METROPOLITAN COUNCIL

Memorandum

DATE: March 21, 2025

TO: David Wall, Minnesota Pollution Control Agency

FROM: Hong Wang and Daniel Henely, Met Council Environmental Services Water Resources

SUBJECT: River Nutrient Trend Update (1976 – 2023)

EXECUTIVE SUMMARY

Council staff updated water quality trends for nutrients at three major river monitoring sites in the Twin Cities metro area to support the MPCA's Nutrient Reduction Strategy Program. This update focused on total phosphorus (TP), nitrate plus nitrite (NO_x), and total nitrogen (TN) for the Minnesota River at Jordan and the Mississippi River at Anoka, and at Lock and Dam 3, covering the period from 1976 to 2023. The analysis was completed using the latest version of the USGS R-QWTREND model, released in 2020.

Declining Trends (Improving)

The findings indicate a consistent decline in TP concentrations across all three monitoring sites over the assessment period, with a notable decrease in the last ten years that aligns with the general trend model. At the same time, nitrogen concentrations steadily declined in the Minnesota River at Jordan over the assessment period.

Increasing Trends (Degrading)

Increasing trends for NOx were noted in the Mississippi River at Anoka and at Lock and Dam 3 over the entire assessment period. The trend for TN for the Mississippi River at Anoka also exhibited a continuous increase over the assessment period.

Non-Significant Trends (No Apparent Change)

The model indicates that the trends for NO_x and TN over the last ten years are statistically non-significant at all sites, suggesting minimal changes in concentration. After an initial uptick in TN for the Mississippi River at LD3 from 1976-1980, the remainder of the assessment period (1981-2023) found no significant change.

INTRODUCTION

This memo presents updated long-term trends of total phosphorus (TP), nitrate plus nitrite (NO_x), and total nitrogen (TN) at the selected Twin Cities Metro area river sites. The analysis was performed to support the Minnesota Pollution Control Agency's Nutrient Reduction Strategy Program. In this analysis, the Metropolitan Council Environmental Services staff updated its river nutrient trends completed in 2018 to cover the years from 1976 to 2023. The river sites analyzed include:

- Minnesota River at Jordan
- Mississippi River at Lock and Dam 3
  Mississippi River at Anoka

METHODS

The analysis utilizes the recently released USGS R-Version statistical model, R-QWTREND, officially published in 2020. This software employs a statistical parametric time-series approach designed to account for seasonality, flow-related variability, and complex serial correlation structure to detect long-term trends in flow-adjusted concentrations. Flow-adjusted trends are assessed under conditions of smoothed flow to mitigate the impact of flow variations on concentration levels.

While non-flow-adjusted trends reflect actual river conditions influenced by natural and human factors, flow-adjusted trends allow identification of the influence of pollutant sources, pollution control efforts, and other human activities on water quality over time. The resulting trend shows changes in pollutant concentrations over time, influenced by factors such as point discharge variations, implementation of best management practices (BMPs), stream restoration efforts, or land use changes like urban development.

The statistical significance of combined-trend models and sub-trends of the models is evaluated using calculated probabilities or p-values. In this analysis, trends and trend models are considered statistically significant at a 90% confidence level ($p \leq 0.1$). Selecting the preferred trend model from among several candidates with different trend periods is performed using the generalized likelihood ratio (GLR) test as defined in the R-QWTREND model manual. For this model selection, the significance level for the GLR test p-value is set at 0.01 as recommended by the published methods. If the p-value of the GLR test is less than 0.01, the more complex model was selected. Otherwise, the simpler model with fewer trend periods was selected.

To assist in the MPCA's ten-year progress report on the Nutrient Reduction Program, the period from 2014 to 2023 was incorporated into the preferred trend model to analyze changes in nutrients over the last decade. Conducting the analysis in this way is outside the Council's Standard Operating Procedure and the analysis at the tail ends of the analysis period may be less stable. Therefore, we did not report trends that were not statistically significant for this part of the analysis.

For a more comprehensive understanding of the Met Council's technical methodology for trend analysis using R-QWTREND, please consult the QWTREND manual and the Council's Standard Operating Procedure (SOP) document, which was informed by the R-QWTREND manual and previous trend studies.

RESULTS

Minnesota River at Jordan

Total Phosphorus

Based on this analysis, long-term changes in TP concentration in the Minnesota River at Jordan can be best represented by a one-trend model ($p = 4.8x10^{-12}$) over the assessment period of 1979 to 2023 (Table 1 and Figure 1). The analysis shows a consistent decrease in TP concentration over this assessment period, indicating a sustained improvement in recent decades. During the last ten years, TP concentration decreased by about 12.4%.

Table 1: Statistical Trends for TP Concentration in the Minnesota River at Jordan

Trend Period	Change in Conc. (%)	*p*	Trend
1979 – 2023	-35.4%	0	↓
Last 10 years (2014 – 2023)	-12.4%	0.059	↓

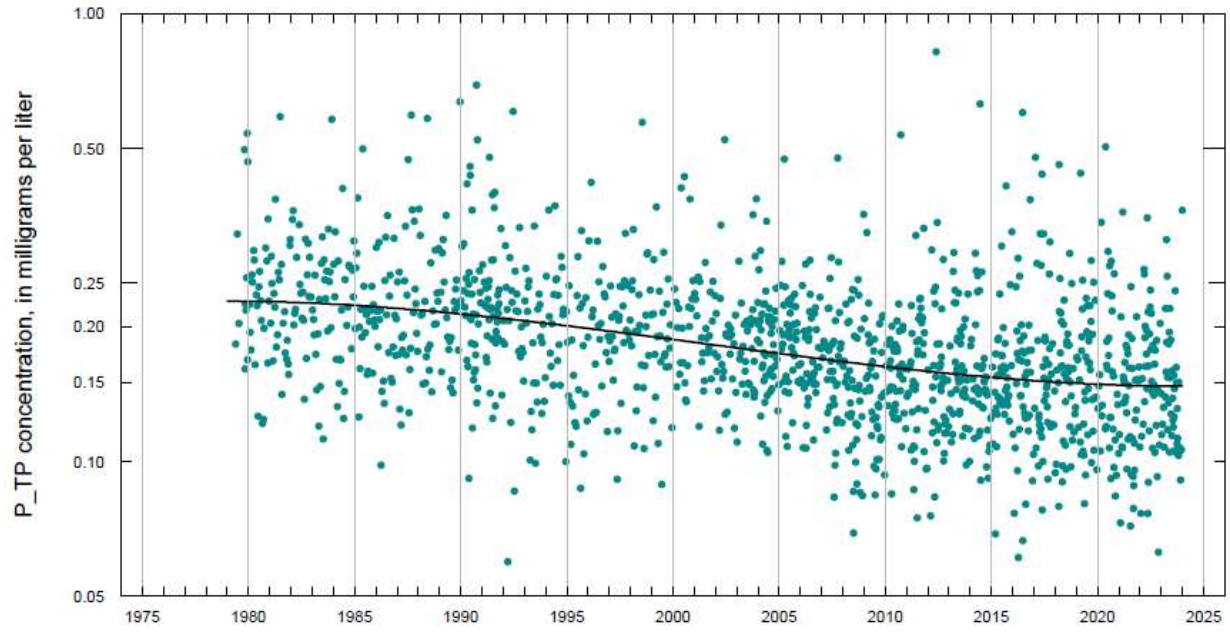

Figure 1: The Best Representative Long-term Trends for TP Concentration in the Minnesota River at Jordan

NOx

Long-term changes in NO_x (NO_2+NO_3) concentration in the Minnesota River at Jordan can be best represented by a one-trend model (p = 0.0007) over the assessment period of 1979 to 2023 (Table 2 and Figure 2). The analysis shows a consistent decrease in NOx concentration over this assessment period, indicating a sustained improvement in recent decades. Looking at the last ten years, the fitted model suggests a possible minor decrease in NOx concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 2: Statistical Trends for NOx Concentration in the Minnesota River at Jordan

Trend Period	Change in Conc. (%)	*p*	Trend
1979 – 2023	-29.7%	0.0046	↓
Last 10 years (2014 – 2023)	-	0.44	NT

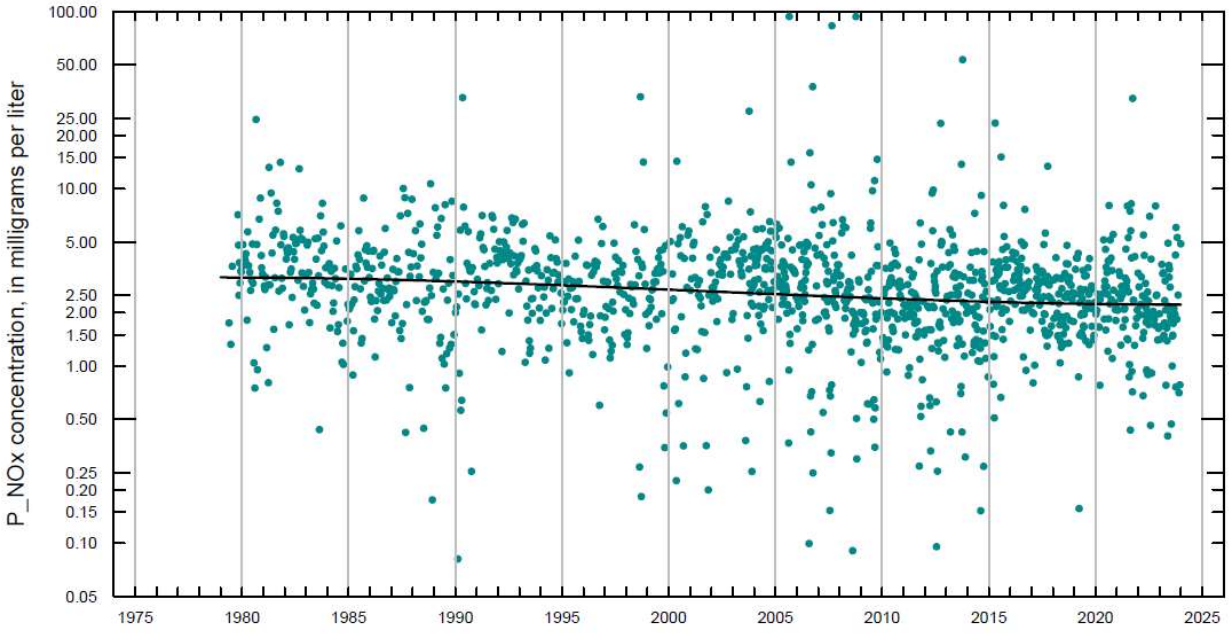

Figure 2: The Best Representative Long-term Trends for NOx Concentration in the Minnesota River at Jordan

Total Nitrogen

Long-term changes in TN concentration in the Minnesota River at Jordan can be best represented by a one-trend model (p = 0.0039) over the assessment period of 1980 to 2023 (Table 3 and Figure 3). The analysis shows a consistent decrease in TN concentration over this assessment period, indicating a sustained improvement in recent decades. Looking at the last ten years, the fitted model suggests a possible minor decrease in TN concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 3: Statistical Trends for NOx Concentration in the Minnesota River at Jordan

Trend Period	Change in Conc. (%)	*p*	Trend
1980 – 2023	-20.6%	0.01	↓
Last 10 years (2014 – 2023)	-	0.34	NT

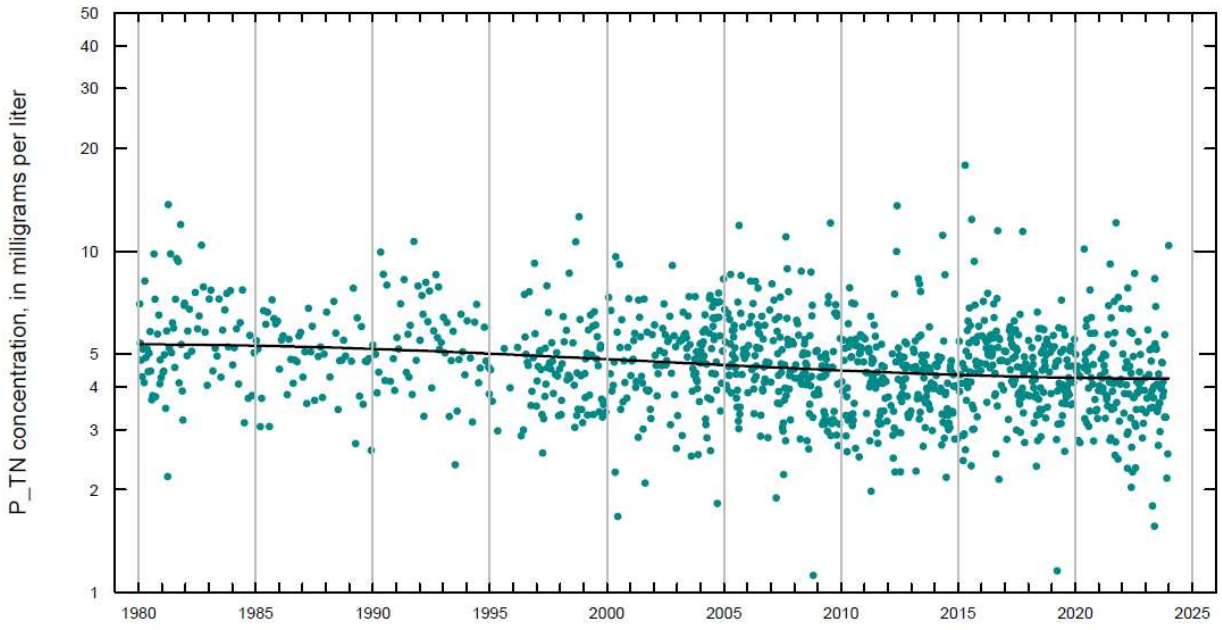

Figure 3: The Best Representative Long-term Trends for TN Concentration in the Minnesota River at Jordan

Mississippi River at Anoka

Total Phosphorus

Long-term changes in TP concentration in the Mississippi River at Anoka can be best represented by a two-trend model (p = 0) over the assessment period of 1976 to 2023 (Table 4 and Figure 4). TP concentration decreased from 1976 to 2018, followed by a sharp decline from 2019 to 2023. During the last ten years, TP concentration decreased by 41.2%.

Table 4: Statistical Trends for TP Concentration in the Mississippi River at Anoka

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 2018	-35.3%	0.00001	↓
2019 – 2023	-49.0%	0.00003	↓
Last 10 years (2014 – 2023)	-41.2%	0.00003	↓

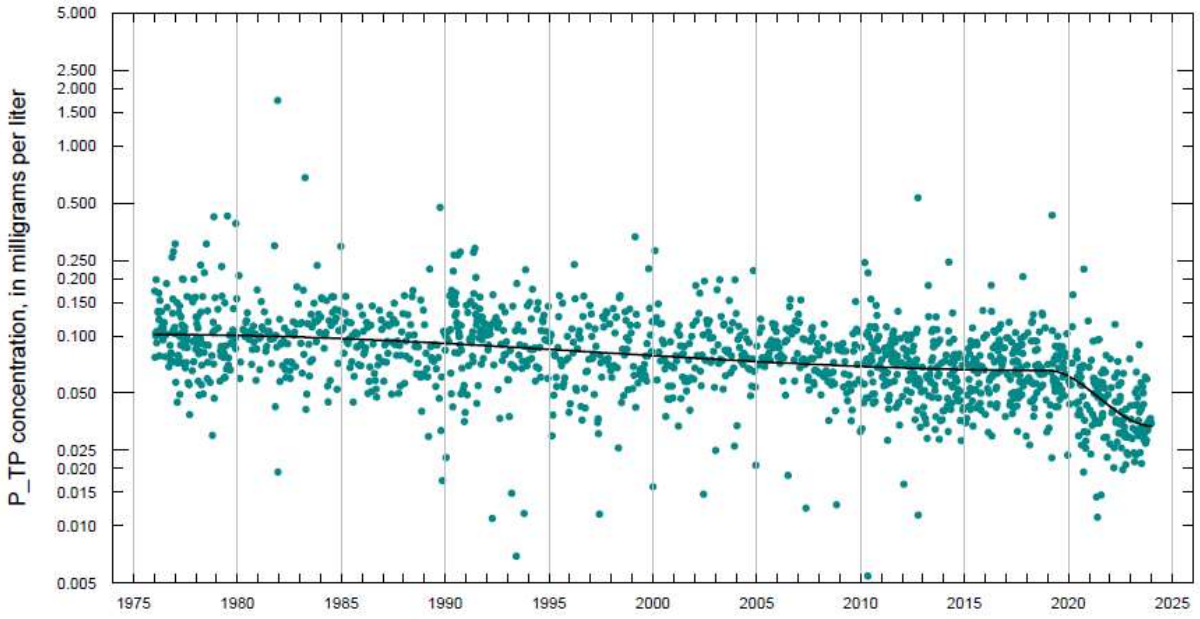

Figure 4: The Best Representative Long-term Trends for TP Concentration in the Mississippi River at Anoka

NO_x

Long-term changes in NO_x (NO_2+NO_3) concentration in the Mississippi River at Anoka can be best represented by a one-trend model ($p = 2.4x10^{-5}$) over the assessment period of 1976 to 2023 (Table 5 and Figure 5). NO_x concentration increased gradually over the assessment period of 1976 to 2023. Looking at the last ten years, the fitted model suggests a possible minor increase in NOx concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 5: Statistical Trends for NOx Concentration in the Mississippi River at Anoka

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 2023	67.0%	0.00085	↑
Last 10 years (2014 – 2023)	-	0.16	NT

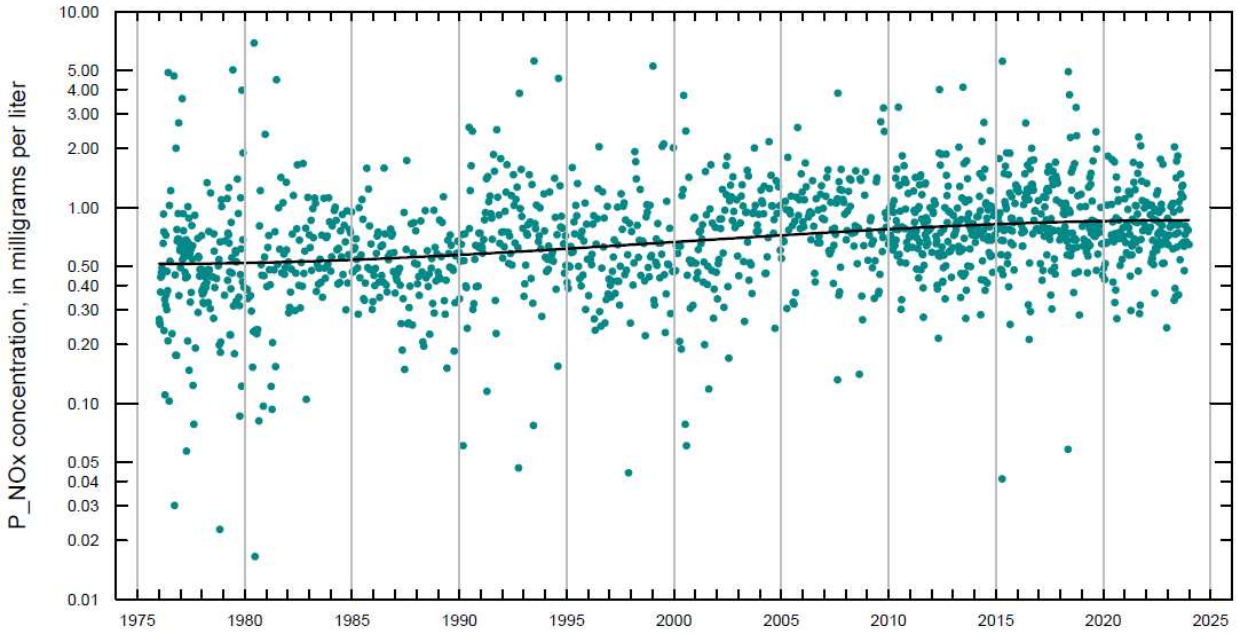

Figure 5: The Best Representative Long-term Trends for NOx Concentration in the Mississippi River at Anoka

Total Nitrogen

Long-term changes in TN concentration in the Mississippi River at Anoka can be best represented by a one-trend model ($p = 2.3x10^{-5}$) over the assessment period of 1976 to 2023 (Table 6 and Figure 6). TN concentration increased gradually from 1976 to 2023 over the assessment period of 1976 to 2023. Looking at the last ten years, the fitted model suggests a possible minor increase in TN concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 6: Statistical Trends for TN Concentration in the Mississippi River at Anoka

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 2023	66.4%	0.00085	↑
Last 10 years (2022 – 2023)	--	0.14	NT

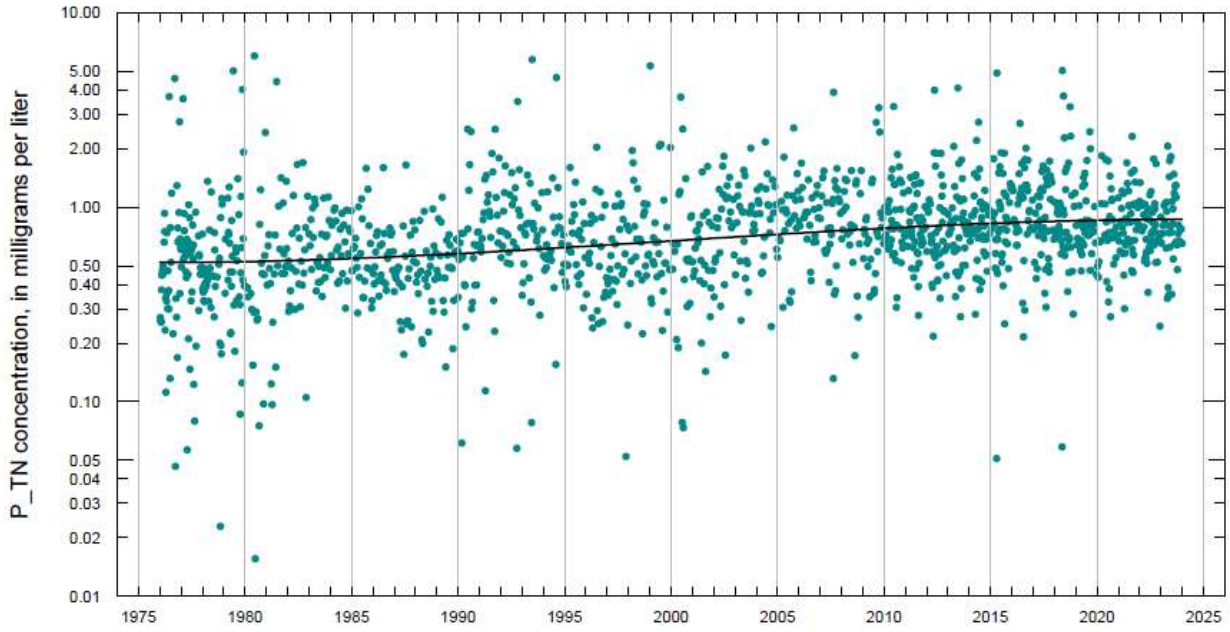

Figure 6: The Best Representative Long-term Trends for TN Concentration in the Mississippi River at Anoka

Mississippi River at Lock and Dam 3

Total Phosphorus

Long-term changes in TP concentration in the Mississippi River at Lock and Dam 3 can be best represented by a two-trend model (p = 0) over the assessment period of 1976 to 2023 (Table 7 and Figure 7). TP concentration did not exhibit a statistically significant trend from 1976 to 1987, followed by a gradual decrease from 1988 to 2023. The statistically non-significant trend suggests a minimal or negligible change in the TP concentration. The results indicate a sustained improvement in water quality in the Mississippi River at Lock and Dam 3 over the past decades. During the last ten years, TP concentration decreased by 17.1%.

Table 7: Statistical Trend for TP Concentration in the Mississippi River at Lock and Dam 3

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 1987	10.2%	0.13	NT
1988 – 2023	-47%	0	↓
Last 10 years (2014 – 2023)	-17.1%	0.0066	↓

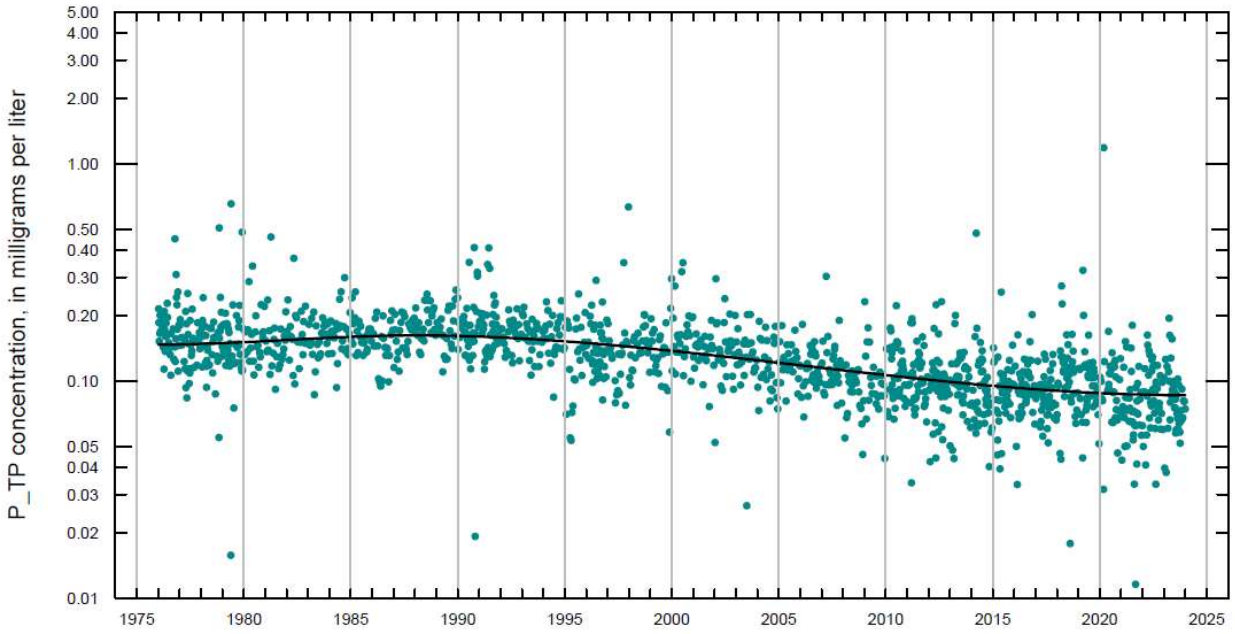

Figure 7: The Best Representative Long-term Trends for TP Concentration in the Mississippi River at Lock and Dam 3

NO_x

Long-term changes in NO_x (NO_2+NO_3) concentration in the Mississippi River at Lock and Dam 3 can be best represented by a two-trend model ($p = 1.68x10^{-9}$) over the assessment period of 1976 to 2023 (Table 8 and Figure 8). NO_x concentration experienced a significant rise from 1976 to 1980, and then a gradual rise from 1981 to 2023. Looking at the last ten years, the fitted model suggests a possible minor increase in NOx concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 8: Statistical Trends for NOx Concentration in the Mississippi River at Lock and Dam 3

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 1980	161.9%	0.00005	⬆
1981 – 2023	24.3%	0.018	⬆
Last 10 years (2014 – 2023)	--	0.50	NT

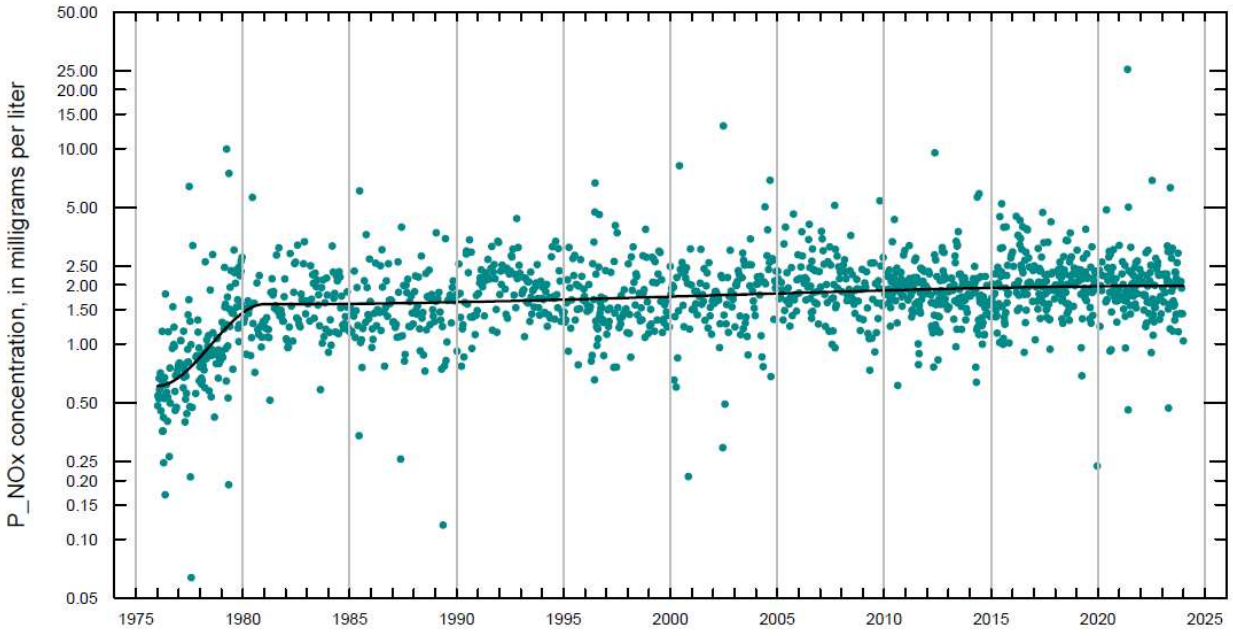

Figure 8: The Best Representative Long-term Trends for NOx Concentration in the Mississippi River at Lock and Dam 3

Total Nitrogen

Long-term changes in TN concentration in the Mississippi River at Lock and Dam 3 can be best represented by a two-trend model (p = 0.094) over the assessment period of 1976 to 2023 (Table 9 and Figure 9). TN concentration experienced a significant rise from 1976 to 1980, followed by a statistically non-significant trend from 1981 to 2023. Looking at the last ten years, the fitted model suggests a negligible change in TN concentrations; however, this was not found to be a statistically significant change. Trend results for this period were not reported due to the lack of statistical significance.

Table 9: Statistical Trends for TN Concentration in the Mississippi River at Lock and Dam 3

Trend Period	Change in Conc. (%)	*p*	Trend
1976 – 1980	28.3%	0.045	↑
1981– 2023	-2.1%	0.72	NT
Last 10 years (2014 – 2023)	-	0.37	NT

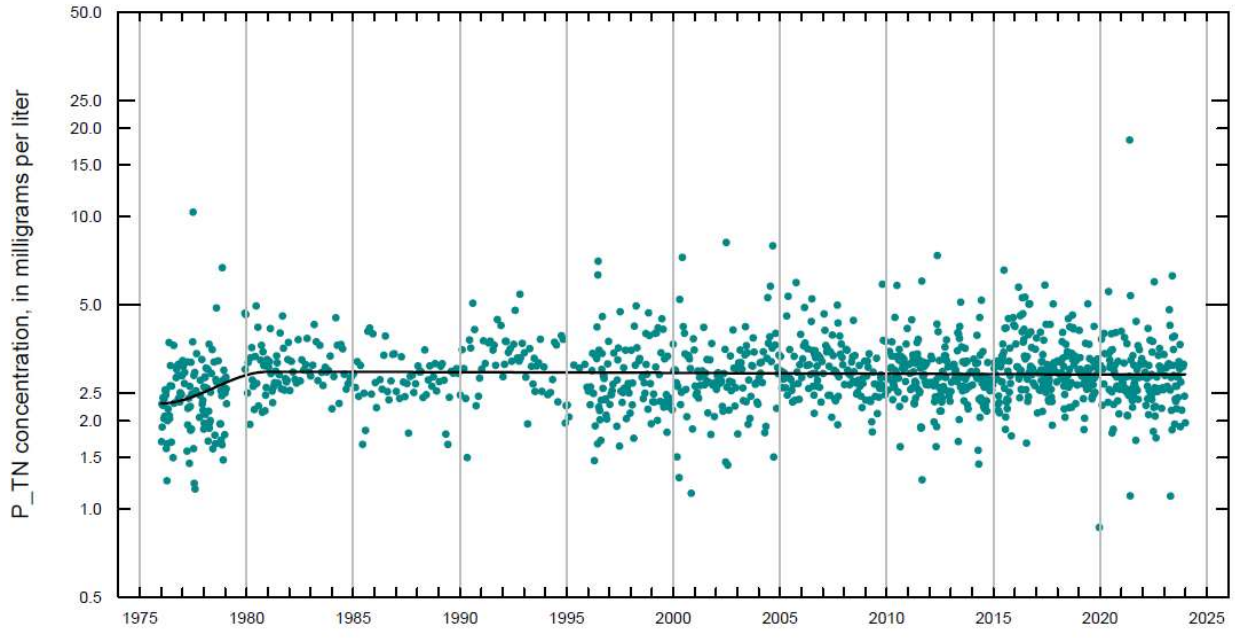

Figure 9: The Best Representative Long-term Trends for TN Concentration in the Mississippi River at Lock and Dam 3