# Assessing Water Quality: Varied Approaches to Measure Change and Show Nutrient Reduction Progress

## Background

This document provides summary level outcomes and information reported by four recent studies of the Mississippi/Atchafalaya River Basin, or MARB; thus, this document does not provide a detailed description of the complexity of assessing water quality trends or the overall status of water quality within the MARB. Each of the four studies provides insight to the Hypoxia Task Force and to the federal agencies, states and Tribes that work to improve water quality and reduce nutrient pollution across the MARB.

While nutrients play a critical role in the biodiversity and healthy functioning of aquatic ecosystems, excess nutrients in waterways are pollutants that can degrade water quality negatively impacting surrounding ecosystems and communities. Managing and reducing nutrient pollution is a major challenge for resource managers: there are many drivers that impact water quality and ecological responses to restoration efforts, including human activities, land use, catchment geology and climatic factors. These drivers can vary significantly across geographic areas and present pressures at various magnitudes across watersheds.

Determining whether water quality in a given area is getting better or worse may appear to be a straightforward question to answer, but it can be very complex. Organizations try to answer this question by quantifying contaminant trends at various scales using several statistical and scientific methods.

Many study factors can contribute to differences in estimated water quality trends, including study design, period of record, water quality monitoring frequency, sampling methods, laboratory analytical methods, data analyses, regional weather patterns and geographic location. Organizations typically decide these study factors based on central questions they are seeking to answer and hard decisions about resources. When studies are designed with different objectives and collect data over different timescales, it may mean that the data cannot be readily compared across studies.

For example, a study that employs a statistical survey method is aimed at sampling a random selection of waters representing an area of interest—such as a state—to draw unbiased estimates of the condition of all waters of the same type within the designated area. In another example, a study that employs targeted monitoring is aimed at targeting specific waters of interest or with known water quality issues. Targeted monitoring is used to provide information needed to support management decisions at watershed and local scales for only those individual waters monitored; this information should not be extrapolated to the larger area, such as waters of an entire state. These are just two examples; there are many variations of central questions an organization may be asking and the study factors, including the sampling design, period of record, methodology approach and data analyzation, will vary depending on that question.

How studies measure and report nutrient data can be unique to each study. Study objectives vary; for example, studies may measure nutrients in different forms (e.g., total nitrogen, nitrate, total phosphorus, orthophosphate, etc.) or use various sampling and analytical methods during the collection and processing of samples—this makes it difficult to compare across studies.

Some studies report nutrient data as concentrations (i.e., the amount of nutrient(s) in a defined volume of water at a given sample location when the sample was collected), while others report the load (evaluation of the mass of nutrients moving downstream within a certain period) or flow-normalized load. Flow-normalization is based on a method that estimates nutrient loads while minimizing the effects of streamflow discharge driven by year-to-year precipitation variability.

Evaluating flow-normalized loads helps to provide a clearer picture of trends in the data and reflect impacts of conservation in the respective watershed.

Other important factors influencing water quality trends include a study's period of record and the watershed size at which the study was conducted. A trend between one set of years, e.g., 1985 and 2022, is very likely to be different than a trend for the same parameter at the same location between a different set of years, e.g., 2010-2020. For example, trends can differ in their directional change (increasing/decreasing/no trend) and the degree at which a trend is directionally changing, or rate of change. Assessing a portion of data within a longer trend record is also likely to provide different outcomes in terms of the trend direction and the rate at which the trend is changing. As it takes time for water quality to show improvement following restoration actions—this is referred to as a 'lag time' —an extended period of record is often essential in documenting water quality trends. Additionally, studies conducted at a smaller watershed size may see a directional change in a water quality trend at a faster rate than a study conducted at larger scales. Effective trend analyses occur at a fixed location, use consistent methodology, have few data gaps and occur over longer periods of record to account for seasonal and other environmental changes that may be impacting the water quality response.

Additional environmental factors may impact water quality, complicating the ability to measure water quality change. For example, known as "legacy nutrients," pre-existing nutrients accumulated in the soil or other environmental media from previous years, or even decades, can mobilize and have the potential to act as a continual nutrient source, masking the effects of conservation efforts on water quality improvement. The hydrologic pathway of nutrient delivery to the monitored location may also impact water quality trends. For example, nutrients traveling through groundwater may take years to decades to reach a monitored location on a river, while nutrients traveling via overland flow or through tile-drain systems would take much less time (e.g., minutes, hours, weeks, months). These four studies do not assess all potential environmental factors that may impact water quality but do provide valuable insights to trends as described by the included study factors.

## Mississippi/Atchafalaya River Basin Water Quality Findings – What Do They All Mean for Resource Managers?

The Hypoxia Task Force recognizes the need to consider data from more than one study, while staying mindful of the challenge of using multiple reports as part of a multi-tiered approach to evaluate progress towards the goals of the Gulf Hypoxia Action Plan.

## What Questions do the Reports Aim to Answer?

Four recently published reports answer questions centered around water quality trends in the MARB. The data in these reports provide different pictures of the complex issues surrounding water quality because the reports' central questions—and thus the study factors employed—are different. While recognizing the studies asked different questions and are not directly comparable, each of these reports provides valuable information on progress towards large-scale watershed improvement, expressed in the authors' own ways to meet their needs. A more detailed summary of information found in the four reports is offered in the Appendix.

Table 1. Summary of the objectives and key findings across the four reports.

| Report | Period of Record | Data Collection Method | Objective | Key Findings |
|---|---|---|---|---|
| 2023 Hypoxia Task Force *Report to Congress* section 1.6 | 1980 – 1996 (baseline period) to 2021 water year | Flow-normalized load | Document cumulative total nitrogen (TN) and total phosphorus (TP) loads for the entire MARB to the Gulf of Mexico under all flow conditions throughout the entire water year compared to the 1980 – 1996 baseline. | Flow-normalized TN loads from the MARB to the Gulf of Mexico—as measured near where the Mississippi and Atchafalaya Rivers enter the Gulf—have decreased by 23%, while TP loads have increased by 3% between 1980 – 1996 baseline period and the 2021 water year. |
| The EPA *National Rivers and Streams Assessment Report* | 2018 – 2019 | Concentration | Provide a snapshot of the Nation's waters conditions through statistically designed survey sampling of ambient concentrations in thousands of miles of streams and small rivers, as well as large rivers including the Mississippi. | The 2018-19 Report shows that approximately 50% of river and stream miles in the MARB are in poor condition for TN and TP. |
| Upper Mississippi River Restoration Program *Status and Trends Report* | 1993 – 2019 | Concentration and flow-normalized load | Present outcomes from collected data for TN and TP through concentrations and flow-normalized loads from 1993 – 2019 in the Upper Mississippi River Basin only, and thus does not account for the lower portions of the MARB. | Various trends were shown for TN and TP concentrations and loads across the study reaches. |
| Upper Mississippi River Basin Association's *How Clean is the River?* Report | 1989 – 2019 | Flow normalized concentration | Present aggregated data collected by monitoring programs for TN and TP concentrations from 1989 – 2019 in the Upper Mississippi River Basin only, and thus does not account for the lower portions of the MARB. | TN trends leaned in the declining direction but did not have a clear, statistically significant trend. There has been an average 34% decline in TP concentrations above Pool 13 but no clear trend in the lower reaches, except for a high confidence increasing trend in Pool 26 (near St. Louis). |

## What Study Factors Make the Answers Different?

Across these reports, sampling design, period of record and data analyses, vary, but all provide useful information to resource managers. Below are a few summary points of the study factors of each report:

**2023 Hypoxia Task Force *Report to Congress* section 1.6**
The trend data for total nitrogen (TN) and total phosphorus (TP) flow-normalized loadings represent the percentage change in flow-normalized TN and TP loads to the Gulf of Mexico from the MARB between the 1980-1996 baseline period and the reported water year. The data are collected for one location at the MARB outflow near St. Francisville, Louisiana. The estimation of the trends compares the current water year to a baseline from 1980-1996, providing an assessment of water quality conditions at the mouth of the MARB and informing progress towards Action Plan goals set by the Hypoxia Task Force.

**The EPA *National Rivers and Streams Assessment Report***
The report data are collected through a statistically designed national survey where sampling sites are selected using a probability-based sample design to avoid selection bias and occur across small headwater streams to mainstem tributaries. This method can provide a snapshot of the ecological condition of the full range of flowing waters in the conterminous U.S. and track changes between survey years or show trends across the surveys. Sampling for the surveys is typically conducted during the spring/summer and collection is aimed to occur at base flow[1] and use standardized field and lab methods, which allow results to be compared from different parts of the country and to the previous surveys (2013-14 and 2008-09). The survey, which includes co-located biological, chemical and physical indicators at approximately 2,000 sites per survey period, provides important information on the general ecological condition of the nation's waters and the key stressors that affect them, both on a national and ecoregional scale.

Nutrient concentrations are categorized as good/fair/poor for analyses using ecoregional benchmarks based on the distribution of values from a set of least-disturbed river and stream reference sites[2]. The report presents data at a national scale and the interactive dashboard provides results for numerous subpopulations, including nine major ecoregions and the MARB and its major sub-basins. A summary of findings for the MARB are provided in the Appendix below.

**The Upper Mississippi River Restoration Program *Status and Trends Report***
This report presents outcomes from data collected by the Long-Term Resource Monitoring element of the Upper Mississippi River Restoration Program, supplemented with data from other sources at approximately six targeted sampling locations on the Upper Mississippi River System[3] and select tributary monitoring sites. The sites include Pool 4 (near Lake City, MN), Pool 8 (near La Crosse, WI),

[1] Base flow occurs when stream flow does not contain any event-based runoff and is driven by groundwater flow to the stream. This typically occurs during summer months when there is less precipitation and warmer temperatures, and the snowpack has been depleted through spring melt.
[2] This report defines a reference site as a river or stream site with attributes (such as water quality) that come as close as practical to those expected in a natural state, i.e., a least-disturbed site.
[3] The Upper Mississippi River System includes the navigable portions of the river near the Twin Cities Metro Area to just above the confluence of the Ohio River, and navigable portions of the Illinois River.

Pool 13 (near Bellevue, IA), Pool 26 (near Alton, IL), Open River (near Cape Girardeau, MO) and La Grange Pool (near Havana, IL). These data are informative to assess long-term trends for the sampled locations in the Upper Mississippi River System, including the current status of the river, how the river has changed at those long-term trend sites since the 1990s and the implications of management and restoration actions on these changes. This report highlights the essential role of long-term monitoring data to understand, manage, and restore large-floodplain rivers.

**Upper Mississippi River Basin Association's *How Clean is the River?* Report**

This report presents aggregated data collected by monitoring programs at targeted sites in the Upper Mississippi River System. Those datasets include monitoring information from state ambient monitoring programs, federal datasets such as USGS, and the Upper Mississippi River Restoration Program.

# Appendix. General Report Summaries and Results

## Report/Program Results

2023 *Hypoxia Task Force Report to Congress*

## Study Sponsor/Time Frame

USGS continuous monitoring of TN and TP loads in Lower MARB outlet; Reported annually
Report published December 2023

| N Load | N Concentration | P Load | P Concentration |
|---|---|---|---|
| ✓ | | ✓ | |

## Summary of Findings

As of 2021, TN loads passing through this monitoring location have decreased by 23 percent and TP loads have increased by three percent compared to a 1980-1996 baseline. This documents cumulative TN and TP loads for the entire MARB to the Gulf of Mexico under all flow conditions throughout the 2021 entire water year compared to the 1980 – 1996 baseline.

## Report/Program Results

EPA's *National Rivers and Streams Assessment Report*

## Study Sponsor/Time Frame

U.S. EPA, 2018-2019
Report published December 2023

| N Load | N Concentration | P Load | P Concentration |
|---|---|---|---|
| | ✓ | | ✓ |

## Summary of Findings

The most recent National Rivers and Streams Assessment report describes water quality conditions at national and ecoregional scales for 2018-19 and changes compared to surveys done in 2013-14 and 2008-09 as well as a trends across the surveys.

The interactive dashboard displays water quality findings for key indicators of chemical, physical and biological condition at the national and ecoregional scales, including the MARB and each of the major MARB sub-basins.

Between 2008-09 and 2018-19 (three surveys), data did not show statistically significant trends across the surveys in the percent of river and stream miles in the MARB in good, fair or poor condition for most indicators, including TP concentrations. Over the ten-year period the survey did find a statistically significant increase in the river and stream miles rated good for fish community health and fewer miles

rated good for total nitrogen. The report indicated an increased likelihood of degraded biological condition where nutrient concentrations are high.

The National Rivers and Streams Assessment survey results for the Upper Mississippi River sub-basin show a statistically significant increase in the percent of river and stream miles rated poor for total nitrogen concentrations. A statistically significant reduction in the percent of river and streams miles rated poor for benthic macroinvertebrate community health was accompanied by small, non-significant increases in waters with good and fair condition.

## Report/Program Results

Upper Mississippi River Restoration *Status and Trends Report*

## Study Sponsor/Time Frame

Upper Mississippi River Restoration Program, a Federal-State Partnership (US Geological Survey; US Army Corps of Engineers, US Fish and Wildlife Service, US Environmental Protection Agency, US Department of Agriculture, and the states of (IL, IA, MN, MO, WI)
1993-2019
Report published June 2022

| N Load | N Concentration | P Load | P Concentration |
|---|---|---|---|
| ✓ | ✓ | ✓ | ✓ |

## Summary of Findings

This report assesses the status and trends of selected ecological health indicators of the Upper Mississippi River System based on the data collected and analyzed by the Long-Term Resource Monitoring element of the Upper Mississippi River Restoration Program, supplemented with data from other sources. The data were collected in the six Long-Term Resource Monitoring element study reaches that span much of the Upper Mississippi River System. Data are collected each year from the six study reaches for water quality, aquatic vegetation and fisheries using a stratified random sampling design that accounts for geomorphic and biological variation within study reaches.

## Summary of Total Nitrogen:

TN was high throughout the period of record in all study reaches. However, there were north-south differences in concentrations and trends. Concentrations were lower in the upper reaches than the lower study reaches. Trends in concentrations and fluxes in the main channel and associated tributaries were upward or neutral in upper study reaches but showed some evidence of TN concentration decrease in lower study reaches, particularly in the Illinois River Basin. There were significant trends in TN in four study reaches—increases in three study reaches (Pools 4, 13, and Open River) and decreases in the La Grange Pool. These spatial differences also match recently observed basin-wide trends in nitrate, which showed increases in upper reaches and northern tributaries and decreases in the Illinois River and southern portions of the Upper Mississippi River System.

All study reaches had increasing flow-normalized TN loads, indicating increasing export of TN from all portions of the Upper Mississippi River System. This indicates that despite some improvements in concentration, export of TN from the basin remains high, making reductions in concentration particularly important for reducing TN export if discharge continues to increase. TN concentrations in the Mississippi Basin will likely remain high without large-scale change. The MARB has a large quantity of legacy nitrogen stored in groundwater and soils that would take decades to drain even if nitrogen applications on the landscape were to stop altogether.

### Summary of Total Phosphorus:

Significant decreases in TP in four of the six study reaches were observed; there was no significant change in the Open River study reach and a significant increase in the La Grange Pool. TP decreases were greatest in Pools 4 and 8, and significant but progressively smaller decreases were observed as far south as Pool 26. Notably, in Pools 4 and 8, TP was substantially above water quality criteria before 2010 but decreased to concentrations near the water quality criteria during 2011–19.

Observed TP significantly decreased in Upper and Lower Pool 4, and flow-normalized TP concentration and flux decreased in many study reaches and tributaries. Flow-normalized TP concentrations decreased in most of the tributaries evaluated and flow-normalized fluxes decreased in the Cannon and Cuivre Rivers indicating some potential for reduced watershed inputs to the Upper Mississippi River System. The Sangamon River, which drains into the La Grange Pool of the Illinois River, increased substantially in flow-normalized TP concentration and flux, likely contributing to the observed increase in flow-normalized TP concentration in the La Grange Pool.

## Report/Program Results

Upper Mississippi River Basin Association's *How Clean is the River?* Report

## Study Sponsor/Time Frame

Upper Mississippi River Basin Association, 1989-2018
Report published January 2024

| N Load | N Concentration | P Load | P Concentration |
|---|---|---|---|
| ✓ | ✓ | ✓ | ✓ |

## Summary of Findings

This report is the result of a second collective effort to describe water quality trends in the Upper Mississippi and Illinois Rivers. The original report was published in 1989 and evaluated water quality trends with data from the 1970s and 1980s. This second evaluation pairs monitoring data and river discharge measurements to calculate a flow adjusted trend analysis. This report evaluates 19 key water quality parameters using data collected from 1989 to 2018, providing both a water quality condition assessment and long-term trend analysis. The report offers the following conclusions:

- Entities (i.e., governments, businesses, NGOs and individuals) have made significant progress improving water quality in the Upper Mississippi River System:
  - Phosphorus levels are declining in the upper portions of the Upper Mississippi River System.

- More work needs to be done by these entities.
  - The trends for nitrogen are unclear and more work is needed to increase reductions.
- Good water quality monitoring is critical to making improvements:
  - Sufficient monitoring information helps to understand current water quality conditions, implementation efforts that are working, and what else needs to be done. It also provides confidence that improvements can be made in water quality when there are commitments to science, policy and action.
- The Upper Mississippi River Basin Association supports the partnership and fosters collaboration among the five states (MN, WI, IA, MO, IL) in the Upper Mississippi River Basin to improve water quality in the Upper Mississippi River System:
  a. This report pulls together and integrates data collected by each of these five states and federal agencies.
  b. Future work includes implementing additional water quality monitoring and developing an integrated nutrient reduction strategy.