



Northern Great Plains Network Water Quality Monitoring Design for Tributaries to the Missouri National Recreational River

Natural Resource Technical Report NPS/NGPN/NRTR—2013/783



ON THE COVER

The Missouri National Recreational River

Photograph by John Macy, National Park Service

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Natural Resource Technical Report NPS/NGPN/NRTR—2013/783

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July 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Rowe, B. L., S. K. Wilson, L. Yager, and M. H. Wilson. 2013. Northern Great Plains Network water quality monitoring design for tributaries to the Missouri National Recreational River. Natural Resource Technical Report NPS/NGPN/NRTR—2013/783. National Park Service, Fort Collins, Colorado.

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Abstract/Executive Summary

The National Park Service (NPS) organized more than 270 parks with important natural resources into 32 ecoregional networks to conduct Inventory and Monitoring (I&M) activities for assessment of natural resources within park units. The Missouri National Recreational River (NRR) is among the 13 parks in the NPS Northern Great Plain Network (NGPN). Park managers and NGPN staff identified surface water resources as a high priority vital sign to monitor in park units. The objectives for the Missouri NRR water quality sampling design are to (1) assess the current status and long-term trends of select water quality parameters; and (2) document trends in streamflow at high-priority stream systems. Due to the large size of the Missouri River main stem, the NGPN water quality design for the Missouri NRR focuses on wadeable tributaries within the park unit. To correlate with the NGPN water quality protocols, monitoring of the Missouri NRR consists of measurement of field core parameters including dissolved oxygen, pH, specific conductance, and temperature; and streamflow. The purpose of this document is to discuss factors examined for selection of water quality monitoring on segments of the Missouri River tributaries within the Missouri NRR.

Awareness of the complex history of the Missouri NRR aids in the current understanding and direction for designing a monitoring plan. Historical and current monitoring data from agencies and entities were examined to assess potential NGPN monitoring sites. In addition, the U.S. Environmental Protection Agency 303(d) list was examined for the impaired segments on tributaries to the Missouri River main stem. Because major tributaries integrate water quality effects from complex combinations of land use and environmental settings within contributing areas, a 20-mile buffer of the Missouri NRR was used to establish environmental settings that may impact the water quality of tributaries that feed the Missouri River main stem. For selection of monitoring sites, anthropogenic and natural influences to water quality were assessed for Missouri NRR tributaries. Factors that were examined include the size and contributions of tributaries within watersheds to the main stem; population density; and land use such as urban development and agricultural practices including concentrated animal feeding operations. Based on examination of these data in addition to the park's legislation and management considerations, two sites were selected for monitoring water quality on Missouri NRR tributaries for the ice-free season (mid-May to mid-October) on a rotational basis every third year. Bow Creek at St. James was selected for water quality monitoring based on lack of long-term water quality monitoring, current recreational use, and proximity of the tributary to intense agricultural practices. In addition, land within the Bow Creek watershed is owned by the NPS. The Niobrara River at Verdel was selected for monitoring due to high use for public recreational activities, adjacent agricultural land use, and documented impairments for designated beneficial uses. Both sites will have access to real-time streamgages that will aid in a greater understanding of water quality.

Acknowledgments

This water quality monitoring plan represents a cooperative effort among natural resource managers and staff of the National Park Service Missouri National Recreational River and the Northern Great Plains Network in addition to personnel from the U.S. Geological Survey Water Science Centers. We appreciate the professional direction and guidance that were generously shared by other NPS Networks. We commend field personnel, who completed pilot studies to generate an increased understanding to aid in the Missouri NRR water quality monitoring design. We appreciate the guidance and data compilation provided by individuals from State agencies including Shannon Minerich, South Dakota Department of Environment and Natural Resources, and Dave Ihrle, Nebraska Department of Environmental Quality. In addition, we appreciate input from management and staff of the Missouri River Institute, the James River Water Development District, and the Spencer Hydropower Dam.

List of Acronyms

CAFO	Concentrated Animal Feeding Operation
DO	dissolved oxygen
<i>E. coli</i>	<i>Escherichia coli</i>
FIB	fecal indicator bacteria
FY	fiscal year
HUC	hydrologic unit code
I&M	Inventory and Monitoring
MNRR	Missouri National Recreational River
NE DEQ	Nebraska Department of Environmental Quality
NGPN	Northern Great Plains Network
NPS	National Park Service
NRR	National Recreational River
NWIS	National Water Information System (U.S. Geological Survey)
QA/QC	Quality Assurance/Quality Control
SC	specific conductivity
SD DENR	South Dakota Department of Environment and Natural Resources
SOP	standard operating procedure
STORET	STORage and RETrieval (National Park Service database)
T	temperature
TMDL	Total Maximum Daily Load
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VTSS	volatile total suspended solids
WQ	water quality

Introduction and Background

The National Park Service (NPS) organized more than 270 parks with important natural resources into 32 ecoregional networks to conduct expanded inventory and monitoring (I&M) activities for assessment of natural resources within park units. The Missouri National Recreational River (Missouri NRR) is among a diverse group of 13 parks that comprise the NPS Northern Great Plains Network (NGPN) I&M Program (Gitzen et al. 2010). The Missouri River is the longest river in the United States and drains nearly one-sixth of the Nation's area that extends from the Rocky Mountains east to the Great Plains (U.S. Geological Survey 2009). The Missouri NRR comprises two free flowing reaches of the Missouri River that are located on the Nebraska–South Dakota border. The park unit is separated by Lewis and Clark Lake that is located within the central part of the park unit and is impounded by Gavins Point Dam (Figure 1). The 59-Mile District in the eastern part starts immediately downriver from Gavins Point Dam and extends to Ponca, Nebraska. The 39-Mile District in the western part starts at Fort Randall Dam and extends downriver to Running Water, South Dakota (Figure 1). The lower 20 miles of the Niobrara River and the lower 8 miles of Verdigre Creek also are designated as recreational rivers, and all segments collectively are known as the Missouri NRR (National Park Service 1997).

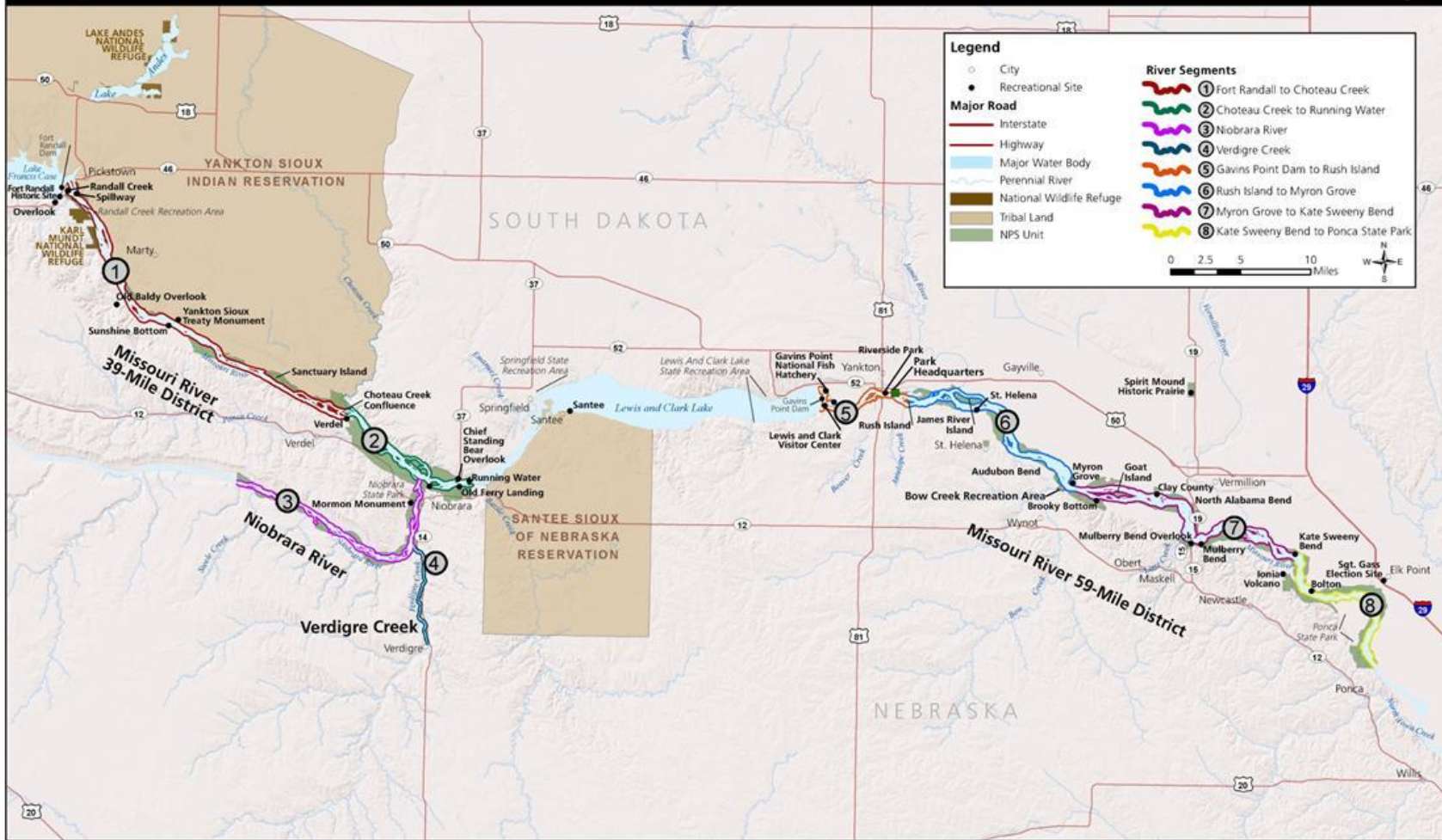
Awareness of the complex history of this waterway aids in the current understanding and appropriate management direction for water resources of the Missouri NRR. Anthropogenic and natural factors historically have affected the Missouri River. The oldest settlement evidence indicates that Paleo-Indian groups lived in the region of the Missouri River about 12,000 years ago (Wedel 1983). Euro-American exploration of the Missouri River area began with the fur trade in the early 1700s, and the Missouri River became the predominant water way to the American West during the 1800s. In addition, the natural habitat of the Missouri River historically has hosted an abundance and biodiversity of species that are associated with aquatic habitat in and around sandbar pools, braided channels, large woody debris, and backwater and oxbow areas, and additionally has provided water to land animals.

The aquatic and riparian ecosystems are important natural resources within the Missouri NRR. However, threats to natural resources include habitat fragmentation and loss resulting from the building of dams for generation of hydroelectric power, flood control, navigation, water supply, and recreation; from agricultural and residential development; from industrial pollution; and from loss of scenic integrity due to erosion control structures. Riparian areas are disappearing as additional homes and recreational cabins are constructed on the riverfront land. In addition, invasive species may outcompete and displace native plants, altering community structure and subsequently affecting the amount and quality of available habitat for aquatic and terrestrial wildlife. Invasive species may include purple loosestrife (*Lythrum salicaria*), salt cedar (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and leafy spurge (*Euphorbia esula*) (Stark et al. 2011). Because of the past history and current (2012) potential detrimental effects, an increased understanding of water quality of the Missouri NRR is merited.

Missouri National Recreational River

Nebraska, South Dakota

National Park Service
U.S. Department of the Interior



Produced by DSC Planning Division

May 2012

Figure 1. Map showing the Missouri NRR (map courtesy of the National Park Service, Denver Service Center).

Legislation and Management Regarding the Missouri NRR

Previous legislation and management of the Missouri River provides basic understanding for the rationale of the NGPN Missouri NRR monitoring design. The Wild and Scenic Rivers Act was designated in 1968 by Congress in Public Law 90-542; 13 U.S.C. 1271 (U.S. Congress 1968). This law specifies that "...with their immediate environments, Wild and Scenic Rivers possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, that shall be preserved in free-flowing condition, and they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." Under the Wild and Scenic Rivers Act, the 59-Mile District of Missouri NRR was established in 1978 and the 39-Mile District was designated in 1991 along with the lower 20-mile section of the Niobrara River, a tributary to the Missouri River, and 8 miles of Verdigre Creek, a tributary to the Niobrara River (Figure 1).

A lasting alteration of the Missouri River and the associated ecosystem resulted from legislation prior to the 1968 Wild and Scenic Rivers Act. The Pick-Sloan Plan authorized a combined effort in 1944 between the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation to complete a comprehensive plan for the Missouri River and its tributaries that addressed flood control, navigation-enhancement dams and reservoirs, irrigation development, and hydroelectric generation (Garrison Diversion 2012). The Flood Control Act turned the Missouri River into the largest reservoir system in North America. Fort Randall and Gavins Point dams are located on the main stem of the Missouri River (Figure 1) and were authorized as multipurpose dams above Sioux City, Iowa (National Park Service 2005). Because of anthropogenic alterations resulting from the 1944 authorization, the Missouri River morphologically has undergone a reduction in sandbars, sloughs, chutes, backwaters, and oxbow lakes (Hesse, 1987). The channelization and/or impoundment of tributary streams have reduced the length of flowing tributary streams (Hesse 1987). This resulted in reduced habitat for ecosystems that are associated with riverine environments (Hesse 1987).

In addition to the effects of legislation, management of the Missouri NRR is complicated by the fact that the NPS owns only about 300 acres of the roughly 69,000 acres that make up the park unit. The Missouri NRR is characterized by a complex pattern of bordering land ownership that consists of private property owners, communities, tribal lands, Federal and State parklands, and recreational facilities (National Park Service 2005). As a result, park staff must make major efforts regarding cooperation and communication among the private sector, and State and Federal governments (Davidson 2004). Within the park unit, about 31,000 acres (45 percent) are open water and about 6,000 acres (17%) consist of cropland (National Park Service 2009). Streamflow of the Missouri River within the Missouri NRR is controlled by a series of upstream reservoirs, and sections of river channel throughout the entire basin are stabilized by infrastructure. However, the Missouri NRR preserves about 98 miles of naturally eroding river.

Purpose and Scope of Study

The objectives of this study correlate with those presented in "Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network" (Wilson et al. 2013). As such, the objectives for the Missouri NRR study are to (1) measure field core parameters including dissolved oxygen, pH, specific conductivity, and water temperature that may be used for indicators to track changes in the riverine system and as indicators to sustain ecosystems; and (2) measure streamflow, which affects water quality. Because of financial and physical constraints

associated with monitoring large rivers, selection of monitoring sites for the Missouri NRR will focus on the tributaries within a 20-mile buffer of the Missouri River main stem.

The purpose of this document is to select water quality monitoring sites on tributaries to the Missouri River within the Missouri NRR. Criteria used for site selection include (1) preliminary NGPN studies, and historical and current studies by other agencies and entities; (2) beneficial uses and 303(d) data; and (3) additional factors controlling water quality including watersheds, population density, and land use. Data from this NGPN monitoring of tributaries to the Missouri NRR will be used to assess the status and long-term trends of select river segments in high-priority stream systems.

Criteria for Site Selection

Preliminary NGPN Studies

The sampling design for tributaries within the Missouri NRR was developed by staff from Missouri NRR and the NGPN through a process that involved meetings and discussions, site reconnaissance, pilot data collection and analyses, and consideration of budget and Network information requirements from the NPS I&M Program.

In 2008 the NGPN, with the aid of the U.S. Geological Survey (USGS) South Dakota Water Science Center, held a workshop at which time natural resource managers from park units within the NGPN prioritized the water quality indicators to monitor. Managers from park units identified core parameters (dissolved oxygen, pH, specific conductance, and water temperature) as a monitoring priority. In addition, fecal indicator bacteria (FIB) was identified as another high priority due to concerns regarding exceedances of water quality standards at selected water bodies.

At the 2008 meeting, park managers prioritized streams within their park that were the highest priority to monitor. The Missouri NRR management initially identified five Missouri NRR tributaries for potential water quality monitoring: Bow Creek, the James River, the Niobrara River, Verdigre Creek, and the Vermillion River (Figure 1). A consideration for site selection was the location of a streamgage at or within 100 feet of the monitoring site. As noted by Gilliom et al. (1995), to effectively evaluate the relation between streamflow and water quality characteristics, it is advantageous to select water quality monitoring sites at or near (less than 100 feet) streamgages.

Based on ranking priority of parameters to measure by Missouri NRR and additional park units within the NGPN, protocol and standard operating procedures (SOPs) were developed for measurement of field core parameters and stream discharge and for enumeration of FIB on wadeable streams within park units. Because monitoring the main-stem Missouri River within the Missouri NRR is beyond the capabilities and budget constraints of the NGPN, a decision was made to monitor water quality of wadeable tributaries that feed the Missouri River within the Missouri NRR. In addition, this approach is used because the quality of the Missouri River is affected by point and nonpoint sources of contaminants that may enter the main-stem tributaries.

NGPN Pilot Studies

The NGPN initiated pilot studies to assess the feasibility of collecting continuous water quality data at five select sites, and subsets of these sites, on the Belle Fourche River in Devils Tower National Monument, the Little Missouri River in Theodore Roosevelt National Park, the Laramie River within the Fort Laramie National Historic Site, and the Niobrara River within Agate Fossil Beds National Monument, and within the Niobrara National Wild and Scenic River. Multi-parameter sondes were installed to measure dissolved oxygen, specific conductivity, pH, and water temperature. Sondes were deployed from the river bank at nonrandomly selected sites and data were logged at 15-minute intervals for a 2-week period. No tributaries of the Missouri River within the Missouri NRR were included in the pilot studies. The experience gained by NGPN pilot studies provided insights regarding the continuous water quality monitoring. Although continuous monitoring was possible, the NGPN did not have time to correct the water quality data due to lack of expertise and time constraints.

The NGPN staff consulted with USGS to initiate a 2010 pilot study that focused on prominent rivers within three parks. Continuous monitoring of core parameters was conducted simultaneously within each reach of a select river to examine data for spatial and temporal variability. Data from this monitoring effort were used for a statistical power analyses to aid in selection of the sampling design.

Power Analyses

The 2009–2010 pilot water quality data were statistically analyzed to examine trade-offs and performances of alternative monitoring designs based on two trend scenarios: (1) power to detect a 2-percent trend per year over 10 years; and (2) power to detect a 1-percent trend per year over 25 years. Power was assessed for eight monitoring design scenarios. Statistical analyses indicated that a 3-year rotation sampling design maximized the number of sites that could be monitored under a moderately robust design while staying within the financial constraints of the NGPN. Details for this statistical analysis are provided in Appendix B of Wilson et al. (2013).

Historical and Current Water Quality Monitoring

A substantial amount of historical water quality data are available for Missouri River tributaries within the Missouri NRR, and several agencies and entities are currently (2012) engaged in water quality monitoring efforts (Table 1). To avoid duplication of monitoring efforts, the NGPN staff summarized current water quality monitoring studies (Table 1 and Figure 2). This compilation is not necessarily comprehensive but includes the major monitoring efforts in the park units that have available data.

Table 1. General listing of agencies and entities that have been or are currently (2012) monitoring tributaries to the main stem of Missouri NRR. Individual States, the National Park Service (NPS), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), academia, and private industry independently monitor sites and also partner with other agencies for implementation of a water quality monitoring design.

[Missouri NRR, Missouri National Recreational River; DO, dissolved oxygen; SC, specific conductivity; T, temperature; FIB, fecal indicator bacteria; TSS, total suspended solids; VTSS, volatile total suspended solids; USEPA, U.S. Environmental Protection Agency; STORET, National Park database STORage and RETRIeval; WQ, water quality; NE DEQ, Nebraska Department of Environment Quality; R., River, Cr., Creek; USGS, U.S. Geological Survey; SD DENR, South Dakota Department of Environment and Natural Resources; NWIS, USGS database National Water Information System]

Name	Description	Scope of Work	Sampling Sites for Missouri River Tributaries within a 20-Mile Buffer of the Missouri NRR	Parameters Measured	Duration of Monitoring and Frequency of Sampling	Sampling Method	Data Storage
James River Development District Water-Quality Study	Political subdivision of the State of South Dakota	Promotes conservation, development, and proper management of water resources according to District priorities	Varies, relevant monitoring sites include locations on the lower James River	DO, pH, SC, and T; FIB; nutrients; TSS; and VTSS	Sites monitored for 3 years, potentially 2 additional years; continuous monitoring for varying durations during March through November	USEPA ¹	Database maintained by District, unpublished data
Missouri River Institute	Co-monitoring efforts with the University of South Dakota	Documents historical data and current WQ changes; characterizes off-channel habitats	Varies by year; backwater, side channel, and wetland sites within a 20-mile buffer of the park unit	Nitrates and select metals; select pesticides; biological monitoring	Monthly during summer	Multi-parameter probe; grab samples; ponar dredge	Data will potentially be provided in STORET

Name	Description	Scope of Work	Sampling Sites for Missouri River Tributaries within a 20-Mile Buffer of the Missouri NRR	Parameters Measured	Duration of Monitoring and Frequency of Sampling	Sampling Method	Data Storage
Spencer Hydro	Nebraska Public Power District, controls hydroelectric power and supports irrigation projects	Monitors and reports WQ regarding processes associated with the hydroelectric plant	Single site located on the Niobrara River near Highway 281 bridge	DO, pH SC, T; seeable solids; secchi disc; and hydrogen sulfide	Sampling once in the spring and once in the fall during 2000–2010, continued monitoring planned	USEPA ¹	NE DEQ
NE DEQ ²	Ambient stream monitoring and basin rotation	Monitors and compiles current stream WQ data; assesses long-term trends	Keya Paha R. near Naper; Long Pine Cr. at Long Pine State Recreation; Louse Cr. west of Dorsey; Niobrara R. near Sparks; Niobrara R. near Verdel; Ponca Cr. at Verdel; Steel Cr. Near Dorsey; East Branch Verdigre Cr. near Royal; and Verdigre Cr. near Verdigre. Sites sampled for NE DEQ by USACE beginning April 2003; Missouri River near Verdel; Missouri River near Maskell	DO, pH, SC, T, and turbidity; pesticides atrazine, metolachlor, and acetachlor; trace metals; gage height and discharge where possible	Ambient stream monitoring is scheduled the first week of every month for measurement of field core parameters; April through September for nutrients, pesticides, and total suspended solids; trace metals sampled quarterly On a rotational basis, each of Nebraska's 13 basins is intensely monitored once every 6 years.	USEPA ¹	In the future, data will be available in STORET

Name	Description	Scope of Work	Sampling Sites for Missouri River Tributaries within a 20-Mile Buffer of the Missouri NRR	Parameters Measured	Duration of Monitoring and Frequency of Sampling	Sampling Method	Data Storage
State of SD DENR ³	Ambient stream monitoring	Conducts routine WQ monitoring of surface water to ensure that the State's natural resources are protected	Vermillion R. near Vermillion, west of Chancellor, and near Wakonda, Missouri R. near Ft. Randall Dam and Gavins Point Dam, SD; Choteau Cr. east of Perkins, SD; James R. near Yankton, SD; Wolf Cr. above and below Colony, SD; Ponca Cr. near St. Charles	DO, SC, pH; nutrients; organic and inorganic compounds; and radioactive chemicals	Monitoring frequency is station specific, measured either quarterly or monthly; all parameters measured on each visit (May through September) except FIB and calcium, magnesium, sodium (May through August)	USEPA ¹	STORET
USACE ⁴	Responsible for investigating, developing, maintaining, and managing of the Nation's water and related environmental resources	Study of WQ conditions in the MNRR reach from Fort Randall Dam to Ponca State Park	Varies. Sampling frequently partnered with other agencies/entities	Dependent on monitoring plan; monitors the main stem of the Missouri R. system and its tributaries	Dependent on project and monitoring site	Dependent on project and monitoring site	Dependent on project and monitoring site

Name	Description	Scope of Work	Sampling Sites for Missouri River Tributaries within a 20-Mile Buffer of the Missouri NRR	Parameters Measured	Duration of Monitoring and Frequency of Sampling	Sampling Method	Data Storage
USGS ⁵	Within the Bureau of the U.S. Department of Interior. A fact-finding research organization with no regulatory authority	Monitors and reports real-time data from streamgages; at select sites measures core parameters—DO, SC, pH, and T; collects WQ samples to be analyzed for chemical, physical, and biological components ⁶	28 sampling sites; real-time data for a select subset	Continuous measurement of gage height, discharge; water quality parameters; sampling depends on project objectives	Varies by site; generally greater than a three-year study; frequency of sampling dependent on compounds of concern	USGS ⁷	NWIS

¹ U.S. Environmental Protection Agency, <http://www.epa.gov/region8/water/monitoring/documents.html> (2013).

² Nebraska Department of Environmental Quality (2010).

³ South Dakota Department of Environment and Natural Resources <http://denr.sd.gov/documents/10irfinal.pdf> (2010).

⁴ Projects include but are not limited to: Vermillion River Assessment; sampling and analyses plan for the Lower Missouri River to support application of the CE-QUAL-W2 hydrodynamic and water quality model; and intensive survey of Gavins Point reservoir.

⁵ USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

⁶ <http://water.usgs.gov/owq/data.html> (2010). USGS streamgages associated with the Missouri NRR and its tributaries include the following: monitoring of Ponca Creek at Verdel, NE; Missouri River below Greenwood, SD; Verdigre Creek near Verdigre, NE; Missouri R. at Niobrara, NE; Bazile Creek near Niobrara, NE; Lewis and Clark Lake at Springfield, SD; Missouri R. at Yankton, SD; Missouri R. near Gayville, SD; Missouri R. near Maskell, NE; Niobrara River near Verdel, NE; and Vermillion R. near Vermillion, SD. Select USGS streamgages record temperature.

⁷ U.S. Geological Survey, <http://pubs.water.usgs.gov/twri9A> (2012).

Spatial Location of Historic and Current Monitoring Sites

To address spatial distribution of geographic coverage, surface water sites monitored by other agencies and entities on tributaries to the main stem within the Missouri NRR (Table 1) were plotted on a map. A 20-mile buffer was added to the boundary of the park unit to estimate the spatial extent for tributary contributions (Figure 2). The area of this study within the Missouri NRR does not include tributaries downstream that do not feed to the Missouri River. Sampling sites were designated as “short term” if water quality was monitored for about three consecutive years and “long term” if the water quality was monitored for greater than three consecutive years. Tributaries downstream from the 59-Mile District (yet within the 20-mile buffer) were not considered in site selection.

Tributaries to the main stem with the most extensive water quality monitoring sites within South Dakota are the James and Vermillion Rivers (Figure 2). These rivers enter the 59-Mile District of the Missouri River main stem and are monitored by numerous agencies at multiple sites. The James River is monitored by the James River Water Development, which is a political subdivision of the State of South Dakota. In addition, the James River Water Development supports monitoring by other agencies, for example, the USGS operates three streamgages on the James River near Stratford, Redfield, and Yankton. The Vermillion River has comprehensive short-term and long-term monitoring by various agencies and entities (Figure 2). The other tributaries within South Dakota that provide streamflow to the main stem within the Missouri NRR have comparatively less drainage (Figure 2). The Nebraska tributaries that drain to the main stem have long-term monitoring of water quality by various agencies and entities. The Nebraska Department of Environmental Quality has fixed sampling sites and, in addition, intensely monitors water quality within Nebraska’s 13 basins on a 6-year rotational basis (Table 1). Major tributaries that feed the 39-Mile District include the Niobrara River, Ponca Creek, and Verdigre Creek. The Bow Creek and associated tributaries drain to the 59-Mile District. These main tributaries have numerous first- and second-order streams that feed them.

In addition to review of the spatial distribution of water quality monitoring sites, existing data from monitoring sites were examined by the systematic process shown in Figure 3. Collection, analyses, and quality assurance/quality control (QA/QC) were assessed. Examination of the spatial distribution of monitoring sites on the tributaries resulted in potential selection of monitoring sites on segments of Bow Creek, the Niobrara River, and Verdigre Creek.

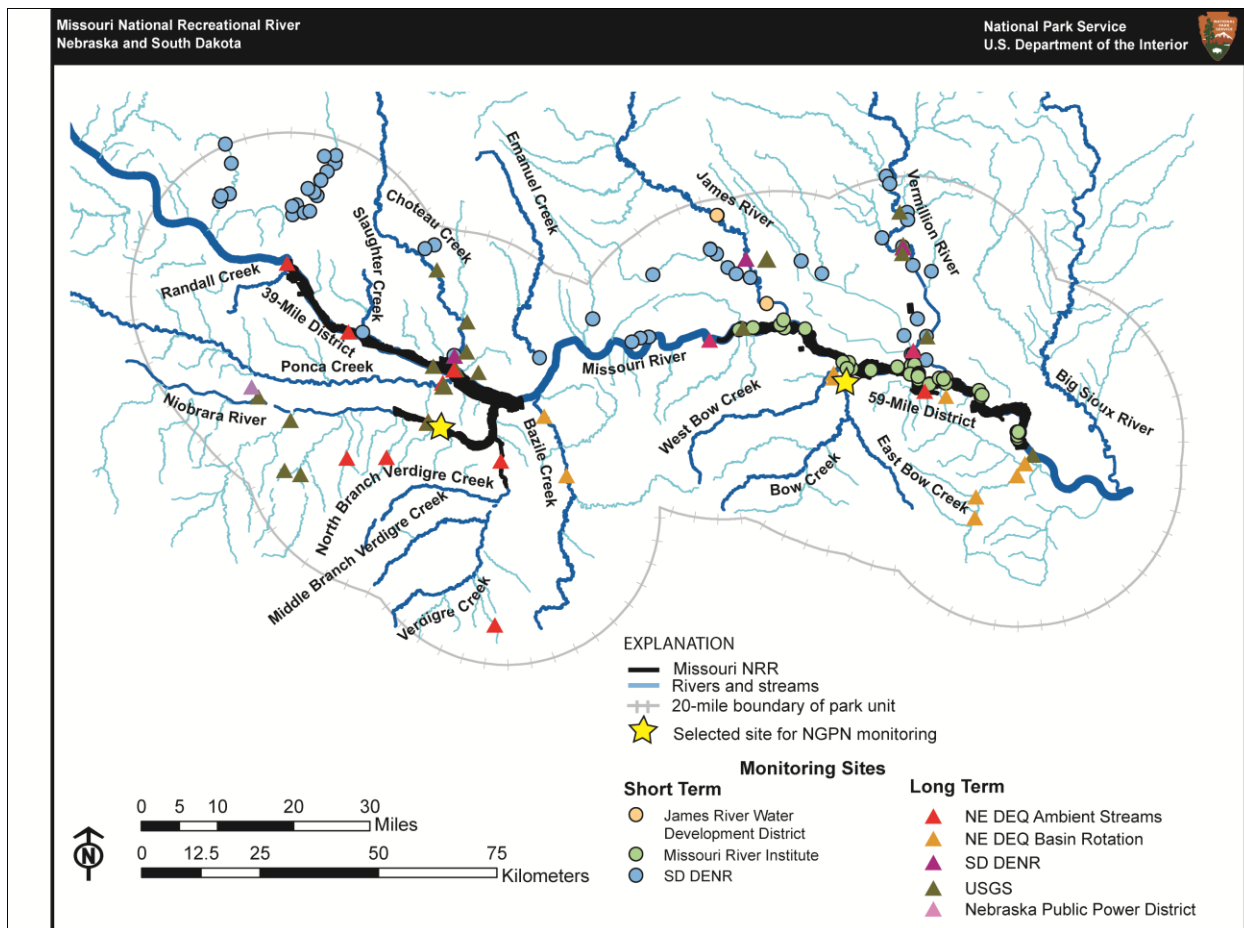


Figure 2. Generalized short-term and long-term water quality monitoring sites by agencies and entities on tributaries within a 20-mile buffer of the Missouri NRR. Symbols may be offset if a site is monitored by more than one agency or entity.

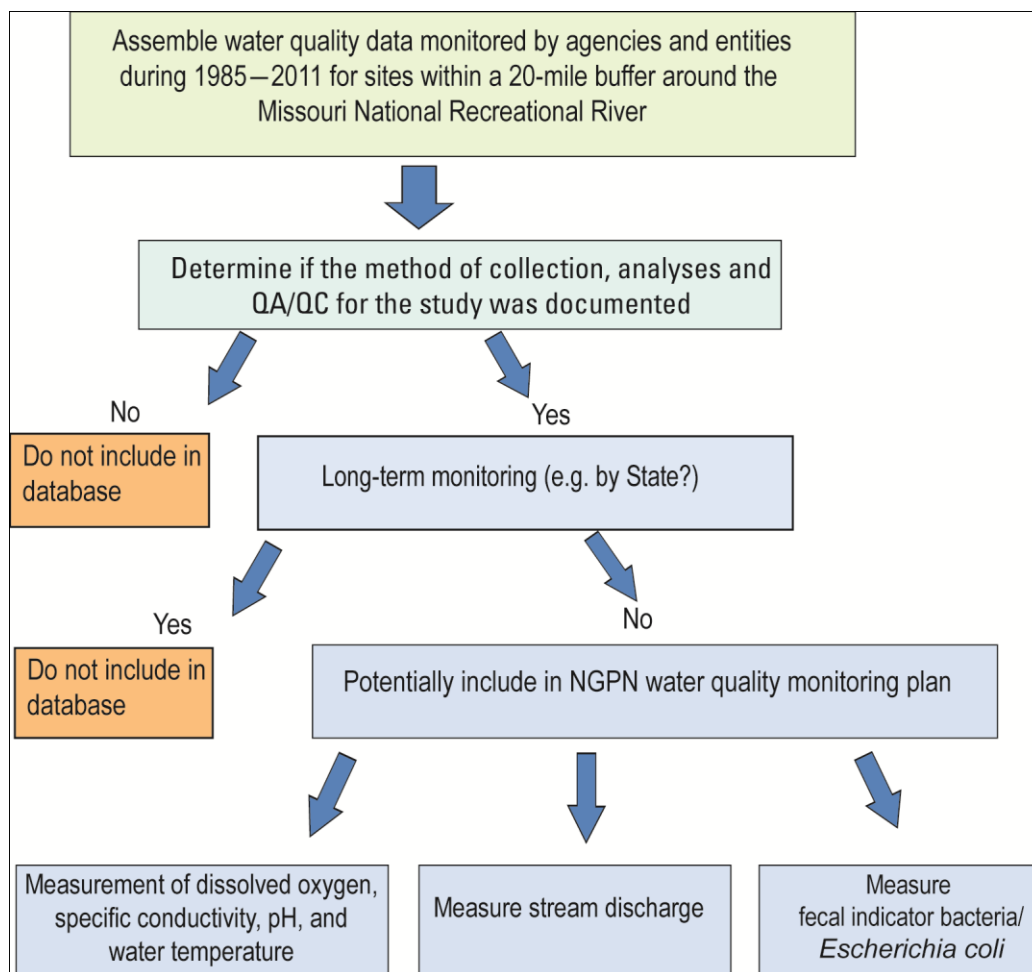


Figure 3. Process used by the Northern Great Plains Network to examine historical and existing water quality data for tributaries to the Missouri NRR.

Water Quality Standards— Beneficial Uses and 303(d) Listings

Water quality standards are set by each State and consist of the waterbody’s designated beneficial use(s) and the water quality criteria (numeric and narrative) to protect and maintain the identified uses (U.S. Environmental Protection Agency 2010). Section 303(d) of the 1972 Federal Clean Water Act requires each State to identify waterbodies that do not meet water quality objectives and are not supporting established beneficial uses.

Because the Missouri River within the Missouri NRR is located on the Nebraska–South Dakota border, each State separately assigned beneficial water uses to the Missouri River main stem and its tributaries. Tributaries south of the main stem of the Missouri NRR are monitored in accordance with the Nebraska Department of Environmental Quality (NE DEQ) ambient monitoring program and the basin rotation program. Nebraska assigned the Missouri River within the Missouri NRR as a Class A State Resource water with an antidegradation clause that designates that existing water quality must be maintained, and that uses are defined for each segment of the river (Nebraska Department of Environmental Quality 2010). Designated uses may include primary contact recreation; aquatic life (coldwater classes A and B and warmwater

classes A and B); water supply (public drinking water, industrial water, and agricultural classes A and B); and aesthetics. Additional information is available at <http://www.deq.state.ne.us/>. Streams are designated by five water categories that are summarized as follows (Nebraska Department of Environmental Quality 2010):

- Category 1. Waterbody meets all designated uses;
- Category 2. Waterbody where some of the designated uses are met but there is insufficient information to determine if all uses are being met;
- Category 3. Waterbody where there is insufficient data to determine if any beneficial uses are being met;
- Category 4. Waterbody is impaired but a total maximum daily load (TMDL) is not needed;
 - 4a. Water is impaired but has an USEPA approved TMDL;
 - 4b. Water is impaired but implementation project for best management practices is in place;
 - 4c. Water is impaired by a parameter that is not considered a “pollutant,” and
- Category 5. Waterbody where one or more beneficial uses are determined to be impaired by one or more pollutants and all of the TMDLs have not been developed. These waters constitute the section 303(d) list subject to USEPA approval/disapproval.

Most tributary reaches within Nebraska are listed as category 3 because no data are available for evaluation (David Rus, USGS Nebraska Water Science Center, personal communication 2012). Stream segments that are included in the 2010 Nebraska 303(d) list are included in Table 2. Contributing tributaries that are impaired within the 39-Mile District or potentially affect main-stem water quality are located within the Lower Niobrara and the Ponca watersheds (Figure 4, Appendix 1). In contrast, the 59-Mile District had one impaired stream within the park unit. Lime Creek (Segment MT2-11000) is located near Maskell, Nebraska and enters the Missouri River south of the confluence of the Missouri River and the Vermillion River (Appendix 1). Lime Creek was impaired for aquatic life (Nebraska Department of Environmental Quality 2010).

Designated beneficial uses of surface water within South Dakota have been assigned by the South Dakota Department of Environment and Natural Resources (2010):

- Coldwater permanent fish life propagation waters;
- Coldwater marginal fish life propagation waters;
- Warmwater permanent fish life propagation waters;
- Warmwater marginal fish life propagation waters;
- Immersion recreation waters;
- Limited contact recreation waters;
- Fish and wildlife propagation, recreation, and stock watering waters;
- Irrigation waters; and
- Commerce and industry waters.

These beneficial uses apply to primary tributaries and less frequently to sub-tributaries of most State of South Dakota rivers and perennial streams. Water quality of the Missouri River main

stem and its tributaries is monitored by the South Dakota Department of Environment and Natural Resources (SD DENR) in accordance to the ambient water program. Categories established for beneficial use are similar to those previously listed for Nebraska Department of Environmental Quality. Choteau Creek, the lower reach of the James River, and the lower reach of the Vermillion River were impaired due to total suspended solids for all three segments and the James River segment also had fecal coliform impairment (Table 2; Figure 2). Additional information is available at <http://denr.sd.gov/des/sw/IntegratedReports.aspx>.

States may choose not to monitor segments of a stream that have been delisted from the 303(d). For this reason, the NGPN examined stream segments that are impaired as of 2010 (Table 2) and also stream segments that historically were listed on the 303(d) list for potential sites to monitor.

Table 2. Tributary segments that are on the 2010 listing of 303(d) impairments within the Missouri NRR and impaired segments of tributaries outside of the park boundary that may potentially affect water quality of the Missouri River main stem.

Creek/River	Identification Number	Cause of Impairment
Nebraska		
Lime Creek	MT2-11000	Impaired aquatic community
Niobrara River	NE-NI2-10000	<i>E. coli</i> , fish consumption advisory
Ponca Creek	NE-NI1-10100	<i>E. coli</i> , selenium
Steel Creek	NE NI2-10800	<i>E. coli</i>
Verdigre Creek	NE-NI2-10100	<i>E. coli</i> , impaired aquatic community
South Dakota		
Choteau Creek	SD-MI-R-CHOTEAU_01	Total suspended solids
James River	SD-JA-R-JAMES_11	Fecal Coliform, total suspended solids
Vermillion River	SD-VM-R-VERMILLION_03	Total suspended solids

Watersheds

Watersheds were examined for spatial extent of tributaries that drain to the Missouri River within the Missouri NRR. Hydrologic unit codes (HUCs) provide a hierarchical cataloging system for specifying watershed boundaries (U.S. Geological Survey 2012). An eight-digit HUC is

commonly used to represent local watersheds, and was used for examining tributaries to the Missouri NRR. Tributaries potentially reflect hydrological and geological components such as channel modification and natural mineralogy, streamflow regulation, land use practices, and other integrated variables associated with their watersheds.

Personnel from the NGPN and Missouri NRR examined six hydrologic units and associated tributaries within the 20 mile-buffer of the Missouri NRR to aid in the selection of monitoring sites within the park unit (Figure 4). Of the major drainages, the Lewis and Clark subbasin comprises one of the largest watersheds within the Missouri NRR and contains tributaries that drain to the 39-Mile District and the 59-Mile District. Drainage systems within the watersheds contain dendritic drainage systems, such as the Niobrara River, and also parallel drainage systems such as Ponca Creek. The correlation between the HUC size or the tributary type and water quality impairments (Table 2) indicated that watershed was not the most apparent factor for site selection of NGPN water quality monitoring sites.

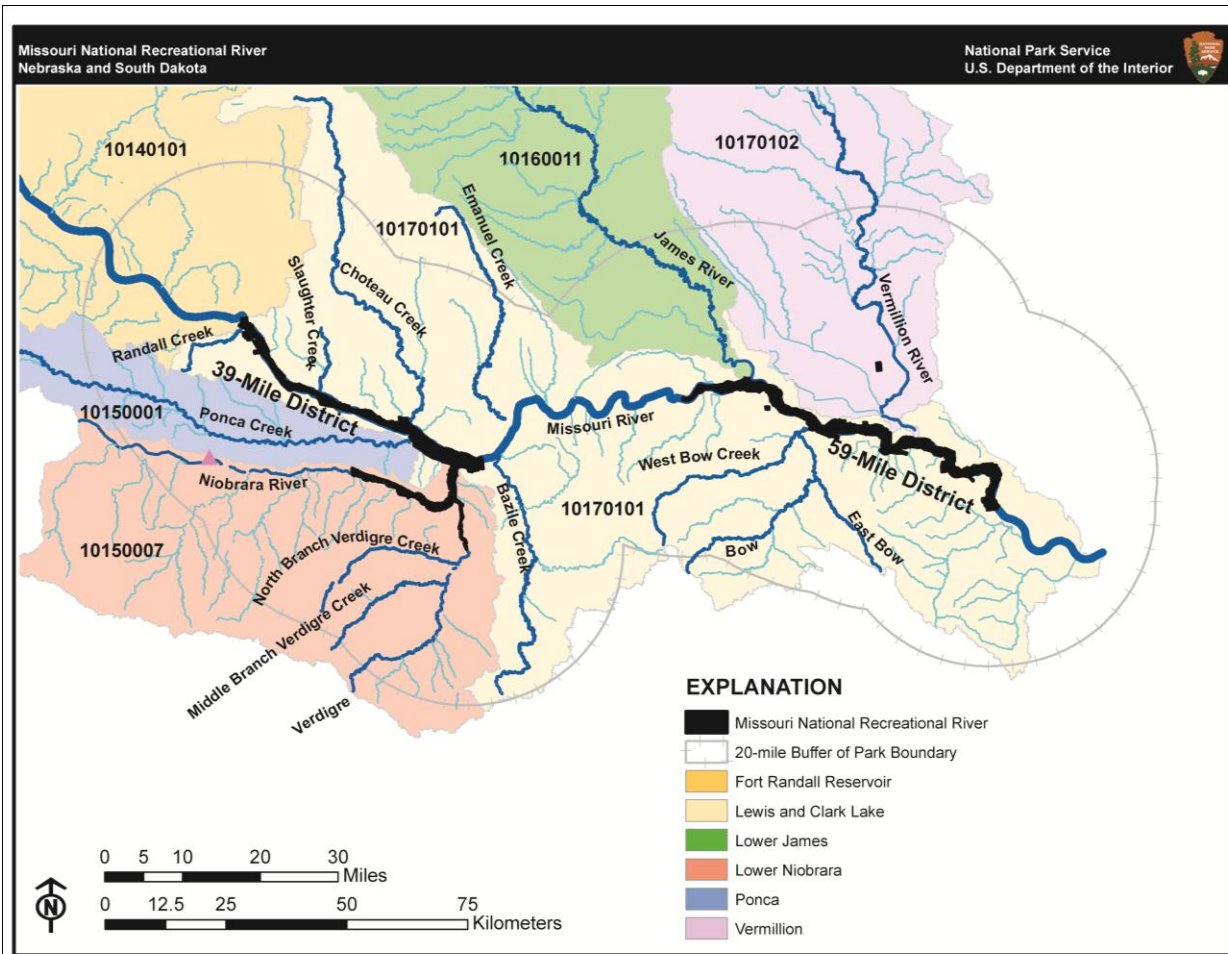


Figure 4. Hydrologic Unit Codes (HUCs) showing the watersheds and tributaries within a 20-mile buffer of the Missouri NRR (U.S. Geological Survey 2012).

Population Density

Population density will be used (as a surrogate) to estimate the number and strength of anthropogenic influences on the physical, chemical, and biological characteristics of a stream. The land bordering the Missouri NRR is privately owned, and also is designated as tribal, State, and Federal land. Portions of the Missouri NRR that are associated with high population density within the 20-mile buffer may result in increased risk to the quality of water resources. For example, waste from improperly designed septic systems and landfills located adjacent to or within the park unit may result in risk to contamination of water by nitrates and phosphates.

The population density for counties that border the Missouri NRR is based on people per square mile from the 2010 block group data (U.S. Bureau of Census, 2010) (Figure 5). The greatest population density in counties adjacent to the Missouri NRR is located in the northeast part of the 59-Mile District within South Dakota and includes the James River within Yankton County and the Vermillion River within Clay County. The population ranges from about 52.6 to 82 persons per square mile within these counties. Because of increased population, the James and Vermillion Rivers currently are two of the most frequently monitored tributaries by agencies and entities within the 20-mile buffer of the Missouri NRR (Figure 2). With the exception of Dixon County that has a population density of about 12.0–28.3 people per square mile, most adjoining counties to the Missouri NRR in Nebraska have population densities of less than 12 persons per square mile (Figure 5).

Although the U.S. Bureau of Census (2010) indicates that the nontransient population associated with the land adjacent to the park unit is relatively low, the Missouri NRR area is highly populated during seasonal recreational activities including boating, canoeing, camping, hiking, fishing, horseback riding, and other outdoor recreation. Although a count is not available for the Missouri NRR only, a total of 2,494,740 individual visits were made to the Missouri River and its tributaries during 2003 (Sheriff et al. 2011). The park accommodation for recreational purposes may increase susceptibility to anthropogenic contamination, such as FIB. Consequently, waterbodies associated with high visitation, such as segments of the Niobrara River, were considered for potential inclusion in the NGPN water quality monitoring.

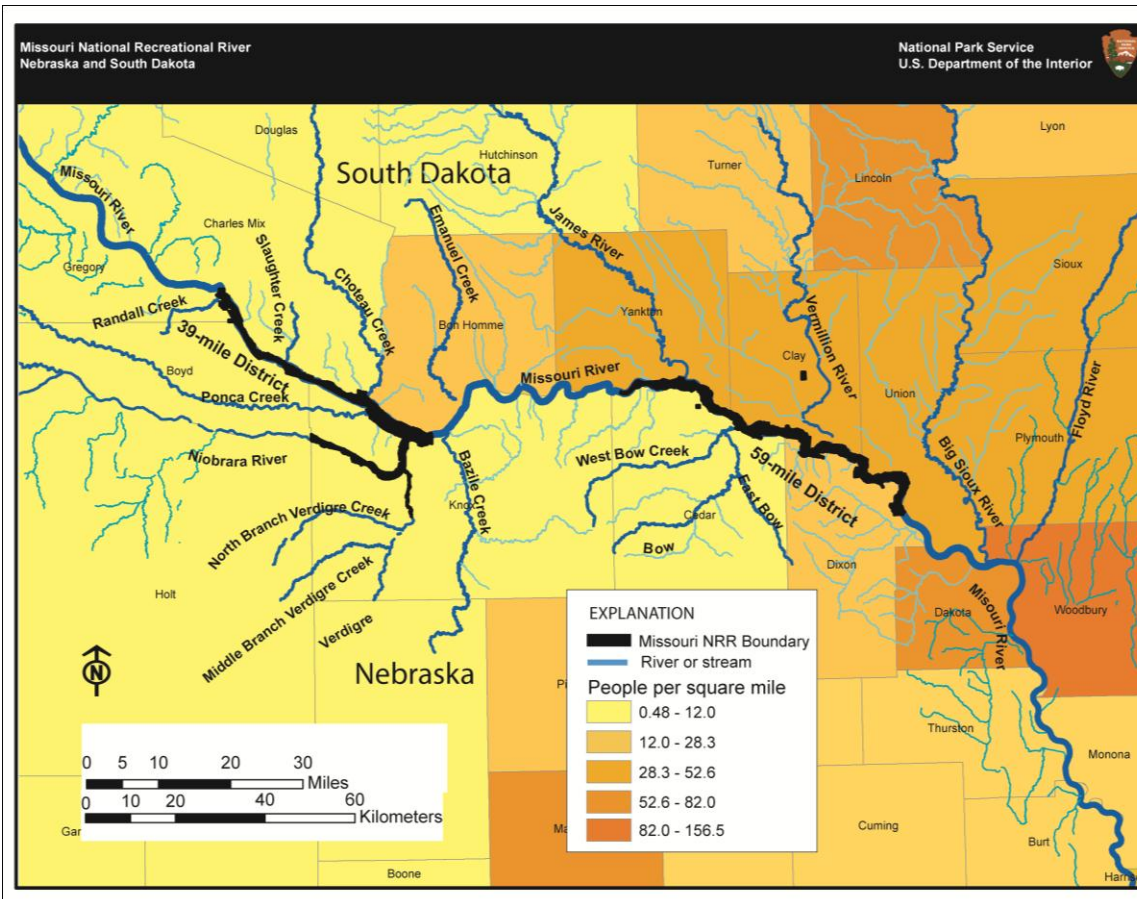


Figure 5. Population density in people per square mile for counties adjacent to the Missouri NRR (U.S. Bureau of Census 2010).

Land Use

Land use maps were used to indicate the spatial distribution of management practices that are likely to affect the quality of water resources within the 20-mile buffer of the Missouri NRR (Figure 6). Land use was placed in categories based on characterization by Fry et al. (2011) including (1) agricultural (planted, cultivated, and grazed); (2) undeveloped (barren, forest, shrub land, herbaceous, and wetlands); and (3) urban (developed). Streams in basins with substantial agricultural land uses, including crops and grazing, almost always contain complex mixtures of nutrients and pesticides (U.S. Geological Survey 1999). This may result in excessive plant growth (eutrophication) in freshwater environments and provide nutrients to nuisance plant growth that affect the ecology of the park unit (U.S. Geological Survey 1999). In addition, pesticides that are introduced into the riverine and wetland areas may affect the delicate balance of ecosystems within the Missouri NRR. Land use within the 20-mile buffer of the Missouri NRR within South Dakota has a strong agricultural signature, particularly within the James River and Vermillion watersheds. Land within the Nebraska buffer consists of undeveloped land intermingled with croplands (Figure 6).

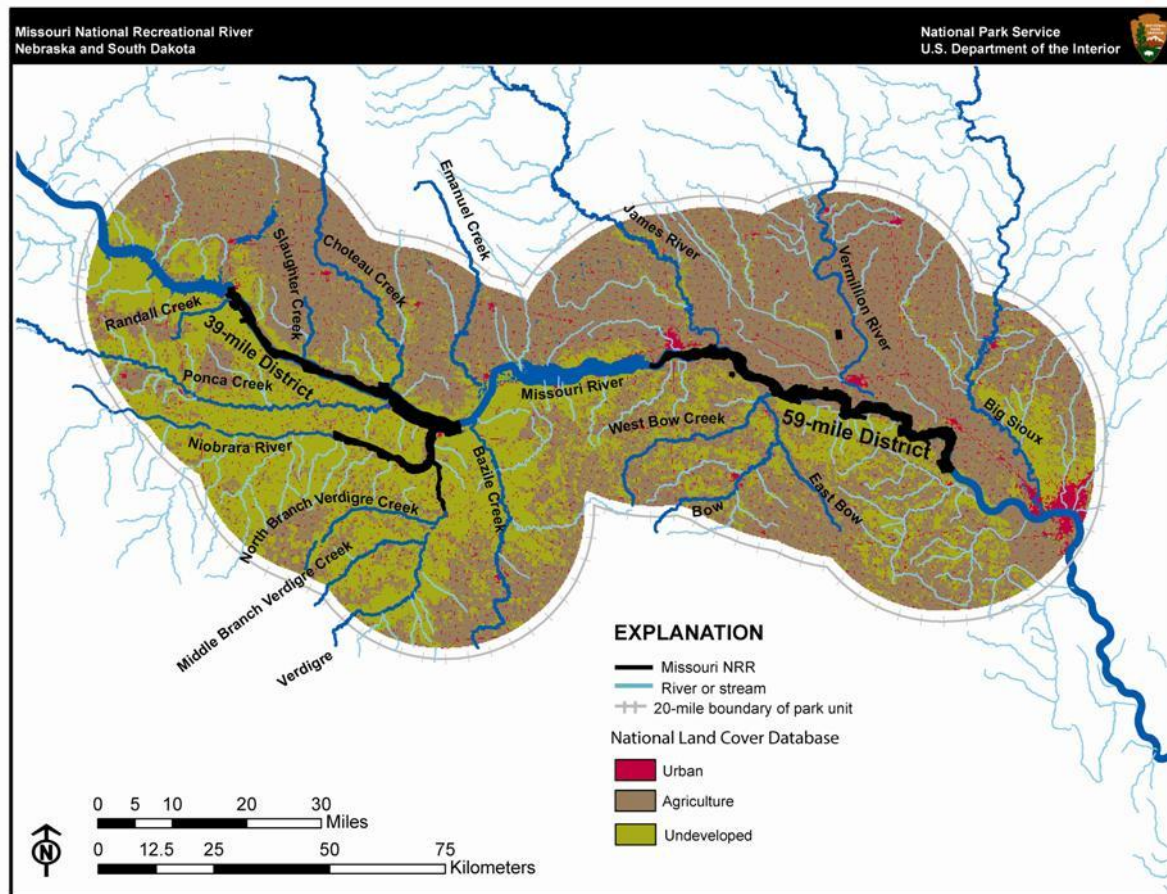


Figure 6. Land use adjacent to and within a 20-mile buffer of the Missouri NRR and tributaries (Fry et al. 2011).

Nebraska is ranked fourth nationally for level and growth of farm output, and South Dakota also is among the Nation's top agricultural producers (U.S. Department of Agriculture 2012). The crops that are produced within proximity to the Missouri NRR are conducive to the support of Concentrated Animal Feeding Operations (CAFOs). CAFOs confine livestock within a much smaller area than traditional pasture operations and result in congregation of animals, feed, manure, urine, and production operations within a confined land area (U.S. Environmental Protection Agency 2012a, 2012b).

CAFOs are regulated by a water pollution control permit; however, feeding operations are within proximity to the corridor of the Missouri NRR within Nebraska and South Dakota (written communication from Nebraska Department of Environmental Quality and South Dakota Department of Environment and Natural Resources) (Figure 7). The environmental effects resulting from release of wastes include excess nutrients in water that contribute to low levels of dissolved oxygen (fish kills), and decomposing organic matter that can contribute to toxic algal blooms (U.S. Geological Survey 1999). In addition, runoff from the CAFO or lagoon leakage can degrade water resources and potentially contribute to illness by exposing people to wastes and pathogens (U.S. Environmental Protection Agency 2012c). Major clusters of CAFOs are

located in the eastern part of Nebraska within watersheds for Bow Creek, West Bow Creek, and East Bow Creek, and within the HUC associated with the James River (Figure 7). Some steroid hormones associated with livestock production have been detected in sediments of Bow Creek, indicating that CAFOs may be affecting the water quality within this creek (Sellin Jeffries et al. 2011).

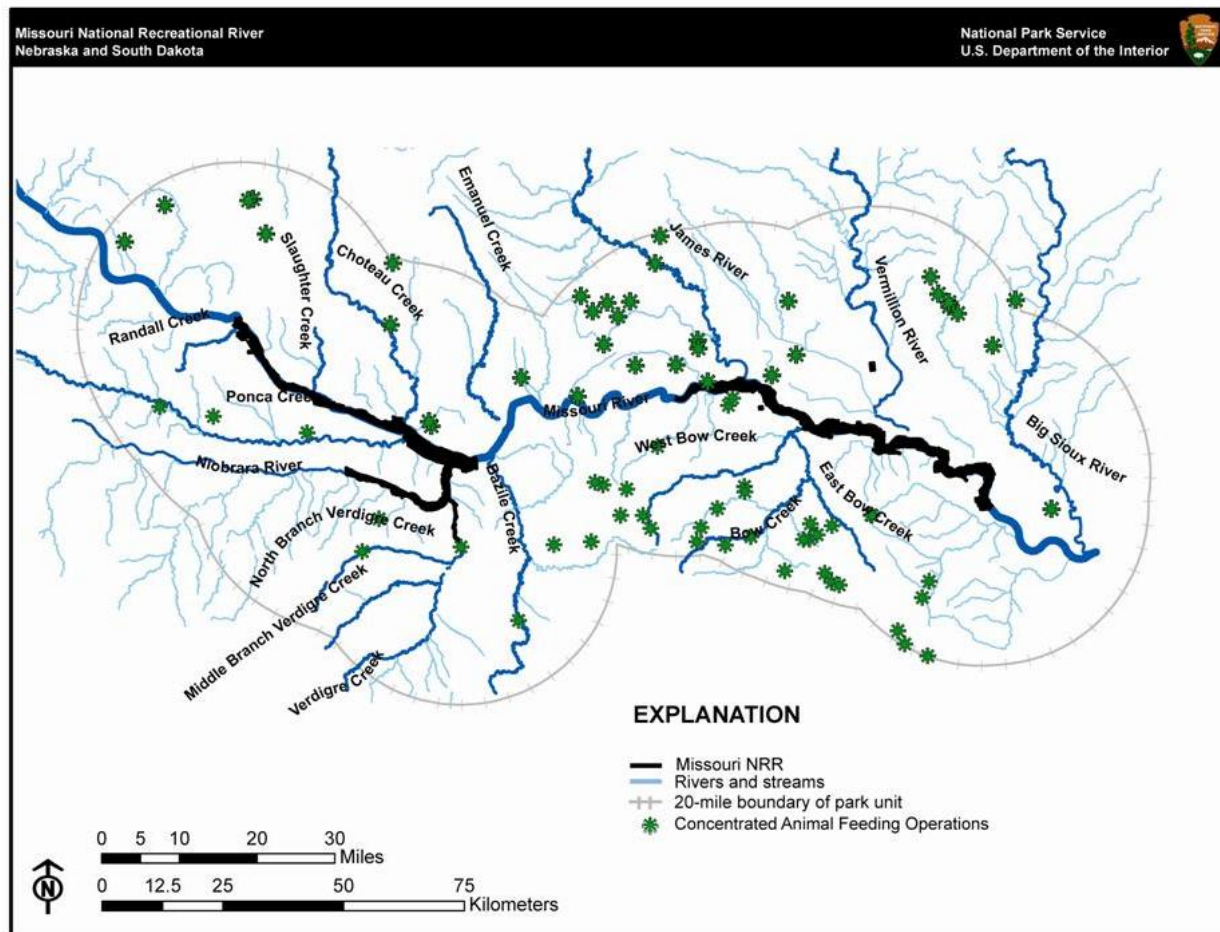


Figure 7. Concentrated Animal Feeding Operations (CAFOs) located near tributaries within the 20-mile buffer of the Missouri NRR (written communication from Nebraska Department of Environmental Quality and South Dakota Department of Environment and Natural Resources).

Urban land use (Figure 6) may result in anthropogenic sources that, once released, move within the hydrologic system and enter tributaries to the Missouri NRR. Inputs of chemical contaminants or sediments at any point along the stream can cause degradation downstream with adverse effects on biological communities and on economically valuable resources, such as fisheries and tourism (Coles et al. 2012). Contaminants, habitat destruction, and increasing streamflow flashiness resulting from urban development have been associated with the disruption of biological communities, particularly the loss of sensitive aquatic species (Coles et al. 2012). Potential contamination may be associated with waste disposal from municipal sewage treatment plants, septic systems, industrial liquid waste, leaking underground storage tanks, and landfills.

Classified urban areas within the 20-mile buffer of the Missouri River predominantly are located near the confluences of the James River and the Vermillion River to the Missouri NRR (Figure 6). However, these rivers are monitored by other agencies and entities (Table 1). Because of high agricultural land use and the number of CAFOs associated with the Bow Creek area (Figure 7), a segment of Bow Creek was considered a priority for NGPN water quality monitoring.

Index Sites Selected for Water Quality Monitoring

A site selected for NGPN monitoring within the Missouri NRR will be referred to as an index site, which is a location determined to be relatively representative of the stream segment within the park boundaries and logistically is feasible to sample water chemistry parameters. After reviewing existing data, an index site was selected for monitoring on Bow Creek near St. James, Nebraska. The monitoring site is within the Bow Creek Recreation Area (Figure 8), which was acquired by NPS in 2008. The area within proximity of the Bow Creek confluence with the Missouri River supports agricultural land use including CAFOs, recreational pursuits, and land and water based hunting. The lack of long-term monitoring, the multiple land uses, and the presence of the Recreation Area made the site a top priority for water quality monitoring.

The Missouri NRR management selected an index site on the Niobrara River near Verdel as its second priority for the proposed NGPN water quality monitoring program. The Niobrara River in this area is used for river-based fishing, hunting, boating, and wading. Selection of the Niobrara River water quality monitoring site was based on public recreational use, agricultural practices, past 303(d) impairments, and the existence of a USGS gaging station.

The Niobrara River at Verdel was monitored during 2002–2012 as part of the NE DEQ Ambient Stream Monitoring Program. One time per month, the NE DEQ measures field core parameters including dissolved oxygen, specific conductivity, pH, turbidity, and water temperature. In addition, monthly samples are collected and analyzed for ammonia, chloride, nitrate-nitrite, total nitrogen, total phosphorous, and total suspended solids; quarterly samples are collected and analyzed for selenium and arsenic. Spring and summer samples are collected and analyzed for estimated measurements of the pesticides atrazine, acetochlor, and metolachlor. The continuous monitoring data collected by the NGPN will provide the foundation for a comprehensive evaluation of the variability in stream characteristics. When continuous estimates are considered over the long term, it may be possible to identify changes in water quality conditions resulting from land use changes and implementation of best management practices in the watershed.

Monitoring of Index Sites

The target population of this water quality study is two nonrandomly selected index sites within the part of the Missouri NRR for which statistical inference can be made about the status and trends of water quality. Selected sites will follow a rotating site approach whereby monitoring will occur in 3-year cycles, with 1 year on and 2 years off. Monitoring will begin at the Bow Creek near St. James, Nebraska, site (historical USGS streamgage 06478518 operated during 1979–1994; <http://waterdata.usgs.gov/nwis/>) in fiscal year (FY) 2014, and at the Niobrara River near Verdel, NE, site (USGS streamgage 06465500) in FY 2015.

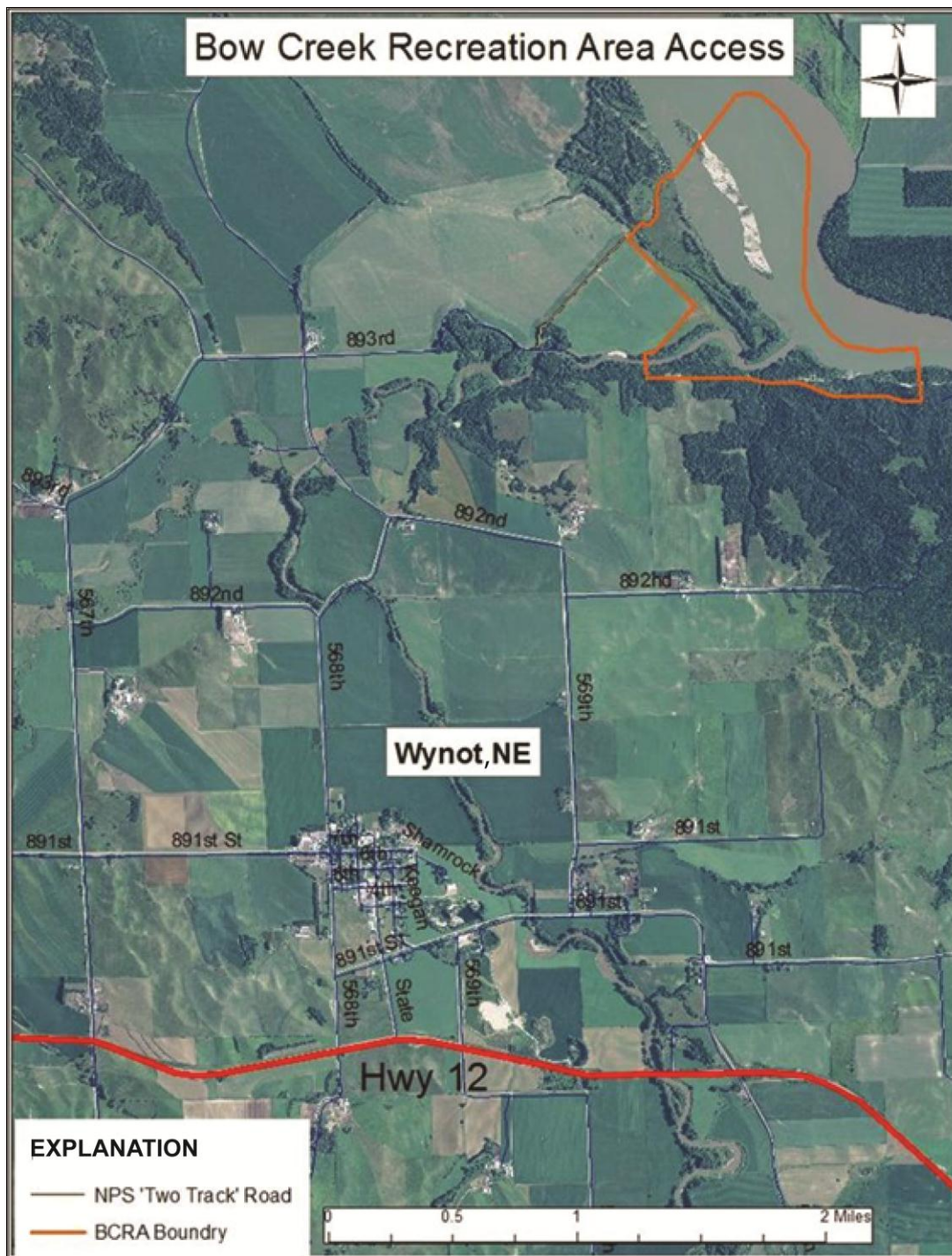


Figure 8. Location of the Bow Creek Recreation Area (BCRA), Nebraska.

Monitoring of tributaries of the Missouri NRR will follow established NPGN Standard Operating Procedures (SOPs) that are presented in the Water Quality Monitoring Protocol for Wadeable Streams and Rivers in the Northern Great Plains Network (Wilson et al. 2013). These SOPs include:

- SOP 1: Pre-season Preparations
- SOP 2: Selection of Water Quality Monitoring Sites
- SOP 3: Measurement of Water Quality Parameters at Index Sites
- SOP 4: Measurement of Streamflow at Index Sites
- SOP 5: Data Management (Quality Assurance/Quality Control)
- SOP 6: Data Acquisition and Analysis
- SOP 7: Reporting
- SOP 8: Post-season Procedures
- SOP 9: Protocol Revision

Water quality monitoring at the selected index sites will consist of measurement of field core parameters including dissolved oxygen, pH, specific conductance, and temperature using a YSI sonde model 6920 or similar instrument/model of equal quality. Sites will be monitored during ice free months from mid-April to mid-October for each scheduled sampling year. Measurements will be collected every 15 minutes during sonde deployment. To maintain high data quality, the frequency of site visits will be scheduled for 3-week intervals with three extra trips to address standard maintenance protocols for fouling and calibration drift (Wagner et al. 2006). Additional details of water quality monitoring are provided in Wilson et al. (2013).

Streamflow (discharge) and stage are used to better understand water quality data. The USGS has been measuring daily discharge since 1928 and water temperature since 1958 at the Niobrara River near Verdel and currently (2012) supplies real-time data that can be obtained from the USGS NWIS web site at <http://waterdata.usgs.gov/nwis>. Streamflow and gauge height were measured at the Bow Creek index site by the USGS during 1979–1994, and core parameter data are available for three measurement events during 1989. Because the Bow Creek index site currently is not instrumented with pressure sensors, a data collection platform capable of high-data-rate satellite transmission needs to be constructed.

FIB will be measured at each site following an NGPN established SOP (Wilson et al. 2013) or an accepted alternative method that has been developed by the individual State in which the data are collected. Data collected by the NGPN I&M program in addition to the historical data will allow for long-term water quality trends analyses for the Bow Creek and the Niobrara River index sites.

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Glossary of Terms

303(d) list: a comprehensive public accounting of all impaired or threatened waterbodies within each State, regardless of the cause or source of the impairment or threat.

Designated beneficial uses: the desirable uses that water quality should support. In general, beneficial uses include drinking water supply, primary contact recreations (such as swimming), and aquatic life support. Each designated use has a unique set of water quality requirements or criteria that must be met for the use to be supported. A waterbody may have multiple beneficial uses. A waterbody is considered impaired when it does not attain the water quality standards needed to support its designated uses.

Dissolved oxygen (DO): the measure of the amount of oxygen in the water column. Dissolved oxygen in rivers and streams typically declines as the temperature increases and as flow decreases, and also responds to photosynthesis resulting in natural variation during the day and additional natural variation through the season. DO in water can vary over extended periods of time due to changes in the landscape or climate. DO levels are considered as important indicators of a water body's ability to support aquatic life.

Impaired or threatened waterbody: any waterbody that is listed according to section 303(d) of the Clean Water Act. A waterbody is considered impaired if it does not attain water quality standards that are set by the State. Standards may be violated due to an individual pollutant, multiple pollutants, thermal pollution, or an unknown cause of impairment. A waterbody is considered threatened if it currently attains water quality standards but is predicted to violate standards by the time the next 303(d) list is submitted to the U.S. Environmental Protection Agency.

Index site: a location determined to be relatively representative of the stream segment within park boundaries and logistically is feasible to sample water chemistry parameters.

Indicators: a subset of monitoring attributes that is information-rich because their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems selected to represent the overall health or condition of the system.

Inventory: an extensive point-in-time survey to determine the presence/absence, location, or condition of a biotic or abiotic resource.

Measures: specific feature(s) used to quantify an indicator, as specified in a sampling protocol. For example, pH, temperature, dissolved oxygen, and specific conductivity are all parameters that can be measured in waterbodies.

Monitoring: collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective. Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry.

Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory.

Multiprobe: the combination of several sensors, electrodes, or probe assemblies into a complete, stand-alone piece of equipment that simultaneously measures several parameters for profiling, spot checking, or logging readings and data. A multiprobe is a multi-parameter instrument typically with built-in algorithms that may automatically compensate measurements (e.g. dissolved oxygen, pH, turbidity) for other parameters measured simultaneously such as temperature and conductivity.

Northern Great Plains Network (NGPN): includes 13 constituent parks, their staffs, NPS staff stationed with the NGPN I&M office in Rapid City (I&M core staff), and other NPS and non-NPS collaborators developing and implementing the NGPN long-term monitoring and inventory program.

pH: the measure of the hydrogen ion concentration in a solution. pH values of less than 7 indicate that water is acidic, a pH value of 7 indicates that water is neutral, and pH values greater than 7 indicate that water is alkaline. The pH for surface water typically ranges from 6.5 to 8.5 and rainfall is more acidic (around 5). Changes in pH may provide indications of changes in the source water and within the watershed. pH is also dependent on atmospheric deposition (acid rain) and the composition of the surrounding rock. Different organisms flourish within different ranges of pH.

Power analysis: The power of a statistical test is the probability that the test will reject a false null hypothesis, or in other words that it will not take a Type II error. As power increases, the changes of a Type II error decrease, and vice versa. The probability of a Type II error is referred to as b . Therefore power is equal to $1 - b$. Power is a function of effect size or minimum detectable change, variance of the parameter (e.g., standard error of the mean), and sample size. A power analysis determines the probability of correctly rejecting a false null hypothesis given fixed values of effect size, variance, and sample size.

Protocols: detailed design plans that explain how data are to be collected, managed, analyzed, and reported and are a key component of quality assurance for natural resource monitoring programs.

Revisit design: schedule for visiting and measuring sample units (monitoring sites) across years.

Sampling design: method of choosing monitoring sites from the target population within each park and the schedule for collecting data from these sites.

Specific conductivity (SC): the measurement of the water's ability to conduct electricity. Concentrations of conductivity typically are proportional to the dissolved major ions in the water such as calcium, magnesium, sodium, and sulfate. A change in conductivity is an indication of a change in the concentrations of these various major ions. Small changes in conductivity are common through the day and through the seasons.

Status: the quantitative condition of a park resource across all monitoring sites at a single point in time or over a temporal window.

Temperature (T): water temperature is affected by solar radiation, air temperature, rainfall, flow dynamics, physiography of the water body (i.e., depth), and the amount of development in the watershed. Water temperature monitoring indicates response to daily and annual climatic variations and may track short-term drought or long-term climate changes. Temperature can also be an indicator of changes in water use, source, and flow dynamics. Aquatic organisms are dependent on specific temperature ranges for their optimum health and survival.

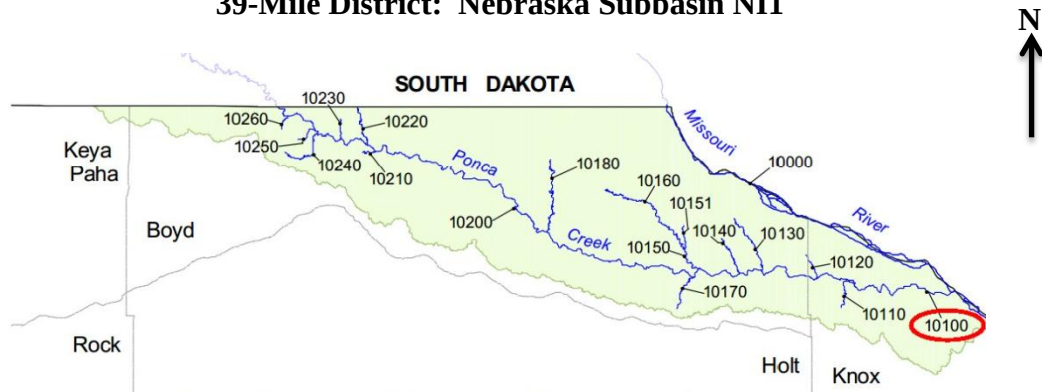
Total Maximum Daily Load (TMDL): the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards regarding assigned beneficial uses.

Trend: directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units).

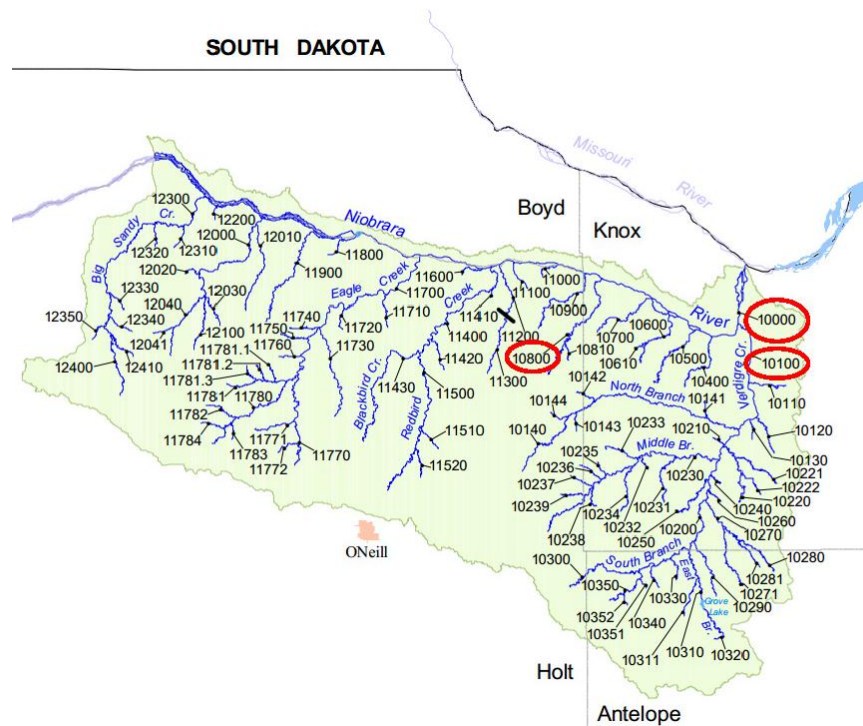
Vital Signs: as used by the National Park Service, a subset of physical, chemical, and biological elements and processes of park ecosystems selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The monitored elements and processes are a subset of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations,” including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Appendix 1. Map showing 303(d) impairments within a 20-mile buffer of the Missouri NRR within the 39-Mile District and the 59-mile District within Nebraska. Numbers represent segments within a stream (Nebraska Department of Environmental Quality 2010). Impaired segments are outlined with a red oval¹.

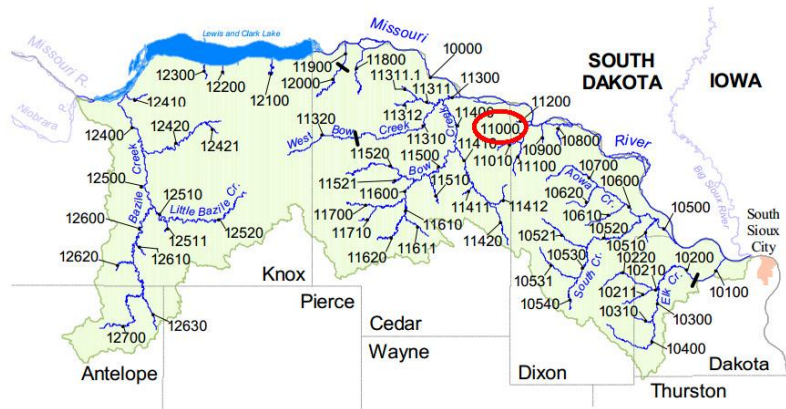
39-Mile District: Nebraska Subbasin NI1



39-Mile District: Nebraska Subbasin NI2



59-Mile District: Nebraska Subbasin MT2



1 Segment NE-NI1-101000 is Ponca Creek. Segments NE-NI2-10000, 10100, and 10800 are Niobrara River, Verdigre Creek, and Steel Creek respectively. Segment MT2-11000 is Lime Creek in the 59-Mile District.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 651/121799, July 2013

National Park Service
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