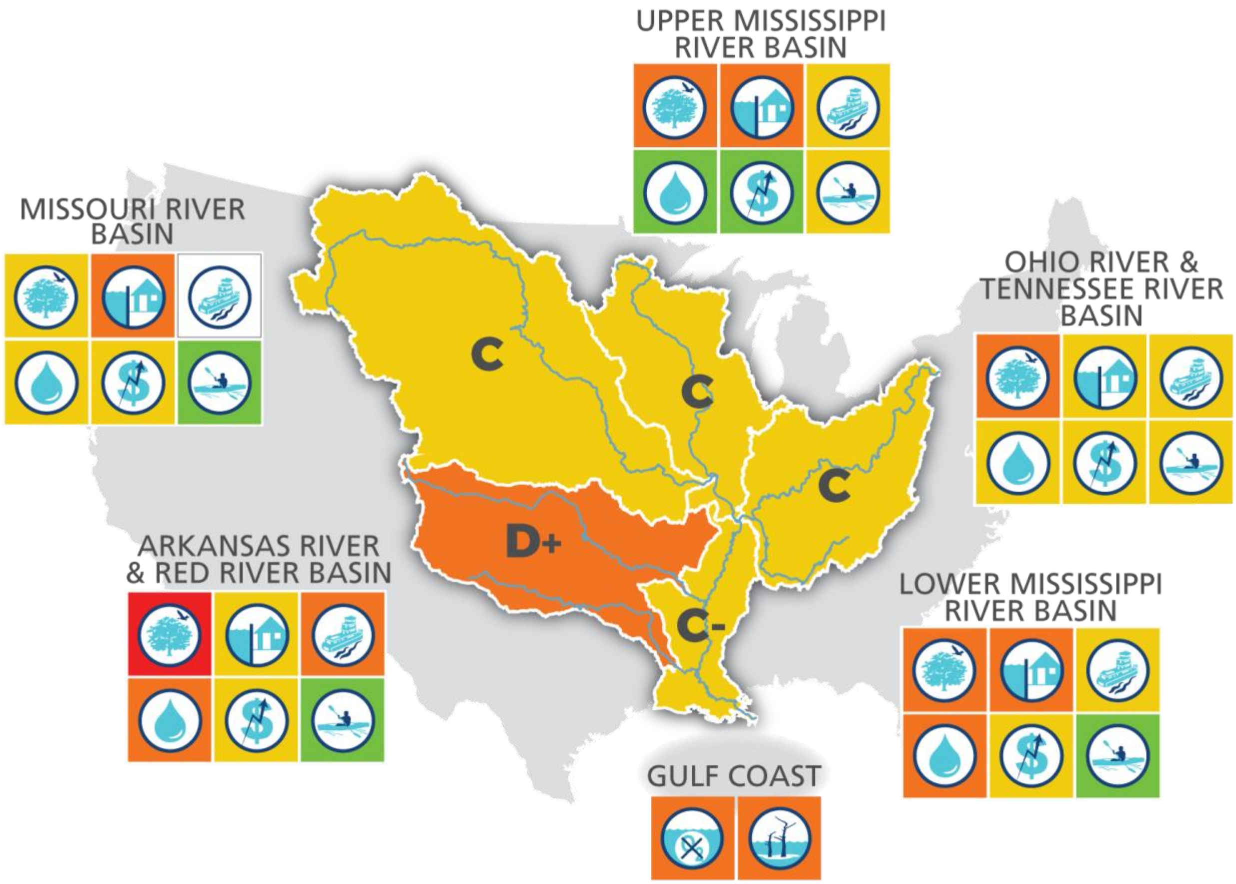
America's Watershed Initiative
Report Card for the
Mississippi River Watershed

Methods report on data sources, calculations, and additional discussion



December 7, 2020

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Overview

This companion document to the report card contains information about data sources for all indicators, summary of analysis methods, and scoring details for each of the six America's Watershed Initiative goals, and for two Gulf Coast indicators. Additional information regarding the goals is included to provide greater detail and discussion than is possible in the report card document.

Who is America's Watershed Initiative?

America's Watershed Initiative (AWI) is a collaboration including public and private-sector leaders from the 31 states comprising the Mississippi River Watershed, working together to find solutions for the challenges we face managing the Mississippi River; and its 250 tributaries. The challenges facing the waters and lands in America's Watershed are large and growing; only by working together and seeking collaborative solutions will we make meaningful and sustained progress to meet these many challenges.

AWI Board of Directors

The America's Watershed Initiative Board of Directors includes members from throughout the watershed and a diversity of sectors including conservation, navigation, agriculture, flood control and risk management, industry, academics, basin associations, local & state government, and the U.S. Army Corps of Engineers/Mississippi River Commission.

Kimberly Lutz, *AWI Executive Director*
Bob Beduhn, *HDR Inc.*
Sean Duffy Sr., *Big River Coalition*
Joan C. Freitag, *Hanson Professional Services*
Stephen Gambrell, *Mississippi Valley Flood Control Association*
Teri Goodmann, *City of Dubuque, Iowa*
Steve Mathies, *Stantec Consulting Services*
Dan Mecklenborg, *Ingram Barge Company*
Frank Morton, *Turn Services LLC*
Rachel Orf, *National Corn Growers Association*
Michael Reuter, *The Nature Conservancy*
Rainy Shorey, *Caterpillar Inc.*
Robert Sinkler, *Streamside Systems, Inc, and Dawson & Associates*
David Simmons, *Consultant for Viking Cruises*
BG (Ret.) C. David Turner, *American Water Military Services Group*
Kirsten Wallace, *Upper Mississippi River Basin Association*
Larry Weber, *University of Iowa*

Goals for the Mississippi River Watershed

During an extensive stakeholder process in 2012-2015, described more fully below, AWI gathered extensive input from a diversity of stakeholders who expressed their vision for the watershed. The goals below, established in the 2015 report card process, are based on this input and continue to drive our goals today.

Table 1.1: Goals for the Mississippi River Watershed

Support and enhance healthy and productive ecosystems
Conserve, enhance, and restore ecosystems within the Mississippi River Watershed to support natural habitats and the fish and wildlife resources that depend upon them.

Provide reliable flood control and risk reduction
Provide reliable flood protection and risk reduction through well managed and maintained infrastructure, including appropriate floodplain connections for water conveyance and ecosystem benefits, and management of surface and storm water runoff to better protect life, property, and economies.

Serve as the Nation's most valuable river transportation corridor
Provide for safe, efficient, and dependable commercial navigation within the Mississippi River Watershed to ensure a competitive advantage for our goods in global markets.

Maintain supply of abundant clean water
Ensure the quality and quantity of water in the Mississippi River Basin is adequate to support the economic, social, and environmental functions that are dependent on it.

Support local, state, and national economies
Sustain a water use system to efficiently and effectively support agricultural, industrial, and energy productivity.

Provide world-class recreation opportunities
Enrich the quality of life for people and recreation-based economies by maintaining and enhancing riverine, lake, and wetland-associated recreation within the basin.

The goal for the Mississippi River Watershed report card is simple—provide decision makers, watershed leaders, and the public with easy-to-understand information about the state of the Mississippi River Watershed's health to aid them in taking steps to improve health and resilience in key sectors across the watershed. From the start, the groups working together to support America's Watershed Initiative had three key objectives for the report card project:

- Bring together key leaders, stakeholders, and experts representing all of the basins and sectors to develop a single, shared document to measure the current status of six broad goals for the watershed;
- Build a report card supported by data that will help us to identify successes, opportunities for improvement, and areas needing additional research;
- Use this tool to identify opportunities for collaborations and a shared vision for the watershed.

How Was the Report Card Developed?

The first AWI Report Card was developed over two years with the help of hundreds of people from throughout the Mississippi River Watershed and Nation, and was released in 2015. The 2015 Mississippi River Watershed Report Card incorporated information and advice provided by leaders, stakeholders, and experts from more than 400 businesses, organizations, agencies, and academic institutions from every major river basin in the watershed and from key stakeholder groups. More than 700 diverse participants joined us in workshops, summits, webinars, and meetings to gather data, provide feedback, and give advice in the creation of the 2015 Mississippi River Watershed Report Card. For additional detail on the process of creating the 2015 Report Card, please visit http://americaswatershed.org/reportcard/.

The 2020 Mississippi River Watershed Report Card is an updated and revised version of the 2015 Report Card. New metrics were added and additional avenues explored, as a result of feedback during and after the completion of the 2015 Report Card. The process for creating the 2020 Mississippi River Watershed Report Card was similar in some ways to the 2015 process, and different in others. As in the 2015 process, engagement of diverse expertise from around the watershed was a critical component of the process for completing the 2020 Mississippi River Watershed Report Card. However, because the 2020 Report Card was intended to primarily be an information update to the 2015 Report Card, the process of stakeholder engagement was more targeted. Moreover, the Covid-19 outbreak in early 2020 curtailed some of the stakeholder engagement activities that were planned. Engagement activities were accomplished virtually, using video conferencing tools.

We convened a group of about 50 stakeholders (including AWI board members, see Appendix I for list of invited stakeholders) through two on-line discussions, in which a draft report card was shared for reaction and feedback. The results of these discussions guided the direction toward new indicators and highlighted key topics and areas to include in the report card either as potential indicators or as key points that should be made in the narrative.

The report card project was led by the Report Card Committee:

Bob Beduhn	*HDR Inc./AWI Board*
Joan Freitag	*Hanson Professional Services*
Stephen Gambrell	*Mississippi Valley Flood Control Association/AWI Board*
Heath Kelsey	*University of Maryland Center for Environmental Science*
Katie May Laumann	*University of Maryland Center for Environmental Science*
Kim Lutz	*AWI Executive Director*
Steve Mathies	*Stantec Consulting Services/AWI Board*
Delaney McMullen	*Weber Shandwick*
Dan Mecklenborg	*Ingram Barge Company/AWI Board*
Frank Morton	*Turn Services LLC/AWI Board*
Michael Reuter	*The Nature Conservancy/AWI Board*
David Simmons	*Consultant for Viking Cruises/AWI Board*
Robert Sinkler	*Streamside Systems Inc./AWI Board*
Carolyn Sofman	*Weber Shandwick*
BG (Ret.) C. David Turner	*American Water Military Services Group/AWI Board*
Vanessa Vargas-Nguyen	*University of Maryland Center for Environmental Services*
Larry Weber (chair)	*University of Iowa, Civil and Environmental Engineering/AWI Board*

Facilitation and production of the report card is the work of a team from the University of Maryland Center for Environmental Science Integration and Application Network (UMCES IAN), led by Drs. Heath Kelsey, Vanessa Vargas-Nguyen, and Katie May Laumann. The IAN team facilitated the information-gathering virtual workshops and meetings, compiled and analyzed the data to calculate the report card grades, and designed and produced the preliminary and final report card documents. Many individuals contributed to the work of the UMCES IAN team. Science Communication was performed by Jane Hawkey, Skyler Swanson, and Joseph Edgerton. Data tracking and analysis was mostly done by Steven Guinn and the rest of the UMCES IAN team.

Stakeholder convenings and subject expert meetings

The 2020 Report Card was developed in three stages. In the first stage, UMCES IAN updated the results of the 2015 Report Card with new data that was available for the suite of existing indicators, which was completed in early 2020. The initial, updated 2020 Report Card was missing several key components, including most of the information on ecosystem condition (Water Quality, Living Resources, and Streamside Habitat), one indicator in the Flood Control and Risk Management Category (Building Elevation), and one indicator in the Transportation category (Infrastructure Condition). This directed our efforts in the second phase, in which UMCES IAN pursued new indicators that would complement or replace indicators for which data were unavailable.

In the second phase, UMCES IAN and the Report Card Committee facilitated numerous meetings with stakeholder groups focusing on Water Quality and Ecosystems, Flood Control and Risk Management, Transportation, Natural Infrastructure, and Renewable Energy. Specific issues with data availability and potential metrics that could be used as indicators were discussed, as well additional considerations in crafting the messaging for the report card until a general consensus was reached.

The third phase of the 2020 Report Card process was to create the messaging from the results of indicator scores and from additional context about important issues in the watershed. The full AWI Board was convened to review the near final 2020 Mississippi River Watershed Report Card draft, and ensure that the messaging reflected the reality of conditions in the basin. The messaging attempted to balance the urgency of critical issues affecting the watershed while providing tangible examples of how groups are implementing projects with on-the-ground benefits that are already underway in the region.

Missing information

A key theme that emerged in both the 2015 and 2020 Report Card processes is that data that we anticipated would be accessible and available were not. In many cases, data were either not available, as in the case of the EPA Rivers and Streams Assessment Report, or were not easily accessible, as in the Infrastructure Condition data. We believe that significant effort and resources should be placed in creating reliable access to data critical to evaluating the health of the watershed and the effects of decisions that are being on conditions. We also believe that significant areas of applied and basic research remain necessary to advance our understanding of the Mississippi River Watershed as a holistic system.

How Are the Grades Calculated?

This report documents the data sources, calculations for each indicator, interpretation, calculation and assignment of scores, and calculation of basin and watershed average scores.

Results of the report card were calculated for the Upper Mississippi, Ohio-Tennessee, Lower Mississippi, Arkansas-Red, and Missouri River Basins. Results from these five basins were summarized in an overall watershed score. In addition to the goals and basin results, we also include results for Gulf Coast indicators including the size of the Gulf of Mexico hypoxic “dead zone” and the rate of coastal wetland loss in Louisiana.

Scoring and Letter Grades

All measurements were standardized to a 0–100 scale to enable aggregation of individual indicator results to the goal score. Scores were distributed in even increments to enable ease of aggregation. It is important to note that the scoring scheme is not a reflection of a curve or a lenient grading system; the Report Card team determined through data analysis what data values represented good and bad grades, and those values were then translated to the final scoring scheme, distributed into the 0–100 scale in 20-point increments. Final scores were given a grade based on the simple grading scheme as below:

Table 1.2: Scoring scheme for the Mississippi River Report Card.

Score	Grade
80–100	A
60–79	B
40–59	C
20–39	D
0–19	F

To calculate basin scores for each indicator, weighting schemes were assigned to reflect the nature of the data and the information they contained. Weighting was objective, and based on relevant data properties (Table 1.4). Weighting was necessary in many instances to account for the varied impact that some states or regions may have on the overall result. For instance, water supply results for a state with a small population in the basin should not count as highly in the basin water supply score as a state with a larger population in the basin. The weighting schemes were designed to account for these differences, and create a result that is reflective of the actual conditions in the basin. Table 1.4 presents the factors that were used for weighting each indicator to the basin result.

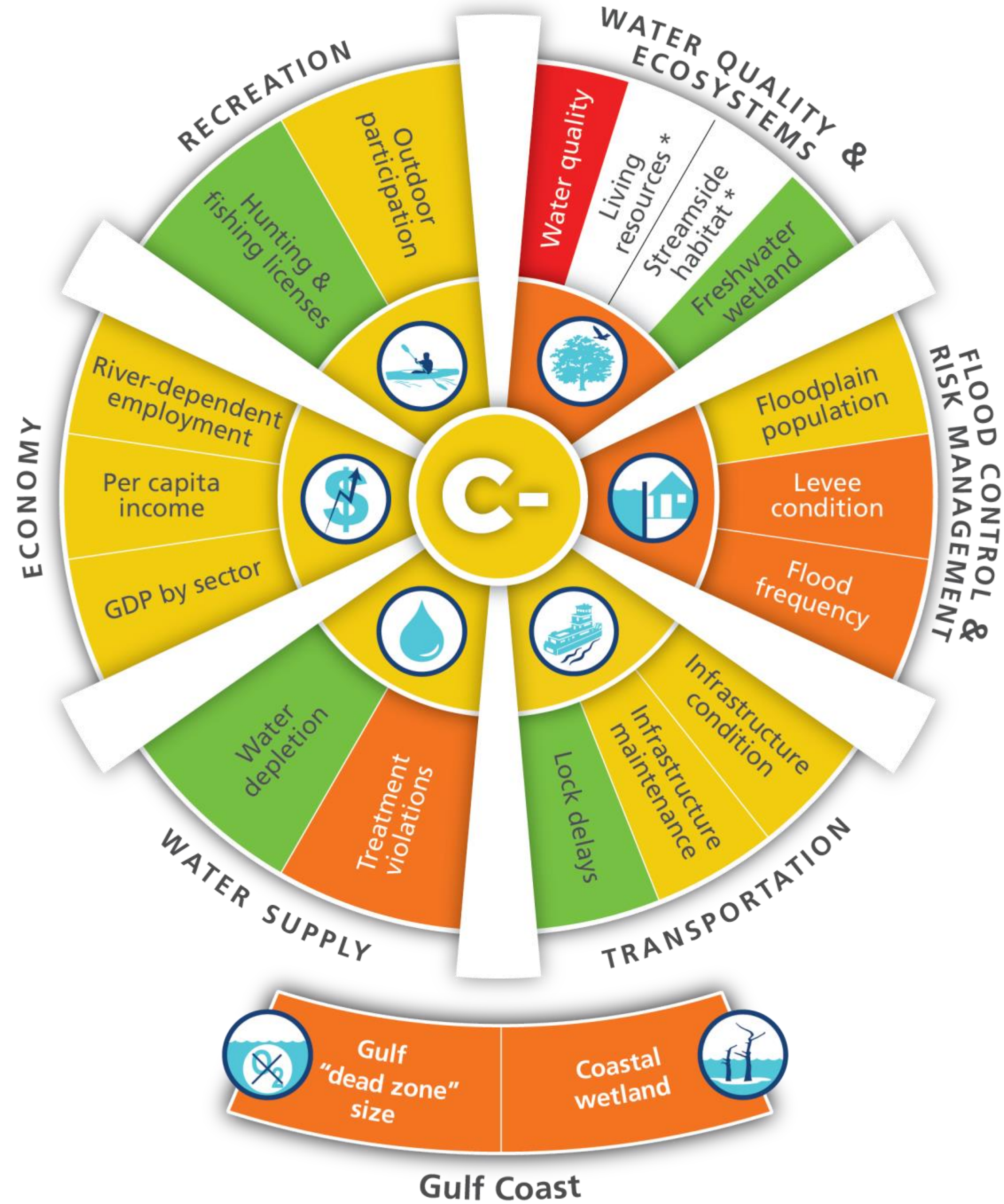

Figure 1.1: Report Card Results for the Mississippi River Watershed.

** Data from the US EPA Rivers and Streams Assessment to update scores for Living Resources and Streamside Habitat is not yet publicly available.*

What's New in the 2020 Mississippi River Watershed Report Card?

General calculation approaches

As we updated data from the 2015 Report Card, we identified several improvements and adjustments to calculations that we applied generally throughout the analysis and scoring of indicator data. For example, we developed new, more precise methods to estimate population location. These methods were to all of the indicators that required weighting based on population in each basin. Additionally, we moved to a five-year moving average of data for certain indicators. This approach reduces the effect of extreme values (high or low) that result sometimes from inter-annual variability. The five-year average also generally reflects the five years between the 2015 and the 2020 Report Cards. Similar to the 2015 Report Card, the 2020 Mississippi River Watershed Report Card used the most recent data available for each indicator; these data periods varied; specific data periods for each indicator are reflected in the indicator description.

Water Quality and Ecosystems

In the 2015 Report Card, data for the Water Quality, Living Resource, and Streamside Habitat indicators were sourced from the 2008–2009 USEPA National Rivers and Streams Assessment. Unfortunately, the next update to the Rivers and Streams Assessment had not yet been completed, and data for the 2020 Report Card were not available—the Rivers and Streams Assessment is performed roughly every five years or so. The uncertainty surrounding the Rivers and Streams Assessment and reporting schedule prompted the report card team to develop different data sources and indicators for the Water Quality and Ecosystems category in the 2020 Report Card so that regular updates to indicators could be more assured. Water Quality was derived from nutrient and sediment data from USGS river sampling stations and data sets, as described in the Water Quality and Ecosystems Section. This approach added dimensionality (described) and the ability to expand upon this data set by including additional locations in future report cards. This approach also helped achieve an objective to tie water quality issues in the watershed to issues in the Gulf of Mexico, a suggestion resulting from the 2015 Report Card process.

Flood Control and Risk Management

New construction standards for building elevation that are required by state regulatory agencies was an indicator in the 2015 Report Card that also was not available for inclusion in the 2020 Report Card. In 2015, the data were provided by the State Flood Managers Association. In the opinion of UMCES IAN, this indicator was not ideal—although highly relevant to management concerns, we felt that the score for this indicator was not likely to change much over time. Another suggestion that came from the 2015 Report Card process was to develop an indicator that reflected flooding conditions occurring in the watershed. The indicator that we created for the 2020 Report Card reflects the frequency of flooding throughout the Mississippi River Watershed and in each of the five basins. This new indicator replaces Building Elevation as an indicator in the Flood Control and Risk Management category.

Transportation

Infrastructure Condition was an important indicator in the 2015 Mississippi River Watershed Report Card. It was a measure of the actual condition of critical infrastructure at locks in the inland waterways transportation system in the Mississippi River Watershed. The USACE provided a summary of conditions at each lock, which we converted to a score. These data, however, were not available for use in the 2020 Report Card. A new indicator was created based on the age and effective life remaining based on recent upgrades. We feel that this is a better indication of overall condition at each lock.

Table 1.3: Participants in goal-area working groups

Transportation Sub-Committee	
Debra Calhoun	Waterways Council Inc.
Sean Duffy	Big River Coalition/AWI Board
Marty Hettel	American Commercial Barge Lines
Health Kelsey	University of Maryland Center for Environmental Science
Dan Mecklenborg	Ingram Barge Company/AWI Board
Frank Morton	Turn Services LLC/AWI Board
Mark Pointon	US Army Corps of Engineers
Steven Riley	US Army Corps of Engineers
Vanessa Vargas-Nguyen	University of Maryland Center for Environmental Science

Flood Control and Risk Management Sub-Committee	
Bob Beduhn	HDR Inc./AWI Board
Chad Berginnis	Association of State Floodplain Managers
Stephen Gambrell	Mississippi Valley Flood Control Association/AWI Board
Steven Guinn	University of Maryland Center for Environmental Science
Heath Kelsey	University of Maryland Center for Environmental Science
Frank Morton	Turn Services LLC/AWI Board
Robert Sinkler	Streamside Systems Inc./AWI Board
Vanessa Vargas-Nguyen	University of Maryland Center for Environmental Science
Gabriele Villarini	University of Iowa, Civil and Environmental Engineering
Kirsten Wallace	Upper Mississippi River Basin Association/AWI Board
Larry Weber	University of Iowa, Civil and Environmental Engineering/AWI Board

Water Quality and Ecosystems Sub-Committee

Gretchen Benjamin	The Nature Conservancy
Steven Guinn	University of Maryland Center for Environmental Science
Heath Kelsey	University of Maryland Center for Environmental Science
Dan Mecklenborg	Ingram Barge Company/AWI Board
Frank Morton	Turn Services LLC /AWI Board
Vanessa Vargas-Nguyen	University of Maryland Center for Environmental Science
Kirsten Wallace	Upper Mississippi River Basin Association/AWI Board
Larry Weber	University of Iowa, Civil and Environmental Engineering/AWI Board

Natural Infrastructure Sub-Committee

Sean Duffy	Big River Coalition/AWI Board
Stephen Gambrell	Mississippi Valley Flood Control Association/AWI Board
Heath Kelsey	University of Maryland Center for Environmental Science
Katie May Laumann	University of Maryland Center for Environmental Science
Steve Mathies	Stantec Consulting Services /AWI Board
Don McNeil	Caterpillar Inc.
Frank Morton	Turn Services LLC/AWI Board
Robert Sinkler	Streamside Systems Inc./AWI Board
Vanessa Vargas-Nguyen	University of Maryland Center for Environmental Science
Larry Weber	University of Iowa, Civil and Environmental Engineering/AWI Board

Table 1.4: Indicator summary—including weighting factors used in calculating watershed averages.

Indicators	Source of Data	Weighting Scheme
Water Quality and Ecosystems		
Water Quality Index (Nutrient and Sediment Loading)	USGS Water Data for the Nation, National Water Quality Monitoring Council's Water Quality Portal	
Freshwater Wetland Area Change	Multi-Resolution Land Characteristics data	Wetland area in basin
Flood Control and Risk Management		
Flood Frequency	Slater and Villarini 2016, US Geological Survey, US Army Corps of Engineers, and National Weather Service (NOAA)	
Floodplain Population Change	US Census, and FEMA Special Flood Hazard Area	Population in 500-yr floodplain
Levee Condition	US Army Corps of Engineers 2018 National Levee Database	Total levee length in basin
Transportation		
Lock Delays	US Army Corps of Engineers 2019	5-year average annual tons moved in basin per lock
Infrastructure Condition	US Army Corps of Engineers, Web searches, Inland Waterway Trust Fund	Annual tons moved in basin per lock
Infrastructure Maintenance	USACE Inland Waterway Trust Fund, USACE Mississippi Valley Operations and Maintenance	Scored for watershed
Water Supply		
Water Treatment Violations	2019 Government Performance and Results Act (GPRA) of Total Water Systems.	Population served by community water systems
Water Depletion	2015 WaSSI model results for HUC8 watersheds	Population
Economy		
River-Dependent Employment	Bureau of Labor Statistics 2018	Total river-related employment in basin
GDP by Sector	Bureau of Economic Analysis 2018	Total GDP in basin
Per Capita Income	Bureau of Economic Analysis 2018	Population in basin
Recreation		
Outdoor Participation	US Fish and Wildlife Service survey by US Census Bureau, and National Park Service	Participation totals in basin
Hunting and Fishing Licenses	US Fish and Wildlife Service	License totals in basin
Gulf Coast		
Coastal Wetland Change	US Geological Survey	(scored for watershed)
Gulf of Mexico "Dead Zone"	Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force	(scored for watershed)

Water Quality and Ecosystems

Support and enhance healthy and productive ecosystems

People value the natural ecosystems of the Mississippi River Watershed for the abundant and diverse fish and wildlife resources they support, but this is only part of the reason why it is important to conserve and restore natural ecosystems. Maintaining the health of ecosystems in the watershed also contributes to achieving goals for water supply, flood protection, recreation, and the economy. Healthy and productive ecosystems provide a range of services such as improving water quality, reducing the risk of flooding, and providing recreational opportunities.

Indicators

The 2015 Mississippi River Watershed Report Card used data from the 2008–2009 USEPA National Rivers and Streams Assessment to provide an assessment of Water Quality, Living Resources, and Streamside Habitat indicators (Appendix II). Data from the USEPA 2013–2014 National Rivers and Streams Assessment are not yet available to update these scores.

We established a new 2020 Report Card indicator for water quality based on nutrient and sediment loading, in part to establish a secondary water quality analysis, and in part to increase the dimensions of water quality to include nutrient and sediment loading (suggested as possible indicators in the 2015 Report Card process). We believe that this new indicator is a better reflection of relevant water quality issues in the watershed, and that it can be improved in future report cards to include additional locations and longer time series (see below).

Similar to the 2015 Report Card, the indicator selected for ecosystem health in the Mississippi River Watershed measures the effectiveness of efforts to protect and restore freshwater wetlands throughout the watershed. The effectiveness of ecosystem protection and restoration is evaluated by the measured change in wetland area within each basin between 2011 and 2016, in response to adoption of the “no net loss” policy for freshwater wetland protection.

Nutrient and Sediment Loading

Water quality indicators were designed to evaluate trends in nutrient loading in each of the five basins. Water quality stations were selected based on the availability of nitrate nitrogen (NO3-N, mg/l), phosphorus (total dissolved P, mg/l), sediment (TSS, mg/l), and discharge (volume of water flow, m^3/sec).

This indicator is meant to represent nutrient reductions in the watershed which are a component of the Gulf of Mexico Hypoxia Task Force's goal of reducing the size of the summer hypoxic area in the Gulf of Mexico to a five-year moving average size of less than 5,000 km^2 by 2015 (Battaglin, et al. 2010). Decreasing nutrient load trends would be an indication that nutrient reduction strategies were having an effect on reducing overall nutrient loading in the watershed.

Data source

- Discharge data: USGS Water Data for the Nation

- Nutrient and sediment data were retrieved for a maximum range of 2010–2019, minimum range of 2016–2019 from the National Water Quality Monitoring Council's Water Quality Portal (WQP)

- Annual nutrient and sediment load data were calculated using LOADEST.

Data Pre-processing

Annual nutrient and sediment load data were calculated using an external estimator designed for this purpose, called LOADEST (https://engineering.purdue.edu/mapserve/LOADEST/), which integrates monthly nutrient and sediment concentration data with near continuous discharge data to provide estimates of daily loads and annual loads. This load estimator product is widely used and accepted as a method to estimate loads using monthly water quality testing and daily discharge data.

Discharge data for each station were downloaded from the USGS NWIS data portal, cleaned of extraneous information, and uploaded to a local database. Nutrient data were downloaded from the Water Quality Data Portal, cleaned of extraneous information, and also uploaded to the local database. Discharge and water quality data were exported and uploaded to the Purdue mapserver LOADEST site for load calculation. Load results were then downloaded, cleaned of extraneous information and uploaded back to the local database. Annual nutrient and sediment loads for each station were exported for trend analysis in R.

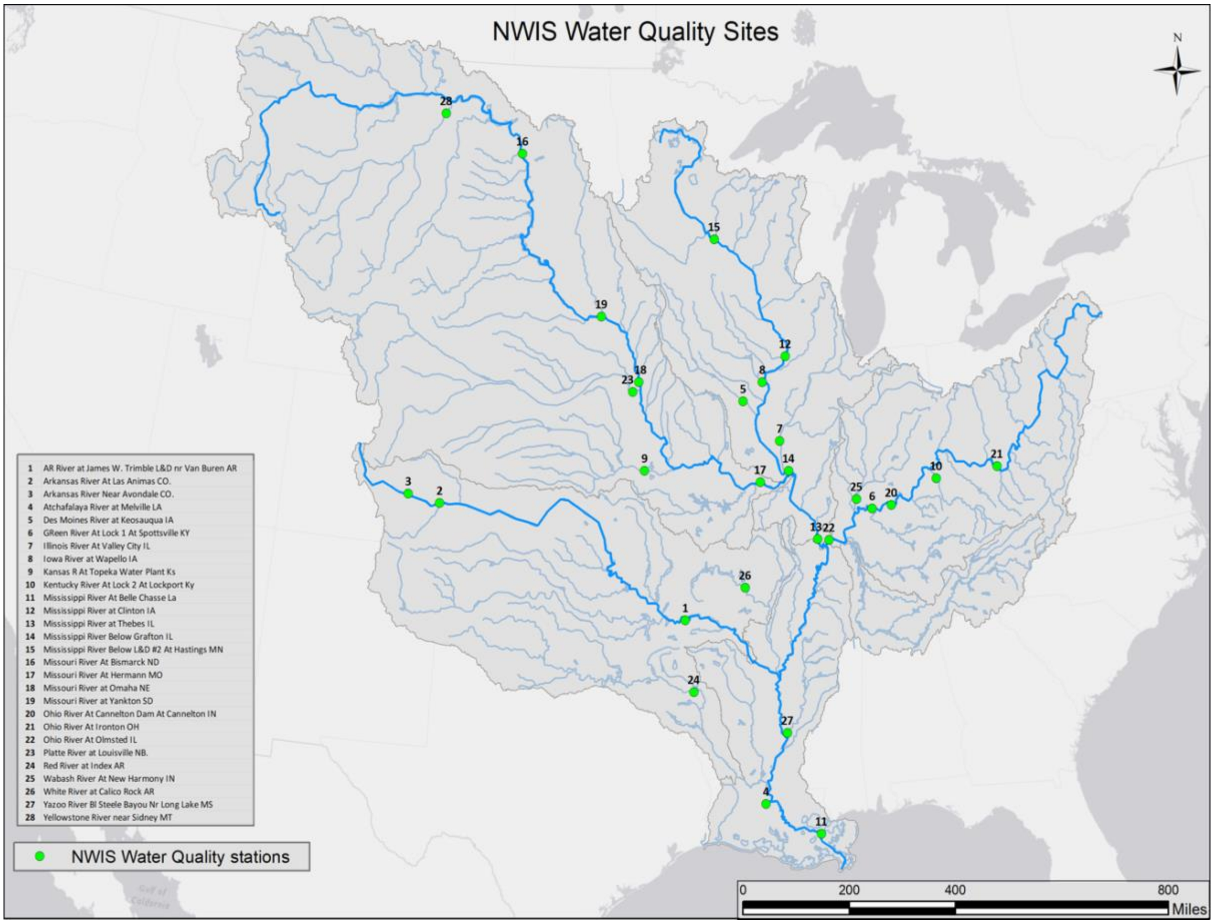

Figure 2.1.1: Sites chosen for analysis of nitrogen, phosphorus, and sediment trends. Where possible, sites were meant to represent outlet, middle, and upstream locations in each of the basin.

Calculation Method and Scoring

Simple trend analysis was performed using the R statistical software program (https://www.r-project.org/) by evaluating the relationship of year to total annual load at each station using a simple linear regression of the form lm(load~year). Because data were not expected to be normally distributed, a $\log_{10} + 1$ transformation was used prior to analysis.

The analysis resulted in an evaluation of the trends in each constituent over the time series at each station. Trends were determined to be statistically significant at the $p < 0.1$ level.

To develop a score for each basin based on the trends, a ratio was calculated of stations that exhibited statistically significant negative trends (nutrient loads are decreasing over time) to those that exhibited positive trends (nutrient loads are increasing over time). The target for each location is to exhibit a negative trend. Nutrient reduction strategies are designed to achieve overall reductions in nutrient loads in the watershed; decreasing trends would illustrate that these reductions were having an overall effect on nutrient loading.

Score = $n_d/n_i * 100$ [n_d = number of stations in the basin with decreasing trends, n_i = number of stations in the basin with increasing trends.]

Results

No stations in any basin exhibited decreasing trends in nutrient or sediment loads. However, two stations in the Upper Mississippi, one station each in the Ohio-Tennessee and the Missouri River Basin exhibited increasing trends in annual nitrogen, phosphorus, and sediment loads (the same stations exhibited positive trends in all constituents). As the score for this indicator is derived from a ratio of the number of stations with negative trends to those with positive trends, each basin scored a zero for this indicator.

Table 2.1.1: Stations with statistically significant trends in nutrient loading

River Basin	Number of stations with Trends		Score	Letter Grade
	Positive/Increasing	Negative/Decreasing		
Upper Mississippi	2	0	0	F
Ohio-Tennessee	1	0	0	F
Lower Mississippi	0	0	0	F
Arkansas-Red	0	0	0	F
Missouri	1	0	0	F
Mississippi River Watershed	**4**	**0**	0	**F**

Freshwater Wetland Area Change

The indicator selected for ecosystem health in the Mississippi River Watershed measures the effectiveness of efforts to protect and restore wetlands throughout the watershed. The effectiveness of ecosystem protection and restoration is evaluated using the measured change in wetland area within each basin between 2011 and 2016, in response to adoption of the “no net loss” policy for wetland protection. The Freshwater Wetland Area Change index scores the percent change in wetland area in each basin by state.

Data source

Calculations are based on data from the National Land Cover Database (NLCD). NLCD uses multiple dates of Landsat satellite imagery and other ancillary datasets to produce nationally standardized land cover and land change information for the Nation. These products support a wide variety of federal, state, local, and nongovernmental applications that seek to assess ecosystem status and health, understand the spatial patterns of biodiversity, examine the effects of climate change, and help develop land management policy.

*Data accessed 10/2019 from the National Land Cover Database using Multi-Resolution Land Characteristics data

Calculation Method and Scoring

The Freshwater Wetland Area Change index is scored based on the change in wetland area for each state between 2011 and 2016, the two most recent years in the database; data are compiled every five years. The change in wetland area is calculated as a percent of the total wetland area. The score for each basin is calculated from the percent change in wetland area using the formula $y = 200x + 50$; where y is the score and x is the percent change in wetland area. The score for the watershed is calculated as the average of the basin scores weighted by the wetland area in each basin.

Table 2.2.1: Scores for Freshwater Wetland Area Change

Sub-basin	% loss	Score	Letter grade	Basin Wetland %
Ohio-Tennessee	1%	70	B	4%
Upper Mississippi	1%	69	B	29%
Lower Mississippi	0%	51	C	39%
Missouri River	8%	100	A+	18%
Arkansas-Red	-3%	0	F	9%
Mississippi River		**61**	**B-**	**100%**

Additional discussion on water quality indicators

Annual nutrient loads at key locations in each basin have been steady or have gone up over the last five years, resulting in poor Water Quality scores in the 2020 Report Card. The USGS reports that about 1.5 million tons of nitrogen are delivered to the Gulf every year, a large proportion of this is from agriculture. Crop production, even on well-managed fields, invariably results in nutrient losses through surface runoff and tile drainage. Farmers struggle with producing crops to meet world demand while minimizing nutrient losses and environmental impacts. More farmers, across several states, are adopting precise nutrient management techniques using state nutrient loss reduction strategies, but more needs to be done. In Iowa, it is estimated that over 1 billion pounds of nitrogen was delivered to the Mississippi River and its tributaries in two of the last four years, resulting in a doubling of the nitrogen load leaving the state in the past 20 years.

Limitations

Curating the data required for the assessment of nutrient and sediment loads was time consuming. Identifying stations that had time series data for these constituents and also had available discharge data (necessary to calculate nutrient and sediment load) was an iterative and labor-intensive process. Ideally, we would be able to use a long time series of data—30 years or more would be preferable. We were able to complete the analysis using data from a five to ten-year time period from 2011–2019. We feel that it is likely that significant trends at more stations would have been identified if we had been able to include additional years of data in the analysis.

Additional potential indicators

We also investigated the utility of analyzing daily measurements of nitrogen concentration at drinking water source areas for water treatment facilities in the basin. Based on stakeholder feedback and discussions with the AWI Board, the Racoon and Des Moines Rivers were chosen as test locations for this analysis. We were provided data reflecting the daily nitrate nitrogen (NO3-N) concentration at test locations in each river directly upstream of source water intakes. We counted and plotted the number of days for which test results exceeded guidelines of 10 mg/l NO3-N. Results are plotted below and discussed in the report card text in the water quality section. In 2015, exceedances of the safe standard occurred on 270 days.

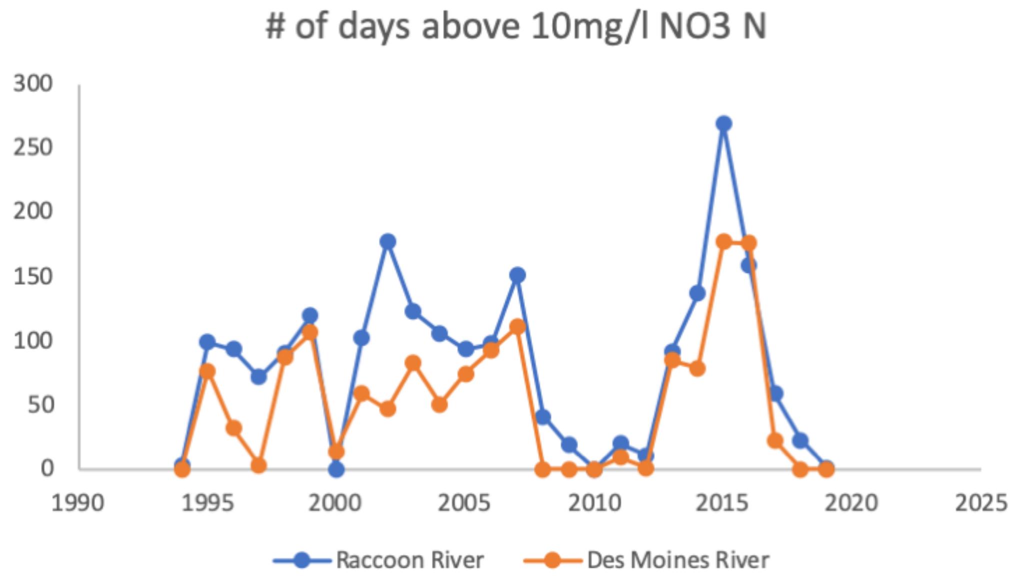

Figure 2.2.1: Number of days annually that nitrate concentrations exceeded safe drinking water standards of 10mg/l at the Raccoon and Des Moines Rivers which are sources of drinking water for the city of Des Moines. When these exceedances occur, drinking water facilities must find alternate water sources to dilute the concentration, or engage nutrient reduction treatments. *Data from Des Moines Water Works (http://www.dmww.com/water-quality/water-quality-data/advanced-water-quality-data/)*

We believe that this indicator has potential for inclusion in the Water Supply category of the report card. This will require significant data sourcing and analysis to identify data from municipal water suppliers throughout the watershed that rely on surface water sources, and routinely test for nitrate concentration. We believe that this will increase the relevance of Water Quality indicators to the Water Supply category in the report card.

Flood Control and Risk Management

Provide reliable flood control and risk management

The challenge for flood control and risk management is to maintain existing measures that have proven effective—both structural and nonstructural—while at the same time finding new strategies that respond to a changing climate, rising sea levels, and coastal subsidence and erosion. Flood losses increase when watersheds lose their natural capacity to store water, communities and other permanent structures are developed in flood-prone areas, changes in the landscape increase runoff, and when infrastructure—such as levees and dams originally built to manage flood risk—begin to age or are not maintained. A variety of strategies can be used to reduce flooding, including structural solutions such as: storing water in reservoirs to reduce peak river discharge, constructing levees and flood walls to contain flood waters. Increasingly, natural infrastructure solutions are being added to the list of potential alternatives, such as preserving wetlands to provide natural flood storage and redirection of flood waters. The possibility that flooding will occur can never be reduced to zero; especially in a climate altered world, therefore, reducing risk also means constructing buildings and making plans in preparation to accommodate intense rainfall and high-water levels when they do occur.

Indicators

The indicators selected for Flood Control and Risk Management in the Mississippi River Watershed assess the trend in the number of people at risk, the condition of flood protection infrastructure, and frequency of flooding. The trend for number of people at risk is evaluated based on the population within the 500-year floodplain. The condition of flood protection infrastructure is evaluated based on the results of levee inspections regularly conducted by the Corps of Engineers. Evaluation of the number of people at is based on the proposed new federal flood protection standards. The Flood Frequency indicator evaluate trends in the frequency of flooding in the Mississippi River Watershed, both in the main channel and the tributaries. Increases in the frequency of flooding has implications in flood risk management strategies that need to be adapted to account for these changes.

Flood Frequency

The Flood Frequency indicator is meant to evaluate trends in the frequency of flooding in the Mississippi River Watershed. Changes in the frequency and magnitude of flooding have been identified for the entire US in previous research by Slater and Villarini (2016), but these trends had not been specifically evaluated for the Mississippi River Basin or separately evaluated for the five river basins. Increases in the frequency of flooding would suggest that flood risk management strategies will need to adapt to account for these changes.

We used the existing analysis from Slater and Villarini (2016), supplemented with additional locations to evaluate trends of conditions in both the main river channels in the five river basins, and in their tributaries. Conditions in the main river channels reflect an integration of discharge from all upstream areas, including the tributaries. An analysis of the tributaries was specifically included to evaluate more localized changes in flood conditions.

Data sources

Tributary flood data
Trends in days over flood stage provided to UMCES by the authors:

Slater, L. J., and G. Villarini (2016), Recent trends in U.S. flood risk, Geophys. Res. Lett., 43, 12,428–12,436, doi:10.1002/2016GL071199.

Main river channel flood data
Data was retrieved for the maximum range of 1950–2019, minimum range of 2012–2019

1. Discharge and Stage Data
    a. USGS Water Data for the Nation
    b. US Army Corp of Engineers
2. Flood Stage data
    a. National Weather Service Advanced Hydrologic Prediction Service

Calculation Method and Scoring

Tributary Data

Trends for all stations had previously been established in the statistical analysis results provided by Slater and Villarini (2016). We subset the trends based on station location to calculate the percent of trends that were significantly significant ($p < 0.1$) and calculated the percentage of stations that exhibited negative trends compared to those stations that exhibited positive trends.

Main River Channels

Simple trend analysis was performed using the R statistical software program (https://www.r-project.org/) by evaluating the relationship of year to the number of days reaching or exceeding the flood stage threshold at each station using a simple linear regression of the form lm(FloodDays~year). Because data were not expected to be normally distributed, a $\log_{10}+1$ transformation was used prior to analysis.

The analysis resulted in an evaluation of the trends in the frequency of flooding over the time series at each station. Trends were determined to be statistically significant at the $p < 0.1$ level.

The target for each location was to have negative trends, indicating that days above flood stage were decreasing.

Score = $n_d/n_i * 100$ [n_d = number of stations in the basin with decreasing trends, n_i = number of stations in the basin with increasing trends.]

Results

Results in the tributary locations varied by basin: More locations in the Upper Mississippi, Ohio-Tennessee, and Missouri River Basins had positive trends in days above flood thresholds than had negative trends, and so had low scores. In the Lower Mississippi and Arkansas-Red Rivers Basins, more stations had negative trends than had positive, and so had higher scores. This likely reflects regional changes in precipitation patterns.

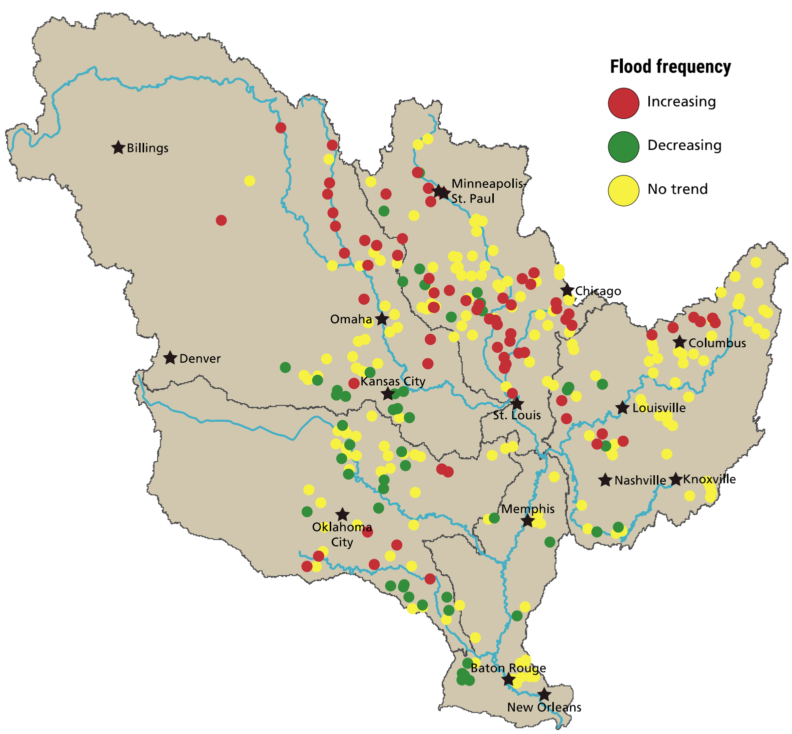

Figure 3.1.1: Locations and trends in the frequency of flooding at each station in the analysis. The frequency of flooding is increasing at more stations than stations where it is decreasing.

Table 3.1.1: Tributary Locations

	Number of stations with trends			
Basin Name	Positive/Increasing	Negative/Decreasing	Score	Letter Grade
Upper Mississippi	9	42	**18**	**F**
Ohio-Tennessee	7	11	**39**	**D+**
Lower Mississippi	9	1	**90**	**A**
Arkansas-Red	19	7	**73**	**B**
Missouri	13	18	**42**	**C-**
Mississippi River			**52**	**C**

Table 3.1.2: Main River Channel Locations

	Number of stations with trends			
Basin Name	Positive/Increasing	Negative/Decreasing	Score	Letter Grade
Upper Mississippi	2	0	**0**	**F**
Ohio-Tennessee	0	0	**0**	**F**
Lower Mississippi	0	0	**0**	**F**
Arkansas-Red	1	0	**0**	**F**
Missouri	1	0	**0**	**F**
Mississippi River			**0**	**F**

Table 3.1.3: Flood Frequency Summary Scores

		Flood Frequency		
Sub-basin	**Tributaries**	**Main Channel**	**Score**	**Grade**
Ohio-Tennessee	39	0	19	**F**
Upper Mississippi	18	0	9	**F**
Lower Mississippi	90	0	45	**C-**
Missouri River	42	0	21	**D-**
Arkansas-Red	73	0	37	**D+**
Mississippi River	**52**	**0**	**26**	**D**

Floodplain Population Change

The Floodplain Population Change indicator compares the change in number of people most at risk to flooding with the change in number of people living in a basin overall. The desired condition is that the number of people most at risk is decreasing, or at least increasing less quickly than the total population of the basin.

Data source

We use the Federal Emergency Management Agency (FEMA) designated 500-year flood plain to define areas most at risk to flooding, and we use a dasymetric mapping product derived from US Census data for 2010 and 2015 to calculate the change in number of people living in the flood plain and in the basins.

*Data accessed 10/2019 from The National Flood Hazard Layer (NFHL) geospatial database

2015 Mississippi Basin dasymetric mapping product. (See Appendix III)
2010 Mississippi Basin dasymetric mapping product. (See Appendix III)

Calculation Method and Scoring

The indicator score is calculated from the difference between floodplain population trends and the overall population trends in the basin between 2010 and 2015. A positive difference indicates that population increased at a faster rate in the floodplain than in the basin, while a negative difference indicates that population increased at a slower rate in the floodplain than in the basin.

The formula $y = 50-10x$ converts the difference between floodplain population trends and basin trends (x) to a value between 0–100, which then becomes the score for that state. The formula was calculated using -5% and 5% as the lower and upper bounds, corresponding to scores of 100 and 0, respectively.

The score for the Mississippi River Watershed is calculated as the average of basin scores weighted by the basin's percentage of the total watershed population in floodplains.

Table 3.2.1: Scoring Method

y = -20x + 50		Letter Grade Conversion and Color Schematic			
Diff between floodplain and sub-basin	Sub-basin score	Diff between floodplain and sub-basin	Sub-basin score	Letter grade	Color
-2.5	100	-2.5 to -1.5	80–100	A	
-1.5	80	-1.5 to -0.5	60–80	B	
-0.5	60	-0.5 to 0.5	40–60	C	
0.5	40	0.5 to 1.5	20–40	D	
1.5	20	1.5 to 2.5	0–20	F	
2.5	0				

Table 3.2.2: Floodplain Population Change. Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the number of people living in the 500-year floodplain.

Sub-basin	Score	Letter grade	Flood Zone Pop	Sub-basin Fldz Pop
Arkansas-Red	70	B	242,069	13%
Upper Mississippi	63	B-	266,394	14%
Missouri River	68	B	278,144	14%
Ohio-Tennessee	96	A+	447,707	23%
Lower Mississippi	18	F	695,659	36%
Mississippi River	**56**	**C+**	**1,929,973**	**100%**

Levee Condition

The Levee Condition indicator evaluates the status of levees inspected by the US Army Corps of Engineers (USACE).

Data source

Results are based on the 2018 inspection results reported in the USACE National Levee database from the US Corp of Engineers. *Accessed 11/2019*

Calculation Method and Scoring

Scores are assigned as follows based on inspection results as reported in the National Levee Database: Acceptable = 100, Minimally Acceptable = 50, and Unacceptable = 0. Basin scores are calculated as the average for all levees in the region weighted by the length of each levee. The score for the Mississippi River Watershed is calculated as the average of the basin scores weighted by the basin's percent of the total watershed levee length.

Table 3.3.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the miles of levee in each basin.

Sub-basin	Levee Condition Overall Score	Letter grade	Basin Levee %
Ohio-Tennessee	44	C-	5%
Upper Mississippi	40	C-	22%
Lower Mississippi	29	D	24%
Missouri River	25	D	27%
Arkansas-Red	20	D-	21%
Mississippi River	**29**	**D**	**100%**

Additional discussion of frequency of flooding

Data and results provided by Slater and Villarini (2016) was crucial to developing the Flood Frequency indicator. Results suggest that the frequency of flooding in the watershed is increasing, except in the Lower Mississippi and Arkansas-Red Rivers Basins. These data represented a high degree of effort on the part of the authors to locate, retrieve and curate these data for their analysis. We are grateful to the Dr. Villarini and Dr. Slater for allowing the use of the data in this analysis. However, the data do not represent the most recent time period covered by the 2020 Mississippi River Watershed Report Card. In future iterations of the report card, it will be necessary to update the data for all of the locations, which will be a substantial effort.

We augmented data provided by Slater and Villarini (2016) with additional data from stations that reflected conditions in the main river channels in each basin. The number of stations could be expanded in future iterations of the report card to have more representation of main river channel trends on the frequency of flooding trends.

The poor Flood Frequency scores in the report card reflect increasing trends in annual days of high-water flow (discharge). Over the last several decades, the number of days that exceed flood discharge thresholds every year has been increasing, likely as a result of changes in precipitation patterns, and changes in the landscape. These patterns are becoming more extreme, with alternating periods of drought and high rainfall storms; these changes make risk management challenging. Extreme flooding occurred in the watershed in five of the last ten years.

The Bonnet Carré Spillway, just upstream of New Orleans, diverts floodwater from the Mississippi River to protect the city. The floodway has been opened only 15-times in its 90-year history, but six of those times have occurred in the last ten years. The opening of the spillway reduces flood risk in New Orleans, but also has ecological consequences: the massive influx of fresh water into Lake Pontchartrain not only affects the fish and shellfish there, it also brings high doses of nutrients into the lake, that can cause certain types of algae to grow, which can be toxic.

Many activities are occurring in the Mississippi River Watershed to reduce the impact of increased flood trends. For example, communities are reconnecting flood plains to the river channel to create water storage areas. Additionally, in some areas affected by flood damage, people are relocating rather than rebuilding in flood-prone areas, supported by state and federal programs designed to “buy-out” homes in these areas. These types of activities will need to be accelerated due to the observed changes in rainfall and flooding.

Transportation

Serve as the Nation's most valuable River transportation corridor

People value safe, secure, well-maintained, and future-oriented inland navigational infrastructure that is integrated with rail and highway transport to support cost-effective movement of goods and materials. Commercial navigation is critical to the economic and social well-being of the United States and the world. The Mississippi River and its tributaries serve as the Nation's most valuable river transportation corridor.

Indicators

The indicators selected for transportation in the Mississippi River Watershed assess system performance, condition of navigation infrastructure, and sustainability of operations. System performance is assessed based on delays due to navigation locks taken out of service. The condition of navigation infrastructure is based on the assessed condition of critical components of the lock and dam facilities. Long-term sustainability is evaluated based on an assessment of the planning process that determines the resources annually allocated to operations and maintenance for the entire transportation system in the watershed.

System performance and the condition of essential components are evaluated based on data collected by the USACE for each lock and dam facility on the Mississippi River and its tributaries. The results are rolled up and scored for each basin in the watershed except the Missouri River Basin. Navigation is restricted to the lower portion of the Missouri River, below Sioux City, and there are no navigation locks or dams on this section of the river. Therefore, the Missouri River Basin does not receive a grade for navigation in this report card.

Note on Calculation of Watershed Score

The overall watershed score for Transportation is calculated differently from the overall watershed scores in the other goal areas. A different approach is taken for Transportation because the transportation indicators emphasize the lock and dam infrastructure components of the inland navigation system. This infrastructure is unevenly distributed among the basins; most of it is in the Upper Mississippi and Ohio-Tennessee Rivers Basins. And also, the distribution of infrastructure is independent of the amount of traffic that moves through the system; navigation along the Lower Mississippi River, which has the highest volume of traffic, requires no locks or dams.

Therefore, the overall transportation score for the watershed is calculated as the average of the overall transportation scores for each basin, except the Missouri River Basin which is not scored, weighted by the annual average tonnage moved in each basin. Note that the annual average tonnage moved in a basin is different that the tonnage recorded moving through the locks, which is used to calculate the watershed scores for lock delays.

Lock Delays

The index for Lock Delays compares the average amount of time that locks in a basin were unavailable from 2015–2019 with the middle 90% the historical range from 2000–2014. Delay times for individual locks are weighted by the amount of traffic passing through the lock in scoring the indicator for the entire basin.

Data source

Summary data reported by the US Army Corps of Engineers (USACE) on the use and performance of navigation locks includes the amount of time each lock was unavailable and the amount of cargo passing through each lock measured in tons.

*Data accessed 08/2020 from US Army Corps of Engineers Lock Performance Monitoring System (LPMS)

Calculation Method and Scoring

For each basin, we calculated the average total time each lock was unavailable from all causes, weighted by the total tonnage that moved through the lock in a year. The tonnage-weighted average time unavailable was computed for each lock between 2000–2019. For each basin, we calculated the five-year average of total time each lock was unavailable from all causes from 2015–2019 weighted by the total annual tonnage that moved through the lock. To calculate the range, we used the middle 90% of data to capture the range of the historical data (2000–2014).

Range = 95th percentile–5th Percentile
The basin score is Score = 1 - ((5yrAvg – 5th Percentile)/Range)*100

The score for the Mississippi River Watershed is the average of the basin scores weighted by the five-year annual average tonnage moved in each basin.

Table 4.1.1: Results for each basin and overall Mississippi River Watershed. Score for the overall watershed is a weighted average based on the annual average of tons of cargo moved in the basin.

Sub-basin	Score	Letter grade	Weighting Factor
Upper Mississippi	68	B	32%
Ohio-Tennessee	50	C	34%
Lower Mississippi	0	F	9%
Arkansas-Red	88	A	25%
Mississippi River	**61**	**B-**	**100%**

Infrastructure Condition

The Infrastructure Condition indicator scores a lock's "Design Life" or "Useful Life". Locks are primarily designed to last 50 years, but when a major renovation or rehabilitation is performed, an additional 25 years is added to its Useful Life.

Data source

Compared to the 2015 Report Card, an updated locks list was used for each basin in the 2020 Report Card. Information on the dates each of the locks were opened were provided by the USACE (Justin R Carlson, CIV, USARMY CELRH via Deb Calhoun, Waterways Council). Information on major renovations and rehabilitations were provided by Marty Hettel based on IWTF funded projects. Supplemental web searches from August to September 2020 (primarily USACE website) were conducted to get additional information on major lock renovations and rehabilitations.

Calculation Method and Scoring

Scoring of Infrastructure Condition is based on a lock's "Design Life" or "Useful Life". Locks are primarily designed to last 50 years, but when a major renovation or rehabilitation is performed, an additional 25 years is added to its Useful Life. A lock that is within its original 50 years of Design Life is given a score of 1, if a lock is over 50 years but after renovation is still within its additional 25 years of Useful Life, a score of 0.5 is given. A score of 0 is given if it's well beyond both its Useful and Design Life.

The age for the individual locks is then weighted by the amount of traffic passing through the lock in 2019 in scoring the indicator for the entire basin.

Table 4.2.1: Results for each basin and overall Mississippi River Watershed. Score for the overall watershed is weighted based on 2019 tonnage of cargo moved in the basin.

Sub-basin	Score	Letter grade	Weighting Factor
Upper Mississippi	42	C-	33%
Ohio-Tennessee	62	B-	58%
Lower Mississippi	43	C-	4%
Arkansas-Red	32	D	6%
Mississippi River	**53**	**C**	**100%**

Infrastructure Maintenance

The adequacy of maintenance for navigation infrastructure evaluates the adequacy of funding for operations and maintenance against the goals: (1) funding is provided at the level needed to maintain the current infrastructure in working order, and (2) continued funding is assured, so that maintenance can be efficiently scheduled and performed.

Data source

To evaluate the level and sustainability of infrastructure maintenance funding, we reviewed the annual allocations to the Inland Waterways Trust Fund, which is the principal source of funds for construction to rehabilitate aging infrastructure at locks and dams. The Inland Waterways Trust Fund is a good indication of maintenance security for much of the Mississippi River Watershed waterborne transportation system, but it has limitations: (1) the Missouri River System does not have locks and dams as part of the transportation system, and (2) the Lower Mississippi River has a limited number of locks that control transport to and from canals that branch out from the main river channel. Most of the waterborne transportation infrastructure in the Lower Mississippi River Basin is reliant on deep draft ports. Deep draft port limitations are largely related to access and maintenance of the depth of channels via dredging operations.

We reviewed the long-term trends in allocation to both the USACE Inland Waterways Trust Fund, which funds lock and dam construction and major rehabilitations, and the 2015–2020 USACE Mississippi Valley Operations and Maintenance Budget, which funds dredging operations (Sean Duffy, Big River Coalition, personal communication).

Calculation Method and Scoring

The adequacy of maintenance for navigation infrastructure is qualitatively evaluated based on weight of evidence and review by the transportation workgroup. Factors that determine the adequacy of maintenance for navigation infrastructure in the Mississippi River Watershed equally affect the inland navigation system for the entire US; the score for this indicator applies to the entire watershed.

Based on increases in funding for both the Inland Waterways Trust Fund and the Mississippi Valley Operations and Maintenance Budget, consensus among the group is that the situation has somewhat improved since the publication of the 2015 Mississippi River Watershed Report Card. Additionally, major construction projects have progressed or completed and others are on schedule for completion. For example, the Olmsted lock and dam complex on the Ohio River replaced two aging lock and dam structures, and represented a major improvement in the overall condition of inland waterways infrastructure.

However, the workgroup also recognized that many more major rehabilitation projects are needed, and continued funding is somewhat unpredictable. Given these realities, the qualitative score for this indicator was determined to be a C-.

Additional Discussion on Transportation Goal

Transportation scores in the 2020 Report Card improved from the 2015 Report Card, partly due to lock delay and infrastructure funding improvements. New methods were developed to reduce the variability of results from year to year, and an updated infrastructure list was used to better reflect the locks, dams, and ports within the river system. However, improvements in the amount of transparency and the sustainability of funding for the river system are still needed. Infrastructure upgrade, regular maintenance, and capacity expansion are urgently needed to accommodate increasing demands on transportation and frequency of emergency situations, such as flooding and natural disasters.

Significant repairs to critical locks are continuing. For example, the construction of the Olmsted Locks and Dam complex in 2018 represented a milestone in upgrading transportation infrastructure on the Ohio River. Numerous additional infrastructure projects are ongoing or are scheduled, particularly on the Upper Mississippi River. Funding of, and expenditures from, the Inland Waterways Trust Fund have also been improving. In addition, funds for the maintenance and operation of the Mississippi River Ship Channel—which are vital to the Lower Mississippi deep draft navigation—have substantially increased since 2015.

Overall, lock delays were reduced in the Mississippi River Watershed over the last five years. An increase in 'scheduled' lock delays was observed, as a result of needed infrastructure construction and repairs; managing these delays is still a major challenge for transporters. While overall trends in this indicator improved, the near-record flooding in 2019 increased lock delays across the watershed. Importantly, the average age of transportation infrastructure along the Mississippi River is far beyond their designed life expectancy of 50 years. While major rehabilitation of these locks can extend their useful life by as much as 25 years, increased maintenance and required system upgrades often result in required, scheduled closures that also increase delays.

Finally, funding for maintaining authorized channel dimensions at deep draft ports in the lower part of the Mississippi River is increasing. Dredge contractors are building new dredges to overcome the limited capacity of the commercial dredging fleet. These ports are vital to US exports and imports, and maintaining access for deep draft shipping is critically important. In 2020, seven draft restrictions (times and locations at which water depth is less than the 47-foot target) were recorded.

Water Supply

Maintain supply of abundant, clean water

People value clean surface and ground water for multiple uses, including domestic uses, recreational, agricultural, and industrial water uses. The term "water supply" relates to a broad range of uses that go beyond direct use of water for drinking and home use. It is critical to improve the capacity of the Mississippi River Watershed to provide water that is of sufficient quality and quantity for this range of uses, and to support the heath of ecosystems and the services they provide.

Indicators

The indicators selected for water supply in the Mississippi River Watershed assess the safety of municipal water supplies and the quantity of surface water available to meet existing demands. The safety of municipal water supplies is evaluated using data on violations by community water treatment systems reported to the EPA. The quantity of surface water available is evaluated using a water stress index developed for this report card.

Water Treatment Violations

This indicator measures drinking water quality and was frequently discussed at the basin workshops and in the expert review team meetings for revising the 2015 Report Card following the October 2014 Summit. Measured and reported violations of water treatment standards are considered to represent unsatisfactory operation of public water supply facilities.

Data source

The data are from the Safe Drinking Water Information System compiled by the EPA and summarized by the state. Government Performance and Results Act (GPRA) of Total water systems 2019 Q1-Q3

*Data accessed 12/2019 from SDWIS/FED drinking water data

2015 Mississippi Basin dasymetric mapping product. (See Appendix III)

Calculation Method and Scoring

This indicator is calculated based on the percent of the population served by community water systems that had no reported violations in 2019. Three categories of violations were counted: maximum contaminant level, maximum residual disinfectant level, and treatment technique violations. A state with 99% or more of its population served by water supply systems without any of these violations was considered an "A" score and a state with 96% or less of its population served by water treatment facilities without treatment violations was considered failing. Basin scores are weighted averages of state scores based on percent of total basin population served by community water systems in each state. The overall Mississippi River Watershed score is an average of basin scores weighted by a basin's percentage of total watershed population served.

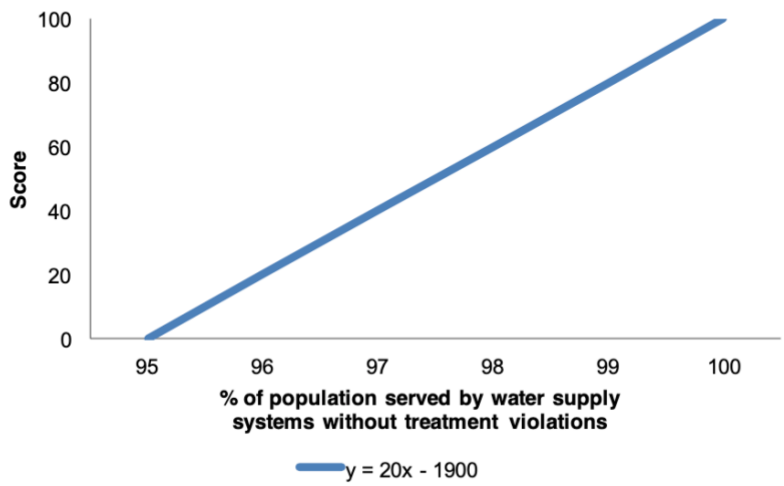

Figure 5.1.1: Scoring method for calculating scores for each state based on the percentage of population served by water supplies without treatment violations.

Table 5.1.1: Results for each state and overall Mississippi River Watershed. Score for the overall watershed score is a weighted average based on the population of each basin served by a community water system.

Water Supply Score—Population % Without health-based violations				
Sub-basin	**Score**	**Letter grade**	**CWS Pop %**	**CWS Pop**
Upper Mississippi	61	B-	27%	21,808,968
Ohio-Tennessee	40	C-	34%	27,715,901
Lower Mississippi	12	F	10%	8,382,561
Arkansas-Red	9	F	13%	10,411,044
Missouri	35	D+	16%	12,736,594
Mississippi River	**38**	**D+**	**100%**	**81,055,068**

Water Depletion

This indicator compares the available amount of surface water in a region with the net amount of water used by people. This indicator was developed based on discussions at the 2015 basin workshops and in subsequent revision meetings with sector experts. It assesses the degree to which the availability of water is limited relative to existing demand.

The scores for this indicator are based on a water depletion index, which measures the degree to which net water use depletes the amount of available surface water. Net water use is the amount of water consumed by people, and it is calculated as the difference between total water withdrawals from rivers, streams and lakes, and the total amount discharged back into surface water bodies. Available surface water is the amount provided by precipitation and stream flow minus losses from natural evaporation; evaporation lost from irrigated agriculture is counted as part of the net water use.

The depletion index is calculated as the ratio of net water use by people in a region and the total amount of water naturally available. Values of the depletion index vary between zero and one. Values close to one indicate very dry conditions in which people are using very nearly all available surface water. The depletion index approach to evaluating regional water scarcity was developed by Brian Richter, Director of Freshwater Strategies and Emily Powell, Global Water Analyst, in The Nature Conservancy's Global Freshwater program, who assisted us in this application.

Data Source

The depletion index is calculated using water fluxes compiled by the US Forest Service Water Supply Stress Index (WaSSI) model (Appendix IV). The WaSSI model calculates land-surface hydrology and ecosystem productivity based on historical climate data for the period 1960–2015. Consumptive use of water is estimated based on data on consumptive use (1995) and water withdrawals and return flows (2005) compiled by the US Geological Survey (USGS).

Water budget calculations are performed on the HUC8-level drainage units. The HUC8 regions are defined by a system for classifying river systems developed by the US Geologic Survey. The Mississippi River Basin contains 847 of the 2200 HUC8 units defined for the contiguous 48 states of the US. These are distributed within the Mississippi River Watershed as follows: 152 in the Ohio-Tennessee Rivers Basin, 131 in the Upper Mississippi River Basin, 82 in the Lower Mississippi River Basin, 173 in the Arkansas-Red Rivers Basin, and 309 in the Missouri River Basin.

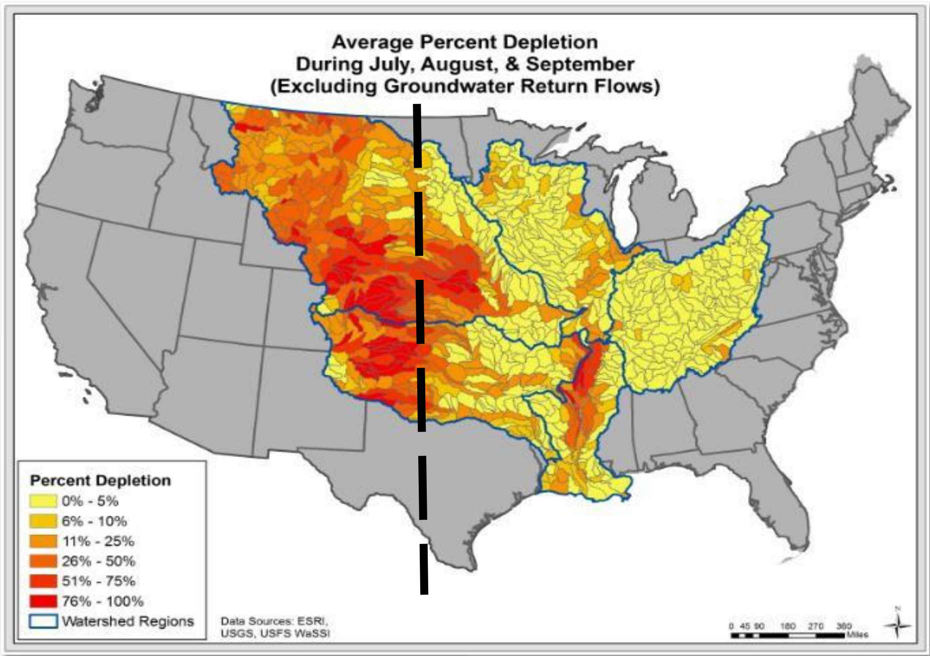

Figure 5.2.1: Values of the water depletion index used to score the Water Depletion indicator. High values indicate areas where human activities consume water at nearly the rate that supplies are renewed. The dashed line is the 100th meridian, which marks the transition between low precipitation to the west and wetter conditions in the east.

Calculation Method and Scoring

The water depletion in each HUC8 unit is scored based on the average depletion index, calculated by the WaSSI model, for the months July, August, and September (JAS-average). Water depletion is scored on a scale 0–100 by comparing the JAS-average depletion index in each HUC8 region to the JAS-average depletion index for all HUC8 units in the contiguous 48 states of the US. Scores are assigned based on the percentile rank of each HUC8 unit in the distribution of all HUC8 units, and ranks are assigned so that high values of the depletion index, indicating dry conditions, receive low scores.

Using the JAS-average values of the depletion index accounts for seasonal changes in water supply and water use. Conditions during the low-flow time period of July, August, and September are the most pressing for evaluating water scarcity. Annual-averaged values of the depletion index would not accurately provide information about water scarcity in a low supply month. In the water budget calculations using the WaSSI model, it is assumed that water supply in excess of demand during high flow months does not provide any benefit in the months when supply does not meet demand.

Scores for each basin in the Mississippi River Watershed are calculated as the average of the scores for the HUC8 units weighted by the unit area. The score for the Mississippi River Watershed is calculated as the average of basin scores weighted by the basin’s percentage of the total watershed population. Therefore, the average for the Mississippi River Watershed provides a measure of water availability conditioned by where people live, by giving weight to the water-rich, smaller but more densely populated Upper Mississippi River Basin and Ohio-Tennessee Rivers Basin over the dry Missouri River Basin, which accounts for over 40% of the area in the watershed.

Table 5.2.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is a population-weighted average of basin scores.

	Water Depletion (WaSSI)		
Sub-basin	**Score**	**Letter grade**	**Basin Pop%**
Ohio-Tennessee	67	B	35%
Upper Mississippi	67	B	29%
Lower Mississippi	54	C	9%
Missouri River	54	C	15%
Arkansas-Red	64	B-	12%
Mississippi River	**64**	**B-**	**100%**

Additional Discussion on Water Supply Goal

People and communities throughout the watershed value clean, abundant water for many uses, including drinking water, supplies for farms and industry, recreation, and natural systems. The issues related to water quality and supply are complex, often controversial, and vary among the different basins and regions of the watershed. Demand for surface and groundwater is growing as populations increase and more water is needed to grow crops and support industry. These growing demands combine with an aging water treatment and supply infrastructure to put unprecedented pressure on water resources. In the future, there must be an integrated management approach that assures that water supplies support society’s needs and opportunities in a balanced manner throughout the watershed.

The Mississippi River Watershed provides water for many purposes, including drinking water for millions of people, wildlife, irrigation for agriculture, industrial uses, recreation, and transportation. But these critical resources are threatened. For example, drinking water supplies are frequently affected by high nitrogen concentrations. Additionally, groundwater from deep aquifers is being extracted much faster than it is refilled. Current withdrawal rates for the Ogallala Aquifer—a significant source of irrigation water in the corn belt—will eventually completely deplete it. AWI calls for a detailed research agenda to evaluate the timing and impacts of aquifer depletion in the watershed.

Challenges

Basic data needed for the management and protection of water supplies in the Mississippi River Watershed are missing or inaccurate. The EPA and the states are required to compile and report this information under the Clean Water Act. Many of the experts we consulted recommended these data as the basis for an indicator related to the water supply goal. However, over the course of this project and in discussions with USEPA, it was determined that the information compiled to evaluate water quality in states and in the Mississippi River Watershed is not adequate and because of this could lead to erroneous conclusions.

Problems with data collection and reporting under the Clean Water Act are long-standing and have been the subject of investigations by the GAO[1] and the National Research Council.[2] Problems with the designated used data, i.e., the 303(d) list, arise from disparities among the states in determining a water body's designated use, the criteria for each use, and the methodology evaluating suitability for these uses. As a result, the information that is compiled is unreliable in the view of the analysts and experts who worked to develop this indicator, including those at the EPA. The administration of the Clean Water Act, which relies on voluntary compliance by the states to a large degree, is complicated by the fact that the Mississippi River and its major tributaries constitute shared, inter-state waters over much of their length. The NRC 2008 report concludes that the problems with monitoring and assessment arise from the EPA's reluctance to assume a strong leadership role, using authorities already available to it in existing legislation. However, the GAO 2012 report calls for Congress to address the issue of limited authority by revising the Clean Water Act.

References:

[1]GAO, 2012. NONPOINT SOURCE WATER POLLUTION: Greater Oversight And Additional Data Needed For Key EPA Water Program. US Government Accounting Office, GAO-12-335. May 2012; and GAO, 2005. Environmental Information: Status of Federal Data Programs That Support Ecological Indicators. US Government Accounting Office, GAO-05-376. September 2005.

[2] NRC, 2008. Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities. Committee on the Mississippi River and the Clean Water Act, Water Science and Technology Board, Division on Earth and Life Studies, National Research Council. National Academies Press, Washington, DC.

Economy

Support local, state, and national economies

Many sectors in local, state, and national economies depend on reliable access to high-quality water in sufficient quantity. Many businesses rely on water supply for operations and production of goods. Water is used in power generation, agricultural irrigation, animal husbandry, and industrial production. The total amount of water available for use is limited, and allocation decisions become increasingly difficult as demand increases and supplies become less reliable. Diminished water quality adds to this difficulty. As water stresses nationally increase, greater pressures will be placed on local water resources, with potentially harmful effects to the economy of the watershed.

Indicators

The indicators selected for economy in the Mississippi River Watershed assess the employment and productivity in river-related sectors of the economy and per capita income for each basin. Information is compiled from national economic statistics summarized by state, and the indicators are scored by state, by comparing with all other states in the country.

River-Dependent Employment

The number of people employed in river dependent sectors (farming, fishing, & forestry; production; transportation and material moving) in each state for 2018 is compared to the average employment in these industries for all states.

Data source

*Data accessed 01/2020 from the Bureau of Labor Statistics

Calculation Method and Scoring

The standard score for river-dependent employment in each state is calculated from the difference between the state total and the average for all US states, standardized by the standard deviation of the state totals (number of standard deviations away from the national average). The formula $y = 20x + 50$ is designed to convert the standard score to a value between 0–100, which then becomes the score for that state. The formula was calculated using -2.5 and 2.5 as the lower and upper bounds, corresponding to scores of 0 and 100, respectively. The state score = y, while the standard score = x.

Basin scores are calculated as the average of the state scores weighted by the population of each state in the basin. The overall score for the Mississippi River Watershed is the average of the basin scores weighted by the total river-related employment in each basin.

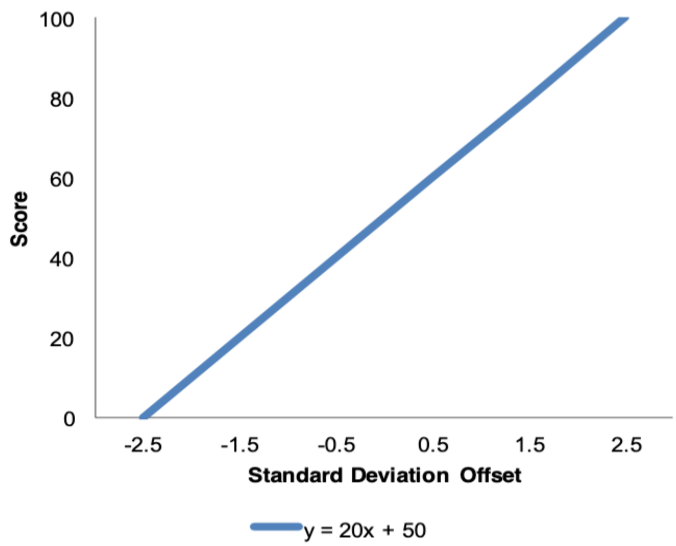

Figure 6.1.1: Scoring method for economy indicators.

Table 6.1.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the total river-related employment in each basin.

	Employment by Sector		
Sub-basin	**Score**	**Letter grade**	**Pop % of whole basin**
Upper Mississippi	65	B	30%
Ohio-Tennessee	66	B	30%
Lower Mississippi	46	C	13%
Arkansas-Red	50	C	17%
Missouri	43	C-	10%
Mississippi River	**58**	**C+**	**100%**

GDP by Sector

This indicator uses data on gross domestic product (GDP) for selected industries in each state for 2018 and is compared to the average GDP in these industries for all US states.

Data source

Gross Domestic Product (GDP) for selected industries in each state for 2018 and is compared to the average GDP in these industries for all US states. The data are from the Bureau of Economic Analysis for the following river-dependent industries:

- Agriculture, forestry, fishing, and hunting
- Arts, entertainment, recreation, accommodation, and food services
- Manufacturing
- Mining
- Transportation and warehousing
- Utilities

*Data accessed 12/2019 from the U.S. Bureau of Economic Analysis

Calculation Method and Scoring

The standard score for GDP in river-related industries for each state is calculated from the difference between the state total and the average for all US states, standardized by the standard deviation of the state totals (number of standard deviations away from the national average). The formula $y = 20x + 50$ is designed to convert the standard score to a value between 0–100, which then becomes the score for that state. The formula was calculated using -2.5 and 2.5 as the lower and upper bounds, corresponding to scores of 0 and 100, respectively. The state score = y, while the standard score = x.

Basin scores are calculated as the sum of the state scores weighted by the population of each state in the basin. The overall score for the Mississippi River Watershed is the sum of the basin scores weighted by the GDP in river-related industries for each basin.

Table 6.2.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the GDP in river-related industries for each basin.

	Economy Scores—Productivity		
Sub-basin	**Score**	**Letter grade**	**% of whole basin**
Upper Mississippi	60	B-	20%
Ohio-Tennessee	57	C+	30%
Lower Mississippi	47	C	11%
Arkansas-Red	47	C	26%
Missouri	43	C-	14%
Mississippi River	**52**	**C**	**100%**

Per Capita Income

The median per capita income (PCI) in each county for 2018 is compared to the median (PCI) for all Mississippi River Watershed counties.

Data source

*Data accessed 10/2019 from the Bureau of Economic Analysis

Calculation Method and Scoring

The standard score for median PCI for each county is calculated from the difference between the county total and the average for all Mississippi River Watershed counties, standardized by the standard deviation of the state totals (number of standard deviations away from the watershed average). The formula y = 20x + 50 is designed to convert the standard score to a value between 0–100, which then becomes the score for that state. The formula was calculated using -2.5 and 2.5 as the lower and upper bounds, corresponding to scores of 0 and 100, respectively. The state score = y, while the standard score = x.

Basin scores are calculated as the average of the county scores weighted by the population of each county in the basin. The score for the Mississippi River Watershed is calculated as the average of basin scores weighted by the basin's percentage of the total watershed population.

Table 6.3.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the population in each basin.

Economy Scores—Per Capita Income			
Sub-basin	**Score**	**Letter grade**	**Pop % of whole basin**
Arkansas-Red	46	C	12%
Lower Mississippi	41	C-	9%
Missouri	60	B-	15%
Ohio-Tennessee	45	C	35%
Upper Mississippi	56	C+	29%
Mississippi River	**50**	**C**	**100%**

Additional Discussion on Economy Goal

The diverse economy of the Mississippi River Watershed continues to drive the national economy and other global economies. Although incomes are not recovering as fast as in some areas of the country after the 2009 global economic downturn, the area has shown signs of resilience. For example, employment has remained relatively high compared to other areas in the US, owing in part to the regions' incredible economic diversity, which includes agriculture, energy, industry, transportation, and recreation, among many other sectors. However, as important as the Mississippi River Watershed is to the national economy, national investment to support the watershed has not kept pace.

Challenges

The challenge is to develop a similarly detailed, up-to-date picture of the role of the Mississippi River in supporting the economies in all five basins. The grades for the overall watershed and the five basins reflect general economic conditions nationwide, only slightly differing among the basins. Additional data is needed to better reflect how local economies directly tie to the management of the Mississippi River Watershed and its rivers. Such data will be included in future report cards. Planning for the efficient use of water among a diversity of stakeholders is critical to sustaining our viable economies.

Indicators considered during the 2015 Report Card development

Several possible indicators were discussed during the regional workshops and during the working group meetings during the 2015 Report Card development. Although the project team was not able to implement these ideas in this version of the report card, they merit consideration for inclusion in a revised, future report card.

- Economic impacts of recreation, water supply, flood control, transportation
- Benefit and value of water to regional economies

Recreation

Provide world-class recreational opportunities

People value access to diverse recreational opportunities including hiking, boating, fishing, etc. People also value the economic benefits of a vibrant tourist economy. Access to recreational areas and other opportunities for outdoor recreation enriches people's lives. Every year in all seasons, millions of people fish, boat, hike, watch birds, and visit cultural sites along the rivers. These activities support a multi-billion-dollar recreational economy that is vital to the communities and businesses that provide related equipment and services.

Indicators

The indicators selected for recreation in the Mississippi River Watershed measure the number of people participating in various recreational activities. Participation is evaluated both directly based on numbers of people engaged in recreational activities and indirectly based on sales of licenses and permits.

Outdoor Participation

The index of hunting, fishing, and birding activity and national park visitation compares the most recent numbers available for numbers of participants in hunting, fishing, and birding (2016, average by state) and visitors to national parks (2016) within each basin with their 20-year historical ranges.

Data source

Participation numbers for fishing, hunting and birding are from the National Survey of Fishing, Hunting, and Wildlife Associated Recreation (FHWAR), which is performed every five years by the US Fish and Wildlife Service and the US Census. The survey tracks participation in fishing, hunting, and other wildlife-associated recreation, such as wildlife observation, photography, and feeding. The numbers of people visiting national parks were obtained from the NPS Visitor Use Statistics website.

- Fishing, hunting, and wildlife associated recreation data from the National Survey of Fishing, Hunting, & Wildlife-Associated Recreation 1996–2016
- National Park Visitation Numbers from 1999–2018
- National Park boundaries extracted from the USGS National Boundary Dataset, retrieved from The National Map Viewer

Calculation Method and Scoring

The participation score in each basin is calculated as the average of the basin participation scores for each category of participation, i.e. hunting, fishing, birding, and national park visitation. The basin scores within categories are calculated from the scores for each state weighted by the population of the basin in each state. Hunting, fishing, and birding participation numbers for each state from the 2016 survey are scored relative to 20-year historical range of data (as a % of that range). The number of visitors to national parks within each basin is compared to the 20-year range (as a % of that range). Park visitation numbers are annually updated.

The score for the Mississippi River Watershed is calculated, first, as the average of the basin participation scores weighted by the percent of the participation for the watershed in each basin for each category. The overall score for the watershed is then calculated as the average of the basin category scores. We take this approach because the relative numbers of people participating in hunting, fishing and birding (taken together) and visiting national parks varies widely between the basins.

Table 7.1.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an area-weighted average of basin scores.

	Fishing, Hunting, and Wildlife Observation		NPS Visitations		FHWAR & NPS Average	FHWAR & NPS Average	Sub-basin FHW Weight	Sub-basin NPS Weight
Sub-basin	Score	Grade	Score	Grade	Score	Grade		
Ohio-Tennessee	62	B-	46	C	54	C	41%	45%
Upper Mississippi	46	C	48	C	47	C	34%	7%
Lower Mississippi	46	C	57	C+	52	C	3%	13%
Missouri River	13	F	94	A	53	C	17%	26%
Arkansas-Red	34	D	72	B	53	C	5%	9%
Mississippi River	**46**	**C**	**62**	**B-**	**54**	**C**	**100%**	**100%**

Hunting and Fishing Licenses

The index of sales of licenses, tags, stamps, and permits for hunting and fishing compares the three-year (2016–2018) average hunting and fishing license sales with the 20-year historical range of the license sales.

Data source

Numbers of sales of licenses and permits are from the National Hunting License Report and National Fishing License Report. *Data for the years 1999–2018 retrieved from the FWS portal on 11/2019*

Calculation Method and Scoring

The three-year (2016–2018) average of sales of tags, permits, and licenses is compared with 20-year range (as a percent of that range). Basin scores are calculated as the average of the state-level scores weighted by the percent of the basin's license/permit holders in each state. The score for the Mississippi River Watershed is the average of the basin scores weighted by the basin percentage of the total watershed license and permit sales.

Table 7.2.1: Scoring results for each basin and the Mississippi River Watershed. The watershed score is an average of basin scores weighted by the combined hunting and fishing license sales in each basin.

	Hunting and Fishing Licenses		
Sub-basin	**Score**	**Grade**	**Sub-basin Weight**
Ohio-Tennessee	37	D+	25%
Upper Mississippi	66	B	32%
Lower Mississippi	77	B+	10%
Missouri River	75	B+	23%
Arkansas-Red	67	B	10%
Mississippi River	**62**	**B-**	**100%**

Additional Discussion on Recreation Goal

Recreation is a major economic driver for the watershed. In the Upper Mississippi River Basin, for example, outdoor recreational activities are valued at $4 billion per year, supporting 420,000 jobs. Likewise, he Mississippi River Delta, with its unique assemblage of species, is known for fishing and hunting.

Outdoor recreation area use and park visitation have increased dramatically in 2020 as a result of the Covid-19 pandemic; more people are seeking natural open spaces closer to home. This increased public demand and need for additional natural land clearly illustrates the vital role these areas provide in both ecosystem services, and public health and well-being.

But recreational areas and opportunities are under pressure by competing uses and ecological stresses like invasive species. Asian Carp, for example, continue to take over the habitat of other beneficial fish species. To ensure that recreational opportunities continue to improve, continued investment is needed from local, state, and federal sources.

Challenges

The challenge going forward is to develop a more comprehensive understanding of recreational activities that people pursue in the watershed and to identify sources of data to improve our ability to track progress towards the recreation goal. Much more needs to be done to support current and emerging recreational opportunities through effective management of natural resources that support recreation. Additional information is also needed to evaluate some recreational uses such as those enumerated below.

Indicators considered during the 2015 Report Card development

Several possible indicators were discussed during the regional workshops and during the working group meetings following the 2014 Summit. Although the project team was not able to implement these ideas in this version of the report card, they merit consideration for inclusion in a revised, future report card.

***Recreation Water Suitability* -** Feedback from watershed experts attending the 2015 Report Card workshops encouraged inclusion of an indicator measuring the suitability of waters for recreational uses in the watershed, based on data submitted to the U.S. Environmental Protection Agency (EPA) by the state governments under section 305(b) of the Clean Water Act. However, as the data was gathered and analyzed, it became clear that it was inconsistent among the states, currently making it impossible to compile accurate information for the entire watershed. (see discussion of the Water Supply indicators)

***Access* -** This indicator has been repeatedly suggested as a potential measure of recreation, and we are researching ways to access and interpret these data. Issues include the consistency of local, state, and federal sources of data and the relatively slow change in this indicator over time.

Boating use - We could not find a source for consistent data across all basins related to boating use.

State parks and other facilities use - We could not find a source for consistent data across all basins related to the use of state parks and other recreational facilities.

Economic value of recreation - We could not find a source for consistent data across all basins related to the value of recreation to the regional economies.

Gulf Coast Indicators

The influence of the Mississippi River's outflow extends over a large area of the coast along the northern Gulf of Mexico, and the influence of the river's plume has been detected in ocean water as far away as south Florida. The area directly affected by the river includes the Louisiana coastal zone, which contains the Mississippi's deltaic region and wetlands of the Chenier Plain that are influenced by the river, and shallow waters of the Gulf of Mexico along the coasts of Louisiana and eastern Texas. Communities and ecological resources in this area are linked to the integrated functioning of the Mississippi River Watershed through fluxes of freshwater, sediment, and nutrients carried by the river. The Gulf Coast indicators assess conditions that are directly linked to the river and the watershed, and that affect the sustainability of communities and ecosystems of the Louisiana coast.

Indicators

The Gulf Coast indicators measure the health of the wetlands in the Mississippi River's deltaic region and the extent of low-oxygen water, also known as the "dead zone," that appears each summer in the Gulf of Mexico along the Louisiana coast. The wetland indicator measures the change in wetland area, which is the net result of the dynamic deltaic processes of accretion of new land and the loss of existing wetlands due to subsidence and erosion. The Gulf of Mexico "Dead Zone" indicator compares the annual extent of low-oxygen water along the Louisiana coast with the target set by the Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force. Both phenomena are the direct result of processes occurring across the entire Mississippi River Watershed. Wetland accretion and loss in the delta depends on the availability of sediment delivered to the coast from the watershed, and the extent of the dead zone depends on the amount of nutrients delivered to coastal marine waters in the river's plume.

Coastal Wetland Change

This indicator measures the net rate of wetland loss in coastal Louisiana, which includes the deltaic region of the Mississippi River and wetlands of the Chenier Plain that depend on water and sediment discharged by the river. The area of wetlands in coastal Louisiana has declined consistently since the 1930s. A net-loss rate of zero (no net loss, but no recovery) would earn a C grade. Wetland area must show a net gain in wetland area to score higher than a C grade.

Data source

The score is calculated based on the net rate of wetland loss averaged since the last analysis in the 2015 Report Card (2013–2016) compared to historical loss rates. Rates of land loss and gain are determined from detailed analysis of aerial images by the US Geological Survey. The estimated rates of change apply the concept of persistent land loss or gain to account for the confounding effect of fluctuating water levels in delineating the area of land.

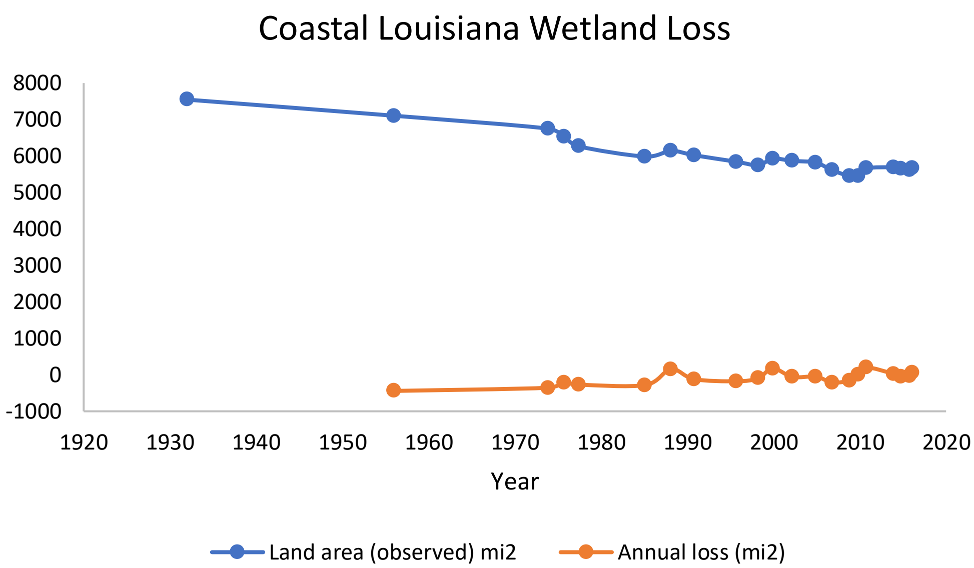

Figure 8.1.1: Rates of historical wetlands loss, wetlands gain, and net-loss rate based on data from Couvillion et al. (2017)*

** Based on Table 1 in Couvillion, Beck, Schoolmaster, and Fischer, 2017. Land area change in coastal Louisiana from 1932 to 2016: U.S. Geological Survey Scientific Investigations Map 3381. [online: https://pubs.usgs.gov/sim/3381/sim3381_pamphlet.pdf]. Accessed October 14, 2020*

Calculation Method and Scoring

The indicator score is calculated from the net rate of loss and the cumulative wetlands loss since the 1930's. The net rate of loss is expressed as a negative number in square miles per year, based on the highest estimated rate of loss from 1973–1985 (~35 sq miles/year, the poorest score) and a no-net-loss rate of 0, which would represent a C grade.
Net-loss scores are calculated based on the following formula:

if loss < 0, score = 1.41 * rate + 50
if loss >= 0, score = 10 * rate + 50

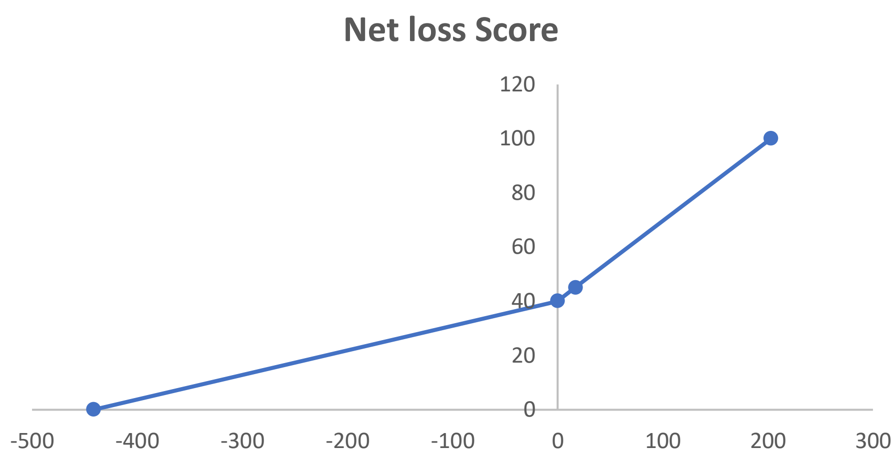

Figure 8.1.2: Relationship between net-loss rate and the report card score.

Net loss from 2013–2016 was approximately 17 square miles, which creates a score of 45.

Cumulative loss is expressed as a percentage of the historical loss, where 100% of the historical loss represents a 0 (poorest score), and half of the historical loss (meaning that approximately ½ of the wetlands had been recovered) would represent a 100 (highest score). Cumulative loss from 1932–2016 was 1887 km^2, creating a score of 7. Combining these scores creates a Coastal Wetland Score of 26, a D.

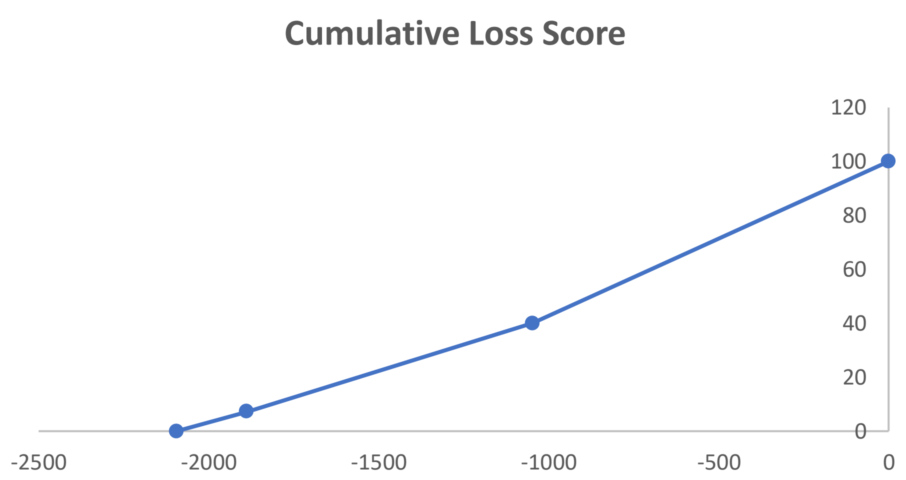

Figure 8.1.3: Relationship between cumulative loss and the report card score.

Table 8.1.2: Scoring result for the watershed-wide Coastal Wetland Change indicator.

Coastal Wetland Change		
	Score	Letter grade
Mississippi River Watershed	26	D

Gulf of Mexico "Dead Zone"

This indicator assesses the impact of excess nutrients discharged from the Mississippi River Watershed on the coastal marine ecosystem in the northern Gulf of Mexico. Scoring is based on the annual maximum extent of the plume of low oxygen (hypoxic) water in the bottom waters of the northern Gulf, also called the "dead zone." The size of the area of low oxygen water reflects the amount of nutrients delivered to the Gulf by the Mississippi River in the preceding year.

Data source

The Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force tracks and reports the annual hypoxia area. The annual extent of the dead zone is defined as the area with dissolved oxygen less than 2.0 mg/l based on a mid-summer survey. The task force has set a remediation goal of 5,000 km^2 for the hypoxic area, based on a running five-year average to account for inter-annual variability.

*Data accessed October 14, 2020

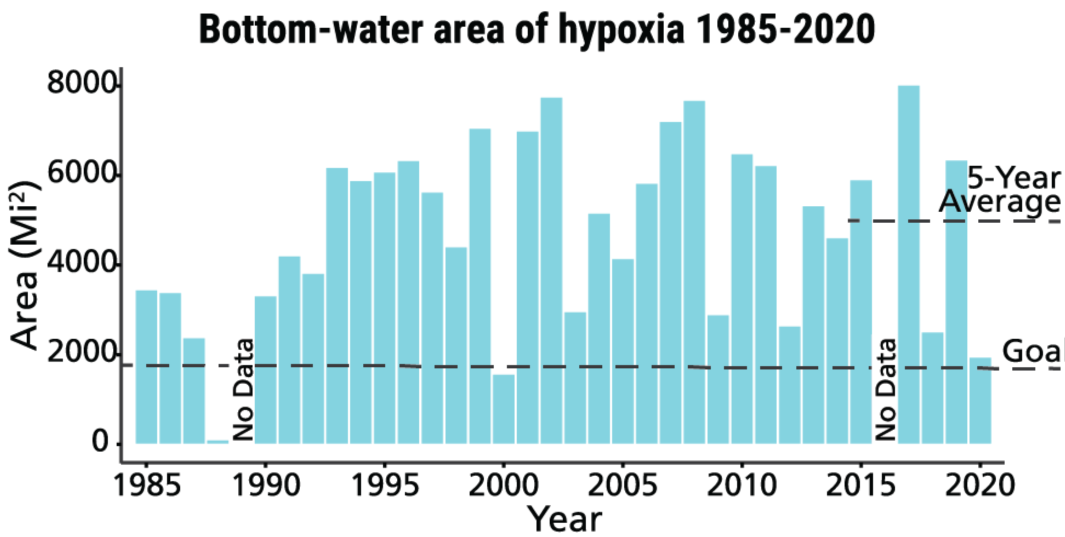

Figure 8.2.1: Annual extent of Gulf of Mexico "Dead Zone" and restoration goal set by the Hypoxia Task Force. LSU/LUMCON 2020.

Available: https://gulfhypoxia.net/research/shelfwide-cruise/?y=2020&p=press_release. Accessed October 14, 2020

The indicator score is calculated from the five-year average of Gulf of Mexico hypoxic zone area from 2015–2020. Scoring is based on a set of thresholds recommended by the expert panel for the 2015 Mississippi River Watershed Report Card:

< 1,000 km^2 = A
< 5,000 km^2 = B
< 10,000 km^2 = C
< 15,000 km^2 = D
> 15,000 km^2 = F

The 2015–2020 average dead zone area was 14,000 square kilometers, nearly three times higher than the target of 5,000 square kilometers, which earns a score of 24 and a D- grade.

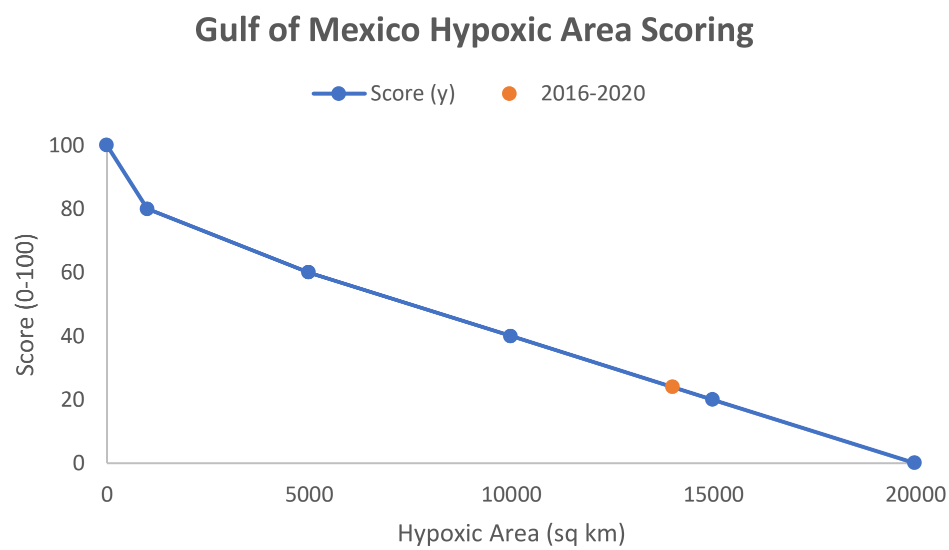

Figure 8.2.2: Scoring method for the Gulf of Mexico "Dead Zone" Indicator.

Table 8.2.1: Scoring result for the watershed-wide Gulf of Mexico "Dead Zone" Indicator.

Gulf of Mexico "Dead Zone"	Score	Letter grade
Mississippi River Watershed	**24**	**D-**

Additional Discussion on Gulf Coast Indicators

The Mississippi River and its tributaries drain 41 percent of the continental United States; the river system has 12,000 miles of navigable channel with depths of 9 feet or more and annually transits 600 million tons of cargo. The cost effectiveness of marine transportation of the Mississippi River system and the vast acreage available for agricultural production provides the US an economic advantage in food exports not found anywhere else in the world. By any standard of measurement, the Mississippi River and Tributaries Project (MR&T) has been enormously successful from both navigation and flood risk management objectives.

The development of the US to superpower status was made possible by the expansion of grain production in the Midwest following the development of reliable navigation and flood control on the Lower Mississippi River. This was made possible by the MR&T planned and executed by the U.S. Army Corps of Engineers at the direction of the United States Congress. The flood of 1927 inundated 16.8 million acres in the Mississippi River Watershed and killed at least 250 people. The record flood of 2011, that thankfully did not take any lives, inundated 6.35 million acres, many of which were designed to be flooded during major flood events as a part of the MR&T and its Room for the River approach to flood damage reduction.

However, these great economic benefits have come at the expense of sacrificing the function and sustainability of the deltaic landscape that comprises coastal Louisiana. Historic annual overflows and typical natural riverine functioning of the Mississippi River resulted in the robust system of coastal wetlands that is coastal Louisiana. Our attempt to manage the river for navigation and flood control purposes has resulted in the devastating land-loss crisis that characterizes the coast of Louisiana today.

The 19th-century proponents of what would evolve into the MR&T project anticipated the consequences for the sustainability and ecological functioning in the deltaic region due to the changes that they were making at the time. As reported in an 1897 article in National Geographic magazine, proponents argued that the near-term economic benefit would greatly outweigh the damages to coastal Louisiana. And, since the devastating impacts would occur two to three generations after the project would be implemented, there would be time to address and/or avoid the inevitable damages to the coast.

Sediments Sustain Coastal Wetlands

Inputs of sediment allow existing coastal wetlands to maintain elevation relative to sea level rise and create new wetland areas to balance losses from erosion. The construction of reservoirs along the Mississippi River and its tributaries during the 20th century has reduced the amount of sediment carried by the river below what it was historically. Channelizing the river and constructing levees to control flooding along the Lower Mississippi River drastically reduces the amount of the remaining sediment that is delivered to coastal wetlands. Currently, most of the sediment carried to the Gulf of Mexico through the Lower Mississippi River is carried out through the river's mouth in the Bird's-foot Delta and deposited in deep water, where it is no longer available to nourish coastal wetlands. This situation is a direct result of engineering the river to maintain high-flow water velocities through the mouth, which reduces the dredging needed to maintain a navigable channel.

The rate at which wetland area is being lost each year has decreased from historically high rates, but the net loss of wetlands continues. The rate at which new wetland area is being added is increasing; wetland area is being added at the outlet of the Atchafalaya River, a distributary of the Mississippi that delivers sediment to shallow, inshore waters. Other efforts to recycle materials dredged from the shipping channel to create wetland areas have also proven successful. If these trends continue, the balance could soon shift to a net increase in wetland area. However, expected increases in the rate of global sea level rise and continuing land subsidence (natural and historic land elevation decline) threaten to increase the rate of loss of wetland area.

Excessive Nutrients Fuel Growth of the "Dead Zone"

Nutrients (primarily nitrogen) from farms, urban areas, and wastewater enter streams and rivers through storm water runoff. Fertilizers that are applied to crops and lawns, and treated and un-treated wastewater are common sources of nitrogen. Nitrogen delivered to estuarine and coastal waters fuels the growth of algae. Oxygen dissolved in the water is depleted when the algae die and decompose, and this creates a large area of low oxygen (hypoxic) water. This area is popularly referred to as a dead zone because the lack of oxygen in the water prevents most animals from living there. The annual extent of hypoxic bottom water reflects the amount of nutrients that enter the Mississippi River and its tributaries and are carried into the Gulf of Mexico. Reducing nutrients in runoff and wastewater on the watershed will reduce the size of the algae bloom and the subsequent area of the dead zone.

Challenges

The challenge today is to implement new river management approaches that preserve and restore this vitally important coastal landscape, while preserving the navigation and flood risk management functions of the MR&T. Three generations have now passed since large-scale engineering of the river began, and the coast of Louisiana is experiencing the greatest ecosystem collapse in modern history. Delivery of needed sediment and freshwater to sustain and rebuild these critical coastal landscapes must be part of the future management of the Mississippi River Watershed.

Indicators considered during the 2015 Report Card development

Several possible indicators were discussed during the regional workshops and during the working group meetings following the 2014 Summit. Although the project team was not able to implement these ideas in this version of the report card, they merit consideration for inclusion in a revised, future report card.

- ***Economic impact of deep draft shipping*** - The issue of the five deep draft ports in the lower Mississippi River (Baton Rouge, New Orleans, South Louisiana, St. Bernard, Plaquemines) which are not covered in the current transportation metrics used in the report card was raised. The barge traffic is being assessed as part of the transportation goal for each of the five basins, but the ocean-going ships—that import and export goods connecting the Mississippi River with the rest of the world—have not been assessed. It is proposed that the value of deep draft shipping be included as an indicator of watershed-wide economic vitality. It appears that two-year increments of tonnage are available and hopefully these tonnages can be converted into economic terms.

- ***Economic impact of coastal commercial fisheries*** - The Louisiana delta serves as a major fishery resource and is second only to Alaska in commercial fisheries landings. The valuation of the commercial fisheries can be obtained from the annually produced NOAA Office of Science and Technology commercial fisheries statistics. Two-year increments are proposed that correspond to the Economic Impact of Deep Draft Shipping indicator.

Additional Discussion on the 2020 Gulf of Mexico Hypoxic Zone

The Gulf of Mexico Hypoxic Zone was smaller than expected in 2020, as a result of Tropical Storm Hannah, which caused the bottom hypoxic water to mix with more oxygenated surface water. The following is an excerpt from the press release for the results of the 2020 sampling cruise (LSU/LUMCON 2020):

> "This summer's Dead Zone size was the third smallest area since mapping began in 1985. The average hypoxic zone size over 2015 to 2020 is 5,407 square miles (14,000 square kilometers) (about three times the size of the Hypoxia Task Force five-year goal reduction of 1,930 square miles (5,000 square kilometers). This size of this summer's Dead Zone is close to the Task Force goal, but not because of a reduction in nitrogen loading, but because of weather conditions.
>
> The LSU forecast on 2020 size (https://gulfhypoxia.net/research/shelfwidecruise/?y=2020&p=hypoxia_fc) included a caveat about tropical storms or other wind and wave disturbances. If storms occur just before or during the cruise, then the predicted size was estimated to be 30% (i.e., reduced to 14,000 square kilometers). Tropical Storm/Hurricane Hanna moved from east to west across the central Gulf of Mexico and crossed the Texas shore as Hurricane Hanna on July 25, which was the beginning of the hypoxia cruise. Storm's high winds and waves affected all coastal Louisiana and disrupted hypoxia by mixing the water column from the surface down to May N load Cruise about 65 feet. The persistent winds from the south generated downwelling favorable conditions pushing what remained of the hypoxic water mass into deeper, offshore waters."

Available: https://gulfhypoxia.net/research/shelfwide-cruise/?y=2020&p=press_release. Accessed October 14, 2020

Renewable Energy

The Mississippi River Watershed provides energy from hydropower (25% of the Nation's hydropower is produced in the Mississippi River Watershed) and renewable sources like wind, solar, and biofuel, and there is capacity for more. Each of these can contribute to a diverse and safe energy portfolio, while providing new jobs and supporting a diverse economy. The Mississippi River Watershed has historically been an important source of renewable energy, particularly hydropower. The Upper Mississippi River was, in fact, the site of the first commercial hydropower operation in the United States.

Indicators considered

Renewable energy was considered as a new indicator category in the 2020 Mississippi River Watershed Report Card, with a focus on hydropower. In particular, capacity factor (CF) was used to assess the efficiency and amount of hydropower generation against the potential of the watershed. Capacity factor measures the amount of energy generated against the amount of energy that a facility could theoretically harness if it constantly operated. Facility operational schedules may be based on stream or river flows reaching required levels, energy demand, and water storage needs, additionally, capacity factors widely vary. Because most US hydropower facilities maintain CF between 0.4 and 0.6, we scored CF against a baseline of 0.4. Capacity factor scores were initially calculated for each basin but a consensus on how to interpret it wasn't reached.

Figure 9.1.1: Potential indicators considered for renewable energy included Human Safety, Water Storage Capacity, Environmental Impact, and the amount of energy generated compared to the amount theoretically achievable from Hydropower.

Conclusion

AWI supports an integrated renewable energy system that addresses environmental concerns using a combination of these and other sources. Many of the indicators that were considered were deemed valuable for assessing the condition of renewable energy in the watershed, but holding stakeholder workshops to thoroughly vet them was not possible. Additionally, data were not easily accessible for several indicators. Moving forward, AWI will continue to develop meaningful ways to evaluate renewable energy in the region; we envision indicators that reflect renewable energy will be included in future report cards.

Natural Infrastructure

Natural Infrastructure was identified after the release of the 2015 Mississippi River Watershed Report Card as an area that would reflect some of the core values of America's Watershed Initiative approach, which is to identify activities that could simultaneously support multiple goals.

Green and Natural Infrastructure are often interchangeably used. They are not universally defined but both address wet weather impacts, reduce and treat stormwater at its source, and could be used to harvest, reuse, store, or reduce the flows/input of stormwater. Green infrastructure mimics natural processes and are often used in urban and developed areas as engineered solutions (green roofs, permeable pavements, rain gardens). Natural infrastructure, on the other hand, uses natural processes and are often used in rural areas as restoration solutions (uses/restores natural resources such as natural floodplains, wetlands, and forests).

For the 2020 Mississippi River Watershed Report Card, the consensus was to focus on Natural Infrastructure, including the beneficial use of dredged materials and restoration projects. We define Natural Infrastructure as referring to restored networks of floodplains, wetlands, and uplands that work together to provide benefits such as flood damage reduction, water storage, and habitat conservation. For example, floodplains can be 'reconnected' to river channels, so that rivers can safely expand beyond their banks as floodwaters rise. Floodplains, natural and restored wetlands, and other natural areas offer numerous benefits, such as providing critical habitat for aquatic and bird species, combatting land loss caused by subsidence and erosion, and reduced nutrient load. Along the coast, wetlands provide critical storm surge protection to vulnerable communities during hurricanes and tropical storms.

Process of establishing a Natural Infrastructure report card indicator

A workgroup was formed to discuss the inclusion of Natural Infrastructure in the 2020 Mississippi River Report Card. The group met on several occasions with the following objectives:

- Achieve consensus on the definition of Natural Infrastructure.
- Align messaging with other activities with regards to Natural Infrastructure, such as the Natural Infrastructure Initiative, which has representatives from Caterpillar, The Nature Conservancy, and other private firms.
- Discuss how an indicator or suite of indicators could be developed for the 2020 Mississippi River Watershed Report Card to reflect progress toward Natural Infrastructure goals.

Key messages from these discussions included:

- Consensus on the definition of Natural Infrastructure (as described above).
- Messaging around Natural Infrastructure should include coastal protection, beneficial use of dredged materials, reconnected floodplains, restored wetlands, etc. The ability of Natural Infrastructure restoration to add resilience and protection should be part of this messaging.

- Potential benefits include coastal protection, water quality improvement, and flood risk reduction in both coastal and inland area habitat.
- Natural Infrastructure projects could be a component of improving conditions by providing these benefits, thus raising the report card grades in several potential categories.
- Potential indicators could include the number of acres restored, reconnected, or improved, but data sources were varied and not centralized. Locating, accessing, and curating the data required to reflect on Natural Infrastructure progress will be challenging. Moreover, targets for this indicator have not been agreed upon, or likely even discussed—how many acres of restored areas is enough to achieve water quality, flood risk reduction, habitat, or coastal protection goals?
- Although, specific targets may not be identified for all areas, the group recognized that large investments in Natural Infrastructure projects will be required to advance natural infrastructure. One estimate is that $10 Billion over 50 years for Natural Infrastructure projects would be needed to achieve targeted water quality reductions in Iowa.
- Natural Infrastructure restoration efforts will have the most impact if they were coordinated at the watershed-wide scale. Current efforts are more independent, often organized at a state or smaller scale.

Conclusions

Natural Infrastructure is a critical component of a restoration and protection strategy for many of the indicator categories in the Mississippi River Report Card, and future report card iterations should work toward including this as a potential indicator. But the creation of a relevant and informative indicator will be difficult. Data are not centralized and interpretation of data regarding restored areas is likely to be difficult. Therefore, additional effort should be developed to locate, access, and analyze the data necessary to create a useful indicator for Natural Infrastructure.

Appendices

Appendix I: Stakeholder Convenings Invited Participants

Adam Schnieders, *Iowa Department of Natural Resources*
Cara Eisel, *Walton Family Foundation*
Chad Berginnis, *Association of State Floodplain Managers*
Charles A MVD Camillo, *Mississippi River Commission and U.S. Army Corps of Engineers*
Charles C Somerville, *Ohio River Basin Alliance (AWI Board of Directors)*
Christy Prouty, *American Society of Civil Engineers*
Colin Wellenkamp, *Mississippi River Cities and Towns Initiative*
Dan Mecklenborg, *Ingram Barge Company* (AWI Board of Directors)
David Ross, *US Environmental Protection Agency*
David Simmons, *Consultant for Viking Cruises (AWI Board of Directors)*
David Wilhelm, *Hecate Energy*
Debra Calhoun, *Waterways Council Inc.*
Delaney McMullen, *Weber Shandwick*
Dru Buntin, *Missouri Department of Natural Resources*
Duke DeLuca, *The Roosevelt Group*
Dustin Boatwright, *The Little River Drainage District*
Edward Belk, *U.S. Army Corps of Engineers*
Ellen Herbert, *Ducks Unlimited*
Frank Morton, *Turn Services LLC (AWI Board of Directors)*
Gretchen Benjamin, *The Nature Conservancy*
Heath Kelsey, *University of Maryland Center for Environmental Science*
Jay Harrod, *The Nature Conservancy*
Jeffrey Graschel, *National Oceanic and Atmospheric Administration*
Jennifer A. Carpenter, *American Waterways*
Joan Freitag, *Hanson Professional Services (AWI Board of Directors)*
John Goodin, *US Environmental Protection Agency*
Katie Flahive, *US Environmental Protection Agency*
Katie May Laumann, University of Maryland Center for Environmental Science
Kirsten Wallace, Upper Mississippi River Basin Association (AWI Board of Directors)
Kris Johnson, *The Nature Conservancy*
Kristin Tracz, *Walton family foundation*
Larry Weber, *University of Iowa (AWI Board of Directors)*
Laura Brown, *The Nature Conservancy*
Maj. General John Peabody (ret), *Mott MacDonald*
Maj. General Michael Walsh (ret.), *U.S. Army Corps of Engineers (former)*
Malcolm Woolf, *National Hydropower Association*

Mark Gaikowski, *U.S. Geological Survey*
Marty Hettel, *American Commercial Barge Lines*
Michael Reuter, *The Nature Conservancy (AWI Board of Directors)*
Paul Rohde, *Waterways Council Inc.*
Rachel Orf, *National Corn Growers Association (AWI Board of Directors)*
Rainy Shorey, *Caterpillar Inc*. (AWI Board of Directors)
Rear Adm. John P Nadeau, *United States Coast Guard*
Rebecca Smith, *Mississippi State University*
Robert Beduhn, *HDR Inc. (AWI Board of Directors)*
Rob Rash, *Mississippi Valley Flood Control Association*
Roger Wolf, *Iowa Soybean Association*
Scott Sigman, *Illinois Soybean Association*
Sean M. Duffy, *Big River Coalition (AWI Board of Directors)*
Stephen Gambrell, *Mississippi Valley Flood Control Association (AWI Board of Directors)*
Steve Buan, *National Oceanic and Atmospheric Administration*
Steve Mathies, *Stantec Consulting Services (AWI Board of Directors)*
Teri Goodmann, *City of Dubuque, Iowa (AWI Board of Directors)*
Tom Wall, *US Environmental Protection Agency*

Appendix II: National Rivers and Streams Assessment

The National Rivers and Streams Assessment 2008–2009: A Collaborative Survey[1] (NRSA) reports the results of a nationwide field study conducted by the U.S. Environmental Protection Agency and its state and tribal partners. The purpose of the study was to assess the condition of river and stream ecosystems on a national and regional scale as a benchmark to document environment change over time. The assessment is based on data collected at 1,924 river and stream sites using standardized methods. Sites were selected using a random sampling technique to ensure that the results reflect the full variety of river and stream types and sizes across the US. Ecological conditions were assessed using a suite of indicators, and the indicators were evaluated based on comparison with conditions at least-disturbed (or reference) sites in different ecological regions.

The 2015 Mississippi River Watershed Report Card used data from the 2008–2009 USEPA National Rivers and Streams Assessment to provide an assessment of Water Quality, Living Resources, and Streamside Habitat indicators. Data from the USEPA 2013–2014 National Rivers and Streams Assessment are not yet available to update these scores for the 2020 Report Card.

For the 2015 Report Card, results for each site are compiled based on sampling a number of transects along a segment of a river or stream. At each site, the NRSA assesses the ecological condition using a set of indicators; conditions associated with each indicator are evaluated as good, fair, or poor relative to conditions at reference sites chosen to represent undisturbed natural conditions. The report card uses a subset of the NRSA indicators to define a set of three indices: Living Resources, Water Quality, and Habitat (Table B.1). We convert the NRSA narrative evaluations into a score for each basin by assigning a value of 100 for good, 50 for fair, and 0 for poor, and computing the average of the results for all NRSA sampling locations in the basin weighted by the length of the stream or river segment sampled.

Scores for the individual indicators obtained for the Mississippi River Watershed are comparable to scores calculated from the NRSA national results, reported for the 48 contiguous states (Table B.1). The largest difference is seen in the scores for the nitrogen indicator. This is unsurprising, given that the watershed's nitrogen discharge is a recognized problem.

[1] EPA, 2013. National Rivers and Streams Assessment 2008–2009: A Collaborative Survey. Draft report EPA/841/D-13/001, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC. February 28, 2013 [*online: http://water.epa.gov/type/rsl/monitoring/riverssurvey/; accessed 19 May 2015*

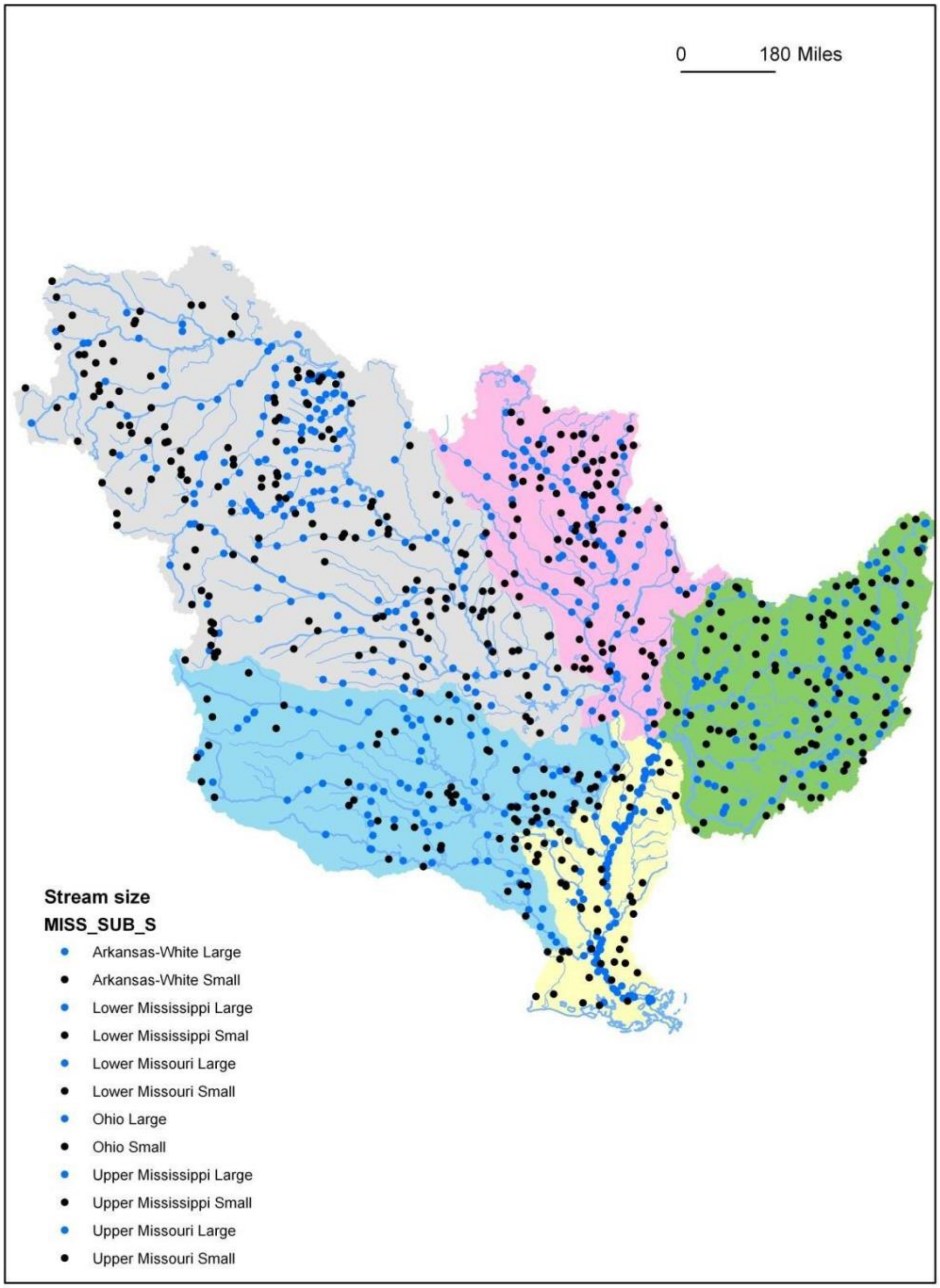

Figure B.1: Locations sampled to evaluate the NRSA indicators

Table B.1: Comparison of AWI scores for the Mississippi River Watershed and for NRSA sites in the 48 contiguous states.

Indicator	Scores	
	AWI Miss. Riv.	EPA National
Living Resources		
Benthic MMI	41	33
Fish MMI	47	51
Water quality		
Nitrogen	39	64
Phosphorus	42	47
Habitat		
Insteam habitat	74	79
Riparian vegetation	61	66
Riparian disturbance	52	57
Streambed stability	71	70

Living Resources Index

The Living Resources Index assesses the condition of aquatic animal communities living in the ecosystem. The index combines the NRSA scores for the Macro-invertebrate Multi-metric Index and the Fish Multi-metric Index. EPA provided synthesized results from 2008–2009 EPA National Rivers and Streams Assessment for each sub-basin, with the percent of stream lengths in good, fair, or poor condition for each index. We calculate a score for each basin by assigning a value of 100 for good, 50 for fair, and 0 for poor, and computing the average of the results for all NRSA sampling locations in the basin weighted by the length of the stream or river segment sampled. The Living Resources Index is computed as the average of the scores for Macro-invertebrate Multi-metric Index and the Fish Multi-metric Index in each basin.

From the NRSA report:

"Scientists developed a Fish MMI using an approach that estimates expected condition at individual sites. Separate indices were developed for each of the three major climatic regions. These indices were based on a variety of metrics including taxa richness, taxonomic composition, pollution tolerance, habitat and feeding groups, spawning habits (specifically, the percent of individuals that deposit eggs on or within the substrate in shallow waters), the number and percent of taxa that are migratory, and the percent of taxa that are native."

From the NRSA report:

"To determine the [Benthic] Macro-invertebrate MMI, ecologists selected six metrics indicative of different aspects of macro-invertebrate community structure:

Taxonomic richness—the number of distinct taxa (family or genus) within different taxonomic groups of organisms, within a sample. A sample with many different families or genera, particularly within those groups that are sensitive to pollution, indicates least-disturbed physical habitat and water quality and an environment that is not stressed.

Taxonomic composition—the proportional abundance of certain taxonomic groups within a sample. Certain taxonomic groups are indicative of either highly disturbed or least-disturbed conditions, so their proportions within a sample serve as good indicators of condition.

Taxonomic diversity—the distribution of the number of taxa and the number of organisms among all the taxa groups. Healthy rivers and streams have many organisms from many different taxa groups; unhealthy streams are often dominated by a high abundance of organisms in a small number of taxa.

Feeding groups—the distribution of macro-invertebrates by the strategies they use to capture and process food from their aquatic environment, such as filtering, scraping, grazing, or predation. As a river or stream degrades from its natural condition, the distribution of animals among the different feeding groups will change, reflecting changes in available food sources.

Habits/habitats—the distribution of macro-invertebrates by how they move and where they live. A stream with a diversity of habitat types will support animals with diverse habits, such as burrowing under streambed sediments, clinging to rocks, swimming, and crawling. Unhealthy systems, such as those laden with silt, will have fewer habitat types and macro-invertebrate taxa with less diverse habits (e.g., will be dominated by burrowers).

Pollution tolerance—the distribution of macro-invertebrates by the specific range of contamination they can tolerate. Highly sensitive taxa, or those with a low tolerance to pollution, are found only in rivers and streams with good water quality. Waters with poor quality will support more pollution-tolerant species.

The specific metrics chosen for each of these characteristics varied among the nine ecoregions used in the analysis."

Water Quality Index

The Water Quality Index assesses nutrient levels in rivers and streams in the watershed. The index combines the NRSA scores for total phosphorous and total nitrogen. EPA provided synthesized results from 2008–2009 EPA National Rivers and Streams Assessment for each sub-basin, with the percent of stream lengths in good, fair, or poor condition for each index. Natural variability in nutrient concentrations is reflected in the regional thresholds set by EPA for high, medium, and low levels, which are based on least-disturbed reference sites for each of the nine NRSA ecoregions. We calculate a score for each basin by assigning a value of 100 for good, 50 for fair, and 0 for poor, and computing the average of the results for all NRSA sampling locations in the basin weighted by the length of the stream or river segment sampled. The Water Quality Index is computed as the average of the total phosphorous and total nitrogen scores in each basin.

Habitat Index

The Habitat Index assesses the condition of stream and river habitat in the ecosystem. The index combines the NRSA scores for the Riparian Vegetative Cover and Riparian Disturbance indices. The EPA provided synthesized results from 2008–2009 EPA National Rivers and Streams Assessment for each sub-basin, with the percent of stream lengths in good, fair, or poor condition for each index. We calculate a score for each basin by assigning a value of 100 for good, 50 for fair, and 0 for poor, and computing the average of the results for all NRSA sampling locations in the basin weighted by the length of the stream or river segment sampled. The Habitat Index is computed as the average of the scores for the four component indices in each basin.

Riparian Vegetative Cover, from the NRSA report:

> ―The NRSA uses a measure of riparian vegetative cover that sums the amount of cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees. Because the amount and complexity of riparian vegetation naturally differs within and among ecoregions, lower-than-expected riparian vegetative cover was assessed by comparison with expected values at least-disturbed sites estimated within ecoregions.

Riparian Disturbance, from the NRSA report:

> ―The NRSA uses a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and their proximity to the river or stream in 22 riparian plots along the waterbody. The same disturbance criteria were applied to define high, medium, and low riparian disturbance in streams and rivers nationwide. For example, a river or stream scored medium if one type of human influence was noted in at least one-third of the riparian plots, and scored high if one or more types of disturbance were observed at all of the plots.

Appendix III. Population Mapping

A Methodology for Spatially Redistributing Discreet Population Data onto High Resolution Continuous Surfaces for the Purpose of Social-Economic Analysis Involving Natural Systems.

The following outlines the data and methods for implementing a Dasymeteric Mapping Model (DMM) for the entirety of the Mississippi River Basin (MRB). We have chosen dasymetric mapping for population density over other methods because of its ability to realistically place data over geography. While other more rigorous methods (co-kriging and regression modeling) have been developed in recent years, the lack of consistent high-resolution, land-use data over large areas prevent these models from being effectively utilized at basin scales. Additionally, the development and processing time of more rigorous models at the MRB scale is not practical given time constraints.

Advantages of the proposed DDM

- The DMM provides a clear improvement of the previous areal weighted methods used in watershed population distributions
- The data requirements can be met across the study area, with the exception of the nominal area of the basin within Canada
- The processing time of the model allows for its use in the relatively short time frame for the project
- The population density predictions are volumetrically constrained by block groups to prevent the predication of more people than the census data provides

Disadvantages of the proposed DDM

- The Land Use data inherently does not discriminate between residential and other urban uses
- Exurban development is under represented in the NLCD products
- Population growth between 2010 and 2015 is not available at the block level

The DDM requires:

- Current population data
    - 2016 American Community Survey Block Groups
- Ancillary Land Use (LU) data
    - 2016 NLCD Continuous Impervious Surface Area (ISA) Data 30m

However, the 2016 ISA data is not classified and the most recent literature research indicates that Residential ISA (RISA) is the best predictor of population density. Therefore, we are proposing a preprocessing step in order to derive the RISA from the 2016 NLCD ISA dataset.

Additional inputs to the DDM model for development of the RISA dataset

- US Census 2010 Zero Population Blocks

- 2016 NLCD ISA Descriptor Dataset

Modeling Residential ISA

To create the RISA that will be the ancillary data layer to the census block group level population data, we will perform the following pre-processing steps:

1. Clip the NLCD 2016 ISA layer to remove all pixels that are classified as 1%
2. Divide the clipped ISA by 100 to create a ratio scale (0–1.0)
    a. See Figure C.1
3. Mask out primary, secondary, and urban tertiary roads using the 2016 NLCD ISA Descriptor data
    a. See Figure C.2
    b. Because the NLCD ISA does not model exurban development well, rural tertiary roads are kept as a proxy for underrepresented rural RISA
4. Mask out zero population census blocks from the 2010 decennial census
    a. See Figure C.3
5. Resulting dataset is the RISA that will be used as the ancillary dataset for mapping the population data in the DMM
    a. See Figure C.4

Population Mapping

The Dasymeteric Mapping Model allocates to each non-zero RISA pixel in a 2015 census Block Group a population density (per 30-meter pixel) value that is the ratio between the Block Group population sum and the Block group RISA sum, weighted by the local RISA for that pixel.

Population Density $$\frac{BGpop_{sum}}{BGrisa_{sum}} RISAlo$$

1. $BGpop_{sum}$ = The 2015 ACS Block Group total population, rasterized at 30 m pixel resolution
    a. See Figure C.5
2. $BGrisa_{sum}$ = The sum of all RISA pixels in the Block Group, rasterized at 30 m pixel resolution
    a. See Figure C.6
3. *RISAloc* = The RISA value of the modeled pixel
    a. See Figure C.4
4. Population Density = the predicted number of people per 30 m pixel
    a. See Figure C.7

Residential Impervious Surface Area (RISA) Example

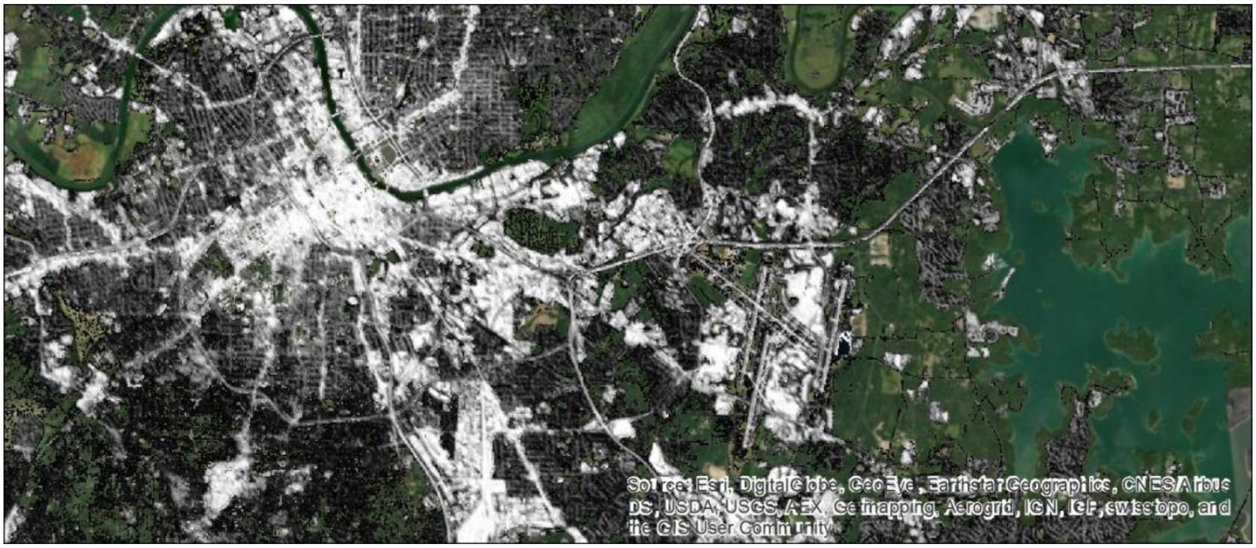

Figure C.1: Nashville, TN with Greater Than 0% NLCD 2016 ISA overlay.

Figure C.2: Nashville, TN with GT 0% NLCD 2016 ISA. Primary, Secondary, and Urban Tertiary roads masked.

Figure C.3: Nashville, TN with GT 0% NLCD 2016 ISA. Primary, Secondary, Urban Tertiary roads, and 2010 0% population Blocks masked.

Figure C.4: Nashville, TN 2016 RISA.

Figure C.5: Nashville, TN 2015 ACS Block Group Population.

Figure C.6: Nashville, TN 2015 Block Group RISA sum.

Figure C.7: Nashville, TN 2015 Population Density/30m pixel.

Appendix IV. Water Stress Index Model

The model calculates monthly outflow from each HUC8 basin based on the balance of inputs, withdrawals, and changes in storage as snow pack and soil moisture. Calculation of the depletion index requires two model runs; one in which water withdrawals for human use are set to zero to calculate the set of natural outflows, and a run including water withdrawals and return flows to calculate the set of depleted outflows. The depletion index is calculated in each HUC8 basin for each month using the formula: 1 - (depleted flow/natural flow).

Calculations with the WaSSI model do not fully take into account the effects of groundwater withdrawals and the operation of reservoirs to capture and store water. These activities provide water for human use at times and locations where precipitation is low. As a result, the depletion index is not an indicator of the availability of water to supply human use. However, water available from reservoirs and groundwater, to a large extent, are not inexhaustible new sources of water; they merely store water that must be recharged from precipitation. Therefore, the depletion index reflects the match between human water use and the renewable supply of water from precipitation.

To partially compensate for the lack of reservoir storage in the water budget calculations, we base the water shortage score on a three-month average of the depletion index. We use the average for the summer months of July, August, and September, because generally this is the time of year when human consumptive use is highest and surface water supplies are lowest.