Southeastern Wisconsin
Regional Planning Commission

Chloride Impact Study for the Southeastern Wisconsin Region

TAC Meeting

November 12, 2025

Speakers

- Laura Herrick, Chief Environmental Engineer
- Tom Slawski, Chief Biologist

Agenda

- Review of Summary Notes from last TAC meeting
- Review of preliminary draft chapters of SEWRPC Technical Report No. 63, Chloride Conditions and Trends in SE WI
    - Chapter 5 – Chloride Conditions and Trends: Lakes
- Next Steps

Chloride Impact Study Reports

- TR-61 Field Monitoring and Data Collection for the Chloride Impact Study
- TR-62 Impacts of Chloride on the Natural and Built Environment
- **TR-63 Chloride Conditions and Trends in Southeastern Wisconsin**
- TR-64 Regression Analysis of Specific Conductance and Chloride Concentrations
- TR-65 Mass Balance Analysis for Chloride in Southeastern Wisconsin
- TR-66 State of the Art for Chloride Management
- TR-67 Legal and Policy Considerations for the Management of Chloride
- PR-57 A Chloride Impact Study for Southeastern Wisconsin

Review of Summary Notes from Technical Advisory Committee Meeting, October 8th, 2025

Technical Report No. 63 Chloride Conditions and Trends in SE WI

TR-63 Chapters

- Chapter 1 – Introduction
- Chapter 2 – Study Area Background
- Chapter 3 – Analysis of Chloride Impact Study Monitoring Data: 2018-2021
- Chapter 4 – Conditions and Trends: Rivers
- **Chapter 5 – Conditions and Trends: Lakes**
- Chapter 6 – Conditions and Trends: Groundwater
- **Chapter 7 – Drivers and Interactions**

TR-63 Chapters

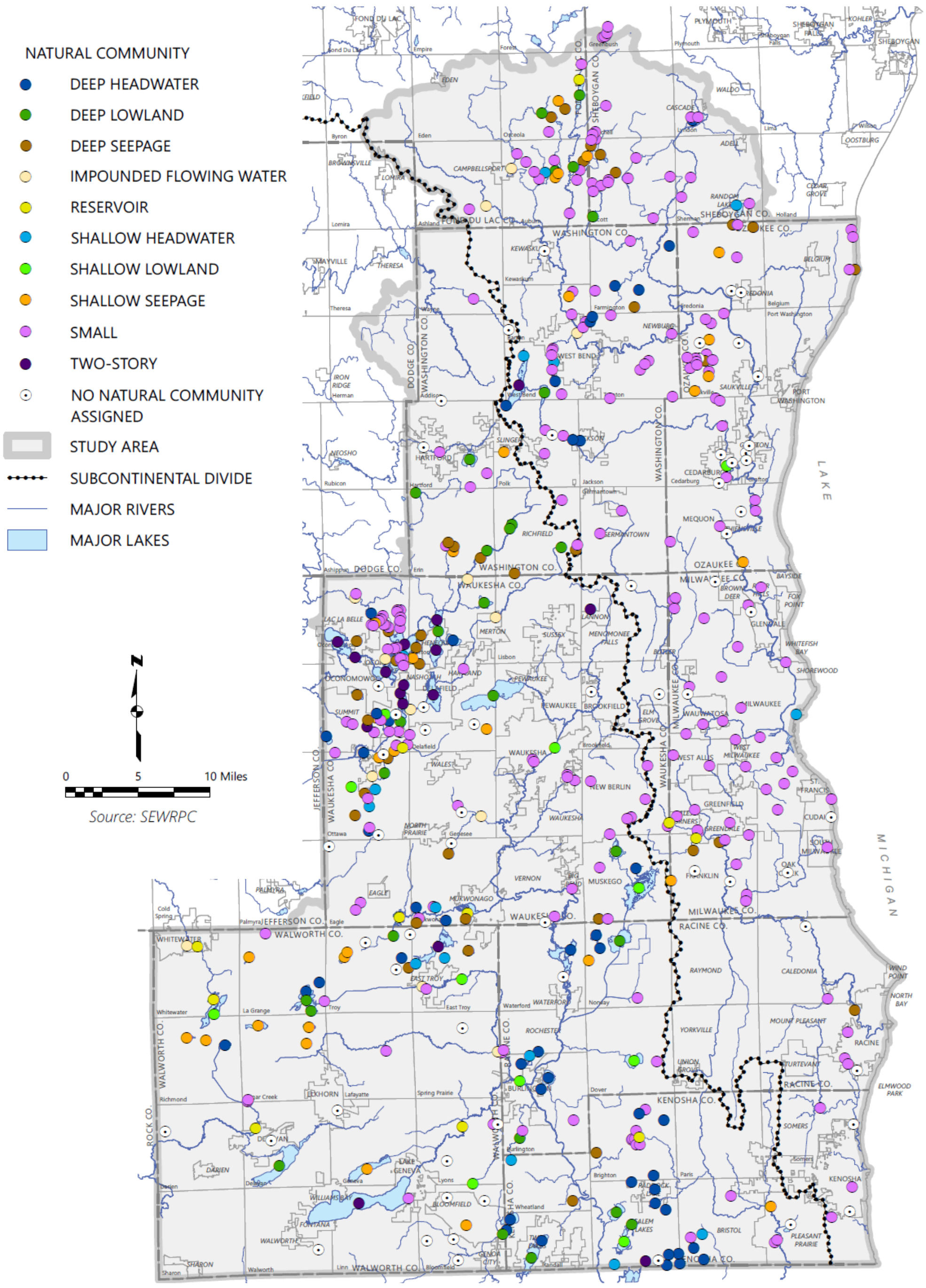
- 5.1 – Introduction
- 5.2 - Study Area Lake Background Information
- 5.3 – Data Collection and Organization
- 5.4 – An Overview of Chloride Conditions and Trends in Lakes Within the Study Area
  - Full Period of Record Conditions (1960 through 2022)
    - Long-term Trends and Land Use Influence
    - Forecasts/Potential Future Chloride Concentrations
    - Seasonal Trends
  - Recent Conditions (2013 through 2022)
    - Relationship of Chloride to Lake and Watershed Characteristics
    - Relationship of Specific Conductance to Chloride
- 5.5 – Chloride Conditions for Lake Michigan
- 5.6 – Summary of Chloride Conditions and Trends in Study Area Lakes

5.4 - Background Information

Description of Lakes in the study area (see Appendix H)

- Region: 492 total lakes
  - Surface Area: 2 to 5,404 acres
  - Max Depth: 1 to 135 ft
  - Watershed Size : 0.04 to 282.3 (sq.miles)
  - Residence Time
  - Lake Types
  - Natural Communities

Map 5.1
WDNR-Designated Natural Communities for Lakes in the Chloride Study Area



5.4 - Background Information

Lakes Data Time Series
Appendix I-Chloride
Appendix J-Specific Conductance

Map 5.2
Total Number of Chloride Samples Among Lakes: 1960 - 2022

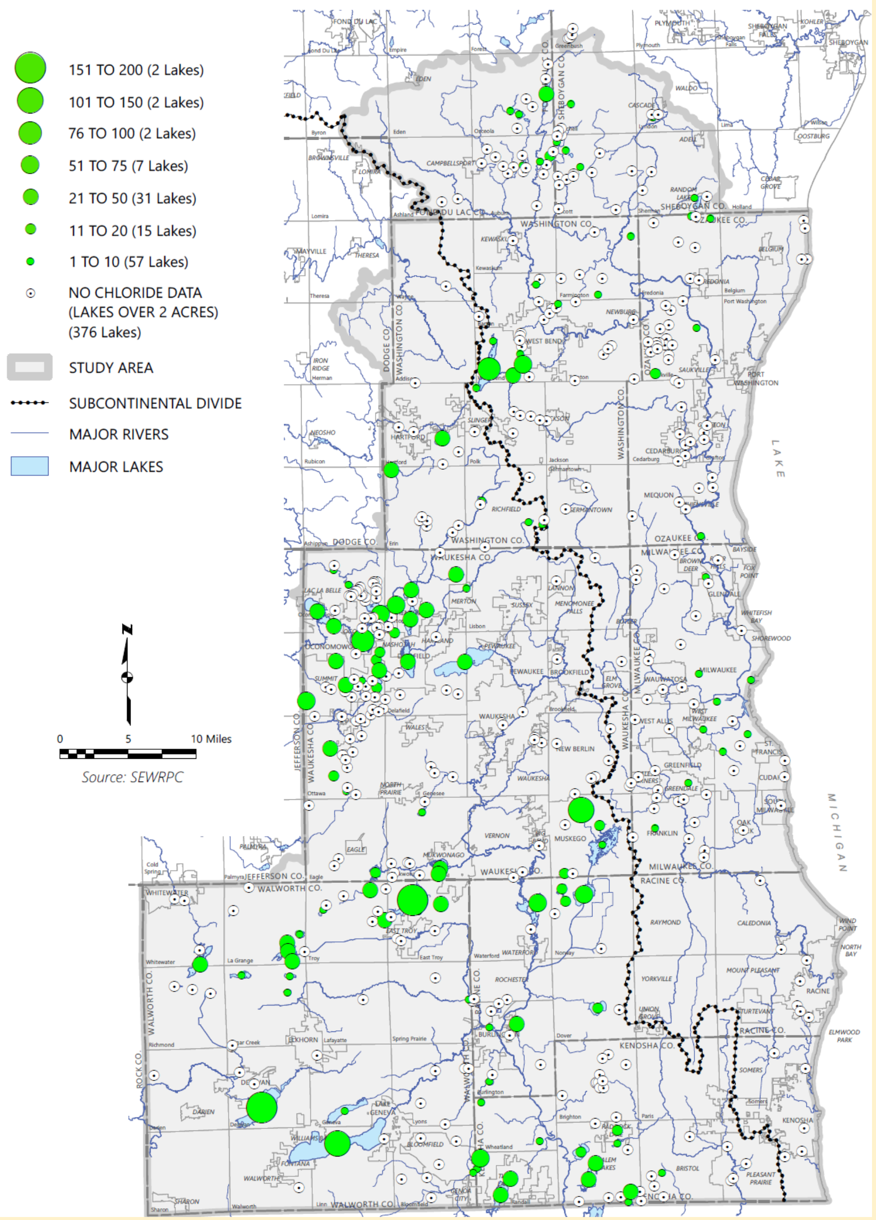


Figure 5. Oconomowoc Lake (Waukesha County), Annual Chloride_TS
Scatterplots of Chloride Concentrations Over Time for Oconomowoc Lake: 1973 to 2022

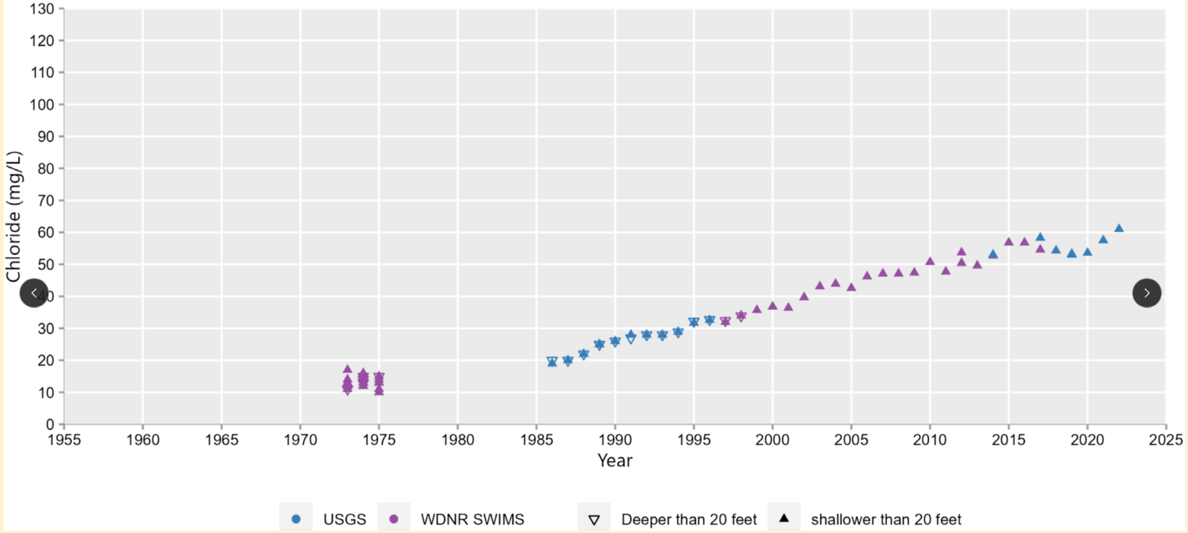
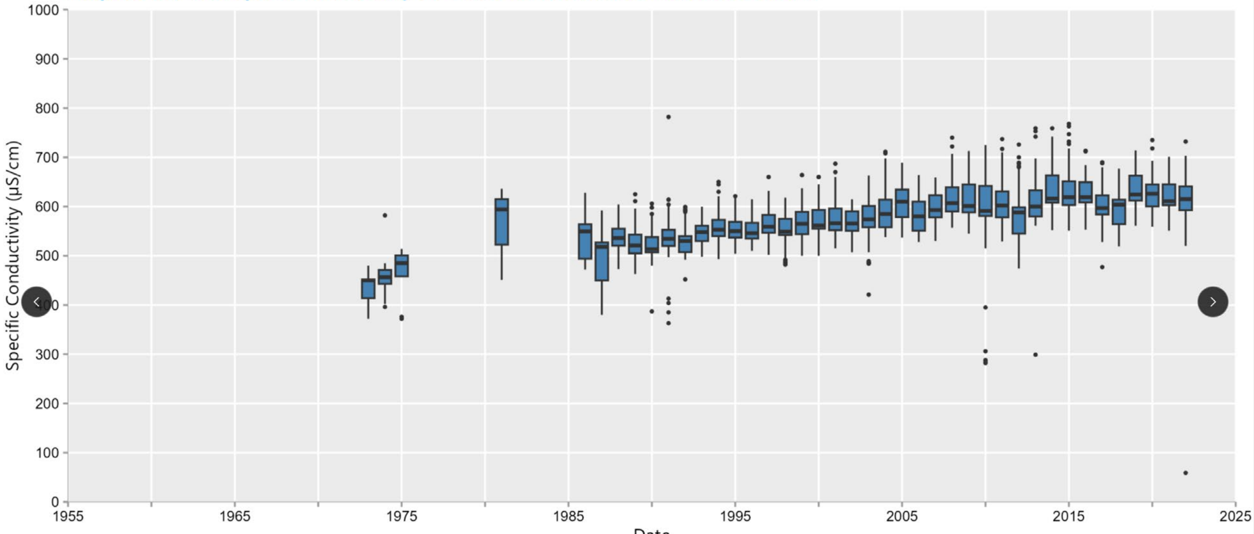
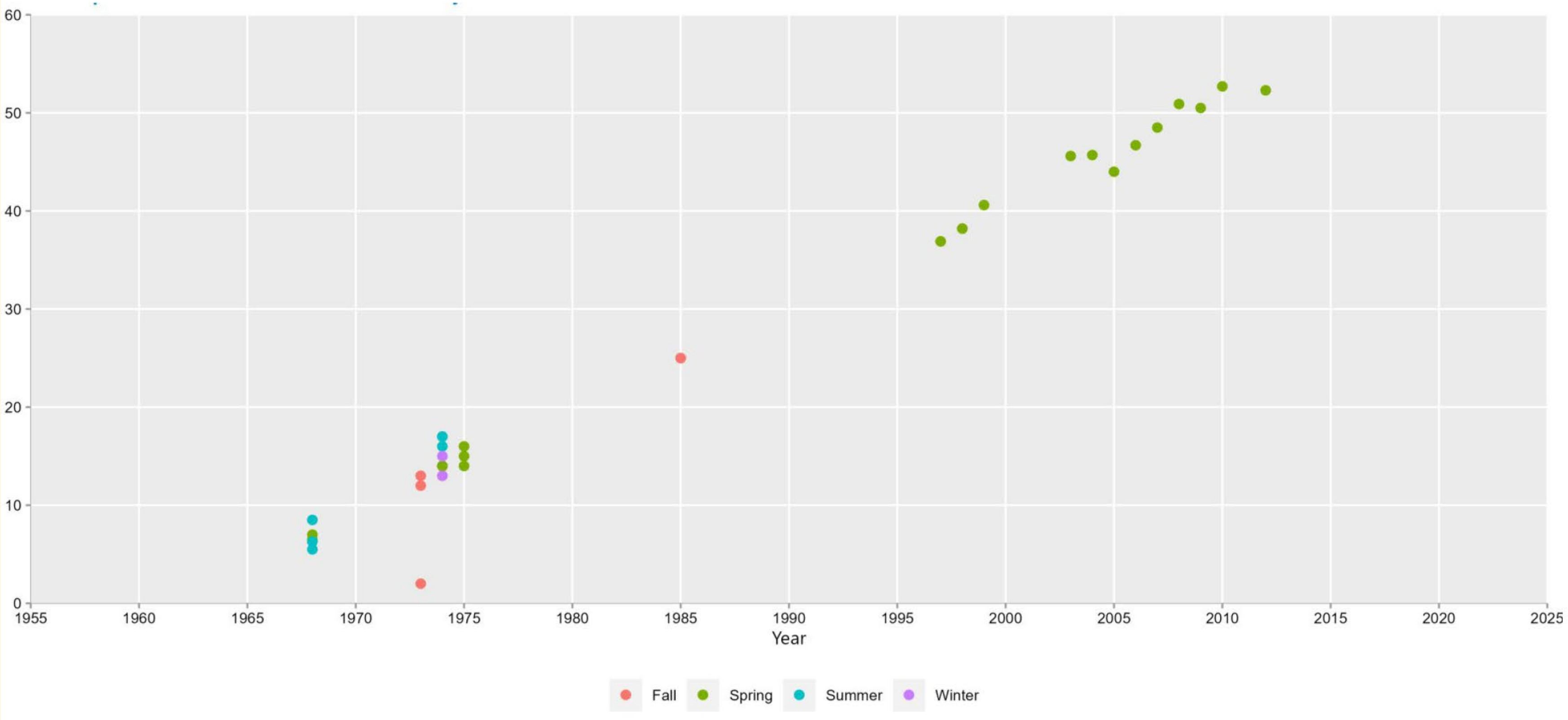


Figure 5. Oconomowoc Lake (Waukesha County), Annual SpCond_TS
Boxplots of Annual Specific Conductivity Over Time for Oconomowoc Lake: 1973 to 2022



5.4 – Background-Data Aggregation and Formatting

Figure 5.1
Little Cedar Lake Chloride Data by Season: 1960 through 2022



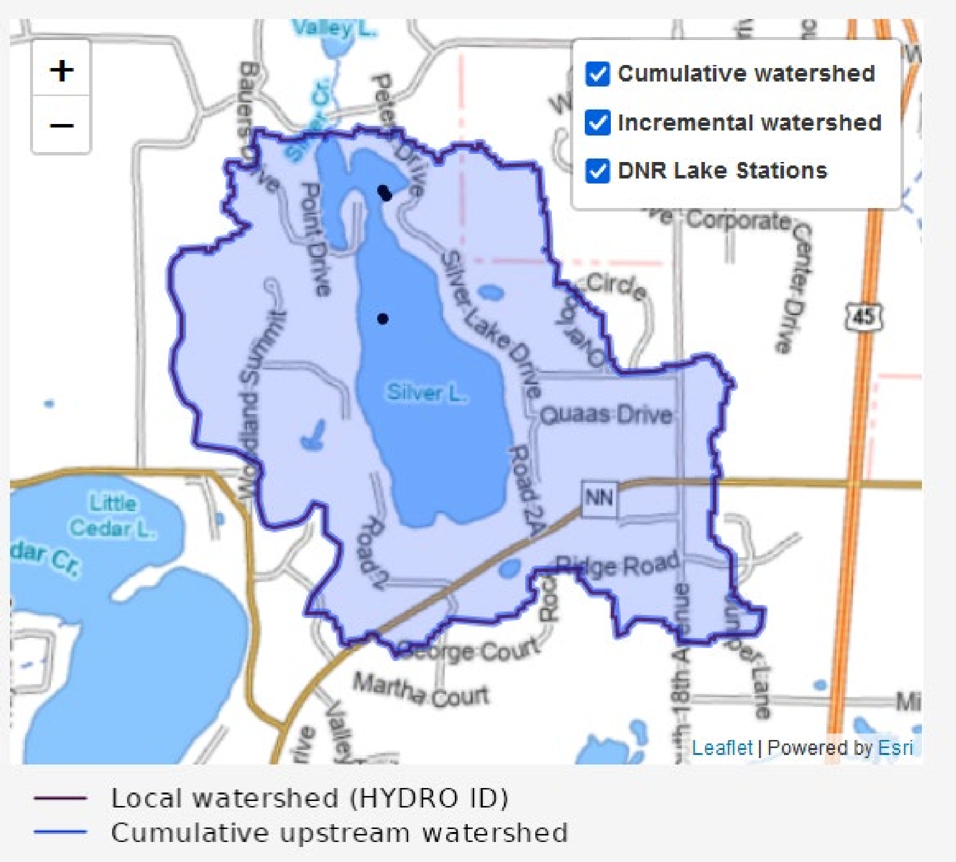
Define seasons and assign to samples

- Spring: Mar-May
- Summer: Jun-Aug
- Fall: Sep-Nov
- Winter: Dec-Feb

5.4 – Background-Data Aggregation and Formatting

Assign lake, watershed, and other attributes for analysis

- Lake characteristics (hydrology, size, residence time)
- Watershed characteristics (size, land use)
- Shoreline land use (within 1,000 feet from lakeshore)

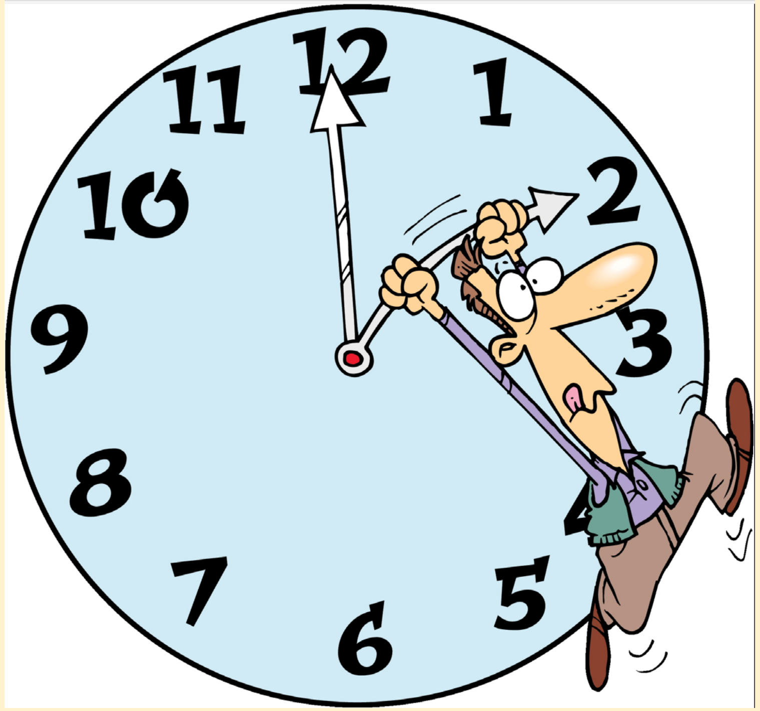


- Used WDNR Water Explorer (WEx) tool to delineate watersheds

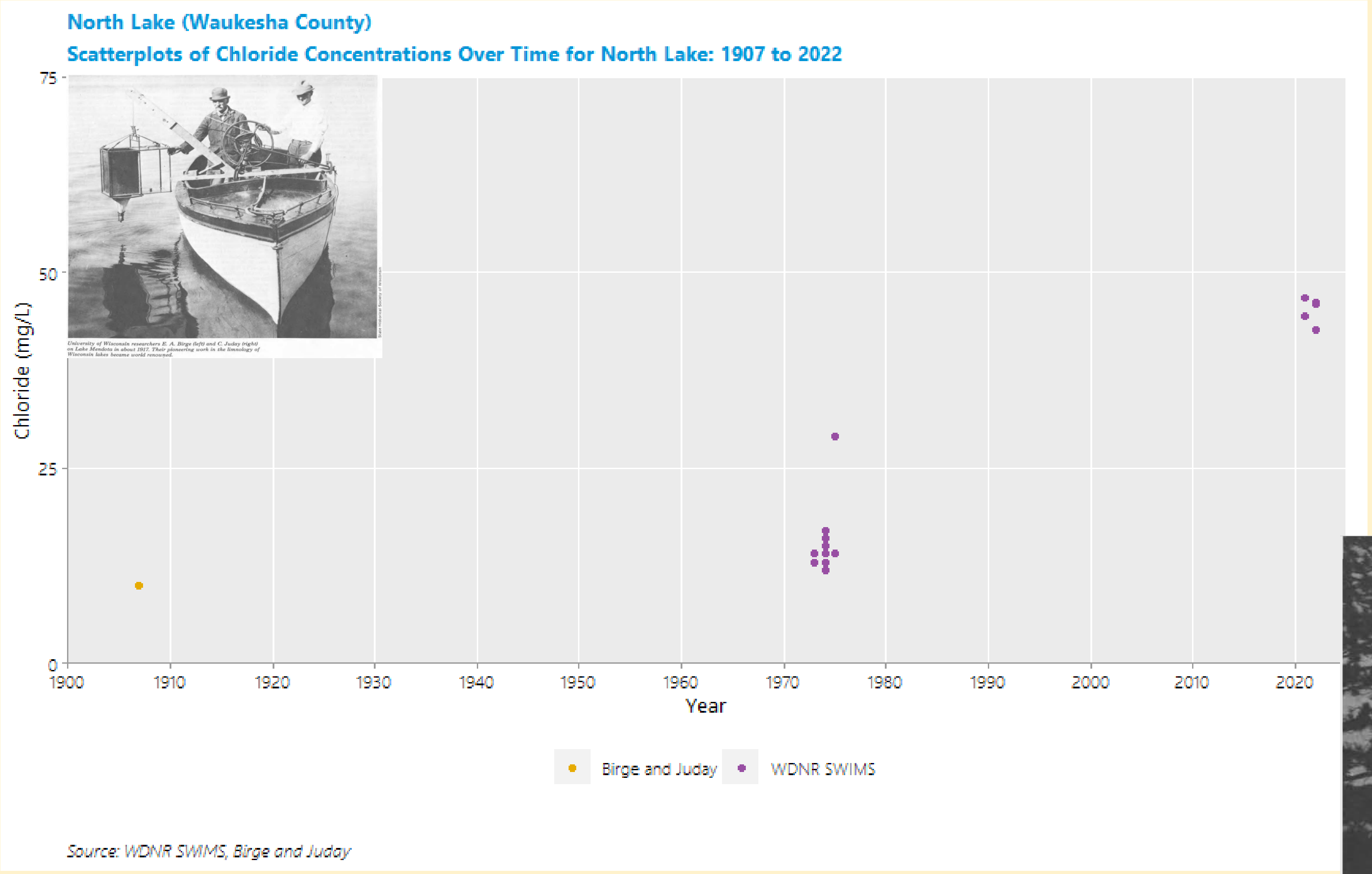
5.4 – Background-Data Aggregation and Formatting

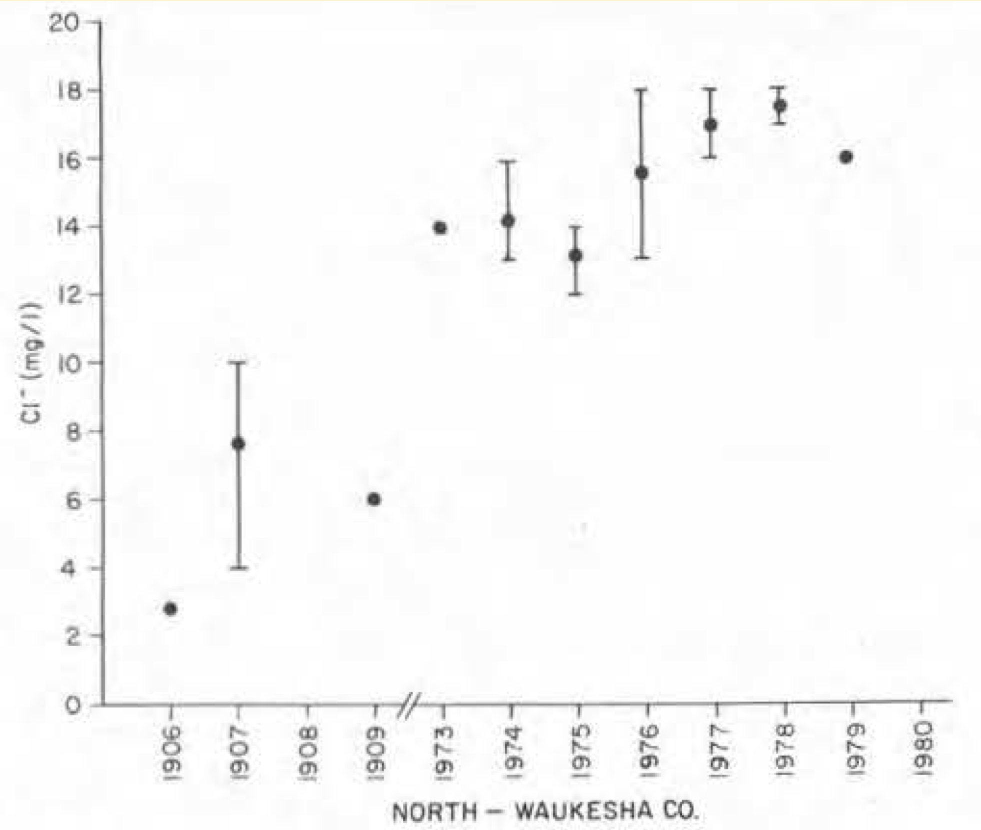
Assign time periods for analysis of chloride and specific conductance in lakes:

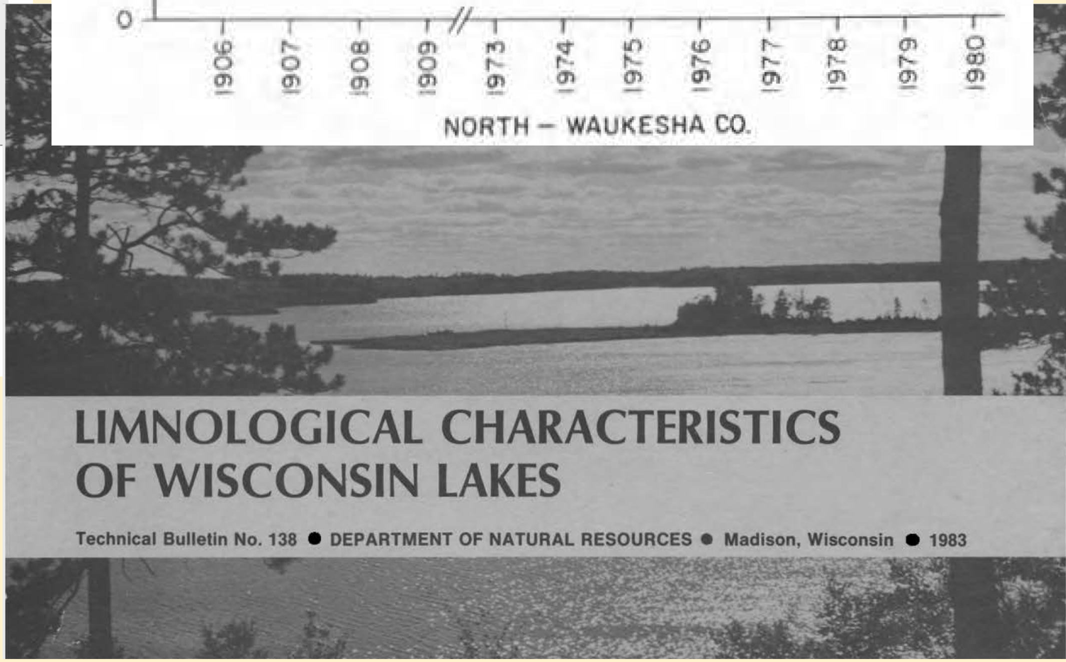
- Full Period of Record (1960-2022)
- Long-term trends (1960-2022)
  - Dataset: at least 9 years and 2 samples
- Recent Conditions (2013-2022)



5.4 - Background Information

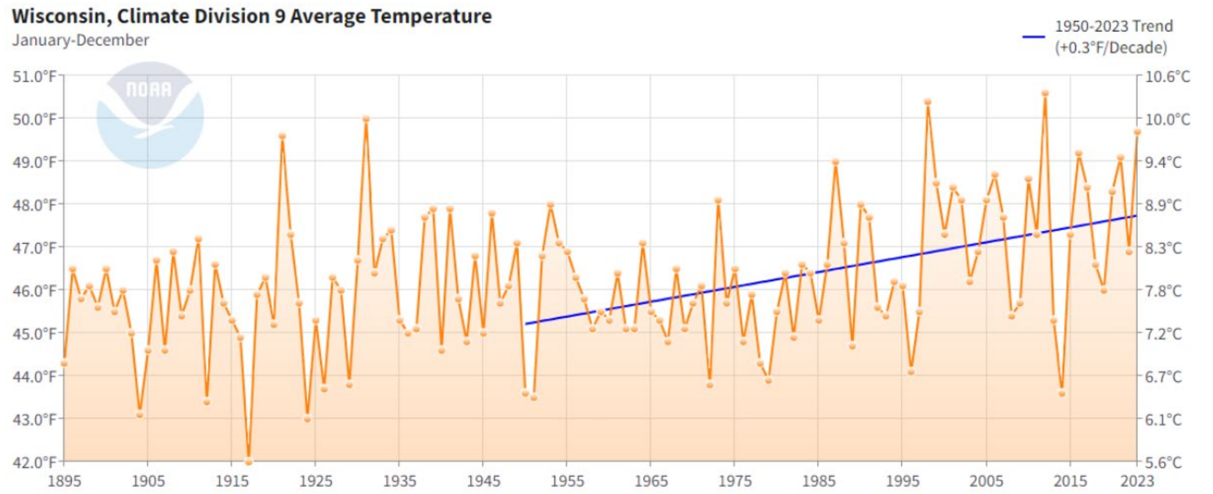






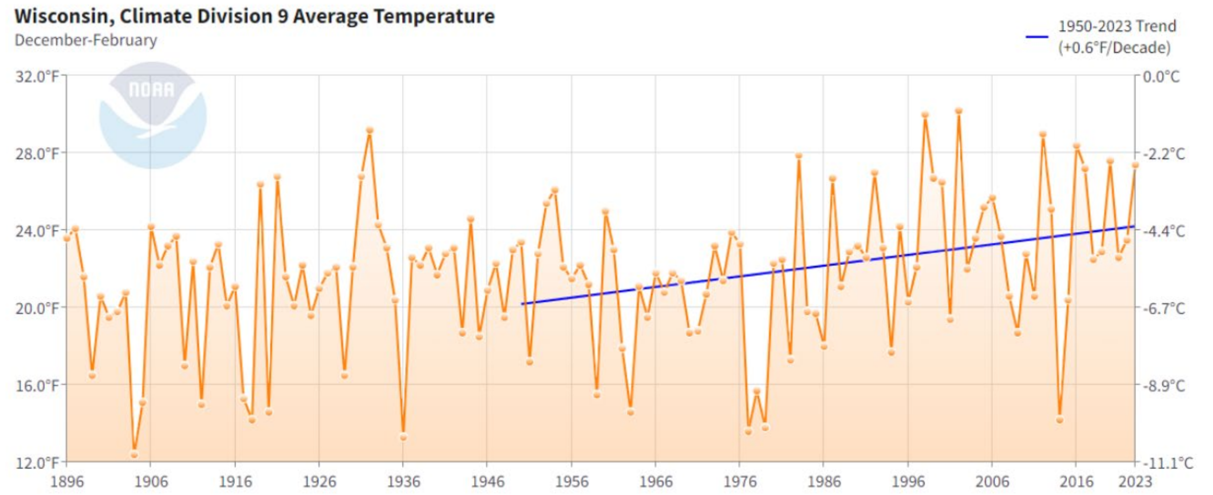
5.4 Full Period of Record Conditions (1960-2022)

Figure 2.TempLongTerm
Annual Average Temperature for Southeastern Wisconsin: 1895-2023



Source: NOAA National Centers for Environmental Information

Figure 2. WinterTempLongTerm
Average Winter Temperature for Southeastern Wisconsin: 1895-2023



Source: NOAA National Centers for Environmental Information

5.4 Full Period of Record Conditions (1960-2022)

Accumulated Winter Season Severity Index (AWSSI) in Milwaukee

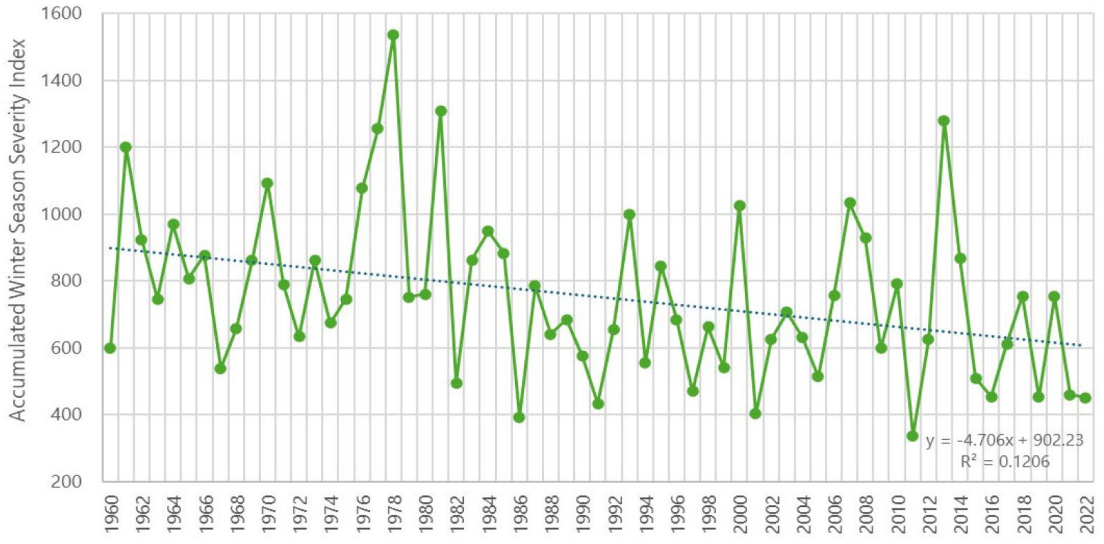
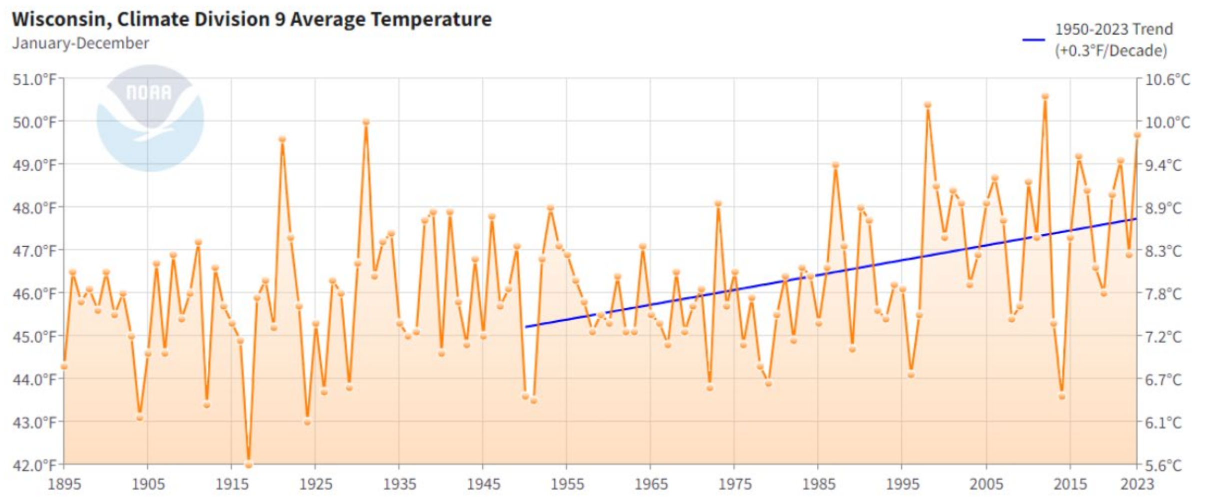
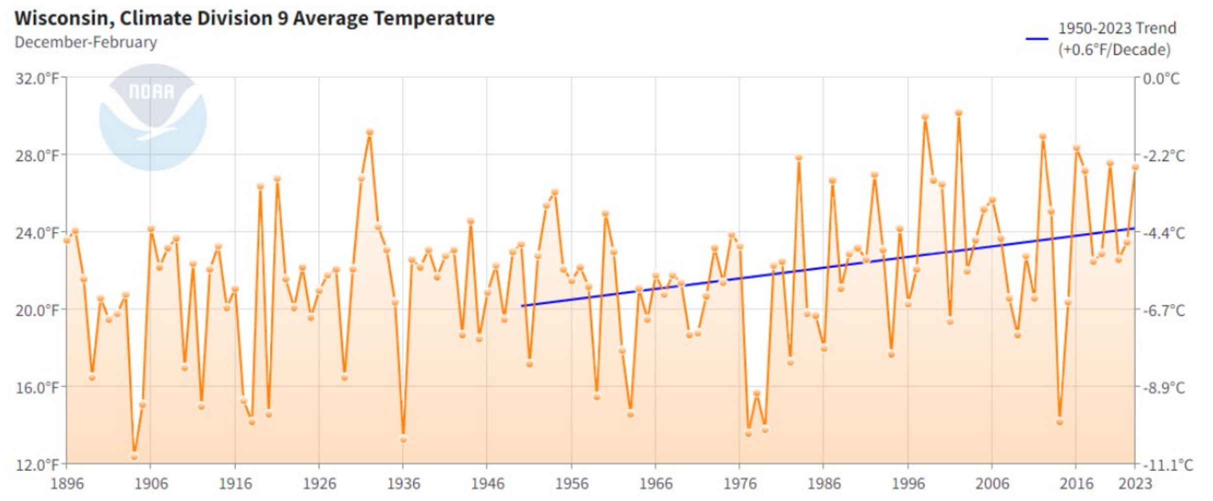


Figure 2.TempLongTerm
Annual Average Temperature for Southeastern Wisconsin: 1895-2023



Source: NOAA National Centers for Environmental Information

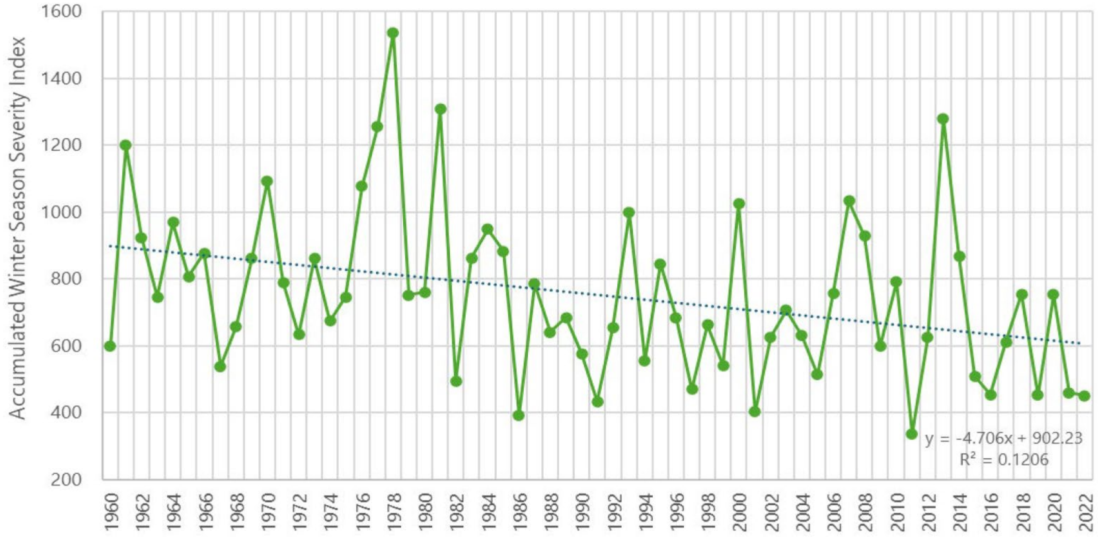
Figure 2. WinterTempLongTerm
Average Winter Temperature for Southeastern Wisconsin: 1895-2023



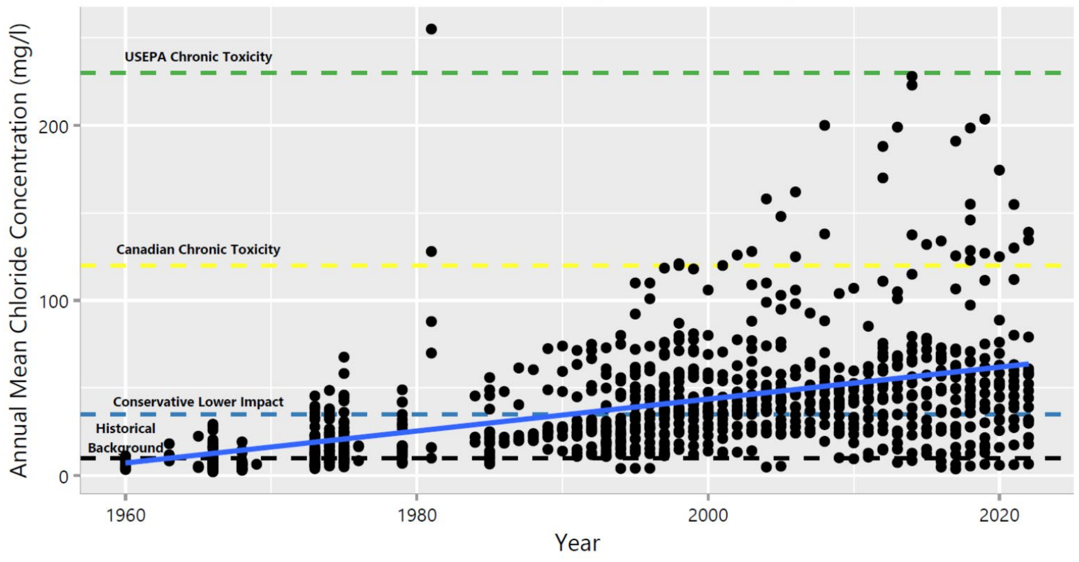
Source: NOAA National Centers for Environmental Information

5.4 Full Period of Record Conditions (1960-2022)

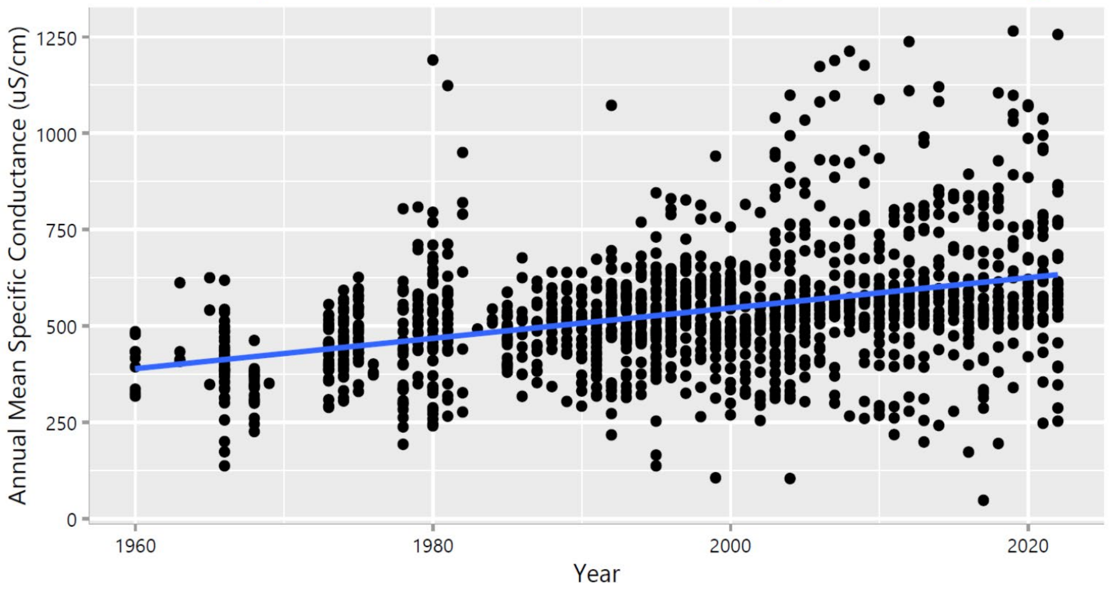
Accumulated Winter Season Severity Index (AWSSI) in Milwaukee



Annual Mean Chloride Across All Lakes in Study Area: 1960 - 2022



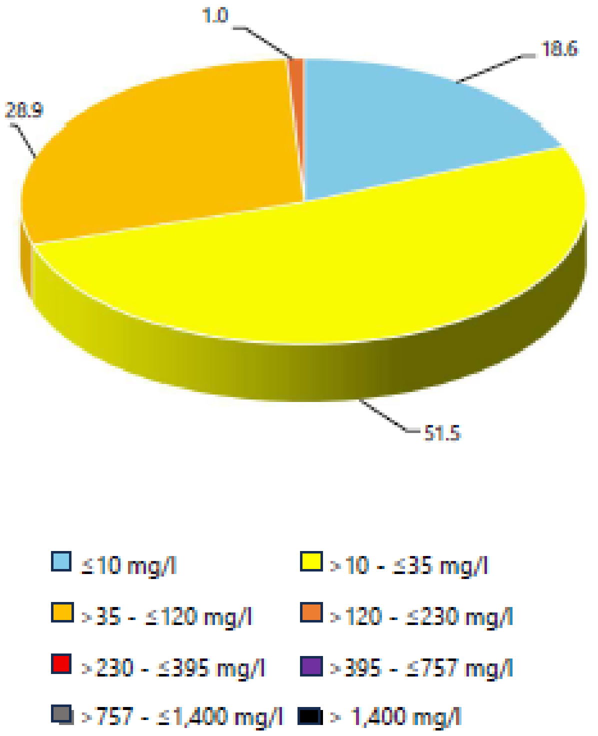
Annual Mean Specific Conductance Across All Lakes in Study Area: 1960 - 2022



5.4 Full Period of Record Conditions (1960-2022)

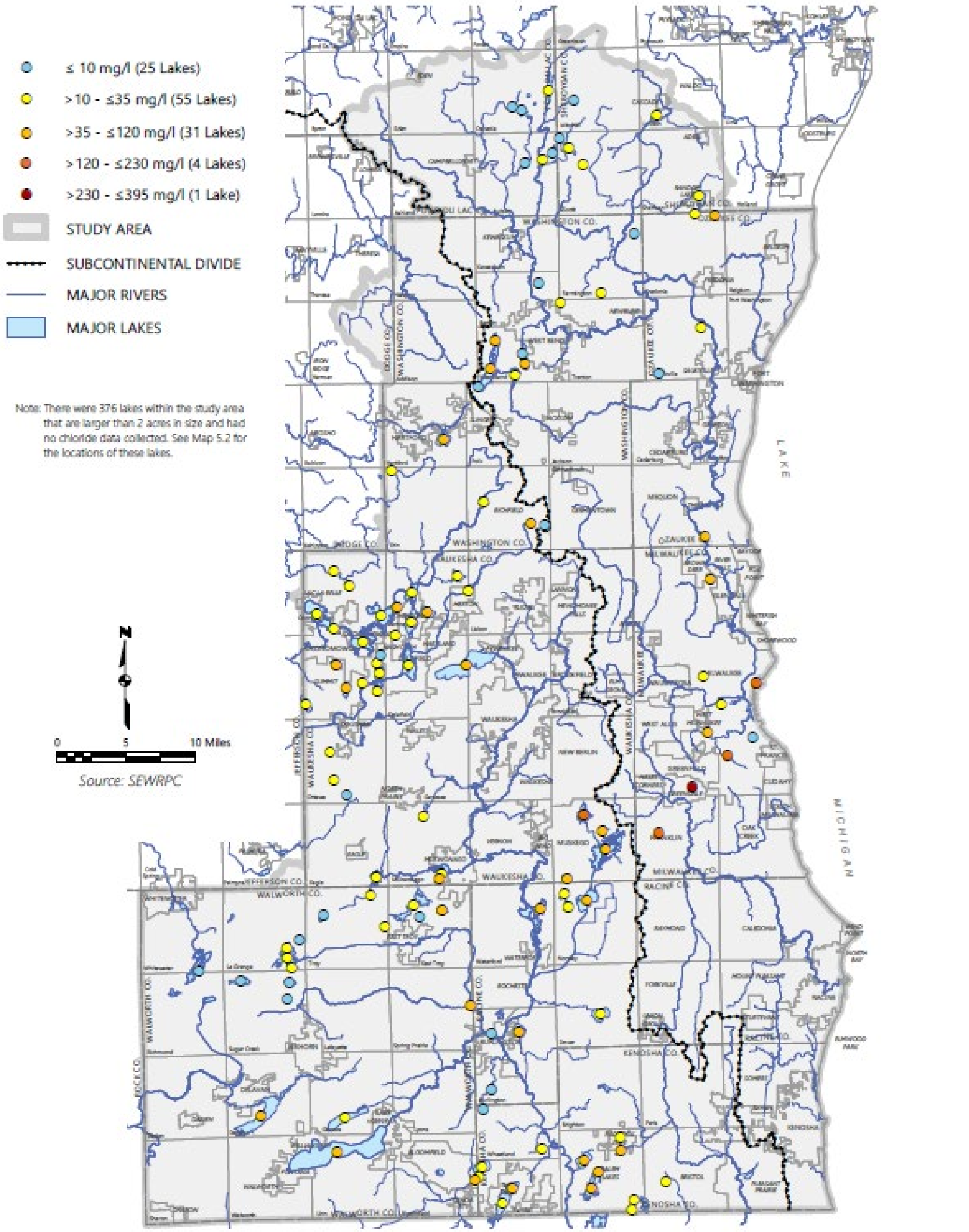
- Nearly 80 percent of all lake chloride samples exceeded 10 mg/l threshold
- About 30 percent of all lake chloride samples exceeded 35 mg/l threshold
- Approximately one percent of all chloride samples exceeded 120 mg/l threshold:

Figure 5.5
Percent of Lake Chloride Samples Collected in the Study Area Within Various Thresholds of Water Quality: 1960-2022



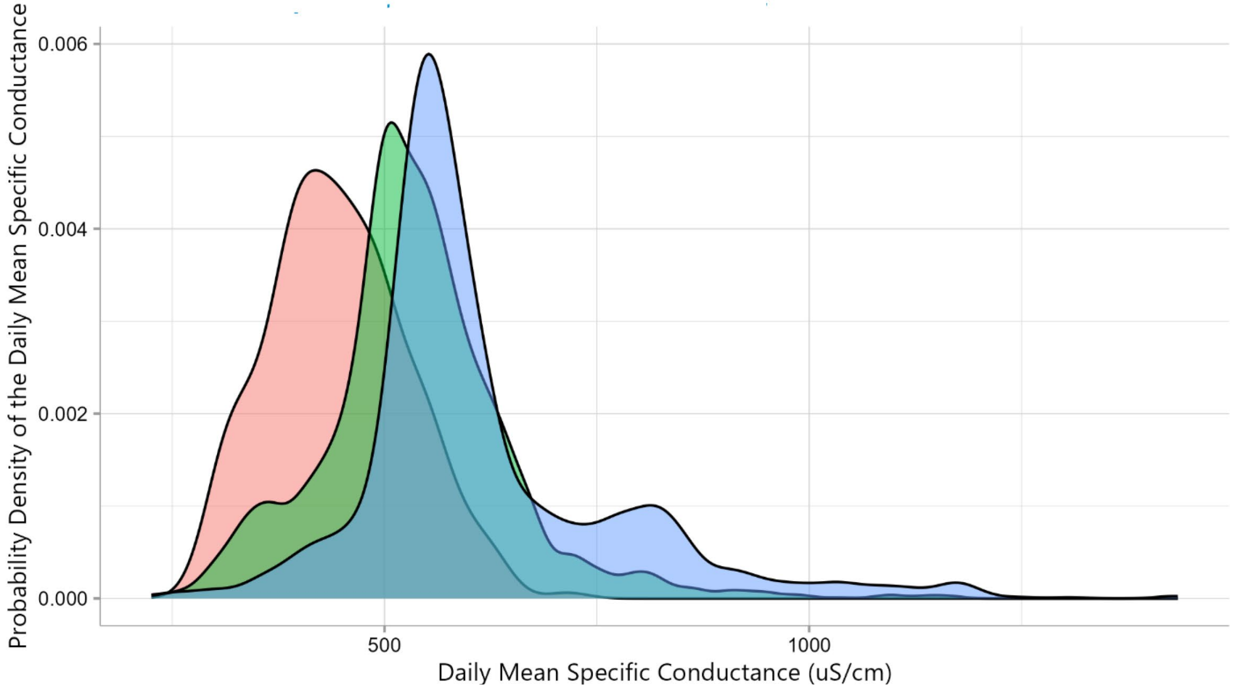
Note: There were 2,646 chloride samples collected among 116 study area lakes during the full period of record. For descriptions of thresholds, see Table 2.12 in Chapter 2 of this Report.

Map 5.4
Mean Chloride Concentration Among Lakes: 1960 - 2022



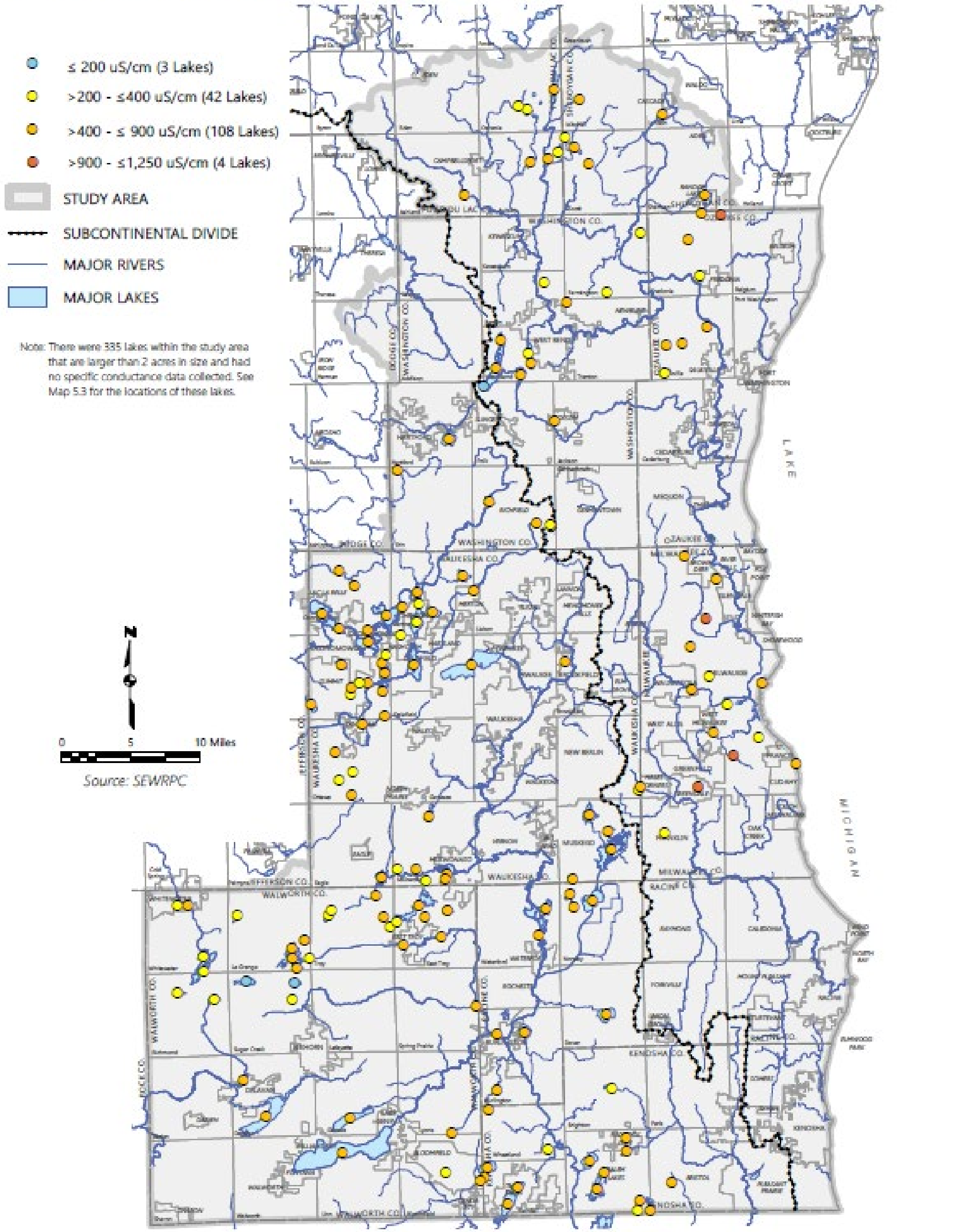
5.4 Full Period of Record Conditions (1960-2022)

Figure 5.6
Distribution of Specific Conductance Across Time Periods



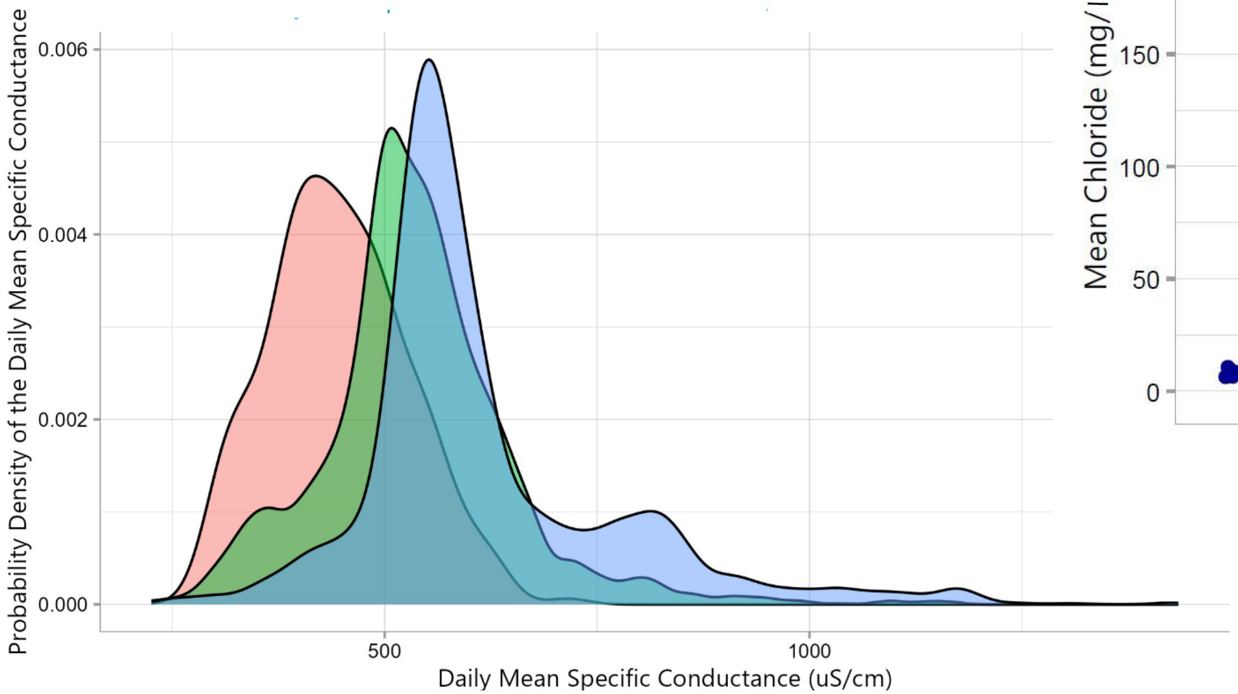
- Demonstrates an overall increase in the mean lake specific conductance over time and dramatic shift in the overall distribution among three different time periods of <1975, 1975-2005, and >2005.

Map 5.5
Mean Specific Conductance Among Lakes: 1960 - 2022



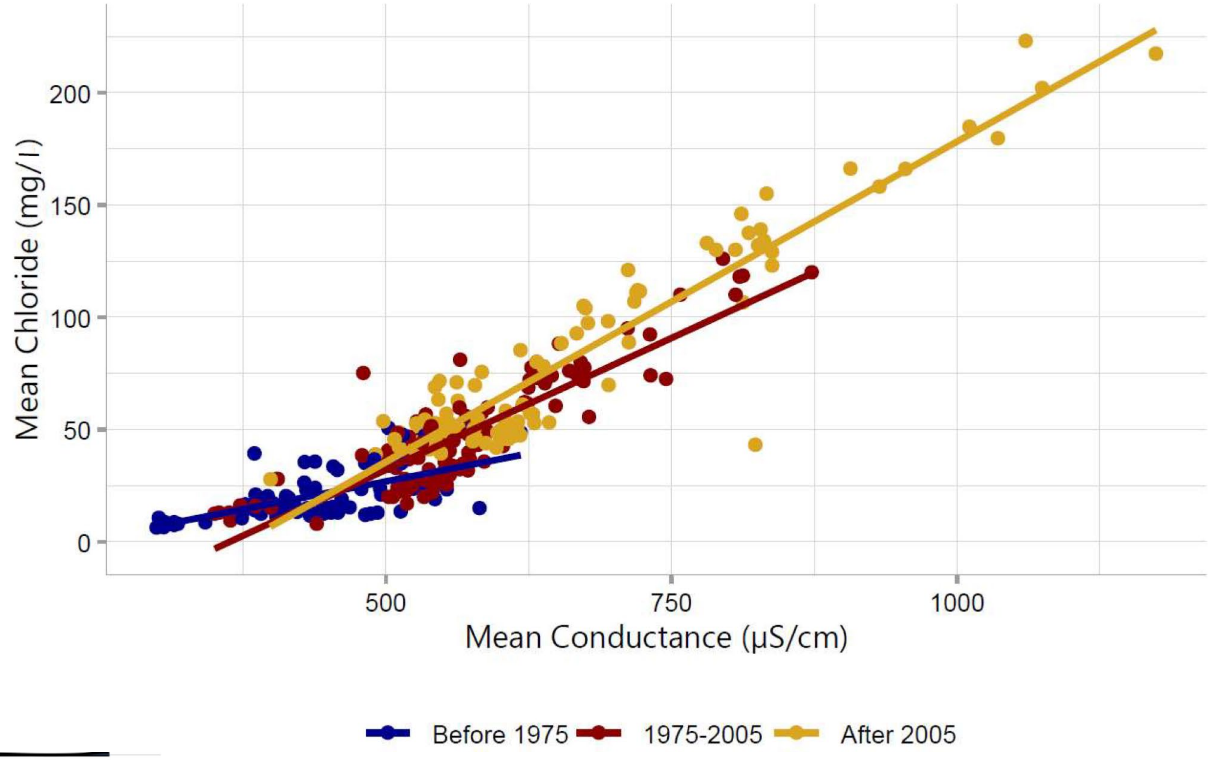
5.4 Full Period of Record Conditions (1960-2022)

Figure 5.6
Distribution of Specific Conductance Across Time Periods



- Demonstrates an overall increase in the mean lake specific conductance over time and dramatic shift in the overall distribution among three different time periods of <1975, 1975-2005, and >2005.

Figure 5.7
Paired Mean Chloride and Specific Conductance by Time Period for 15 Select Lakes Within the Study Area

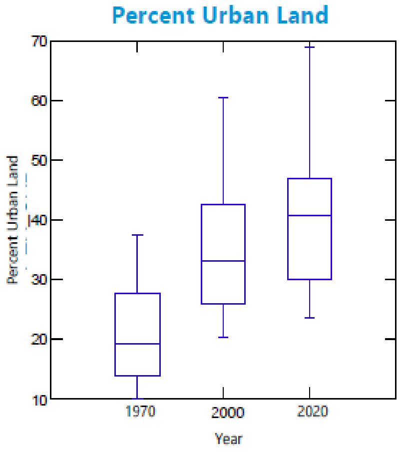


- Results suggest that the strength of the relationship between chloride concentrations and specific conductance with lakes has changed and is getting stronger with time, which likely means that chloride concentrations are comprising greater amounts of the overall specific conductance within lakes.

5.4 Full Period of Record Conditions (1960-2022)

- Based upon the nearest land use data for each of the 15 lake watersheds, there was a significant increase in percent urban land use and percent roads and parking lots over time.

Figure 5.8
Percent Urban Land and Roads and Parking Lots by Time Period for 15 Select Lakes Within the Study Area



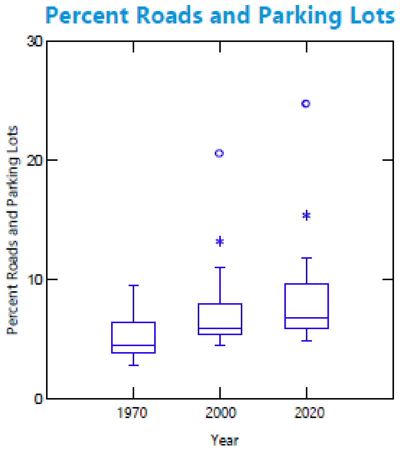
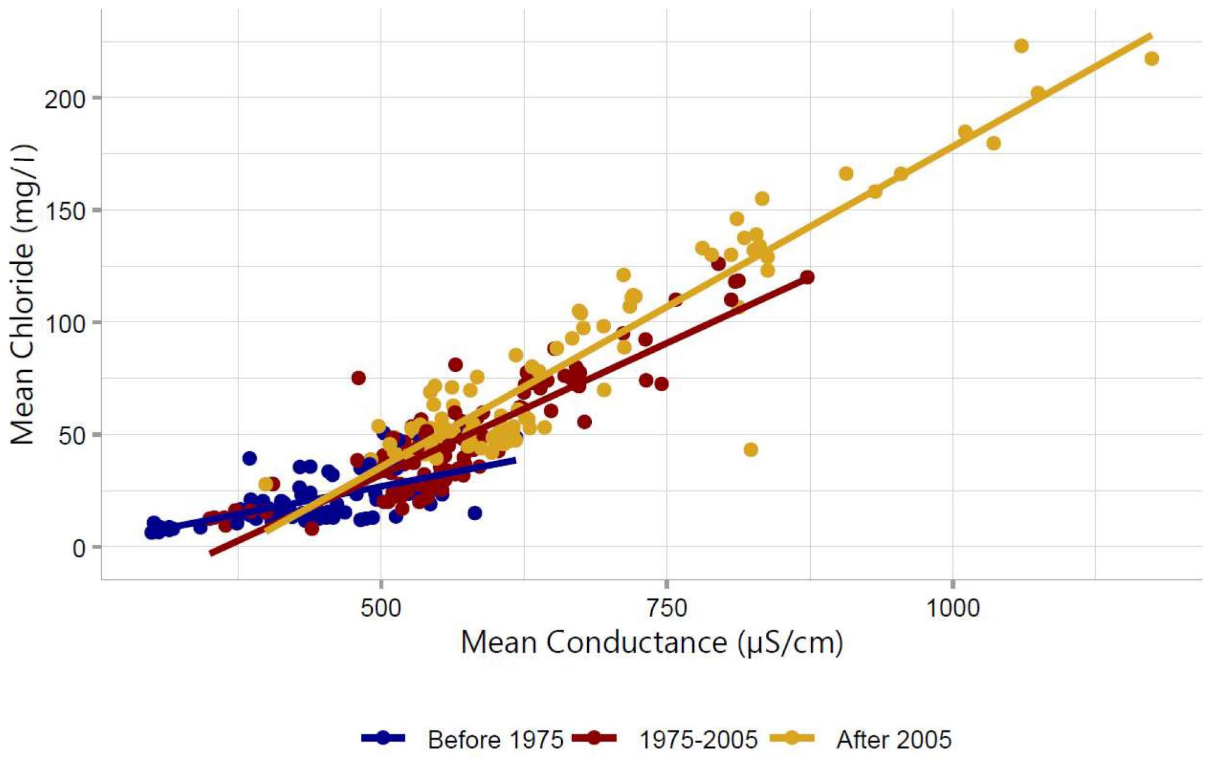
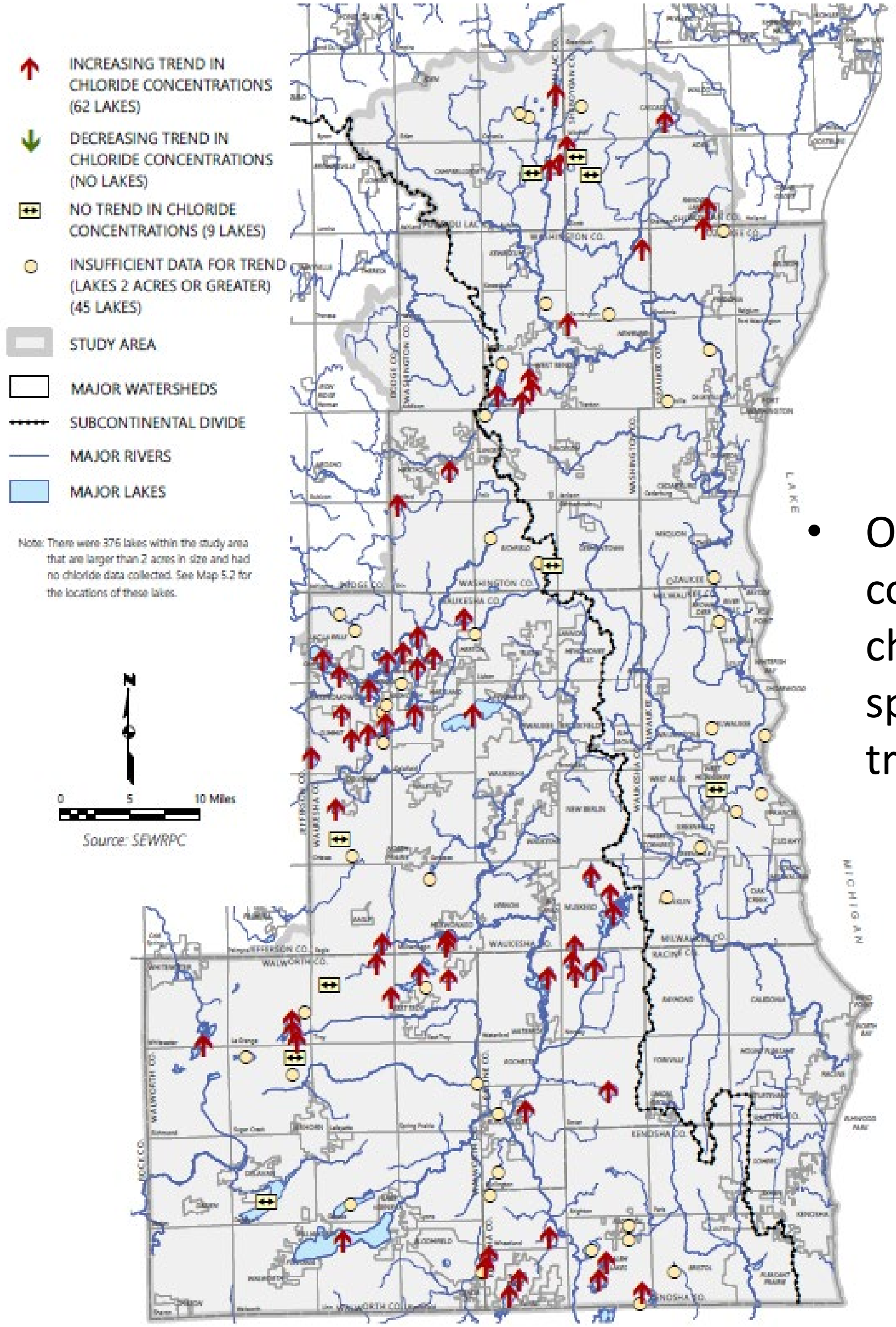


Figure 5.7
Paired Mean Chloride and Specific Conductance by Time Period for 15 Select Lakes Within the Study Area



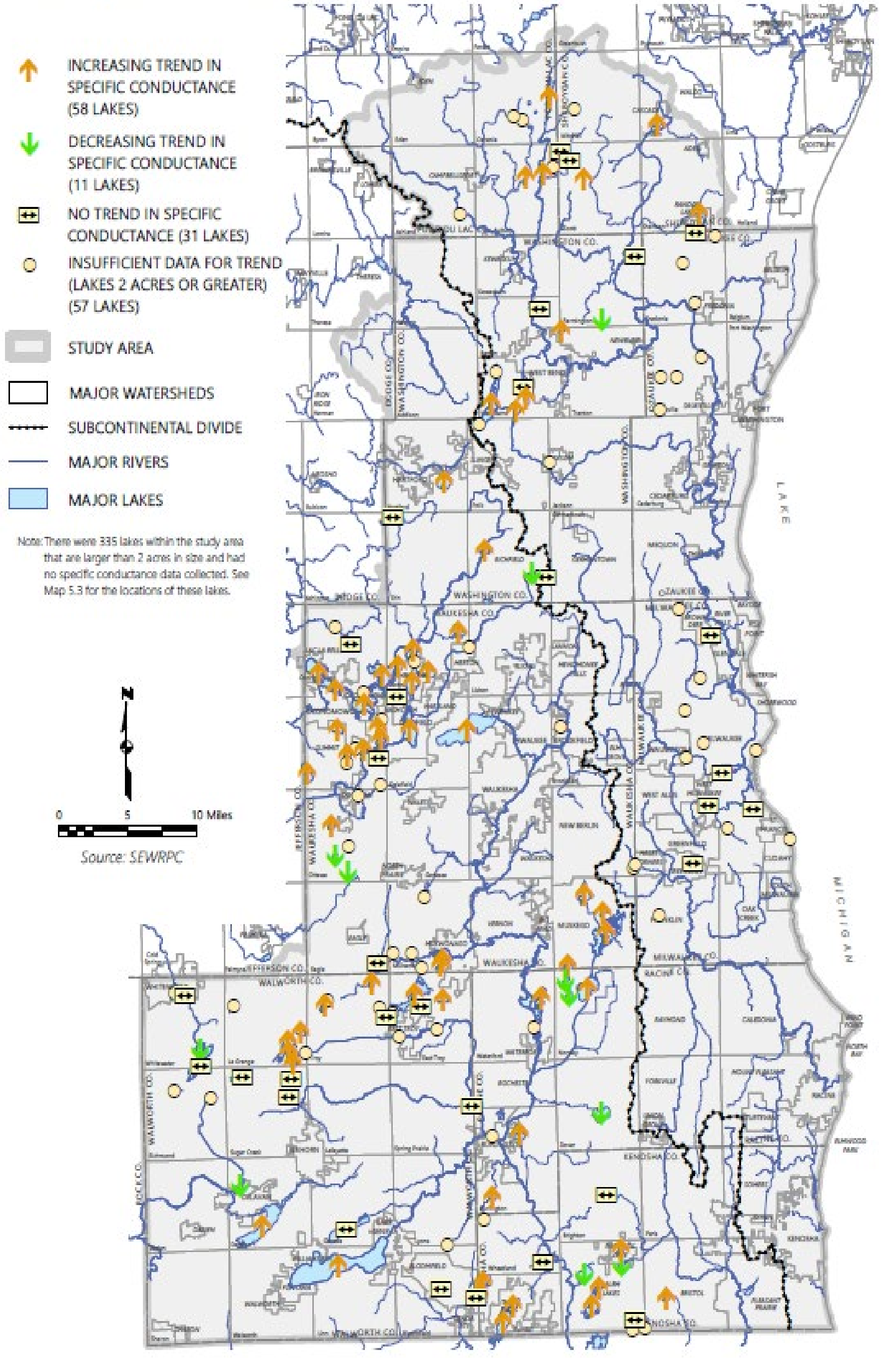
- Results suggest that the strength of the relationship between chloride concentrations and specific conductance with lakes has changed and is getting stronger with time, which likely means that chloride concentrations are comprising greater amounts of the overall specific conductance within lakes.

Map 5.8
Trends in Chloride Concentration in the Lakes of the Study Area: 1960 - 2022



- Overall there is good correspondence between chloride trends and specific conductance trends among these lakes.

Map 5.9
Trends in Specific Conductance in the Lakes of the Study Area: 1960 - 2022



Map 5.8
Trends in Chloride Concentration in the Lakes of the Study Area: 1960 - 2022

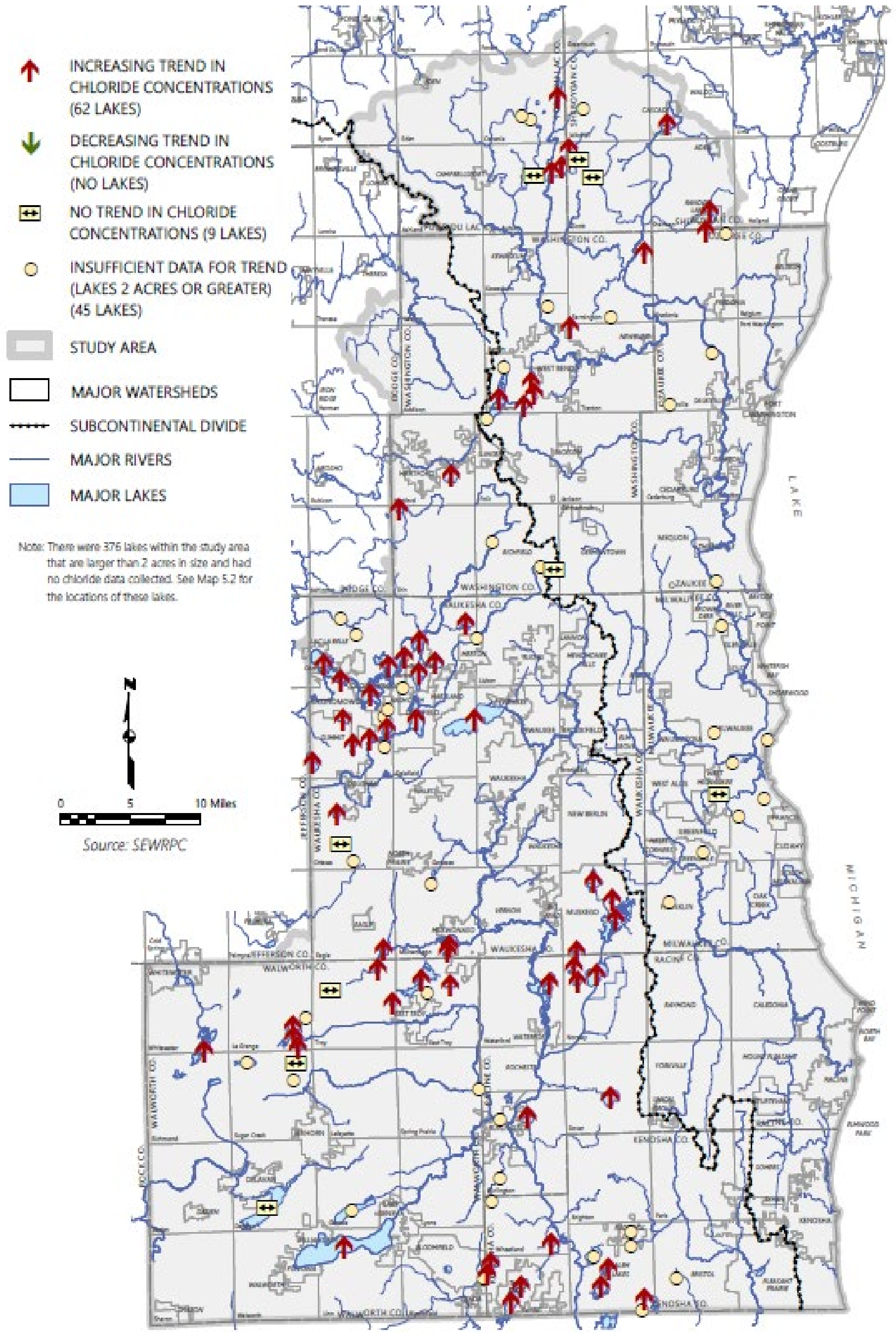
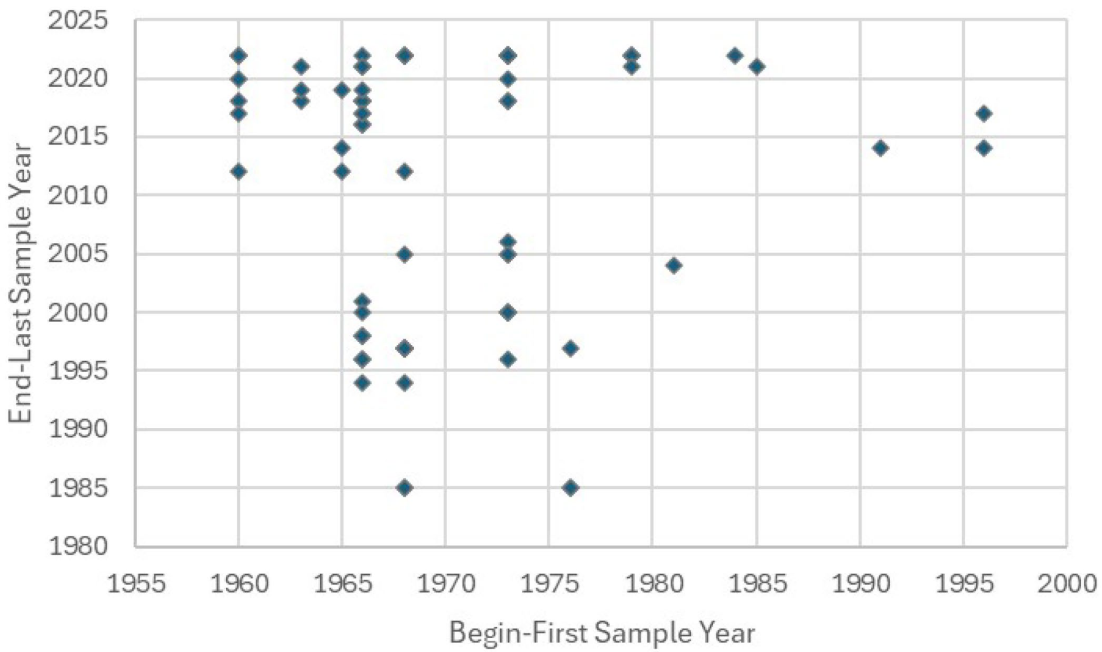
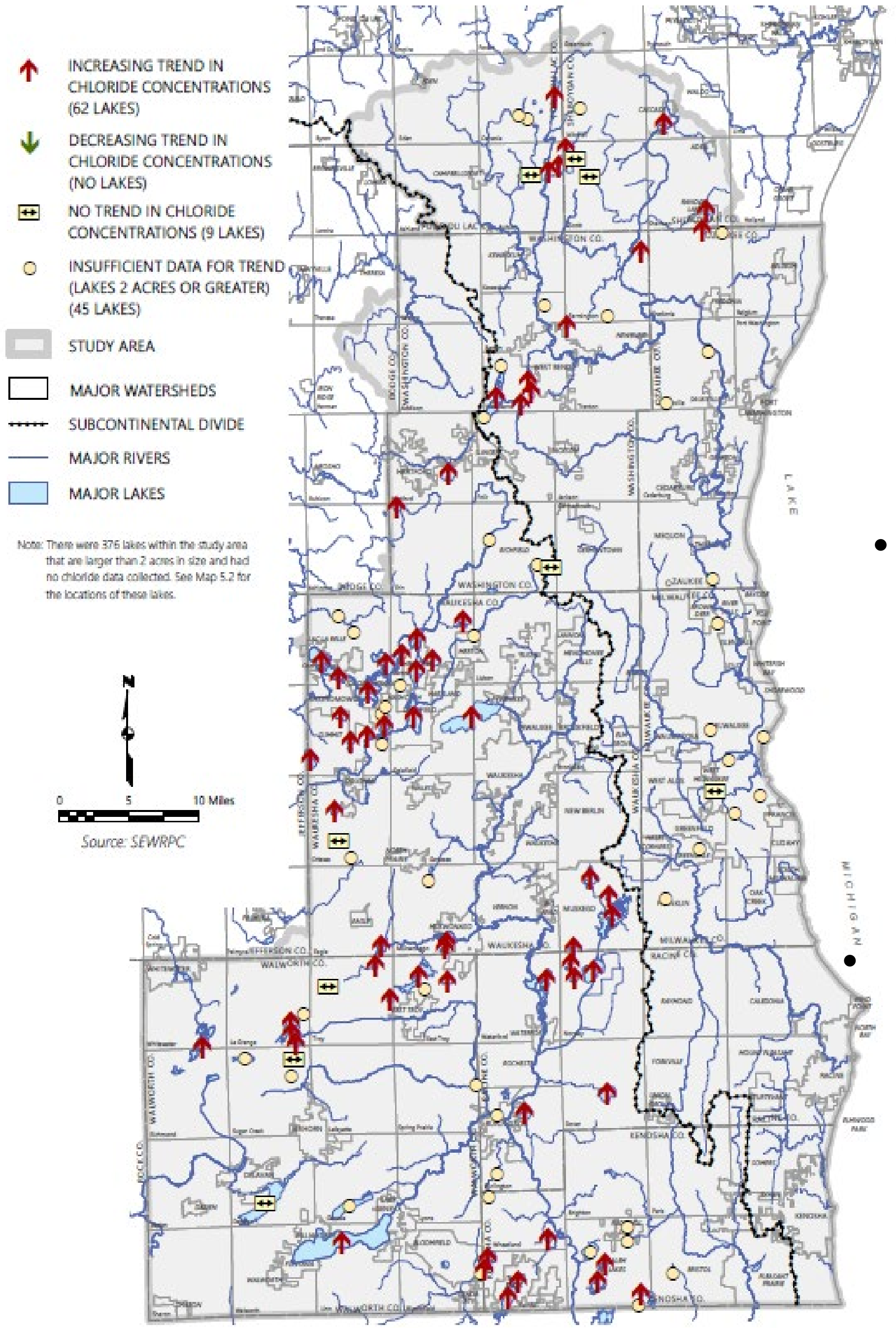


Figure 5.9
Begin Year Versus End Year Period of Record of Chloride Samples for Long-Term Trend Lakes Within the Study Area

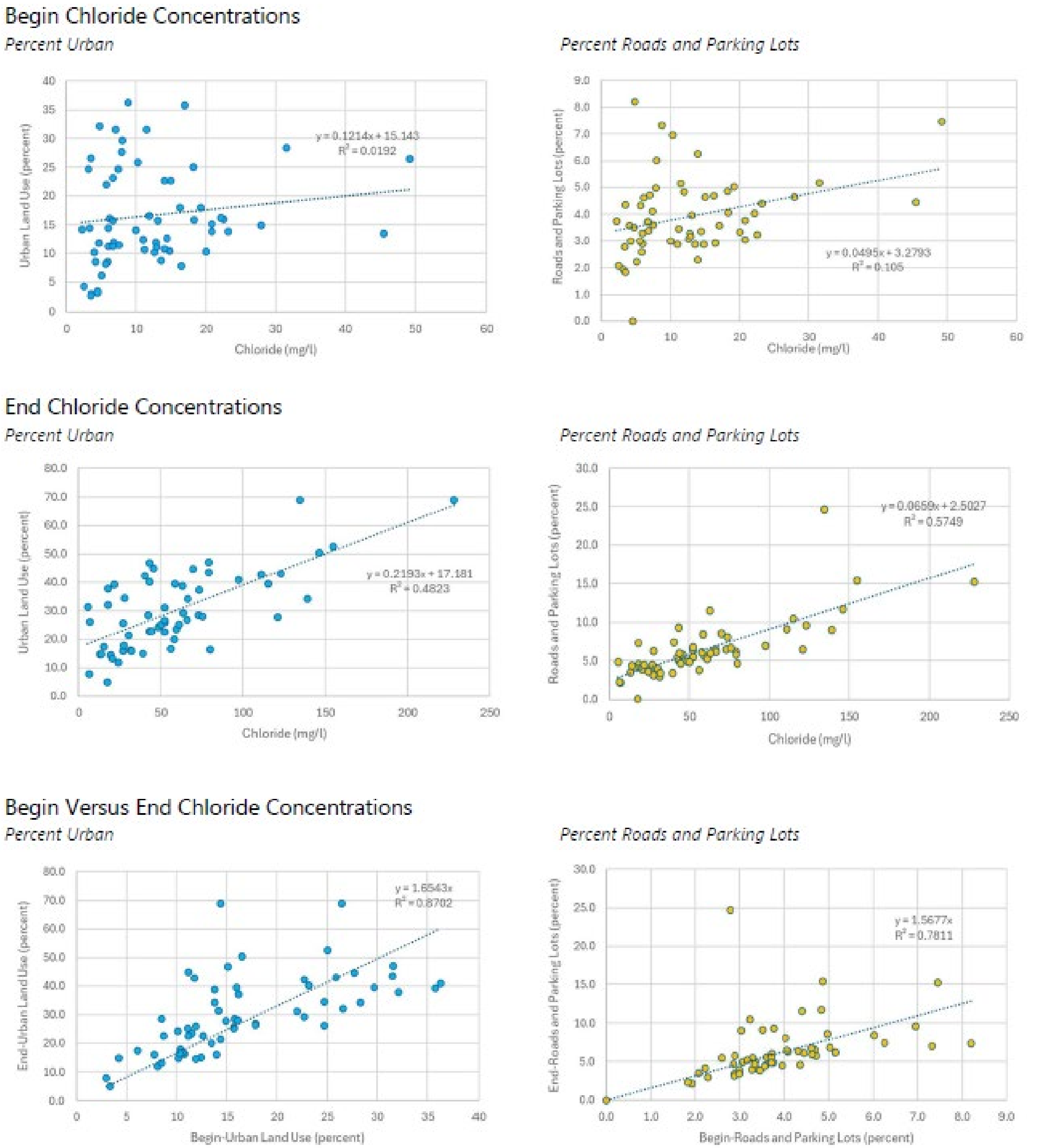


Map 5.8
Trends in Chloride Concentration in the Lakes of the Study Area: 1960 - 2022

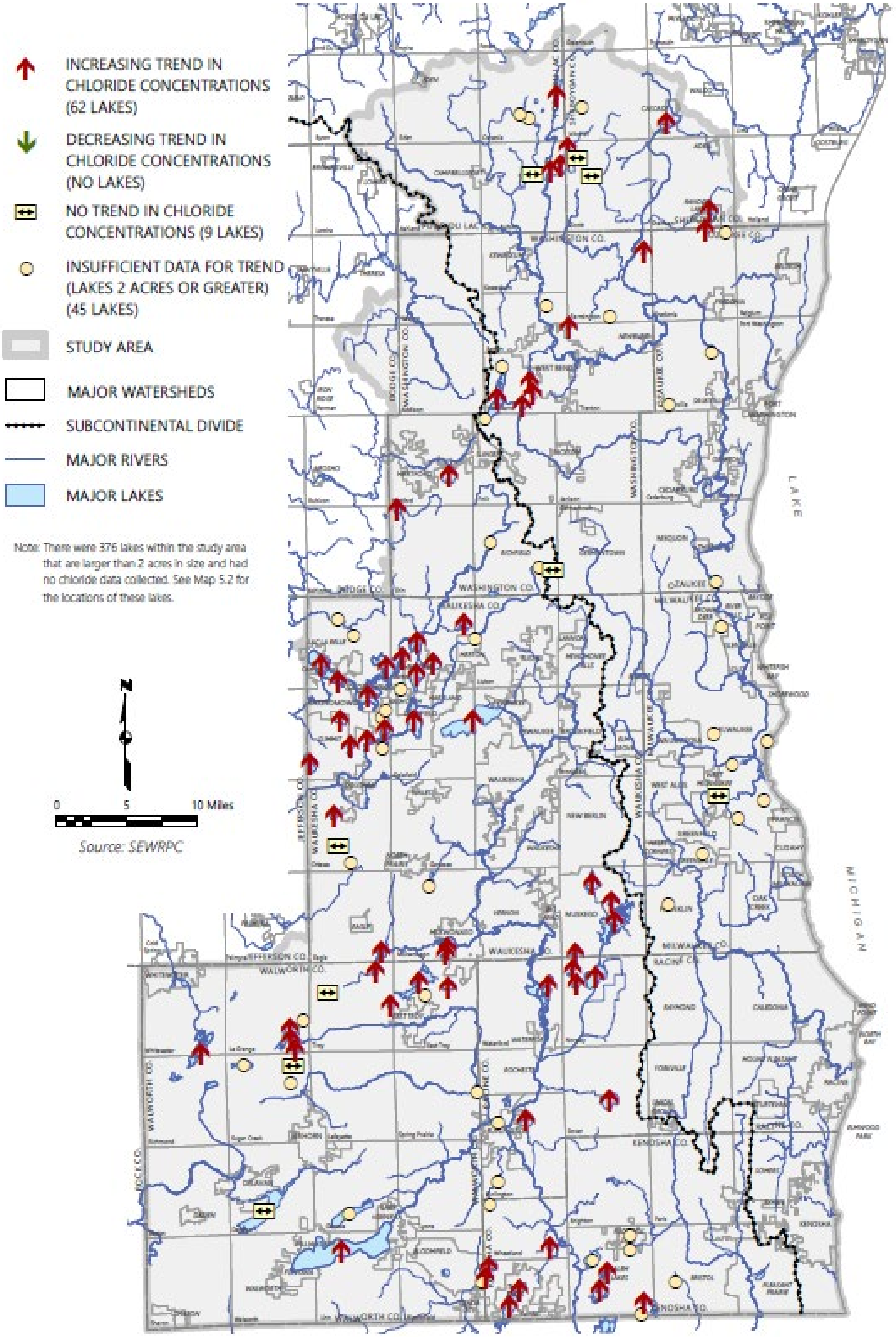


- Begin-not significant
- End-significant
- Significant increase by a rate of about 1.6 percent of the watershed

Figure 5.10
Begin Year Versus End Year Comparisons of Chlorides Concentrations and Percent Land Use

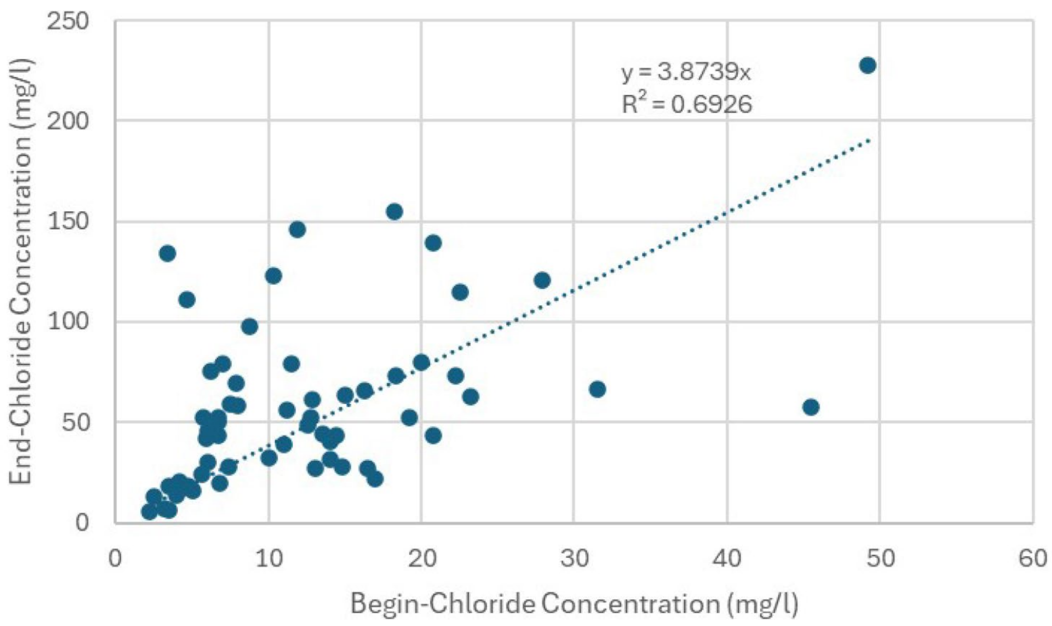


Map 5.8
Trends in Chloride Concentration in the Lakes of the Study Area: 1960 - 2022



5.4 Long-term Trends and Land Use Influence

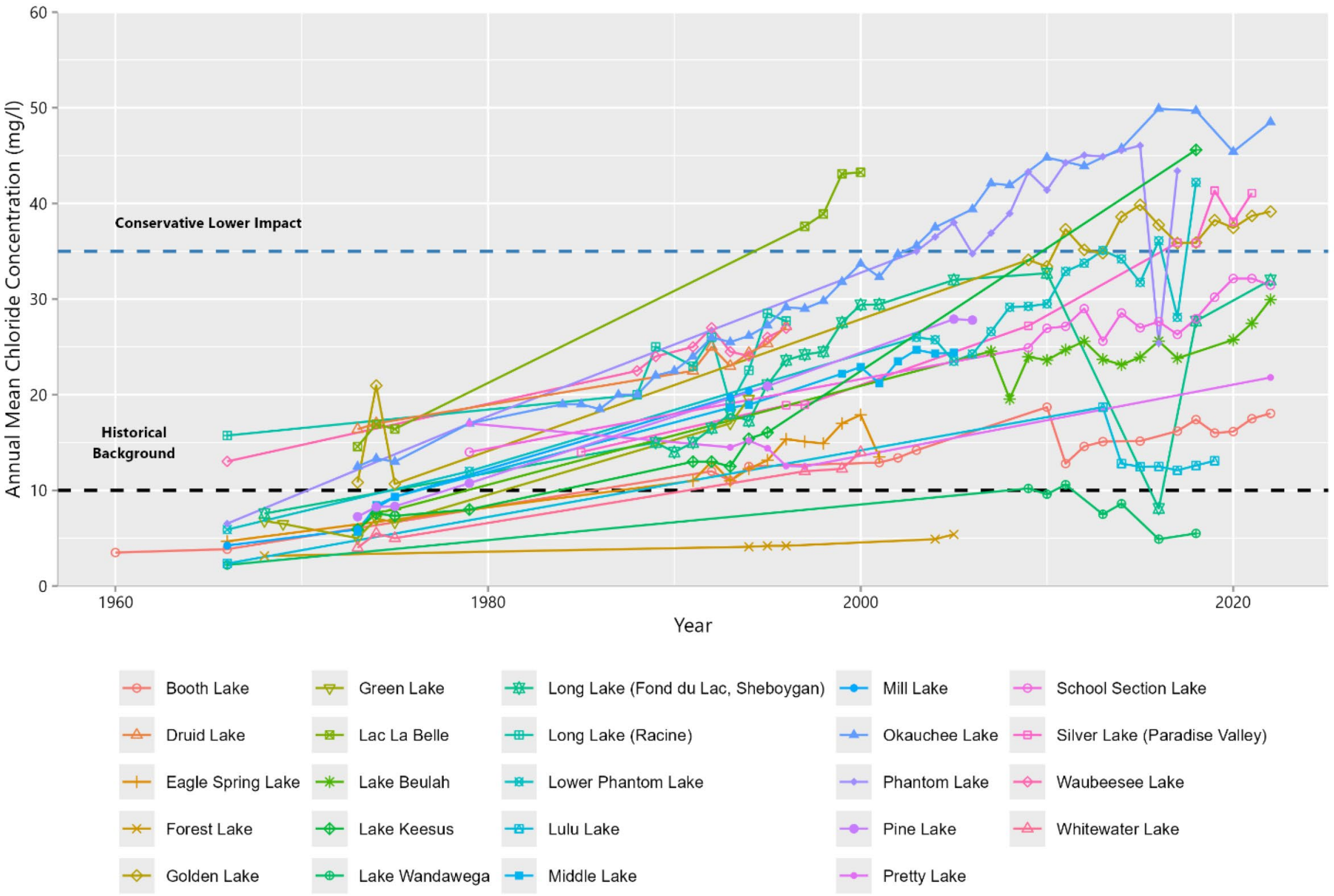
Figure 5.11
Begin Year Versus End Year Period of Record of Chloride Concentrations for Each Long-Term Trend Lake Within the Study Area



- Chloride levels in these lakes increased at a rate of about 3.9 mg/l compared to the starting concentration

5.4 Long-term Trends and Land Use Influence

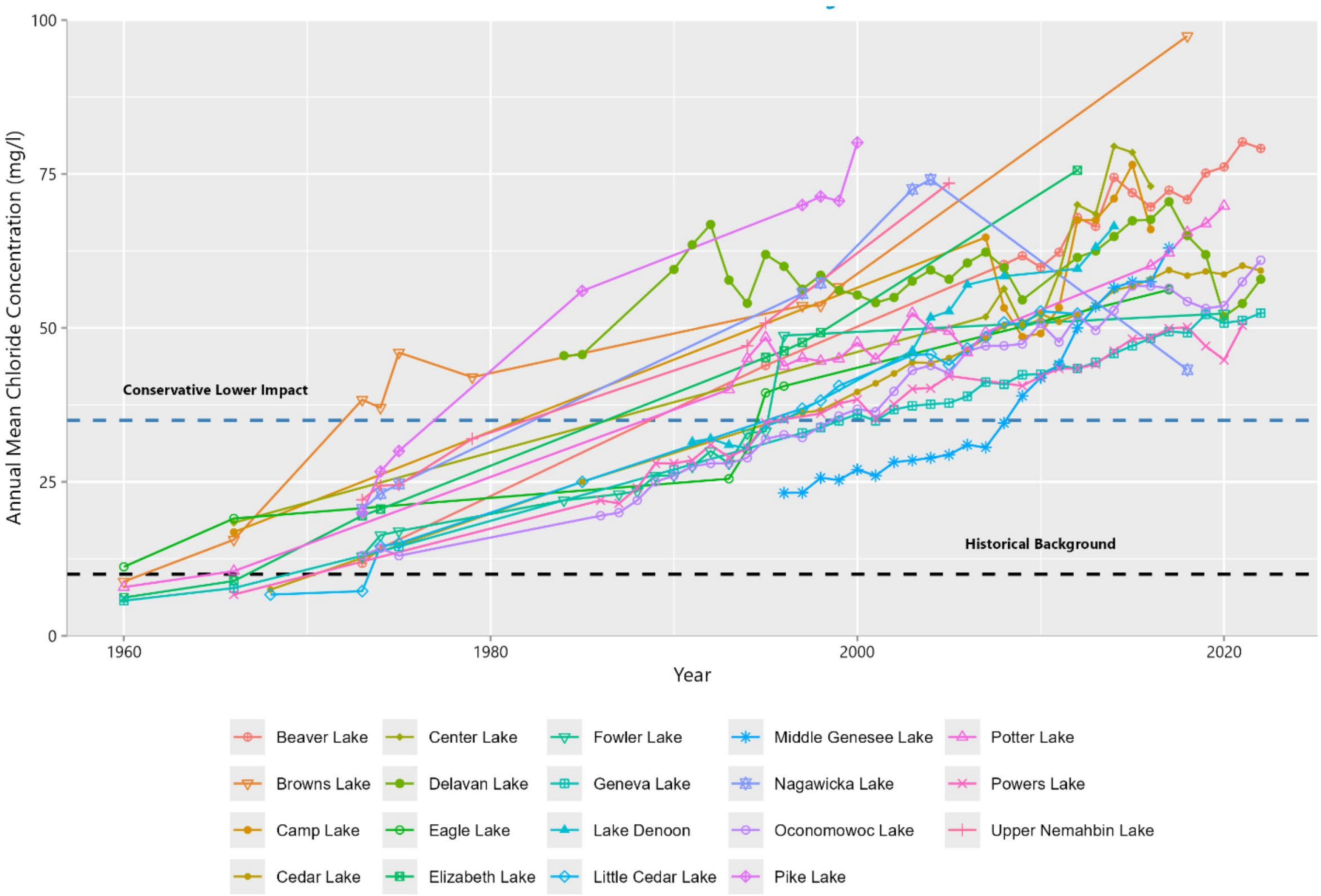
Figure 5.12
Annual Mean Chloride Concentrations Over Time: Lakes Less Than 50 mg/l



- 24 lakes that contain chloride concentrations that have not exceeded 50 mg/l

5.4 Long-term Trends and Land Use Influence

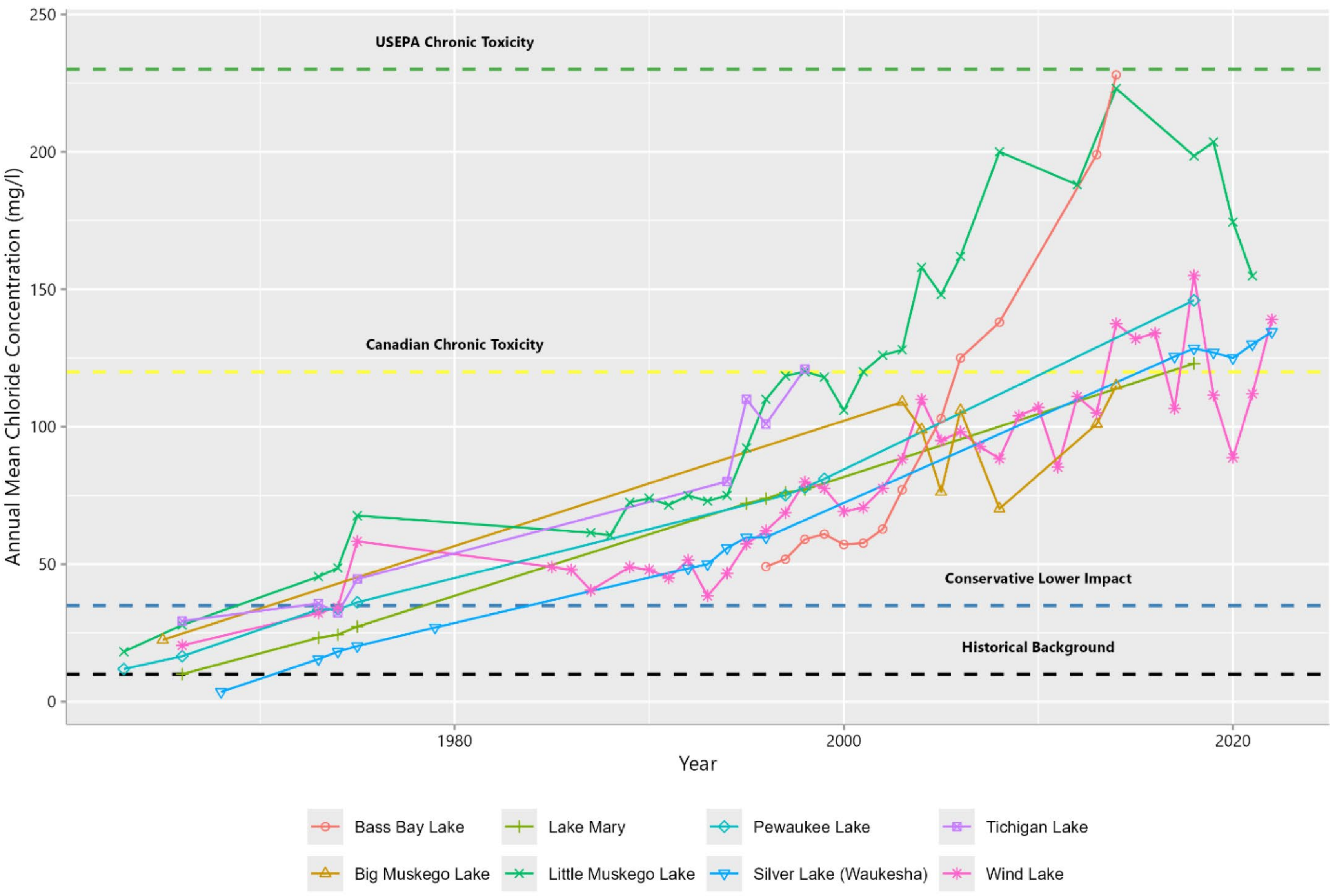
Figure 5.13
Annual Mean Chloride Concentrations Over Time: Lakes Between 50 and 100 mg/l



- 19 lakes that range between 50 and 100 mg/l

5.4 Long-term Trends and Land Use Influence

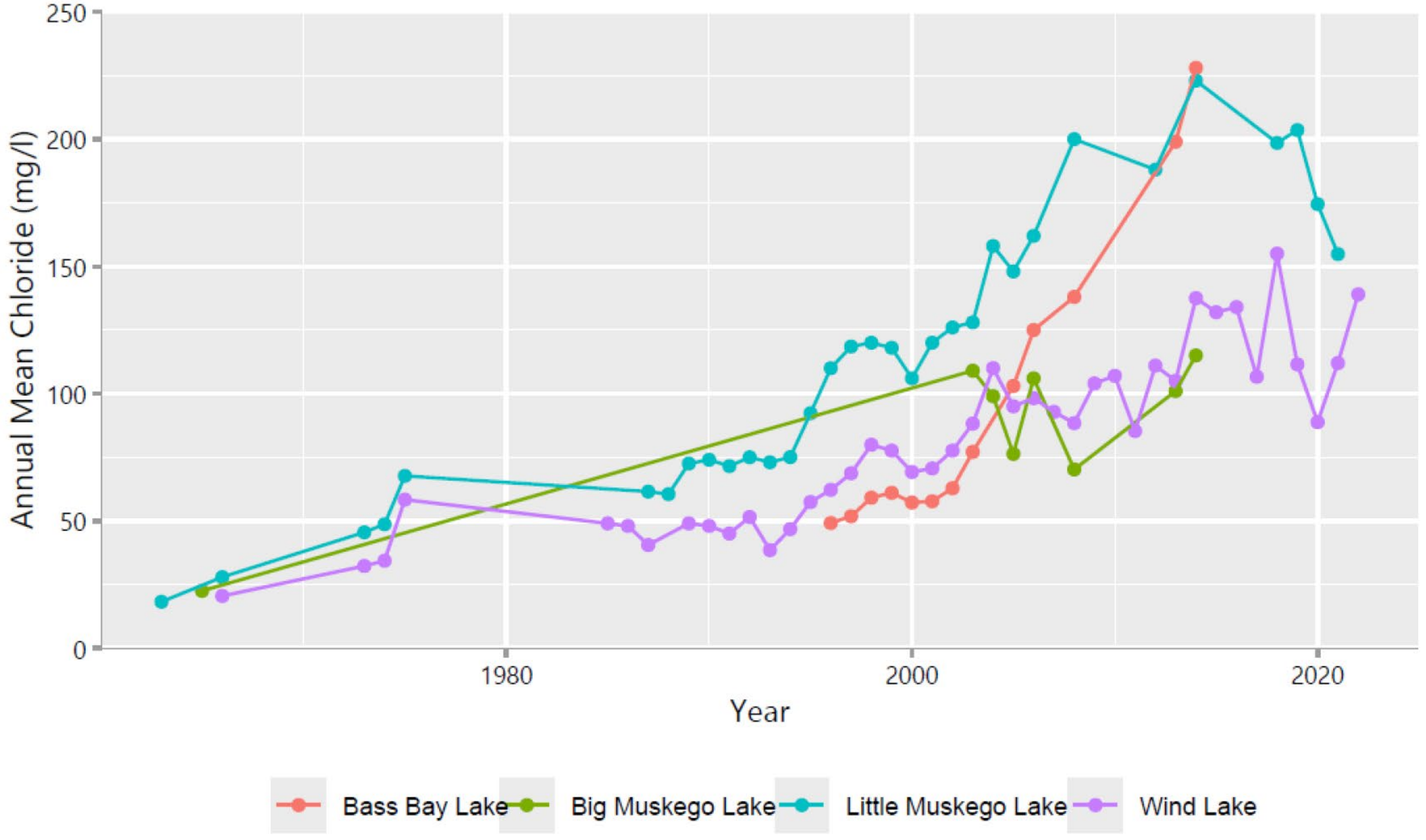
Figure 5.14
Annual Mean Chloride Concentrations Over Time: Lakes Over 100 mg/l



- 8 lakes with the highest chloride concentrations exceeding 100 mg/l over the full period of record

5.4 Long-term Trends and Land Use Influence

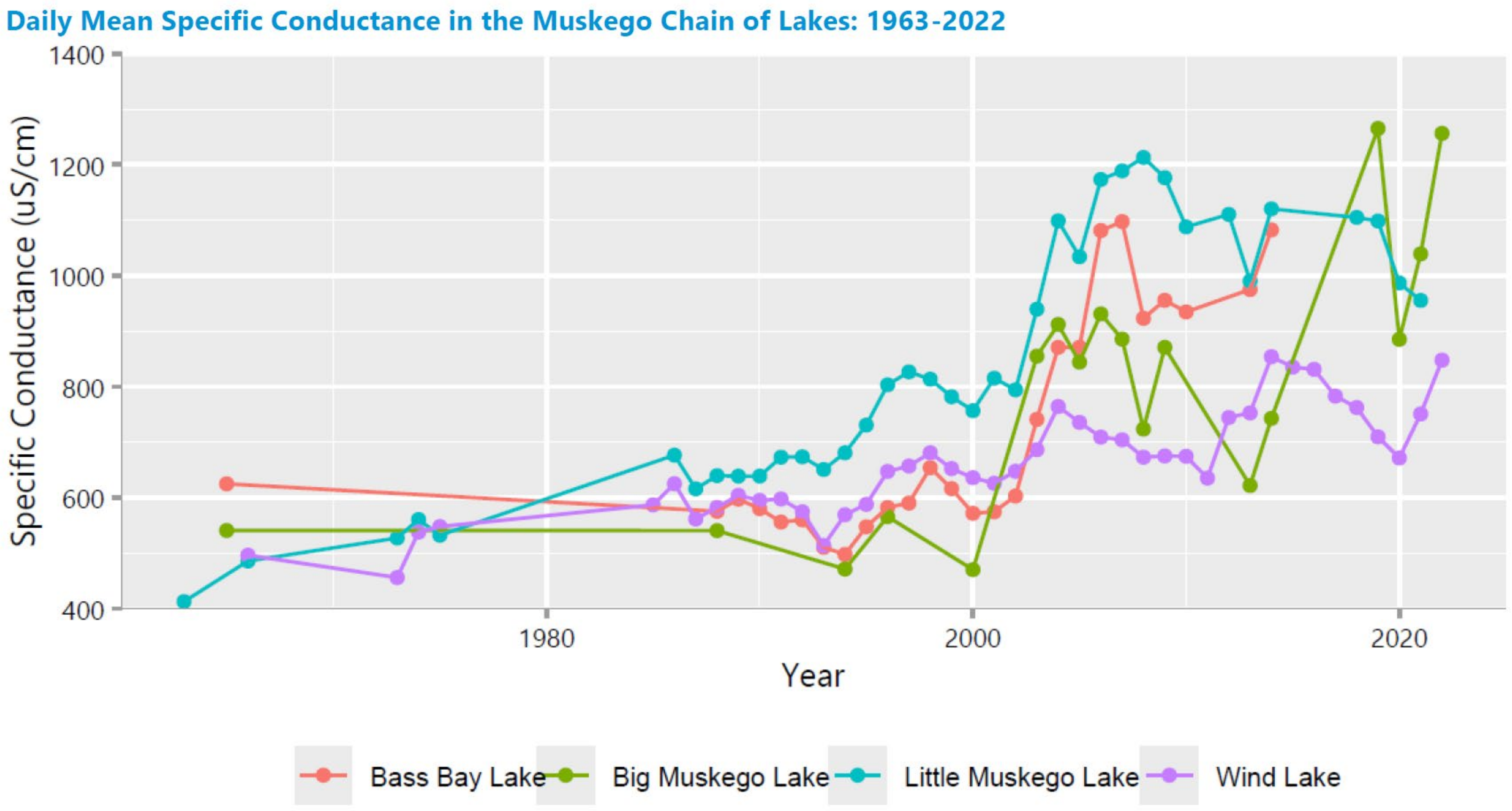
Figure 5.15
Annual Mean Chloride Concentrations in the Muskego Chain of Lakes: 1963-2022



Source: WDNR, USGS, and SEWRPC

Lake	Drainage Order	Urban Land (percent)	Roads and Parking Lots (percent)	Residence Time (years)
Bass Bay Lake	A	69	15	1.32
Little Muskego Lake	A	51.7	15	0.9
Big Muskego Lake	B	39.4	10	0.48
Wind Lake	C	33.5	9	0.6

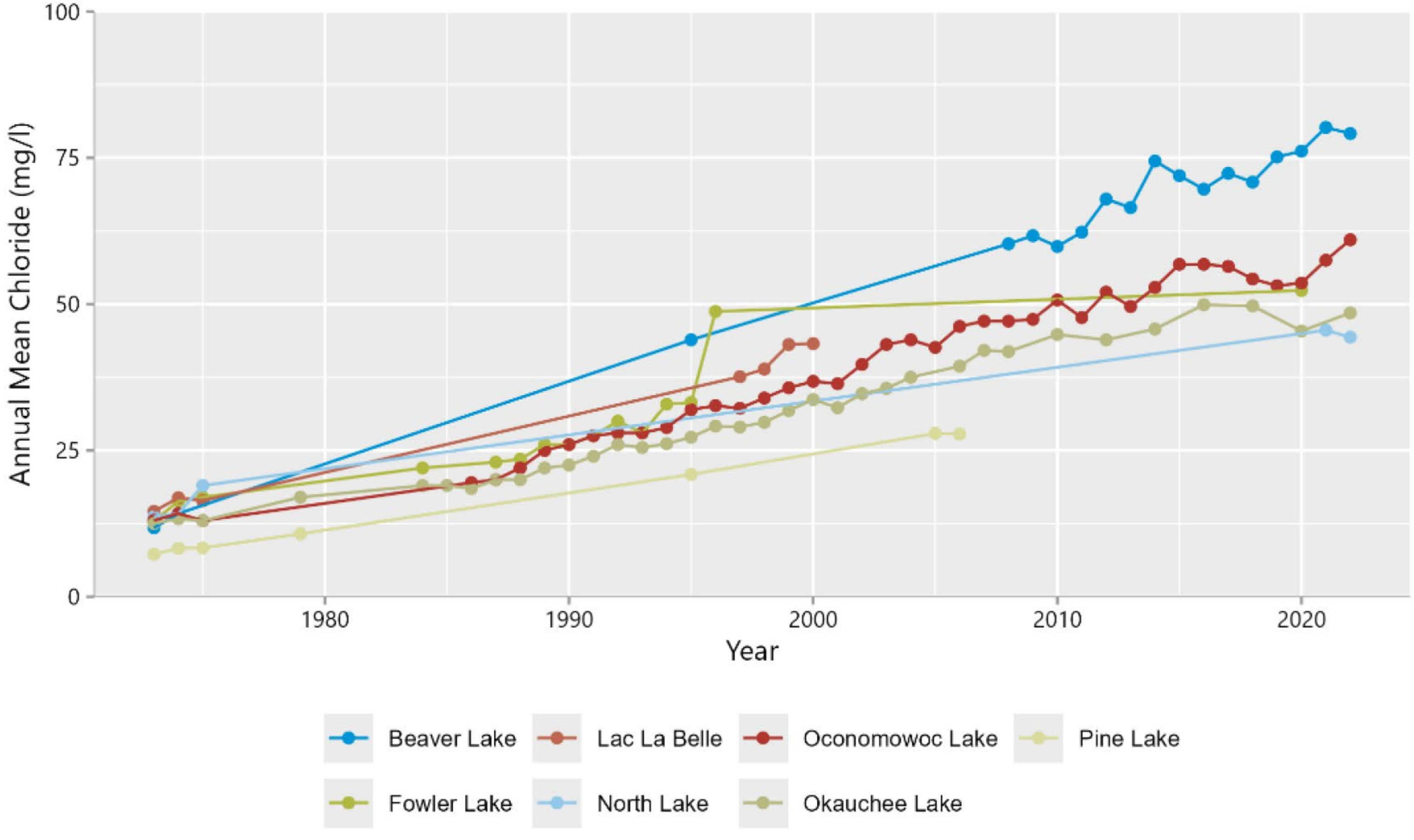
5.4 Long-term Trends and Land Use Influence



Source: WDNR, USGS, and SEWRPC

5.4 Long-term Trends and Land Use Influence

Figure 5.16
Annual Mean Chloride Concentrations in the Oconomowoc Chain of Lakes: 1973-2022

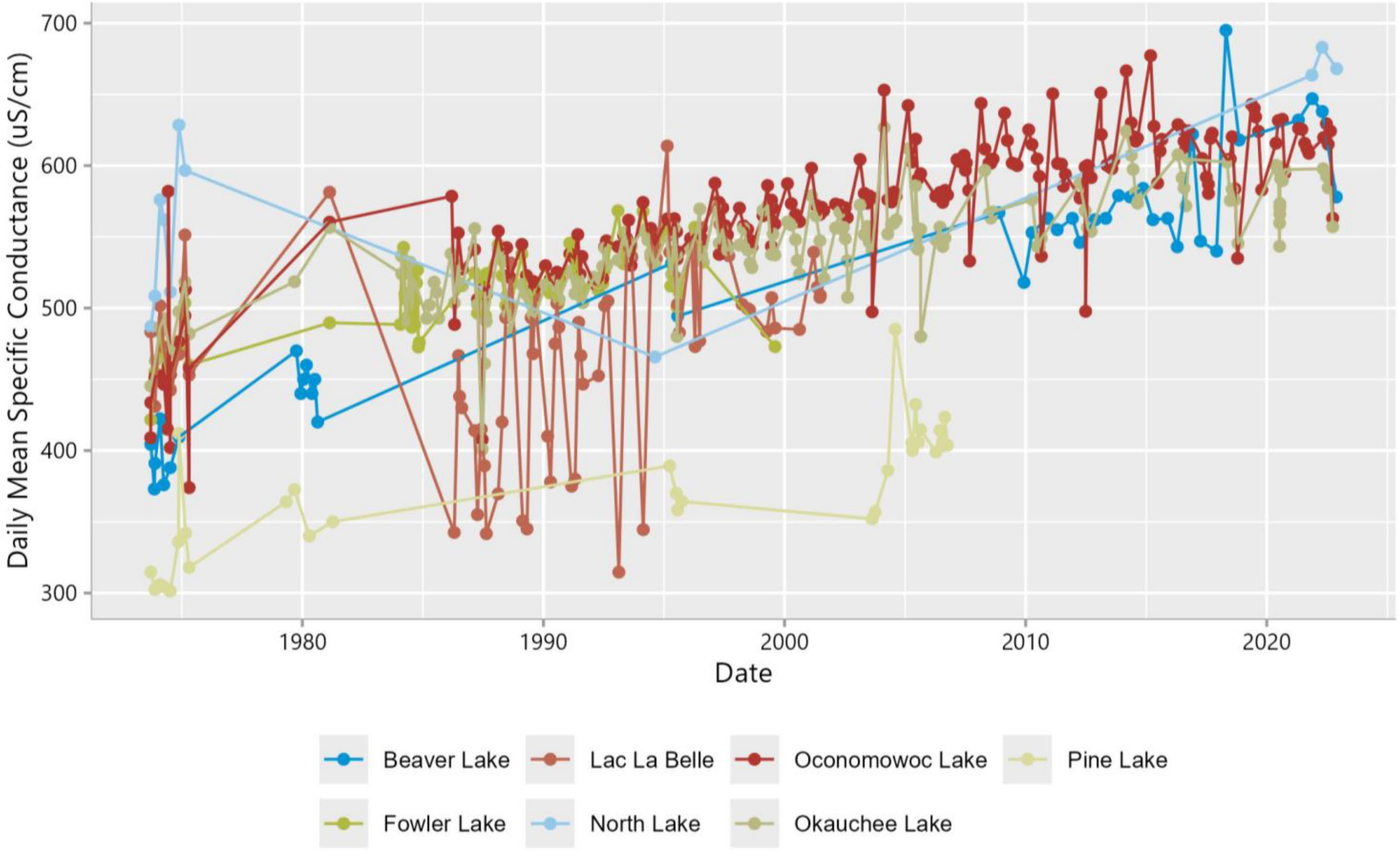


Lake	Drainage Order	Urban Land (percent)	Roads and Parking Lots (percent)	Residence Time (years)
Beaver Lake	A	45	6	2.6
Pine Lake	B	35	6	5.2
North Lake	C	22	5	0.8
Okauchee Lake	D	23	5	0.9
Oconomowoc Lake	E	24	5	0.41
Fowler Lake	F	25	5	0.02
Lac La Belle	G	27	6	0.32

Source: WDNR, USGS, and SEWRPC

5.4 Long-term Trends and Land Use Influence

Daily Mean Specific Conductance in the Oconomowoc Chain of Lakes: 1973-2022



5.4 Forecasts/Potential Future Chloride Concentrations

- Biological communities for most observed lakes in the study area are being negatively impacted by sustained chronic chloride concentrations and these impacts are worsening with time and are forecast to continue this negative trend.

Figure 5.5
Percent of Lake Chloride Samples Collected in the Study Area Within Various Thresholds of Water Quality: 1960-2022

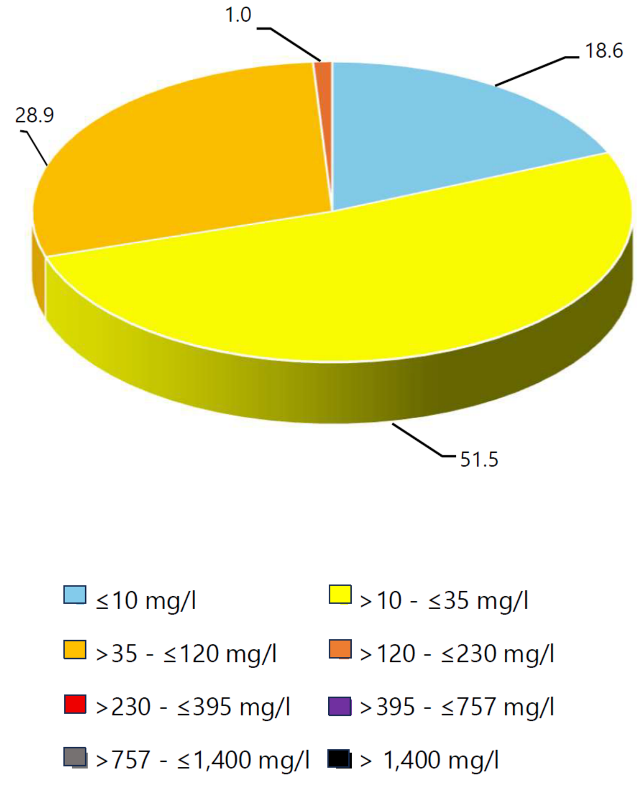
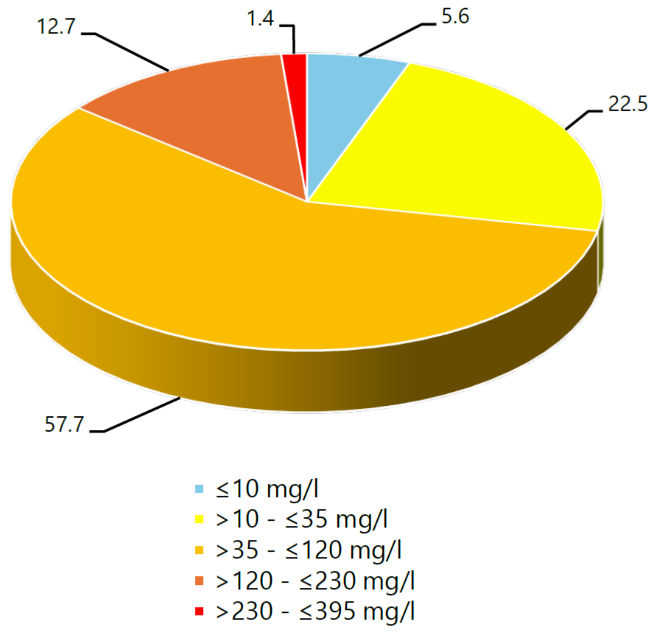
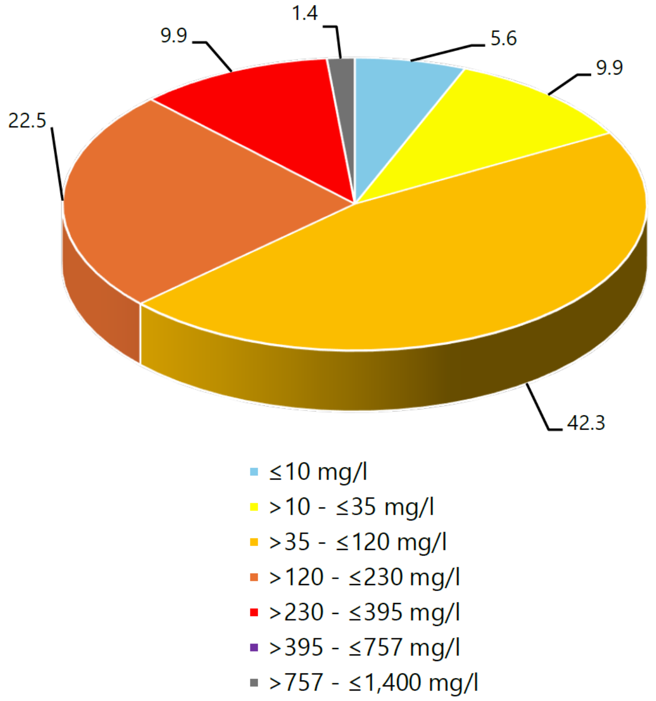


Figure 5.17
Percent of Lakes in the Study Area Forecasted to Exceed Various Thresholds of Water Quality: 2025 and 2075

2025 (Present)



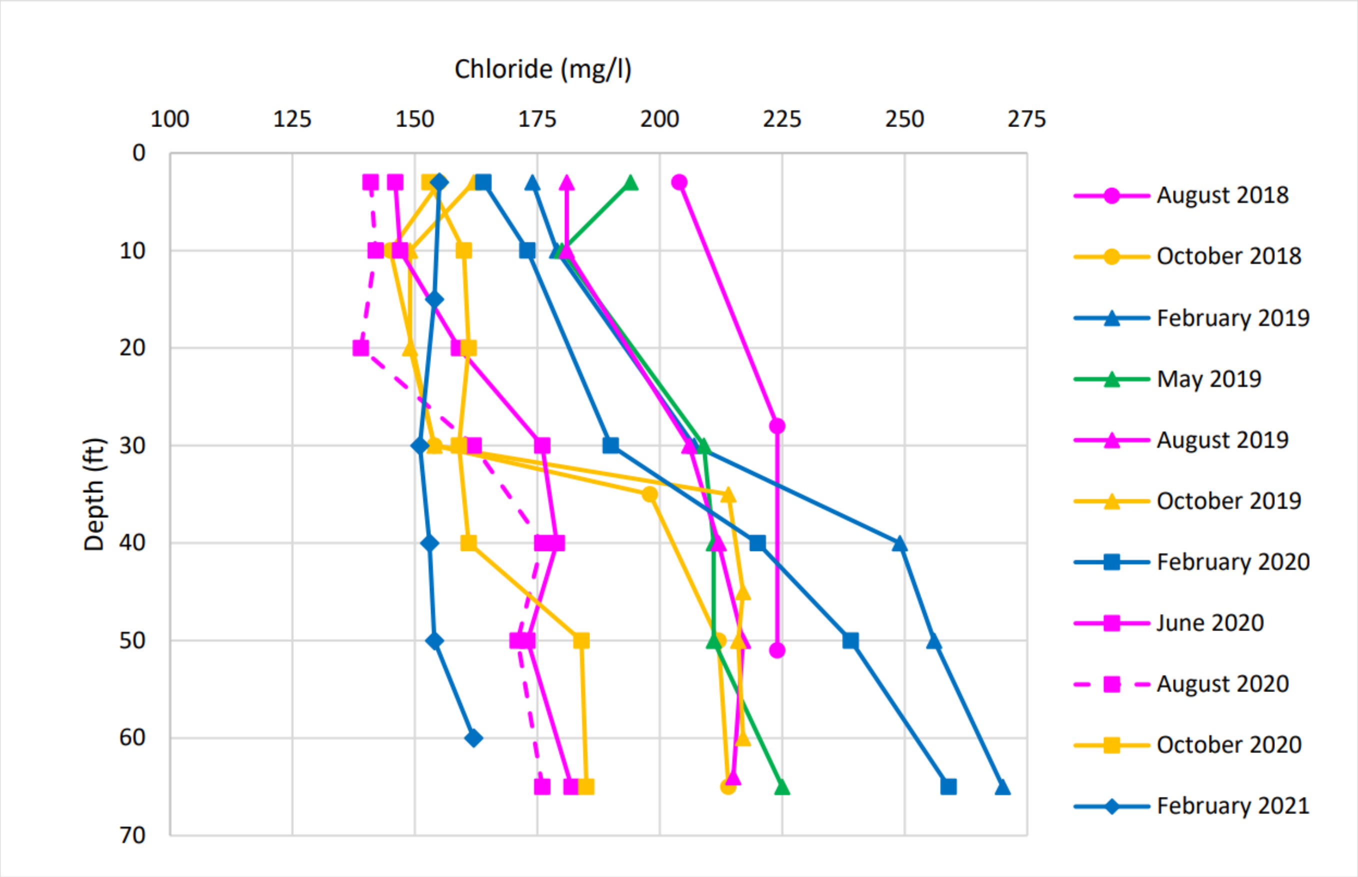
2075 (50-Year Future)



5.4 – Seasonality

Figure 3.18 (Continued)

Little Muskego Lake, Waukesha County



5.4 – Seasonality

Figure 5.18
Composite of Profile Chloride Concentrations of all Depths by Season on Study Lakes: 2018-2021

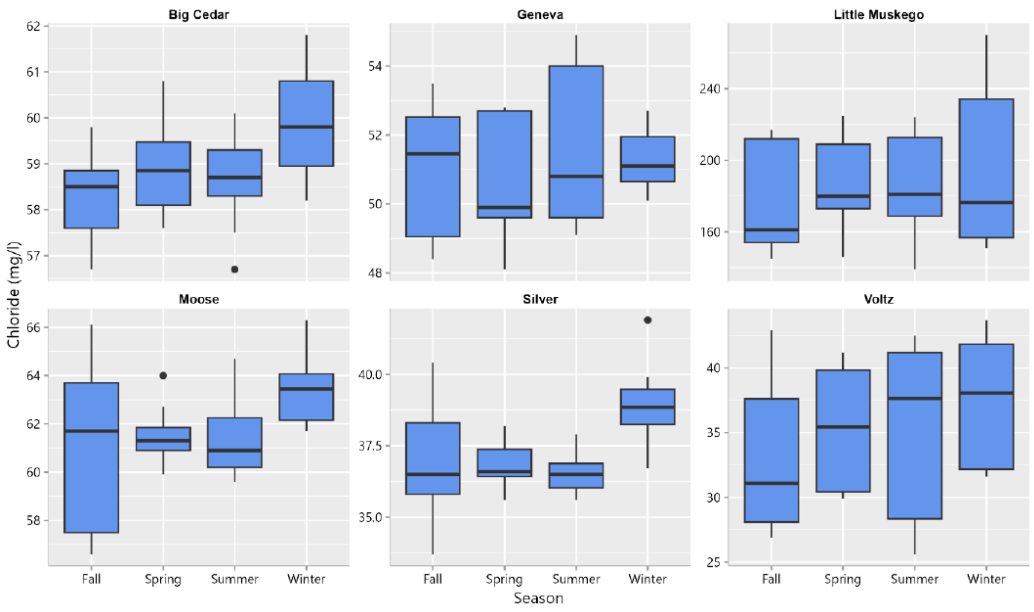
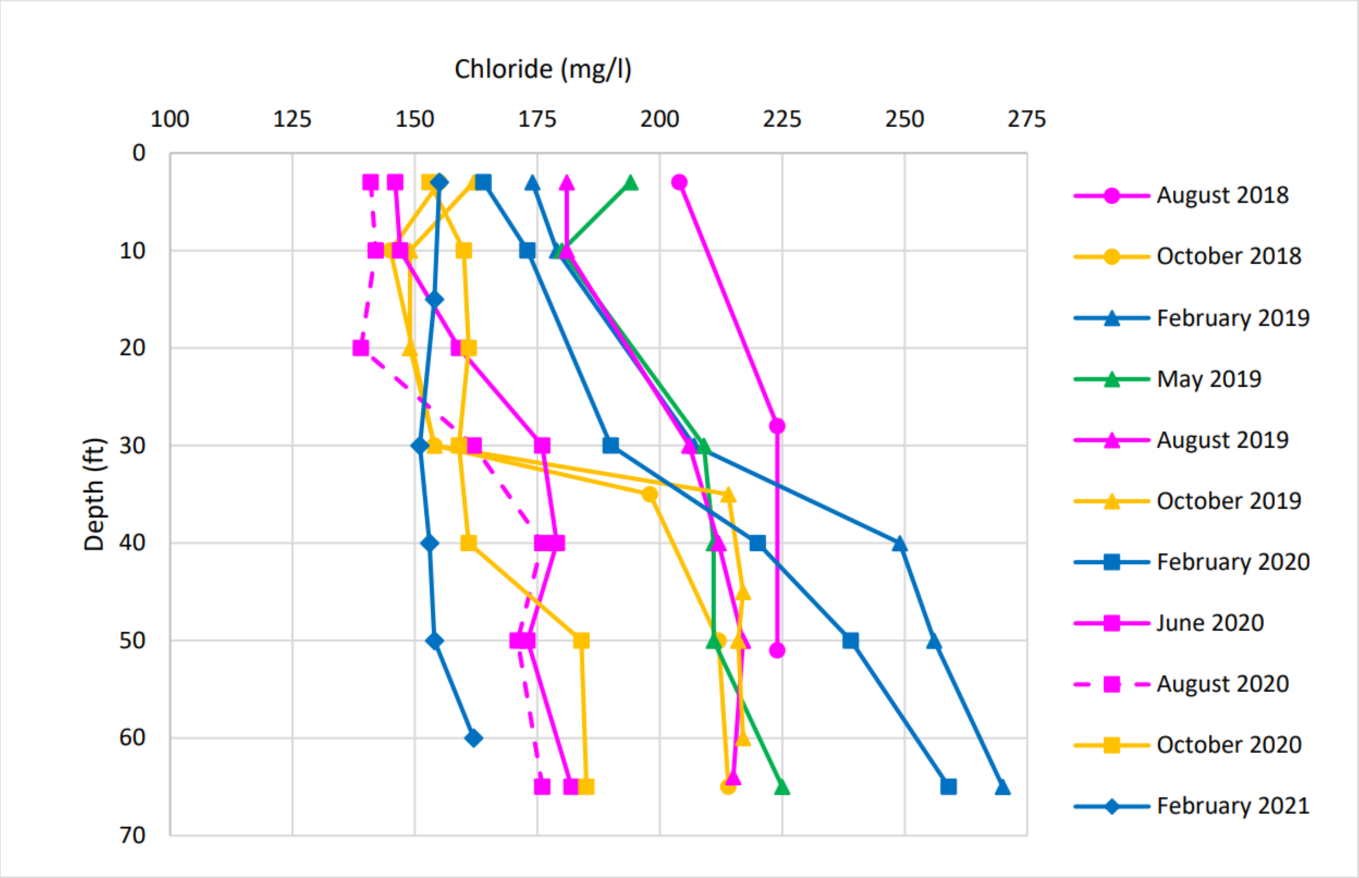


Figure 3.18 (Continued)

Little Muskego Lake, Waukesha County



5.4 – Seasonality

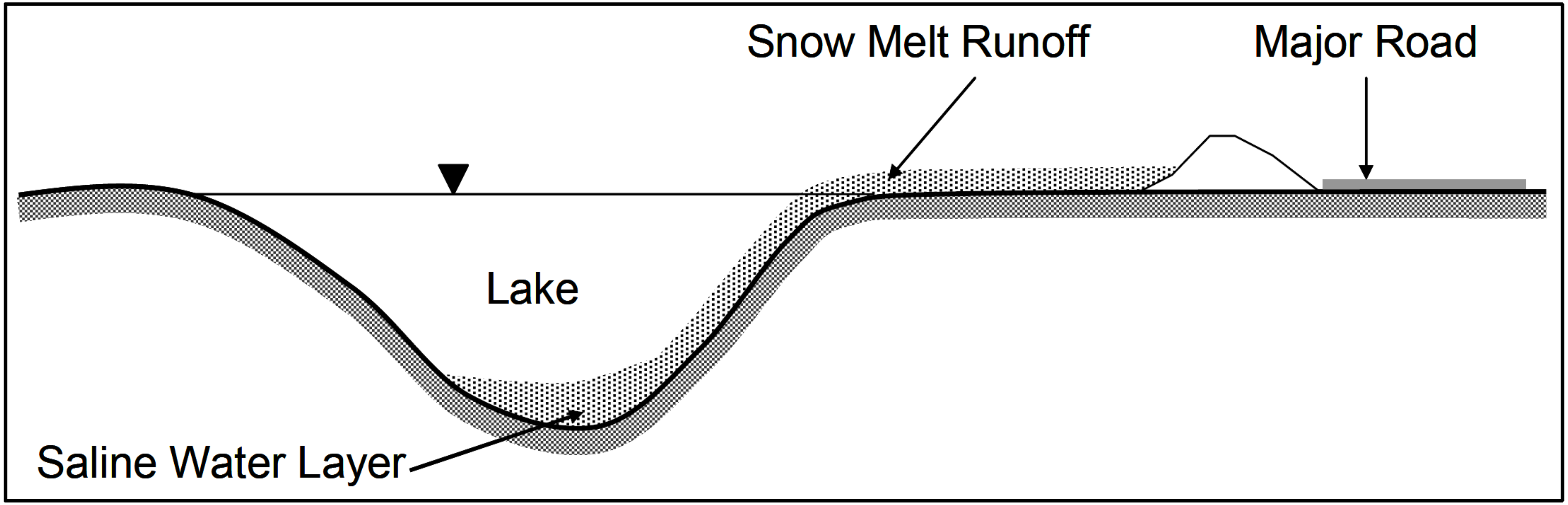
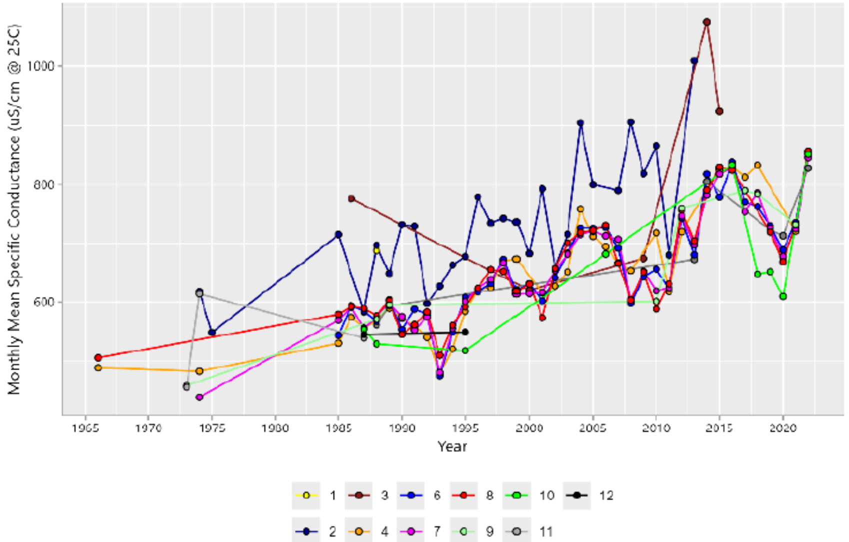


Figure 2. Schematic of a saline water intrusion into a lake.

Source: Eric Novotny, Dan Murphy and Heinz Stefan, Road Salt Effects on the Water Quality of Lakes, in the Twin Cities Metropolitan Area, ST. Anthony Falls Laboratory, Engineering, Environmental and Geophysical Fluid Dynamics, Project Report No. 505, Prepared for Local Road Research Board (LRRB), Minnesota Department of Transportation, St. Paul, Minnesota, December, 2007

5.4 – Seasonality

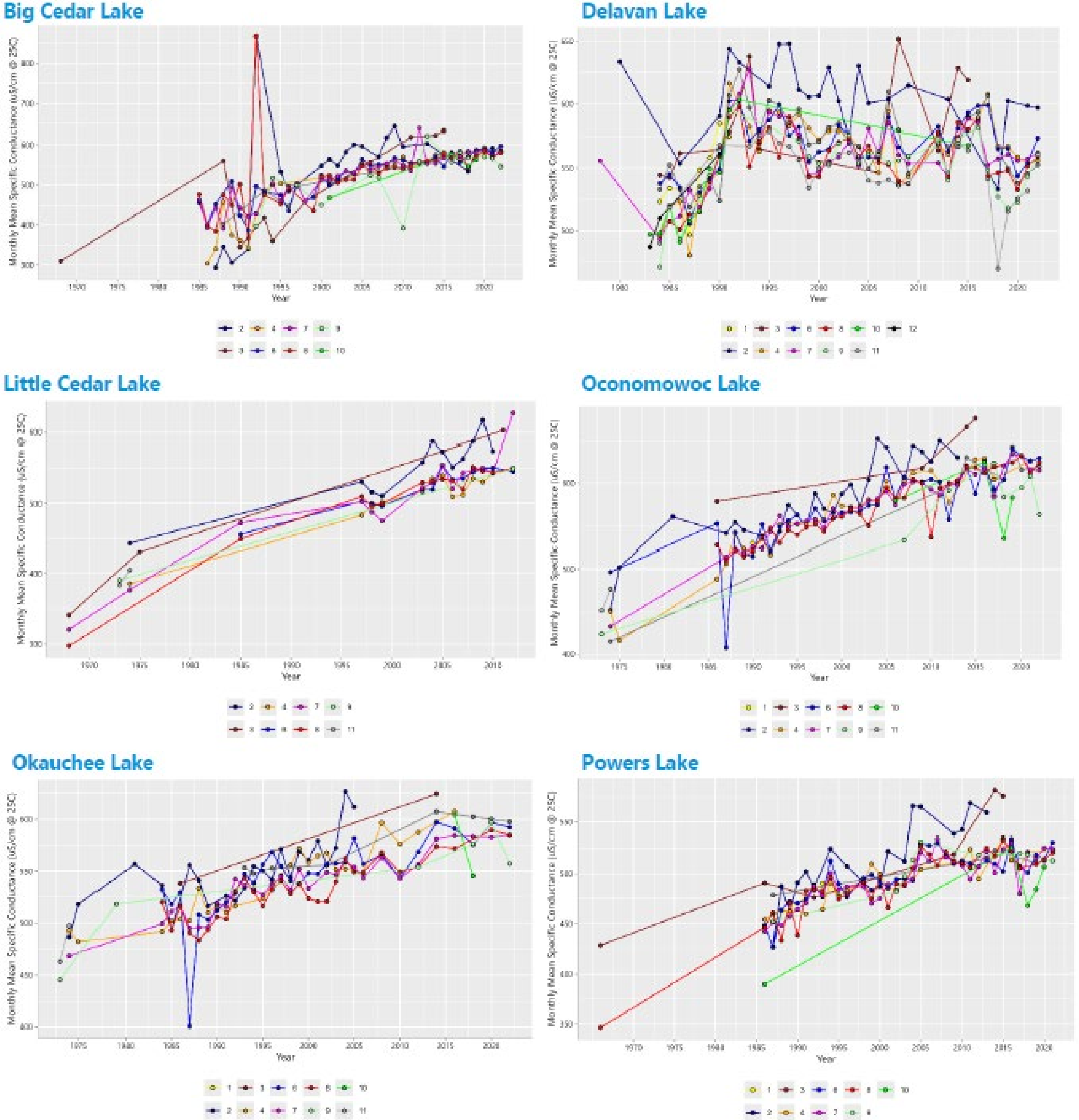
Wind Lake



- **February and March had the highest specific conductance levels compared to all other months; this is hypothesized to be caused by deicing activities.**
- **In general, increasing trends over time, with exception in Delavan Lake**
- **Lack of variability (compared to stream data) suggests influence of residence time dilution effects and increasing chloride concentrations in shallow groundwater**

Figure 5.20

Monthly Mean Specific Conductance Concentrations by Year on Select Study Lakes: 1960-2022



5.4 – Recent Conditions (2013 through 2022)

Table 5.10
Statistical Models and Results for Chloride Relationship Analysis of Recent Lake Data: 2013 through 2022

Variable	Model Used	Slope	p-value	Significant?	R^2
Categorical Variables					
Lake Type	ANOVA	N/A	0.297	No	N/A
Natural Community	ANOVA	N/A	0.643	No	N/A
Numerical Variables					
Lake Surface Area	Linear Regression	0.007	0.401	No	0.016
Lake Maximum Depth	Linear Regression	0.150	0.580	No	0.007
Osgood Index	Linear Regression	-2.667	0.104	No	0.076
Shoreline Length	Linear Regression	0.708	0.566	No	0.008
Lake Residence Time	Linear Regression	-1.078	0.753	No	0.003
Watershed Size	Linear Regression	-0.001	0.671	No	0.004
Watershed Size: Lake Area	Linear Regression	-0.027	0.507	No	0.010
Percent of Agricultural Lands in Watershed	Linear Regression	-0.794	0.089	No	0.067
Percent of Urban Lands in Watershed	Linear Regression	2.130	< 0.01	Yes	0.451
Percent of Roads and Parking Lots in Watershed	Linear Regression	7.487	< 0.01	Yes	0.461
Percent of Urban Lands 1,000-Feet from Lake	Linear Regression	1.014	< 0.01	Yes	0.144
Percent of Roads and Parking Lots 1,000-Feet from Lake	Linear Regression	5.371	< 0.01	Yes	0.280
Percent of Sewered Lands 1,000-Feet from Lake	Linear Regression	0.996	< 0.01	Yes	0.375
Change in Urban Land Percent Between 1963 and 2015	Linear Regression	2.439	< 0.01	Yes	0.357
Change in Roads and Parking Lots Between 1963 and 2015	Linear Regression	7.286	< 0.01	Yes	0.386

Note: Average chloride concentration for each lake (2013-2022) was the dependent variable in the analysis.

Source: SEWRPC

- The only variables observed to be correlated with changing chloride concentrations were related to changes in percent urban land and/or percent roads and parking lots at the watershed scale and within shoreline (1,000 feet from lake).

5.4 – Recent Conditions (2013 through 2022)

Figure 5.22
Scatterplots of Percent Urban Land Use and Percent Roads and Parking Lots in Lake Watershed by Recent Average Chloride Concentration: 2013 through 2022

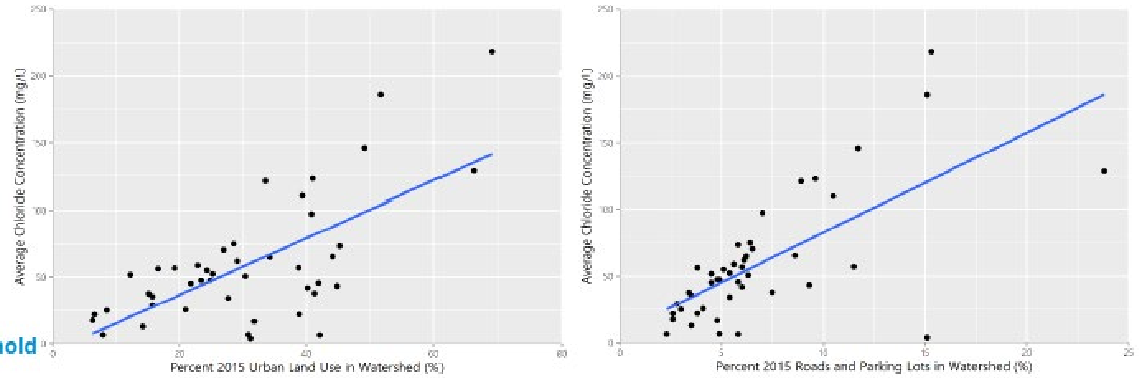
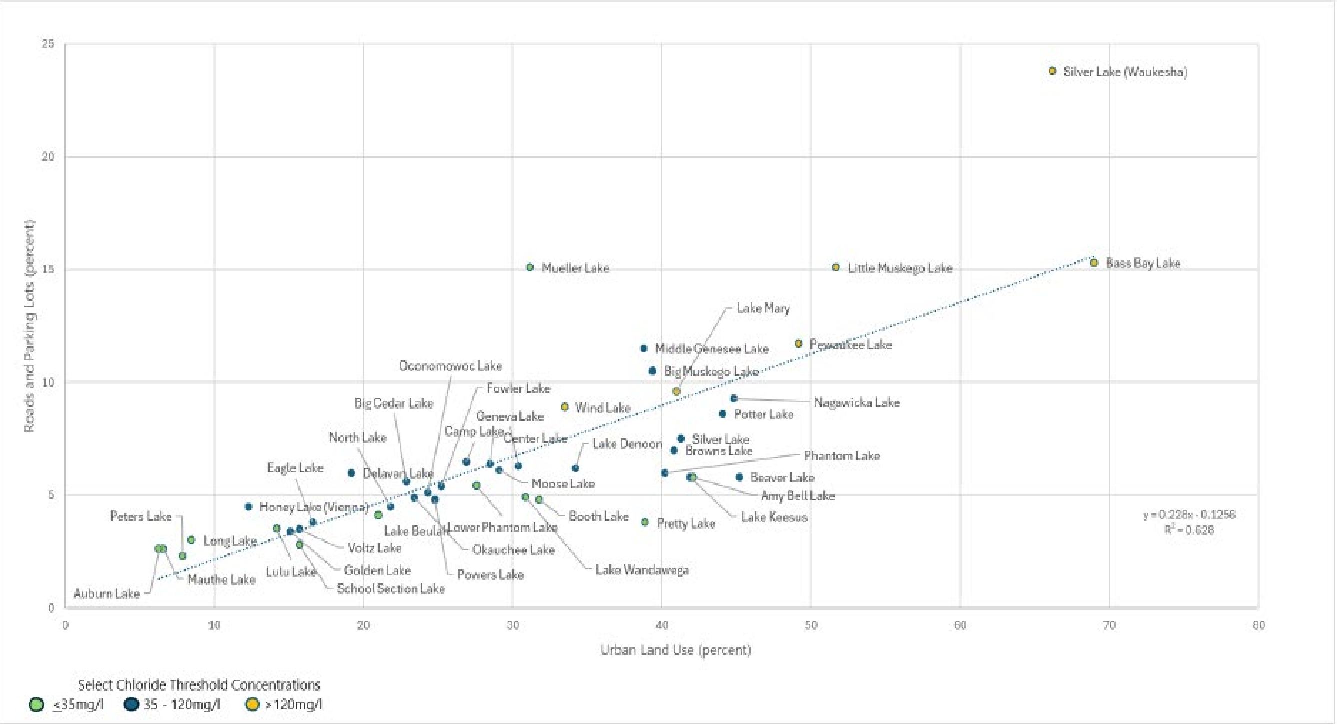


Figure 5.23
Relationship of Watershed Percent Urban Land Use Versus Percent Roads and Parking Lots and Select Mean Lake Chloride Threshold Concentrations: 2013 through 2022

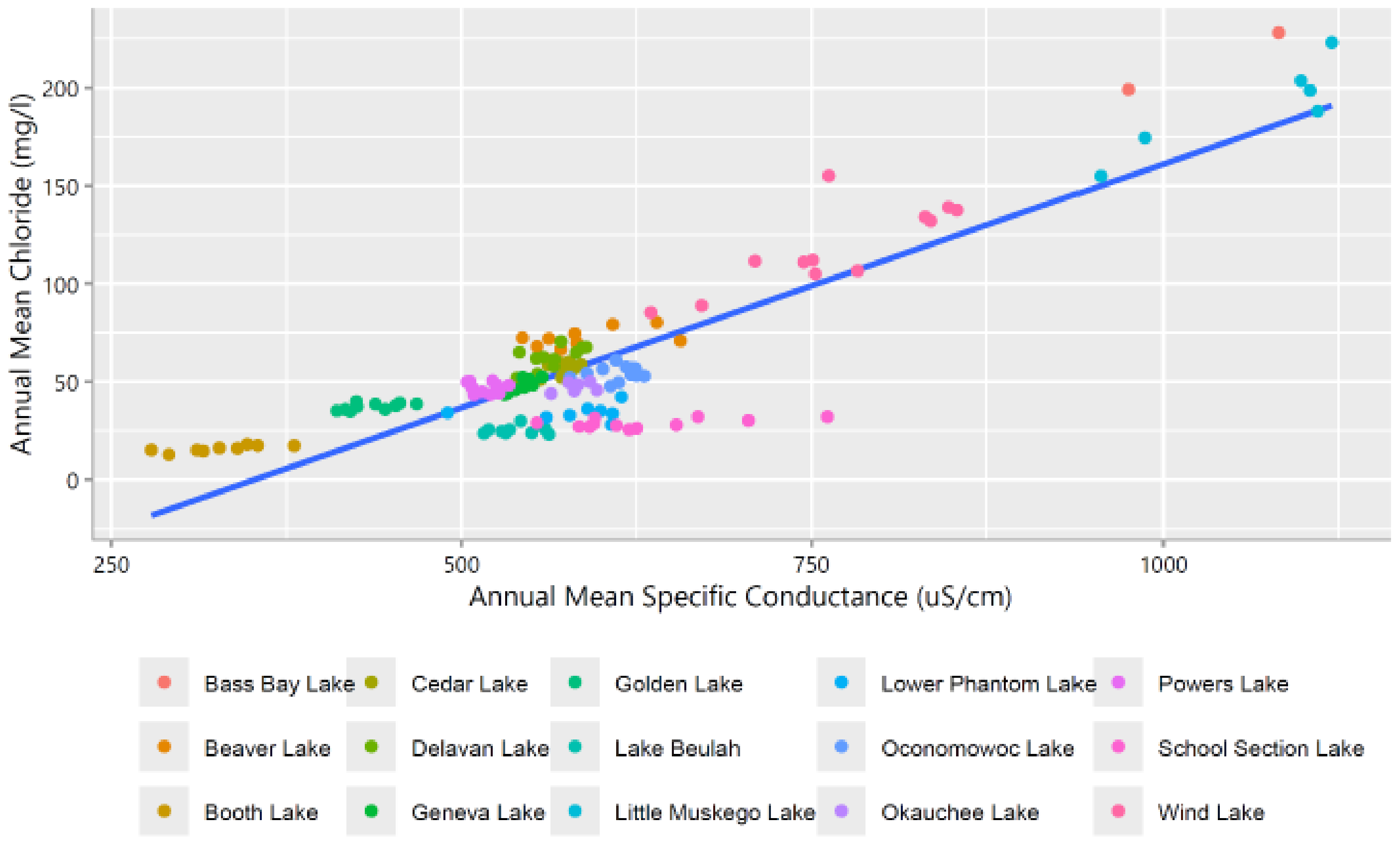


- Lakes within watersheds with greater proportions of urban land had higher mean, minimum, median and maximum chloride concentrations and specific conductance compared to lakes in less urban (i.e. rural lakes) watersheds.

- Lakes within watersheds comprised of at least 40 percent urban land use and/or 7.5 percent roads and parking lots were highly likely to contain the highest chloride toxicity (i.e., worst) levels compared to other less developed watersheds.

5.4 – Recent Conditions (2013 through 2022)

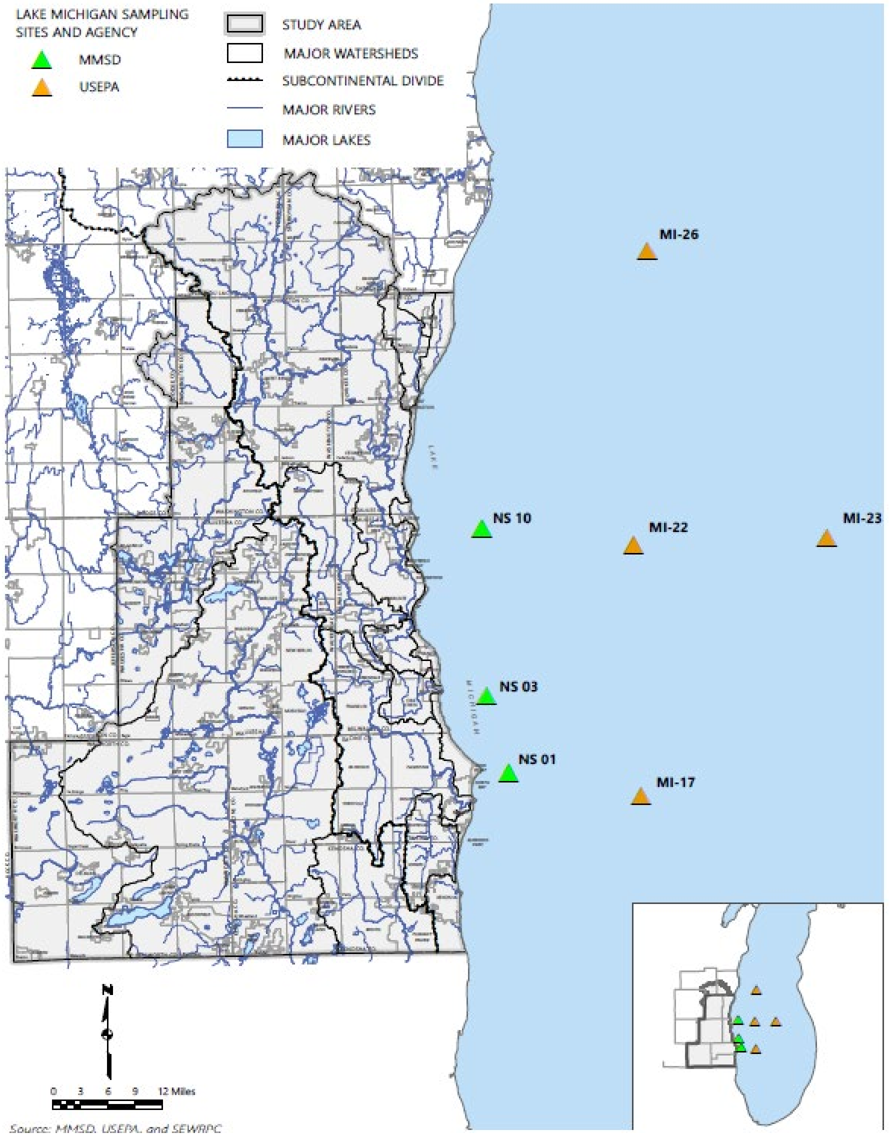
Figure 5.24
Relationship of Paired Specific Conductance and Chloride Concentrations in the Recent Period: 2013-2022



- Demonstrates that there was a significant positive relationship between specific conductance and chloride concentration for these select study area lakes within the recent time period. However, there is not enough paired data to substantiate using the regression equation as a general regional equation and much more paired data would need to be collected in order to verify/refine this relationship.

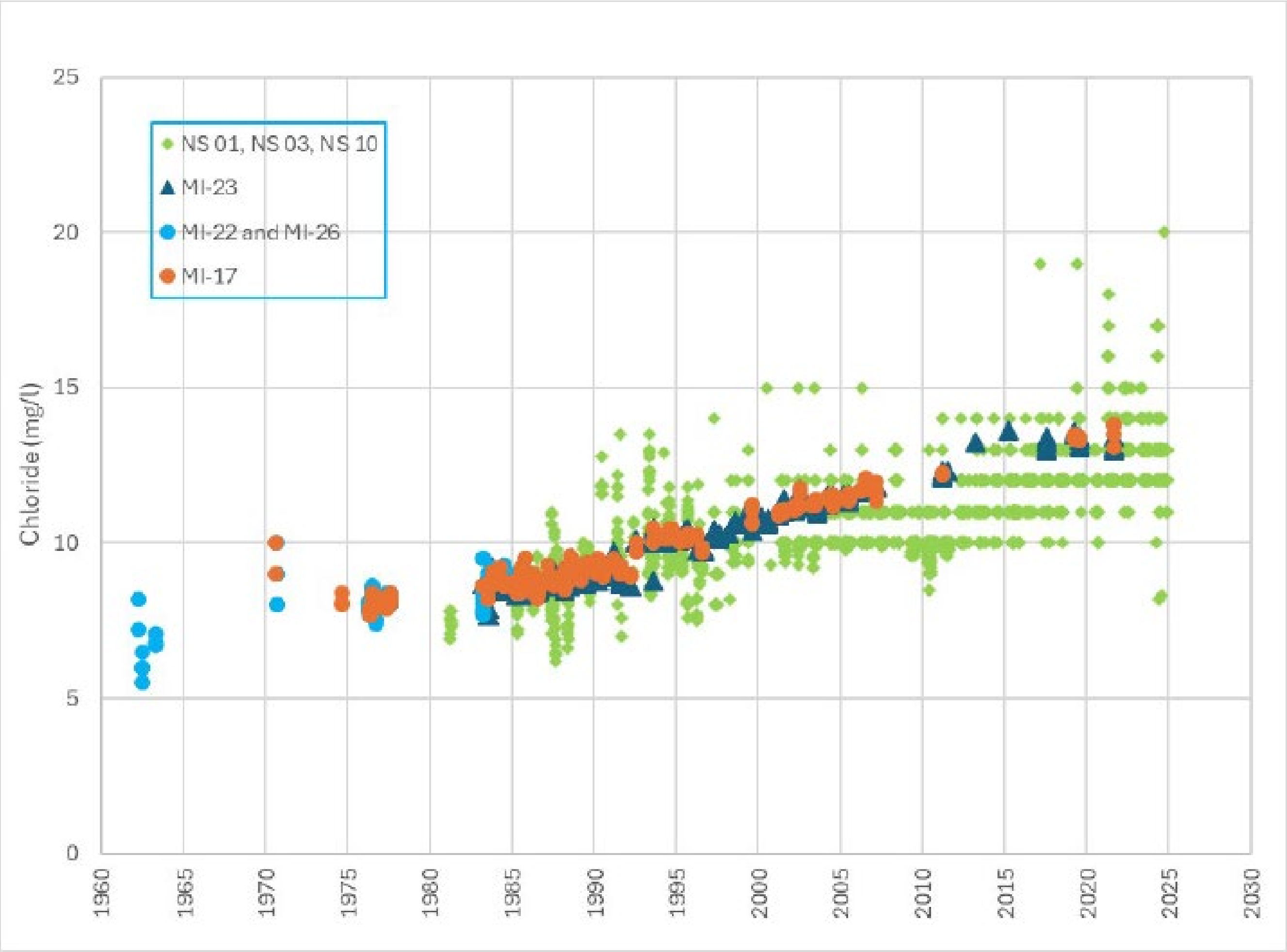
5.5 – Chloride Conditions for Lake Michigan

Map 5.11
Lake Michigan Monitoring Stations with Chloride Samples

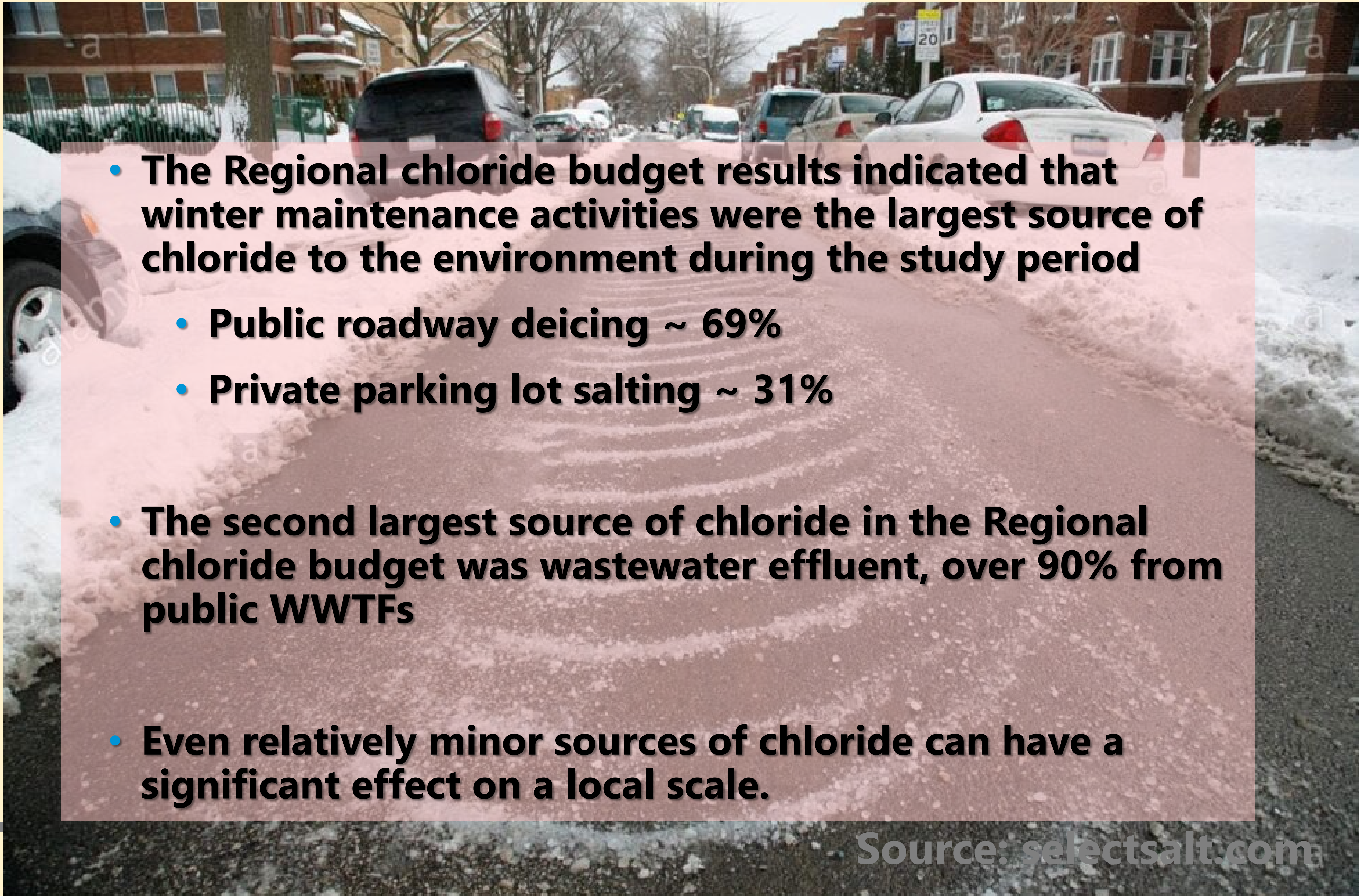


Source: MMSD, USEPA, and SEWRPC

Figure 5.25
Lake Michigan Chloride Levels: 1962-2024



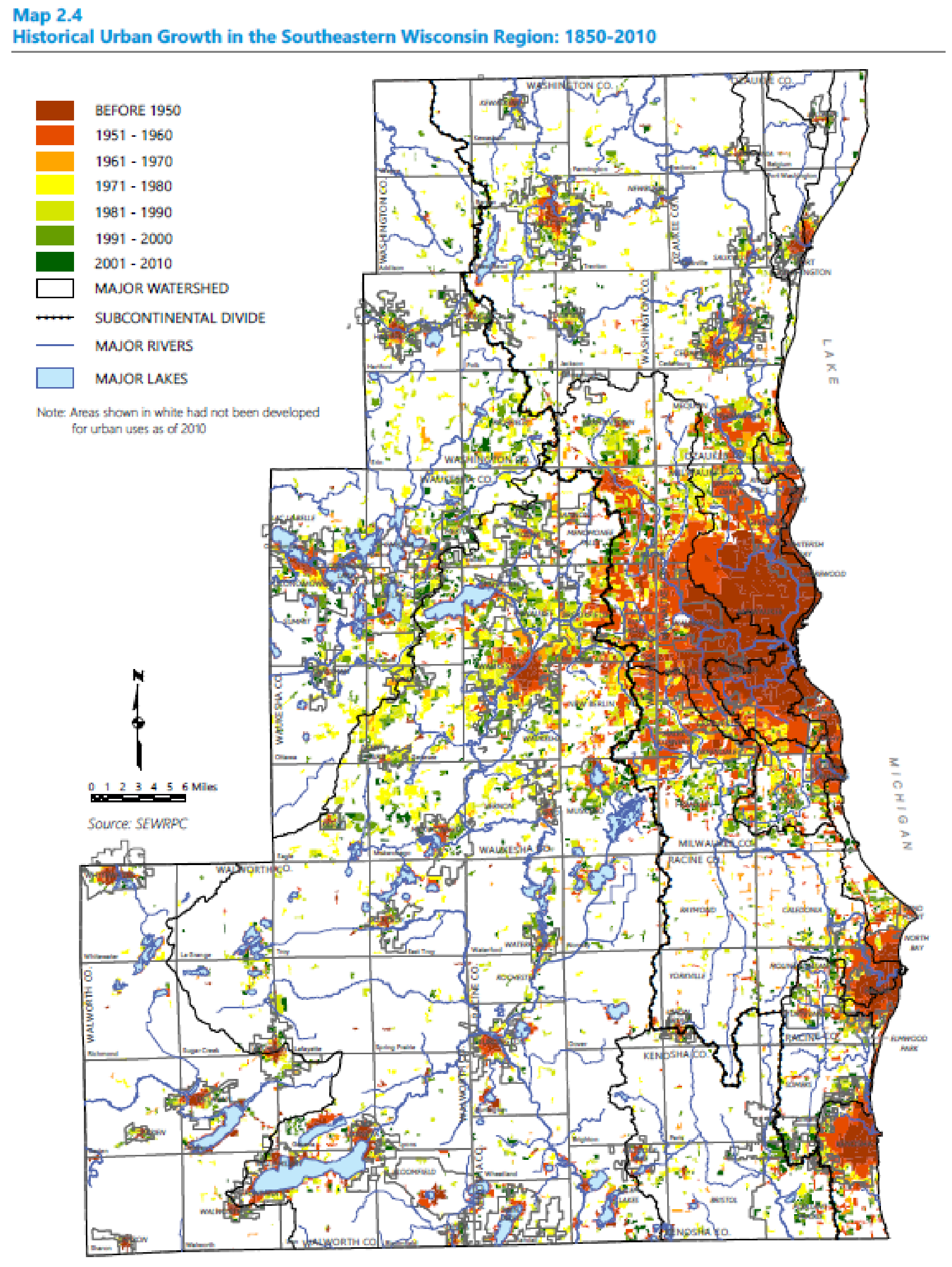
Conclusions TR-65

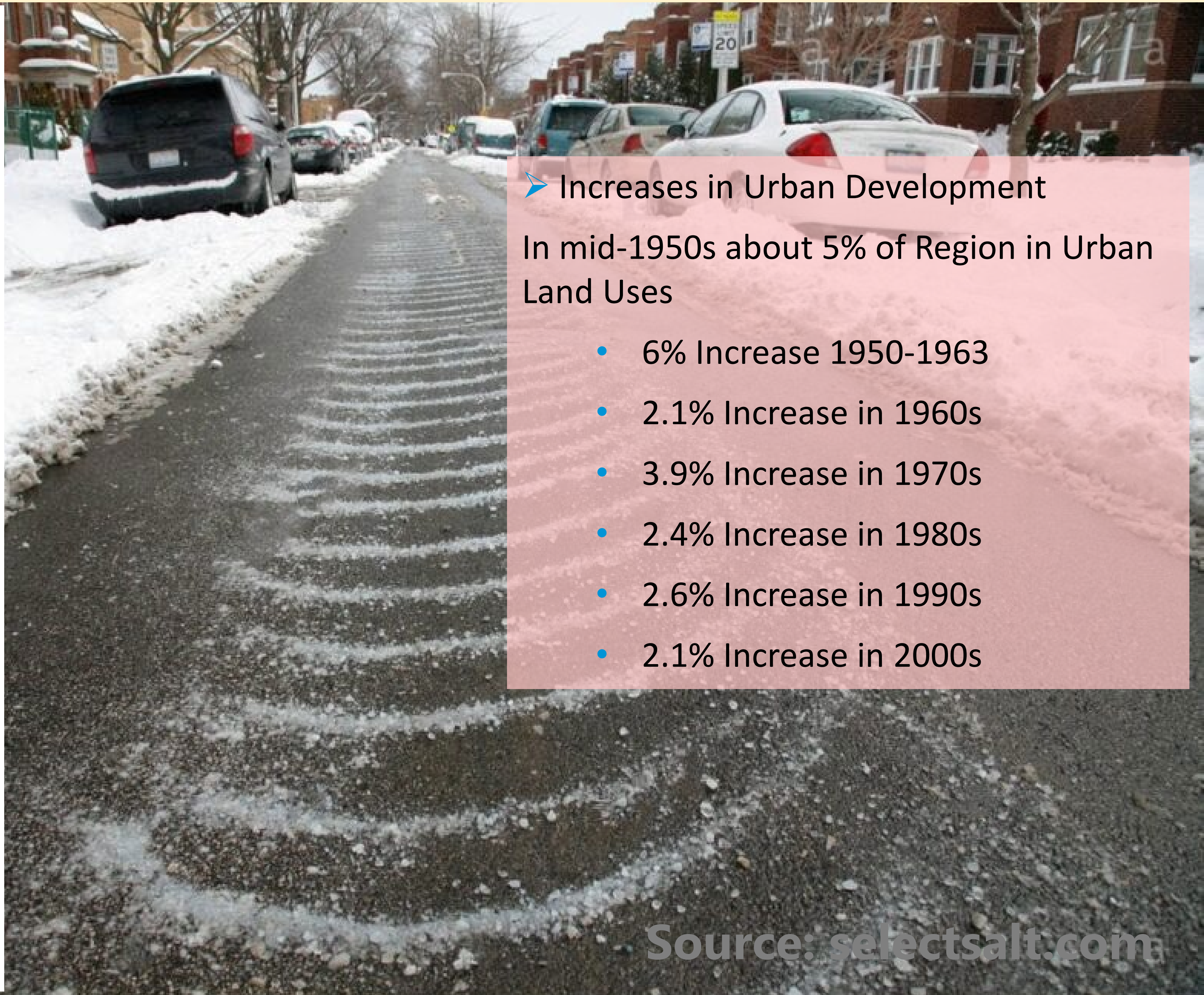


- The Regional chloride budget results indicated that winter maintenance activities were the largest source of chloride to the environment during the study period
  - Public roadway deicing ~ 69%
  - Private parking lot salting ~ 31%
- The second largest source of chloride in the Regional chloride budget was wastewater effluent, over 90% from public WWTFs
- Even relatively minor sources of chloride can have a significant effect on a local scale.

Source: selectsalt.com

Conclusions TR-65 & TR-63





➤ Increases in Urban Development

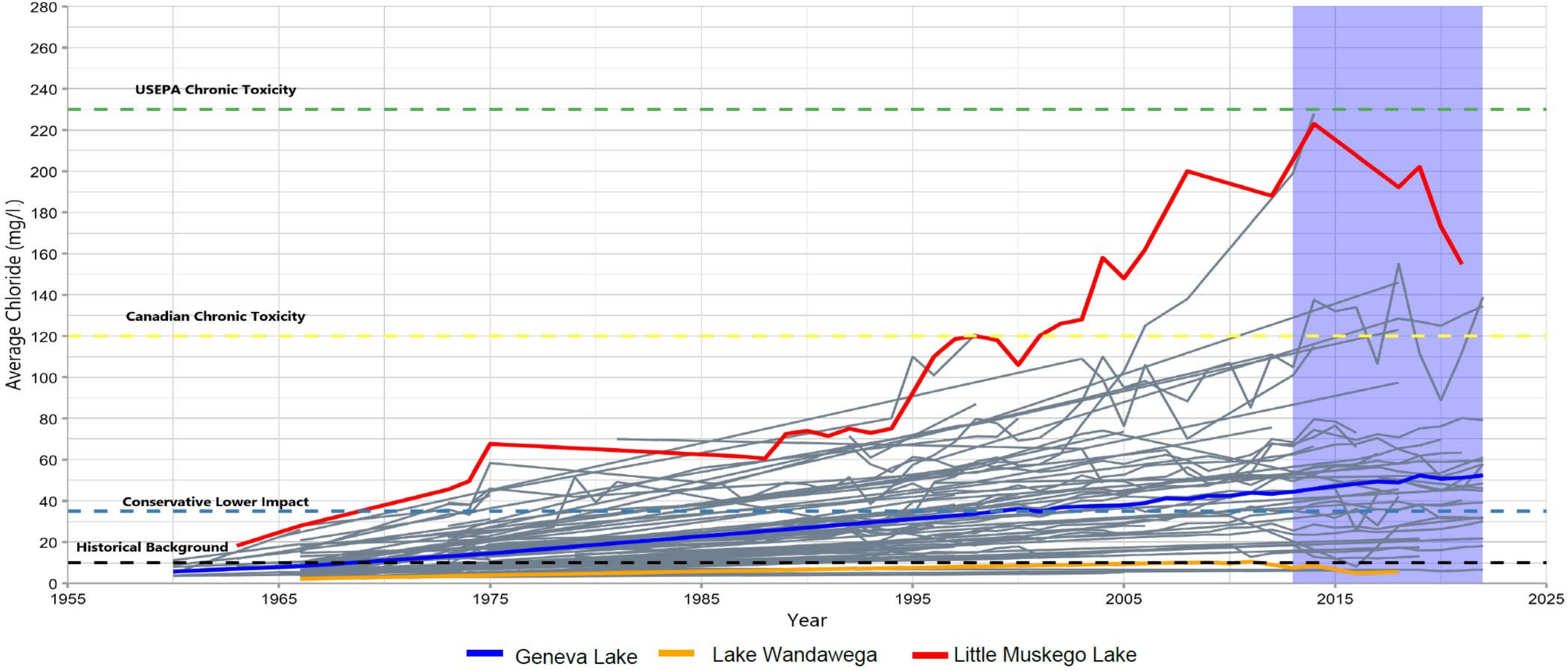
In mid-1950s about 5% of Region in Urban Land Uses

- 6% Increase 1950-1963
- 2.1% Increase in 1960s
- 3.9% Increase in 1970s
- 2.4% Increase in 1980s
- 2.6% Increase in 1990s
- 2.1% Increase in 2000s

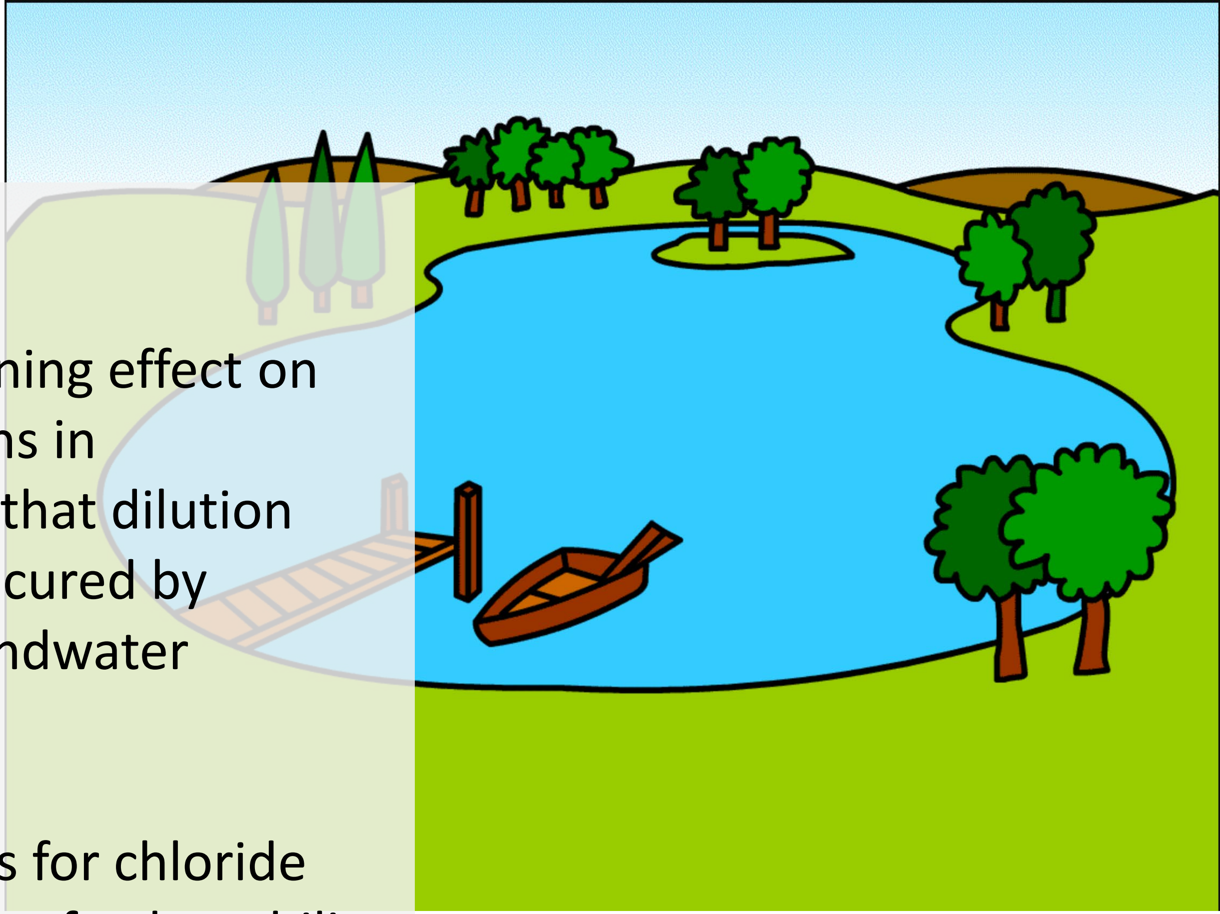
5.6 – Summary

Figure 5.31

Annual Average Chloride Concentrations Among Study Area Lakes Compared to Biological Thresholds: 1960 - 2022



5.6 – Summary



Vulnerability to Chloride Toxicity

- Lakes can have a diluting effect and/or dampening effect on the seasonal oscillations in river chloride concentrations in downstream river reaches and downstream lakes, but that dilution effect was not always obvious and was likely being obscured by increasing chloride concentrations in the shallow groundwater sustaining baseflows.

- Although the Study did not detect any patterns for chloride levels by lake type within the study area lakes, in terms of vulnerability seepage and spring lakes are more susceptible than other lake types, because they have no outlet. Hence, chloride salts have limited ability to be washed out or diluted compared to drainage lakes. In addition, lakes with shorter residence times (high flushing rates) are more vulnerable to chloride toxicity concentrations than lakes with longer residence times.

Questions?

Next Steps

- Comments open on this draft Chapter until November 28, 2025
  - Send to Laura Herrick: lherrick@sewrpc.org

- Next TAC meeting early 2026 to review remaining chapters of TR-66 State of the Art for Chloride Management (public and private deicing, private water softening, agricultural and food processing sources)

Meeting agendas, presentations, and summary notes along with completed reports and preliminary drafts are posted on project website

www.sewrpc.org/chloridestudy

Project Funding Provided By:

U.S. Department of Transportation
Federal Highway Administration

MMSD
PARTNERS FOR A CLEANER ENVIRONMENT

SEWRPC
Serving the counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

WISCONSIN
DEPT. OF NATURAL RESOURCES

Fund for Lake Michigan

Thank You

www.sewrpc.org/chloridestudy

Laura Herrick
Chief Environmental Engineer
lherrick@sewrpc.org
262.953.3224

Thomas Slawski
Chief Biologist
tslawski@sewrpc.org
262.953.3263

SEWRPC.org

/SEWRPC

@SEW_RPC