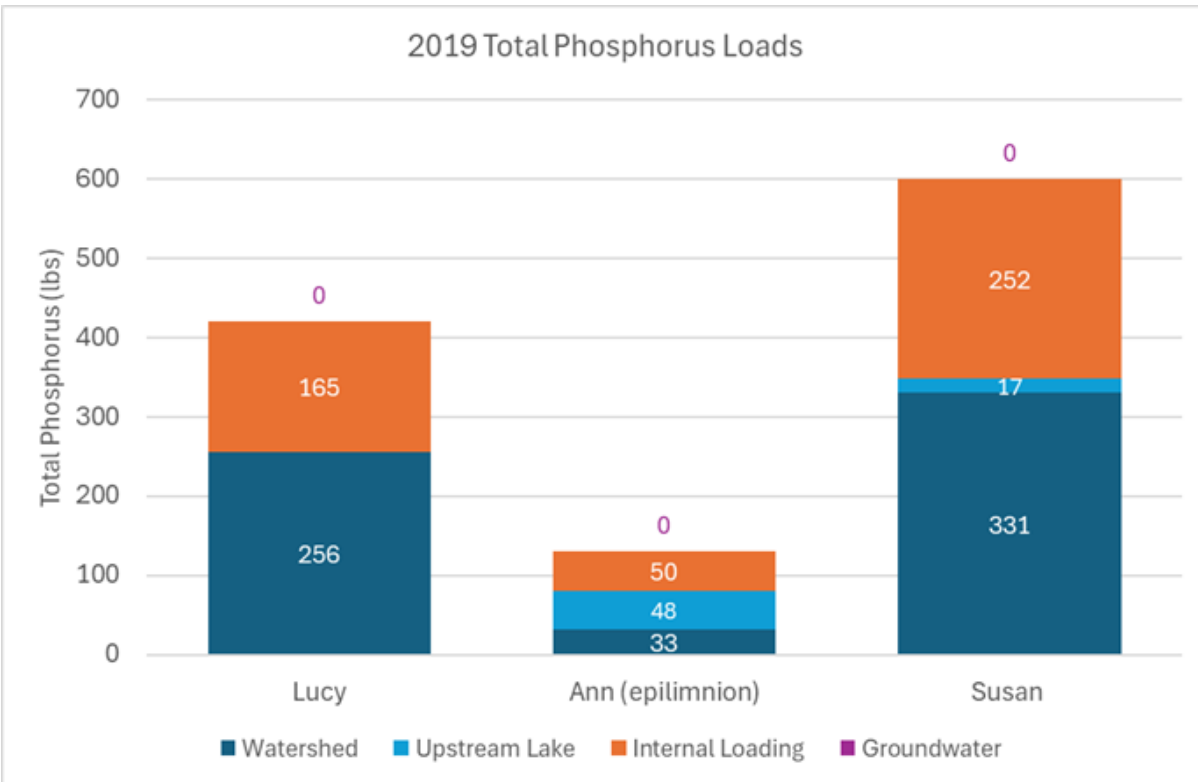
Questions

- What role does N play in driving cyanobacteria blooms?
- What reductions are required to meet state water quality standards?
- Are both N and P reductions beneficial?
- Where should nutrient reductions be pursued?

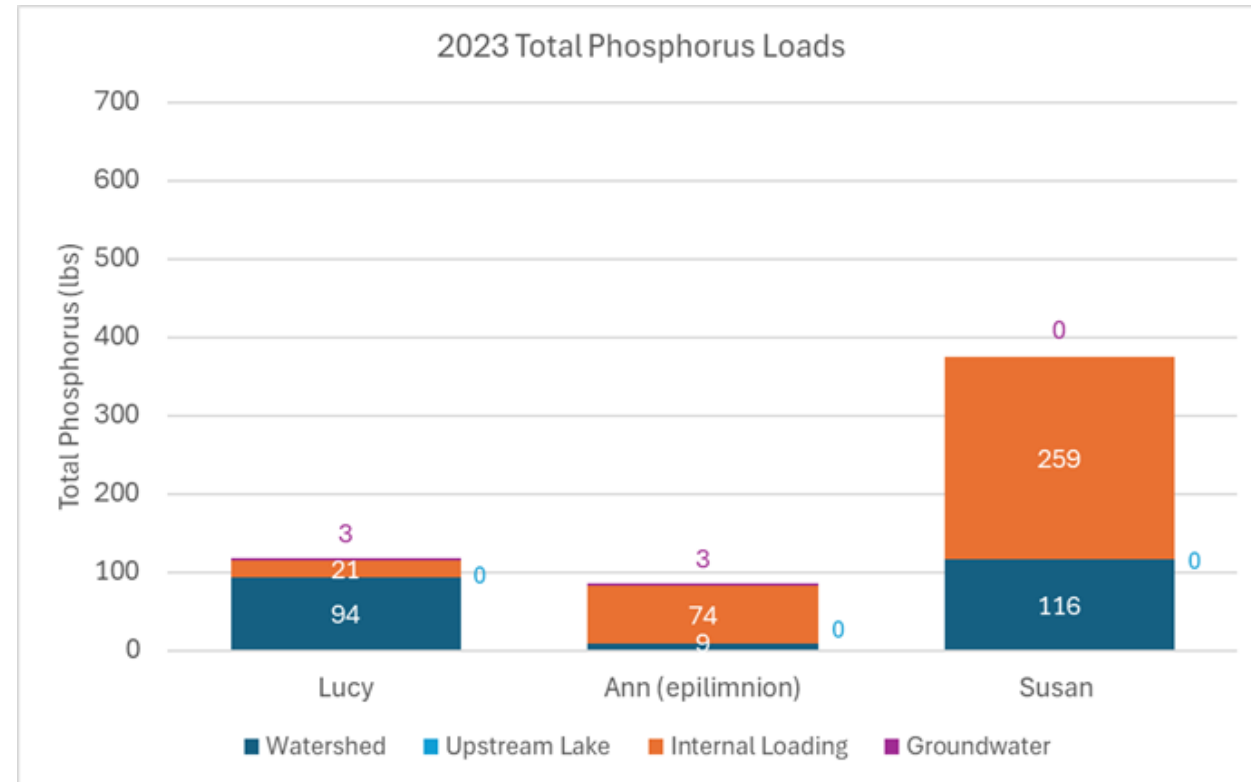


Total P Budgets for Lucy, Ann, and Susan

2019 Total Phosphorus Loads

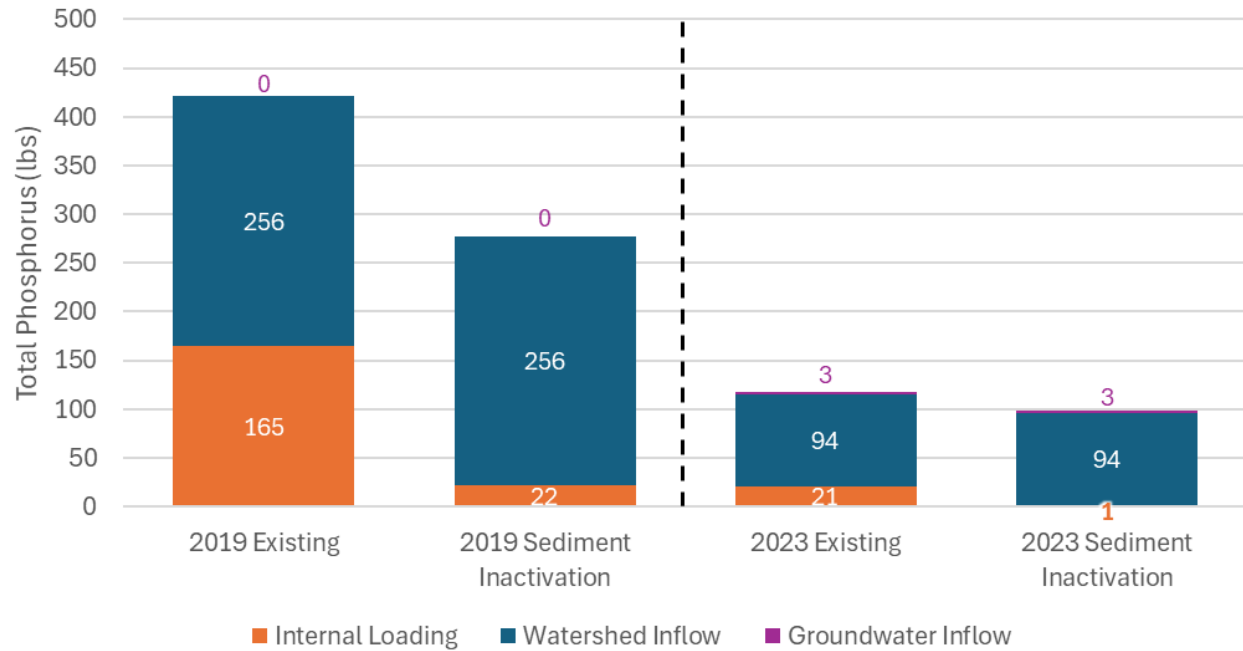


2023 Total Phosphorus Loads

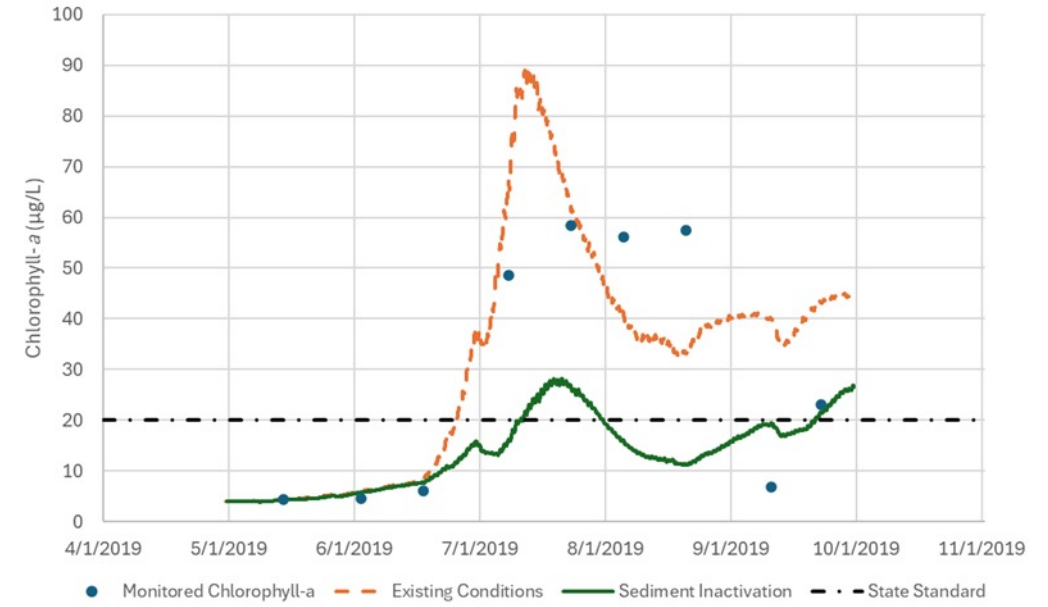


Model Scenarios – Lake Lucy

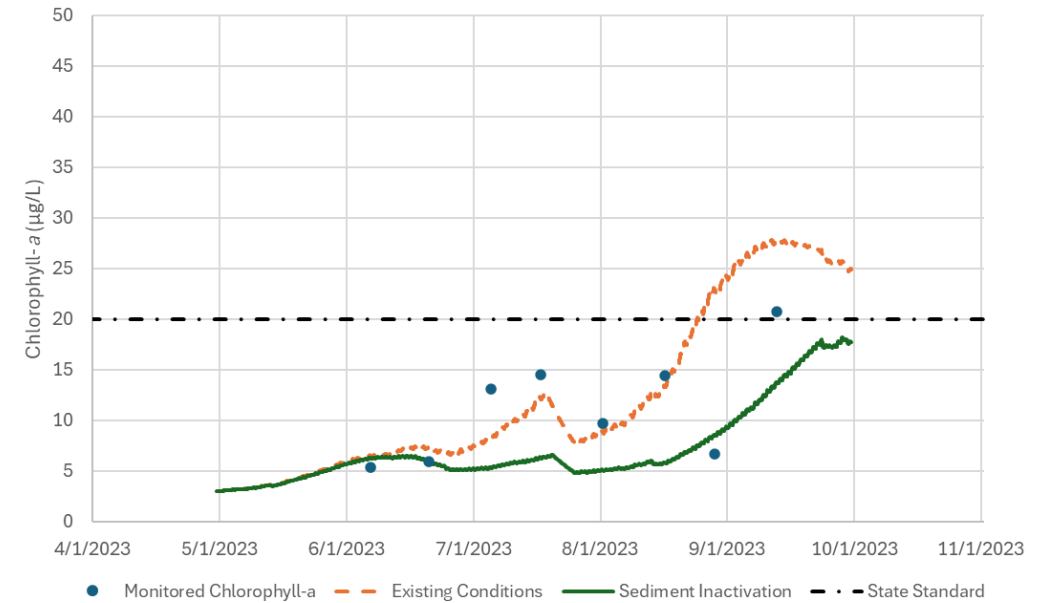
Lake Lucy Total Phosphorous Loads
(June-September)



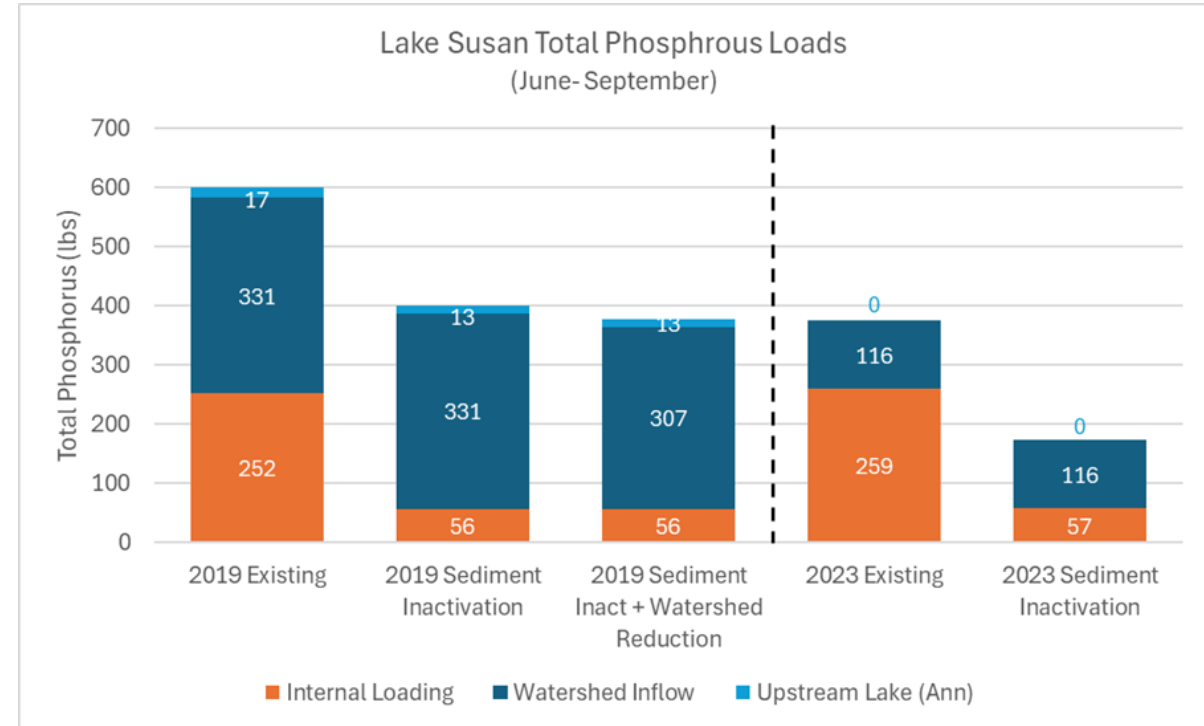
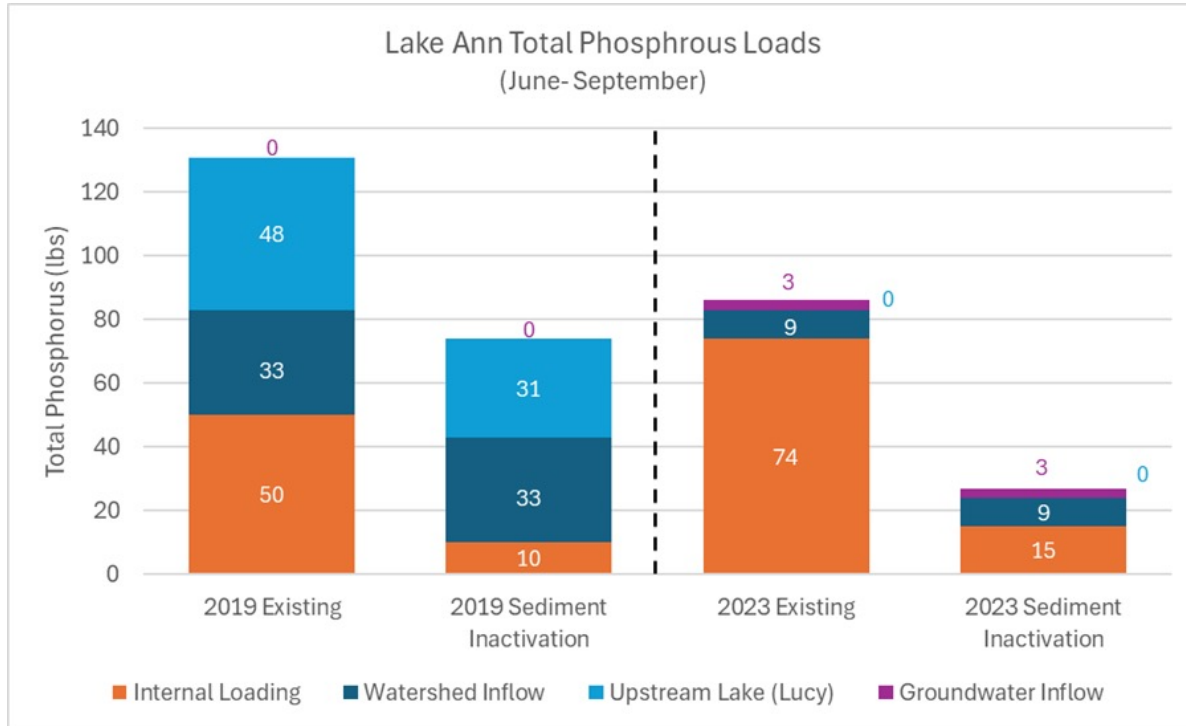
Chlorophyll-a Comparison - Lake Lucy 2019



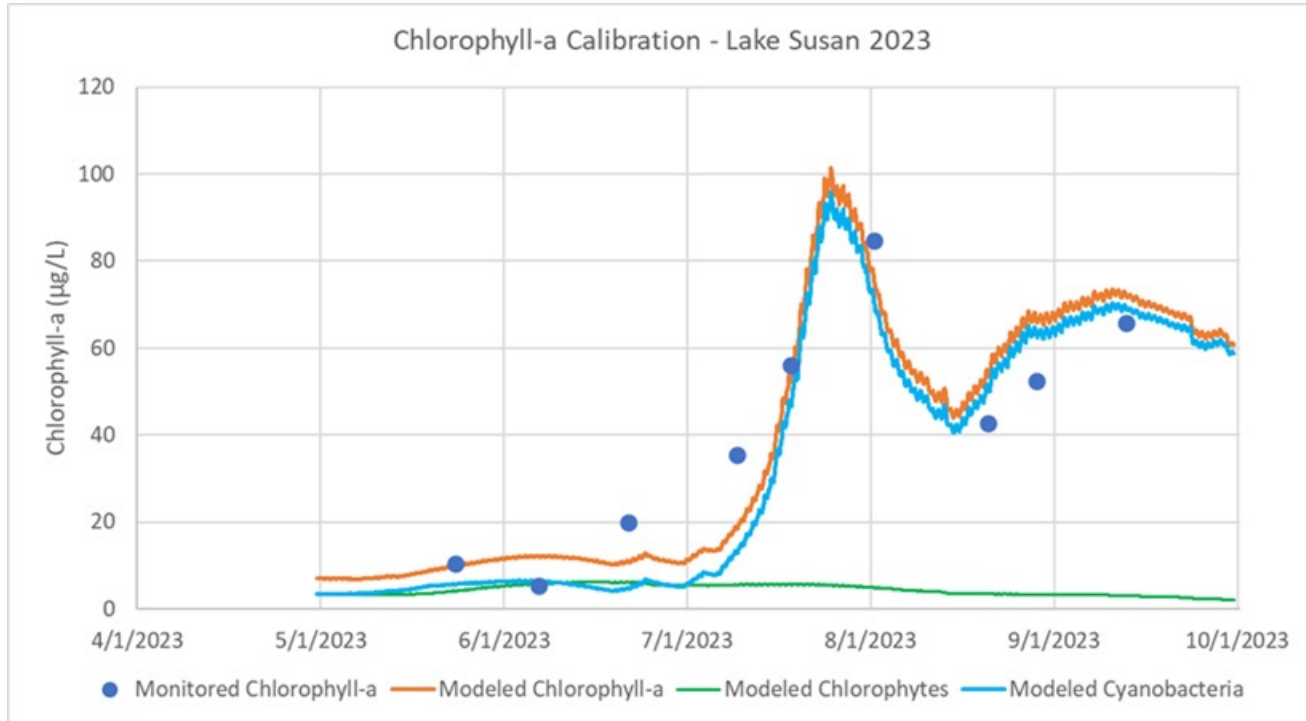
Chlorophyll-a Comparison - Lake Lucy 2023



Lake Ann and Lake Susan Model Scenarios



The Role of Nitrogen



- Limited nitrate data suggest high nitrogen periods in the lakes
- Phytoplankton are co-limited by N+P
 - N-fixation by cyanobacteria starts in mid-to late-June
- N management will have limited benefits to phytoplankton production due to N-fixing cyanobacteria
- However, lower N environments are less likely to produce toxic cyanobacteria blooms
- Opportunistic with N management
- Need better N monitoring in lakes and tributaries

Summary of Lake Water Quality Drivers

- Phosphorus management is still the best approach for reducing nuisance algae blooms and cyanobacteria
 - Internal P loading is a major driver in all three lakes
 - Watershed reductions can be protective long term
- Improved nitrogen monitoring is required to better understand nitrogen conditions
- Nitrogen reductions as opportunities arise
 - Wetland restoration to increase denitrification, N retention

Watershed Project Types

- **Structural engineered projects**

- Spent lime filter, iron enhanced sand filters, new ponds

- **Pond Maintenance**

- Internal phosphorus loading in ponds

- **Wetland restoration**

- Address both nitrogen and phosphorus if possible

- **Non-structural**

- Street sweeping, education and outreach, individual practices
- 

Previously Identified Projects

Lake	Location	Project	Prioritization Score	P Load Reduction to Lake (lbs/yr)	In Current CIP Plan?
Lucy	LU-A1.10c	<i>Iron enhanced sand filter</i>	34	19	Yes (Not constructed)
Lucy	LU-A3.4	<i>Spent lime treatment</i>	32	11	Yes
Susan	Riley Creek	Upper Riley Creek - Upstream Watershed Detention and Phosphorus Load Reduction (URC)	27	--	No
Susan	Riley Creek	Upper Riley Creek Stabilization and restoration	39	231	Yes
Susan	Lake Susan Park Pond	<i>Iron enhanced sand filter</i>	34	31	Yes (20XX)
Susan	Lake Susan Hills West Park	<i>Wetland Restoration</i>	32	67	No
Susan	Target Pond	<i>Iron enhanced sand filter</i>	20	19	No
Susan	Lake Drive West Pond	<i>Iron enhanced sand filter</i>	18	5	No

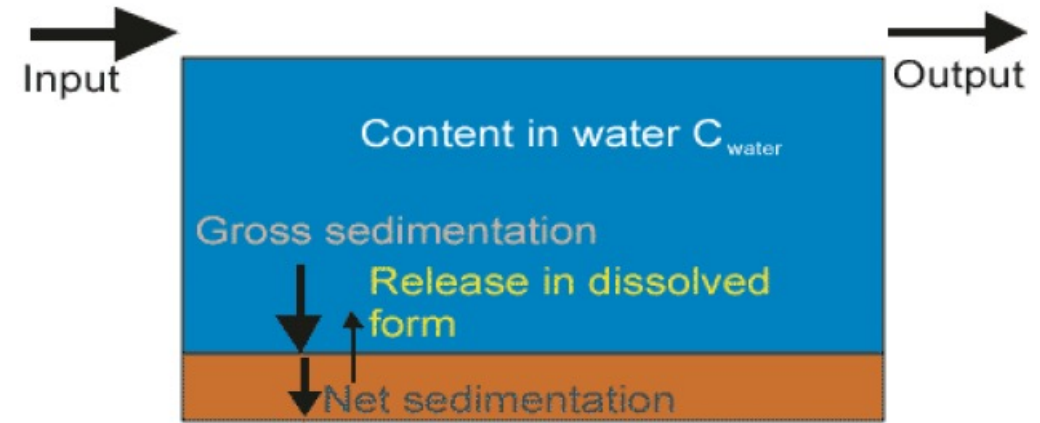
Internal P Loading in Ponds

- **Mitchell and Riley Subwatershed Study (2021)**

- Field assessment of 9 ponds
- High anoxia and high P loading
- Possible source of P to surface waters

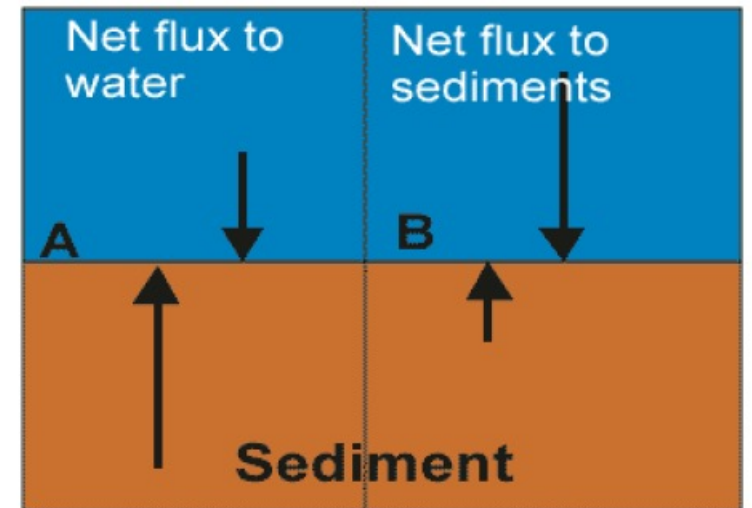
- **Pond Screening**

- Applied average release rates and anoxic factors to estimate P mass load
- Pond >1 acre and >3 feet in depth



Net sedim. < 0
release > gross sedim.

Net sedim. > 0
release < gross sedim.



Pond Maintenance Projects – Pond Screening

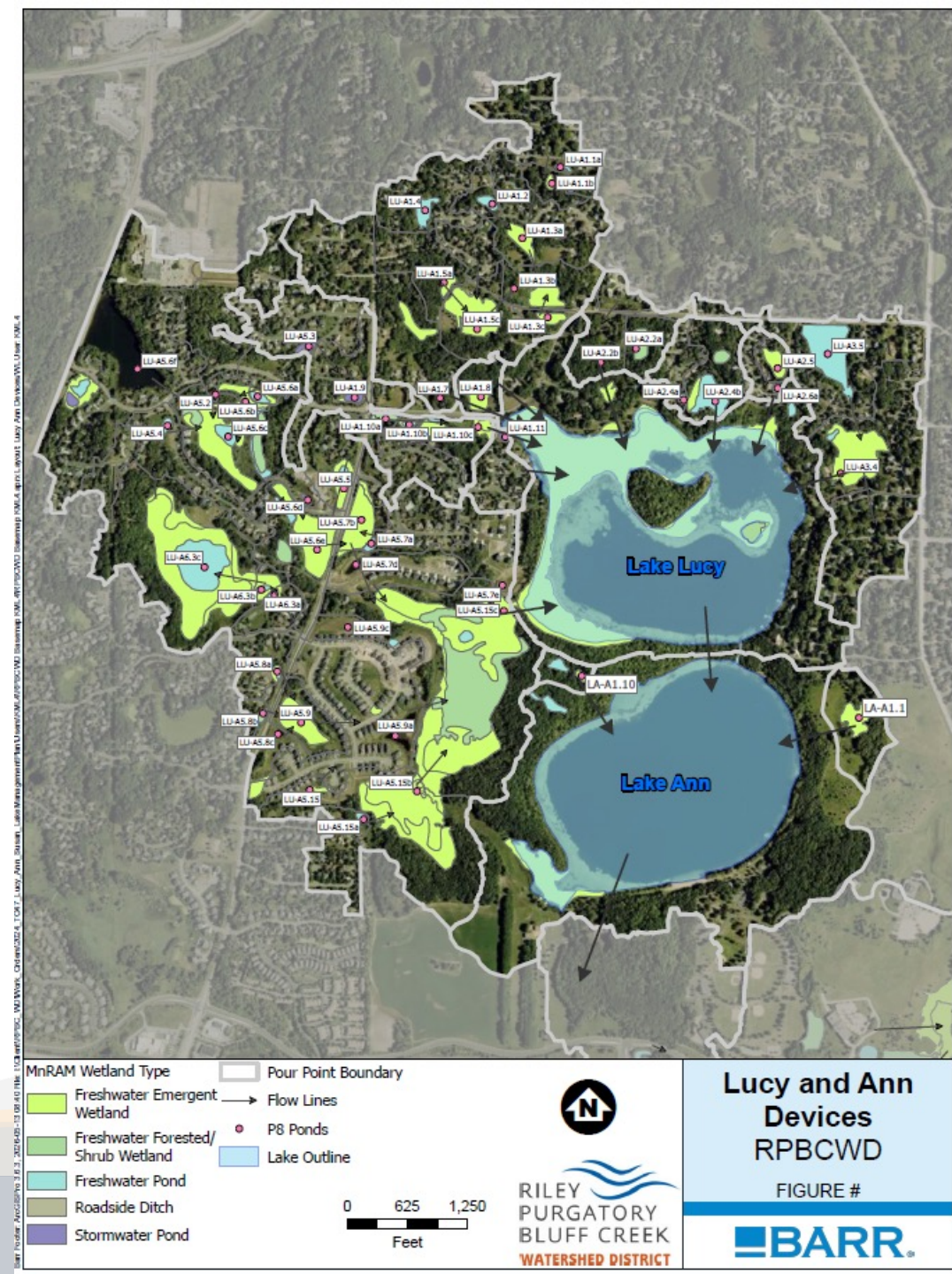
Lake	Pond ID	Pond Area (ac)	Average Depth (ft)	Potential P Load (lbs/yr)	Surveyed?
Lucy	LU-A3.5	4.5	5.7	13.8	No
Lucy	LU-A5.9a	1.4	5.6	4.2	No
Lucy	LU-A6.3c	22.2	5.5	68.0	No
Lucy	LU-A5.6f	9.4	3.3	28.8	No
Susan	3.63	1.5	3.4	4.6	No
Susan	58b_1_a	1.6	6.5	4.9	No
Susan	2.6	2.0	5.3	6.2	No
Susan	3.37	4.3	4.7	13.1	No
Susan	2.13	2.8	3.8	8.5	No

Alum Treatments

Lake	Project	Prioritization Score	In Current CIP Plan?
Lucy	In-lake P load control <i>Alum treatment</i>	28	No
Ann	In-lake P load control <i>Alum treatment</i>	34	No
Susan	In-lake P load control <i>Alum treatment</i>	32	Yes

Wetland Restoration

- Identify wetlands with high restoration potential
- Develop Diagnostic and Feasibility Study
- Explore wetland restoration techniques
 - **N and P sequestration**
 - **Flood control**
 - **Biodiversity**



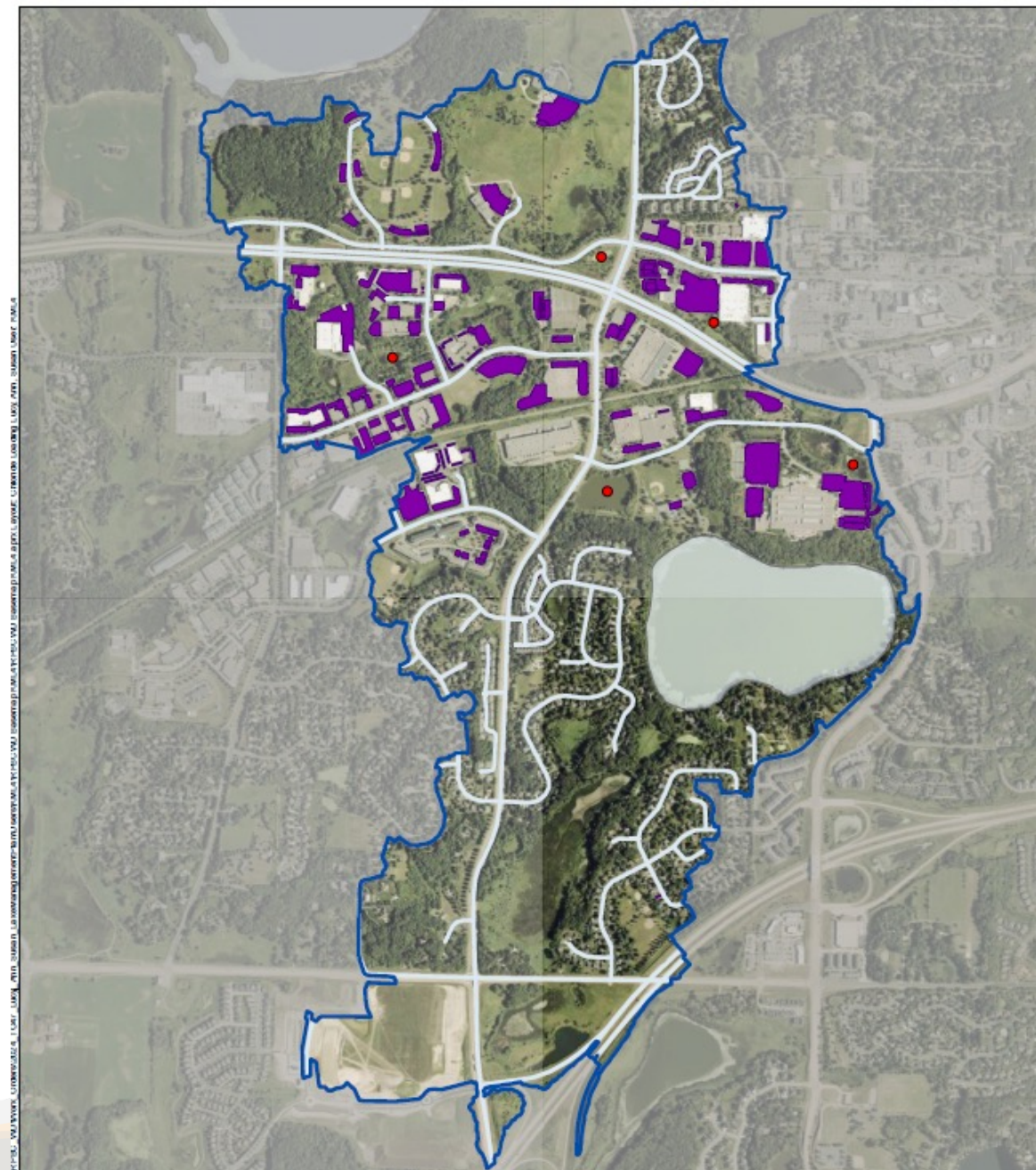
Applied Multiple Measures and P Sorption Indices



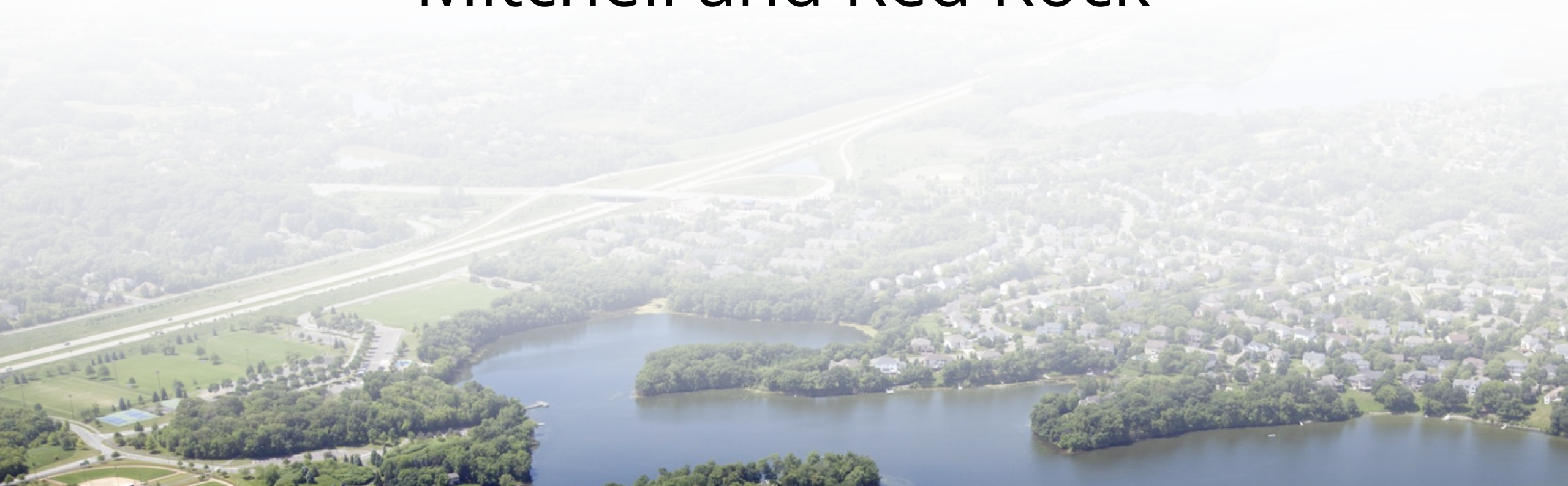
- Multiple extraction techniques
 - DI water extractable P
 - Psenner Sequential Extractions
 - Oxalate extractable Al, Fe, and P
 - Mehlich-1 extractable Al, Fe, and P
- Soil Sorption Indices
 - P saturation ratio (PSR_{OX})
 - Soil P storage capacity (SPSC; Nair et al. 2004)

Non-structural Projects

- **Street sweeping model to identify critical areas**
 - Commercial versus roadway
 - Streets with high canopy cover
- **Street sweeping beneficial to long-term pond function for P retention**
- **Policy: considerations in development maintenance agreements**
 - Need to assess loading from commercial parking lots

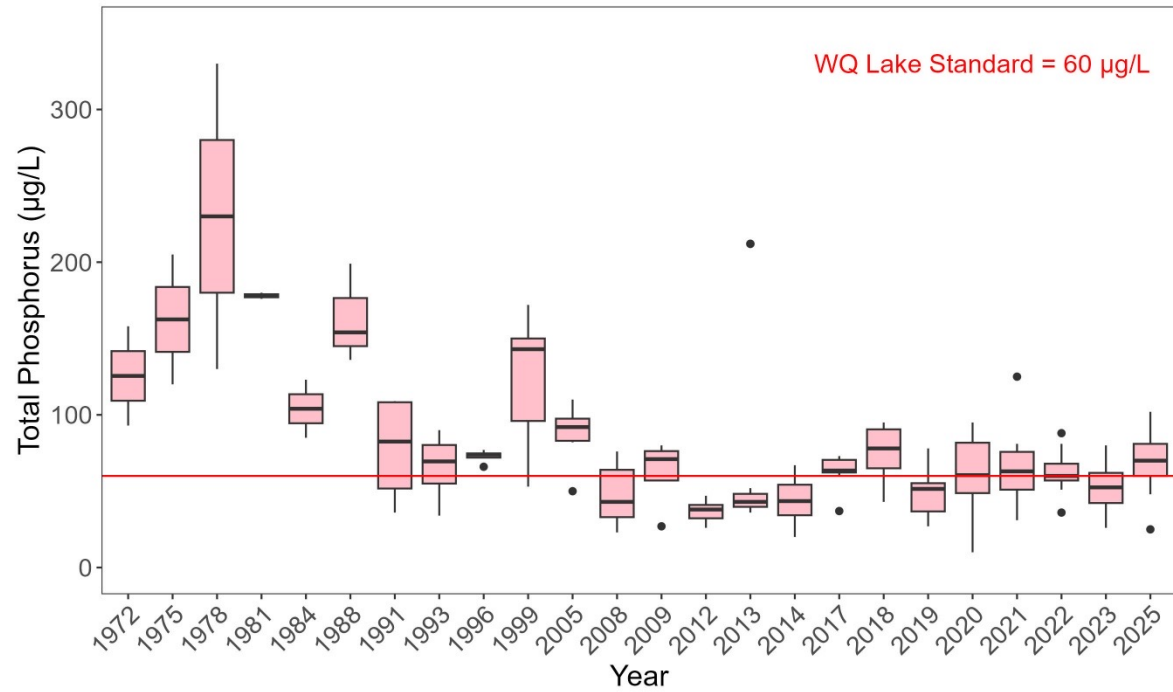


Mitchell and Red Rock

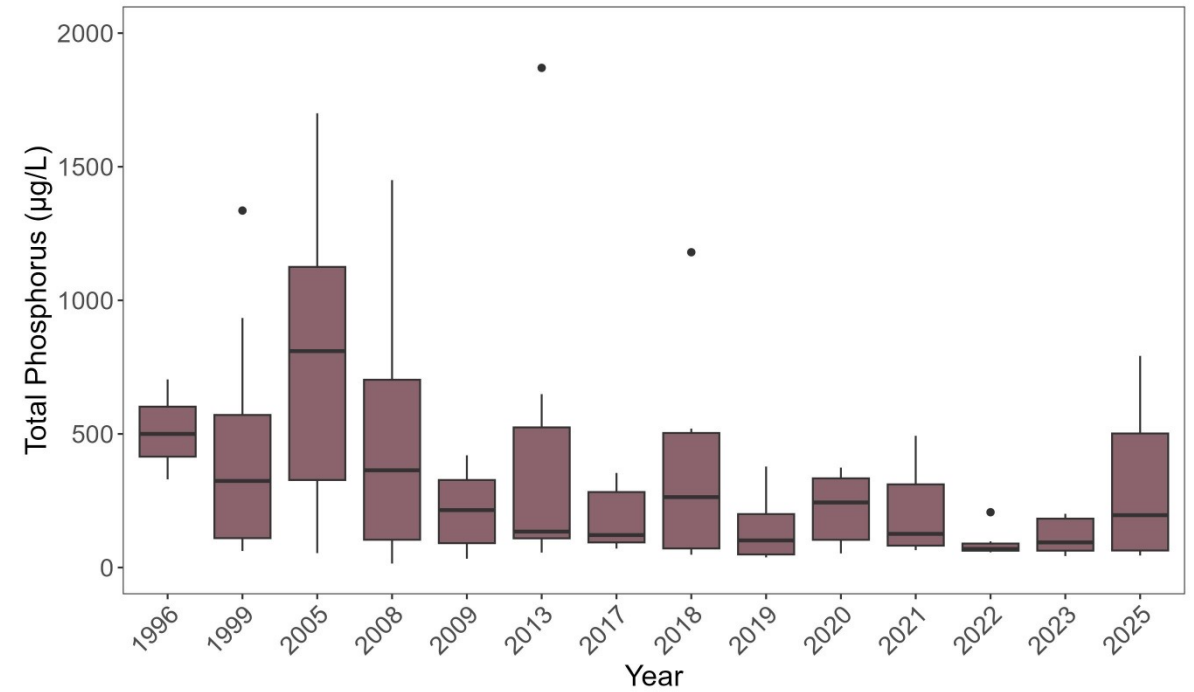


Mitchell Lake Total Phosphorus

Mitchell Lake Surface Total Phosphorus
June through Sept, 1972-2025

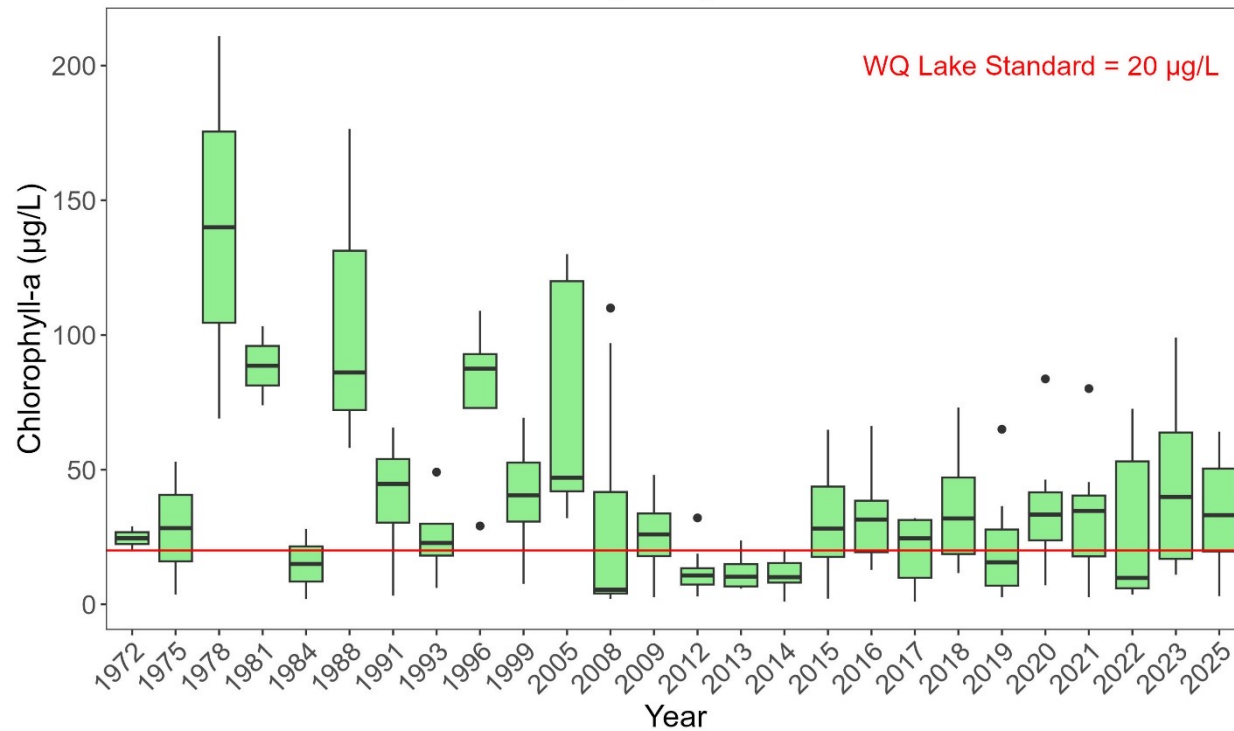


Mitchell Lake Bottom Total Phosphorus
June through Sept, 1996-2025

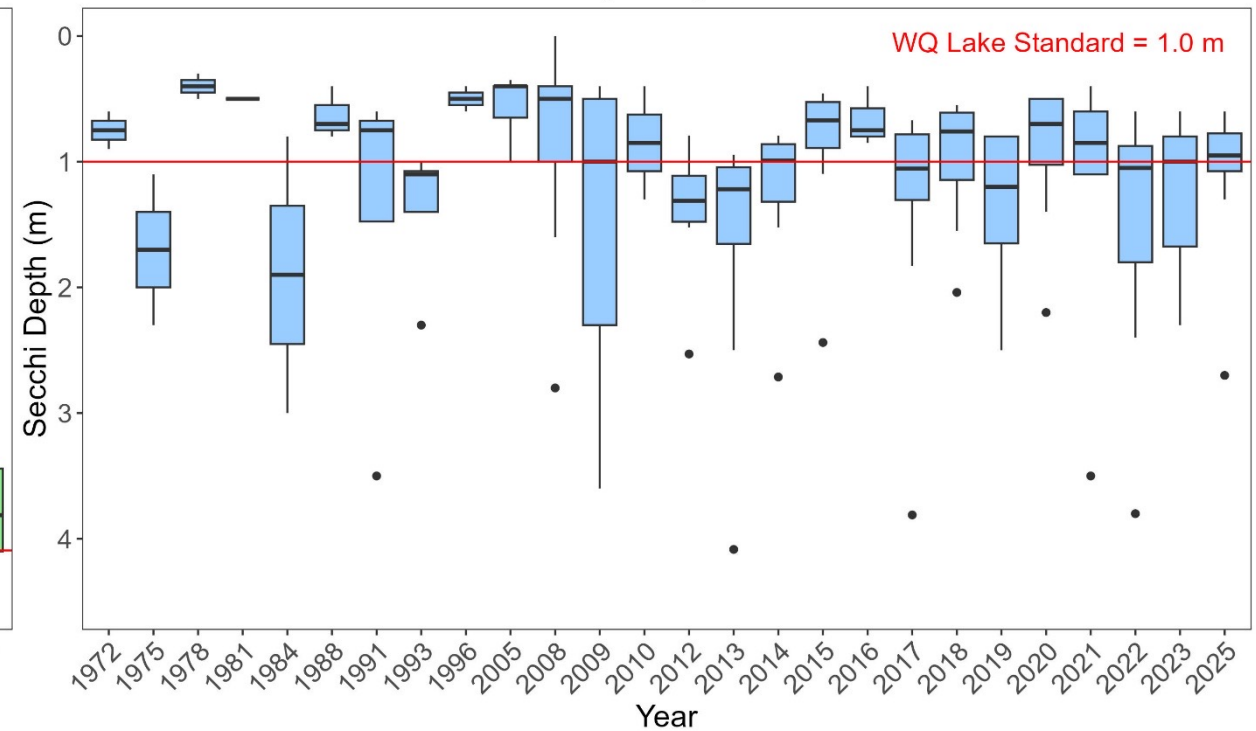


Mitchell Lake Chlorophyll-a and Secchi

Mitchell Lake Surface Chlorophyll-a
June through Sept, 1972-2025

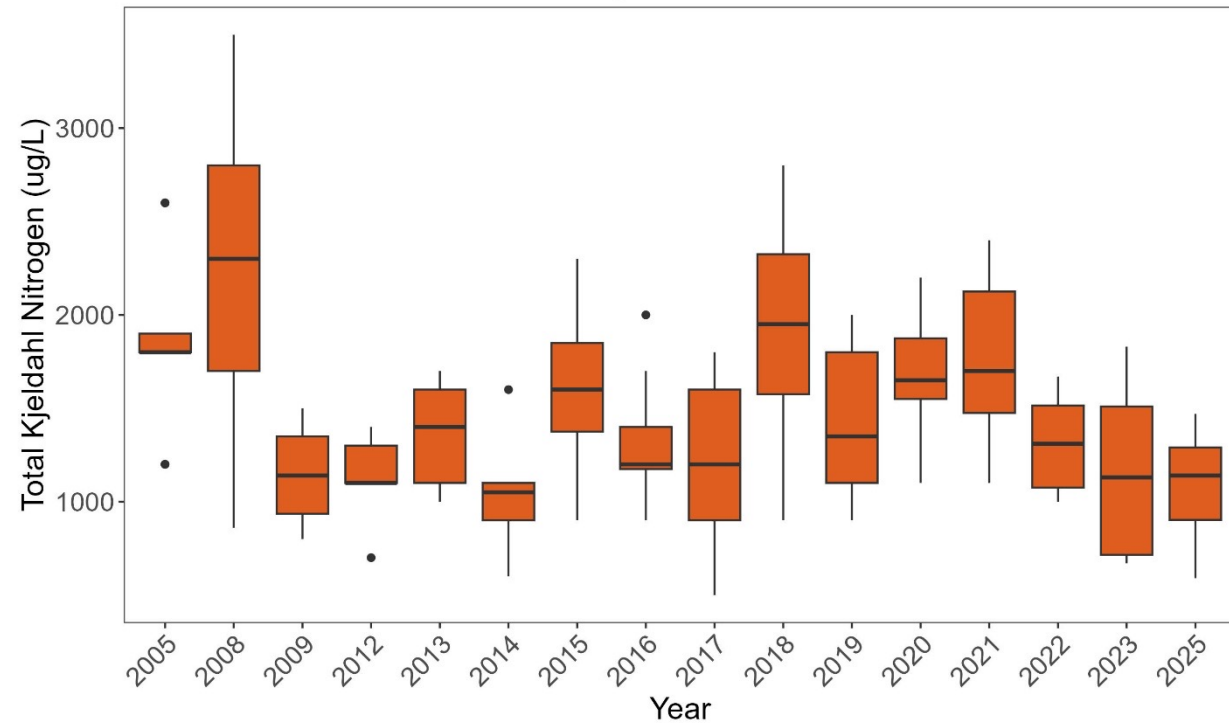


Mitchell Lake Secchi Depth
June through Sept, 1972-2025

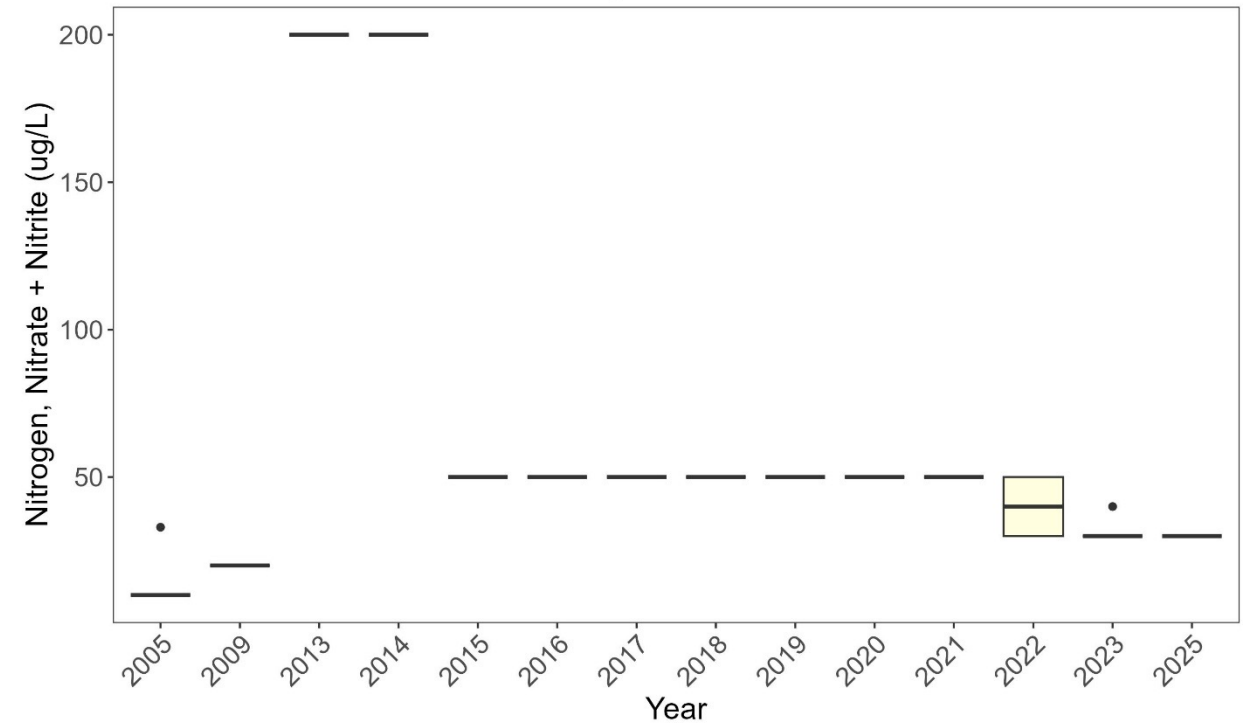


Mitchell Lake Nitrogen

Mitchell Lake Surface TKN
June through Sept, 2005-2025

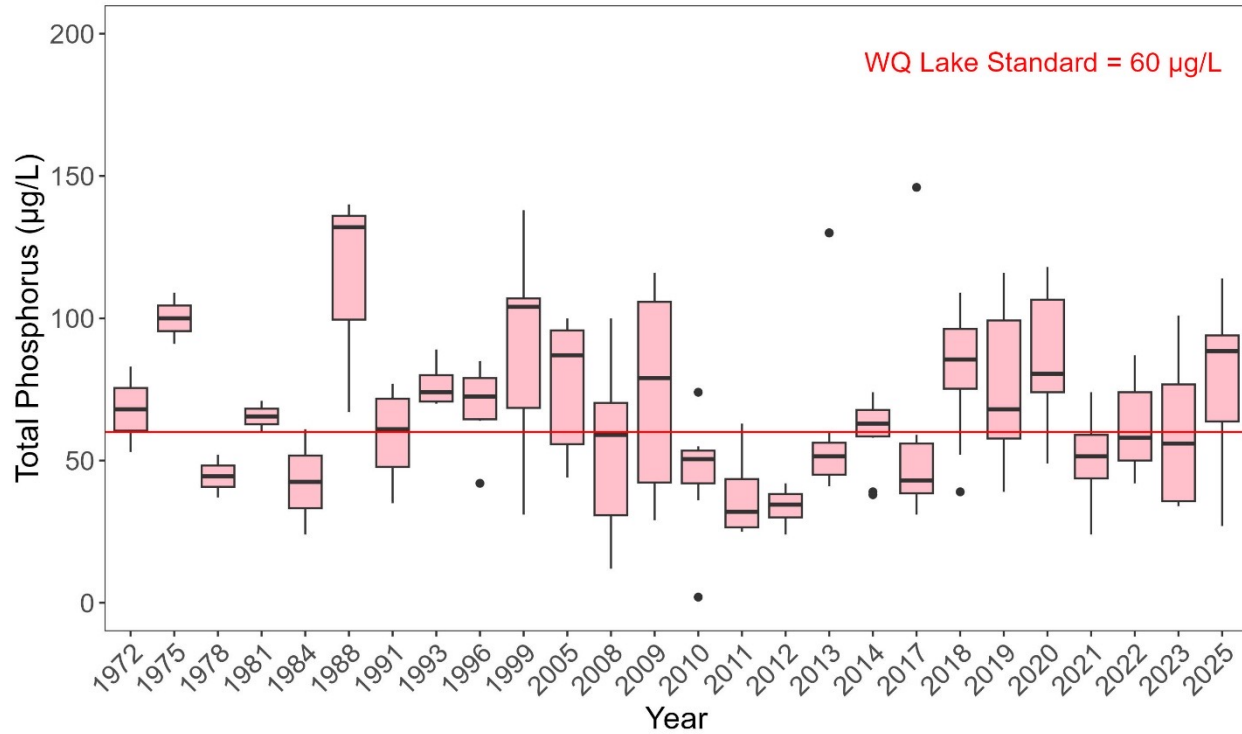


Mitchell Lake Surface Nitrate + Nitrite
June through Sept, 2005-2025

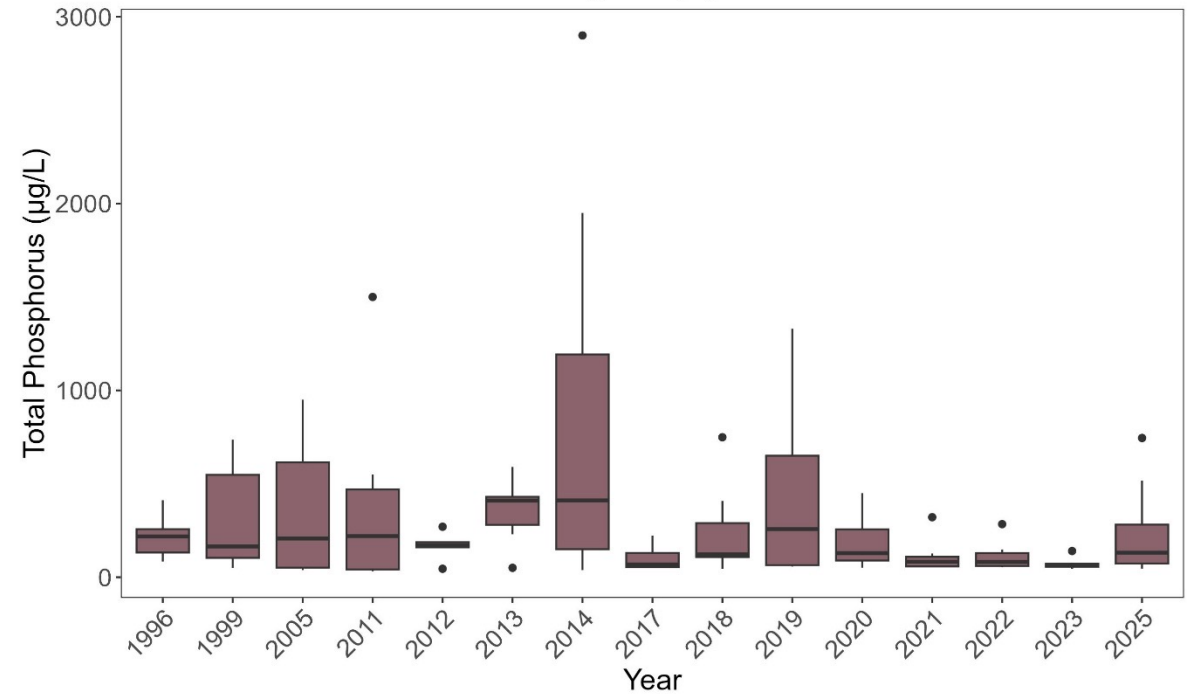


Red Rock Lake Total Phosphorus

Red Rock Lake Surface Total Phosphorus
June through Sept, 1972-2025

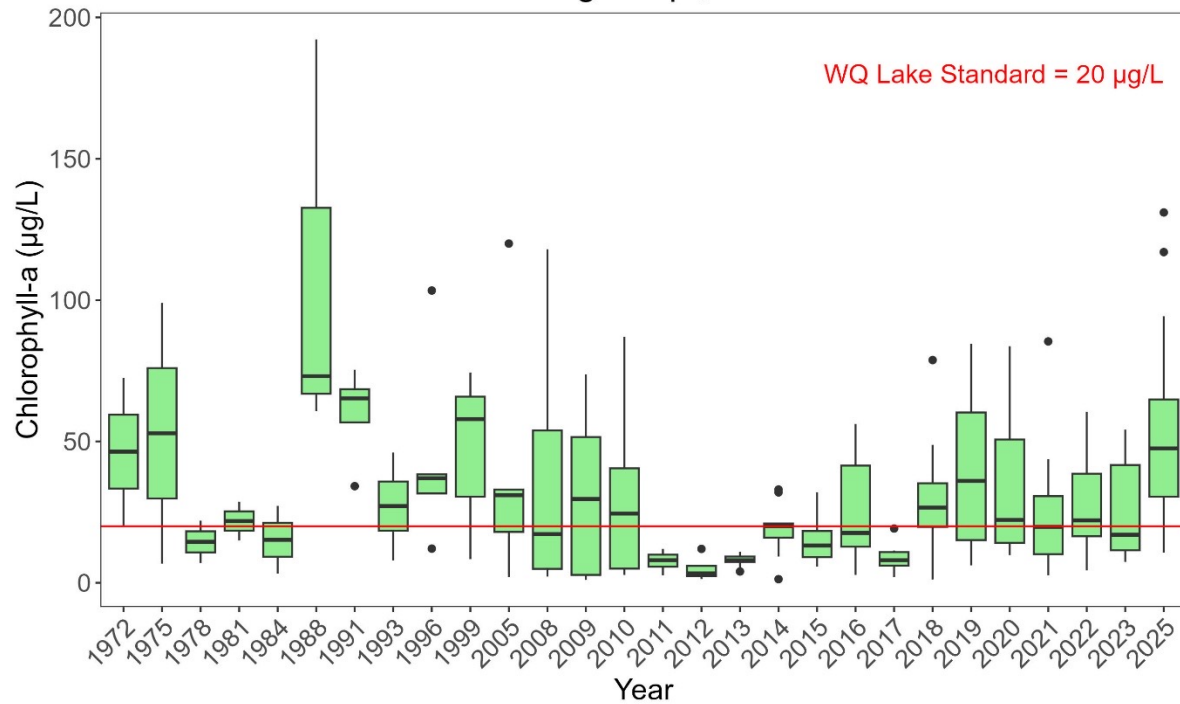


Red Rock Lake Bottom Total Phosphorus
June through Sept, 1996-2025

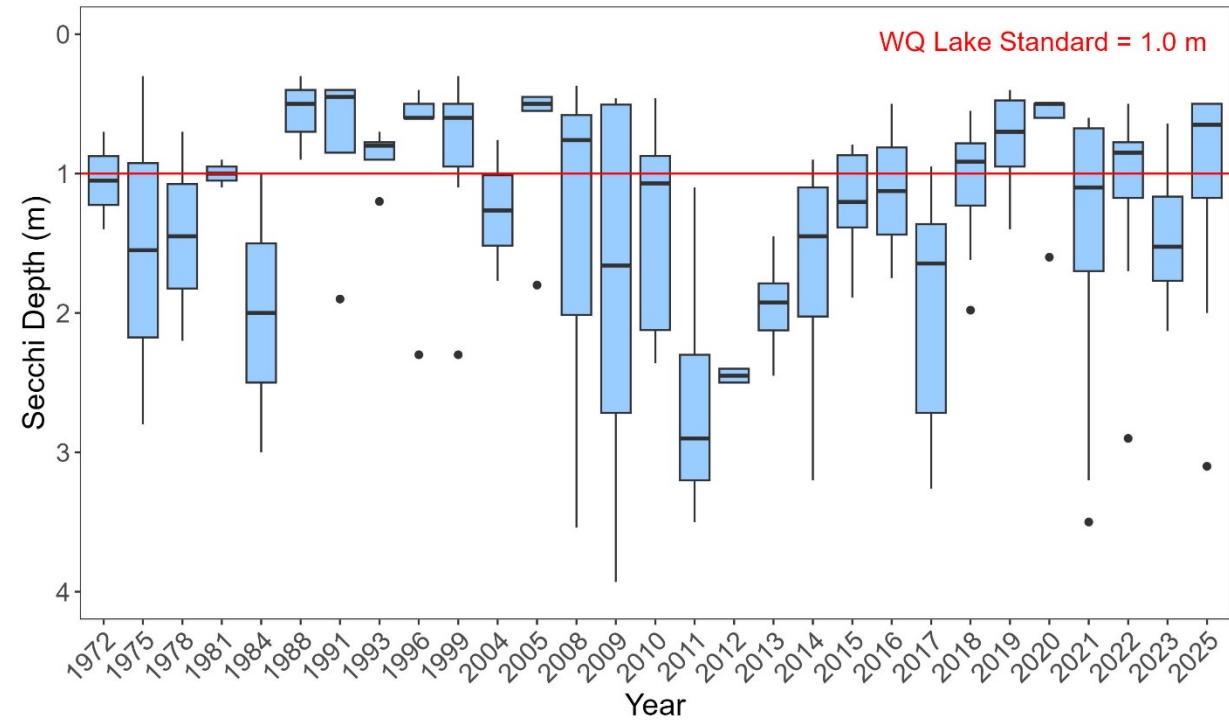


Red Rock Lake Chlorophyll-a and Secchi

Red Rock Lake Surface Chlorophyll-a
June through Sept, 1972-2025

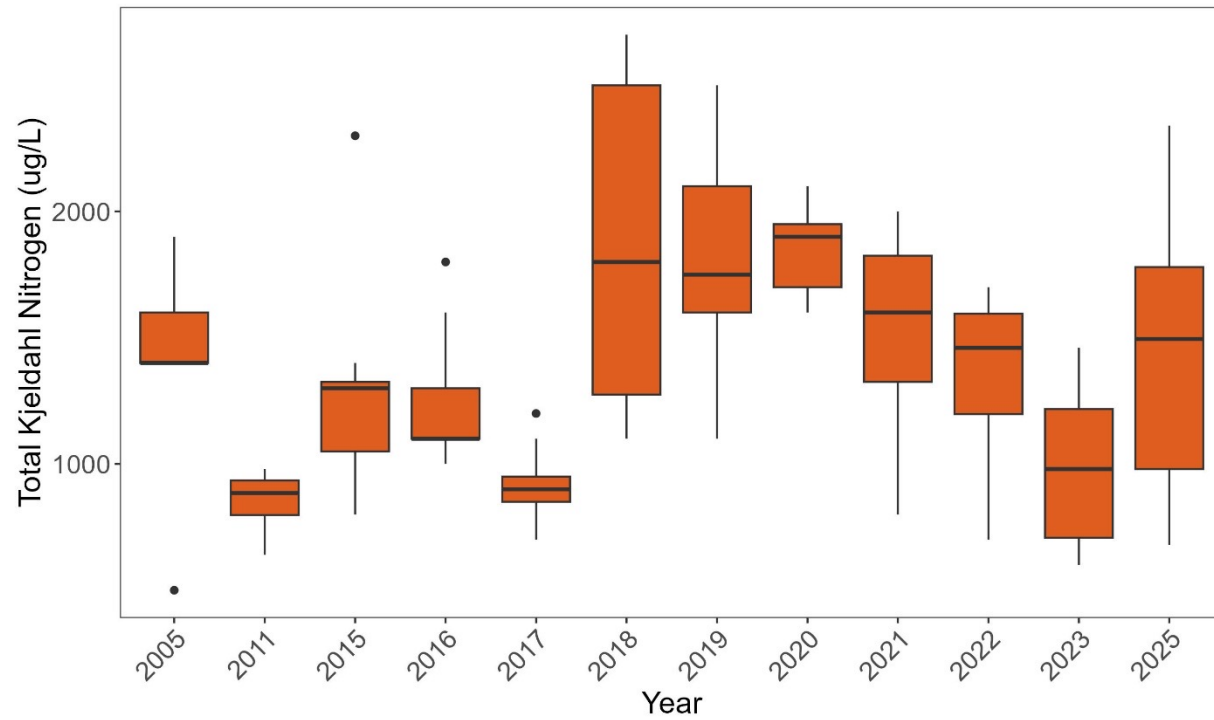


Red Rock Lake Secchi Depth
June through Sept, 1972-2025

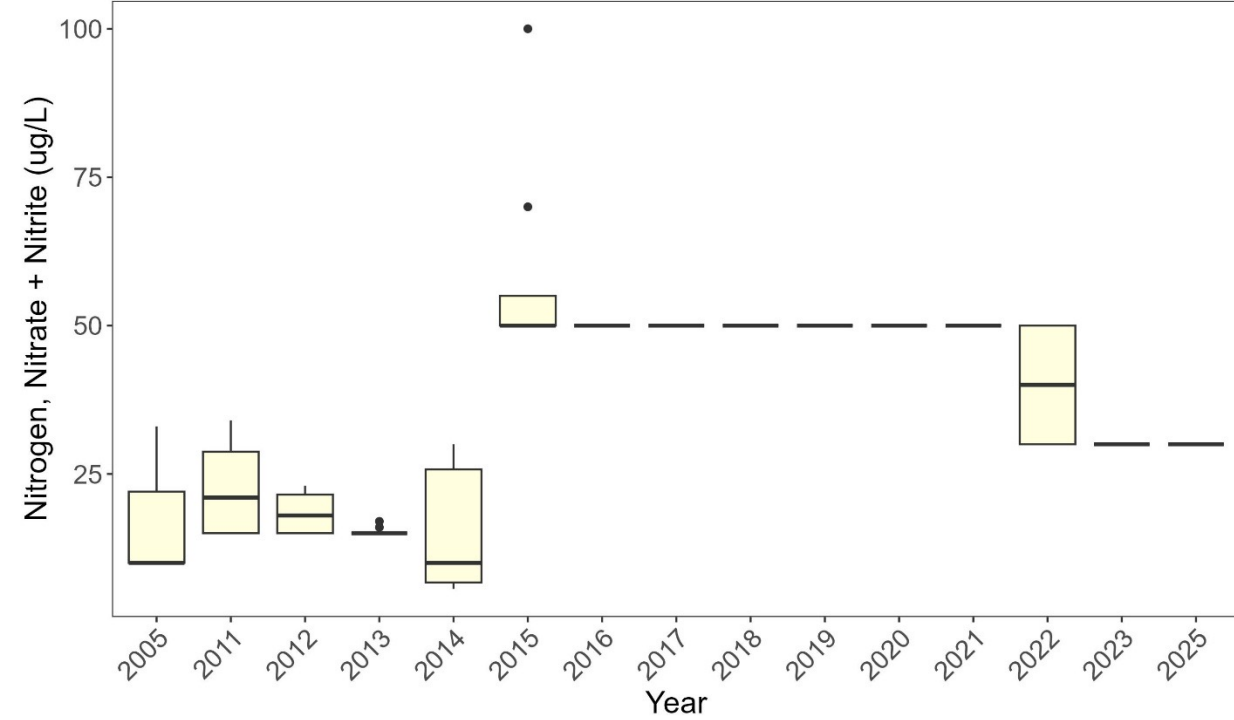


Red Rock Lake Nitrogen

Red Rock Lake Surface TKN
June through Sept, 2005-2025

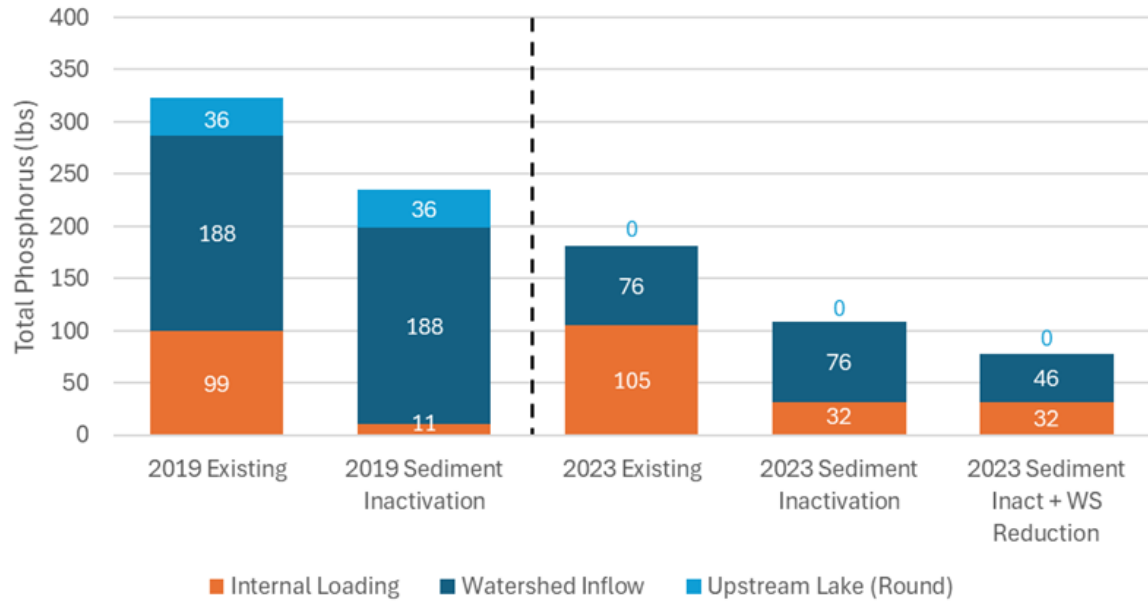


Red Rock Lake Surface Nitrate + Nitrite
June through Sept, 2005-2025

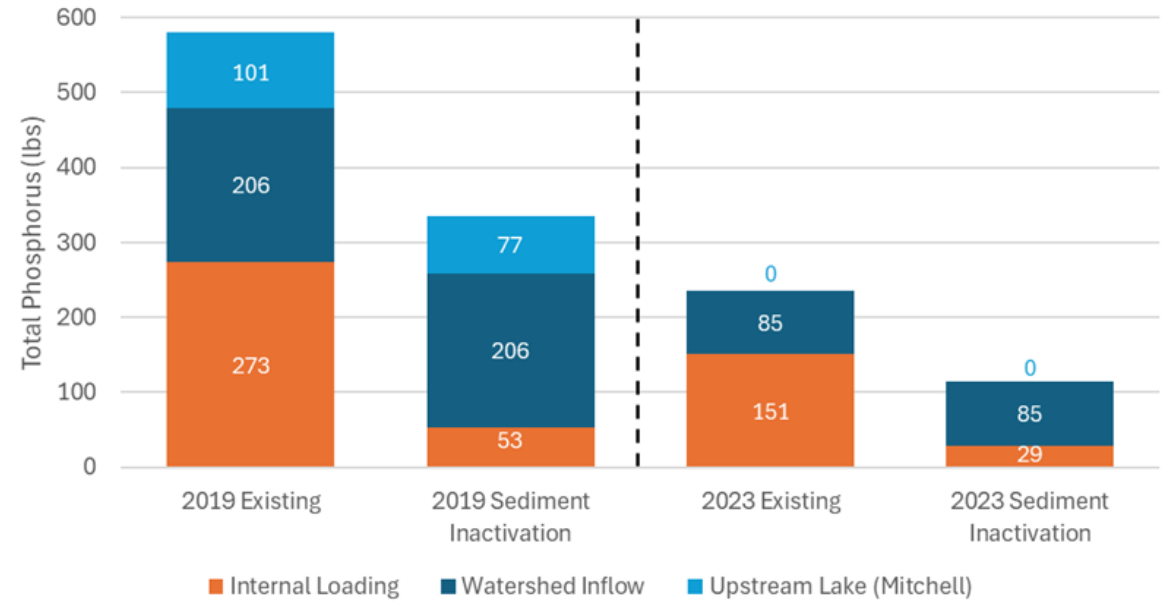


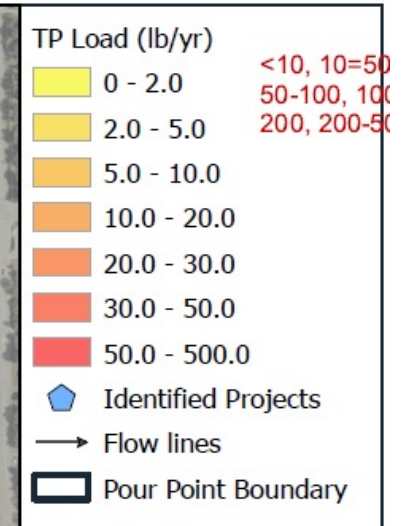
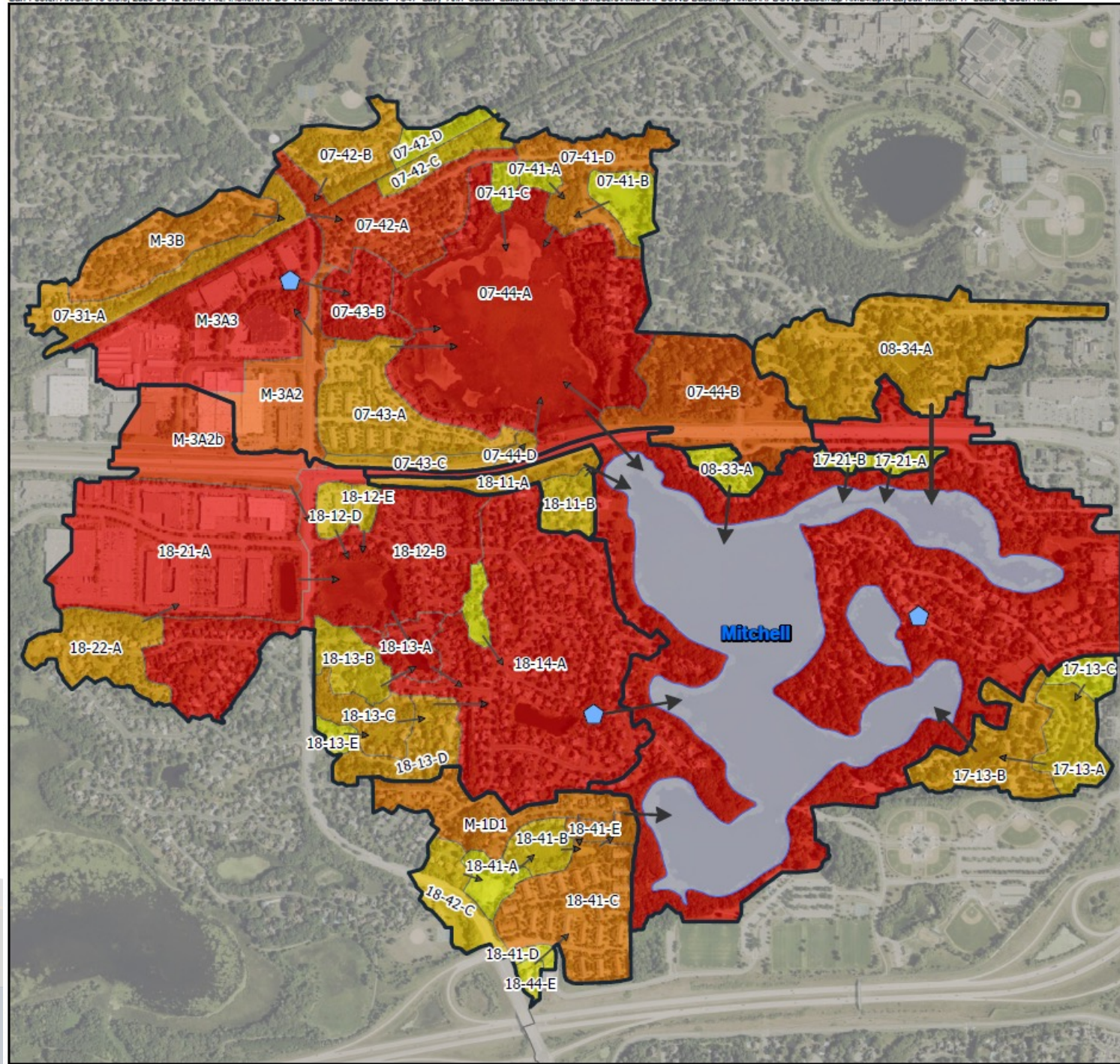
Mitchell and Red Rock Lake Reductions

Lake Mitchell Total Phosphorous Loads
(June-September)



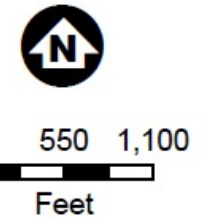
Red Rock Total Phosphorous Loads
(June-September)





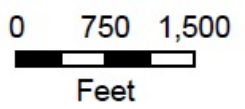
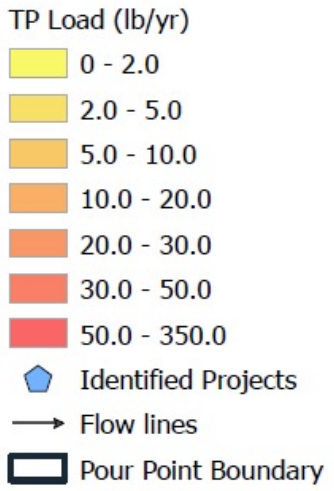
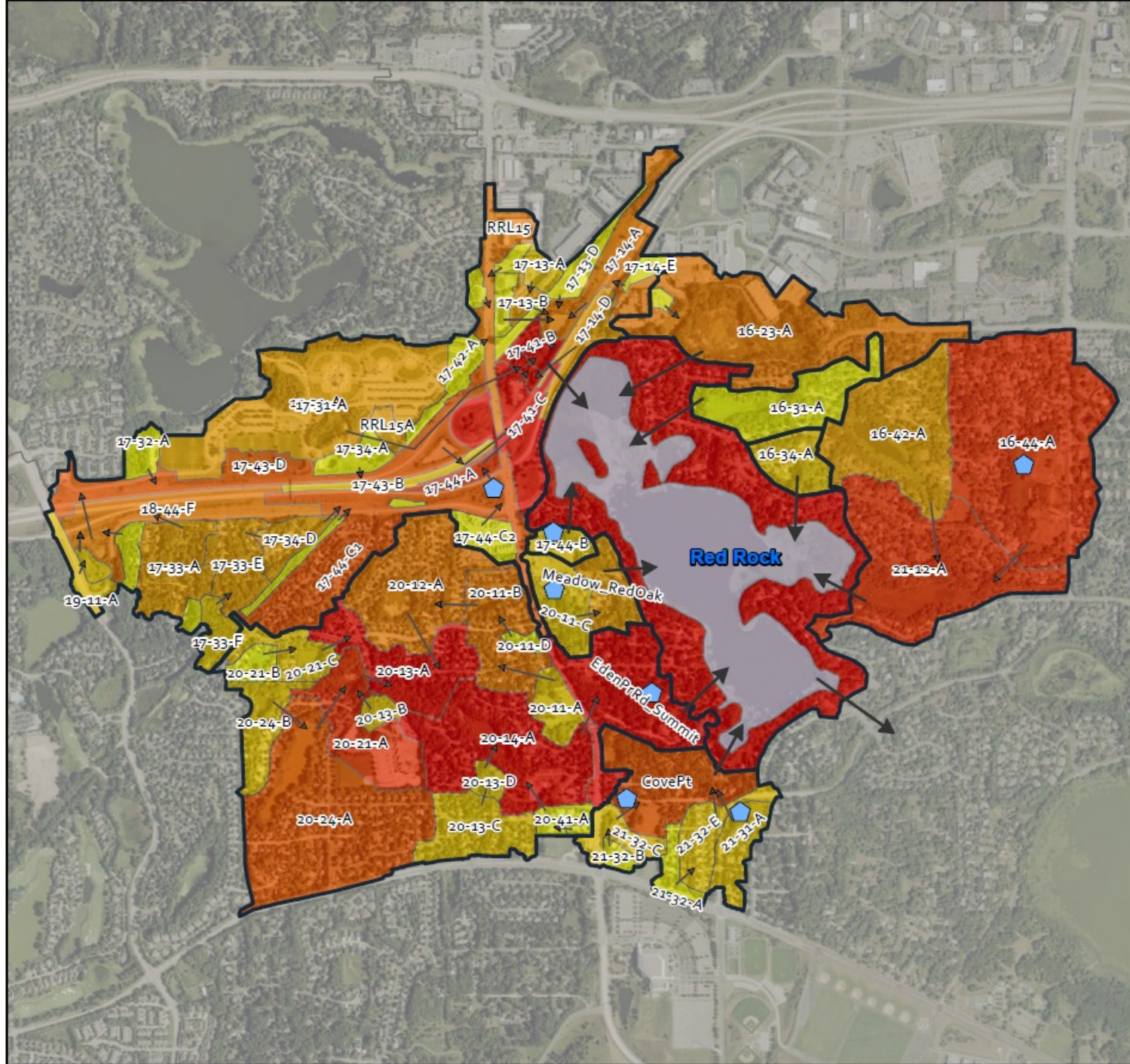
get rid of decimal, lessen the red category, label projects with our naming convention

Make arrows bolder



**Mitchell Lake
TP Loading
RPBCWD**
FIGURE X





**Red Rock Lake
TP Loading
RPBCWD**

FIGURE X



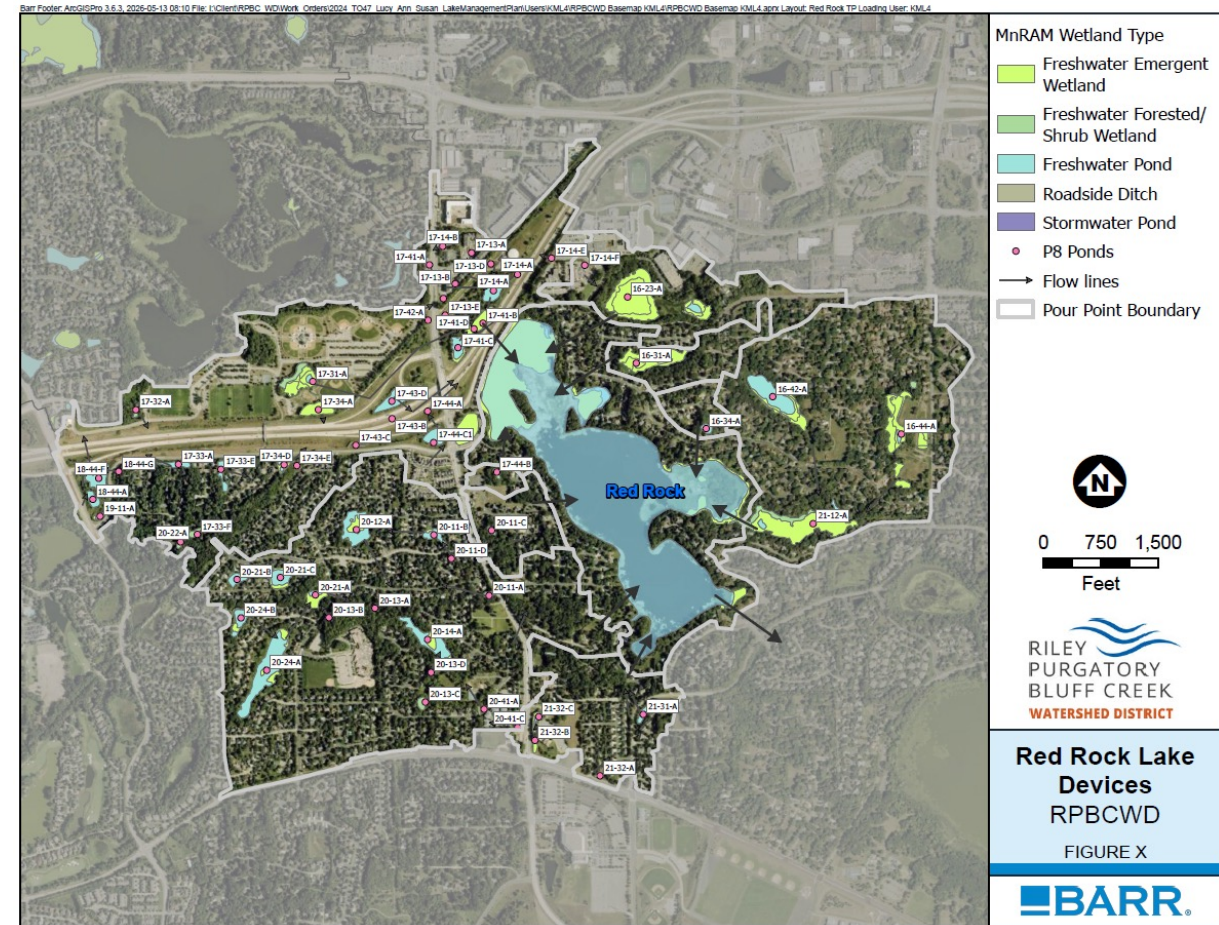
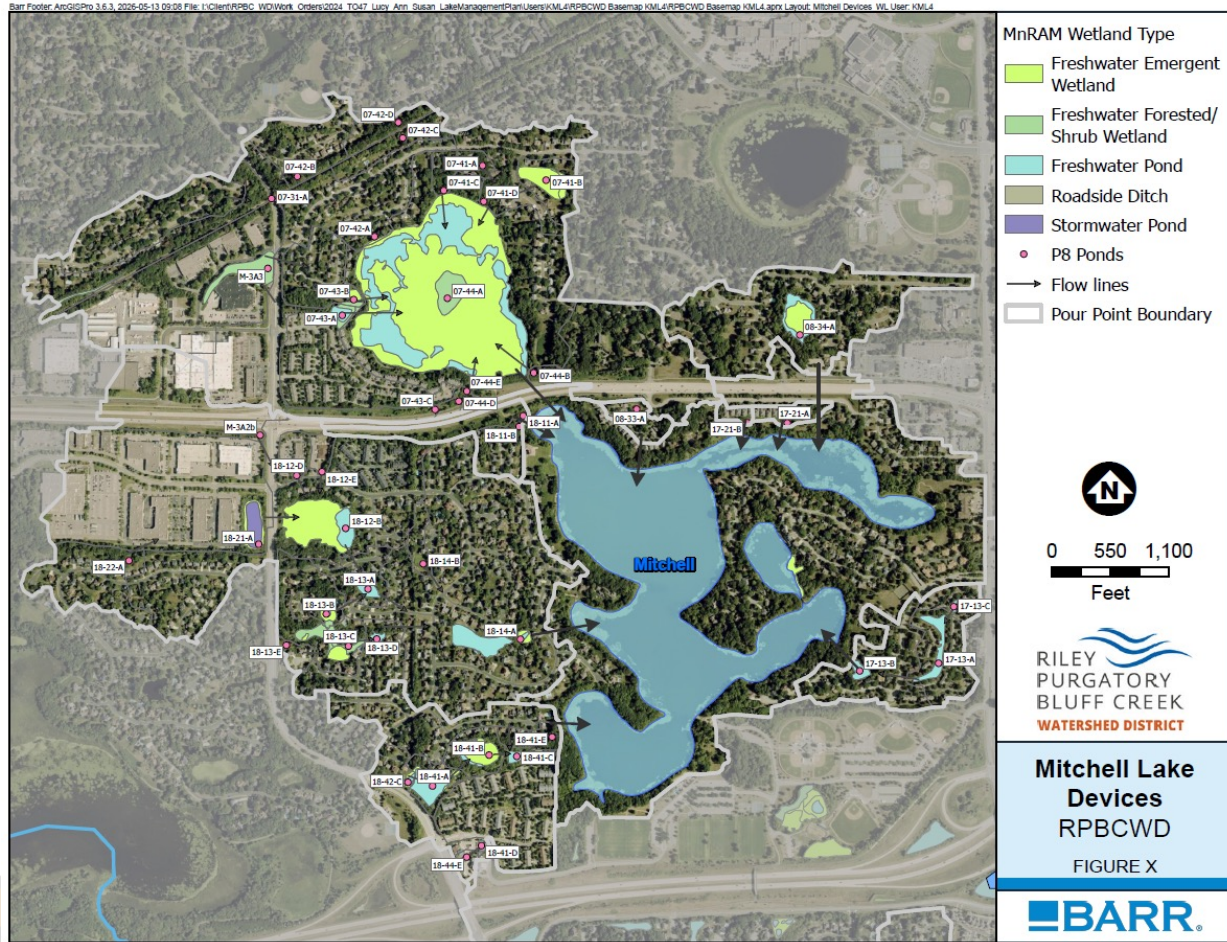
Lake	Pond ID	Wetland Classification	Pond Area (ac)	Average Depth (ft)	Potential P Load (lbs/yr)
Mitchell	18-14-A	Pond	2.0	5.16	6.0
Red Rock	16-42-A	Pond	10.3	10.99	31.6
Red Rock	16-23-A	Emergent Wetland	15.0	10.25	46.0
Red Rock	16-31-A	Emergent Wetland	4.9	5.08	15.0
Red Rock	20-14-A	Emergent Wetland	2.8	4.41	8.4
Red Rock	20-12-A	Emergent Wetland	2.6	3.83	8.1
Red Rock	18-44-F	Pond	1.4	3.67	4.3

Pond Types

- Emergent Wetlands
 - Varying degrees of open water
 - Wetland versus pond restoration
- Large wetted areas can release or transform P

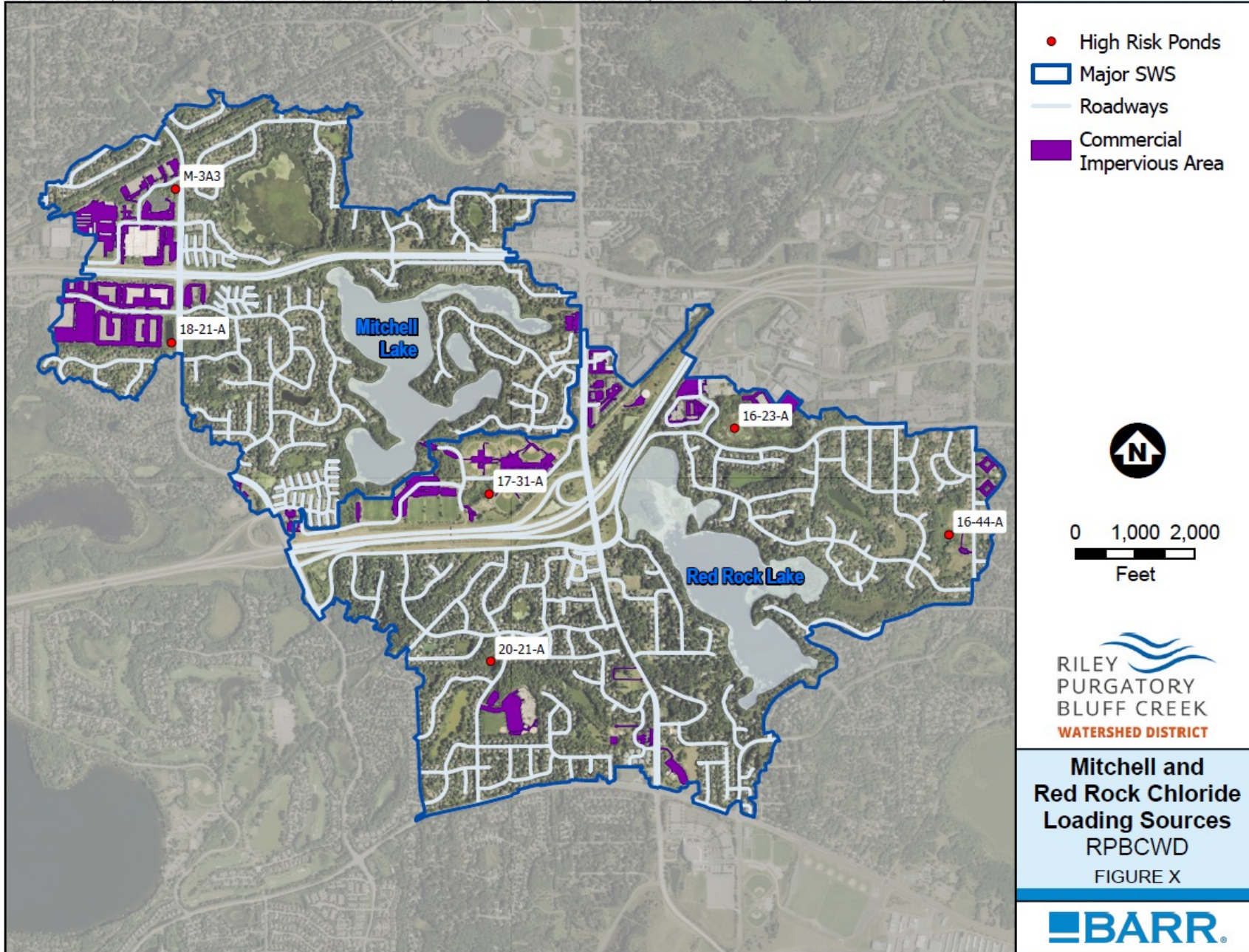


Wetland Restoration



Non-Structural – Street Sweeping

Barr Footer: ArcGISPro 3.6.3, 2026-04-27 13:48 File: I:\Client\RPBC W\Work Orders\2024 TO47 Lucy Ann Susan LakeManagementPlan\Users\KML4\RPBCWD Basemap KML4\RPBCWD Basemap KML4.aprx Layout: Mitchell & Red Rock CI Loading User: KML4



Lake Restoration Summary

- **Lake are co-limited by P and N**

- Phosphorus is still the best path for improving water quality and limiting cyanobacteria
- Requires improved N monitoring to better understand N loading

- **Watershed phosphorus reduction needs are moderate**

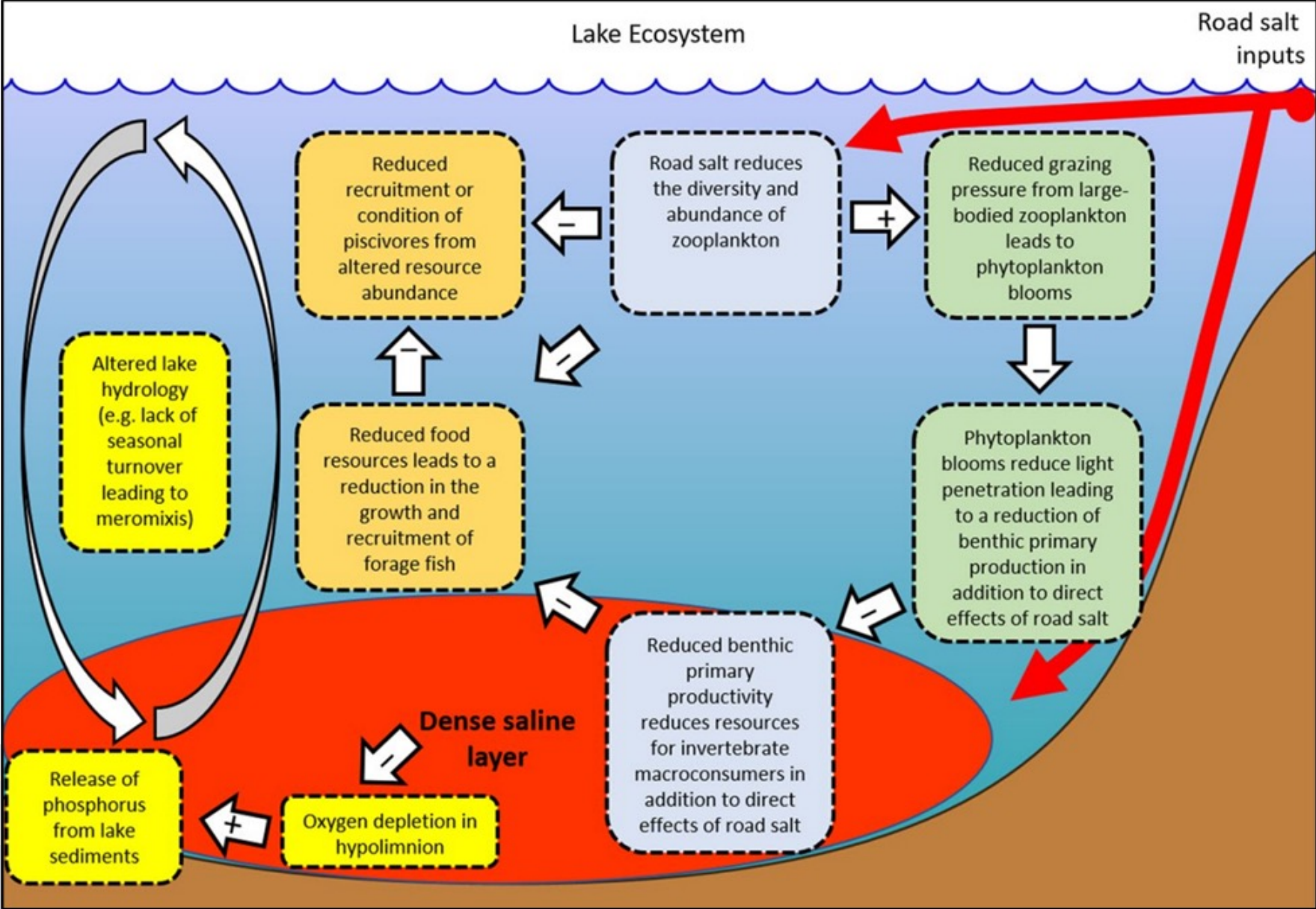
- A few structural projects
- Pond maintenance to minimize sediment P release
- Wetland restoration (addresses both N and P)
- Street sweeping

- **All 3 lakes demonstrated high internal P loading that is likely driving algal blooms**

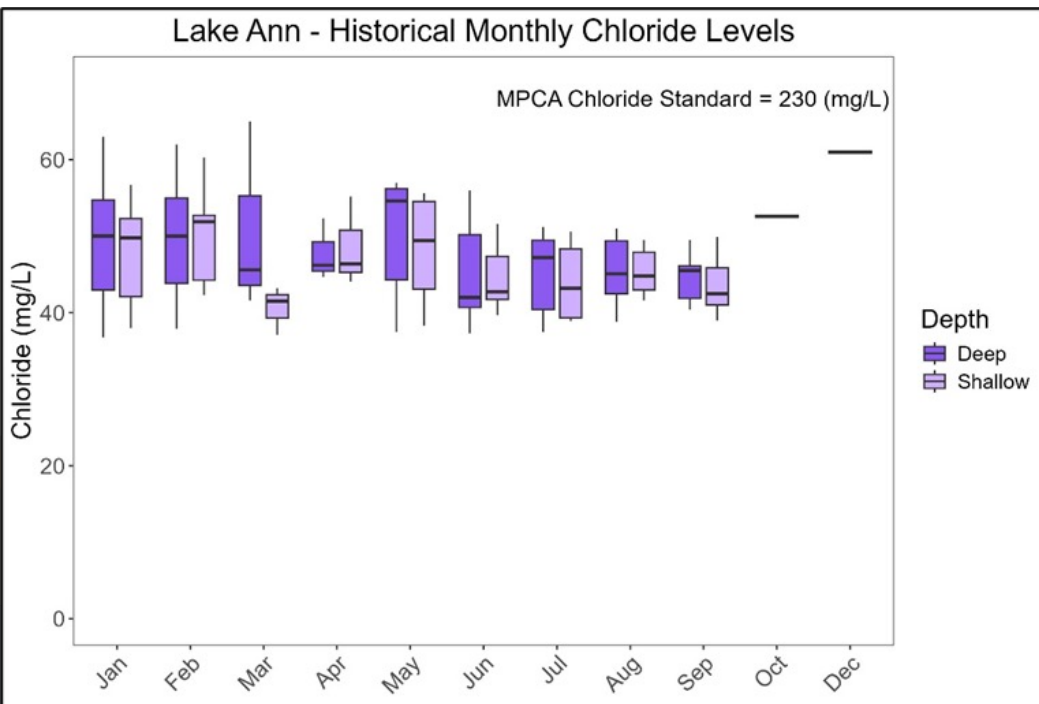
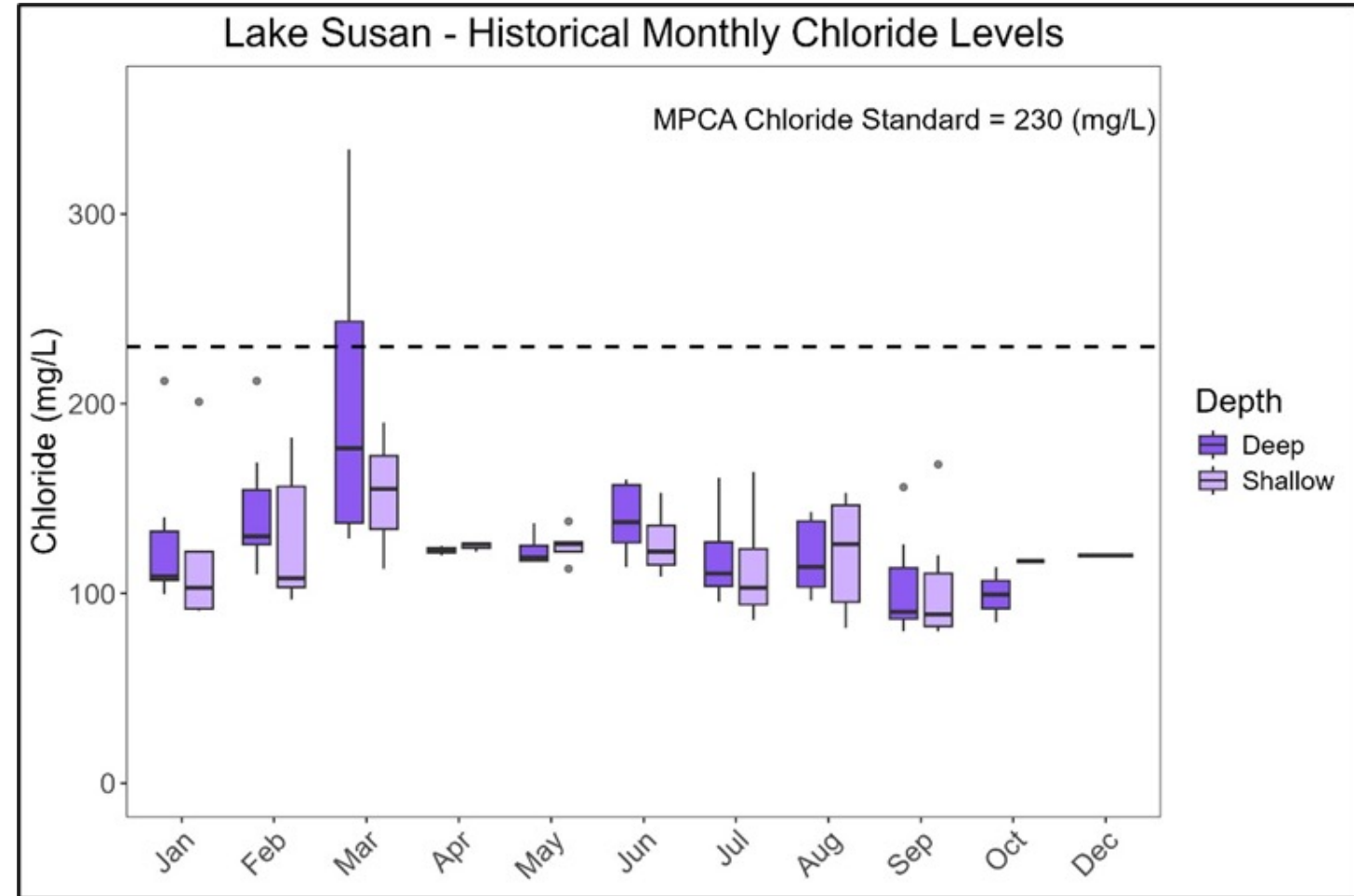
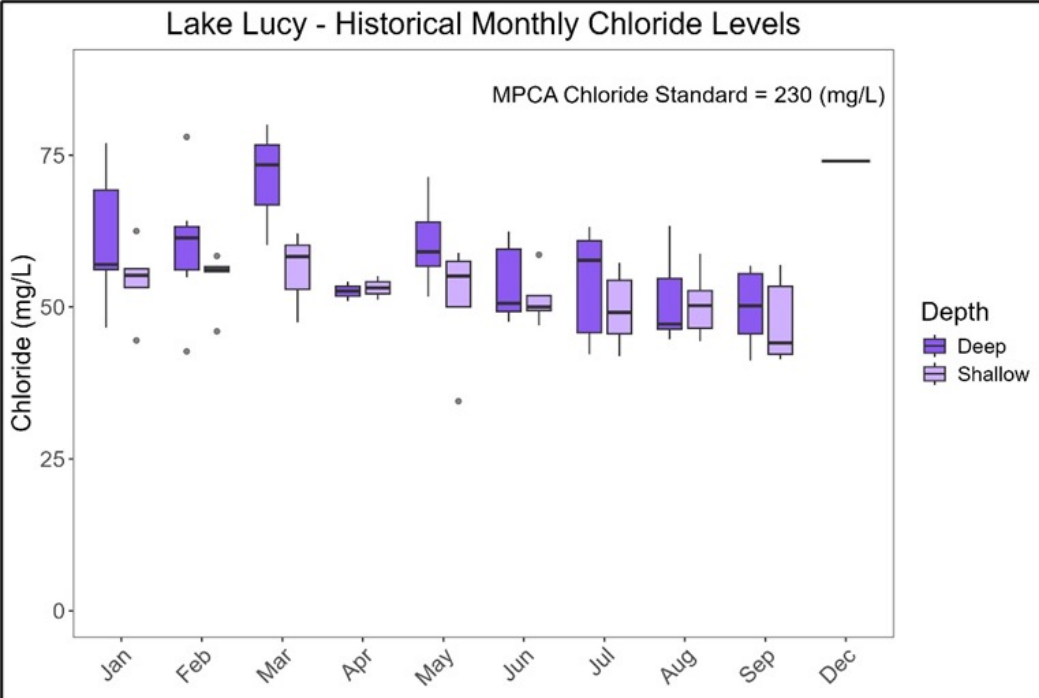
Current Conditions – Chloride



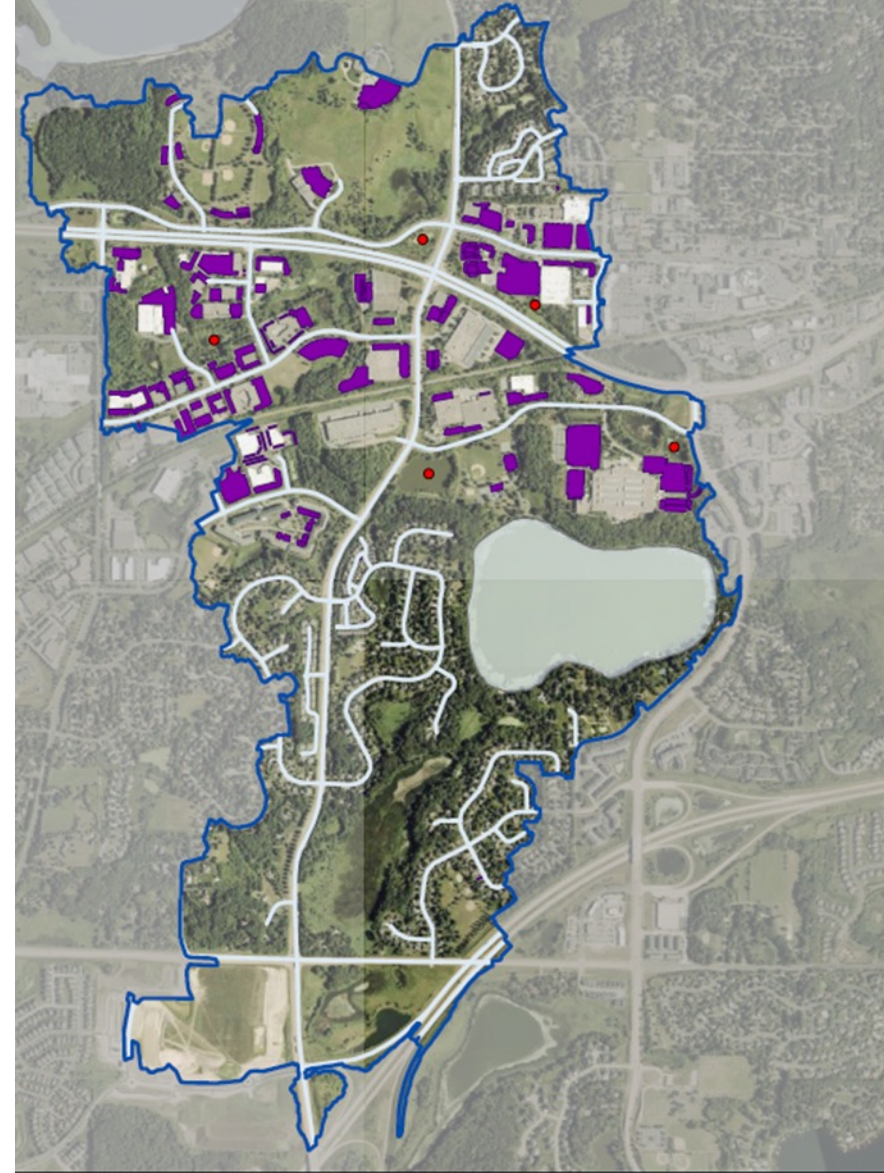
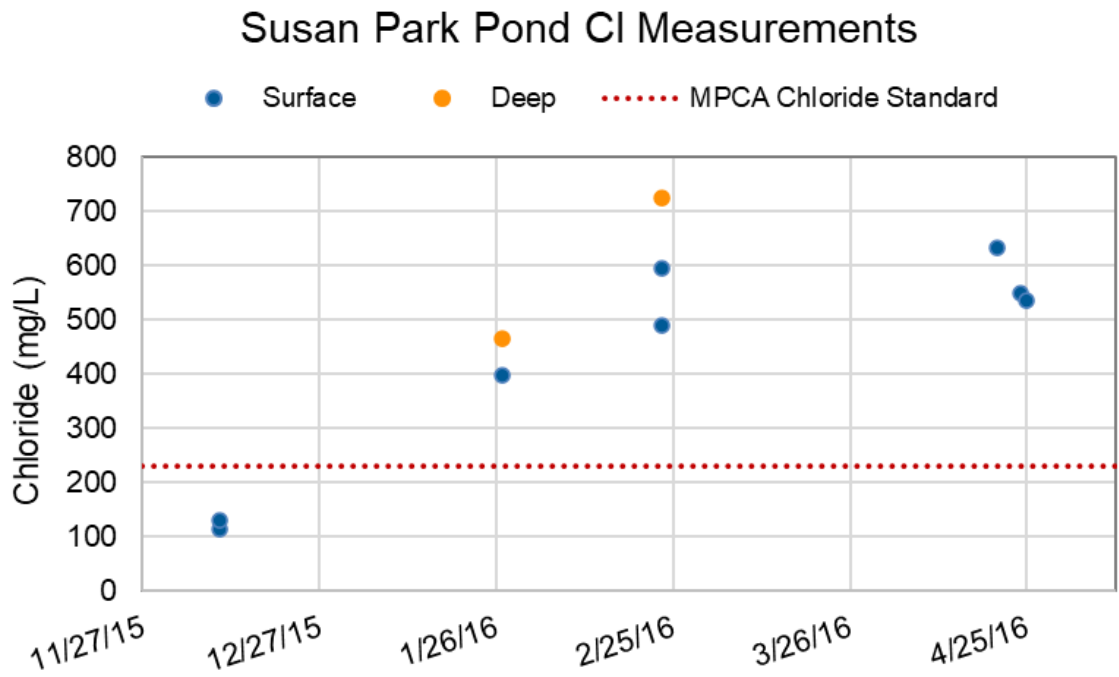
Chloride Impacts to Lakes (and ponds)




Chloride



Pond ID	SWS Annual Cl Loading (lbs/yr)	Pond Area (ac)	Avg Cl (mg/L)
3.63	160,733	3.16	--
3.21	82,714	1.3	--
3.31	86,333	0.47	--
3.37	104,376	7.18	463
3.36	63,990	1.57	--





Impervious Area



0 750 1,500


Feet



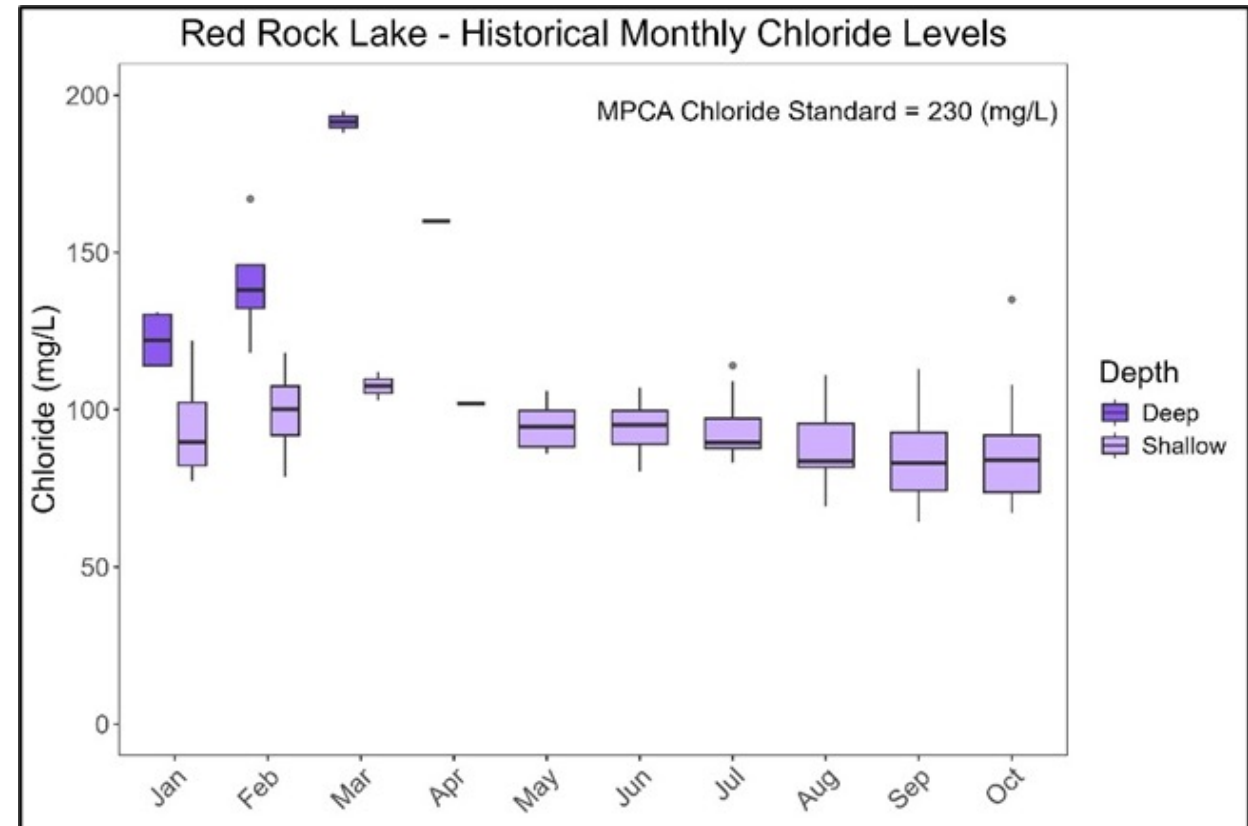
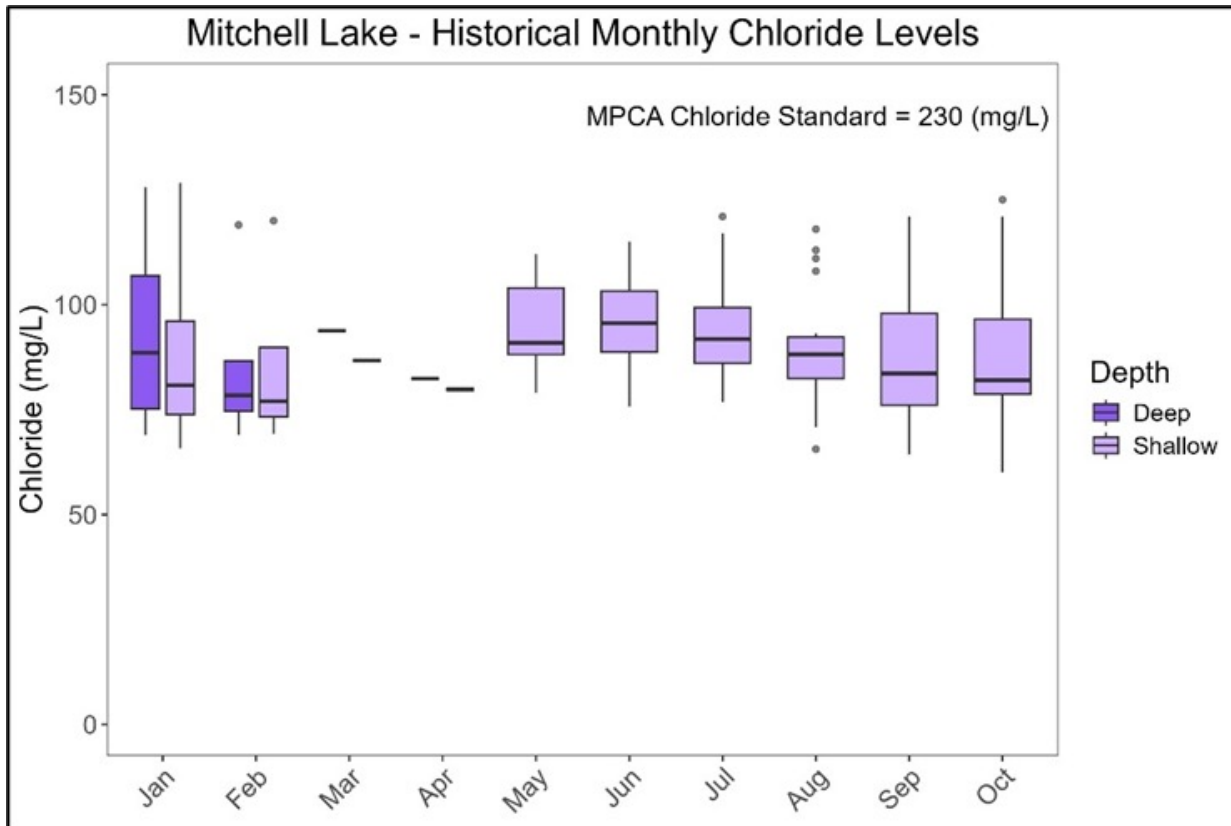


Susan Chloride Loading Sources
RPBCWD

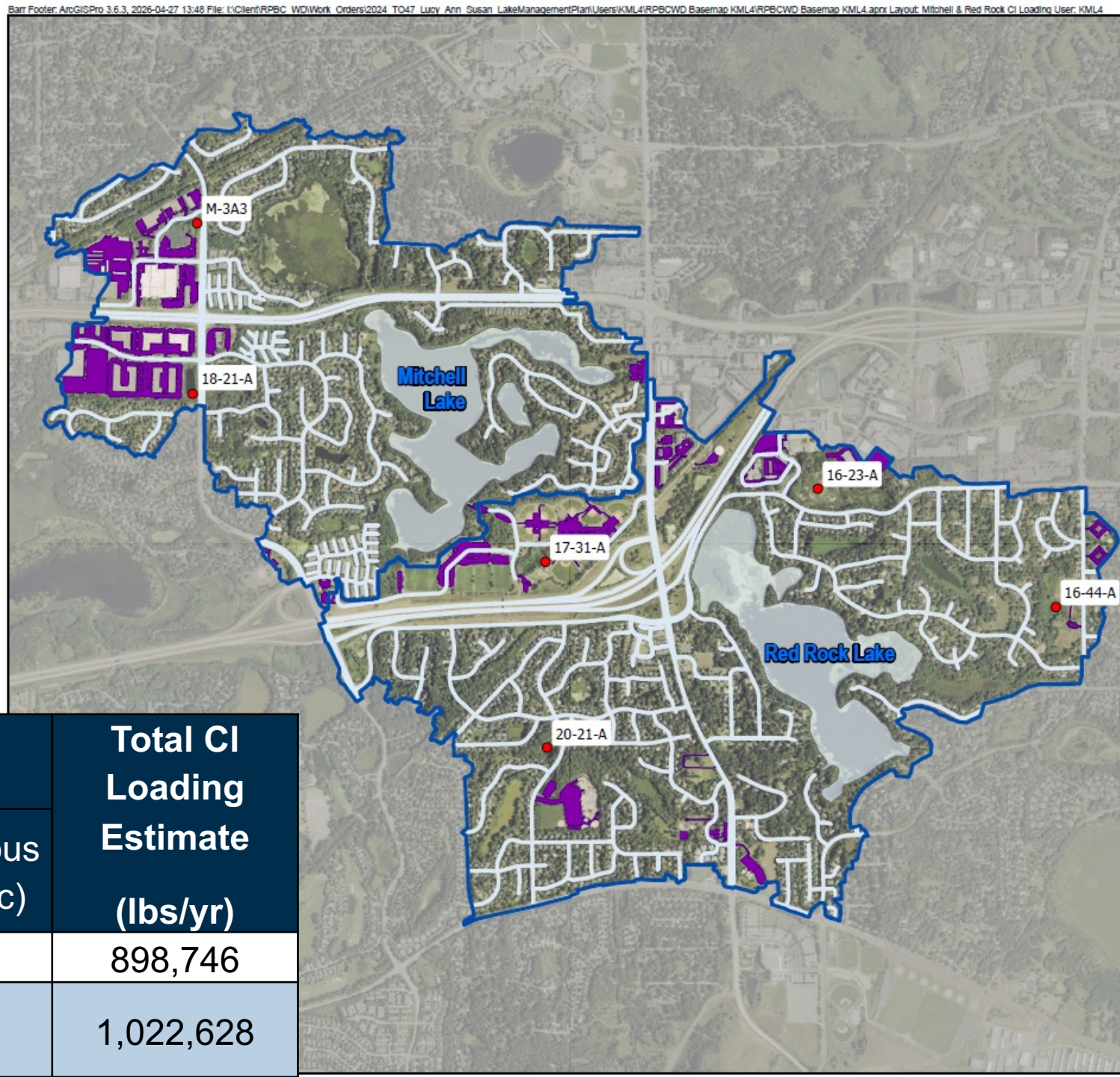
FIGURE #



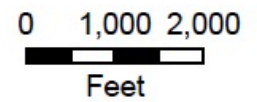
Mitchelle and Red Rock Chloride



Chloride



- High Risk Ponds
- Major SWS
- Roadways
- Commercial Impervious Area



Mitchell and Red Rock Chloride Loading Sources
RPBCWD
FIGURE X

Lake	Chloride Loading Sources		Total CI Loading Estimate (lbs/yr)
	Roadway (ac)	Impervious Area (ac)	
Mitchell	29.6	45.7	898,746
Red Rock	45.7	42.1	1,022,628



Chloride Impacted Ponds

Lake	Pond ID	SWS Annual Cl Loading (lbs/yr)	Pond Area (ac)	Avg Cl (mg/L)
Mitchell	M-3A3	162,968	1.35	--
Mitchell	18-21-A	308,858	2.36	--
Red Rock	17-31-A	195,445	3.52	--
Red Rock	16-23-A	102,677	19.86	--
Red Rock	16-44-A	58,210	22.61	--
Red Rock	20-21-A	74,408	1.52	--

Chloride Summary

- **Lake Lucy and Lake Ann do not demonstrate strong chloride impacts**
 - Elevated when compared to reference conditions but below standard
 - Low road and parking lot impervious density
- **Lake Susan exceeded the standard in spring**
 - High parking lot density in watershed
- **Mitchell and Red Rock show signs on chloride impacts**
 - Remained below the standard but elevated
 - Roads were largest impervious areas receiving salt
- **Ponds in the watershed are likely impacted by road/parking lot salt**
 - High risk ponds were identified using loading

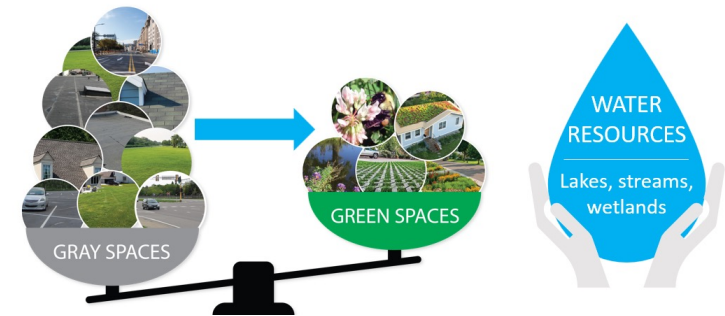
Next Steps

- Upcoming public meetings
 - May 21 – Chan City Hall
 - May 28 – EP Community Center
- Draft plans (late June) with focus group meetings to follow
- Final plans (end of Year)

rpbcwd.org/EHAP

Ecosystem Health Action Plan

Goal: **Expand the green** and **cover/shrink the gray** to **protect the blue**.



Contact

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Dylan Monahan

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rpbcwd.org/systems-approach

- Submit a comment
- Learn more about the project