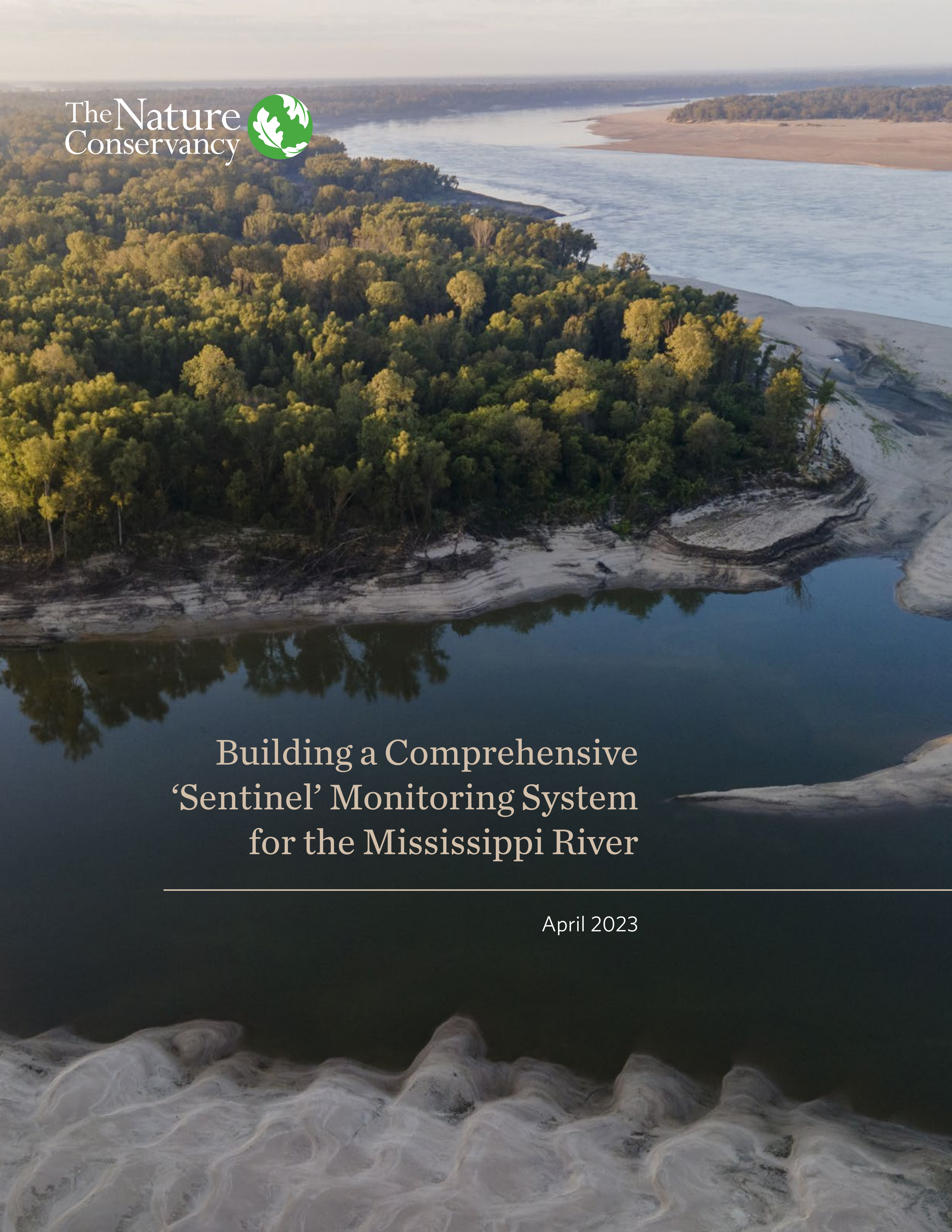


The Nature Conservancy

Building a Comprehensive 'Sentinel' Monitoring System for the Mississippi River

April 2023

GOAL:

A fully funded, constructed, and staffed monitoring system across the Mississippi River in the next five years.

The Nature Conservancy with technical contributions from:
U.S. Geological Survey
U.S. Army Corps of Engineers
National Oceanic and Atmospheric Administration | National Weather Service
Tulane University, School of Science and Engineering

Mississippi River Basin Comprehensive Monitoring System Technical Design Report

1.0 Situation Analysis

The Mississippi River, along with its tributaries and distributaries, flows across 1.245 million square miles and crosses 31 U.S. states and two Canadian provinces, forming the world's fourth largest river basin. Its water nourishes crops, transports goods, provides recreational opportunities, and sustains robust fisheries, providing food, jobs and economic security to millions of Americans. But threats to the Mississippi Basin are having devastating impacts on communities, agriculture, industry, infrastructure, and the environment.

In recent years, intense flooding across the basin has damaged infrastructure around the river, threatening homes and businesses. Flooding causes catastrophic harm to agricultural land, escalating costs for farmers and landowners, damage to communities and livelihoods, and fragmentation of natural habitat. Approximately $10 B has been spent on crop insurance payments for rain and flood damage since 2015.

Further, the frequency, duration, and intensity of flooding are predicted to increase. Scientists forecast a 30% increase in precipitation from today to 2050 in some regions of the basin.[1]

Conversely, the intense flood years of 2018 and 2019 on the Mississippi River were followed by an intense drought in 2022, resulting in extreme low water levels. This increased frequency and/or intensity of weather and climate extremes is well documented.[2]

In addition, massive amounts of nitrogen and phosphorus from aging sewage treatment plants, farms and other sources run off into the river. The consequences include health hazards to people and wildlife, higher water treatment costs, and an annual "dead zone" that costs the Gulf of Mexico seafood and tourism industries $82 million a year.[3]

Furthermore, invasive species in and around the Mississippi are degrading habitat and displacing native species. Rising seas and sinking land create a need for strategic water and sediment management to sustain coastal wetlands and fisheries.

Looking at transportation on the river over the last ten years, commercial maritime allisions (collisions between vessels and stationary objects) on the Mississippi and its tributaries have caused millions of dollars of damage to river control structures and bridges, river communities, and the commercial maritime industry. According to the National Transportation Safety Board, the January 2016 allision of the *Amy Francis* tow with the Natchez-Vidalia Highway 84 Bridge caused $542,000 in property damage and spilled 24,654 gallons of oil into the Mississippi River. At the time of the allision, a U.S Coast Guard safety advisory was in effect warning mariners about hazardous conditions that included "extreme high water" and "missing/off-station aids to navigation and diving buoys" (2017). Similarly, the April 2013 allision between the *Dale A. Heller* tow with the Marseilles Dam caused $3,767,000 in damages to barges and cargo and another $50,000,000 in damage to the dam. This accident also contributed to the flooding of homes, businesses, and other property adjacent to the Illinois River.[4] In another incident, a crane barge struck the Sunshine Bridge on the Mississippi River (Burnside, LA) in October 2018.[5]

---

1 Milks, Jason. 2022. ***Markets for Floodplain Reforestation in the Delta***. The Nature Conservancy.
2 IPCC 6th Assessment Report. August 9, 2021. ***Climate Change 2021: The Physical Science Basis***, Working Group I.
3 Rabotyagov, S.S., Kling, C.L., Gassman, P.W., Rabalais, N.N., Turner, R.E. 2014. The economics of dead zones: causes, impacts, policy challenges, and a model of the Gulf of Mexico hypoxic zone. Review of Environmental Economics and Policy 8: 58–79.
4 U.S. Geological Survey. August 2018. ***Automated River Navigation Data System***.
5 Duffy, Sean M. November 29, 2021. ***NOAA Physical Oceanographic Real-time System (PORTS®), Lower Mississippi River***. Big River Coalition.

As cities, companies, and citizen groups rally for solutions to these challenges, they need good, scientific information from a consistent, integrated, and transparent monitoring system. Unfortunately, the current system is piecemeal, with substantial investment and robust systems in some areas (e.g., Upper Mississippi River Long Term Resource Monitoring System) and substandard investment and systems in other areas (e.g., Lower Mississippi River). Without equal investment and systemwide integration and expansion to consider new threats, critical information will not be available to protect communities, clean the water, and restore critical habitats.

1.1: Tackling the Challenge

In June 2020, scientists from The Nature Conservancy and the U.S. Geological Survey convened a multi-day workshop to address the following question: "Is the current monitoring system in the Mississippi River Basin adequate to determine levels of risk and the effects of action to mitigate those risks?" The team identified the following constraints in the existing system:

- A legacy of inconsistent and insufficient funding for monitoring, forcing agencies to cost-share with multiple partners to provide the existing patchwork of data, often collected using different techniques or with long gaps in measurement. For example, "datum dizziness," which exists when different geographical reference systems are used to standardize measurements, was highlighted by the National Transportation Safety Board as a factor in the collision of the crane barge with the Sunshine Bridge in Louisiana.
- An inability to provide data in easy-to-use formats that meet the different requirements across multiple agencies, maritime operators, and community users.
- A requirement for local cost-sharing for critical national infrastructure, which favors affluent communities and leaves underserved communities (and the nation as a whole) without critical data to prepare for and respond to emergencies. Underserved communities often feel the greatest impacts from disasters.

Protecting the communities and residents of the Mississippi River Basin, restoring priority habitat for migrating species, and ensuring safe and efficient navigation are intrinsically dependent on having an environmentally healthy and economically viable river system.

The team concluded that if this situation does not change, it will be increasingly difficult to protect communities in the Mississippi River Basin, detect environmental changes due to climate variability, promote international commerce, and ensure a clean, vibrant Mississippi River for all.

2.0 Technical Design Methodology

2.1: The Goal

The team of technical advisors and scientists set forth an ambitious goal: A fully funded, constructed, and staffed monitoring system across the Mississippi River in the next five years.

A consistent, integrated, and transparent monitoring system across the Mississippi River Basin will be a "sentinel for the basin" and will provide critical and standardized information on present and future flooding and flood risk, water quality and sediments, and ultimately, ecosystem health. This system must be able to provide information for river forecasting, flood inundation mapping, sediment transport and deposition, community resilience, conservation, restoration, and navigation across the entire basin.

The team identified three overarching design criteria to achieve this goal:

- **Expand the present system at strategic locations** to add to the present monitoring network, with a focus on monitoring key, high-need sites; standardizing and integrating information streams; and **ensuring a long-term, stable funding source** for these strategic sampling sites. This effort will also streamline data use by researchers and stakeholders.
- **Increase monitoring density in the lower Mississippi River Basin to equal that of the upper basin** and ensure that information is consistent and integrated across the entire geography.
- **Directly engage experts in support of the system** by convening government, NGO, and private experts to define standards, develop local models and design a consistent, integrated monitoring plan to meet the needs of a healthy, productive Mississippi River.

2.2: Who Will Benefit

A truly effective Sentinel System will serve a large and diverse audience, including:

1. Maritime and inland navigation operators and recreational boaters navigating the river.
2. Federal and state agencies and local municipalities who use the information to make sound decisions to monitor and control flooding, improve navigation safety, and mitigate the impacts of flood events.
3. Communities and landowners whose homes and livelihoods are affected by the health of the river.
4. Farmers whose lands are in the Mississippi River's 100-year floodplain and are subject to frequent flooding.
5. The agricultural industry.
6. Scientists who need accurate data to analyze river conditions, forecast future scenarios, and inform sound decision-making.
7. National, regional, and local environmental and social nonprofits working to protect and restore habitat and improve vulnerable communities.

2.3: A Coalition for Action

Following the 2020 workshop, The Nature Conservancy reached out to partner organizations to form a coalition of advisors who would guide the technical design of an integrated system and speak with a unified voice to obtain support and funding for its implementation. The Coalition met for the first time in spring 2021, at the Lower Mississippi River Science Symposium hosted by Tulane University and sponsored by the Beyer Hubbell Fund. At the Symposium, and through a broader survey, Coalition members agreed on four priority issues that the Sentinel System should address across the Mississippi River Basin:

1. Water quality and Gulf of Mexico hypoxia
2. Flood risk management, water availability, and resilience to floods and droughts
3. Navigation safety
4. Habitat restoration

These criteria provided the foundation for the technical design of the system described below.

By September 30, 2022, the Coalition had grown to include over 50 active members representing five federal agencies, seven state agencies, two Mississippi River Basin regional partnerships, six nonprofit organizations, and three academic institutions. It serves as an advisory and advocacy body to support the technical design and ultimately, to help secure funding for implementation of the Sentinel System.

Partner Organizations

- The Nature Conservancy
- America's Watershed Initiative
- The Upper Mississippi River Basin Association
- Tulane University
- Big River Coalition
- Theodore Roosevelt Conservation Partnership
- Environmental Defense Fund
- National Wildlife Federation

Technical Advisors

- U.S. Environmental Protection Agency
- U.S. Geological Survey
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration | National Weather Service
- National Academies of Sciences, Engineering, and Medicine–Gulf Research Program
- University of Iowa
- Missouri Department of Environmental Quality
- Tennessee Department of Environmental Quality
- Arkansas Department of Environmental Quality
- Mississippi Department of Environmental Quality
- Louisiana Department of Environmental Quality
- Louisiana Coastal Protection and Restoration Authority
- Kentucky Division of Water
- The Lower Mississippi River Conservation Committee

2.4: Technical Design for a Sentinel System

From September 2021 through August 2022, a cross-disciplinary team of partners worked on the technical design of the system. These partners included the U.S. Geological Survey, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration-National Weather Service, the Louisiana State Government (Coastal Protection and Restoration Authority and Department of Environmental Quality), America's Watershed Initiative, the Upper Mississippi River Basin Association, and Tulane University.

The team kicked off its work at a multi-day workshop sponsored by The Nature Conservancy in September 2021. During the workshop, they defined the key design elements of a comprehensive monitoring system, within the four priority areas identified by the Coalition. The team also refined the initial goal, providing more context and direction to the Technical Design Team:

"To urgently deploy a durable, consistent, integrated, and transparent monitoring system across the Mississippi River Basin that will be a sentinel for the basin, providing critical infrastructure for the nation through standardized information on water quality and sediments, present and future flooding and flood risk, navigation safety, and ecosystem health."

The Sentinel System will share data across agencies, will meet desired data quality standards, and will be readily available to key constituents and users. These factors make it a compelling incentive for agencies, NGOs, and other partners to work together.

2.5: Design Criteria and Objectives

The team identified three sets of design criteria deemed necessary to provide access to high-quality and standardized data, user-friendly ways to access data, and the infrastructure to establish and maintain an integrated Sentinel System over the long-term. Those criteria are as follows:

A. Design Principles

- **Accessible –** is easy to understand and use
- **Efficient** – builds upon the best parts of the existing monitoring programs, with streamlined management and administration
- **Effective** – delivers intended results toward our goal, makes it possible to measure progress
- **Equitable –** invests in under-resourced areas, providing information in relation to populations most at risk, with equitable input and buy-in of system
- **Transparent –** offers timely and easy access to data
- **Collaborative (vs. competitive)** – provides coordination and aligned action among government, NGOs, private partners, and landowners across geographic scales (global, federal, regional, states, local, whole watershed)

B. Design Elements

- **Funding** – includes long-term federally funded network of sentinel stations
- **Data provisioning**
  - Provides real-time, long-term, consistent data
  - Integrates complementary and consistent data between states, agencies, and other sources, with new programs to fill the gaps (e.g., integrated with coastal monitoring)
- **Functionality**
  - Is multi-use and customizable for different types of uses
  - Offers different formats for different users: geospatial, narrative, quantitative

- **Is modular and scalable,** to allow for evolution and adaptation in the future
  - Is usable with different scales and water bodies
  - Includes the option to add features and new inputs in the future
- **Helps with adaptive management,** setting benchmarks and providing trend analysis to inform future action – such as early warnings for floods and impacts from low water levels
- **Can be used to tell the story of the river,** educating key stakeholders and beneficiaries, highlighting the need for investment, and correcting public misperceptions

C. Data and Information

- **Navigational information**
  - Offers real-time velocity measurements to assist commercial navigation traffic
  - Includes height of bridges in similar metrics
  - Includes a real-time dataset to inform dredging needs
- **Data trends**
  - Shows how much of the floodplain is connected and where
  - Monitors sea-level rise and climate change indicators
  - Captures flood duration, capacity, and conveyance
  - Tracks nutrient trends
- **Real-time data**
  - Includes water quality and sediment loading throughout the tributaries and main channel, making it possible to detect change in real time
  - Includes discharge measurements that can help measure flow
  - Can inform how water temperatures affect flood risk
  - Includes frequent stage measurements
  - Includes passive fish measurement

Finally, the team refined the Coalition's design criteria into three technical design objectives and identified 15 priority target monitoring sites along the Mississippi River Basin as indicators of existing sites to meet the objectives. The team also began work to identify a champion for the proposed system who could ultimately help secure sustainable long-term funding for its implementation. At that meeting, the advisory team created a Technical Design Team.

The Technical Design team included technical advisors from Tulane University, the U.S. Geological Survey, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration-National Weather Service, and The Nature Conservancy. Advisors from the Environmental Protection Agency working on the Lower Mississippi River Basin and Hypoxia Task Force, the Upper Mississippi River Basin Association and other partners advised on various aspects of the technical design.

The team also tasked two sub-teams with identifying scientific objectives and the logic for selecting priority sites that would comprise a comprehensive monitoring system for the Mississippi River Basin.

2.6: Core Monitoring System Objectives

Building on the priorities identified by the Coalition, the Technical Design Team identified three core monitoring objectives for the system:

1. Obtain consistent, comparable information on loads and trends in streamflow, water quality, and sediment to understand how changes in climate, land use, and landscape management are affecting the Mississippi River, its major tributaries, and its output to the Gulf of Mexico.
2. Provide real-time information to guide decisions on navigation, flood control, and diversions on the mainstem Mississippi River.
3. Develop an integrated data interface, making data from federal monitoring agencies accessible and easy to use by multiple user groups.

The fourth priority area that the Coalition identified, ecosystem health and habitat restoration, requires further definition and capacity. The Technical Design Team decided that it was out of scope for phase I of the design and should be addressed in a second system design phase and subsequent development.

2.7: Objective 1: Obtain Loads and Trends in Streamflow, Water Quality and Sediment

A working group of the Technical Design Team used the following logic to select monitoring sites along the Mississippi River mainstem and major tributaries to meet Objective 1.

1. **At what time-step do we need loads and trends?**

   Answer: We need annual loads and updates of trends for all but the outlets of major rivers, the mainstem Mississippi, and the Gulf of Mexico, for which continuous information is needed.

2. **What data need to be collected to assess streamflow, water quality, and sediment?**

   Answer: Daily streamflow, nitrate plus nitrite, total nitrogen, total phosphorus, orthophosphate, ammonia, suspended sediment concentration, and sand–silt split should be collected at all sites.

3. **What defines "consistent and comparable"?**

   Answer: Sampling that represents the width, depth, and velocity of the stream/river, as well as documented gaging/continuous water quality monitoring procedures that are consistent with published U.S. Geological Survey / National Water Information System requirements referenced under the section on data quality later in this report on page 17.

4. **How frequently do we need to collect water quality and flow to get trends?**

   Answer: We need at least monthly sampling that accounts for high-flow conditions, along with daily streamflow data. At the farthest downstream station of major tributaries, the mainstem Mississippi, and the Gulf of Mexico, we also require continuous real-time turbidity, nitrate, and supporting parameters (temperature, specific conductance, pH, dissolved oxygen) to support computation of daily loads and supporting parameters (temperature, specific conductance, pH, dissolved oxygen).

5. **Where should sites be located and how many sites are needed across major tributaries, the mainstem Mississippi, and the Gulf of Mexico?**

   Answer: We analyzed accumulated SPARROW loads of mean flow, total nitrogen, total phosphorus, and suspended sediment concentration. We decided to locate sites at every point at which there was a change of at least 5% of the maximum load for the nearest upstream sites and to continue this as far downstream as practical to the Gulf of Mexico. Part of our reason for prioritizing sites based on a 5% change was to be able to establish long term trends of climate and land-use changes. While we want to understand major tributaries, it was not our responsibility to assign non-point contributions. Our focus was on how climate change causes long-term changes in larger tributaries.

Applying the logic developed for Objective 1, the group began identifying geographic points along each of the major tributaries to the Mississippi River Basin and the upper and lower Mississippi River that met the criteria for monitoring loads and trends in streamflow, water quality, and sediment.

2.8: Objective 2: Provide Information for Flood Control, Navigation and Diversions

The Technical Design Team's second objective is based on the growing need to accurately monitor, model, and mitigate flood events and their impacts to landowners and communities in the 100-year floodplain of the Mississippi River Basin and to provide automated gaging and standardized information to aid navigation safety.

Technical Advisors from the U.S. Army Corps of Engineers, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration and Big River Coalition evaluated existing infrastructure and gaps to identify a set of priority sites, as well as new needs, particularly with regard to river surface height and current under bridges where allisions pose a threat.

2.9: Objective 3: Develop an Integrated Data Interface

The Technical Design Team determined that, as the Mississippi is one of the largest river systems in the world and is used by multiple entities, it should have a government-hosted, public-facing data portal. The portal will aggregate and present water quality and other field parameter data through a multitude of human and machine-readable interfaces and will address the needs of many user types and data consumers, ranging from ship pilots and barge operators navigating the river to scientists modeling the future of the hydrologic basin.[6]

6 Hunnicutt, Christina. 2022. ***USGS Mississippi River Data Portal***, U.S. Geological Survey.

3.0 System Design

3.1: Site Selection for Objective 1 (Obtain Loads and Trends in Streamflow, Water Quality and Sediment)

The U.S. Geological Survey led the site selection process for Objective 1. Using data and maps from SPARROW, the working group identified existing gages that met all or a portion of the monitoring parameters located along the Mississippi River mainstem and major tributaries. Whenever there was a change of at least 5% of the maximum load, or a monitoring gap existed, we determined that a new station should be added.

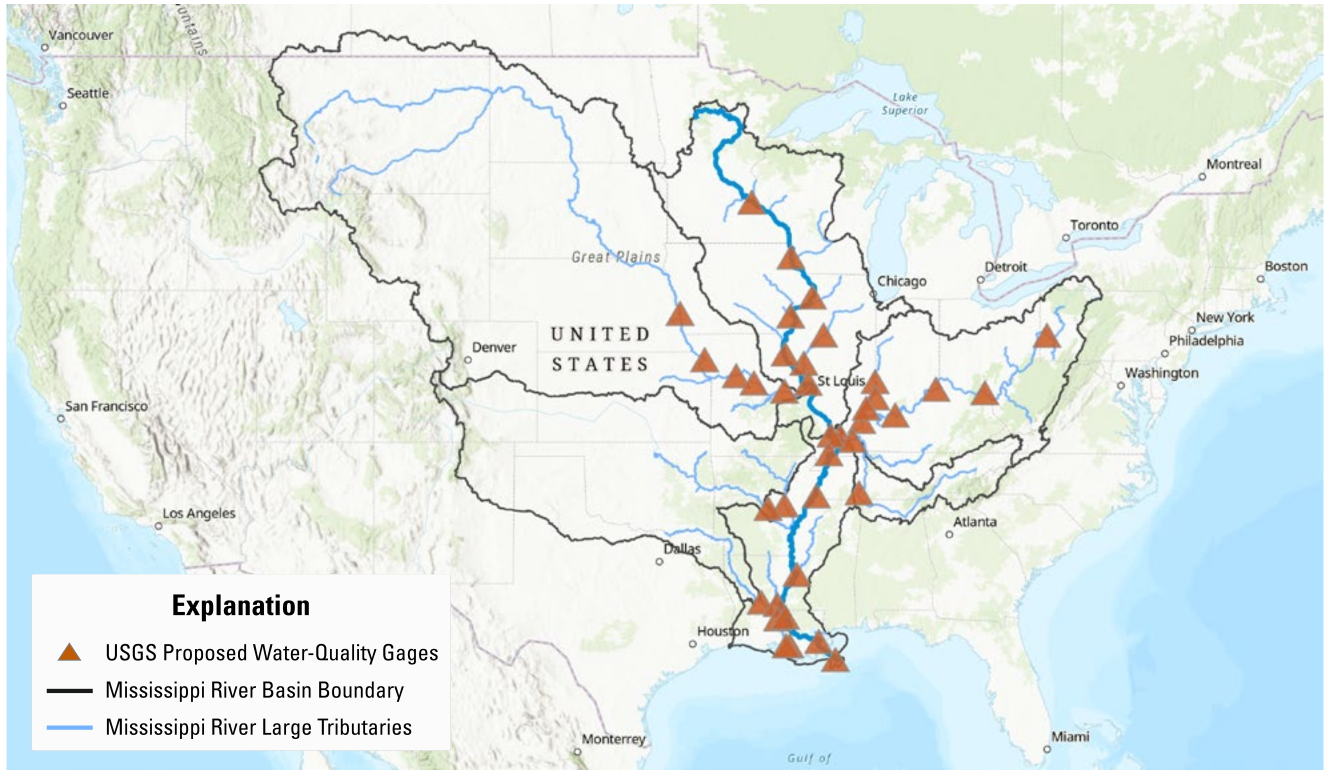
The team identified 38 priority monitoring sites. The U.S. Geological Survey currently operates and maintains stations at 35 of those sites. The remaining three sites do not have stations and funds should be designated to build, operate, and maintain new stations there. Based on a detailed analysis of existing sites, the U.S. Geological Survey identified those that would require infrastructure or technical upgrades to meet the established monitoring thresholds. The proposed existing and new sites are as follows:

SITE LOCATION (TRIBUTARY OR MAINSTEM)
Ohio River mainstem (six sites)
1. On the Ohio River downstream from where the Tennessee River enters the Ohio River, but before the Ohio River enters the Mississippi River
2. On the Ohio River upstream of the Kentucky / Tennessee watershed load contribution but downstream of the Wabash River
3. On the Ohio River upstream of the Wabash River
4. On the Ohio River somewhere near the Indiana / Ohio border
5. On the Ohio River somewhere near the middle of Ohio
6. On the Ohio River somewhere near the Pennsylvania / Ohio border
Wabash River (three sites)
7. At the headwaters of the Wabash River before the confluence with the White River
8. On the White River just upstream from the confluence with the Wabash River
9. On the Wabash River between the confluence with the White and Ohio Rivers
Tennessee River (two sites)
10. On the Tennessee River headwaters upstream where water is still flowing
11. On the Tennessee River downstream from the dam
Missouri River (five sites)
12. On the mainstem Missouri River upstream of the Platte River
13. On the mainstem Missouri River above the confluence with the Kansas River
14. On the mainstem Missouri River below the Kansas River and upstream of the Grand River
15. On the Missouri River between the Grand and Osage Rivers
16. On the Missouri River downstream of the Grand River near the confluence with the Mississippi River

Illinois River (two sites)
17. On the Illinois River upstream of the Spoon River
18. Along the lower Illinois River toward the confluence with the Mississippi River
Upper Mississippi River (seven sites)
19. On the Mississippi River mainstem above or at the border of Minnesota, upstream of the Rock | Hudson | Chippewa | St. Croix Rivers
20. On the Mississippi River between Hastings and Clinton (NEW)
21. Upstream on the Mississippi River mainstem, north of the confluence of the Iowa River
22. On the downstream end of the Iowa River
23. Downstream on the Mississippi River below the Des Moines River (NEW)
24. On the Mississippi River between the Illinois and Missouri Rivers
25. Between the Missouri and Ohio Rivers on the Mississippi River at Thebes
Lower Mississippi River (seven sites)
26. On the Mississippi River mainstem between the Ohio & Arkansas Rivers at New Madrid
27. On the Mississippi River mainstem between the Ohio & Arkansas Rivers at Memphis
28. On the White River
29. On the Arkansas River
30. On the Mississippi River mainstem between the Arkansas River & Old River Diversion
31. On the Red River upstream of the Black River
32. On the Red River downstream of the Black River
Atchafalaya River (three sites)
33. On the Atchafalaya River below the Old River Control Structure Complex
34. At the Lower Atchafalaya River Outlet
35. At the Wax Lake Outlet

Lower Mississippi River Outlet to the Gulf (three sites)
36. On the mainstem Mississippi River downstream of the Old River Control Structure Complex
37. On the mainstem Mississippi River upstream from Ft. St. Philip diversion
38. On the mainstem Mississippi River at or near the outlet to the Gulf of Mexico (Pilottown) (NEW)

The map below shows the locations of the proposed monitoring stations along the Mississippi River mainstem and major tributaries to the Basin.



Map of U.S. Geological Survey proposed water-quality stations

Building on the existing infrastructure and stations, which are currently funded by federal dollars, and enhancing that capacity to provide adequate monitoring coverage and defined capability, is a cost-effective approach. There are gaps in the existing infrastructure that need to be filled to meet the parameters for measuring loads and trends in streamflow, water quality, and sediment. Not all of the existing stations conduct discrete sampling or the continuous water quality monitoring that the advisory group is recommending. Filling these gaps will require a one-time investment in the following upgrades and additions:

1. A one-time cost to upgrade infrastructure at 12 sites to provide continuous water sampling capability.
2. A one-time investment at five additional sites to replace existing infrastructure and install new stations.
3. A one-time investment in the three proposed new sites to fill gaps along the river where priority monitoring requirements are not currently being met.

The expense of these one-time upgrades and new sites, and the cost of annual operations and maintenance over 25 years, are provided in the cost section that follows on page 17.

In addition, it is important to note that The Nature Conservancy has been discussing with agencies the need to create a fully integrated system for years. We adopted a science-based framework in this design process. There are other important reasons to add or not add a particular site. One of the first steps in implementation would be to work with local entities to refine site locations. For example, the Hypoxia Task Force Report of 2021 specified a set of priority 1 and 2 sites that they chose using a slightly different set of criteria. That having been said, our recommendations feature 17 sites that include Hypoxia Task Force priority 1 and 2 sites, where our monitoring specifications will support their efforts. Our goal is to ensure consistent measurement standards that are readily accessible and usable by multiple audiences.

3.2: Site Selection for Objective 2 (Provide Real-time Information for Flood Control, Navigation and Diversions)

The U.S. Army Corps of Engineers led the design of this objective. First, the technical team interviewed Corps experts from 13 U.S. Army Corps of Engineers Districts in the Basin to determine which gages were critical for flood risk management throughout the Basin. We also interviewed flood forecast modelers from the National Weather Service to determine which gages they needed long-term to be able to perform their important job. Together, the U.S. Army Corps of Engineers and National Weather Service identified 1,414 existing gages that were critical to providing adequate coverage related to flood, risk management, and navigation safety along the tributaries and mainstem of the Mississippi River Basin. These included the National Oceanic and Atmospheric Administration's National Weather Service gages for flood forecasting in the Lower Mississippi River. Many of these gages are operated in conjunction with the U.S. Geological Survey.

The full list of existing gages operated and maintained by the U.S. Army Corps of Engineers that should be included as part of the Sentinel System can be found here. All of these sites are currently funded, but we want to ensure that the funding is sustained into the future. In addition, we recommend covering the cost for their data managers to work with the U.S. Geological Survey data development and implementation team to make their data available through the integrated data portal. The U.S. Army Corps of Engineers will need to evaluate those costs.

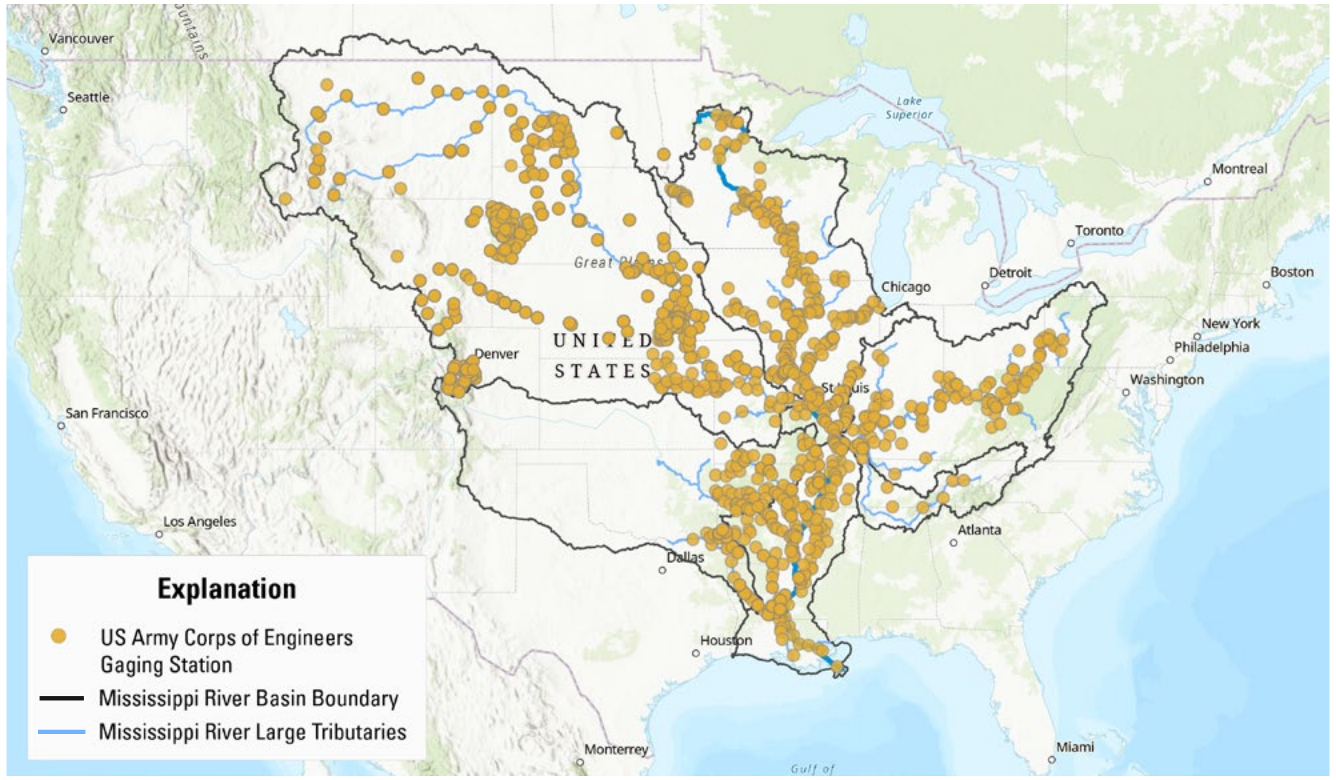


Figure 3.2: Map of U.S. Army Corps of Engineers flood and river navigation gaging stations

Technical advisors from the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and Big River Coalition determined where priority gaps exist in air gap sensors and current meters. Air gap sensors provide critical information to maritime operators about the clearance between the bottom of the bridge deck and the water surface along the Mississippi River and its major tributaries. Air gap sensors include both the Coastal Dynamics Applications Radar (CODAR) sensors used by the U.S. Geological Survey and the and air gap sensors used in the National Oceanic and Atmospheric Administration Physical Oceanographic Real-Time Systems (PORTS) System in the Lower Mississippi River. Current meters provide critical information on the rate and direction of flow of water. While many of the flow and discharge gages in Figure 3.2 are also used for navigation safety, we were focused on a problem called "datum dizziness," which forces captains to do a series of calculations to determine whether their vessel will fit under a bridge. This problem has caused allisions of vessels with bridges and many millions of dollars in damages and can be avoided with air gap sensors that report the distance from a fixed point on the bottom of a bridge deck to the water surface in real time. The technical design group interviewed experts who were working to solve this problem and who already had proposals to add sensors at critical bridges that lacked them.

The agencies identified the following priority sites, at areas with heightened navigational safety hazards, where new air gap sensors and current meters should be installed.

SITE LOCATION (TRIBUTARY OR MAINSTEM)
U.S. Geological Survey CODAR Sensors
1. Highway I-80 bridge over the Mississippi River at Vicksburg (NEW)
2. Ill-23/Veterans Memorial Bridge over the Illinois River at Ottawa, Illinois (NEW)
3. Burlington Northern Bridge over the Illinois River at Ottawa, Illinois (NEW)
4. Chessie System Railroad bridge over the Illinois River (NEW)
5. Illinois Central Bridge over the Ohio River at Cairo, Illinois (NEW)
6. Chesapeake & Ohio Bridge over the Ohio River at Parkersburg, West Virginia (NEW)
7. Second Street Bridge (Portland Canal / McAlpine Locks and Dam) at Louisville, Kentucky (NEW)
8. Olmsted Locks and Dam, Illinois (NEW)
National Oceanic and Atmospheric Administration Air Gap Sensors on the Lower Mississippi River
9. Baton Rouge I-10 Bridge, Louisiana (Funded and to be installed)
10. Sunshine Bridge, Louisiana (NEW)
11. Veterans Memorial Bridge, Louisiana (NEW)
12. Hale Boggs Bridge, Louisiana (NEW)
13. Huey P. Long Bridge, Louisiana
14. Crescent City Connection, Louisiana
National Oceanic and Atmospheric Administration Water Current Meters on the Lower Mississippi River
15. Baton Rouge I-10, Louisiana (NEW)
16. Sunshine Bridge, Louisiana (NEW)
17. Veterans Memorial Bridge, Louisiana (NEW)
18. Hale Boggs Bridge, Louisiana (NEW)
19. Huey P. Long Bridge, Louisiana (NEW)
20. Crescent City Connection, Louisiana (NEW)

The biggest needs identified by the U.S. Geological Survey are hazardous bridge intersections along the Ohio and Illinois Rivers where tow vessels and barges passing under railroad bridges pose primary hazards. The new air gap gages and current meters proposed by the National Oceanic and Atmospheric Administration and Big River Coalition are located in the Lower Mississippi River Basin in Louisiana, near the outlet to the Gulf of Mexico.

The addition of 11 new air gap sensors and six current meters will build on these agencies' existing infrastructure and fill critical gaps in their current monitoring systems.

Figure 3.3: Map of U.S. Geological Survey and National Oceanic and Atmospheric Administration air gap sensors and current meters

3.3: Objective 3 (Develop an Integrated Data Interface)

The U.S. Geological Survey's Wetlands and Aquatic Research Center has submitted a proposal to build an integrated data portal with interfaces that meet the different needs of multiple audiences. The current systems are not readily accessible by the public and multiple user groups. Data collected by different agencies are not always updated concurrently and do not meet desired data quality standards. The new system will provide current, accurate and accessible data, collected to U.S. Geological Survey standards.

The design and development will be a nonpartisan cooperative effort among multiple federal, state, and nonprofit organizations through the U.S. Geological Survey's Wetland and Aquatic Research Center, Advanced Applications Team. Data will be provided and made publicly accessible by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration.

The design process will include a detailed requirements definition to assess and gather the different data needs of various human user groups and identify what formats they need in order to most readily access and use the data. It will include data system design and development, data services, systems maintenance and periodic updates. In addition, it will look at the machine user interfaces across agency information systems that hold monitoring data collected by those agencies (i.e., the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, and the U.S. Army Corps of Engineers).

4.0 Oversight and Management

The funding for this proposed monitoring system will go to the federal agencies responsible for managing the system and gathering the data, with the provision that the data will be made available to the public through the data portal in a timely and transparent fashion, and that the data will meet U.S. Geological Survey data standards.

We propose the creation of a process to ensure that funds allocated to the Sentinel System are dedicated to the priority needs identified in this report.

This initiative is an opportunity to coordinate with state monitoring entities to align monitoring objectives, methods, and standards to U.S. Geological Survey data quality standards, as recommended in this report. By doing so, we leverage our collective efforts to further expand the unify monitoring capacity within the Sentinel System.

4.1: Data Quality

Data quality (accuracy and timeliness) are key to a fully functioning and usable monitoring system. The team proposes using the data standards set by the U.S. Geological Survey, which are ratified by the International Organization for Standardization and the Federal Geographic Data Committee. These standards include methods and protocols for sampling water resources, analyzing water quality, and measuring field parameters, and specialized procedures for sampling water for specific contaminants. Specific data can be found in the U.S. Geological Survey's *National Field Manual for the Collection of Water-Quality Data*.[7] Further standards exist for continuous water quality monitoring,[8] continuous nitrate monitoring,[9] stage[10] and flow[11] measurement, and sediment data collection.[12] Data standards increase the efficiency and effectiveness of research and enable the sharing of comparable data across multiple user groups.

4.2: System Cost

The Technical Design Group conducted a detailed cost analysis for the Sentinel System, which can be found here.

As shown in the table that follows, the cost of existing gages, infrastructure, operations and maintenance is approximately $20 million in current U.S. dollars. To acquire the additional infrastructure needed to upgrade or support new gages, add the specified number of new gages and meters, and operate and maintain the system, assuming completion in year one, would require an additional $23.4 million in current U.S. dollars. These amounts add up to a total estimated investment of $43.4 million in year one.

7 U.S. Geological Survey. 2018. General introduction for the "National Field Manual for the Collection of Water-Quality Data" (ver. 1.1, June 2018): U.S. Geological Survey Techniques and Methods, book 9, chap. A0, 4 p., (https://doi.org/10.3133/tm9A0).

8 Wagner, R.J., Boulger, R.W. Jr., Oblinger, C.J., and Smith, B.A. 2006. Guidelines and standard procedures for continuous water-quality monitors: station operation, record computation, and data reporting. U.S. Geological Survey Techniques and Methods 1-D3 (http://pubs.usgs.gov/tm/2006/tm1D3/).

9 Pellerin, B.A., Bergamaschi, B.A., Downing, B.D., Saraceno, J.F., Garrett, J.A., and Olsen, L.D. 2013. Optical techniques for the determination of nitrate in environmental waters: Guidelines for instrument selection, operation, deployment, maintenance, quality assurance, and data reporting. U.S. Geological Survey Techniques and Methods 1–D5, 37 p.

10 Sauer, V.B., and Turnipseed, D.P. 2010. Stage measurement at gaging stations. U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p. (http://pubs.usgs.gov/tm/tm3-a7/).

11 Turnipseed, D.P., and Sauer, V.B. 2010. Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (http://pubs.usgs.gov/tm/tm3-a8/.); Levesque, V.A., and Oberg, K.A. 2012. Computing discharge using the index velocity method: U.S. Geological Survey Techniques and Methods 3–A23, 148 p. (https://pubs.usgs.gov/tm/3a23/); Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A., and Rainville, F. 2013. Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013). U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p. (http://dx.doi.org/10.3133/tm3A22).

12 Edwards, T.K., and Glysson, G.D. 1999. Field methods for measurement of fluvial sediment. U.S. Geological Survey Techniques and Methods book 3, chap. C2, 97 p. (https://pubs.usgs.gov/twri/twri3-c2/pdf/TWRI_3-C2.pdf).

The percentage difference (gap) between currently funded monitoring stations and the proposed Sentinel System new stations in year one, excluding operations and maintenance, are as follows[13]:

- U.S. Geological Survey water quality monitoring: Only 32% of total funds are currently appropriated for the total stations that will be required.
- U.S. Army Corps of Engineers flood and navigation monitoring: Current funding will meet year one funding needs. Additional funding will be necessary for their data managers to work with the U.S. Geological Survey portal development team to bring all of the data into one place. The U.S. Army Corps of Engineers will need to evaluate those additional costs.
- National Oceanic and Atmospheric Administration air gap and water current monitoring: 7% of total funds required are currently appropriated for the required sensors and meters.
- U.S. Geological Survey new air gap monitoring: None of the total funds required are currently appropriated to install sensors.

System Design Element	A. Total current annual funding provided for existing network	B. Year 1: additional one-time cost to add probes and meters	C. Year 1: estimated one-time cost to build new stations	D. Total year 1 Sentinel System start-up costs (B + C)	E. Total year 1 annual operating and maintenance costs for new system	Gap between current and proposed year 1 start-up and O&M costs (D + E) – (A)	Total 25-year cost of existing system with no upgrades with 3% compounded inflation	Total 25-year cost of Sentinel System with 3% compounded inflation
Water flow, quality and sediment gages (USGS)	$2,448,252	$1,200,000	$6,350,000	$7,550,000	$7,921,097	$13,022,845	**$94,387,563**	**$312,932,387**
Key navigation air gap gages and current meters (NOAA)	$60,000	$0	$804,000	$804,000	$288,000	$1,032,000	**$2,313,183**	**$11,907,276**
Key navigation CODAR sensors (USGS)	$0	$0	$1,600,000	$1,600,000	$320,000	$1,920,000	**$0**	**$13,936,974**
Flooding and navigation gages (USACE)	$17,500,000	$0	$0	$0	$17,500,000	$0	**$674,678,239**	**$674,678,239**
MSR data interfaces and services	$0	$0	$4,800,000	$4,800,000	$2,600,000	$7,400,000	**$0**	**$116,737,910**
Total item cost	**$20,008,252**	**$1,200,000**	**$13,554,000**	**$14,754,000**	**$28,629,097**	**$23,374,845**	**$771,378,985**	**$1,130,192,786**
Funding gap between existing and Sentinel System over 25 years	**$358,813,801**							

13 Does not include costs associated with other monitoring stations outside of those included in the proposed Sentinel System specified in this report.

The nation already spends approximately $20 million on the existing piecemeal system that does not meet current data needs. Investing an additional $23.4 million in year one to build, operate, and maintain the Sentinel System will provide the foundation for a comprehensive integrated system that meets the growing demand for accurate, timely, and readily accessible data. This investment will:

1 Add necessary infrastructure to support upgraded monitoring stations
2. Upgrade monitoring capabilities of existing stations or gages
3. Add new monitoring stations for stream flow where there are currently significant data gaps in water quality, flood risk management, and navigational safety along the Mississippi River mainstem and tributaries, and
4. Develop integrated data interfaces to serve the needs of multiple users and share data across agency systems.

We also calculated the 25-year inflation-adjusted costs of both the existing system and the Sentinel System. Over a 25-year period, with compounded inflation at 3% per year, the total cost of the existing system would come close to $771.4 million dollars, which is taxpayer money that is already allocated for this purpose. The 25-year cost of the Sentinel System would come to approximately $1.13 billion. This means that over 25 years (assuming the same rate of compounded inflation), the cost to build, operate, and maintain the Sentinel System would require just over $358.8 M in total additional funds.

We are already spending 68% of the necessary funds to operate and maintain systems that are not providing critical, comparable information across the Mississippi River. By wisely investing 32% more, we can improve this critical national infrastructure to provide consistent, comparable, real-time information for the river that will benefit communities, commerce, and the environment and be accessible to the U.S. taxpayer.

4.3: Advocacy and Funding

Building on the work of the Technical Design Team and recommendations within this report, the Advocacy and Funding Team has begun work to leverage funding to support the proposed comprehensive Mississippi River Basin Monitoring System. An Advocacy and Funding Team of nonprofit organizations working in the Basin, led by The Nature Conservancy, is exploring opportunities to fund the system through a variety of avenues, including:

- Secure long-term public funding through sources such as Congressional appropriations, the Infrastructure Investment and Jobs Act, and the Inflation Reduction Act
- Private fundraising and grants
- Private sector investment in ecosystem services

The team is conducting a gap analysis and identifying possible sources of funding. In addition, we are communicating the results of this initiative to recruit champions and advisors and obtain the critical buy-in needed from key federal and state agencies, partner organizations, and local municipalities.

5.0 Implementation Recommendations

The monitoring stations listed in this report are critical national infrastructure for water quality, flood management, and navigation. To achieve the goal to have “a fully funded, constructed, and staffed monitoring system across the Mississippi River in the next five years,” we make the following recommendations:

1. Sustain current levels of funding to operate and maintain all existing monitoring capacity of the U.S. Geological Survey, U.S. Army Corps of Engineers, and National Oceanic and Atmospheric Administration PORTS® Systems. Funding below current levels will further degrade the ability of the network to meet existing needs.
2. Appropriate $23.4 million in new funding to build, operate, and maintain, in year one, the recommended additional system upgrades to infrastructure and gage capabilities, build the new stations to fill critical monitoring gaps, and develop and implement the integrated government-hosted, public-facing data portal proposed in this report. In addition to this year one investment, appropriate another $335.4 million over the remainder of the 25 years, to cover the cost of 3% annual inflation to operate and maintain the full system during that time.
3. Evaluate the additional funds needed by the U.S. Army Corps of Engineers for their data managers to work with the U.S. Geological Survey data portal development team so that their data are accessible and maintained.
4. Convene a nonpartisan stakeholder group to determine the design specifications of the integrated data interfaces and guide the design and development of the system.
5. Create a process to ensure that funds allocated to the Sentinel System are dedicated to the priority needs identified in this report.
6. Leverage this effort, in collaboration with states, to unify monitoring criteria across the Mississippi River Basin to support state monitoring programs, align their data standards with those specified by the U.S. Geological Survey, and incorporate their data into the Sentinel System.
7. Form a representative technical working group to identify monitoring criteria and sites to collect ecological data and other elements (e.g., silica).
8. At the time of publication of this report, we are aware of new, emerging needs for additional monitoring gages at key navigational points along the Ohio River and elsewhere. To ensure that the Sentinel System incorporates critical monitoring needs and funding to support a healthy and safe Mississippi River Basin, we recommend conducting annual needs assessments utilizing the criteria identified in this report.

6.0 Summary

Our analysis by some of the best technical experts in the country finds a definite benefit from building and maintaining the Sentinel System over the next 25 years. Most of the system is in place, and the nation already spends considerable funds measuring water levels, flow, and quality within the Mississippi River Basin. However, the current data collection is performed by a patchwork of agencies and is hampered by a legacy of inconsistent and insufficient funding. As a result, the current monitoring network does not meet the needs of its multiple users, is incomplete, and is inequitable. We found that a wise investment of additional funding can transform the disparate pieces of the current monitoring system into a valuable, highly functional, and world-class monitoring network befitting our nation's most economically and environmentally important watershed.

The Nature Conservancy

The Nature Conservancy is a leading conservation organization working around the world to protect ecologically important lands and waters for nature and people.

Visit us at **nature.org.**

For more information, contact:

Bryan P. Piazza, Ph.D.
Director of Science,
Louisiana and Mississippi River Basin

bpiazza@tnc.org
225-773-1841

Liz Crow
Government Relations Director,
North America Agriculture and Mississippi River Basin

elizabeth.crow@tnc.org
918-812-7834