UMRBA
Upper Mississippi River Basin Association

How Clean is the River?

A 30-year evaluation of water quality in the Upper Mississippi River System

AUGUST 2023

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The *How Clean is the River?* Report was produced by the Upper Mississippi River Basin Association (UMRBA) Water Quality Task Force.

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NON-DISCRIMINATION AND ACCESSIBILITY STATEMENT

As the leading organization in the Midwest dedicated to solving the complex water resource challenges facing the Upper Mississippi River watershed, UMRBA recognizes the essential importance of including all people and communities in the process of creating and implementing solutions to these challenges. UMRBA welcomes, respects, and appreciates all of the ways individuals identify by race, ethnicity, gender identity, sexual orientation, religion, disability, and socioeconomic stratum, and is consistently striving to expand the range of voices, experiences, and perspectives that are heard in the discussions we convene throughout the watershed. UMRBA is also committed to understanding and addressing the impact that its policies and programs have on different people and communities, and working to ensure equity in opportunity and outcomes.

If you need this document in another format, please contact UMRBA staff at umrba@umrba.org.

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Executive Summary

This report, entitled "How Clean is the River?," is the result of a second collective effort to describe water quality trends in the Upper Mississippi and Illinois Rivers. The purpose of this analysis is to provide information that allows the five states to more effectively identify problem areas, target management actions, and measure progress in protecting water quality. This evaluation pairs monitoring data with river discharge measurements to understand the impact of high and low discharge on the concentration of pollutants in the Upper Mississippi and Illinois Rivers.

In comparison to the 1989 report, this analysis includes the Illinois River, which is a major tributary to Upper Mississippi River. The first report, published in 1989,[1] led UMRBA to focus its water quality program on heavy metals and sediment. This new report evaluates 19 key water quality parameters using data collected from 1989 to 2018, providing both a condition assessment and long term trend analysis. The results support UMRBA's current focus on nutrients and chloride as well as emerging contaminants.

1 UMRBA. How clean is the river? report. UMRBA 1989. https://umrba.org/document/umrba-1989-how-clean-river-report.

Introduction

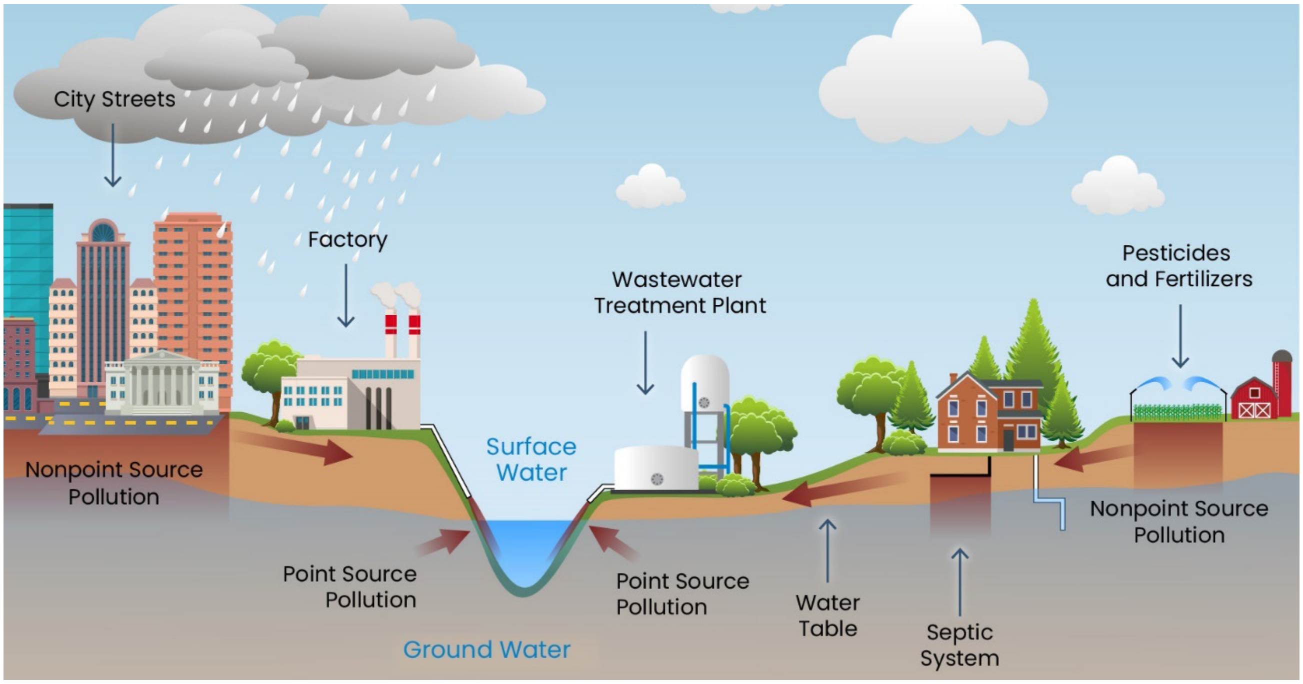
Protecting water quality is critical to sustaining the Upper Mississippi River System (encompassing the Upper Mississippi and Illinois Rivers) as a water supply, diverse ecosystem, recreational area, and commercial artery. Water quality in the System has improved greatly in the past fifty years due to successes from nonpoint source (e.g., soil health management) and point source reductions (e.g., the Clean Water Act). The river's physical and biological complexity and its multiple jurisdictions present unique challenges for Clean Water Act implementation.

The Upper Mississippi River is a border between UMRBA's member states (i.e., Illinois, Iowa, Minnesota, Missouri, and Wisconsin) and falls under the jurisdiction of many state and federal authorities. Each state sets its own monitoring schedule, water quality standards, and designated uses of the water. These separate approaches result in inconsistencies among states in managing water quality on the Upper Mississippi River.

There are many sources of pollution in the river basin. Point source and nonpoint source pollutants from all five states contribute to the water quality in the Upper Mississippi River System (Figure 1).

- **Point source pollutants** are discharged directly into water bodies from an identifiable source like wastewater treatment plants and industrial facilities. Point source pollutants are regulated by the Clean Water Act.
- **Nonpoint source pollutants** enter streams from unidentifiable sources through runoff and groundwater. Urban, industrial, and agricultural lands are significant contributors of nonpoint source pollution to the Upper Mississippi River System. Nonpoint source pollutants are not regulated under the Clean Water Act.

FIGURE 1: A depiction of point and nonpoint sources of water pollution.



Annual discharge to the Upper Mississippi River System is increasing.[2] Between 1940 and 2019, U.S. Geological Survey gages observed increases in maximum, mean, and minimum discharge. More water, more of the time in the rivers can be attributed both to climate and land use changes, but ultimately the drivers of increasing discharge are complex. Appendix 1 details how the climate is changing in the Upper Mississippi River System.

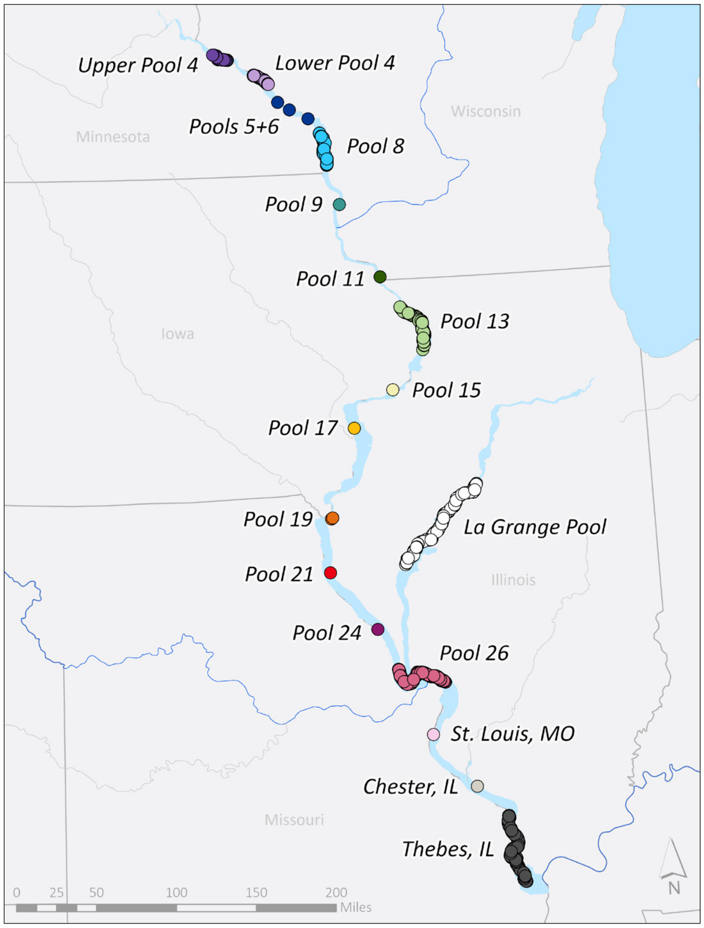
Accounting for the year-to-year variability of discharge helps detect the underlying trend regardless of the weather in any particular year. Statistical analyses estimate how much, and in what direction, concentrations change over time (trends) and the likelihood (confidence) that the trend is occurring.

Accurate water quality monitoring and assessment is challenging because of the complexity of the river system. Monitoring captures a snapshot of conditions at the time and place that the monitoring occurs, but the river is physically complex with the many pools, side channels, and backwaters. Water quality conditions may be different in each of these locations. Additionally, pollutant concentration can change as the amount of water in the river changes. Because of the sheer size and complexity of the river ecosystem, it can be difficult to extrapolate from specific monitoring sites to larger reaches. This report aggregates existing datasets on the Upper Mississippi River System (Figure 2), but there is a greater need for more comprehensive and long-term data collection.

Note that the data utilized for this report were from raw water sources prior to any treatment for drinking water.

The Upper Mississippi River Interstate Water Quality Monitoring Plan is a holistic and collaborative approach among multiple levels of government to comprehensively monitor the Upper Mississippi River. The Monitoring Plan outlines data collection for the river's multiple uses (aquatic life, recreation, drinking water, and fish consumption) to identify problem areas, target management actions, and measure progress in protecting water quality.

FIGURE 2: A map of monitoring sites on the Upper Mississippi River System utilized in this report. Some sites are grouped by multiple sub-sites and are denoted by the same color circles.



2 Houser, J.N., ed., Ecological status and trends of the Upper Mississippi and Illinois Rivers. U.S. Geological Survey Open-File Report 2022–1039, 38-54 p. (2022) https://doi.org/10.3133/ofr20221039. https://pubs.er.usgs.gov/publication/70174673.

GEOGRAPHIC SETTING

The Upper Mississippi River watershed is a complex and dynamic system for water and sediment movement. The river's tributaries have significant influence on the river system, primarily for their discharge and sediment contributions. Floods and sedimentation are both inevitable and natural ecological processes but are also the most vexing problems facing the Upper Mississippi River System particularly as climate- and human-driven activities modify these processes. The river floodplain experiences natural flooding following snowmelt in the spring and after large rainfall events. Sources of water quality parameters to the river are wide ranging and could be described generally as the lands and streams within the watershed.

Congress defines the Upper Mississippi River System by its 9-foot navigation channel, extending from the confluence of the Ohio River north on the Mississippi River to the Twin Cities and on the Illinois Waterway to Chicago. Together, the Upper Mississippi and Illinois Rivers along with small portions of the Minnesota, St. Croix, Black, and Kaskaskia Rivers provide a 1,200-mile commercially navigable river network in the upper Midwest. Of the 850 river miles on the Upper Mississippi River, the northern 670 miles are made navigable by a series of 29 locks and dams that create a stairway of water. The Illinois Waterway includes a system of eight locks. The 9-foot navigation channel is regulated by training structures south of St. Louis to the confluence of the Ohio River.

Water levels are regulated to maintain a continuous 9-foot navigation channel. All of the dams are "run-of-the-river" dams, meaning that they are operated to simply pass incoming flows and do not store water for flood control or other purposes. Each dam is operated to maintain a targeted water surface elevation at one or more control points within the pool.

The Upper Mississippi and Illinois River floodplains encompass over 193,051 square miles of urban and agricultural areas and aquatic, wetland, forest, and grassland habitats. The floodplains have extensive existing flood control projects consisting of levees and floodwalls. Over 140 classified systems of floodwalls and levees extend over 2,200 miles along floodplains, protecting urban and agricultural areas. Most of these floodwalls and levees (approximately 100) are federally constructed and locally owned and operated. There are also many small communities located along the river that lack flood protection structures and are directly vulnerable to overbank flooding. The other systems were built by private interests. In addition, many unaccounted levees exist throughout the floodplain that are privately owned.

Historically characterized as a rich mosaic of braided channels that flowed past countless islands and through abundant lakes and wetlands where diverse riparian plant communities flourished, the Upper Mississippi and Illinois Rivers' floodplain is a critically important source of food and shelter for an abundant array of birds, fishes, mammals, and other wildlife. The construction and operation of the 9-foot navigation channel, as well as other land use changes in the floodplain, inundated much of the original floodplain forest or significantly restricted the lateral floodplain. This has significantly reduced the area available to absorb flood waters. At the same time, and in large part due to the Upper Mississippi River Restoration program, many areas of the river still retain several of their natural floodplain ecosystem characteristics such as flood pulses. Over 300,000 acres of the river-floodplain are designated by the U.S. Fish and Wildlife Service as Wetlands of International Importance.

UPPER MISSISSIPPI RIVER BASIN ASSOCIATION

Formed by the Governors of Illinois, Iowa, Minnesota, Missouri, and Wisconsin in 1981, UMRBA fosters cooperative action in managing the Upper Mississippi River System for multiple purposes including by serving as the states' interstate water quality entity. UMRBA coordinates the states' river-related policies and programs and works with federal agencies on inter-jurisdictional river programs. As such, UMRBA is involved in a broad range of river management issues including water quality, ecosystem restoration, navigation improvements and channel maintenance, hazardous spills contingency planning, and floodplain management.

In all of its endeavors, UMRBA strives to promote the states' mutual interests and shared perspectives and to enhance their ability to collectively and individually address issues related to the river as a shared border waterbody. While UMRBA was founded as a 501(c)(3) nonprofit organization, in many ways, it functions similarly to a regional agency, governed by gubernatorial appointees from state agencies.

UMRBA established the Water Quality Task Force (WQTF) in 1993 to create a long-term water quality protection strategy for the Upper Mississippi River and to provide interstate coordination on a variety of water quality issues. The WQTF is composed of representatives from UMRBA's five member states as well as the U.S. Environmental Protection Agency Regions 5 and 7. The WQTF's work is guided by the Water Quality Executive Committee (WQEC), a governing body of water quality administrators from each state. The WQTF focuses mostly on improving water quality monitoring and assessment and enhancing consistencies in the states' Upper Mississippi River water quality programs.

DATA AND TREND INTERPRETATION AND TERMINOLOGY

This report assesses water quality data collected between 1989 to 2018 by a select number of water quality management agencies of the UMRBA member states and federal government agencies. Water quality measurements are paired with discharge measurements from U.S. Geological Survey or U.S. Army Corps of Engineers. There are differences among trend analyses in terms of period of record. Specific details of the trend analyses are provided in Appendices 2A through 2E.

This report provides a status of concentrations and attempts to characterize trends for 19 parameters in the Upper Mississippi and Illinois Rivers. A description of how the trends are characterized is described below.

High Confidence: There is at least a 95% probability the trend is occurring (p-value <0.05). The trend is statistically significant. And, more than half of the sites are trending in a direction (i.e., increasing or decreasing). The trend direction is denoted as high confidence with shaded and colored text. **Red** text indicates an undesirable trend and **green** text indicates a desirable trend.

Example: Total Suspended Solids Trend: **DECREASING**

Moderate or Low Confidence: There is a 65%– 95% probability that the trend is occurring (0.05 < p-value < 0.6). More than half of the sites are trending in a direction; however, the data are not statistically significant.

The trend direction is denoted as high confidence with colored text. **Red** text indicates an undesirable trend and **green** text indicates a desirable trend.

Example: Sulfate Trend: **INCREASING**

In some cases, the trend has low confidence (0.6 > p-value). The indicator may still have some directionality i.e., increasing or decreasing.

Example: Fecal Coliform Trend: **NO TREND — DECREASING**

No Trend: There is no consistent increase or decrease in concentration over time, and there is little confidence in the results (0.6 > p-value). The indicator may be stable, or it may be highly variable without a consistent change.

Example: pH Trend: **NO TREND**

Concentration: Amount of a parameter in a volume of water. This amount is often expressed as milligrams per liter (mg/L) or micrograms per liter (µg/L).

ppm: Parts per million = 1mg/L. 1ppm is the equivalent of one drop in a 13-gallon fish tank.

ppb: Parts per billion = 1µg/L. 1 ppb is the equivalent of one drop in a backyard swimming pool.

Indicators and Results

INDICATOR OVERVIEW

Physical: total suspended solids, pH, dissolved oxygen, and conductivity

Water chemistry impacts how chemical and biological processes occur in the water. Changes in these five parameters influence the behaviors of other indicators.

Salts and pathogens: chloride, sulfate, and fecal coliform

Salts (two indicators) increase the salinity of the water affecting aquatic ecosystems. Recreational uses may be impacted by pathogens (one indicator).

Nutrients: total phosphorus, total nitrogen, inorganic nitrogen, ammonia, and chlorophyll-a

Nutrients (four indicators) are essential compounds for all life, including aquatic organisms, but excess nutrients can cause algal blooms (one indicator) that can be harmful to aquatic ecosystems.

Heavy metals: aluminum, arsenic, lead, zinc, copper, mercury, and cadmium

Heavy metals (seven indicators) can be toxic to humans, including accumulation through the bodies of fish living in impaired waters making them dangerous to eat.

Water quality trend information by site and parameter can be found in Appendices 3A to 3C. Water quality maps by parameter can be found in Appendix 4.

Physical Indicators

SUMMARY

- **Physical water quality parameters impact how other chemical and biological processes occur in the watershed**
- **Total suspended solids (TSS) have decreased by up to 66%**
- **Conductivity has increased throughout the watershed since 1989**

RESULTS

Dissolved Oxygen Trend: **INCREASING**

Dissolved oxygen concentrations have increased by an average of 8% throughout the system. There is high confidence in the increasing trends observed in Pools 5 and 6, 13, and below Pool 24. At the other sites above Pool 24, there is a combination of no trend or lower confidence increasing trends. Concentrations depend on a variety of factors including temperature, sediment, nutrients, and aquatic plants. Dissolved oxygen is a useful metric that informs our understanding of other indicators.

While an increase in dissolved oxygen may appear good, it could also be a sign of an overgrowth of algae which can harm aquatic ecosystems and impact human uses of the water. When there is a lot of human or animal waste in the water or in areas where high nutrient concentrations have fueled an overgrowth of algae, dissolved oxygen may initially increase, but when algae decompose, dissolved oxygen is reduced.

The term is known as supersaturation. Only 3% of sites indicated supersaturation, so in this case, the increase in dissolved oxygen trend is likely positive.

pH Trend: NO TREND

While significant trends were observed at Pool 9 and Pool 26, increasing and decreasing, respectively, overall pH showed no trend throughout the river system. pH is a measure of how basic or acidic the water is; the ideal range is between 6.5 and 9. pH affects the availability of nutrients and pollutants for various chemical and biological processes. In highly acidic or basic water, compounds may dissolve more easily and thereby increase their toxicity. pH is influenced by temperature, local geology, urban and industrial pollution, and runoff from mines.

Total Suspended Solids Trend: DECREASING

Total suspended solids (TSS) have significantly decreased throughout the river system although there is less confidence in the trends on the lower portion of the Upper Mississippi River. TSS is a measure of the amount of sediment, suspended algae, and other particles in the water column. Waters with high TSS are murky and have little or no aquatic vegetation, limiting the availability of habitat, food, and dissolved oxygen for aquatic life. Major sources of TSS are runoff from agricultural lands, stormwater discharges, and algal growth in the river. Sediment can also carry other pollutants like metals, fertilizers, and pesticides that cling to the particles. Improvements in TSS may be linked to the adoption of conservation practices.[3]

Conductivity Trend: INCREASING

Conductivity is a measure of water's ability to carry an electrical current. Conductivity increases as the water temperature increases and with more dissolved salts and other compounds in the water. Significant increasing trends in conductivity throughout the system follow the trends of higher concentrations of dissolved salts like chloride in the waterway (see Salts pages 9-11).

INTERPRETATION

Physical indicators measure characteristics of the water that are important for aquatic life. While changes in some of these parameters can be closely linked to specific pollutants, many of these indicators reflect a suite of complex interactions in the ecosystem that are influenced by the presence of contaminants. Aquatic plants and animals are adapted to survive within a specific range for each of these parameters.

Long-term monitoring of physical indicators reveals that our efforts to reduce pollution in the watershed are effective. Sediment was identified as a key water quality challenge in the 1989 publication of the How Clean is the River? Report because of its role in transporting phosphorus and other pollutants. Since 1989, TSS has decreased by an average of 44% above Pool 11 and 32% below Pool 11.

3 Kreiling, R. M. and Houser, J. N., Long-term decreases in phosphorus and suspended solids, but not nitrogen, in six upper Mississippi River tributaries, 1991–2014. Environmental Monitoring and Assessment 188, 454. (2016) https://pubs.er.usgs.gov/publication/70174673.

In such a large watershed, realizing benefits from management actions takes time. Agricultural producers have taken significant action regarding how to maintain their production while reducing water quality impacts. Farmers across the watershed have applied best management practices on their land to reduce erosion and nutrient pollution. The U.S. Department of Agriculture estimated that farmers applied erosion control practices on 45% of the cropland in the watershed between 2003 and 2006, reducing sediment loss from fields by 61%.[4] Changes in land management practices are beginning to be seen in the waterbodies throughout the watershed. Between 1994 and 2014, TSS concentrations in major tributaries declined between 18 and 74%.[5]

Reducing TSS can result in a cascade of positive effects on the environment. Lower TSS concentrations can reduce turbidity (i.e., the amount of light that can pass through the water) that, in turn, may stimulate more plant growth.[6] Additional plant growth provides habitat and food for aquatic species and increases dissolved oxygen concentrations.[7]

Salts and Pathogen Indicators

SUMMARY

- **More saline (saltier) water harms aquatic ecosystems and is expensive and impractical to treat**
- **Sulfate concentrations increased up to 72% in the Upper Mississippi River System**
- **Average chloride increases of 35% were observed throughout the river system**
- **Fecal coliform is an indicator that other pathogens may be present in the water, which can impact human health and recreation**

RESULTS

Sulfate Trend: **INCREASING**

Sulfate concentrations appear to be increasing throughout the watershed, but there is only high confidence in trends at four locations. Sulfate occurs naturally in soils and rocks, in volcanic eruptions, and from the decomposition of organic matter. Mining, fertilizers, industrial pollution, and burning coal are major human sources of sulfate in the ecosystem.[8] Sulfate plays an important role in the biochemical process in freshwater systems. Changes in sulfate can lead to changes in pH and the cycling of nutrients and other compounds in soils and the river.

4 Lund, D. et al. Assessment of the effects of conservation practices on cultivated cropland in the Upper Mississippi River basin. USDA NRCS. (2012). https://naldc.nal.usda.gov/catalog/60832.

5 Kreiling, R. M. and Houser, J. N. Long-term decreases in phosphorus and suspended solids, but not nitrogen, in six upper Mississippi River tributaries, 1991–2014. Environmental Monitoring and Assessment 188, 454 (2016).

6,7 Bouska, K. L. et al. Conceptualizing alternate regimes in a large floodplain-river ecosystem: water clarity, invasive fish, and floodplain vegetation. Journal of Environmental Management 264, 110516 (2020).

8 Killingsworth, B. A. and Bao, H. Significant human impact on the flux and δ(34)S of sulfate from the largest river in North America. Environmental Science and Technology 49, 4851–4860 (2015) https://pubs.acs.org/doi/10.1021/es504498s.

Chloride Trend: INCREASING

Chloride concentrations have increased by an average of 35% for sites with high confidence trends and are increasing throughout the river system. Chloride is a commonly occurring element that often bonds with other elements to form salts. Chloride makes water saltier, which may harm freshwater aquatic plants and animals that are adapted to low salt environments. Runoff carrying deicing salts from roads, sidewalks, and driveways is the major source of chloride to the river. Effluent from homes that use water softeners also contributes to the chloride pollution.

Fecal Coliform Trend: NO TREND — DECREASING

Fecal coliform appears to be declining at monitoring sites, but the trends are low confidence. Fecal coliform are bacteria from human or animal feces. It is an important indicator that other pathogens may also be present in the water. Fecal coliform and other pathogens can make people ill if they come in contact with contaminated water. Sources of fecal coliform are wildlife, wastewater treatment plants, septic systems, and runoff carrying manure. Improved land management practices and upgrades to wastewater treatment plants can reduce pathogens in the river. Note that *E. coli (Escherichia coli)*, a type of bacteria found in human and animal feces, is a more commonly used parameter than fecal coliform to measure public safety for water-based recreation activities.

INTERPRETATION

Over the past three decades, the Upper Mississippi River watershed has become saltier (Figure 3).[9] High concentrations of chloride can harm aquatic species by impacting osmoregulation and reproductive cycles and inhibiting vegetation growth. Chloride can also release nutrients and metals that are attached to soil particles, mobilizing them in the watershed.

There are no easy solutions for removing chloride from runoff and wastewater. Our best solution is to address the source by reducing the salts that are applied in the watershed.

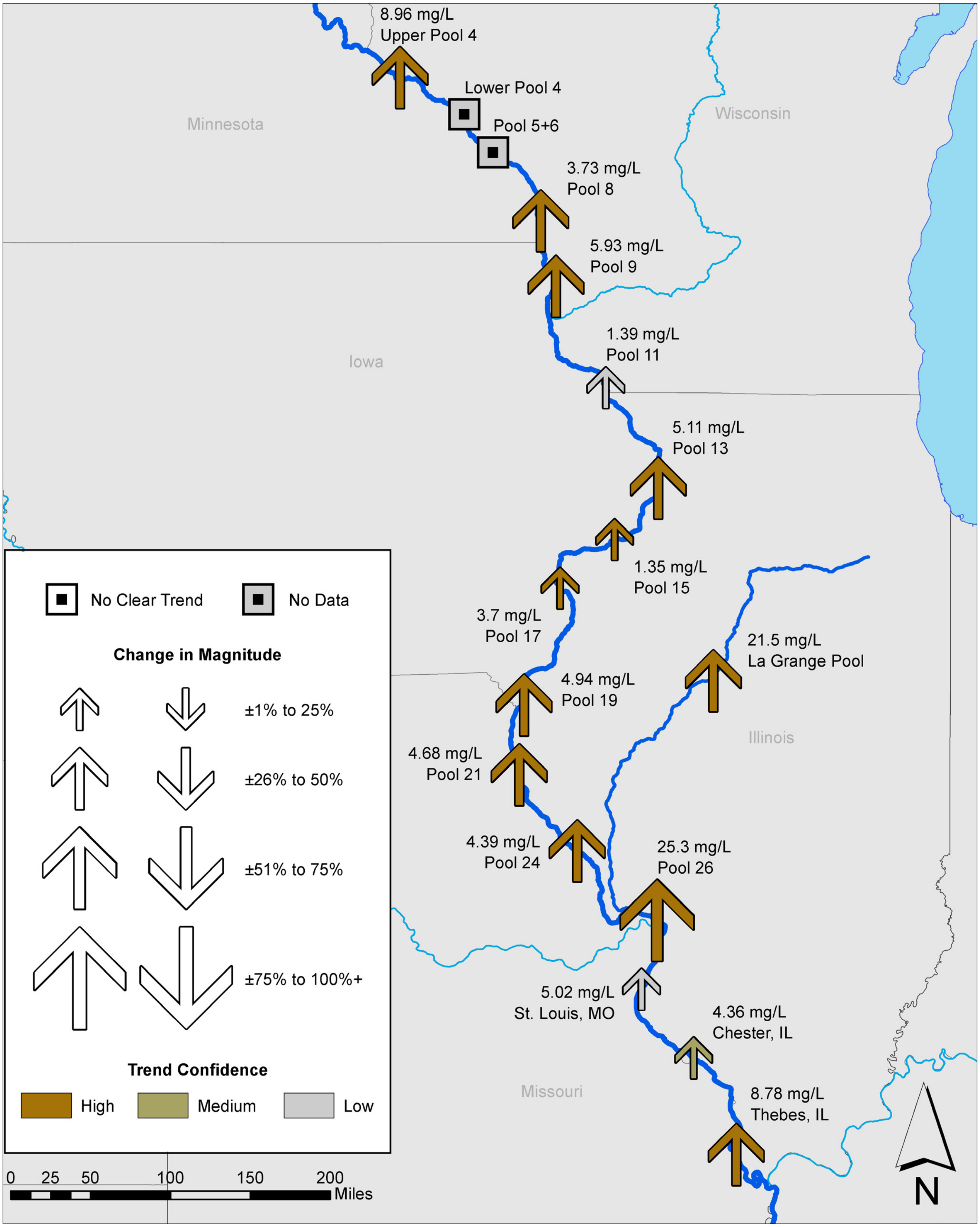
On February 22, 2022, UMRBA adopted a resolution recognizing chloride contamination in the system. UMRBA member states agreed to support research and monitoring and coordinate with federal, state, and local governments to improve chloride application.[10]

Key strategies to reduce chloride in the watershed include:

- Apply best management practices to road salting techniques (e.g., switching from rock salt to brine salt application) that minimize chloride runoff while ensuring public safety
- Invest in training for road salt applicators and proper calibration of salt application equipment
- Incentivize moderate application of deicing salts with policies like limited liability protection for private applicators
- Encourage public and private support for monitoring and research programs

8 Dugan, H. et al. Salting our freshwater lakes. PNAS 114, 4453-4458 (2017) https://www.pnas.org/doi/10.1073/pnas.1620211114.
9,10 UMRBA. UMRBA chloride resolution. (2022) https://umrba.org/document/umrba-chloride-resolution.

FIGURE 3: Concentrations of chloride across the Upper Mississippi River System. The majority of sites showed increasing concentrations. The size of arrows denotes the change in magnitude, and the color of the arrow represents the statistical confidence.



Nutrient Indicators

SUMMARY

- **Nutrients from agricultural and urban sources can fuel algal blooms that harm aquatic habitat in the Upper Mississippi River System and the Gulf of Mexico**
- **Improvements in phosphorus are related to wastewater treatment plant upgrades and erosion reduction from agricultural lands**
- **All measures of nitrogen are improving on the Illinois River**

RESULTS

Total Phosphorus Trend:	DECREASING **above Pool 13** NO TREND **below Pool 13 and in La Grange Pool, Illinois River** INCREASING **in Pool 26**

There has been an average 34% decline in total phosphorus concentrations above Pool 13 but no clear trend in the lower reaches, except for a high confidence increasing trend in Pool 26. Phosphorus is a key nutrient for plant growth. High phosphorus concentrations drive excess algae growth that can cause low-oxygen hypoxic conditions in the river. Organic matter from city wastewater, livestock and poultry manure, septic systems and runoff carrying fertilizers are major sources of phosphorus. Phosphorus clings to sediment and is transported off disturbed lands with erosion and runoff. Significant improvements are the result of actions such as Clean Water Act compliance and wastewater treatment plant upgrades along with decades of soil and water conservation work.

Total Nitrogen Trend:	NO TREND — INCREASING **above Pool 13** DECREASING **in La Grange Pool, Illinois River**

Nitrogen is present in the watershed in many different forms like ammonia, nitrate, nitrite, and organic nitrogen. Total nitrogen is a measure of all these different forms. Like phosphorus, nitrogen is a key nutrient for plant growth. Biological processes convert nitrogen between the different forms, having significant impacts on algal growth and aquatic habitat. Excess nitrogen is flushed into the river through runoff and drainage from agricultural and urban lands and treated effluent from wastewater treatment plants. Although total nitrogen appears to be increasing above Pool 13, there is low confidence or no trend at most sites on the river. A high confidence, decreasing trend of 14% was observed at the La Grange Pool on the Illinois River.

Ammonia Trend: **NO TREND — DECREASING**
INCREASING in Pool 15

Ammonia concentrations are low confidence decreasing or show no trend in all reaches except Pool 15 (129% increase, high confidence). Ammonia comes from treated effluent, animal waste, and fertilizers. At high levels, ammonia gas is toxic to aquatic organisms like fish. Although it is a form of nitrogen, ammonia cannot be used directly by most plants. Microbes convert ammonia into nitrite and nitrate, a form of nitrogen that plants use to grow. Through this process, high ammonia concentrations can affect nitrate and nitrite concentrations that drive algal growth in the river. Ammonia concentrations may be decreasing (improving) due to improvements in wastewater treatment, and perhaps reductions in feedlot and manure runoff.

Inorganic Nitrogen Trend: **NO TREND — INCREASING**
DECREASING in La Grange Pool, Illinois River

Concentrations are increasing at over one-half (58%) of the monitored sites but there is only high confidence in the increasing trend at one site (Pool 13). The Illinois River at La Grange has experienced a 17% decline since 1994. The primary sources of inorganic nitrogen are fertilizers and manure from cultivated crops, although urban landscaping, feedlots, and septic systems can also contribute nitrate to waters. Excess nitrogen can fuel algal growth. Overgrowth of algae can significantly reduce the oxygen available for other aquatic organisms and block light from entering the water column. Elevated inorganic nitrogen in drinking water poses a human health risk and can also be toxic to aquatic life in rivers and streams.

Chlorophyll-a Trend: **DECREASING above Pool 13**
INCREASING in Pool 24 and the Open River

Chlorophyll-a (chl-a) is the most abundant chlorophyll pigment in most algae and is used as an indicator to track total amount of algae in water. Large growths of cyanobacteria sometimes called blooms of blue green algae, occur in warm, slow-moving water with excess nitrogen and phosphorus. Cyanobacteria blooms deplete oxygen in the water and block sunlight in the water column which can be harmful to aquatic ecosystems. If a bloom contains blue-green algae, then there is a potential for dangerous, toxic compounds to be produced in that bloom (often called a harmful algal bloom and cyanotoxin). Chl-a appears to be decreasing above Pool 13. The La Grange Pool is decreasing but has a lower confidence trend. There does not appear to be a clear trend between Pool 13 and Pool 24. Significant increasing trends were observed in Pool 24 and the Open River. Significant declines in total phosphorus concentrations likely led to declines in chl-a in the same reaches.

INTERPRETATION

Nutrient pollution is one of the most challenging problems facing the Upper Mississippi River System. Warm, slow-moving water with high nutrient concentrations fuel the growth of algae in the water far beyond normal levels. These algal blooms can block sunlight and deplete the oxygen (during the respiration process at night) that fish and other organisms need to survive. High nutrient concentrations can also increase treatment costs for drinking water. In some cases, algal blooms may produce toxins that can make people sick if they consume or come in contact with the water. Many public drinking water systems are taking action to manage toxic blooms in drinking water and notifying their users of possible health concerns. In the long term, reducing the sources of nutrient pollution is the most effective solution for reducing the risk of toxic algal blooms to the public and aquatic life.

Nutrient pollution does not just affect local stretches of the river. The warm, nutrient-rich waters of the Mississippi River empty into the Gulf of Mexico. Massive algal blooms fueled by the river water create an oxygen-depleted area – the Gulf of Mexico Hypoxic Zone – that threatens nationally important fisheries and impacts tourism along the Gulf Coast.

There are several key challenges to reducing nutrient pollution:

- **Nonpoint sources are not regulated by the federal government**

  Nonpoint sources are a primary source of nutrient pollution to Upper Mississippi River System but are not regulated by the Clean Water Act. Although state and local laws have been written in some areas of the watershed to help reduce nonpoint source pollution from fertilizers, manure, stormwater, barnyards, and septic systems, much of nonpoint source pollution remains unregulated. Agricultural runoff and urban stormwater are two large contributors of nonpoint source nutrients to the Upper Mississippi River System. Addressing elevated nutrients in our waterways will take widespread voluntary action.

- **Legacy pollutants continue to result in elevated nutrient concentrations**

  Some nutrients are stored in the sediment or groundwater for years or even decades before they enter into streams. Nitrate, a common form of nitrogen in fertilizers, dissolves in water and is carried into the soil and groundwater as the water seeps into the ground. It may be many years before groundwater carrying nitrogen reaches the rivers. Groundwater contributes elevated nitrogen concentrations to the rivers even as agricultural producers and cities reduce nutrient application on the landscape.

- **Increasing discharge masks nutrient reduction progress**

  Increasing discharge has been documented since the 1940s at U.S. Geological Survey gage stations on the Upper Mississippi and Illinois Rivers. Despite the implementation of best management practices on the landscape, more water in the system diminishes the effectiveness in water quality improvements from conservation practice implementation. The complexities of nutrient transport, climate, and land use changes are not fully understood and warrant additional research.

Over the last 30 years, communities have worked hard to build effective strategies to reduce nutrient pollution. States and local communities are taking an active lead to reduce nutrient pollution to protect communities and resources in their states. Each UMRBA member state has developed a nutrient reduction strategy that outlines a suite of conservation practices tailored to fit local needs and conditions. These strategies are part of a broader national effort to reduce nutrient pollution in the Mississippi River.[11]

11 Hypoxia task force 2008 action plan. (2008) https://www.epa.gov/ms-htf/hypoxia-task-force-action-plans-and-goal-framework.

Smaller-scale watersheds with decreasing trends in total nitrogen show that voluntary, collaborative efforts can have positive impacts. However, increasing discharge make meeting nutrient reduction targets even more challenging. Over the last twenty years, states have developed effective relationships with partners. Continued investment in these partnerships can further build on these collaborations.

Since 1989, there has been a 43% reduction in phosphorus concentrations in the upper portions of the watershed. These changes are due to improvements at wastewater treatment plants and other point sources as well as in agricultural land management.[12] Farmers throughout the upper Midwest have implemented best management practices to reduce erosion from farmlands.[13] Although phosphorus load reduction targets have not yet been reached, watershed-wide declines in phosphorus show the effectiveness of implementing best management practices in the watershed.

Metal Indicators

SUMMARY

- **Metals typically attach to sediments and settle to the bottom of the river**
- **Decreases in metals are likely due to actions such as Clean Water Act compliance for pretreatment of industrial wastewater.**
- **Although the percent increases appear large for some metals, the actual concentrations are far below drinking water and aquatic life standards**

Metals are a challenging category for trend analysis due to limitations in available data, variable field sampling, and analytical methodologies as well as an elevated potential for cross contamination compared to the other categories of indicators. All the data below are reported with the same previously established p-value criteria. However, caution should be given to interpreting the reliability of these results as many of the trends had high predictive error rates.

RESULTS

Aluminum Trend: DECREASING

Aluminum concentrations have decreased across the watershed. Aluminum enters waterbodies from the natural weathering of rocks and human sources like treated wastewater, industrial processes, and mining. In acidic waters, aluminum can be particularly dangerous for fish because it accumulates on their gills.

12 Stackpoole, S., Sabo, R., Falcone, J. and Sprague, L. Long-Term Mississippi River trends expose shifts in the river load response to watershed nutrient balances between 1975 and 2017. Water Resources Research 57, e2021WR030318 (2021).

13 Kreiling, R. M. and Houser, J. N. Long-term decreases in phosphorus and suspended solids, but not nitrogen, in six upper Mississippi River tributaries, 1991–2014. Environmental Monitoring and Assessment 188, 454 (2016).

Zinc Trend: **DECREASING**

Zinc concentrations appear to have decreased throughout the watershed but only two sites have medium confidence trends – i.e., in Upper Pool 4 and the Open River. The majority of the sites analyzed have decreasing, but lower, confidence trends. Although small amounts of zinc naturally occur in water bodies, most zinc enters water from mining, smelting metals, burning coal, steel production, industrial waste, and urban runoff carrying car tire residue.

Copper Trend: **DECREASING**

Copper concentrations appear to be improving throughout the river; however, only four of eight sites have high confidence trends. At high concentrations, copper can be toxic to aquatic species. Copper enters water bodies from mining runoff, solid waste from wastewater treatment plants, pesticides, and industrial manufacturing. Copper, lead, mercury, and cadmium are regulated under the Safe Drinking Water Act, and the Upper Mississippi River is a drinking water source for many communities. The concentrations measured for copper were well below the calculated limits for aquatic life protection (Table 1). In general, water hardness, caused by compounds of calcium and magnesium, can lower the toxicity of metals like copper, lead, cadmium, and zinc.

TABLE 1: **Concentrations of copper measured on Upper Mississippi River pools compared to the hardness adjusted USEPA chronic criteria. None of the field measured values exceed the chronic criteria for copper.**

	Most Recent Annual Concentration	Hardness Dependent EPA Criteria (Chronic)
	field measured	based on mean hardness
Total Copper		
Upper Pool 4	1.83	21.05
Lower Pool 4	1.43	12.77
Pool 11	1.79	15.53
Pool 13	1.80	15.62
Pool 15	1.96	15.89
Pool 17	2.56	18.39
Pool 19	2.48	16.74
Pool 21	2.87	17.00
Pool 24	2.51	16.58
Pool 26	3.07	18.91
St. Louis, MO	4.42	18.06
Chester, IL	3.97	18.09
Thebes, IL	4.79	17.36

All recent annual concentrations and EPA criteria concentrations are presented in µg/L. None of the annual field measured values exceeded the EPA's recommended criteria.

Arsenic Trend: DECREASING
INCREASING **in Pool 26**

Arsenic is a naturally occurring element that is abundant in soil and rock and is released to the environment by coal combustion, waste incineration, smelting, and fertilizers. Arsenic dissolves in water and is carried into rivers with runoff or in groundwater. High levels of arsenic in drinking water can cause serious health effects. Arsenic concentrations are so low in the Upper Mississippi River that a 40% increase in Pool 26 represents a total increase of less than 1 ppb. Concentrations remain far below federal standards for drinking water (10 ppb) and aquatic life (150 ppb).

Lead Trend: INCREASING **in Pools 15 and 17**
DECREASING **in Pool 4**
DECREASING **below Pool 26**

Although lead concentrations appear to have increased over the last 30 years in Pool 15 and Pool 17, the changes represent actual changes in concentration between 1 ppb and 3 ppb. Lead in drinking water primarily comes from corroded pipes and plumbing. In contrast, major sources of lead to the watershed are the combustion of leaded fuels, coal emissions, and discharges from mining and industrial sites. Lead emissions from burning gasoline and coal deposit on the soils in the watershed and are carried into waterways in runoff. These levels are far below the chronic aquatic life threshold of 7.47 ppb at Pool 15 and 9.29 ppb at Pool 17 (Table 2). Monitoring locations below Pool 26 have experienced a 52% decrease (9 ppb) in lead concentrations since 1989. In Pool 4, there is also an observed high confidence decrease in lead.

TABLE 2: Concentrations of lead measured on Upper Mississippi River pools compared to the hardness adjusted USEPA chronic criteria. Chronic USEPA Criteria for lead were recalculated based on arithmetic mean and using hardness data for the Upper Mississippi River. None of the field measured values exceed the chronic criteria for lead.

	Most Recent Annual Concentration	Hardness Dependent EPA Criteria (Chronic)
	field measured	based on mean hardness
Total Lead		
Upper Pool 4	0.54	11.36
Pool 11	2.43	7.23
Pool 13	3.46	7.28
Pool 15	3.72	7.47
Pool 17	2.42	9.29
Pool 19	2.66	8.08
Pool 21	3.37	8.27
Pool 24	2.76	7.97
Pool 26	3.11	9.68
St. Louis, MO	3.97	9.05
Chester, IL	4.33	9.06
Thebes, IL	4.31	8.53

All recent annual concentrations and EPA criteria concentrations are presented in µg/L. None of the annual field measured values exceeded the EPA's recommended criteria.

Mercury (Upper and Lower Pool 4 only) Trend **NO TREND — DECREASING**

Of the two sites with mercury data, Upper Pool 4 exhibits no clear trend and Lower Pool 4 has a low confidence decreasing trend. Mercury enters the environment through mining and emissions from burning fossil fuels like coal and waste incineration. It is deposited on the landscape where it clings to soil particles. Soil and sediment then carry mercury into the water via runoff and erosion. Mercury bioaccumulates up the food chain, meaning that it is stored in the body of animals and then is transmitted to the body of any animal that ingests it. Because of this process, humans are advised against consuming fish high on the food chain exposed to high levels of mercury. Improvements may be partially attributed to industrial pretreatment programs mandated in 1981.[14]

Cadmium (Upper Pool 4 only) Trend: **DECREASING**

Cadmium naturally occurs in small amounts throughout the environment. It also enters the environment through smelting, coal combustion, mining, or runoff from landfills or other waste disposal sites. Phosphate fertilizers also commonly contain small amounts of cadmium. Cadmium is transported by clinging to sediments rather than dissolving in the water column. Like mercury, cadmium can be toxic in large amounts and bioaccumulates in fish. Improvements may be partially attributed to a 1981 mandate for pretreatment of industrial wastewater before it was sent to municipal treatment plants.

INTERPRETATION

Industrial pollution and emissions from burning fossil fuels and smelting used to be significant sources of trace metals to rivers. Trace metal concentration dropped significantly in the 1970s when the Clean Water Act and other significant pollution control measures began to regulate waste. Since then, metal concentrations have dropped throughout the watershed and remain low today.

Following the reduction measures in the 1970s, many trace metals are only present in the river in extremely small concentrations. Because of these low concentrations, a small increase in concentrations can appear as a large percent change. Lead trends in the river are a great example of this phenomenon.

Lead concentrations are generally decreasing or show no significant trend except at Pool 15 and Pool 17. Both of these sampling locations indicate increases in lead of 410% and 250%, respectively. These changes represent an increase in lead of 3 ppb in Pool 15 and 1.7 ppb in Pool 17. These increases are all below the aquatic life chronic standard of 7.5 ppb and 9.3 ppb for Pool 15 and Pool 17, respectively.

There are many explanations for these changes, but the exact cause is unknown. Like many other heavy metals, lead tends to bond with compounds (e.g., iron) to form small particulates. These particles eventually settle out of the water into the sediments at the bottom of the river. Large storms that produce high discharge can stir up sediments, which may cause short-term spikes in concentrations. These lead results warrant future exploration and research.

14 Balogh, S. J. et al. A sediment record of trace metal loadings in the Upper Mississippi River. J Paleolimnol 41, 623–639 (2009).

Conclusion and Recommendations

Understanding and improving water quality of the Upper Mississippi River and Illinois River (collectively referred to as the Upper Mississippi River System; "UMRS" or "System") is vital to the prosperity and sustainability of human communities and economies within the watershed.

Collecting, compiling, and analyzing water quality data is essential to understanding and improving water quality in the UMRS.

This report has generated the following conclusions:

NOTABLE POSITIVE TRENDS

- Dissolved oxygen concentrations have increased throughout the UMRS
- Total suspended solids have decreased significantly throughout the System
- Total phosphorus concentrations have decreased in the UMR above Pool 13
- Total nitrogen and inorganic nitrogen have decreased in the La Grange Pool of the Illinois River
- Lead has decreased in UMR Pool 4

NOTABLE NEGATIVE TRENDS

- Concentrations of chloride and sulfate have increased throughout the System
- Conductivity has increased throughout the System
- Total phosphorus is increasing in UMR Pool 26
- Ammonia is increasing in UMR Pool 15
- Lead has increased in UMR Pools 15 and 17 but levels are below the chronic aquatic life use threshold

IMPORTANT DATA GAPS

- Water quality monitoring frequency, sampling methods, and laboratory analytical methods are not consistent across the Upper Mississippi River System
- Metals data and emerging contaminants data is not collected sufficiently for analyzing trends
- Important data gaps continue to reduce our ability to effectively identify problems and target management actions to protect water quality

MANAGEMENT RECOMMENDATIONS

- State and local governments, as well as conservation and agricultural organizations, should continue to support actions that will maintain positive trends, in particular the total suspended solids and nitrogen and phosphorus improvements that have likely occurred due to changes in land management
- State and local governments, as well as conservation, agricultural, and transportation organizations, should continue to take actions to address negative trends, in particular managing and reducing of chloride, nitrogen, and phosphorus pollution
- State and local governments, as well as conservation, agricultural, and transportation organizations, should continue to support data collection efforts that fill in important information gaps, in particular supporting the Upper Mississippi River Interstate Water Quality Monitoring Plan to provide consistent and uniform data collection on the Upper Mississippi River

Appendices

APPENDIX 1

Climate Change Brief developed by National Weather Service, Chanhassen, MN.

Upper Mississippi River Basin

Climate Change Brief

1.34"

decadal increase in mean annual precipitation

We're Getting More Precipitation

Annual precipitation averages are rising across much of the U.S., and some of the largest increases are in the Upper Mississippi River Basin.

Over the past 30 years, average annual precipitation has increased by +1.34" per decade. This is a big leap from the +0.18" decadal trend from the preceding century (1895-1990).

Rains are Gaining Intensity

There is a clear pattern of large precipitation amounts being concentrated in high-intensity events. The frequency of heavy precipitation events within the Upper Mississippi River Basin has risen over the past 50 years. In fact, this area saw a 37% increase in the heaviest (1%) events from 1958 to 2012.

This includes mega-rains, which are defined by their high intensity (≥6"), large coverage area (≥1,000 mi²), and often catastrophic impacts.

37%

increase in heaviest storms from 1958-2012

Winter

precipitation increased by 0.40" per decade since 1991

Every Season is Wetter

Rising precipitation has been observed across all seasons over the last 30 years in the Upper Mississippi River Basin. The biggest increases have been in the winter and spring, with +0.40" and +0.41" decadal trends, respectively.

Upper Mississippi River Basin

Climate Change Brief

UMRBA Upper Mississippi River Basin Association

decadal increase in flood magnitude as high as **15%**

The River is Responding

How is the Mississippi River handling all of this extra water? Annual flood magnitudes are increasing across most of the Upper Mississippi River Basin, with decadal rises as high as +15%. This region is seeing the most significant increasing flood trends of any area in the U.S

Higher Flows and Longer Floods

In some river reaches, the increased precipitation has resulted in:

- Increased days above flood stage
- Larger mean annual flow
- Higher average peak flow

At several sites, the Mississippi River was above flood stage approximately 5-10x longer in the past decade than on average over the preceding 80 years.

5-10x

longer floods observed at some sites on Mississippi River in past decade than preceding 80 year average

+4.0"

increase in average annual precipitation projected for parts of the Upper Mississippi River Basin in 2041-2070

Where Are We Heading?

Projections for the rest of the century show that many of the observed upward trends will continue.

- Increase in average precipitation
- More intense precipitation events
- Winter and spring will continue to see the largest increases in precipitation

Consequently, high river flows and longer floods may also continue.

About the data: This brief was prepared using the latest publicly available information. Data was sourced from the Fourth National Climate Assessment, National Center for Environmental Information, United States Geological Survey, and Minnesota Board of Water and Soil Resources. Any transposition errors are unintentional and every effort was made to accurately represent the original sources. **Contributors:** Masha Hoy [1], Steve Buan[1], Doug Kluck[2], Mike Timlin[3]. [1]NOAA/NWS North Central River Forecast Center. [2]NOAA/NESDIS National Center for Environmental Information. [3]Midwest Regional Climate Center.

APPENDIX 2A

Parameter, site, period of record, and data source for individual **physical indicators: dissolved oxygen, pH, total suspended solids, and conductivity**. Percent censored is an indicator of how reliably the trend can be detected — i.e., the higher the trend, the more limited the reliability of the trend.

	Data Record	Sample Size	Percent Censored*	Data Provider**
Dissolved Oxygen				
Upper Pool 4	1989 to 2018	1398	0.4%	LTRM, MPCA
Lower Pool 4	1994 to 2017	263	3.0%	LTRM
Pool 5+6	1989 to 2018	284	0.0%	MPCA
Pool 8	1994 to 2017	425	1.4%	LTRM
Pool 9	1989 to 2018	318	0.0%	WDNR
Pool 11	2001 to 2018	73	0.0%	IEPA
Pool 13	1989 to 2018	636	0.0%	IEPA, LTRM
Pool 15	2000 to 2018	126	0.0%	IEPA
Pool 17	2000 to 2018	83	0.0%	IEPA
Pool 19	1989 to 2018	171	0.0%	IEPA
Pool 21	2000 to 2018	81	0.0%	IEPA
Pool 24	2000 to 2018	81	0.0%	IEPA
Pool 26	1989 to 2018	609	0.3%	IEPA, LTRM
St. Louis, MO	2000 to 2018	72	0.0%	IEPA
Chester, IL	2001 to 2018	72	0.0%	IEPA
Thebes, IL	1989 to 2018	710	1.3%	IEPA, LTRM
La Grange Pool	1994 to 2017	478	0.8%	LTRM
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
pH				
Upper Pool 4	1994 to 2017	154	0.0%	LTRM
Lower Pool 4	1994 to 2017	263	0.0%	LTRM
Pool 5+6	1989 to 2018	287	0.0%	MPCA
Pool 8	1994 to 2017	425	0.0%	LTRM
Pool 9	1989 to 2018	309	0.0%	WDNR
Pool 11	2001 to 2018	75	0.0%	IEPA
Pool 13	1989 to 2018	635	0.0%	IEPA, LTRM
Pool 15	2000 to 2018	127	0.0%	IEPA
Pool 17	2000 to 2018	83	0.0%	IEPA
Pool 19	1989 to 2018	169	0.0%	IEPA
Pool 21	2000 to 2018	80	0.0%	IEPA
Pool 24	2000 to 2018	79	0.0%	IEPA
Pool 26	1989 to 2018	594	0.0%	IEPA, LTRM
St. Louis, MO	2000 to 2018	72	0.0%	IEPA
Chester, IL	2001 to 2018	72	0.0%	IEPA
Thebes, IL	1989 to 2018	710	0.0%	IEPA, LTRM
La Grange Pool	1994 to 2017	474	0.2%	LTRM

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Suspended Solids				
Upper Pool 4	1994 to 2017	151	0.0%	LTRM
Lower Pool 4	1994 to 2017	259	0.0%	LTRM
Pool 5+6	1989 to 2018	433	0.9%	MPCA
Pool 8	1994 to 2017	419	0.0%	LTRM
Pool 9	1989 to 2018	316	0.0%	WDNR
Pool 11	2001 to 2018	69	1.4%	IEPA
Pool 13	1989 to 2018	624	0.3%	IEPA, LTRM
Pool 15	2000 to 2018	121	0.8%	IEPA
Pool 17	2000 to 2018	71	1.4%	IEPA
Pool 19	1989 to 2018	157	0.0%	IEPA
Pool 21	2000 to 2018	70	0.0%	IEPA
Pool 24	2000 to 2018	71	0.0%	IEPA
Pool 26	1990 to 2018	572	0.0%	IEPA, LTRM
St. Louis, MO	2000 to 2018	60	0.0%	IEPA
Chester, IL	2001 to 2018	64	0.0%	IEPA
Thebes, IL	1989 to 2018	575	0.0%	IEPA, LTRM
La Grange Pool	1994 to 2017	471	0.0%	LTRM
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Conductivity				
Upper Pool 4	1994 to 2017	154	0.0%	LTRM
Lower Pool 4	1994 to 2017	264	0.0%	LTRM
Pool 5+6	1989 to 2018	291	0.0%	MPCA
Pool 8	1994 to 2017	425	0.2%	LTRM
Pool 9	1989 to 2018	313	0.0%	WDNR
Pool 11	2001 to 2018	76	0.0%	IEPA
Pool 13	1994 to 2018	583	0.0%	LTRM, IEPA
Pool 15	2000 to 2018	128	0.0%	IEPA
Pool 17	2000 to 2018	83	0.0%	IEPA
Pool 19	2000 to 2018	94	0.0%	IEPA
Pool 21	2000 to 2018	80	0.0%	IEPA
Pool 24	2000 to 2018	80	0.0%	IEPA
Pool 26	1994 to 2018	579	0.0%	LTRM, IEPA
St. Louis, MO	2000 to 2018	72	0.0%	IEPA
Chester, IL	2001 to 2018	72	0.0%	IEPA
Thebes, IL	1994 to 2018	667	0.0%	LTRM, IEPA
La Grange Pool	1994 to 2017	478	0.0%	LTRM
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

APPENDIX 2B

Parameter, site, period of record, and data source for individual **salt indicators: sulfate and chloride**. Percent censored is an indicator of how reliably the trend can be detected — i.e., the higher the trend, the more limited the reliability of the trend.

	Data Record	Sample Size	Percent Censored*	Data Provider**
Sulfate				
Upper Pool 4	1989 to 2018	587	0.0%	LTRM, MPCA
Pool 8	1995 to 2000	84	0.0%	LTRM
Pool 11	2001 to 2018	61	3.3%	IEPA
Pool 13	1995 to 2018	148	2.7%	LTRM, IEPA
Pool 15	2000 to 2018	116	6.9%	IEPA
Pool 17	2000 to 2018	72	5.6%	IEPA
Pool 19	2000 to 2018	81	7.4%	IEPA
Pool 21	2000 to 2018	69	13.0%	IEPA
Pool 24	2000 to 2018	71	7.0%	IEPA
Pool 26	1995 to 2018	201	3.0%	LTRM, IEPA
St. Louis, MO	2000 to 2018	63	1.6%	IEPA
Chester, IL	2001 to 2018	62	0.0%	IEPA
Thebes, IL	1995 to 2018	127	0.0%	LTRM, IEPA
La Grange Pool	1995 to 2000	75	0.0%	LTRM

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Chloride				
Upper Pool 4	1989 to 2018	743	0.1%	LTRM, MPCA
Pool 8	1995 to 2000	84	0.0%	LTRM
Pool 9	1989 to 2018	309	0.0%	WDNR
Pool 11	2001 to 2018	74	0.0%	IEPA
Pool 13	1989 to 2018	209	0.0%	IEPA, LTRM
Pool 15	2000 to 2018	124	0.0%	IEPA
Pool 17	2000 to 2018	74	0.0%	IEPA
Pool 19	1989 to 2018	158	0.0%	IEPA
Pool 21	2000 to 2018	74	0.0%	IEPA
Pool 24	2000 to 2018	74	0.0%	IEPA
Pool 26	1989 to 2018	237	0.0%	IEPA, LTRM
St. Louis, MO	2000 to 2018	67	0.0%	IEPA
Chester, IL	2001 to 2018	67	0.0%	IEPA
Thebes, IL	1989 to 2018	174	0.0%	IEPA, LTRM
La Grange Pool	1994 to 2000	80	0.0%	LTRM
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

APPENDIX 2C

Parameter, site, period of record, and data source for the individual **pathogen indicator: fecal coliform**. Percent censored is an indicator of how reliably the trend can be detected — i.e., the higher the trend, the more limited the reliability of the trend.

	Data Record	Sample Size	Percent Censored*	Data Provider**
Fecal Coliform				
Pool 5+6	1989 to 2003	105	8.6%	MPCA
Pool 13	1989 to 2018	83	4.8%	IEPA
Pool 15	2001 to 2018	61	1.6%	IEPA
Pool 19	1989 to 2018	119	0.8%	IEPA
Pool 26	1989 to 2018	206	1.5%	IEPA
Thebes, IL	1989 to 2018	99	1.0%	IEPA
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

APPENDIX 2D

Parameter, site, period of record, and data source for individual **nutrient indicators: total phosphorus, total nitrogen, ammonia, inorganic nitrogen, and chlorophyll-a**. Percent censored is an indicator of how reliably the trend can be detected — i.e., the higher the trend, the more limited the reliability of the trend.

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Phosphorus				
Upper Pool 4	1989 to 2018	1155	0.3%	LTRM, MPCA
Lower Pool 4	1994 to 2017	228	0.0%	LTRM
Pool 5+6	1989 to 2018	369	0.0%	MPCA
Pool 8	1994 to 2017	351	0.0%	LTRM
Pool 9	1989 to 2018	314	0.0%	WDNR
Pool 11	2001 to 2018	68	0.0%	IEPA
Pool 13	1989 to 2018	555	0.0%	IEPA, LTRM
Pool 15	2000 to 2018	120	0.0%	IEPA
Pool 17	2000 to 2018	72	0.0%	IEPA
Pool 19	1989 to 2018	162	0.0%	IEPA
Pool 21	2000 to 2018	72	0.0%	IEPA
Pool 24	2000 to 2018	75	0.0%	IEPA
Pool 26	1989 to 2018	508	0.0%	IEPA, LTRM
St. Louis, MO	2000 to 2018	64	0.0%	IEPA
Chester, IL	2001 to 2018	63	0.0%	IEPA
Thebes, IL	1989 to 2018	562	0.0%	IEPA, LTRM
La Grange Pool	1994 to 2017	393	0.0%	LTRM

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Nitrogen				
Upper Pool 4	1994 to 2017	128	0.0%	LTRM
Lower Pool 4	1994 to 2017	233	0.0%	LTRM
Pool 8	1994 to 2017	357	0.0%	LTRM
Pool 9	1989 to 2018	318	0.0%	WDNR
Pool 13	1994 to 2017	434	0.0%	LTRM
Pool 26	1994 to 2017	364	0.0%	LTRM
Thebes, IL	1994 to 2017	499	0.0%	LTRM
La Grange Pool	1994 to 2017	403	0.0%	LTRM

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Ammonia				
Upper Pool 4	1989 to 2018	1368	22.7%	LTRM, MPCA
Lower Pool 4	1994 to 2017	230	3.5%	LTRM
Pool 5+6	1989 to 2016	146	33.6%	MPCA
Pool 8	1994 to 2017	352	9.9%	LTRM
Pool 9	1989 to 2018	262	9.9%	WDNR
Pool 13	1994 to 2018	479	10.2%	LTRM, IEPA
Pool 15	2006 to 2018	101	45.5%	IEPA
Pool 26	1994 to 2018	467	18.2%	LTRM, IEPA
Thebes, IL	1994 to 2018	523	5.4%	LTRM, IEPA
La Grange Pool	1994 to 2017	397	1.8%	LTRM

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Inorganic Nitrogen				
Upper Pool 4	1994 to 2018	194	0.0%	LTRM, MPCA
Lower Pool 4	1994 to 2017	229	0.0%	LTRM
Pool 5+6	1989 to 2018	430	0.0%	MPCA
Pool 8	1994 to 2017	354	0.8%	LTRM
Pool 9	1989 to 2018	328	1.5%	WDNR
Pool 11	2001 to 2018	75	4.0%	IEPA
Pool 13	1989 to 2018	559	0.9%	IEPA, LTRM
Pool 15	2000 to 2018	124	0.0%	IEPA
Pool 17	2000 to 2018	76	1.3%	IEPA
Pool 19	1989 to 2018	162	0.0%	IEPA
Pool 21	2000 to 2018	74	0.0%	IEPA
Pool 24	2000 to 2018	75	0.0%	IEPA
Pool 26	1990 to 2018	507	0.4%	IEPA, LTRM
St. Louis, MO	2000 to 2018	67	0.0%	IEPA
Chester, IL	2001 to 2018	66	0.0%	IEPA
Thebes, IL	1989 to 2018	565	0.0%	IEPA, LTRM
La Grange Pool	1994 to 2017	398	0.3%	LTRM

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Chlorophyll-a				
Upper Pool 4	1994 to 2017	154	3.9%	LTRM
Lower Pool 4	1994 to 2017	264	5.7%	LTRM
Pool 8	1994 to 2017	424	6.4%	LTRM
Pool 9	1991 to 2018	290	0.0%	WDNR
Pool 11	2001 to 2018	70	0.0%	IEPA
Pool 13	1994 to 2018	566	5.3%	LTRM, IEPA
Pool 15	2002 to 2018	103	1.0%	IEPA
Pool 19	2001 to 2018	69	1.4%	IEPA
Pool 24	2001 to 2018	65	0.0%	IEPA
Pool 26	1994 to 2018	564	0.4%	LTRM, IEPA
Chester, IL	2001 to 2018	65	0.0%	IEPA
Thebes, IL	1994 to 2018	512	0.2%	LTRM, IEPA
La Grange Pool	1994 to 2017	480	0.0%	LTRM

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

APPENDIX 2E

Parameter, site, period of record, and data source for individual **metals indicators: aluminum, zinc, arsenic, lead, mercury, and cadmium**. Percent censored is an indicator of how reliably the trend can be detected — i.e., the higher the trend, the more limited the reliability of the trend.

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Aluminum				
Pool 11	2001 to 2018	73	6.8%	IEPA
Pool 13	1989 to 2018	139	2.9%	IEPA
Pool 15	2000 to 2018	125	1.6%	IEPA
Pool 17	2000 to 2018	82	2.4%	IEPA
Pool 19	1989 to 2018	164	3.0%	IEPA
Pool 21	2000 to 2018	78	0.0%	IEPA
Pool 24	2000 to 2018	78	0.0%	IEPA
Pool 26	1990 to 2018	147	0.0%	IEPA
St. Louis, MO	2000 to 2018	67	0.0%	IEPA
Chester, IL	2001 to 2018	67	0.0%	IEPA
Thebes, IL	1989 to 2018	180	1.1%	IEPA
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Zinc				
Upper Pool 4	1989 to 2018	189	25.4%	MPCA
Pool 11	2001 to 2018	75	30.7%	IEPA
Pool 13	1989 to 2018	138	58.7%	IEPA
Pool 15	2000 to 2018	118	23.7%	IEPA
Pool 17	2000 to 2018	80	32.5%	IEPA
Pool 19	1989 to 2018	166	63.9%	IEPA
Pool 21	2000 to 2018	74	27.0%	IEPA
Pool 24	2000 to 2018	74	29.7%	IEPA
Pool 26	1990 to 2018	146	28.1%	IEPA
St. Louis, MO	2000 to 2018	66	25.8%	IEPA
Chester, IL	2001 to 2018	66	27.3%	IEPA
Thebes, IL	1989 to 2018	179	49.2%	IEPA

Data record axis: 1990, 2000, 2010, 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Arsenic				
Upper Pool 4	1989 to 2018	185	8.1%	MPCA
Pool 11	2001 to 2018	75	41.3%	IEPA
Pool 13	1989 to 2018	140	50.0%	IEPA
Pool 15	2000 to 2018	122	50.0%	IEPA
Pool 17	2000 to 2018	76	47.4%	IEPA
Pool 19	1989 to 2018	159	49.7%	IEPA
Pool 21	2000 to 2018	69	43.5%	IEPA
Pool 24	2000 to 2018	71	35.2%	IEPA
Pool 26	1990 to 2018	148	35.8%	IEPA
St. Louis, MO	2000 to 2018	62	27.4%	IEPA
Chester, IL	2001 to 2018	62	17.7%	IEPA
Thebes, IL	1989 to 2018	113	23.0%	IEPA

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Lead				
Upper Pool 4	1989 to 2018	184	22.3%	MPCA
Pool 11	2001 to 2018	77	59.7%	IEPA
Pool 13	1989 to 2018	140	75.7%	IEPA
Pool 15	2000 to 2018	125	51.2%	IEPA
Pool 17	2000 to 2018	79	48.1%	IEPA
Pool 19	1989 to 2018	165	77.6%	IEPA
Pool 21	2000 to 2018	79	51.9%	IEPA
Pool 24	2000 to 2018	77	53.2%	IEPA
Pool 26	1990 to 2018	151	49.0%	IEPA
St. Louis, MO	2000 to 2018	68	45.6%	IEPA
Chester, IL	2001 to 2018	70	41.4%	IEPA
Thebes, IL	1989 to 2018	161	49.1%	IEPA

1990 2000 2010 2020

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Mercury				
Upper Pool 4	2002 to 2018	169	45.6%	MPCA, WDNR
Lower Pool 4	2002 to 2017	69	0.0%	WDNR
	2005 2010 2015			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

	Data Record	Sample Size	Percent Censored*	Data Provider**
Total Cadmium				
Upper Pool 4	1989 to 2018	239	65.3%	MPCA, WDNR
	1990 2000 2010 2020			

* Percent of sample with a qualifier of less than (<) or greater than (>).

** Data providers include the Illinois Environmental Protection Agency (**IEPA**), Upper Mississippi River Restoration Program Long Term Resource Monitoring (**LTRM**), Minnesota Pollution Control Agency (**MPCA**), and Wisconsin Department of Natural Resources (**WDNR**).

APPENDIX 3A

Trend information, percent change, concentration change, and confidence level for 19 parameters in the **Upper Impounded area, from Pool 4 to Pool 11 on the Upper Mississippi River.**

Trends in Water Quality on the Upper Mississippi River, 1989-2018

trend direction (▲▼), total percent change (±%), and concentration change (± amount) over the trended period

UMRBA	Upper Impounded River					
	Upper Pool 4	Lower Pool 4	Pool 5+6	Pool 8	Pool 9	Pool 11
Physical Indicators						
Total Suspended Solids (mg/L)	**▼ -25% (-6.45)**	**▼ -34% (-2.86)**	**▼ -55% (-12.1)**	**▼ -39% (-7.04)**	**▼ -66% (-25.3)**	▲ 24% (4.81)
pH (SU)	--	▼ -1.5% (-0.09)	▼ -0.3% (-0.11)	--	**▲ 5.5% (0.32)**	▼ -2.3% (-0.16)
Dissolved Oxygen (mg/L)	--	▼ -1.4% (-0.30)	**▲ 12% (0.89)**	▼ -2.7% (-0.24)	▲ 3.9% (0.23)	--
Conductivity (µS/cm)	▲ -2.1% (10.4)	▼ -15% (-26.4)	**▲ 21% (64.6)**	--	**▲ 15% (36.7)**	**▲ 17% (51.0)**
Salts and Pathogens						
Chloride (mg/L)	**▲ 32% (8.96)**			**▲ 27% (3.73)**	**▲ 42% (5.93)**	▲ 9.1% (1.39)
Sulfate (mg/L)	▲ 24% (5.60)			▼ -14% (-5.29)		**▲ 48% (9.45)**
Fecal Coliform (#/100mL)			▼ -71% (-281)			
Nutrients						
Total Phosphorus (mg/L)	**▼ -58% (-0.12)**	**▼ -39% (-0.05)**	**▼ -59% (-0.12)**	**▼ -21% (-0.02)**	**▼ -44% (-0.07)**	▲ 6.9% (0.01)
Total Nitrogen (mg/L)	▲ 11% (0.24)	--		**▲ 17% (0.32)**	▲ 14% (0.29)	
Inorganic Nitrogen (mg/L)	▲ 19% (0.34)	▲ 1.6% (0.13)	▲ 36% (0.46)	▲ 23% (0.38)	▲ 27% (0.34)	▲ 29% (0.54)
Ammonia (mg/L)	▲ 28% (0.03)	▼ 11% (-0.01)	**▼ -56% (-0.07)**	--	--	
Chlorophyll-a (µg/L)	▼ -15% (-3.27)	▼ -33% (-4.84)		▼ -41% (-19.5)	**▼ -54% (-23.0)**	▼ -19% (-7.89)
Heavy Metals						
Total Aluminum (µg/L)						▼ -12% (-50.5)
Total Arsenic (µg/L)	▼ -9.8% (-0.18)					▼ -40% (-0.34)
Total Lead (µg/L)	**▼ -72% (-1.20)**					--
Total Zinc (µg/L)	**▼ -78% (-11.1)**					▲ 38% (6.62)
Total Copper (µg/L)	**▼ -42% (-1.02)**	--				**▼ -54% (-1.95)**
Total Mercury (µg/L)	--	▼ -6.8% (0.00)				
Total Cadmium (µg/L)	▼ -86% (-0.11)					

» Color denotes a desirable (**green**) or undesirable (**red**) meaningful trend direction. Here, high and moderate confidence trends are considered meaningful. Ideal pH falls within a range of 6.5 and 9, therefore, trend direction for pH cannot be simply characterized as desirable or undesirable. Meaningful pH trends are instead neutrally colored (**black**).
» High confidence trends are emphasized by having bold, colored text with a colored border and background. Moderate confidence trends have colored text only. Low confidence trends have **gray** text. Dashes (--) signify no clear trend. Empty gray cells are parameters not trended due to insufficient sample size.

APPENDIX 3B

Trend information, percent change, concentration change, and confidence level for 19 parameters in the **Lower Impounded area, from Pool 13 to Pool 26 on the Upper Mississippi River.**

Trends in Water Quality on the Upper Mississippi River, 1989-2018

trend direction (▲▼), total percent change (±%), and concentration change (± amount) over the trended period

UMRBA	Lower Impounded River						
	Pool 13	Pool 15	Pool 17	Pool 19	Pool 21	Pool 24	Pool 26
Physical Indicators							
Total Suspended Solids (mg/L)	**▼ -50% (-22.3)**	▼ -13% (-7.78)	▲ 11% (8.25)	▼ -47% (-41.0)	▼ -32% (-36.9)	▼ -35% (-39.4)	▼ -32% (-12.4)
pH (SU)	▼ -1.4% (-0.12)	**▼ -3.4% (-0.23)**	--	--	▼ -1.0% (-0.10)	▼ -2.1% (-0.18)	**▼ -4.6% (-0.30)**
Dissolved Oxygen (mg/L)	**▲ 5.1% (0.72)**	--	--	--	**▲ 9.5% (0.84)**	**▲ 11% (0.92)**	**▲ 9.8% (0.49)**
Conductivity (µS/cm)	▲ -0.9% (12.0)	**▲ 18% (48.4)**	**▲ 11% (35.4)**	**▲ 15% (51.8)**	**▲ 20% (56.7)**	**▲ 22% (66.5)**	**▲ 15% (70.0)**
Salts and Pathogens							
Chloride (mg/L)	**▲ 37% (5.11)**	**▲ 10% (1.35)**	**▲ 19% (3.70)**	**▲ 29% (4.94)**	**▲ 27% (4.68)**	**▲ 26% (4.39)**	**▲ 89% (25.3)**
Sulfate (mg/L)	▼ -18% (-5.29)	▲ 35% (6.43)	▲ 40% (5.31)	▲ 16% (3.31)	**▲ 72% (10.8)**	▲ 48% (8.96)	▲ 22% (4.44)
Fecal Coliform (#/100mL)	--	▼ -56% (-95.2)		▼ -87% (-541)			▼ -38% (-139)
Nutrients							
Total Phosphorus (mg/L)	**▼ -41% (-0.07)**	--	▲ 28% (0.05)	▼ -12% (-0.03)	--	▼ -14% (-0.02)	**▲ 25% (0.05)**
Total Nitrogen (mg/L)	▲ 9.8% (0.22)						--
Inorganic Nitrogen (mg/L)	**▲ 48% (0.49)**	▲ 16% (0.24)	▼ -16% (-0.51)	--	▼ -22% (-0.74)	▼ -12% (-0.44)	▲ 27% (0.66)
Ammonia (mg/L)	**▼ -24% (-0.04)**	**▲ 129% (0.13)**					**▼ -48% (-0.04)**
Chlorophyll-a (µg/L)	▲ 16% (2.71)	▼ -40% (-10.1)		▲ 27% (7.48)		**▲ 116% (21.4)**	▲ 8.6% (3.64)
Heavy Metals							
Total Aluminum (µg/L)	**▼ -44% (-503)**	▼ -26% (-103)	--	▼ -50% (-755)	▼ -45% (-654)	▼ -43% (-568)	▼ -63% (-1077)
Total Arsenic (µg/L)	▲ 42% (0.51)	▼ -42% (-0.66)	▼ -38% (-0.66)	▲ 40% (0.56)	--	▼ -33% (-0.46)	**▲ 40% (0.96)**
Total Lead (µg/L)	--	**▲ 410% (2.95)**	**▲ 250% (1.68)**	▲ 5.8% (1.10)	▲ 267% (2.57)	▲ 49% (1.35)	▼ -39% (-3.03)
Total Zinc (µg/L)	▼ -48% (-12.6)	--	▲ 23% (10.9)	▼ -54% (-11.2)	▼ -29% (-2.84)	▼ -43% (-8.73)	▲ 24% (4.57)
Total Copper (µg/L)	--	--	▲ 17% (0.52)	--	▼ -25% (-1.56)	▼ -48% (-2.63)	▼ -64% (-4.62)
Total Mercury (µg/L)							
Total Cadmium (µg/L)							

» Color denotes a desirable (**green**) or undesirable (**red**) meaningful trend direction. Here, high and moderate confidence trends are considered meaningful. Ideal pH falls within a range of 6.5 and 9, therefore, trend direction for pH cannot be simply characterized as desirable or undesirable. Meaningful pH trends are instead neutrally colored (**black**).

» High confidence trends are emphasized by having bold, colored text with a colored border and background. Moderate confidence trends have colored text only. Low confidence trends have **gray** text. Dashes (--) signify no clear trend. Empty gray cells are parameters not trended due to insufficient sample size.

APPENDIX 3C

Trend information, percent change, concentration change, and confidence level for 19 parameters in the **Open River portion of the Upper Mississippi River as well as the Illinois River.**

Trends in Water Quality on the Upper Mississippi River, 1989-2018

trend direction (▲▼), total percent change (±%), and concentration change (± amount) over the trended period

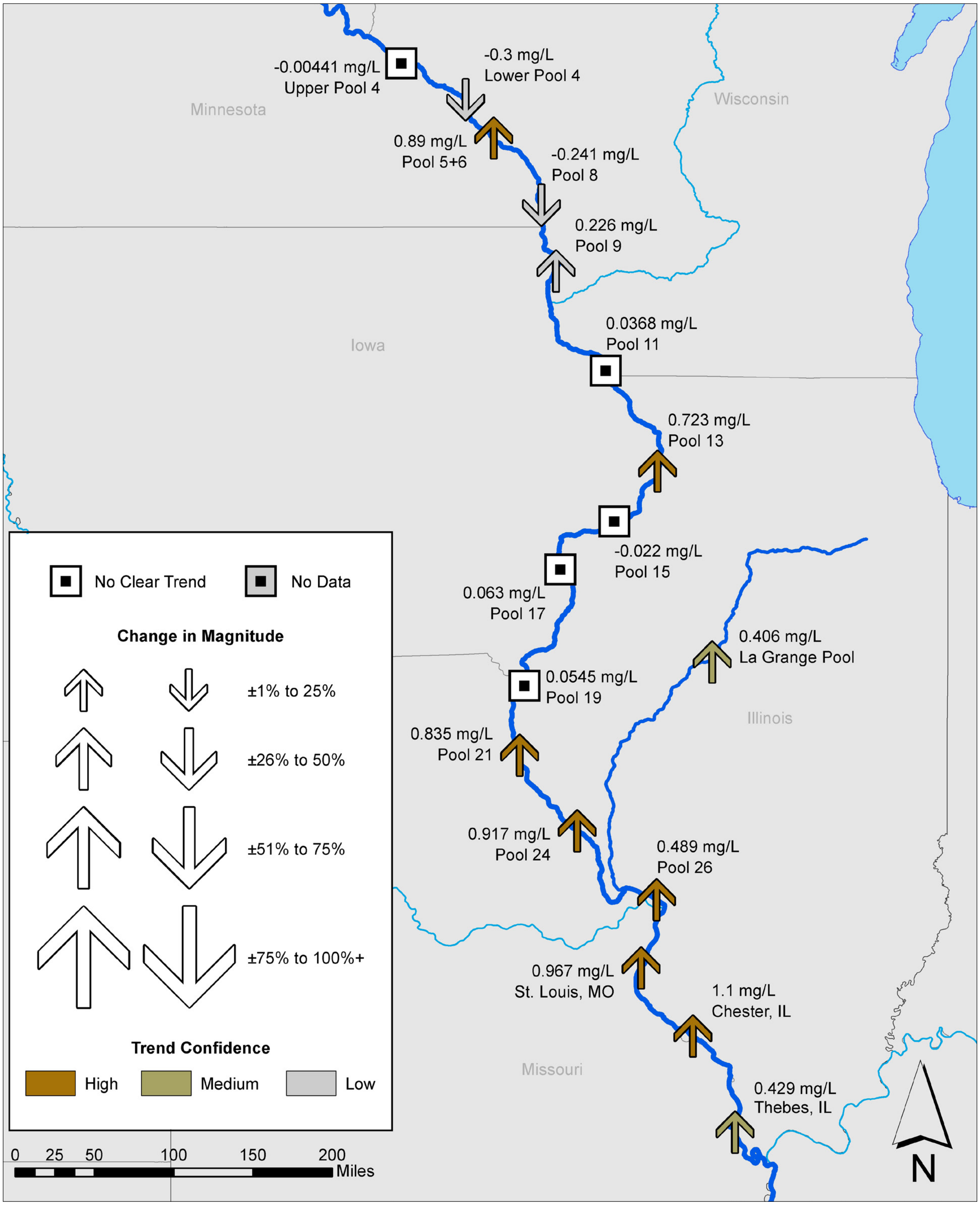
UMRBA	Open River			Illinois River
	St. Louis, MO	Chester, IL	Thebes, IL	La Grange Pool
Physical Indicators				
Total Suspended Solids (mg/L)	**▼ -33% (-59.7)**	▼ -53% (-201)	▼ -49% (-84.8)	**▼ -17% (-18.8)**
pH (SU)	▲ 2.2% (0.02)	▲ 5.5% (0.33)	--	▲ 1.2% (0.01)
Dissolved Oxygen (mg/L)	**▲ 11% (0.97)**	**▲ 13% (1.10)**	▲ 7.5% (0.43)	▲ 4.9% (0.41)
Conductivity (µS/cm)	**▲ 18% (91.5)**	**▲ 26% (124)**	**▲ 6.2% (49.7)**	**▲ 11% (74.8)**
Salts and Pathogens				
Chloride (mg/L)	▲ 18% (5.02)	▲ 16% (4.36)	**▲ 48% (8.78)**	**▲ 35% (21.5)**
Sulfate (mg/L)	**▲ 34% (14.1)**	**▲ 46% (21.5)**	--	--
Fecal Coliform (#/100mL)			--	
Nutrients				
Total Phosphorus (mg/L)	▲ 22% (0.05)	▼ -13% (-0.05)	▼ -16% (-0.02)	--
Total Nitrogen (mg/L)			--	**▼ -14% (-0.87)**
Inorganic Nitrogen (mg/L)	--	--	▲ 25% (0.40)	**▼ -17% (-0.70)**
Ammonia (mg/L)			**▼ -53% (-0.06)**	**▼ -69% (-0.15)**
Chlorophyll-a (µg/L)		▼ -20% (-6.25)	**▲ 54% (7.99)**	▼ -0.1% (-3.66)
Heavy Metals				
Total Aluminum (µg/L)	▼ -57% (-1659)	▼ -60% (-1956)	**▼ -82% (-6484)**	
Total Arsenic (µg/L)	--	▼ -10% (-0.29)	▼ 19% (-0.65)	
Total Lead (µg/L)	▼ -32% (-1.39)	▼ -49% (-2.66)	▼ -88% (-28.9)	
Total Zinc (µg/L)	▼ -62% (-24.0)	▼ -30% (-7.09)	**▼ -72% (-48.7)**	
Total Copper (µg/L)	**▼ -52% (-4.66)**	▼ -49% (-3.67)	**▼ -75% (-11.4)**	
Total Mercury (µg/L)				
Total Cadmium (µg/L)				

» Color denotes a desirable (**green**) or undesirable (**red**) meaningful trend direction. Here, high and moderate confidence trends are considered meaningful. Ideal pH falls within a range of 6.5 and 9, therefore, trend direction for pH cannot be simply characterized as desirable or undesirable. Meaningful pH trends are instead neutrally colored (**black**).
» High confidence trends are emphasized by having bold, colored text with a colored border and background. Moderate confidence trends have colored text only. Low confidence trends have **gray** text. Dashes (--) signify no clear trend. Empty gray cells are parameters not trended due to insufficient sample size.

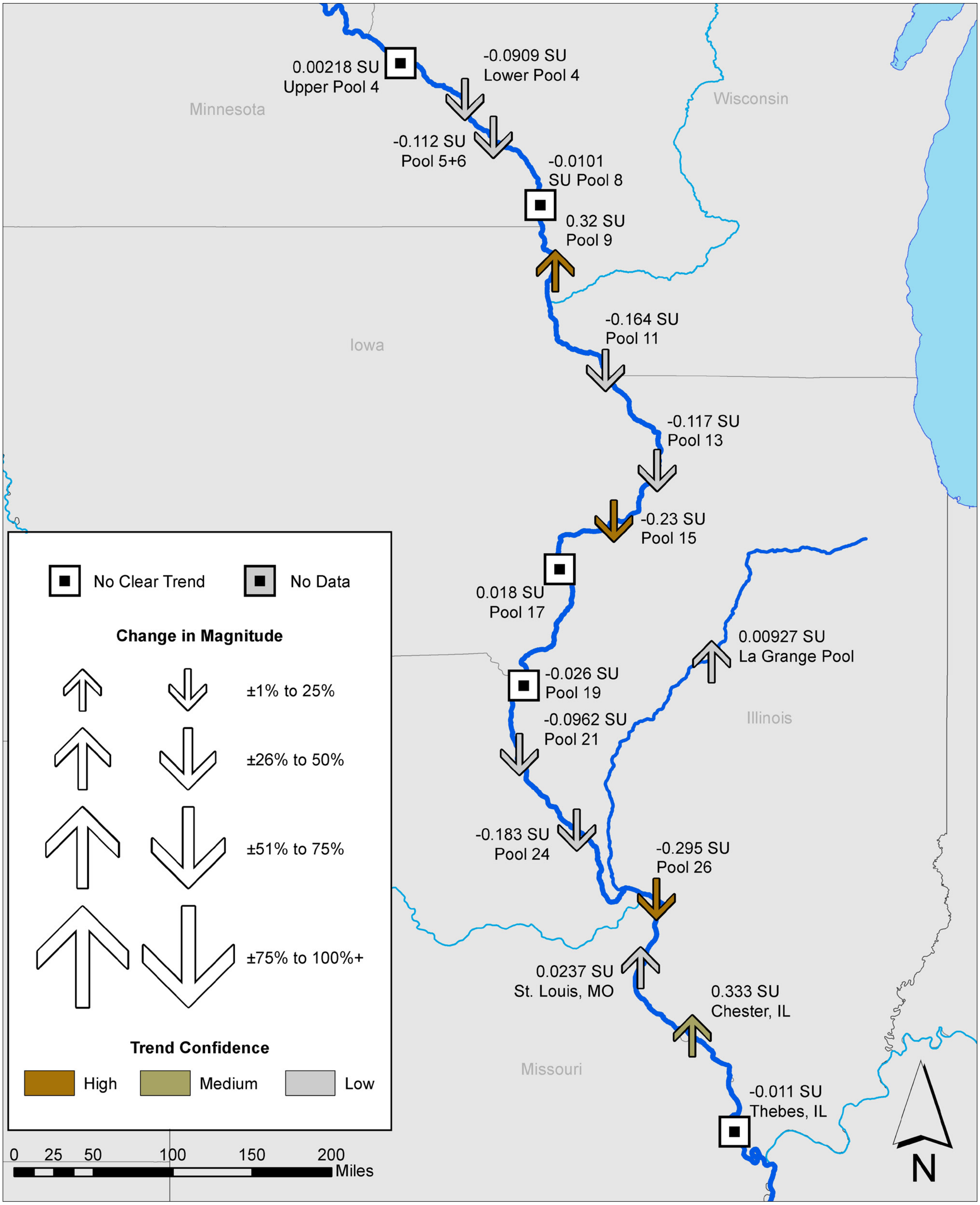
APPENDIX 4

Maps for each parameter showing the change of the concentration (or magnitude) with different sizes of arrows and the statistical confidence in the trend with a color scheme for high, medium, and low confidence.

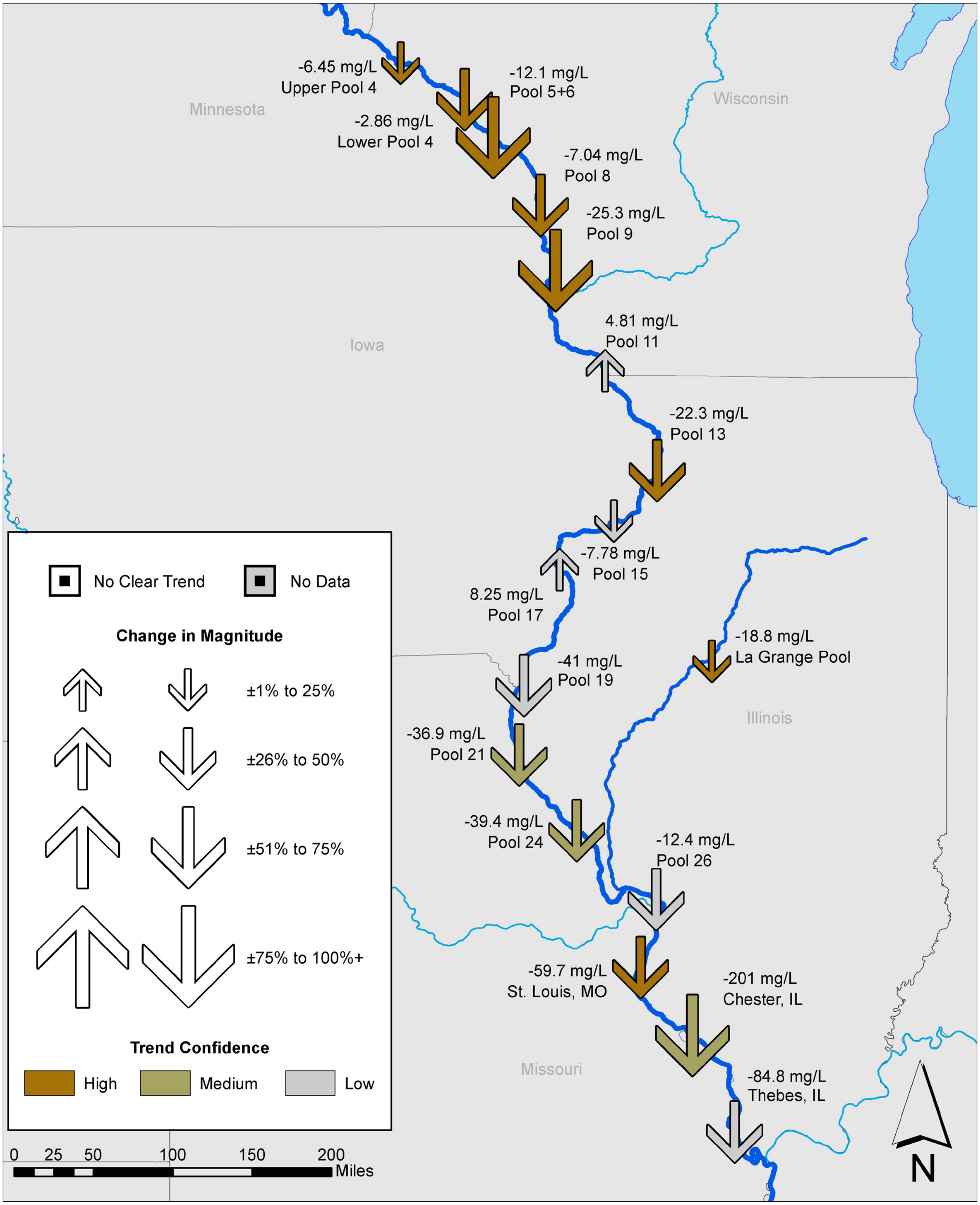
Dissolved Oxygen



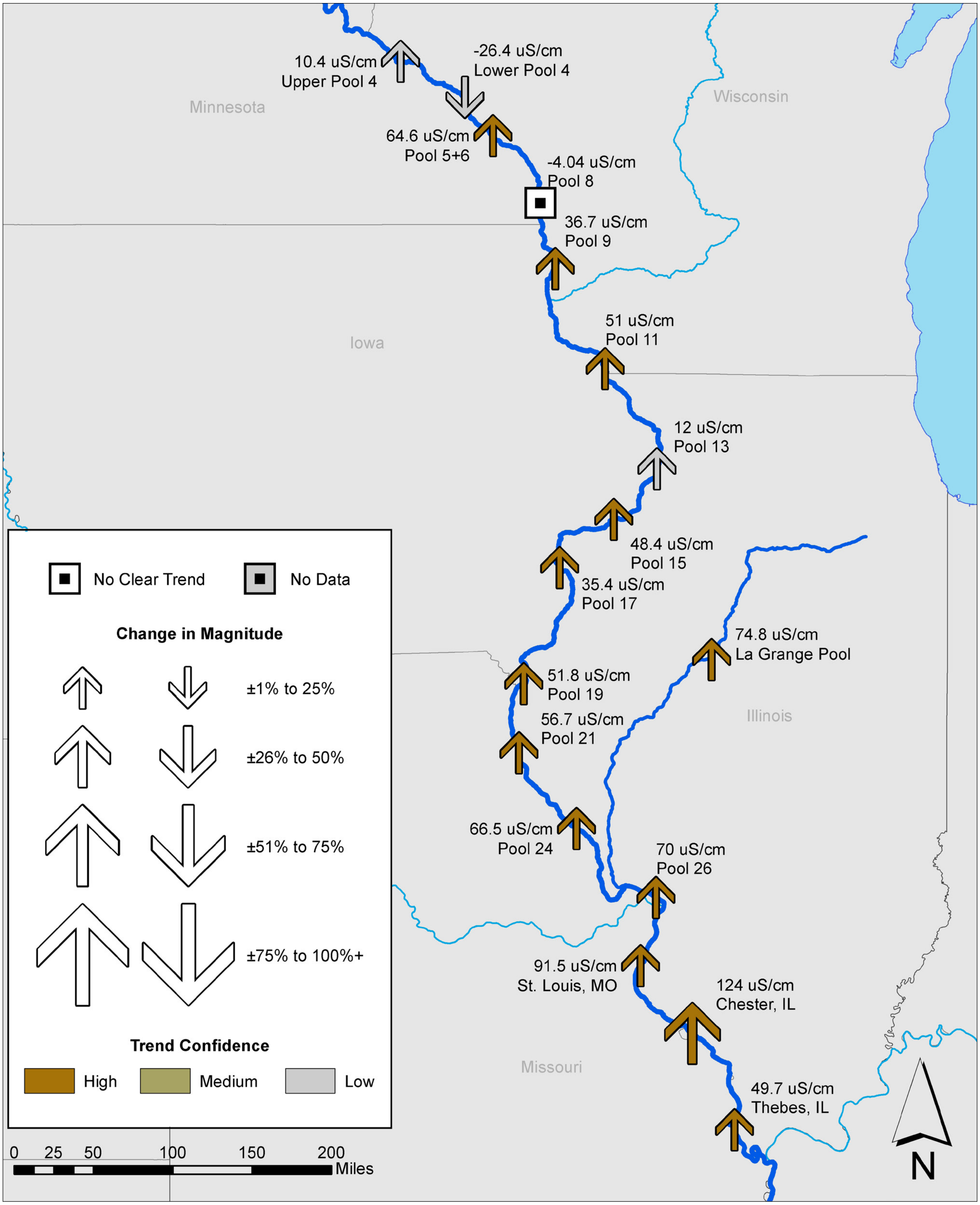
pH


0.00218 SU
Upper Pool 4
-0.0909 SU
Lower Pool 4
Minnesota
Wisconsin
-0.112 SU
Pool 5+6
-0.0101
SU Pool 8
0.32 SU
Pool 9
Iowa
-0.164 SU
Pool 11
-0.117 SU
Pool 13
-0.23 SU
Pool 15
0.018 SU
Pool 17
0.00927 SU
La Grange Pool
-0.026 SU
Pool 19
Illinois
-0.0962 SU
Pool 21
-0.183 SU
Pool 24
-0.295 SU
Pool 26
0.0237 SU
St. Louis, MO
0.333 SU
Chester, IL
Missouri
-0.011 SU
Thebes, IL
N
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
0
25
50
100
150
200
Miles

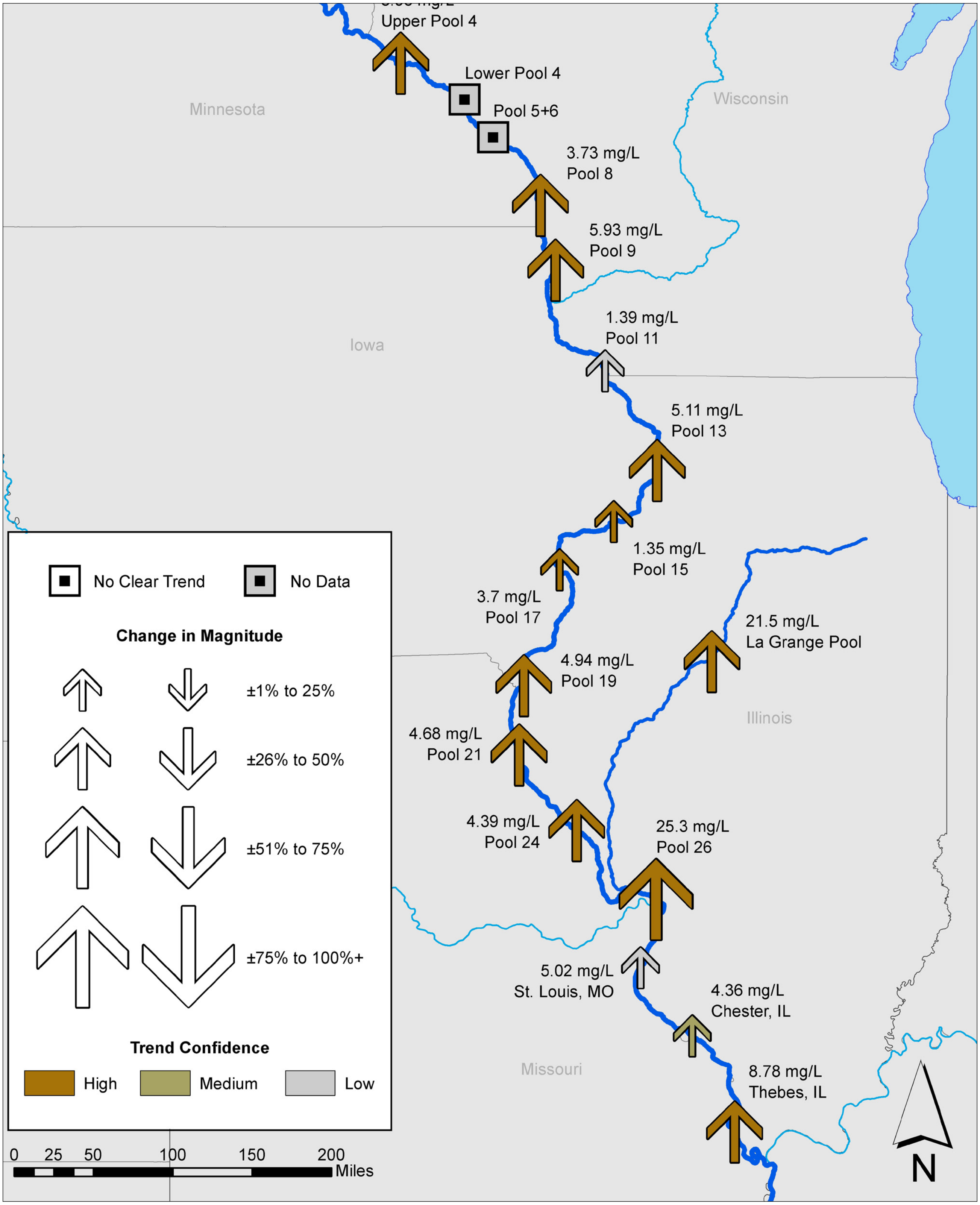
Total Suspended Solids



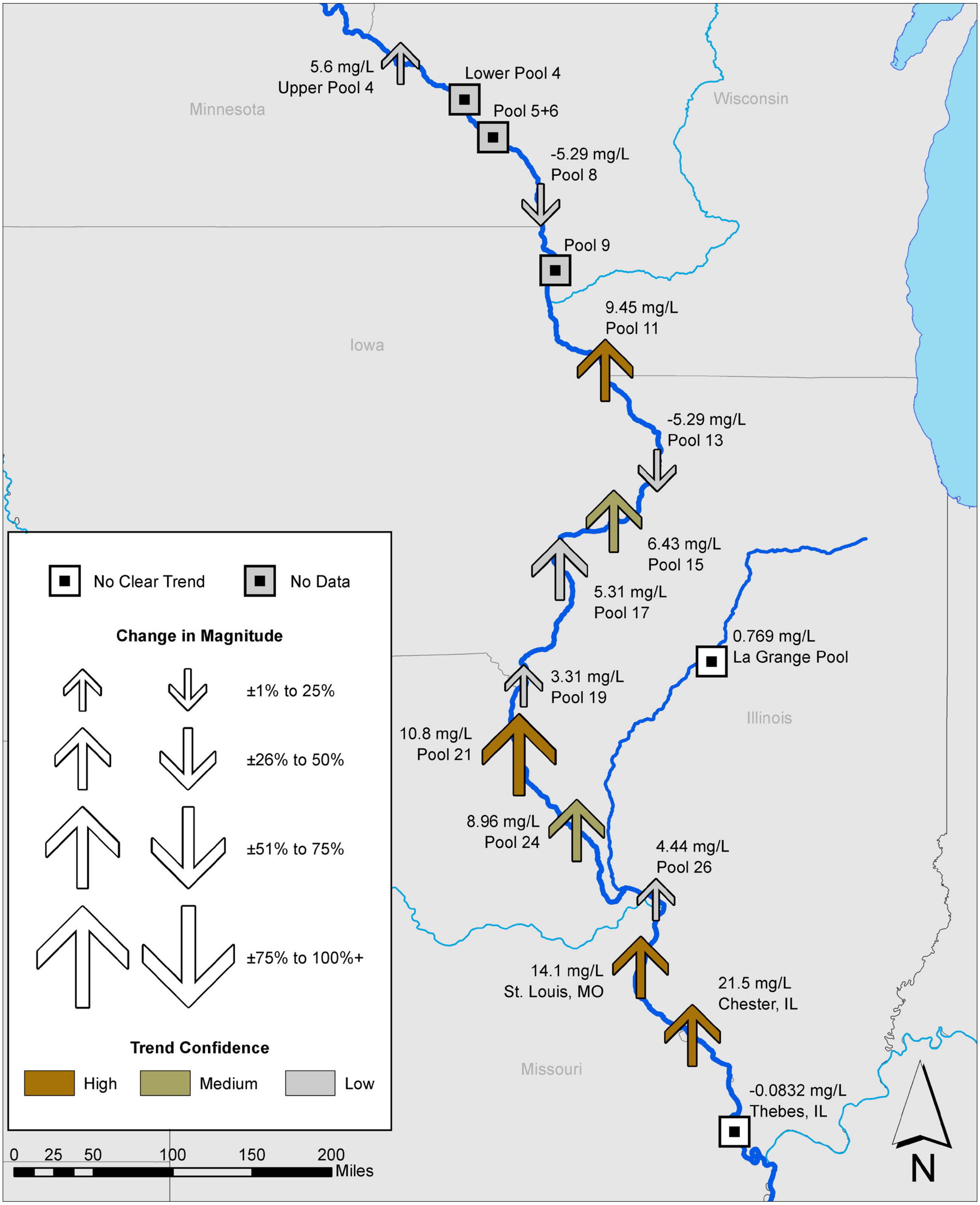
Conductivity



Chloride

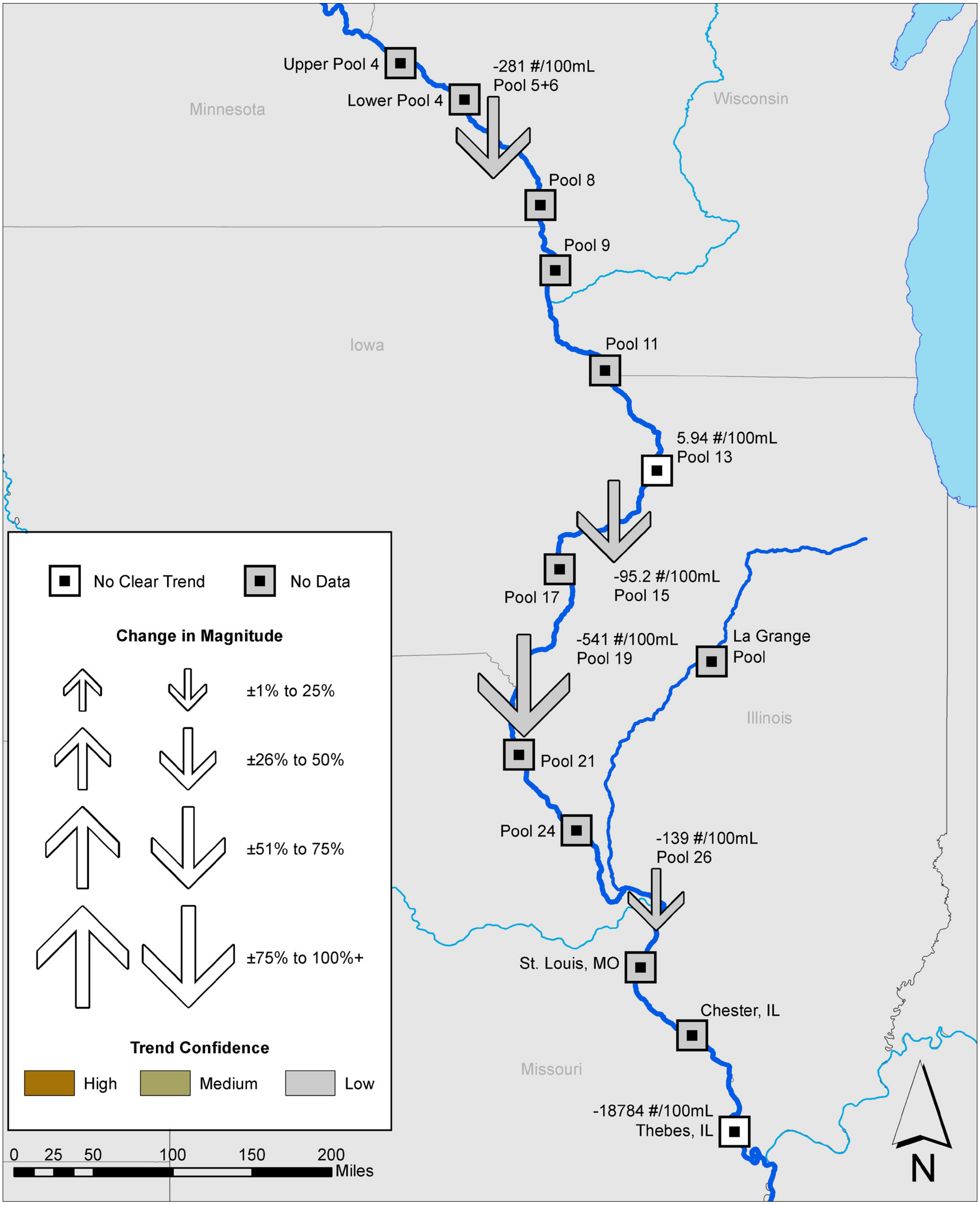

Upper Pool 4
Lower Pool 4
Pool 5+6
3.73 mg/L
Pool 8
5.93 mg/L
Pool 9
1.39 mg/L
Pool 11
5.11 mg/L
Pool 13
1.35 mg/L
Pool 15
3.7 mg/L
Pool 17
4.94 mg/L
Pool 19
21.5 mg/L
La Grange Pool
4.68 mg/L
Pool 21
4.39 mg/L
Pool 24
25.3 mg/L
Pool 26
5.02 mg/L
St. Louis, MO
4.36 mg/L
Chester, IL
8.78 mg/L
Thebes, IL
Minnesota
Wisconsin
Iowa
Illinois
Missouri
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
0 25 50 100 150 200
Miles
N

Sulfate

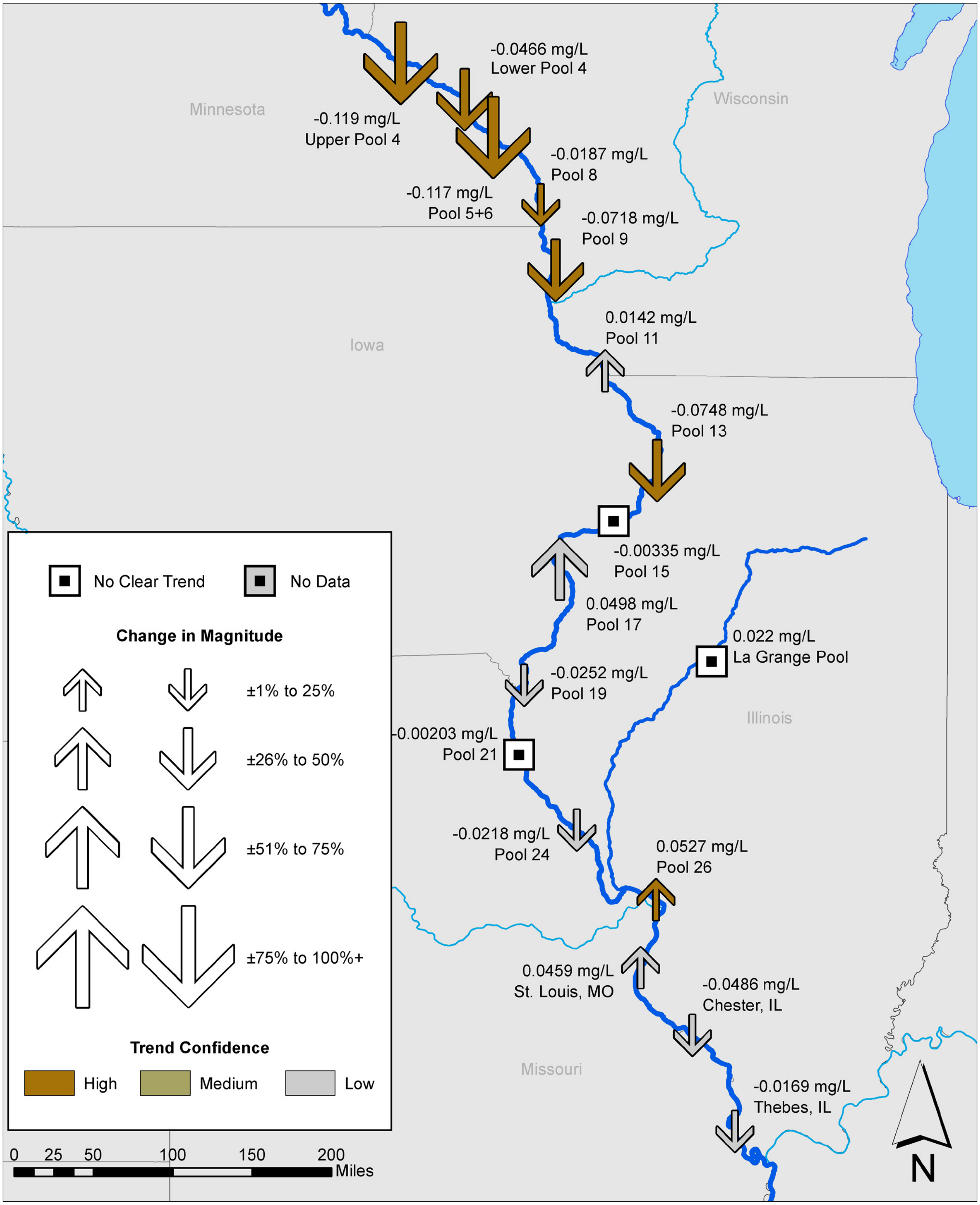


5.6 mg/L
Upper Pool 4
Lower Pool 4
Pool 5+6
-5.29 mg/L
Pool 8
Pool 9
9.45 mg/L
Pool 11
-5.29 mg/L
Pool 13
6.43 mg/L
Pool 15
5.31 mg/L
Pool 17
0.769 mg/L
La Grange Pool
3.31 mg/L
Pool 19
10.8 mg/L
Pool 21
8.96 mg/L
Pool 24
4.44 mg/L
Pool 26
14.1 mg/L
St. Louis, MO
21.5 mg/L
Chester, IL
-0.0832 mg/L
Thebes, IL
Minnesota
Wisconsin
Iowa
Illinois
Missouri
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
0 25 50 100 150 200
Miles
N

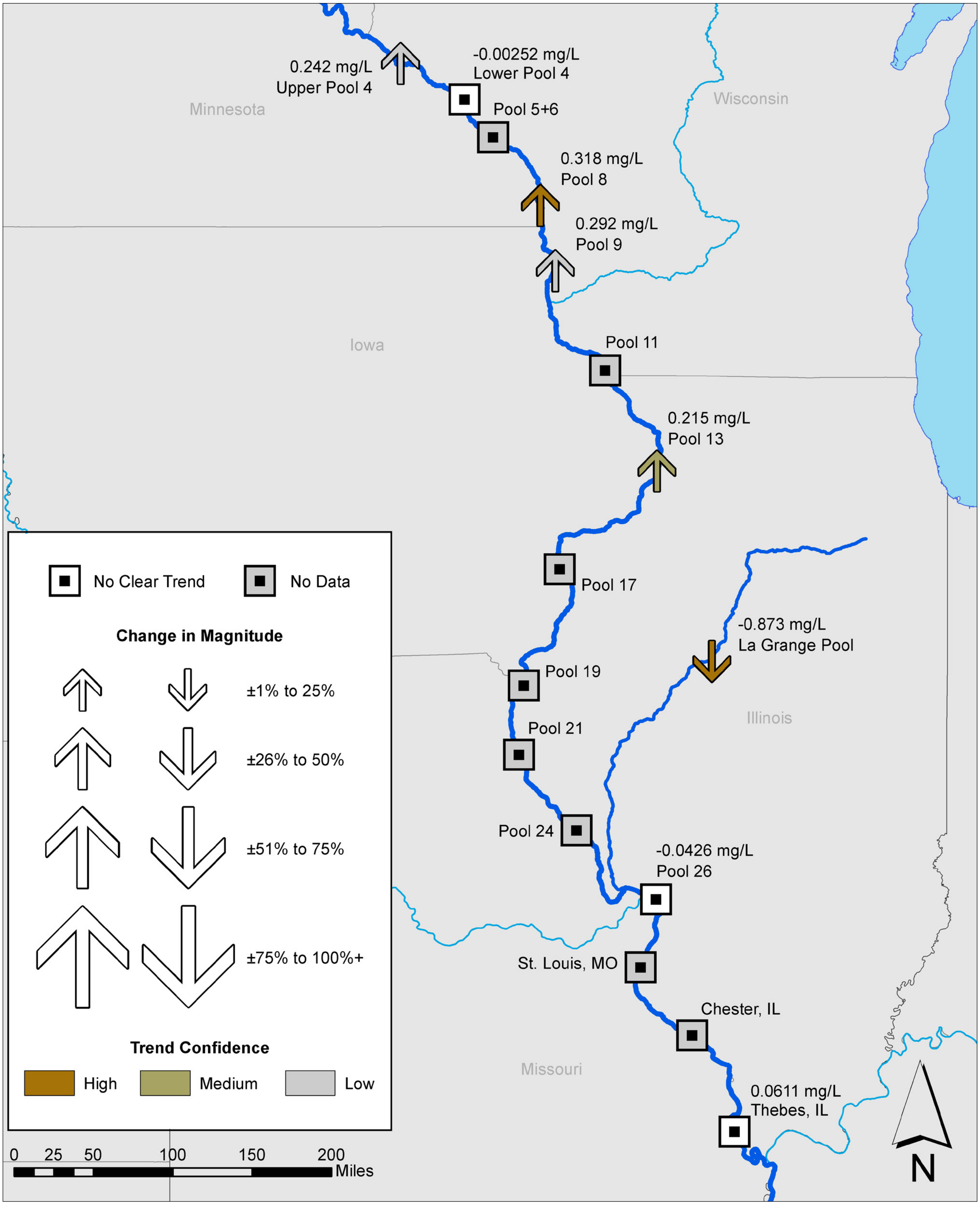
Fecal Coliform



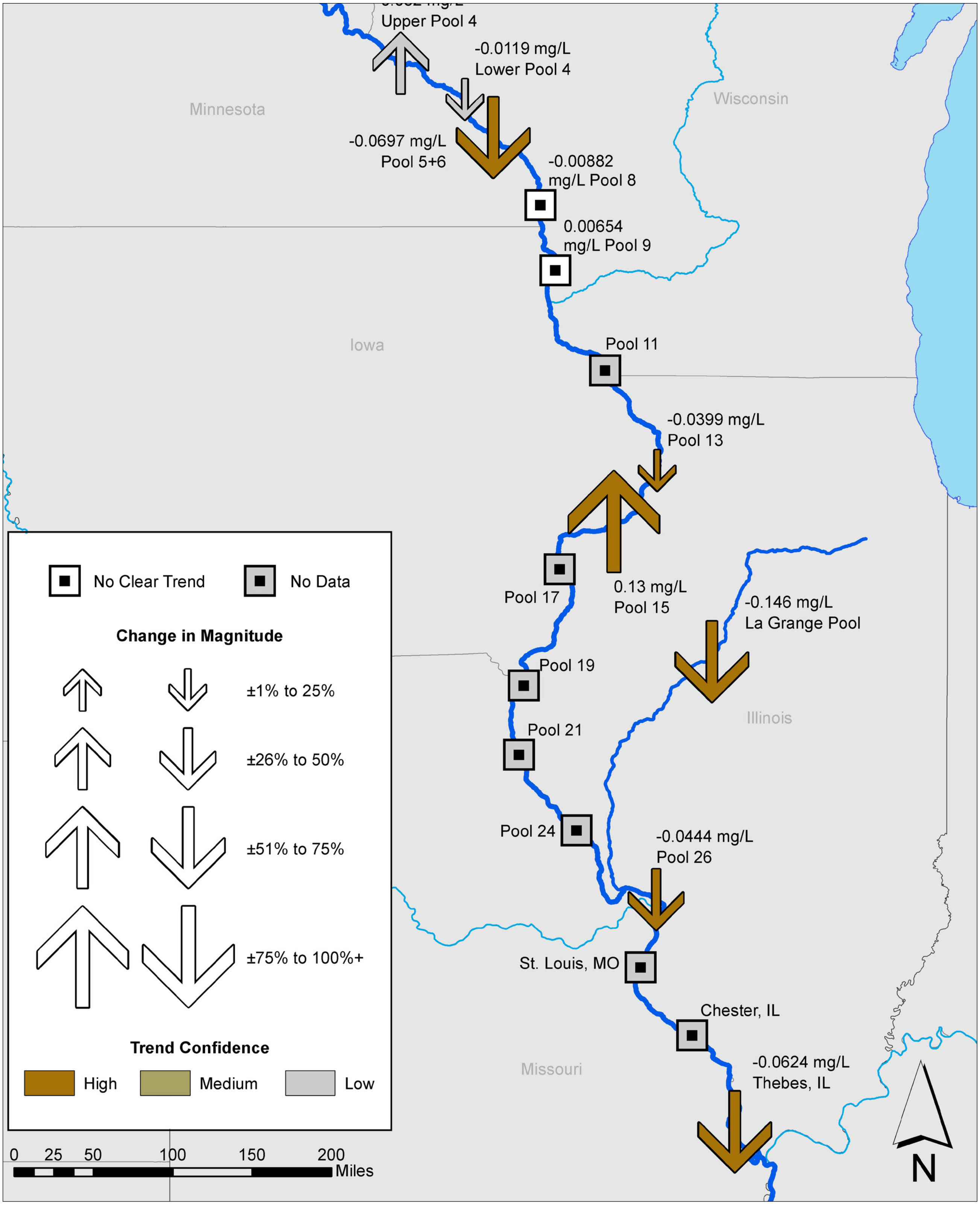
Total Phosphorus



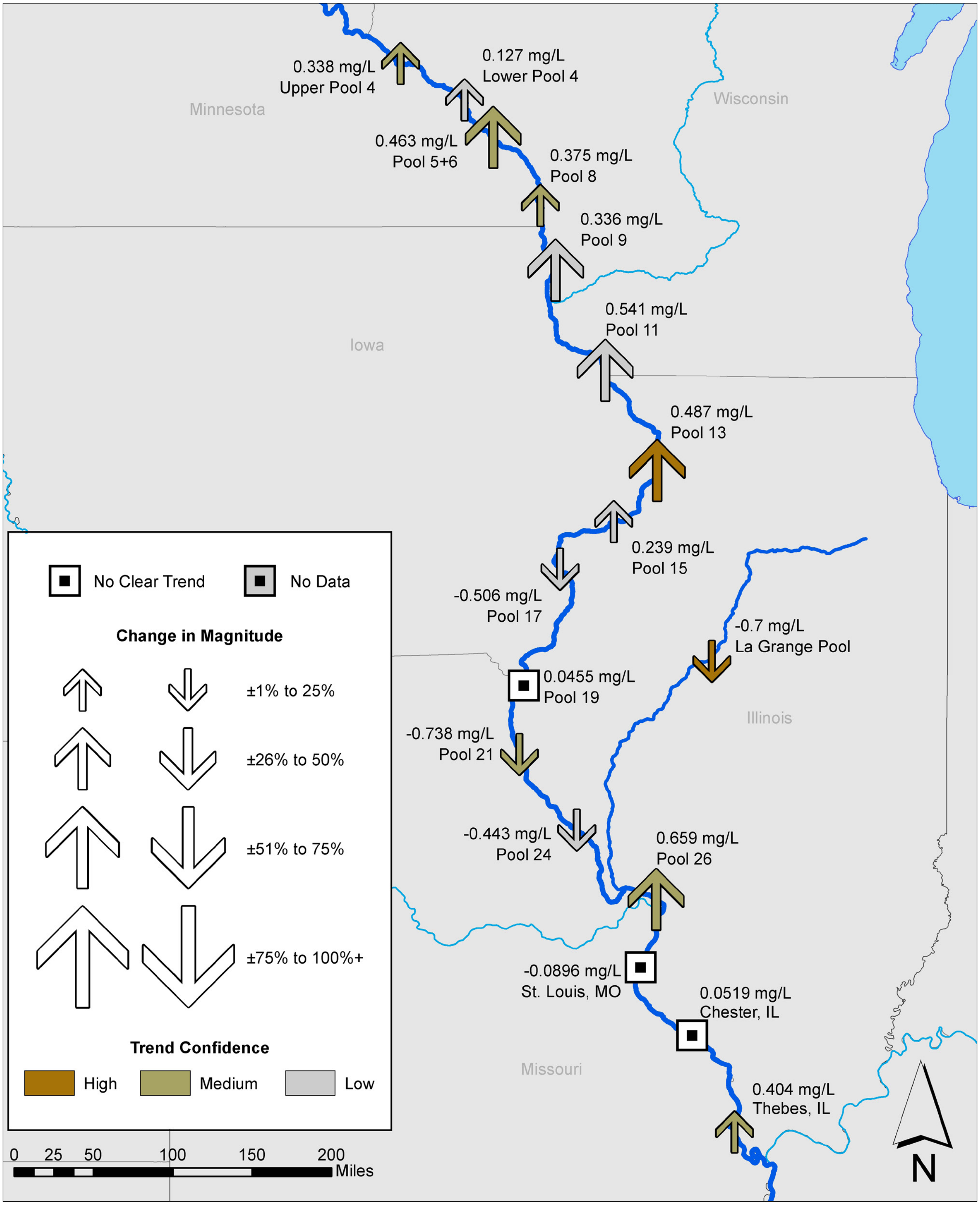
Total Nitrogen



Ammonia

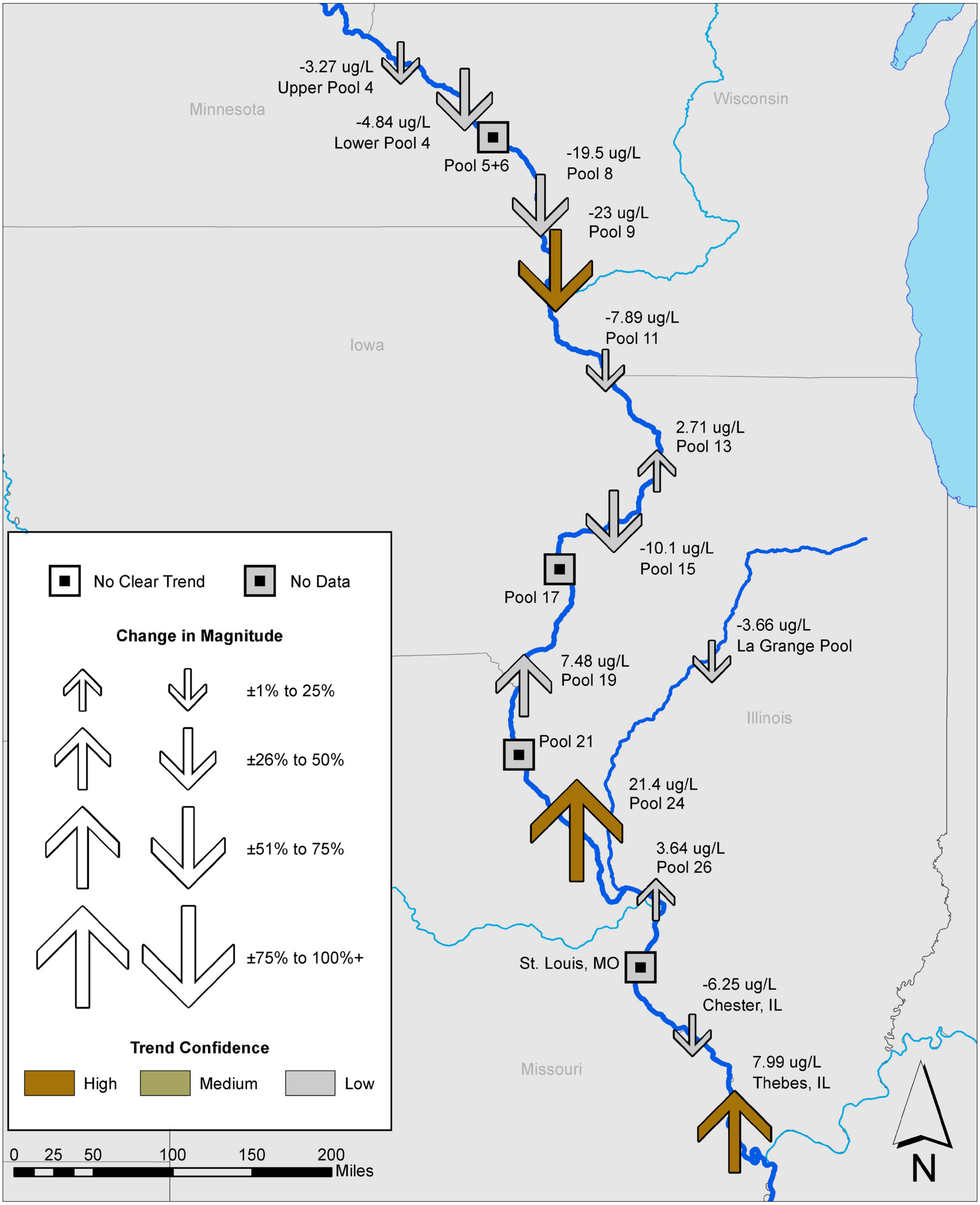

Upper Pool 4
-0.0119 mg/L
Lower Pool 4
Minnesota
Wisconsin
-0.0697 mg/L
Pool 5+6
-0.00882
mg/L Pool 8
0.00654
mg/L Pool 9
Iowa
Pool 11
-0.0399 mg/L
Pool 13
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
Pool 17
0.13 mg/L
Pool 15
-0.146 mg/L
La Grange Pool
Pool 19
Illinois
Pool 21
Pool 24
-0.0444 mg/L
Pool 26
St. Louis, MO
Chester, IL
Missouri
-0.0624 mg/L
Thebes, IL
0
25
50
100
150
200
Miles
N

Inorganic Nitrogen

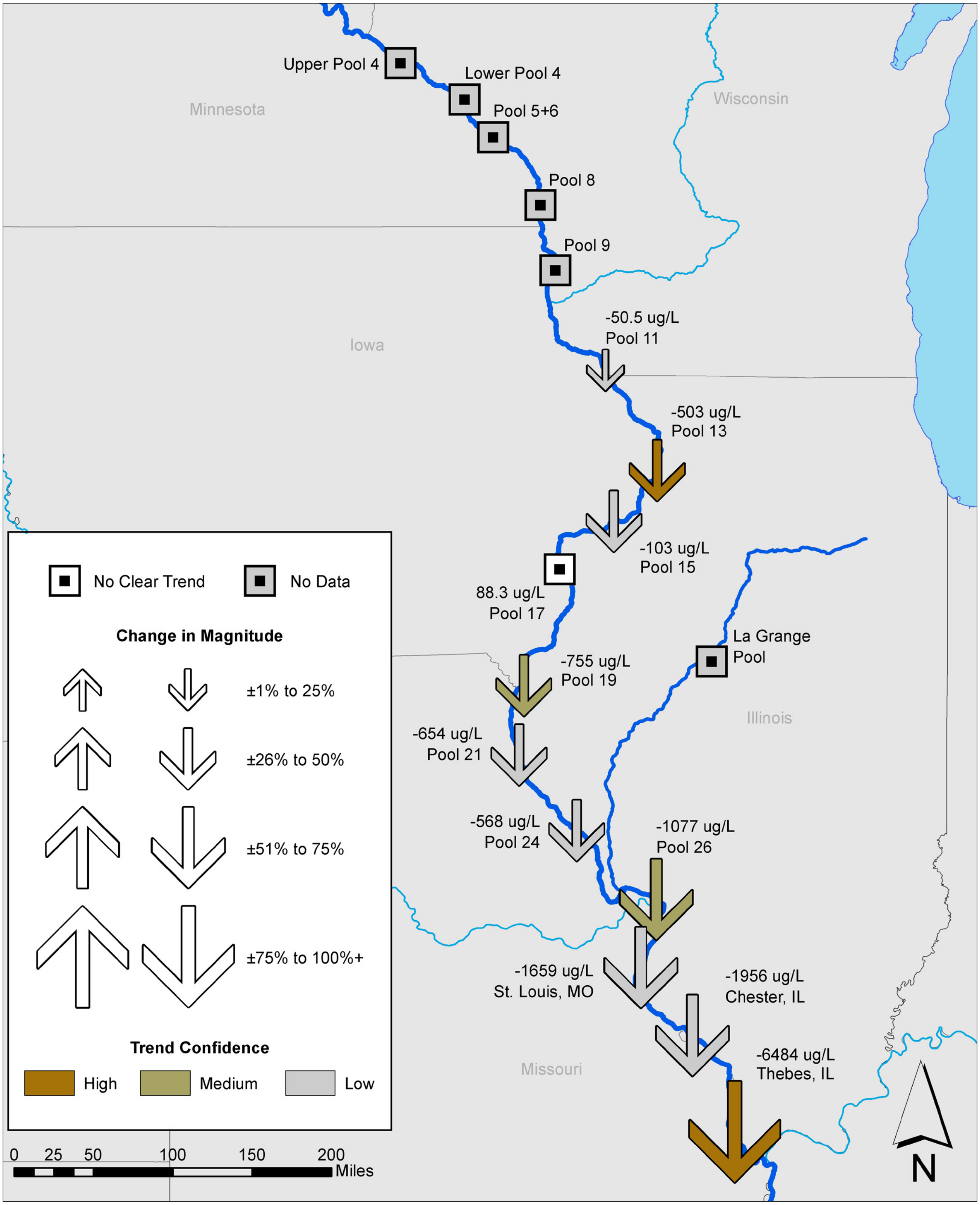


APPENDIX 4 Parameter Maps

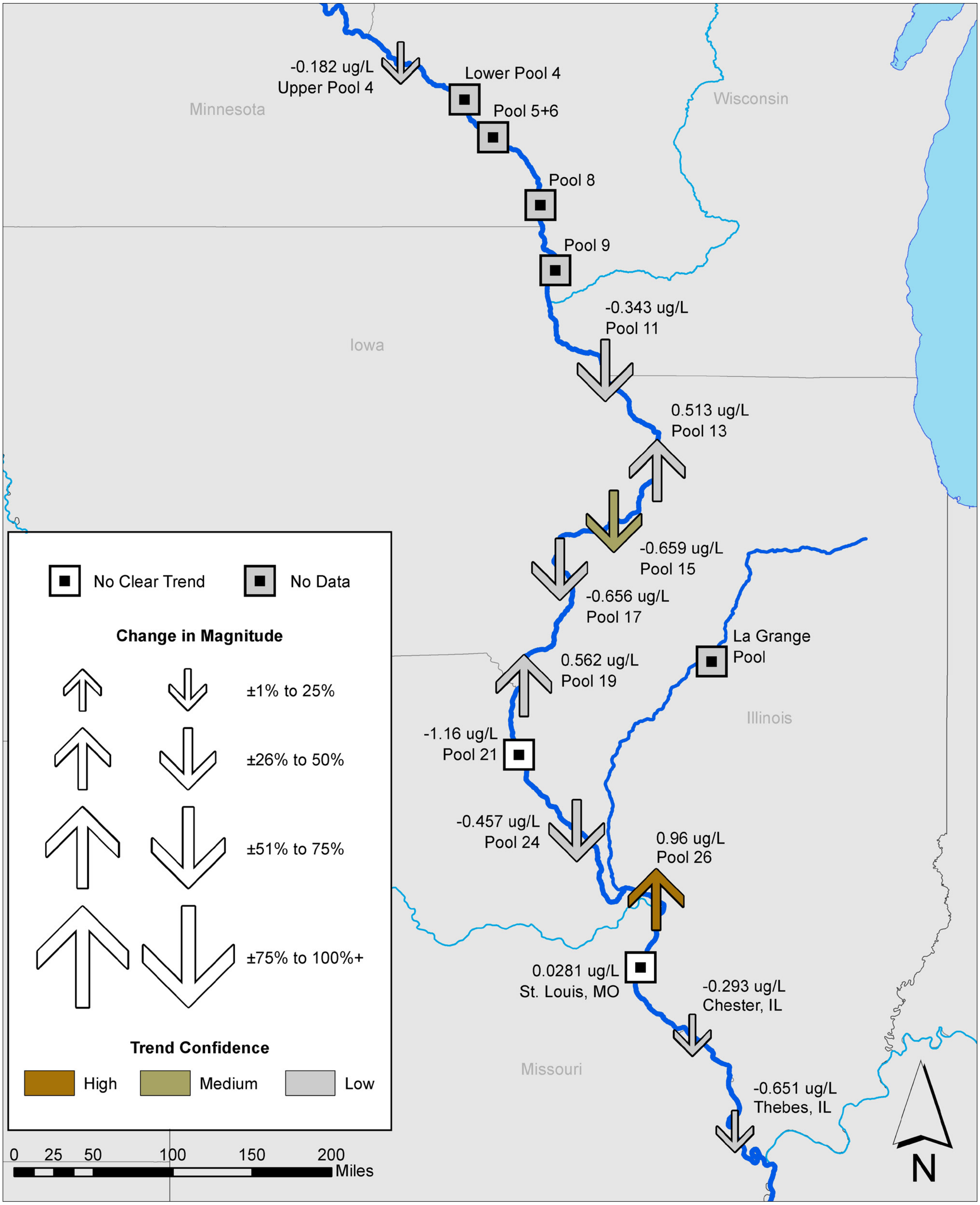
Chlorophyll-a



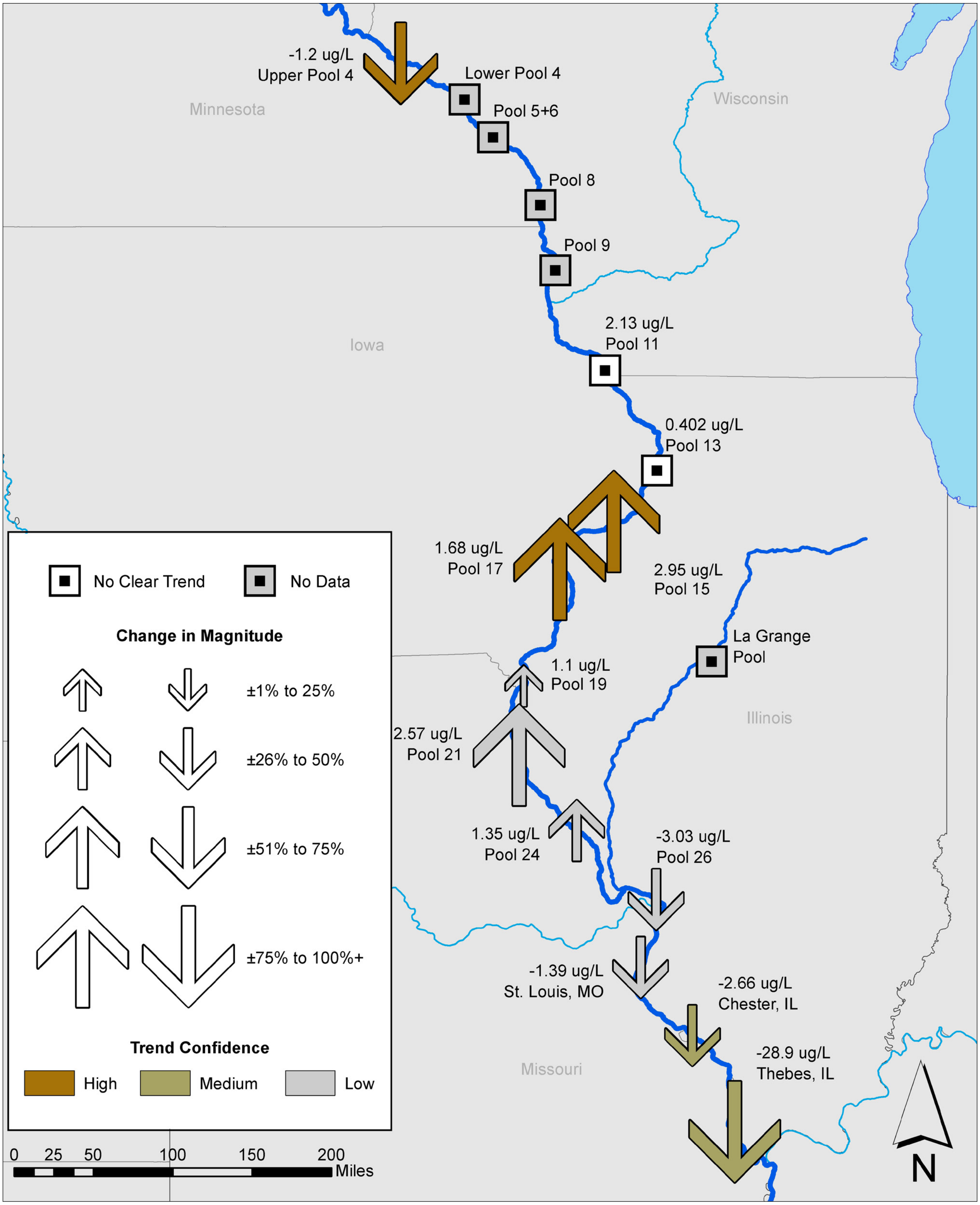
Total Aluminum



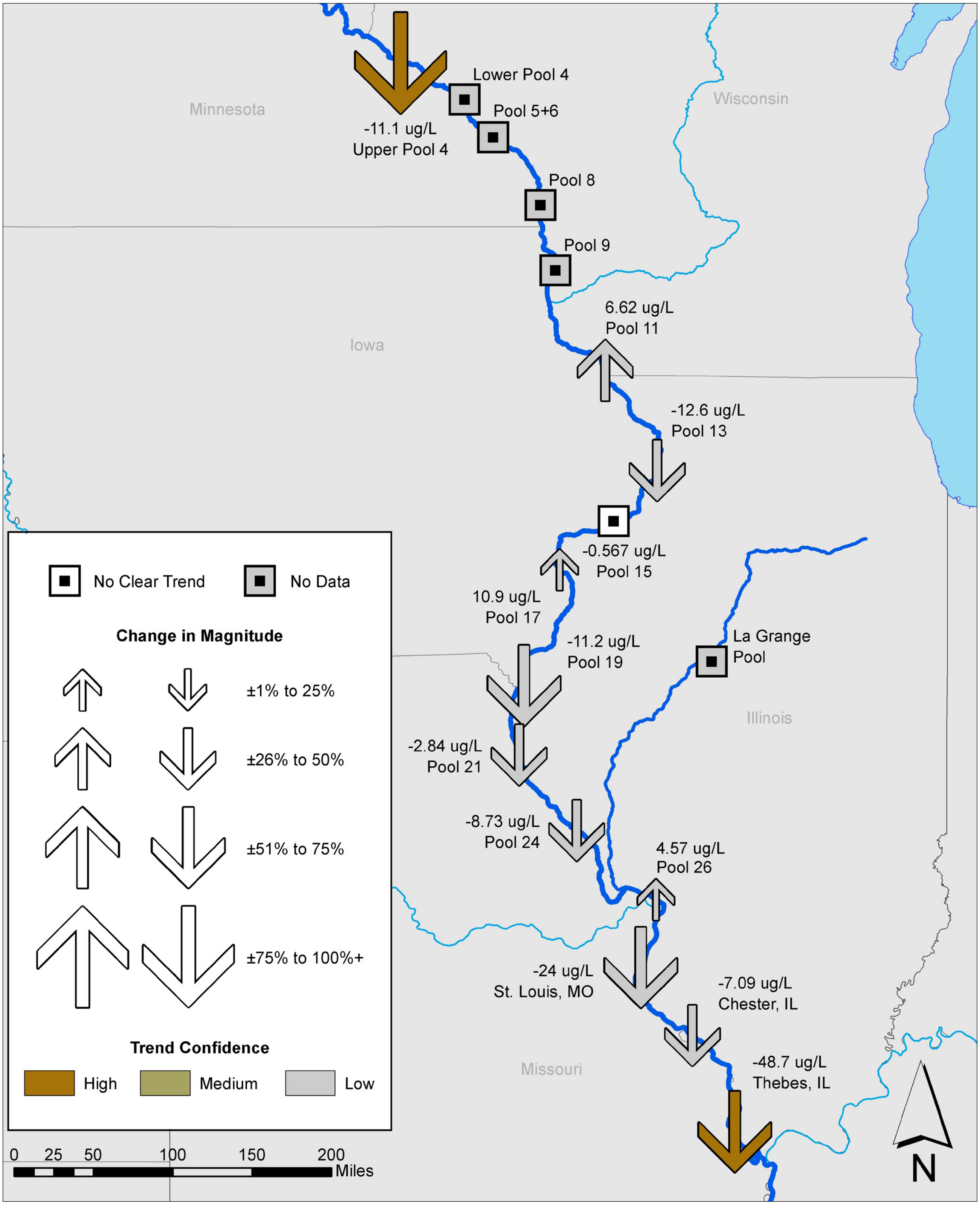
Total Arsenic



Total Lead

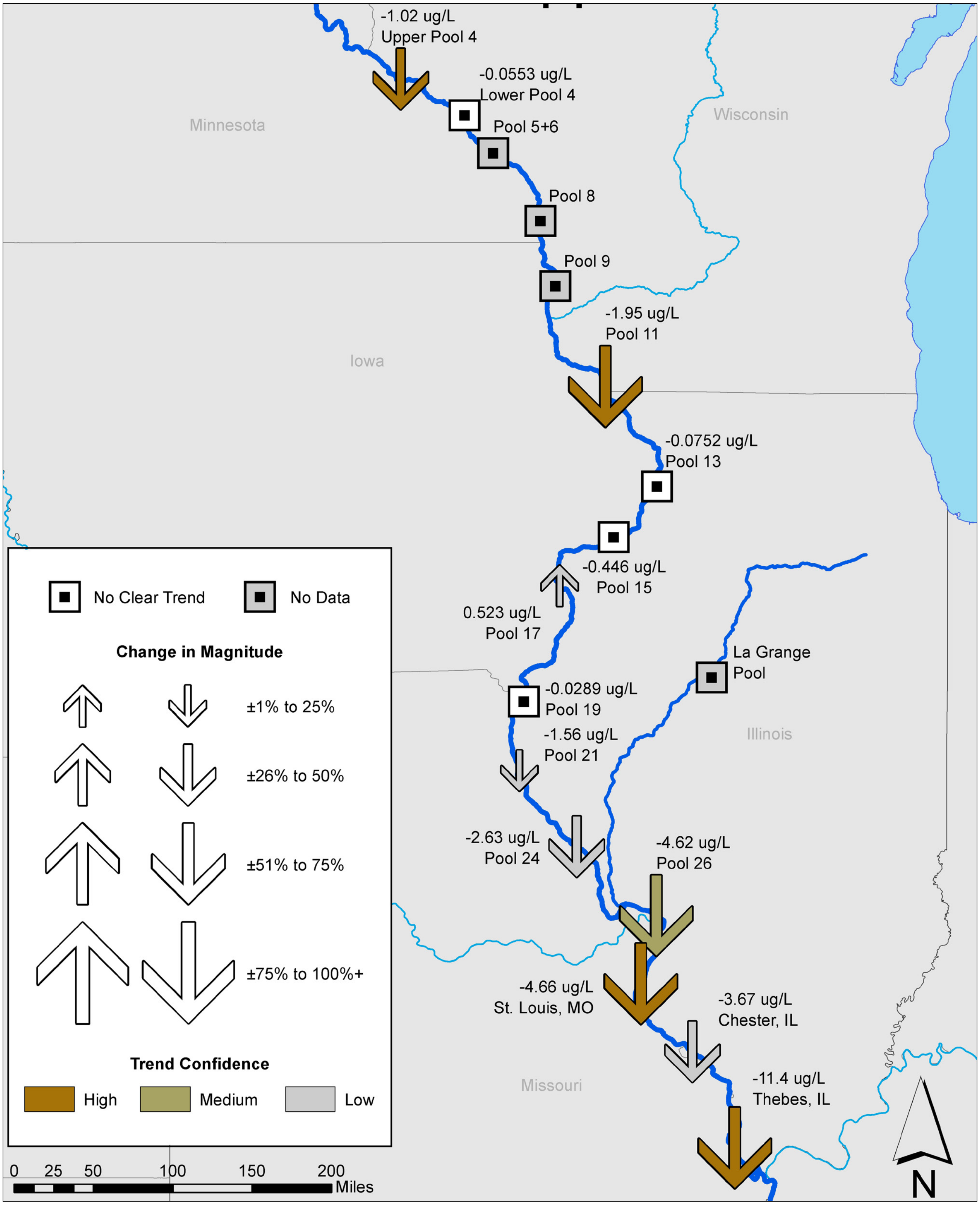

-1.2 ug/L
Upper Pool 4
Lower Pool 4
Pool 5+6
Pool 8
Pool 9
2.13 ug/L
Pool 11
0.402 ug/L
Pool 13
1.68 ug/L
Pool 17
2.95 ug/L
Pool 15
La Grange
Pool
1.1 ug/L
Pool 19
2.57 ug/L
Pool 21
1.35 ug/L
Pool 24
-3.03 ug/L
Pool 26
-1.39 ug/L
St. Louis, MO
-2.66 ug/L
Chester, IL
-28.9 ug/L
Thebes, IL
Minnesota
Wisconsin
Iowa
Illinois
Missouri
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
0 25 50 100 150 200
Miles
N

Total Zinc

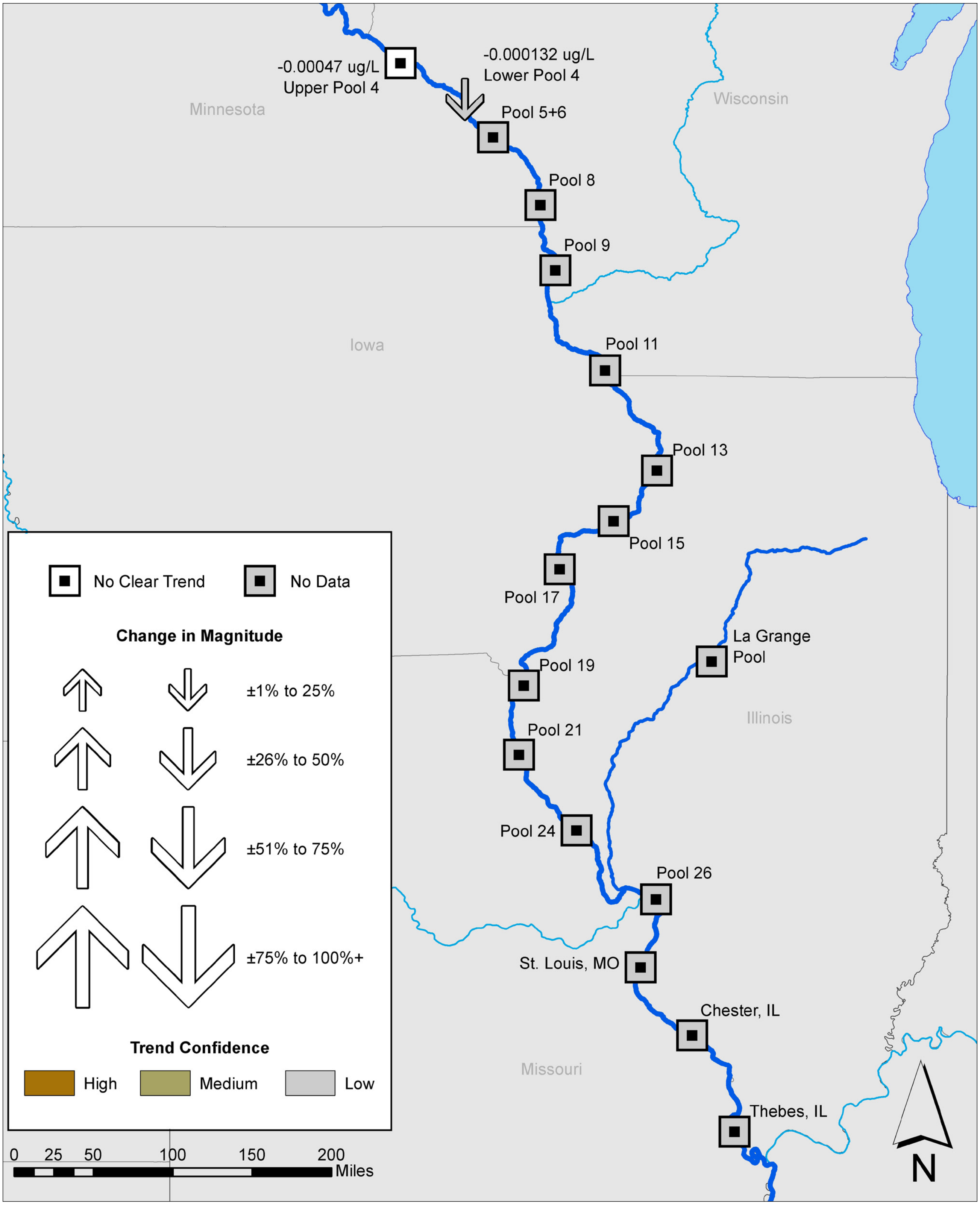


Minnesota
Wisconsin
Iowa
Illinois
Missouri
Lower Pool 4
Pool 5+6
-11.1 ug/L
Upper Pool 4
Pool 8
Pool 9
6.62 ug/L
Pool 11
-12.6 ug/L
Pool 13
-0.567 ug/L
Pool 15
10.9 ug/L
Pool 17
-11.2 ug/L
Pool 19
La Grange
Pool
-2.84 ug/L
Pool 21
-8.73 ug/L
Pool 24
4.57 ug/L
Pool 26
-24 ug/L
St. Louis, MO
-7.09 ug/L
Chester, IL
-48.7 ug/L
Thebes, IL
No Clear Trend
No Data
Change in Magnitude
±1% to 25%
±26% to 50%
±51% to 75%
±75% to 100%+
Trend Confidence
High
Medium
Low
0 25 50 100 150 200
Miles
N

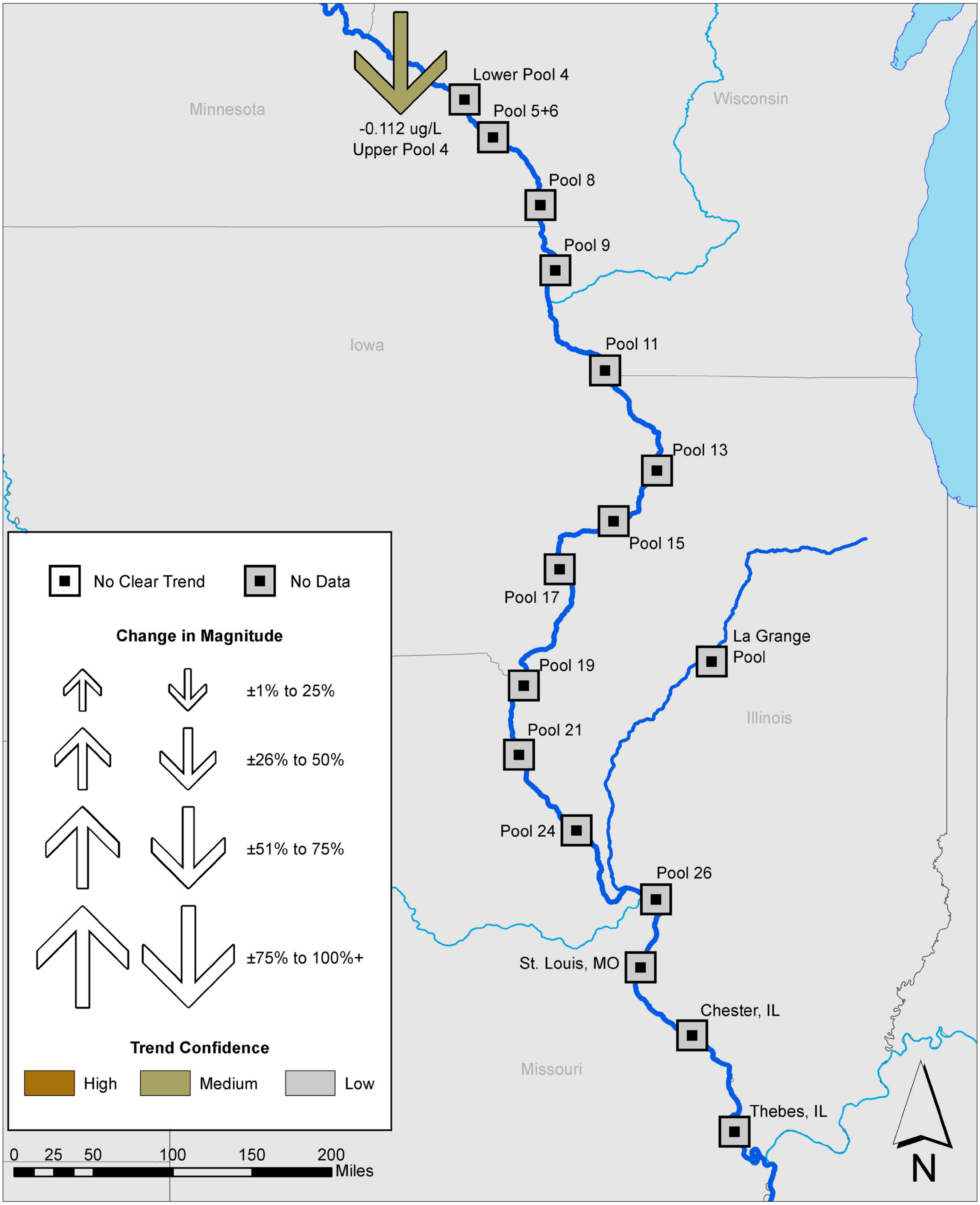
Total Copper



Total Mercury



Total Cadmium



UMRBA
Upper Mississippi River
Basin Association