

U.S. Army Corps of Engineers
Omaha District

**A SCOPING STUDY OF WATER QUALITY CONDITIONS
IN THE MISSOURI NATIONAL RECREATIONAL RIVER
REACH FROM NEAR GAVINS POINT DAM TO PONCA
STATE PARK, NEBRASKA**



March 2002

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**A SCOPING STUDY OF WATER QUALITY CONDITIONS IN THE MISSOURI
NATIONAL RECREATIONAL RIVER REACH FROM NEAR GAVINS POINT DAM
TO PONCA STATE PARK, NEBRASKA**

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March 2002

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1. INTRODUCTION

The unchannelized reach of the Missouri River below Gavins Point Dam has several ongoing water resource management issues that involve and affect the U.S. Army Corps of Engineers (Corps). Water quality management considerations are of particular importance to three issues: 1) management of a portion of the reach as a recreational river under the Federal Wild and Scenic Rivers Act, 2) the reach is included in an action area identified by the U.S. Fish and Wildlife Service (USFWS) under the Federal Endangered Species Act (ESA) for three species (pallid sturgeon, least tern, and piping plover) identified as being in jeopardy, and 3) the State of Nebraska has given the reach Tier 3 protection under the antidegradation provisions of the state's water quality standards and Federal Clean Water Act (CWA). To facilitate identification of water quality management concerns and information needs regarding these issues, the Omaha District's Water Quality Unit (ODWQU) conducted a scoping study of water quality conditions on the portion of the reach from Gavins Point Dam to Ponca State Park, Nebraska.

1.1. BACKGROUND

1.1.1. Wild and Scenic Rivers Act Provisions

The approximate 57-mile reach of the Missouri River from about one-mile below Gavins Point Dam to Ponca State Park, Nebraska has been classified as a recreational river under the Federal Wild and Scenic Rivers Act. All the rivers in the Wild and Scenic System must be free-flowing and the related adjacent land must possess outstanding remarkable characteristics for at least one of the following: scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. The Secretary of the U.S. Department of Interior is mandated to administer the river in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations. Therefore, the recreational, fish and wildlife, aesthetic, historical, and cultural values that qualified the segment for designation are to be protected and enhanced. Plate 1 shows the location of the Missouri National Recreational River (MNRR) reach within the Omaha District.

The National Park Service (NPS) is designated as the overall administrator of the MNRR. In 1999, the Corps and the NPS jointly finalized an updated version of the General Management Plan (GMP) for the MNRR. The existing GMP, which was developed in 1980, was updated because of the identification of additional federally-designated threatened and endangered species that inhabited the reach. The new GMP provides a management strategy to protect and enhance the values for which the reach was designated as a recreational river, which includes "fish and wildlife" values. The NPS and the Corps manage the MNRR through a cooperative agreement with the NPS generally administering land-related resources and the Corps generally managing water-related resources. Bank stabilization is still a project component, primarily to protect the MNRR values.

1.1.2. Endangered Species Act and Biological Opinion Provisions

The Corps, in early 2000, requested that formal Section 7 consultation under the ESA begin with the USFWS on Corps projects affecting the Missouri River. An ESA Section 7 consultation addresses the effects of a Federal action on listed species and the ecosystem upon which they depend. An ecosystem-based consultation was conducted that addressed three

listed bird species – bald eagle (threatened), Interior population of the least tern (endangered), and Northern Great Plains population of the piping plover (threatened); and one fish species – pallid sturgeon (endangered). A Biological Opinion (BiOp) regarding the four evaluated species was issued concerning the continuing operation and maintenance of the following Missouri River Basin Corps projects:

- Missouri River Main Stem Reservoir System,
- Kansas River Tributary Reservoir System, and
- Maintenance of the Missouri River Bank Stabilization and Navigation Project.

The BiOp stated that the continuing operation of these projects is likely to jeopardize the continued existence of the least tern, piping plover, and pallid sturgeon, but is not likely to jeopardize the continued existence of the bald eagle.

Of the three species identified to be in jeopardy, water quality conditions have the most direct impact on the pallid sturgeon. Pallid sturgeon historically occupied warm, turbid river systems. Current research indicates that pallid sturgeon spawning is directly linked to water temperature – as water temperature increases to 16.7° to 18.3°C (62° to 65°F) pallid sturgeon initiate spawning activity (USFWS, 2000). Current operation of the Fort Peck, Garrison, and Fort Randall Dams with hypolimnetic hydropower releases, provides unsuitable colder water temperatures that negatively impact spawning by native river fishes, including the pallid sturgeon, and production at all trophic levels (USFWS, 2000). More suitable water temperatures for native fish spawning and invertebrate production exist in the free-flowing river below Gavins Point Dam. Pallid sturgeon avoid areas without turbidity and current (Bailey and Cross, 1954 and Erickson, 1992). Turbidity levels below all the Missouri River mainstem reservoirs have been significantly reduced from pre-impoundment conditions due to sediment trapping in the impounded reservoirs. Due to the long potential life span of pallid sturgeon (i.e., greater than 50 years), the fish is particularly susceptible to the bioaccumulation of pollutants that may contribute to early mortality and reduced reproductive viability. The BiOp stated the Corps was to consider the Missouri River reaches from Fort Peck Dam to Lake Sakakawea and from Gavins Point Dam to the Mississippi River as high priority segments for pallid sturgeon management efforts (USFWS, 2000). The reach from Gavins Point Dam to the Mississippi River was also one of four recovery priority management areas on the Missouri River identified by the Pallid Sturgeon Recovery Plan (USFWS, 1993) for priority implementation of recovery actions.

The BiOp stated that the Corps should adopt adaptive management as one tool to preclude jeopardy to least terns, piping plovers, and pallid sturgeon. The BiOp requested that the Corps: 1) evaluate the cumulative effects of bank stabilization, as permitted by the Corps, to determine to what extent continued stabilization is reducing sedimentation, turbidity, import of organic matter, and elimination of cut-bank habitat on the Missouri River; 2) evaluate the capability and practicality of increasing water temperature of the Missouri River in priority reaches during critical periods for native warm-water fish through adjustment of water discharge requirements for power plants and other industries; 3) research and develop a way to restore the dynamic equilibrium of sediment transport and associated turbidity in river reaches downstream of Fort Peck, Garrison, Fort Randall, and Gavins Point Dams; and 4) restore turbidity to functional levels downstream of Fort Peck, Fort Randall, and Gavins Point Dams. Given the water quality issues raised by the BiOp, the collection of targeted water quality data could greatly facilitate implementation of an adaptive management approach by the Corps.

1.1.3. Nebraska Water Quality Standards Provisions

The MNRR reach has been designated by the State of Nebraska as a State Resource Water – Class A in its water quality standards (NDEQ, 2000). By Nebraska's definition, Class A State Resource Waters constitute an outstanding State or National resource, such as waters within national or state parks, national forests or wildlife refuges, and waters of exceptional recreational or ecological significance. These include waters that provide a unique habitat for federally designated endangered or threatened species and rivers designated under the Wild and Scenic Rivers Act. Designation of a waterbody as a Class A State Resource Water in Nebraska's water quality standards identifies that waterbody for Tier 3 protection under the state's antidegradation policy. Tier 3 protection as an Outstanding National Resource Water is also inferred to the MNRR reach under the Federal CWA's antidegradation provisions. The water quality implication of Tier 3 protection is that the existing water quality within the MNRR reach must be maintained and protected.

The CWA requires water quality to be maintained and protected in Tier 3 waters. The U.S. Environmental Protection Agency (EPA) has interpreted this provision to mean no new or increased discharges to Tier 3 waters and no new or increased discharge to tributaries of Tier 3 waters that would result in lower water quality in the Tier 3 waterbody. The only exception to this prohibition, as discussed in the preamble to the Water Quality Standards Regulation (48 F.R. 51402), permits States to allow some limited activities that result in temporary and short-term changes in the water quality of Tier 3 waters. Such activities must not permanently degrade water quality or result in water quality lower than that necessary to protect the existing uses in the Tier 3 waterbody. The intent of EPA's provision clearly is to limit water quality degradation to the shortest time possible (USEPA, 1994).

1.2. WATER QUALITY CONSIDERATIONS

1.2.1. Need for Water Quality Data in the MNRR Reach

Water quality data is needed by the Corps in the MNRR reach to facilitate current and future efforts regarding: 1) the management of the reach as a recreational river, 2) enhancing riverine habitat in the reach for jeopardized species, and 3) management of water quality in the reach pursuant to the antidegradation provisions of the State of Nebraska's water quality standards and the CWA. Water quality conditions are intrinsic to the values for which the reach was designated a recreational river under the Wild and Scenic Rivers Act. Knowing baseline water quality conditions and how water quality may be changing due to anthropogenic influences is paramount to managing the water resource aspects of the recreational river. Water temperature, turbidity, nutrient cycling, and sediment transport are water quality factors that have been identified as concerns regarding the jeopardization of pallid sturgeon, least terns, and piping plovers in the Missouri River. Documenting existing water quality conditions in the MNRR will facilitate the evaluation of any implemented actions to enhance water quality conditions for jeopardized species in the reach. Gaining insights into whether pollutants could be impacting the pallid sturgeon population in this reach of the Missouri River is also important. Knowing existing water quality conditions for pertinent parameters is also needed to facilitate implementation of the Tier 3 antidegradation provisions applicable to the reach.

1.2.2. Water Quality Scoping Study

A preliminary review of water quality monitoring activities along the MNRR reach found limited historic and ongoing water quality sampling. The Corps is collecting water quality data at

the Gavins Point Dam discharge. Although this sampling has occurred over a fairly lengthy time, the water quality parameters monitored are limited to water temperature, dissolved oxygen, pH, and conductivity. The Nebraska Department of Environmental Quality (NDEQ) has sampled the Missouri River at Ponca State Park on a periodic basis (i.e., every 5 years) as part of its rotating river basin monitoring network. The City of Yankton utilizes the Missouri River as a drinking water source, and regularly monitors the “raw” river water for numerous water quality parameters. Water quality data to define temporal and spatial water quality conditions throughout the MNRR reach are generally lacking.

In an initial effort to begin addressing the water quality information needs for the MNRR reach, the ODWQU conducted a scoping study of water quality conditions within the reach. The monitoring objectives established for the scoping study were:

- 1) Define “baseline” water quality conditions for the period of the study.
- 2) Assess longitudinal variation in selected parameters from the upstream to downstream boundaries of the MNRR reach.
- 3) Assess “horizontal” (i.e. thalweg versus backwater) and “vertical” (i.e., near-surface versus near-bottom) variation of selected water quality parameters.
- 4) Assess the impact, if any, that the inflows of the James and Vermillion Rivers have on turbidity levels in the Missouri River. Estimate the suspended solids load being delivered by these tributary rivers to associate with measured turbidity levels in the Missouri River above and below the tributary inflows.

Monitoring for the scoping study occurred over a 6-week period from late August through September 2001, and included the collection of water quality samples at 9 locations.

2. DESCRIPTION OF STUDY AREA

2.1. SURFACE WATER HYDROLOGY

The MNRR reach starts about one mile below Gavins Point dam and extends downstream to Ponca State Park in Nebraska; a distance of approximately 57 miles. Two major tributaries, the James and Vermillion Rivers, flow into the reach from South Dakota (Plate 2). Several small tributaries (Beaver Creek, Antelope Creek, Bow Creek, Ames Creek, Lime Creek, Deer Creek, Walnut Creek, Turkey Creek, and Gibbs Creek) flow into the reach from Nebraska.

2.2. WATERSHED CHARACTERISTICS

The 8-digit Hydrologic Units (HUCs) that make up the watershed of the MNRR reach below Gavins Point Dam are shown in Plate 2 and described in Table 1. The size of the watershed contributing runoff to the MNRR reach below Gavins Point Dam is approximately 25,120 square miles. Of the total 25,120 square mile watershed, approximately 21,590 square miles is in the James River watershed and approximately 2,650 square miles is in the Vermillion River watershed. Approximately 880 square miles is in the watersheds of the other tributaries discharging directly to the MNRR reach (mainly from tributaries in Nebraska). The coteau region, HUCs 10160007, 10160010, and 10170103 (2,530 square miles), are largely internally drained and generally non-contributing to surface water runoff within the watershed.

The predominate land use within the watershed is agricultural, with both cropland and livestock operations present. There are numerous industries in the James River basin, most which are related to agriculture (SDDENR, 1998). Major towns in the watershed include

Vermillion, South Dakota (population 11,970), Yankton, South Dakota (14,330), Mitchell, South Dakota (14,390), Huron, South Dakota (17,180), Aberdeen, South Dakota (24,870) and Jamestown, North Dakota (15,570). All of these towns, except Vermillion, are in the James River basin.

2.3. WATER QUALITY CONDITIONS AND CONCERNS IDENTIFIED IN STATE 305(B) REPORTS

2.3.1. Missouri River (MNRR Reach)

Assessment of water quality conditions in the MNRR reach of the Missouri River in state 305(b) reports is limited. The State of Nebraska's 2000 305(b) report indicates that water quality in the MNRR reach was relatively good for the assessed period. This was based on water quality samples collected in 1995 from the Missouri River at Ponca State Park (i.e., lower end of MNRR reach). The 1995 sampling indicated that fecal coliform bacteria concentrations were supportive of the designated recreational use, and concentrations of the herbicides atrazine and alachlor met acute and chronic water quality standards criteria.

2.3.1.1. James River Basin (South Dakota)

[Note: The following discussion on the James River basin is taken directly from the State of South Dakota's 1998 305(b) Water Quality Assessment Report.]

Water quality in the James River basin has shown steady improvement over the past 10 years. Better water quality may have resulted in a large part due to completed and ongoing projects for construction and rehabilitation of wastewater treatment facilities for small municipalities and the City of Huron. Completion of an upgrade of the Huron wastewater facility should prevent further emergency discharges which in the past have been responsible for fish kills in the James River. However, river turbidity (cloudy or muddy water) may remain a persistent problem in the James River due to the considerable silt and sediment periodically brought in by its many small tributaries and the large amount of previously accumulated material on the river bottom.

Most of the lower James River basin fully supported its beneficial uses during the assessment period of 1992-97. Moderate impairment was caused by elevated total suspended solids (TSS) in the lowest reach. Minor impacts over the entire lower half of the river course were mainly elevated TSS, fecal coliform, total dissolved solids, pH, and low dissolved oxygen. Oxygen levels in the lower river appeared to have improved since previous assessments whereas instances of elevated TSS (>90 mg/l) increased in 1993 and were particularly high from 1993 to 1995. More rainfall and greater river flows in the area may have further increased stream turbidity at that time.

2.3.1.2. Vermillion River Basin

[Note: The following discussion on the Vermillion River basin is taken directly from the State of South Dakota's 1998 305(b) Water Quality Assessment Report.]

The water quality in the Vermillion River basin is usually marginal for the designated beneficial uses – most often the result of elevated total suspended solids (TSS). During the previous two reporting periods (1991-1995) the warmwater fishery use continued to be impacted by excessive TSS which represented the sole cause of non-support for the entire drainage. Moderate increases in TSS were noted during 1995-1997 which was a similarly wet period in

the watershed. Total dissolved solids showed a moderate decline although there was little change in water pH between reporting cycles. A moderate impairment for secondary contact was noted in the upper and lower reach of the river due to elevated fecal coliform numbers.

Overall water quality in the basin has remained relatively stable since 1986 with moderate fluctuations in TSS during most years and a decline in fecal coliform concentrations from the levels reported in 1986. The present evaluation of the lower quarter of the river course covered 5.75 years of accumulated data and resulted in a rating of non-support due to excessive TSS and moderate impairment owing to elevated fecal coliform bacteria concentrations.

3. METHODS

3.1. MONITORING LOCATIONS AND SAMPLING SITES

3.1.1. Location of Monitoring Sites Along the MNRR Reach

A total of nine monitoring locations were established on the Missouri, James, and Vermillion Rivers as part of the scoping study (Plate 3). Location 1 was on the Missouri River approximately 1 mile below Gavins point Dam at Missouri River Mile (RM) 810 and consisted of a thalweg site only (Plate 4). Location 2 was on the Missouri River, approximately 0.5 miles above the confluence of the James River at RM 801, and had both a thalweg and backwater site (Plate 5). Location 3 was on the James River approximately 0.5 miles upstream from the Missouri River, and water quality samples were collected at a single mid-channel site (Plate 5). Location 3T was located on a side channel of the Missouri River that received the inflow of the James River, and four sites (3T1, 3T2, 3T3, and 3T4) were sampled along an approximate 2 mile distance of the side channel downstream from the mouth of the James River (Plate 5). Location 4 was on the Missouri River, approximately 1 mile below where the side channel receiving the James River flow enters the main channel flow of the Missouri River at RM 797, and consisted of both a thalweg and backwater site (Plate 5). Location 5 was on the Missouri River approximately 1 mile upstream from the confluence of the Vermillion River at RM 774, and consisted of both a thalweg and backwater site (Plate 6). Location 6 was on the Vermillion River approximately 0.5 miles upstream of its confluence with the Missouri River and water quality samples were collected at a single mid-channel site (Plate 6). Location 7 was on the Missouri River, approximately 0.5 miles below the confluence of the Vermillion River at RM 771, and consisted of both a thalweg and backwater site (Plate 6). Location 8 was on the Missouri River at Ponca State Park, Nebraska at RM 753 and consisted of both a thalweg and backwater site (Plate 7).

3.1.2. Sampling Sites

Sampling sites consisted of four types: 1) thalweg, 2) backwater, 3) special turbidity, and 4) tributary. Thalweg sites were defined as locations on the Missouri River where the current was fast (> 2 ft/sec) and the water was deep (> 5 ft). Thalweg sites were sampled at all Missouri River monitoring locations (i.e., Locations 1, 2, 4, 5, 7 and 8). Backwater sites were defined as locations on the Missouri River where the current was slow (< 2 ft/sec) and the water was shallow (< 5 ft). Backwater sites were sampled at all Missouri River locations except Location 1 (i.e., Locations 2, 4, 5, 7, and 8); no extensive backwater conditions existed at Location 1. Special turbidity sites were established on a side channel of the Missouri River into which the James River discharges (i.e., Locations 3T1, 3T2, 3T3, and 3T4). These sites were

established to further evaluate the effects of the James River on turbidity levels in the Missouri River. Tributary sites were located on the James and Vermillion Rivers (i.e., Locations 3 and 6).

3.2. DETERMINATION OF WATER QUALITY CONDITIONS

3.2.1. Field Measurements

Field measurements were obtained using a Hydrolab, Secchi disc, and GPS receiver. A Hydrolab DataSonde 4 was used to take measurements of water quality conditions within one-meter of the surface at all monitoring locations. The water quality conditions measured were water temperature, dissolved oxygen, pH, and conductivity. A Secchi disc was used to measure visual water clarity. A black-and-white Secchi disc was bolted to the end of a pole with a tape measure attached. The pole was used to maintain the Secchi disc parallel to the water surface in the current. The Secchi disc was lowered into the water until the image was judged to just disappear from view. This depth, in inches, was determined from the tape measure and recorded as the Secchi depth. Geo locational data were obtained at each site when a water quality sample was collected. A Garmin, GPSmap 76, hand-held GPS receiver was used to obtain geo-positional data. This GPS unit has a minimum accuracy of 15 meters. All field measurement were taken weekly during the six-week sampling period.

3.2.2. Sample Collection

All water samples for laboratory analysis were collected from a boat anchored at the site being sampled. Near-surface and near-bottom water quality samples were collected weekly at the appropriate sampling sites.

3.2.2.1. Near-Surface Samples

Near-surface water quality samples were collected at all the monitoring locations and sampling sites (i.e., 1T, 2B, 2T, 3, 3T1, 3T2, 3T3, 3T4, 4B, 4T, 5B, 5T, 6, 7B, 7T, 8B, and 8T). Near-surface water samples were collected by dipping a plastic bucket, equipped with a churn, below the water surface and filling the bucket. The bucket was rinsed with site water prior to collecting the sample. Two plastic one-liter bottles were filled from the bucket as it was churned. One bottle was preserved with 5 ml of concentrated sulfuric acid and the other was left unpreserved. When herbicides were to be analyzed a third one-quart glass, amber bottle was also filled.

3.2.2.2. Near-Bottom Samples

Near-bottom water samples were collected at all the thalweg sampling sites (i.e., 1T, 2T, 4T, 5T, 7T, and 8T). Near-bottom water samples were collected by lowering a weighted Kermmerer sampler to the bottom and triggering the device. The triggered sampler was retrieved to the surface and the contents emptied into the plastic bucket equipped with a churn. A single one-liter plastic bottle was filled from the bucket as it was churned.

3.2.3. Laboratory Analysis and Sample Preservation

The collected water samples were delivered to the Corps Waterways Experiment Station (WES) laboratory in Omaha, Nebraska for analysis within 24 hours of their collection. Laboratory analysis of the samples consisted of turbidity; total suspended solids, total organic carbon, total phosphorus, total Kjeldahl nitrogen, total ammonia, nitrate/nitrite nitrogen,

chlorophyll *a*, atrazine, alachlor, and metolachlor. Table 2 gives the method, method detection limit, and reporting limit for each of the parameters analyzed. Values greater than the method detection limit and less the reporting limit were qualified as estimated values. Near-surface thalweg and tributary samples were analyzed for all of the above parameters with the exception that the three herbicides (alachlor, atrazine, and metolachlor) were analyzed for every other week. Near-bottom thalweg samples were analyzed for turbidity and suspended solids. Backwater samples were analyzed for turbidity, suspended solids, and chlorophyll *a*. Special turbidity sites were analyzed for turbidity only. Samples for nutrient analyses were preserved with 5 ml of concentrated sulfuric acid when collected. All samples were placed on ice as soon as possible after collection.

3.3. FLOW ESTIMATION

Accounting for discharge is a primary consideration in any riverine water quality study. Generally, a great deal of the variance in water quality variables in a riverine setting is a function of discharge. This is a result of two different kinds of physical phenomena: dilution and wash off (Hirsch et. al, 1991). If a constituent is being delivered to a river or stream at a reasonably consistent rate (e.g., a point source or ground water discharge), as river flows increase these constituents will tend to be diluted and their concentrations reduced. Wash off from the watershed due to overland flow and streambank erosion can transport a solute, sediment, or a constituent attached to sediment into a river or stream. Under these runoff situations, the concentrations of nonpoint source pollutants tend to rise with increasing discharge. When the flow in a river or stream is regulated by dam releases, water quality in the river below will be highly dependent upon the water quality in the reservoir behind the dam and the discharge rate. Water quality conditions in a regulated river can be a reflection of all of these situations occurring at the same time. Knowing river flows when water quality constituents are measured can go a long way in helping to explain the variability in water quality conditions.

Flows through the MNRR reach were estimated from existing stream gaging stations. Plate 8 shows the location and type of permanent flow gaging stations on the MNRR reach and on tributaries in close proximity to the reach. Mean daily discharge values for the period August 17 through September 26, 2001 were calculated for the five gages capable of recording discharge (i.e., Gavins Point Dam, Scotland Gage, Vermillion Gage, Akron Gage, and Sioux City Gage). Flow in the Missouri River from Gavins Point Dam down to the James River was defined as the discharge from Gavins Point Dam. Flow in the Missouri River from the James River to the Vermillion River was defined as the discharge from Gavins Point Dam plus the flow measured in the James River at the Scotland gage. Flow in the Missouri River below the Vermillion River was taken to be the discharge from Gavins Point Dam plus the James River flow measured at the Scotland gage plus the Vermillion River flow measured at the Vermillion gage. This process discounted the flows contributed to the James and Vermillion Rivers below the Scotland and Vermillion gage sites and the flow contributed by the other tributaries discharging directly to the Missouri River. It is noted that the flow at the downstream boundary of the MNRR reach could also be estimated as the flow recorded at the Sioux City gage minus the flow recorded at the Akron gage. This discounts flow contributed to the Big Sioux River below the Akron gage and flow contributed by tributaries discharging to the Missouri River downstream from the lower boundary of the MNRR reach (e.g., Aowa Creek in Nebraska). Table 3 gives the mean daily discharge values for the five gages determined for the period August 17 through September 26, 2001.

To verify flows through the MNRR reach, a water balance was constructed that compared the estimated flow at the end of the MNRR reach as determined by the addition of the

upstream gages (i.e., Gavins Point Dam, Scotland gage, and Vermillion gage) and as determined by the subtraction of the Akron gage from the Sioux City gage. Table 4 gives the estimated mean daily flows out of the MNRR reach based on these two methods. The average daily flow for the period of August 17 through September 26 determined by adding the upstream gages was 27,565 cfs, while the average daily flow determined from the downstream gages was 27,985 cfs; a difference of 420 cfs (1.52%). The relative percent difference (RPD) between the same day mean daily flows determined from the two methods was calculated (Table 4). The mean RPD value based on 41 pairings was 2.16%. It is noted that the Corps has determined the channel velocity of the Missouri River through the MNRR reach ranges from about 2 to 5 ft/sec. Using an average velocity of 3.5 ft/sec (2.4 mph) an estimated time-of-travel through the 57-mile reach would be about 24 hours. Based on the estimated time-of travel, RPD values were also determined by pairing a 1-day delay in the downstream estimate (i.e., the downstream estimate was paired with the previous day upstream estimate). This resulted in a mean RPD value based on 40 pairings of 1.60%. The RPD values indicate that the two estimation methods yielded very similar results – the addition of the upstream gages (i.e., Gavins Point Dam, Scotland, and Vermillion) account for about 98% of the flow occurring through the MNRR reach as estimated by the downstream gages.

3.4. ASSESSMENT OF WATER QUALITY DATA

The water quality data collected during the scoping study were assessed in the following ways: 1) descriptive statistics (i.e., mean, median, minimum, and maximum) were calculated for all measured parameters, 2) box plots were constructed to visually display the distribution of the measurements for each parameter, and 3) a simple two-tailed, paired t-test was used to test for significant differences between selected monitoring locations and sampling sites. It was assumed that the collected data met the requirements for application of parametric statistics (i.e., normality, homogenous variance, and independence of observations). This assumption was believed valid since no major runoff events occurred during the scoping period. Episodic runoff events tend to skew water quality data and cause the assumptions for use of parametric statistics to be violated. It is also noted that the calculated mean and median values for most measured parameters were quite similar (Table 5).

3.5. DATA QUALITY INDICATORS

Quality assurance/quality control (QA/QC) samples, a field blank and duplicate, were created on each sampling trip to evaluate the quality of the data generated by the scoping study. These QA/QC samples were in addition to the internal QA/QC samples utilized by the WES Laboratory as part of the Laboratory's QA/QC program. The six field blank samples were used to generate a data quality indicator for accuracy. De-ionized water was used to fill a set of sample containers at a random monitoring location. The field blanks were handled identically as the site samples. The measurement quality objective that was established for accuracy was that the field blanks should be below detection limits for all parameters analyzed for in the laboratory. The six collocated field duplicate samples were used to generate a data quality indicator for precision. A collocated sample was collected at random from a near-surface thalweg sampling site on each of the six sampling trips. The measurement quality objective established for precision was that the collocated samples should not deviate by more than 25%, as measured by their relative percent difference.

4. RESULTS AND DISCUSSION

4.1. GENERAL WATER QUALITY CONDITIONS

A statistical summary of the water quality conditions monitored at the surface thalweg and tributary sites during the scoping study is given in Table 5. Monitored dissolved oxygen, pH, and total ammonia values were supportive of state water quality standards at all times. Of the three herbicides measures, only atrazine was present in levels above the detection limit of 0.05 µg/l. The only site where the measured atrazine levels were above the reporting limit of 0.1 µg/l was Site 6 (i.e., Vermillion River) where the measured values ranged from 0.07 to 0.28 µg/l. Measured conductivity, turbidity, total organic carbon, total phosphorus, and total kjeldahl nitrogen levels were noticeable higher and the measured secchi depths noticeable lower at the tributary sites on the James and Vermillion Rivers. All measured total suspended solids concentrations were at or below 100 mg/l and all measured nitrate-nitrite nitrogen concentrations were below 0.2 mg/l. Chlorophyll a concentrations were highly variable at all sites.

4.2. LONGITUDINAL VARIATION IN WATER QUALITY

Longitudinal variation in water quality through the MNRR reach was evaluated by assessing the water quality conditions monitored at “completely-mixed” near-surface thalweg sampling sites. Of the six near-surface thalweg monitoring sites along the Missouri River (i.e., Sites 1Ts, 2Ts, 4Ts, 5Ts, 7Ts, and 8Ts), two sites, 4Ts and 7Ts, did not represent completely-mixed conditions. Site 4Ts, although located below the mouth of the James River, did not represent water quality conditions in the Missouri River resulting from complete mixing of the James River inflow. The James River flows into the Missouri River from the north and enters a side channel of the Missouri River that is separated from the main channel of the river by a large island. Site 4Ts was located near the south bank of the Missouri River just downstream from the large island and was above the “plume” formed in the Missouri River from the James River inflow. Site 4Ts represented conditions very similar to Site 2Ts. Site 7Ts was located approximately one-half mile downstream from the mouth of the Vermillion River. The Vermillion River enters the Missouri River from the north and Site 7Ts was near the north bank of the Missouri River. In reviewing the water quality results it was determined that Site 7Ts did not represent the conditions of the Vermillion River inflow being completely-mixed with the Missouri River. Based on conductivity measurements, a slight plume of “Vermillion River water” was still noticeable at Site 7Ts. Longitudinal variation in water quality along the MNRR reach was assessed by comparing conditions at Sites 1Ts, 2Ts, 5Ts, and 8Ts.

Monitoring results were used to construct box plots for each parameter measured, except alachlor and metolachlor, at Sites 1Ts, 2Ts, 5Ts, and 8Ts during the scoping study. As noted previously, all samples analyzed for alachlor and metolachlor were below method detection limits. The constructed parameter box plots were plotted, by site, on a graph where the x-axis represented Missouri River mileage points (Plate 9). Based on this graphical representation it was determined that water temperature, pH, total organic carbon, total Kjeldahl nitrogen, total ammonia, nitrate-nitrite, chlorophyll a, and atrazine exhibited no noticeable longitudinal variation through the MNRR reach; while, dissolved oxygen, conductivity, Secchi depth, turbidity, total suspended solids, and total phosphorus did. For the six parameters that exhibited longitudinal variation it was concluded that no noticeable difference existed between Sites 1Ts and 2Ts; however, there was a noticeable difference between Sites 2Ts and 5Ts for all six parameters and Sites 5Ts and 8Ts for all the parameters except conductivity. Statistical assessment (two-tailed, paired t-test) of the measured values obtained at Sites 2Ts and 5Ts

where there was a noticeable difference observed in Plate 9, found the following significance levels (rounded to two significant digits): conductivity ($p = 0.02$), dissolved oxygen ($p = 0.05$), Secchi depth ($p = 0.03$), turbidity ($p < 0.01$), total suspended solids ($p < 0.01$), and total phosphorus ($p < 0.01$). A similar assessment of the measured values obtained at Sites 5Ts and 8Ts found the following significance levels: dissolved oxygen ($p = 0.04$), Secchi depth ($p = 0.05$), turbidity ($p = 0.02$), total suspended solids ($p = 0.01$), and total phosphorus ($p < 0.01$).

The differences between Sites 2Ts and 5Ts and Sites 5Ts and 8Ts for all the noted parameters except possibly dissolved oxygen are believed due to the respective inflows of the James and Vermillion Rivers. The differences in dissolved oxygen may be due to other factors. It is noted that the Sites 1Ts and 2Ts were sampled in the early morning, Site 5Ts was sampled around noon, and Site 8Ts was sampled in the late afternoon. The dissolved oxygen percent saturation levels measured at Sites 1Ts and 2Ts were in the low 90's, at Site 5Ts it was in the high 90's, and at Site 8Ts it was above 100%. This downstream pattern of increasing dissolved oxygen concentrations and percent saturations could be reflective of the "normal" diurnal changes in dissolved oxygen due to photosynthesis and respiration. It is also noted that the pattern could be the result of reoxygenation of lower oxygenated water discharged from the reservoir through Gavins Point Dam or a possible bias introduced into the measurements from meter drift.

4.3. LOCALIZED VARIATION IN WATER QUALITY

4.3.1. Near-Surface Versus Near-Bottom Thalweg Sites

Near-surface and near-bottom thalweg turbidity and total suspended solids levels were compared for each of the Missouri River monitoring locations (i.e., Locations 1, 2, 4, 5, 7, and 8). Side-by-side box plots of the near-surface and near-bottom samples for turbidity and total suspended solids are shown in Plates 10 through 15. A statistical assessment (two-tailed, paired t-test) of the turbidity results revealed that no significant difference ($\alpha = 0.10$) existed between the near-surface and near-bottom sites at any of the six assessed monitoring locations. Significant differences ($\alpha = 0.10$) in suspended solids levels did exist between the near-surface and near-bottom samples at monitoring locations 1 ($p = 0.08$), 2 ($p = 0.04$), and 7 ($p = 0.08$) -- in all cases, the total suspended solids concentrations were higher in the near-bottom samples (Plates 10, 11, and 14). The higher suspended solids levels in the near-bottom samples were attributed to the "bed load" material being transported near the bottom of the river. However, the magnitude of the difference between the near-surface and near-bottom suspended solids levels was small, and it did not result in significantly different turbidity levels.

4.3.2. Thalweg Versus Backwater Sites

Measured turbidity, total suspended solids, and chlorophyll *a* levels were compared for near-surface thalweg and backwater samples collected at monitoring locations 2, 4, 5, 7, and 8. Side-by-side box plots displaying the distribution of the measured levels at the five monitoring locations is presented in Plates 11 through 15. The statistical assessment (two-tailed, paired t-test) of the chlorophyll *a* results revealed that no significant difference ($\alpha = 0.20$) existed between the backwater and near-surface thalweg sites at any of the five monitoring locations. Significant differences ($\alpha = 0.05$) in the turbidity and total suspended solids levels existed between the backwater and near-surface thalweg sites at monitoring locations 4 and 7. The significant difference between the backwater and near-surface thalweg sites at monitoring location 4 is attributed to the effects of the James River inflow. The backwater site at this

location, which was in the plume formed below the James River inflow, had higher turbidity and total suspended levels than the near-surface thalweg site that was above the plume (Plate 12). The significant difference between the two sites at monitoring location 7 is believed due to the influence of the Vermillion River inflow. The near-surface thalweg site at this location, which was in the plume formed below the Vermillion River inflow, had higher turbidity and suspended solids levels than the backwater site that was above the plume (Plate 14). The only significant difference between the backwater and near-surface thalweg sites at monitoring locations 5 and 8, which represented completely-mixed conditions, was the difference in turbidity levels ($\alpha = 0.05$) at monitoring location 5. Turbidity levels were higher at the backwater site, but the magnitude of the difference was quite small (Plate 13).

4.4. EFFECTS OF THE JAMES AND VERMILLION RIVERS ON TURBIDITY IN THE MISSOURI RIVER

The inflow of the James River appears to have a significant influence on turbidity levels in the Missouri River (Plate 9). During the scoping study a turbidity plume was observed below the mouth of the James River in the side channel of the Missouri River into which it enters. This turbidity plume can visually be seen in the 1997 orthophoto of the area (Plate 16). Mean turbidity, Secchi depth, and conductivity values calculated from the data collected at Sites 2Ts, 3, 3T1, 3T2, 3T3, 3T4, 4B and 5Ts are given in Table 6. The plume formed below the James River stays relatively intact throughout the entire length of the side-channel of the Missouri River into which it flows. As seen in the data collected at Site 4B, the plume still exists within the Missouri River one-half mile below where the side-channel rejoins the main river, but is dissipating (Table 6).

Based on the average of the estimated mean daily flows for Sites 2Ts (26,286 cfs) and 3 (1,144 cfs) the dilution factor of the Missouri River to the James River inflow is approximately 23:1. This dilution factor was used to project when the James River inflow would be completely-mixed with the Missouri River based on conductivity levels. The mean conductivity levels measured at Sites 2Ts and 3 were respectively 833 and 1,256 μmhos (Table 6). Applying a 23:1 dilution factor to these mean values, a completely-mixed situation would be present when conductivity levels in the Missouri River reached approximately 851 μmhos . The mean conductivity determined for Site 5Ts was 853 μmhos (Table 6). It was therefore concluded that the James River inflow has completely-mixed with the Missouri River by the time the flows have reached Site 5Ts, which is approximately 28 river miles downstream from the mouth of the James River.

It is noted that the turbidity levels measured at Sites 2Ts, 3, and 5Ts do not conform to the 23:1 dilution factor, as does conductivity. This can possibly be attributed to two factors. First, conductivity is a “quantitative measurement” of a physicochemical property of water that conforms to a simple dilution analysis. Turbidity, on the other hand, is a “relative measurement” of an optical property of the water (i.e., “cloudiness” of water caused by the light scattering of suspended particles). The important attributes of suspended particles regarding their optical character and other important aspects of environmental behavior, notably settling velocity, are their particle size, shape and composition (Davies-Colley and Smith, 2001). Thus simple dilution is a lesser factor in determining turbidity levels than the particle size, shape, and composition of the suspended material. Second, streambed degradation and streambank erosion may be contributing to turbidity levels as the river flows downstream between the sites.

Turbidity levels significantly increased between the two sites, 5Ts and 8Ts, where the Vermillion River enters the Missouri River (Plate 9). Mean turbidity, Secchi depth, and

conductivity values calculated from the data collected at Sites 5Ts, 6, 7Ts, and 8Ts are given in Table 6. As seen in the mean conductivity value for Site 7Ts, a limited plume did occur below the inflow of the Vermillion River. Site 7Ts was located approximately one-half mile downstream from the mouth of the Vermillion River near the north bank (Plate 6).

Based on the average of the estimated mean daily flows for Sites 5Ts (27,430 cfs) and 6 (135 cfs) the dilution factor of the Missouri River to the Vermillion River inflow is approximately 203:1. This dilution factor was used to project when the Vermillion River inflow would be completely-mixed with the Missouri River based on conductivity levels. The mean conductivity levels measured at Sites 5Ts and 6 were respectively 853 and 1,385 μmhos (Table 6). Applying a 203:1 dilution factor to these mean values, a completely-mixed situation would be present when conductivity levels in the Missouri River reached approximately 856 μmhos . The mean conductivity determined for Sites 7Ts and 8Ts was, respectively, 864 and 851 μmhos (Table 6). It was therefore concluded that the Vermillion River inflow has completely-mixed with the Missouri River by the time the flows have reached Site 8Ts, which is approximately 19 river miles downstream from the mouth of the Vermillion River.

As was seen in conditions above and below the James River, the mean turbidity levels above and below the Vermillion River (Sites 5Ts and 8Ts) do not conform to a simple dilution analysis, as does conductivity. However, the magnitude of the nonconformity below the Vermillion River is much more apparent given the dilution factor of 203:1. Streambed degradation and streambank erosion may be influencing turbidity levels to a greater degree in the reach between Sites 5Ts and 8Ts.

The daily load of total suspended solids (TSS) delivered by the inflows of the James and Vermillion Rivers was estimated for each of the days (TSS) was measured. The estimate was based on the average daily flows recorded at the Scotland and Vermillion gages and the total suspended solids concentration measured on that day. Table 7 gives the daily total suspended solids loads estimated for each of the 6 days water quality samples were collected during the scoping study. The average daily load of total suspended solids delivered by the James and Vermillion Rivers was estimated to be, respectively, 169.8 and 14.5 tons.

4.5. DATA QUALITY INDICATORS

4.5.1. Accuracy

A review of the analysis results obtained for the six field blank samples found only one occurrence of a reported value greater than a detection limit. The one occurrence was an estimated value of 2 $\mu\text{g/l}$ for chlorophyll *a*. The detection limit for chlorophyll *a* is 1 $\mu\text{g/l}$ and the reporting limit is 3 $\mu\text{g/l}$. Given that this one occurrence was an estimated value near the detection limit, it was not considered significant.

4.5.2. Precision

Table 8 gives the analytical results of the collocated samples and the relative percent difference (RPD) for the analyzed parameter. The RPD was calculated only when the analytical results for a parameter were above the reporting limit. Of the total 36 RPD values calculated for all parameters, 4 were at or above 25%. Two of the 4 RPD values calculated for chlorophyll *a* were at or above 25%, while 1 of 6 were for total phosphorus and turbidity. The RPD values calculated for the 4 chlorophyll *a* paired samples ranged from 10.5 to 93.3%, and raise a

concern on the precision of the chlorophyll a results. It is noted that the 8 reported chlorophyll a values were relatively low (i.e., all less than 15 µg/l). From a water quality standpoint these are low values, and although poor precision is a concern, it is not considered environmentally significant. The reported turbidity values for one pair of collocated samples were 39 and 19 NTUs (RPD = 69.0%). The other 5 paired turbidity values were within 2 NTUs of each other (RPD values of 0.0, 0.0, 4.7, 4.9, and 10.0). Although the RPD of the one pair of turbidity measurements is a concern, the overall precision of the turbidity measurements for the scoping study is considered good based on the other 5 collocated samples. The one high RPD value may represent an outlier situation. The one RPD value for total phosphorus above 25% was 28.6%, and resulted from paired values of 0.04 and 0.03 mg/l. These values are near the detection and reporting limit for total phosphorus and are very low from a water quality standpoint. The “high” RPD value is a reflection of the low magnitude of the paired results and is not considered significant. Overall, the precision of the analyzed parameters is considered good, with some concern regarding the measured chlorophyll a values.

5. SUMMARY

The overall water quality of the MNRR reach appears to be good. All the water quality parameters monitored in the MNRR reach during the scoping study met the appropriate state water quality standards adopted pursuant to the Federal Clean Water Act. Significant longitudinal variation through the reach was observed for the monitored parameters of conductivity, dissolved oxygen, Secchi depth, turbidity, total suspended solids, and total phosphorus. The longitudinal variation of all these parameters except dissolved oxygen, appears to be largely attributed to the inflows of the James and Vermillion Rivers. Little difference was observed between near-surface and near-bottom thalweg water quality conditions and near-surface thalweg and backwater water quality conditions. It is noted that these observations are based on a limited sampling period (i.e., late August through September) of a single year and are probably seasonally biased.

6. RECOMMENDATIONS

6.1. ADDITIONAL WATER QUALITY MONITORING

It is recommended that the ODWQU implement a 2 to 3 year monitoring project to define the water quality conditions that exist in the MNRR reach. The scoping study established that there is longitudinal variation in water quality along the MNRR reach, and it appears that the inflows of the James and Vermillion Rivers play a significant role in this variation. The scoping study was limited in its temporal coverage and additional monitoring is needed to account for seasonal variation in water quality. The monitoring project should include near-surface thalweg sampling at 3 Missouri River sites (immediately below Gavins Point Dam, near Maskell, NE, and at Ponca State Park, NE). These sampling points along the Missouri River will represent completely-mixed conditions that bracket the inflows of the James and Vermillion Rivers. Two additional sites, one on the James River and one on the Vermillion River near their mouths, should also be collected. The sampling sites on the James and Vermillion Rivers could be at the South Dakota state highway 50 bridge crossings. Ongoing South Dakota Department of Natural Resources water quality monitoring activities on the James and Vermillion Rivers should be reviewed for possible partnering and data-sharing opportunities. The recommended sampling period is April through October. During this sampling period it is recommended that systematic monthly grab samples be collected. In addition to the systematic monthly samples, 4 additional spring season grab samples and up to 4 additional runoff grab samples should be collected. Parameters coverage should include field measurements of water temperature,

dissolved oxygen, conductivity, pH, and turbidity; and analytical measurements of nutrients, suspended solids, selected herbicides and priority pollutants. The Nebraska Department of Environmental Quality should be consulted as to the parameters they deemed important regarding implementation of their Tier 3 antidegradation provisions.

6.2. WATER QUALITY MANAGEMENT CONCERNS

A water quality management concern is the seemingly contradictory water quality management goals identified for the MNRR reach under the Federal Endangered Species Act (ESA), Clean Water Act (CWA), and Wild and Scenic Rivers Act (WSRA). The BiOp, developed pursuant to the ESA, directs the Corps to increase turbidity and suspended solids in the MNRR. The BiOp states that sediment transport and turbidity need to be restored to functional levels in the MNRR reach to improve habitat conditions for the jeopardized species inhabiting the reach. State water quality standards (i.e., South Dakota and Nebraska) adopted pursuant to the CWA require that suspended solids and turbidity levels be maintained at “reduced” levels in the MNRR reach, and imply that increasing turbidity and suspended solids levels in the reach could represent a degradation of water quality conditions and a possible impairment of a designated beneficial use. South Dakota has specifically adopted water quality standards criteria to manage total suspended solids levels in the MNRR reach. One of the beneficial uses South Dakota designates on the MNRR reach is “warmwater permanent fish life propagation”. Protection of this use requires that total suspended solids levels are to be ≤ 158 mg/l as a daily maximum, and ≤ 90 mg/l as a 30-day average. Management of the MNRR reach as a recreational river under the WSRA requires that the values for which it was designated as a recreational river (i.e., its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values) be protected and enhanced. Increasing suspended solids and turbidity levels in the MNRR reach may degrade the habitat for recreationally important fish species that were present in the reach when it was designated as a recreational river. The existing water quality literature suggests that elevated levels of turbidity adversely impact the recreational and aesthetic values of a waterbody. The U.S. Environmental Protection Agency’s “Red Book” states; “Turbid water interferes with recreational use and aesthetic enjoyment of water” (USEPA, 1976). The USFWS should enter consultation with EPA Regions VII and VIII, and possibly the NPS, to discuss coordinating the water quality aspects of the BiOp, CWA, and WSRA to ensure that there are consistent water quality management goals on the MNRR reach.

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Table 1. 8-Digit Hydrologic Units (HUCs) that make up the watershed, below Gavins Point Dam, of the MNRR Reach.

HUC Number	HUC Name	Approximate Area (sq. miles)
10160001	James River Headwaters	1760
10160002	Pipestem Reservoir	1040
10160003	Upper James River	4250
10160004	Elm Creek	1600
10160005	Mud Creek	650
10160006	Middle James River	3640
10160007	East Missouri Coteau	890
10160008	Snake Creek	1520
10160009	Turtle Creek	1480
10160010	North Big Sioux Coteau	1230
10160011	Lower James	3530
10170101	Lewis and Clark Lake*	3240
10170102	Vermillion River	2240
10170103	South Big Sioux Coteau	410
10170101*	(MNRR Reach)	880
10170101*	(Above and Below MNRR Reach)	2360

Table 2. Analytical method, method detection limit, and reporting limit for parameters analyzed in the WES Laboratory.

Parameter	Analytical Method	Method Detection Limit	Reporting Limit
Turbidity (NTU)	EPA180.1	1 NTU	3 NTU
Total Suspended Solids (mg/l)	EPA160.2	4 mg/l	10 mg/l
Total Organic Carbon (mg/l)	EPA9060	0.05 mg/l	0.25 mg/l
Total Phosphorus (mg/l)	EPA365.4	0.01 mg/l	0.02 mg/l
Total Kjeldahl Nitrogen (mg/l)	EPA351.2	0.1 mg/l	0.2 mg/l
Total Ammonia (mg/l)	EPA350.1	0.01 mg/l	0.1 mg/l
Nitrate/Nitrate as N (mg/l)	EPA353.2	0.02 mg/l	0.1 mg/l
Chlorophyll a (µg/l)	SM10200H2	1 µg/l	3 µg/l
Atrazine (µg/l)	EPA507	0.05 µg/l	0.1 µg/l
Alachlor (µg/l)	EPA507	0.05 µg/l	0.1 µg/l
Metholachlor (µg/l)	EPA507	0.05 µg/l	0.1 µg/l

Table 3. Mean daily discharge calculated for 5 gaging sites in proximity to the MNRR reach for the period August 17 through September 26, 2001. (Note: The calculated mean daily discharges are based on provisional discharge measurements.)

Date	Mean Daily Discharge (cfs)				
	Gavins Point Dam	Scotland Gage	Vermillion Gage	Akron Gage	Sioux City Gage
17-Aug-2001	25,003	1,259	137	1,603	29,239
18-Aug2001	25,478	1,272	137	1,539	28,012
19-Aug2001	25,499	1,276	133	1,502	28,246
20-Aug2001	25,494	1,263	127	1,466	28,296
21-Aug2001	25,970	1,239	128	1,397	28,413
22-Aug2001	25,993	1,229	120	1,364	28,919
23-Aug2001	26,208	1,227	141	1,281	28,838
24-Aug2001	25,997	1,235	143	1,270	28,832
25-Aug2001	26,005	1,219	147	1,250	28,820
26-Aug2001	26,003	1,220	145	1,213	28,669
27-Aug2001	25,997	1,208	142	1,189	28,585
28-Aug2001	26,000	1,196	138	1,148	28,578
29-Aug2001	26,000	1,181	133	1,123	28,655
30-Aug2001	26,000	1,172	133	1,070	28,917
31-Aug2001	26,000	1,156	132	1,040	28,418
1-Sep2001	25,996	1,131	132	1,255	28,122
2-Sep2001	25,998	1,110	140	1,111	28,551
3-Sep2001	25,999	1,103	134	978	28,441
4-Sep2001	26,796	1,091	123	918	28,148
5-Sep2001	27,504	1,066	120	894	29,012
6-Sep2001	27,957	1,054	121	608	29,660
7-Sep2001	27,994	1,092	121	592	30,171
8-Sep2001	28,005	1,119	119	566	30,760
9-Sep2001	27,998	1,124	118	566	30,663
10-Sep2001	28,002	1,144	123	583	30,318
11-Sep2001	27,998	1,125	130	576	30,190
12-Sep2001	27,753	1,110	126	554	30,303
13-Sep2001	27,501	1,032	122	529	30,371
14-Sep2001	27,504	1,088	129	549	31,169
15-Sep2001	27,991	1,110	139	571	31,668
16-Sep2001	27,081	1,135	144	641	31,049
17-Sep2001	25,480	1,157	148	796	30,532
18-Sep2001	25,005	1,171	153	845	28,352
19-Sep2001	24,999	1,161	158	819	27,627
20-Sep2001	25,001	1,144	155	717	27,503
21-Sep2001	25,010	1,119	151	665	27,400
22-Sep2001	25,002	1,087	146	649	27,457
23-Sep2001	25,007	1,061	141	669	27,365
24-Sep2001	25,004	1,029	136	621	27,158
25-Sep2001	25,499	997	133	579	26,731
26-Sep2001	25,998	974	132	558	27,067
Mean	26,286	1,144	135	924	28,908

Table 4. Water balance based on the mean daily discharges calculated at the 5 gage sites for the period August 17 through September 26, 2001.

Date	GPT + SCT + VER* (cfs)	SC ! AKR* (cfs)	RPD** (Same Day)	RPD** (1-Day Delay)
17-Aug-2001	26,399	27,636	4.58	
18-Aug-2001	26,887	26,473	1.55	0.28
19-Aug-2001	26,908	26,744	0.61	0.53
20-Aug-2001	26,884	26,830	0.20	0.29
21-Aug-2001	27,337	27,016	1.18	0.49
22-Aug-2001	27,342	27,555	0.78	0.79
23-Aug-2001	27,576	27,557	0.07	0.78
24-Aug-2001	27,375	27,562	0.68	0.05
25-Aug-2001	27,371	27,570	0.72	0.71
26-Aug-2001	27,368	27,456	0.32	0.31
27-Aug-2001	27,347	27,396	0.18	0.10
28-Aug-2001	27,334	27,430	0.35	0.30
29-Aug-2001	27,314	27,532	0.79	0.72
30-Aug-2001	27,305	27,847	1.97	1.93
31-Aug-2001	27,288	27,378	0.33	0.27
1-Sep-2001	27,259	26,867	1.45	1.55
2-Sep-2001	27,248	27,440	0.70	0.66
3-Sep-2001	27,236	27,463	0.83	0.79
4-Sep-2001	28,010	27,230	2.82	0.02
5-Sep-2001	28,690	28,118	2.01	0.38
6-Sep-2001	29,132	29,052	0.27	1.25
7-Sep-2001	29,207	29,579	1.27	1.52
8-Sep-2001	29,243	30,194	3.20	3.32
9-Sep-2001	29,240	30,097	2.89	2.88
10-Sep-2001	29,269	29,735	1.58	1.68
11-Sep-2001	29,253	29,614	1.23	1.17
12-Sep-2001	28,989	29,749	2.59	1.68
13-Sep-2001	28,655	29,842	4.06	2.90
14-Sep-2001	28,721	30,620	6.40	6.63
15-Sep-2001	29,240	31,097	6.16	7.94
16-Sep-2001	28,360	30,408	6.97	3.92
17-Sep-2001	26,785	29,736	10.44	4.74
18-Sep-2001	26,329	27,507	4.38	2.66
19-Sep-2001	26,318	26,808	1.84	1.80
20-Sep-2001	26,300	26,786	1.83	1.76
21-Sep-2001	26,280	26,735	1.72	1.64
22-Sep-2001	26,235	26,808	2.16	1.99
23-Sep-2001	26,209	26,696	1.84	1.74
24-Sep-2001	26,169	26,537	1.40	1.24
25-Sep-2001	26,629	26,152	1.81	0.06
26-Sep-2001	27,104	26,509	2.22	0.45
Mean	27,565	27,985	2.16	1.60
		Minimum	0.07	0.02
		25th Percentile	0.72	0.43
		Median	1.58	1.21
		75th Percentile	2.59	1.84
		Maximum	10.44	7.94

* GPT = Gavins Point Dam Discharge, SCT = Scotland gage discharge, VER = Vermillion gage discharge, SC = Sioux City gage discharge, and AKR = Akron gage discharge.

** RPD = $\left[\left| X_1 - X_2 \right| / ((X_1 + X_2)/2) \right] \times 100\%$; where $X_1 = (\text{GPT} + \text{SCT} + \text{VER})$, and $X_2 = (\text{SC} + \text{AKR})$.

Table 5. Summary statistics of water quality conditions monitored at the near-surface thalweg and tributary sites during the scoping study.

Parameter	Site 1Ts					Site 2Ts					Site 3					Site 4Ts				
	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.
Water Temperature (C)	21.7	22.5	18.3	24.6	6	21.5	22.3	18.0	24.5	6	21.4	22.7	16.2	25.3	6	21.6	22.3	17.9	24.7	6
Dissolved Oxygen (mg/l)	7.9	7.9	7	8.8	6	8.0	8.0	7.4	8.8	6	7.5	7.5	6.6	8.6	6	7.9	8.0	7.4	8.6	6
pH (S.U.)	---	8.3	8.3	8.4	6	---	8.3	8.3	8.4	6	---	8.3	8.1	8.3	6	---	8.3	8.3	8.3	6
Conductivity (µmhos)	832	833	815	848	6	833	835	816	849	6	1256	1267	1180	1310	6	833	835	817	850	6
Secchi Depth (Inches)	25	26	23	28	5	25	24	21	30	6	10	10	10	11	5	25	24	22	28	5
Turbidity (NTU)	12	12	8	17	6	14	14	11	17	6	34	35	19	42	6	13	13	11	17	6
Total Suspended Solids (mg/l)	15	13	8	29	6	14	12	6	28	6	55	49	38	100	6	14	12	11	22	6
Total Organic Carbon (mg/l)	4.2	4.2	3.9	4.8	6	4.2	4.1	3.8	4.9	6	12.5	12.5	12.0	13.0	6	4.0	4.1	3.0	4.8	6
Total Phosphorus (mg/l)	0.03	0.03	0.03	0.04	6	0.03	0.04	0.02	0.04	6	0.47	0.48	0.38	0.53	6	0.03	0.03	0.02	0.04	6
Total Kjeldahl Nitrogen (mg/l)	0.3	0.1	<0.1	0.7	6	0.3	0.1	0.1	0.6	6	0.6	0.6	0.4	0.8	6	0.3	0.1	<0.1	0.7	6
Total Ammonia as N (mg/l)	0.08	0.02	<0.01	0.24	6	0.07	0.03	<0.01	0.22	6	0.08	0.03	<0.01	0.25	6	0.07	<0.01	<0.01	0.21	6
Nitrate-Nitrite as N (mg/l)	0.12	0.13	0.07	0.15	6	0.12	0.14	0.07	0.15	6	0.06	<0.02	<0.02	0.17	6	0.12	0.13	0.07	0.15	6
Chlorophyll a (µg/l)	13	7	2	48	6	22	9	4	85	6	21	21	11	38	6	10	10	4	16	6
Atrazine (µg/l)	0.06	0.06	<0.05	0.07	3	0.06	<0.05	<0.05	0.07	3	<0.05	<0.05	<0.05	<0.05	3	0.06	0.06	<0.05	0.06	3
Alachlor (µg/l)	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3
Metholachlor (µg/l)	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3

Parameter	Site 5Ts					Site 6					Site 7Ts					Site 8Ts				
	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.	Mean	Med.	Min.	Max.	Obs.
Water Temperature (C)	21.7	22.6	17.0	24.5	6	20.3	21.4	14.0	24.3	6	21.2	21.8	17.0	24.2	5	22.2	23.5	17.4	25.0	6
Dissolved Oxygen (mg/l)	8.5	8.5	7.9	9.2	6	8.7	8.7	7.9	9.3	5	8.7	8.7	8.3	9.1	4	9.0	9.1	8.7	9.4	5
pH (S.U.)	---	8.3	8.3	8.4	6	---	8.2	8.0	8.3	6	---	8.4	8.3	8.4	5	---	8.4	8.3	8.4	6
Conductivity (µmhos)	853	853	836	865	6	1385	1385	1361	1408	6	864	869	847	874	5	851	854	834	865	6
Secchi Depth (Inches)	20	21	19	21	5	12	12	11	14	5	19	18	18	20	5	19	19	18	20	5
Turbidity (NTU)	18	18	16	22	6	30	27	25	37	6	21	22	18	23	6	22	21	19	29	6
Total Suspended Solids (mg/l)	29	24	21	54	6	41	39	30	62	6	37	31	25	70	6	40	33	30	80	6
Total Organic Carbon (mg/l)	4.8	4.4	4.1	6.4	6	11.2	11.0	11.0	12.0	6	4.8	4.8	4.5	5.5	6	4.4	4.4	4.1	5.2	6
Total Phosphorus (mg/l)	0.06	0.06	0.05	0.07	6	0.21	0.21	0.18	0.26	6	0.08	0.08	0.06	0.09	6	0.07	0.08	0.06	0.08	6
Total Kjeldahl Nitrogen (mg/l)	0.2	<0.1	<0.1	0.6	6	0.5	0.6	0.1	0.9	6	0.3	0.1	<0.1	0.7	6	0.3	0.1	<0.1	0.6	6
Total Ammonia as N (mg/l)	0.06	0.01	<0.01	0.19	6	0.07	0.03	<0.01	0.21	6	0.06	<0.01	<0.01	0.20	6	0.06	0.02	<0.01	0.19	6
Nitrate-Nitrite as N (mg/l)	0.13	0.14	0.08	0.17	6	0.05	<0.02	<0.02	0.13	6	0.12	0.14	0.05	0.16	6	0.09	0.10	<0.02	0.17	6
Chlorophyll a (µg/l)	19	9	<1	79	6	24	27	100	35	6	12	14	2	22	6	10	10	2	19	6
Atrazine (µg/l)	0.06	<0.05	<0.05	0.09	3	0.21	0.27	0.07	0.28	3	0.07	0.07	<0.05	0.08	3	<0.05	<0.05	<0.05	0.06	3
Alachlor (µg/l)	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3
Metholachlor (µg/l)	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	<0.05	3

Mean = Mean value of observations. (Values below detection limit were set at the detection limit when calculating mean values.)

Med. = Median value of observations.

Min. = Minimum value of observations.

Max. = Maximum value of observations.

Obs. = Number of observations on which the mean, median, minimum, and maximum are based.

Table 6. Mean turbidity, Secchi depth, and conductivity values determined from data collected at Sites 2Ts, 3, 3T1, 3T2, 3T3, 3T4, 4B, 5Ts, 6, 7Ts, and 8Ts during the scoping study.

Site	Turbidity (NTU)	Secchi Depth (inches)	Conductivity (μmhos)
2Ts	14	25	833
3	34	10	1,256
3T1	47	10	1,290
3T2	42	10	1,243
3T3	36	11	1,248
3T4	34	12	1,151
4B(1)*	32	13	1,050
4B(2)*	19	19	859
5Ts	18	20	853
6	30	12	1,385
7Ts	21	19	864
8Ts	22	19	851

* 4B(1) was located in a backwater area near the north bank of the Missouri River and was in a noticeable plume formed by the James River inflow. 4B(2) was in a backwater area away from the north bank and just on the edge of the James River plume. See Plate 5.

Table 7. Total suspended solids loading estimates for the James and Vermillion Rivers for selected days during the scoping study.

James River:

Date	Mean Daily Discharge (cfs)	TSS Concentration (mg/l)	TSS Flux Rate (lbs/sec)	Estimated TSS Load (tons/day)
22-Aug-2001	1,229	100	7.67	331.4
29-Aug-2001	1,181	38	2.80	121.0
5-Sep-2001	1,066	44	2.93	126.5
12-Sep-2001	1,110	52	3.60	155.7
19-Sep-2001	1,161	53	3.84	165.9
26-Sep-2001	974	45	2.74	118.2
Average	1,120	55	3.93	169.8

Vermillion River:

Date	Mean Daily Discharge (cfs)	TSS Concentration (mg/l)	TSS Flux Rate (lbs/sec)	Estimated TSS Load (tons/day)
22-Aug-2001	120	62	0.46	20.1
29-Aug-2001	133	32	0.27	11.5
5-Sep-2001	120	30	0.22	9.7
12-Sep-2001	126	45	0.35	15.3
19-Sep-2001	158	33	0.33	14.1
26-Sep-2001	132	46	0.38	16.4
Average	132	41	0.34	14.5

Table 8. Analysis results and percent relative difference (RPD) of collocated samples collected during the scoping study. RPD values calculated only if analysis results were above the reporting limit for that parameter.

Parameter	22-Aug-2001			29-Aug-2001			5-Sep-2001		
	Duplicate	Site 3	RPD*	Duplicate	Site 5Ts	RPD*	Duplicate	Site 7Ts	RPD*
Alachlor (µg/l)	<0.05	<0.05	BRL				<0.05	<0.05	BRL
Atrazine (µg/l)	<0.05	<0.05	BRL				0.06	0.08	BRL
Chlorophyll a (µg/l)	4	11	93.3	9	7	25.0	---	16	---
Metolachlor (µg/l)	<0.05	<0.05	BRL				<0.05	<0.05	BRL
Nitrate/Nitrite as N (mg/l)	0.12	0.12	0.0	0.15	0.16	6.5	0.04	0.05	BRL
Total Ammonia as N (mg/l)	<0.01	<0.01	BRL	<0.01	<0.01	BRL	<0.01	<0.01	BRL
Total Kjeldahl Nitrogen (mg/l)	0.84	0.73	14.0	0.15	<0.1	BRL	<0.1	<0.1	BRL
Total Organic Carbon (mg/l)	13	13	0.0	4.5	4.4	2.3	4.5	4.7	4.4
Total Phosphorus (mg/l)	0.56	0.53	5.5	0.08	0.07	13.3	0.08	0.09	11.8
Total Suspended Solids (mg/l)	104	100	3.9	27	26	3.8	32	37	14.5
Turbidity (NTU)	39	19	69.0	21	22	4.7	20	21	4.9
Parameter	12-Sep-2001			19-Sep-2001			26-Sep-2001		
	Duplicate	Site 1Ts	RPD*	Duplicate	Site 8Ts	RPD*	Duplicate	Site 8Ts	RPD*
Alachlor (µg/l)				<0.05	<0.05	BRL			
Atrazine (µg/l)				<0.05	<0.05	BRL			
Chlorophyll a (µg/l)	2	6	BRL	14	12	15.4	9	10	10.5
Metolachlor (µg/l)				<0.05	<0.05	BRL			
Nitrate/Nitrite as N (mg/l)	0.07	0.07	BRL	0.17	0.17	0.0	0.07	0.09	BRL
Total Ammonia as N (mg/l)	0.02	<0.01	BRL	0.19	0.19	0.0	0.14	0.13	7.4
Total Kjeldahl Nitrogen (mg/l)	0.12	<0.1	BRL	0.48	0.54	11.8	0.58	0.56	3.5
Total Organic Carbon (mg/l)	3.4	3.9	13.7	4.0	4.1	2.5	4.5	4.4	2.3
Total Phosphorus (mg/l)	0.04	0.03	28.6	0.07	0.08	13.3	0.07	0.06	15.4
Total Suspended Solids (mg/l)	11	13	16.7	27	34	23.0	27	30	10.5
Turbidity (NTU)	14	14	0.0	21	19	10.0	19	19	0.0
Parameter	RPD Summary Statistics								
	Mean	Minimum	25 th Percentile	Median	75 th Percentile	Maximum	No. of Obs.**		
Alachlor (µg/l)	---	---	---	---	---	---	0		
Atrazine (µg/l)	---	---	---	---	---	---	0		
Chlorophyll a (µg/l)	36.1	10.5	14.2	20.2	42.1	93.3	4		
Metolachlor (µg/l)	---	---	---	---	---	---	0		
Nitrate/Nitrite as N (mg/l)	2.2	0.0	0.0	0.0	3.2	6.5	3		
Total Ammonia as N (mg/l)	3.7	0.0	1.9	3.7	5.6	7.4	2		
Total Kjeldahl Nitrogen (mg/l)	9.8	3.5	7.6	11.8	12.9	14.0	3		
Total Organic Carbon (mg/l)	4.2	0.0	2.3	2.4	3.9	13.7	6		
Total Phosphorus (mg/l)	14.7	5.5	12.2	13.3	14.9	28.6	6		
Total Suspended Solids (mg/l)	12.1	3.8	5.6	12.5	16.1	23.0	6		
Turbidity (NTU)	14.8	0.0	1.2	4.8	8.7	69.0	6		

* BRL = Analysis results for one or both of the collocated samples were below the reporting limit for that parameter.

** No. of Obs. = Number of observations on which the RPD summary statistics are based.

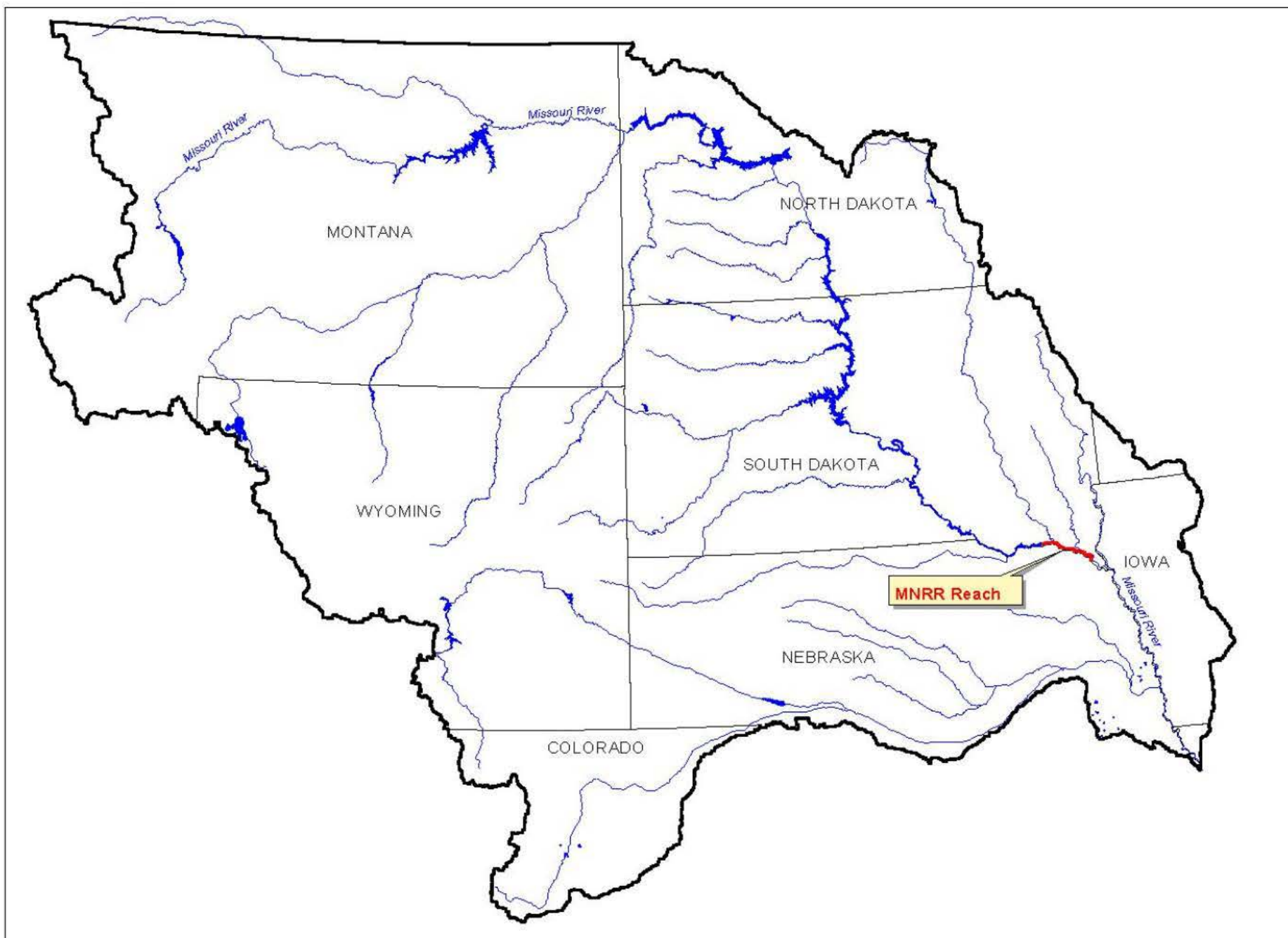


Plate 1. Location of the Missouri National Recreational River (MNRR) reach within the Omaha District.



Plate 2. Watershed area draining to the MNRR reach below Gavins Point Dam as delineated by 8-digit Hydrologic Units (HUCs). Note: The "shaded" area of HUC 10170101 is the area above Gavins Point Dam and below Ponca, Nebraska that does not contribute runoff to the MNRR reach.

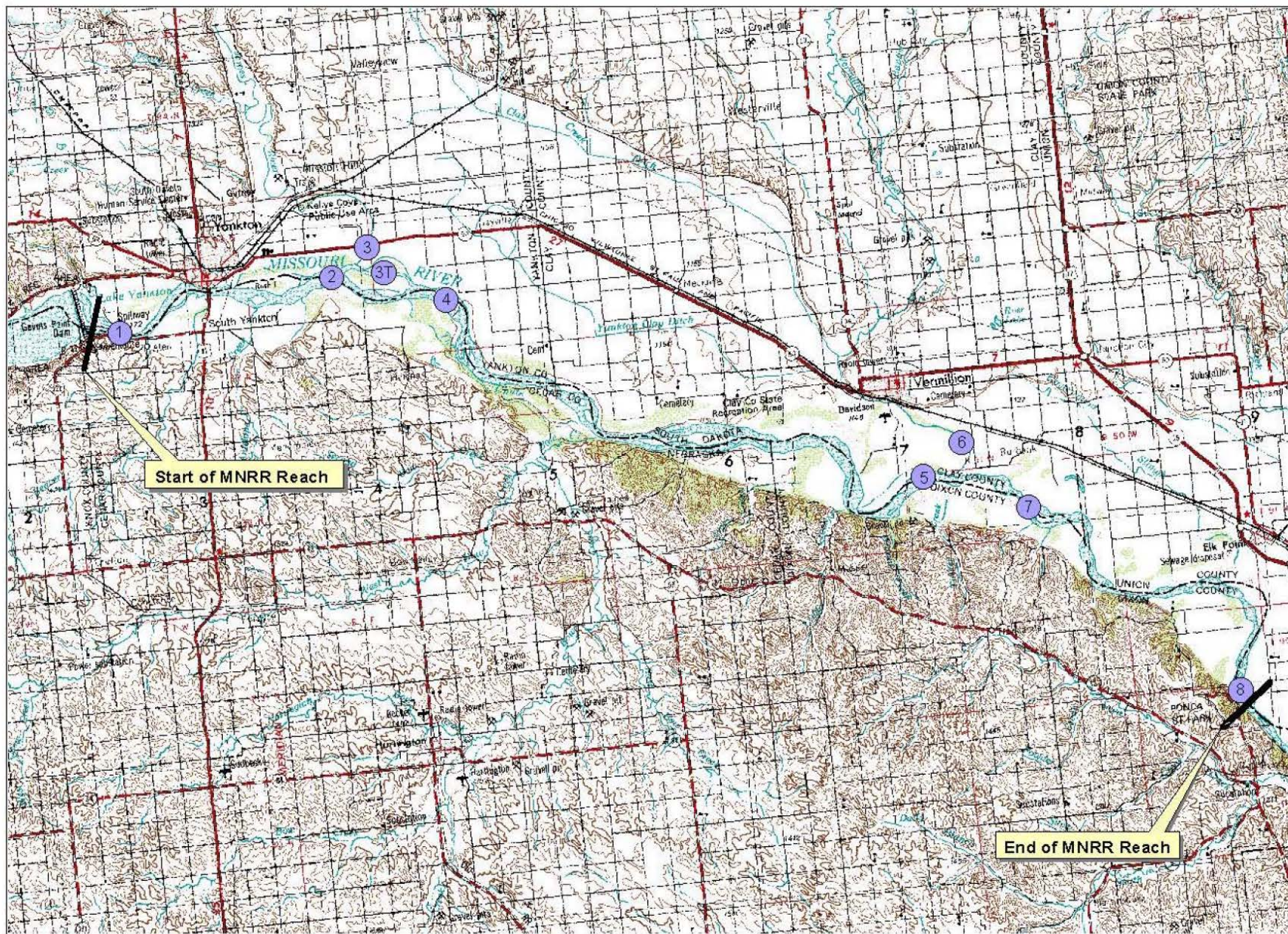


Plate 3. Location of monitoring sites along the MNRR reach where water quality samples were collected as part of the scoping study.



Plate 4. Location of Site 1 based on the average of the obtained GPS coordinates and projected on a 1997 orthophoto of the area.



Plate 5. Location of Sites 2B, 2T, 3, 3T1, 3T2, 3T3, 3T4, 4B, and 4T based on the average of the obtained GPS coordinates and projected on a 1997 orthophoto of the area.



Plate 6. Location of Sites 5B, 5T, 6, 7B, and 7T based on the average of the obtained GPS coordinates and projected on a 1997 orthophoto of the area.



Plate 7. Location of Sites 8B and 8T based on the average of the obtained GPS coordinates and projected on a 1997 orthophoto of the area.

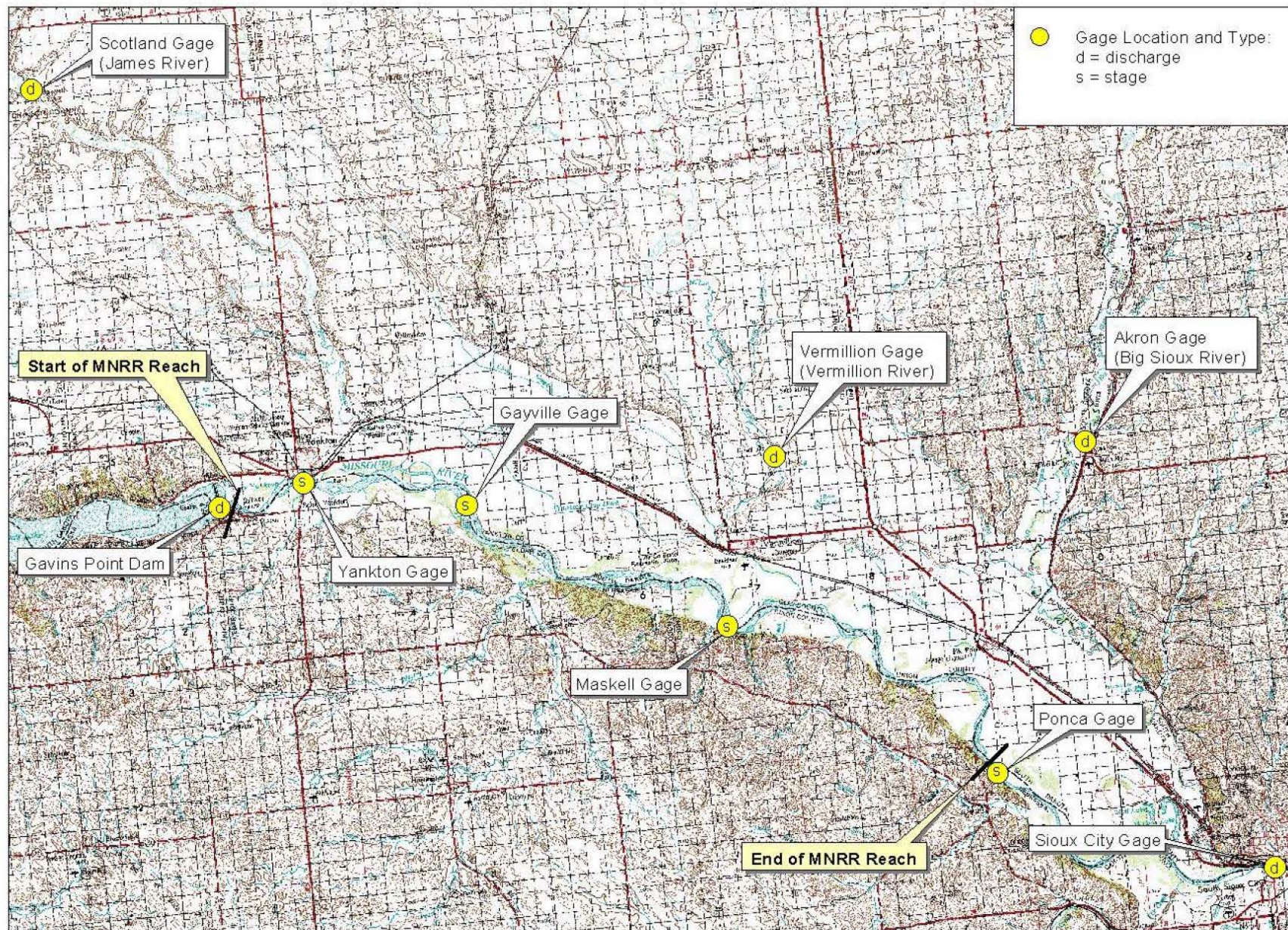


Plate 8. Location of gaging stations along and in proximity to the MNRR reach.

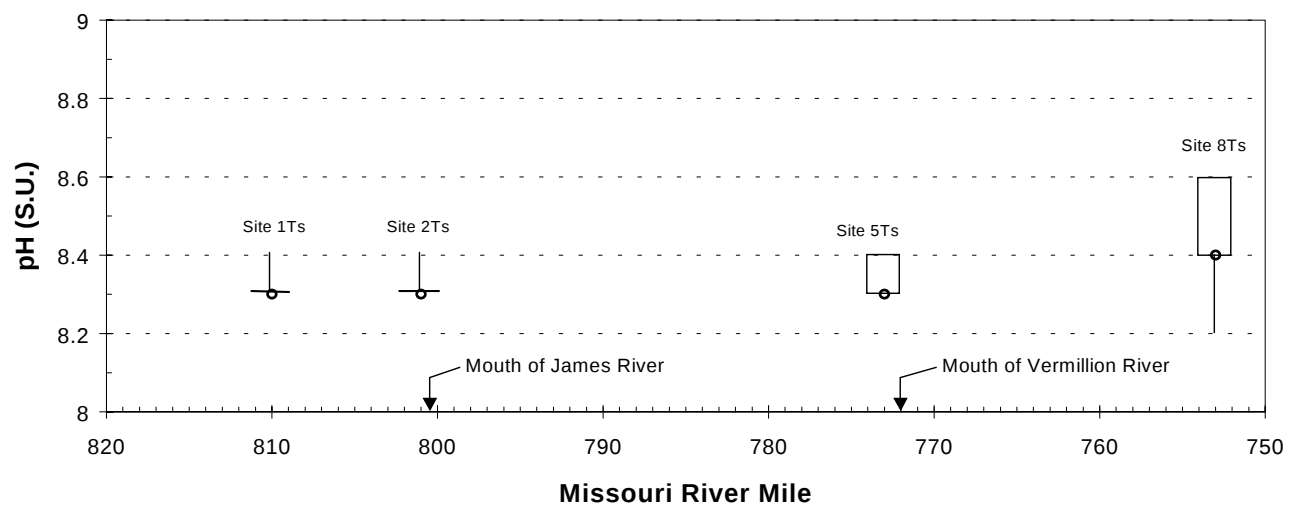
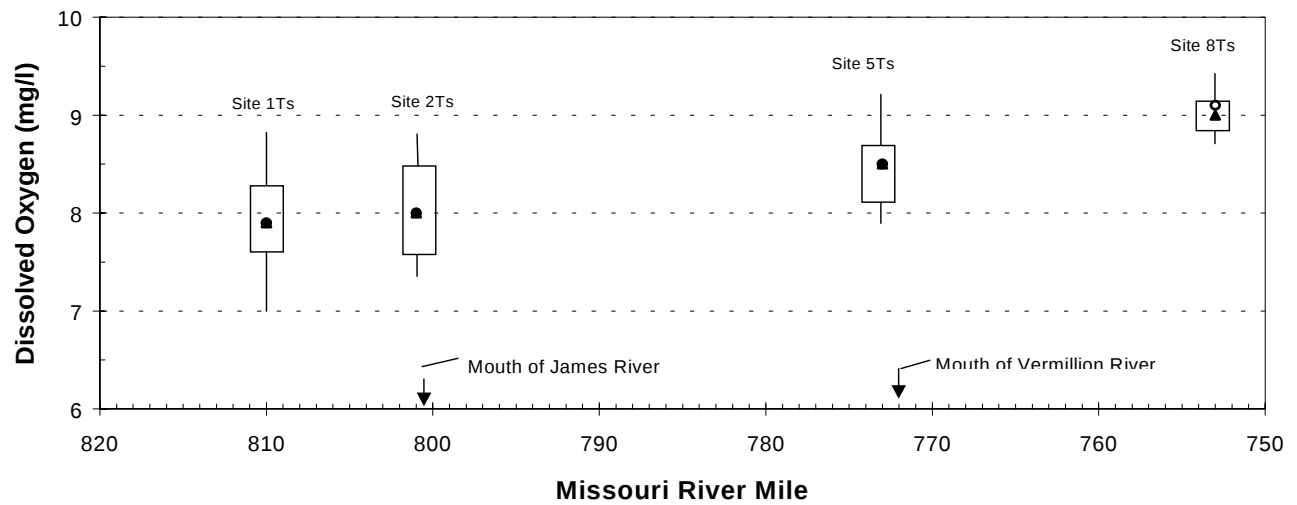
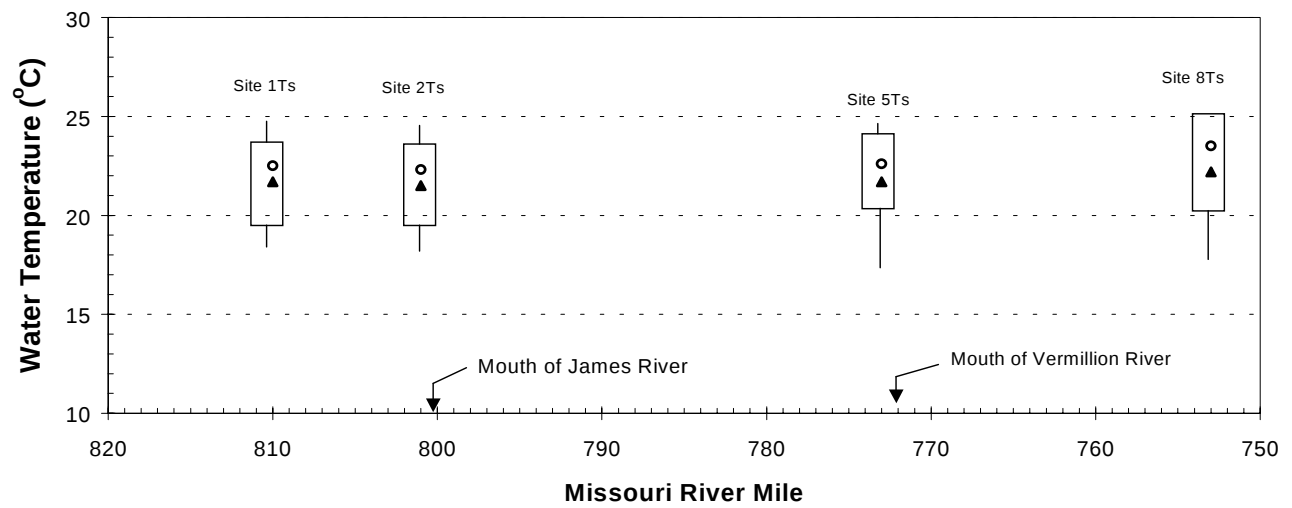


Figure 9. Box plots of water quality parameters monitored at Sites 1Ts, 2Ts, 5Ts, and 8Ts during the scoping study.

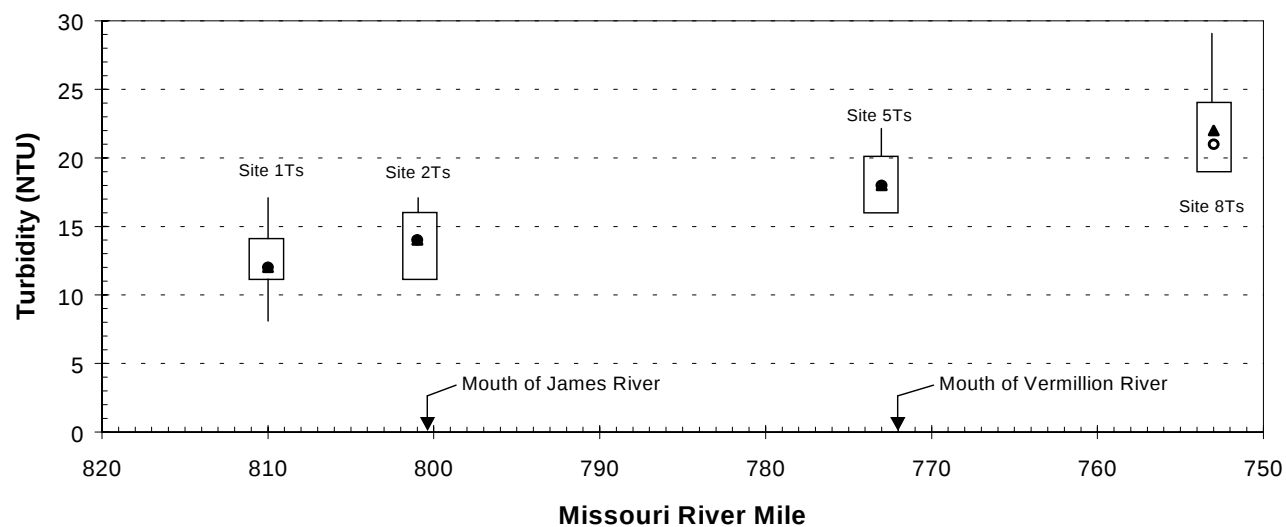
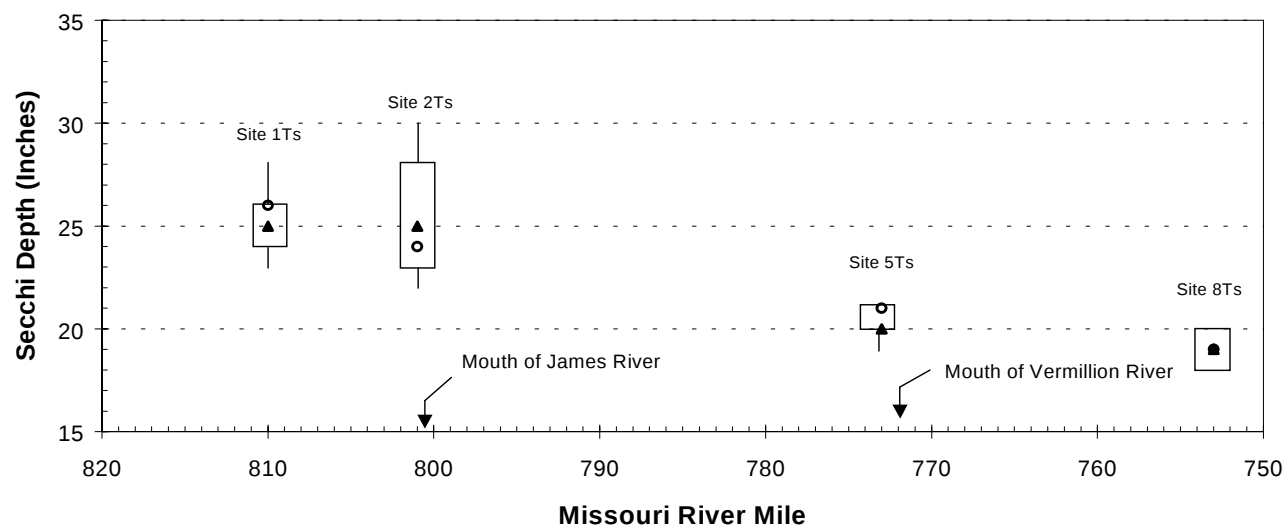
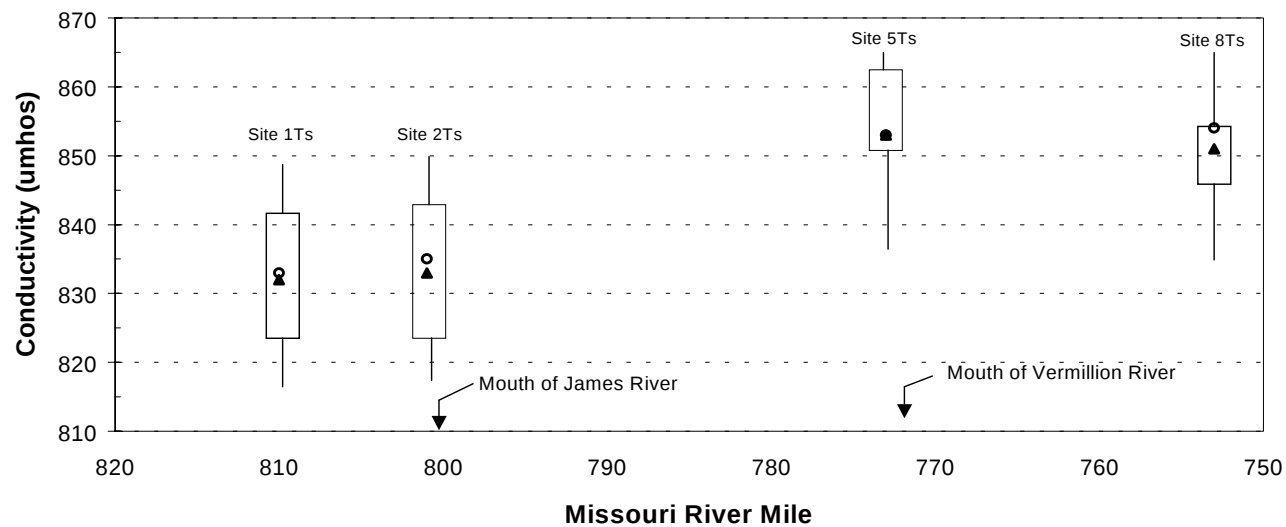


Figure 9. (Continued.)

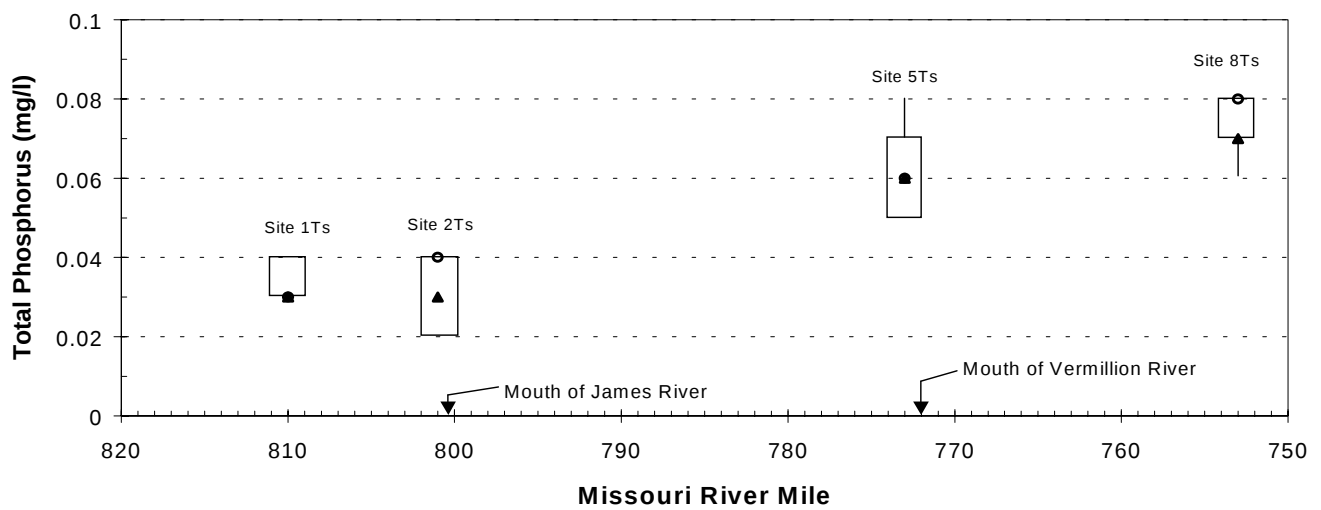
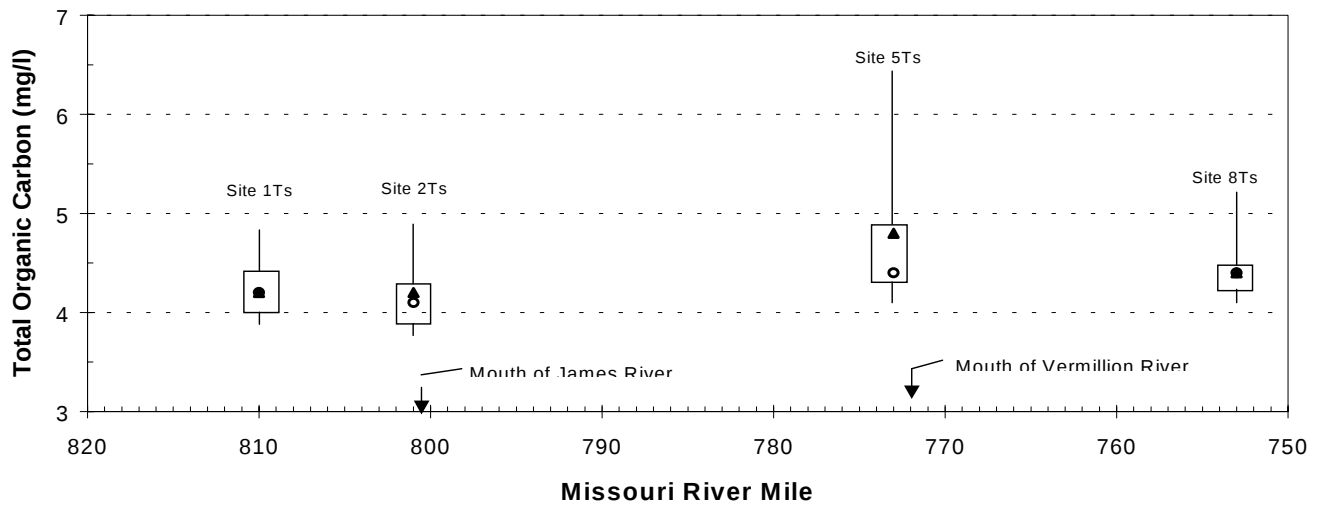
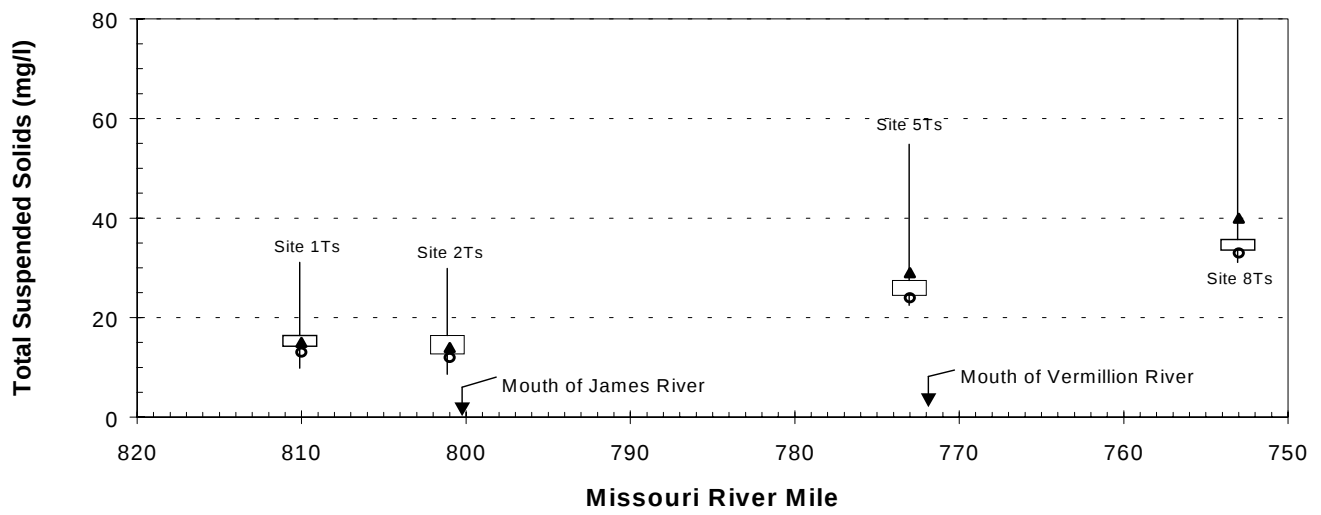


Figure 9. (Continued.)

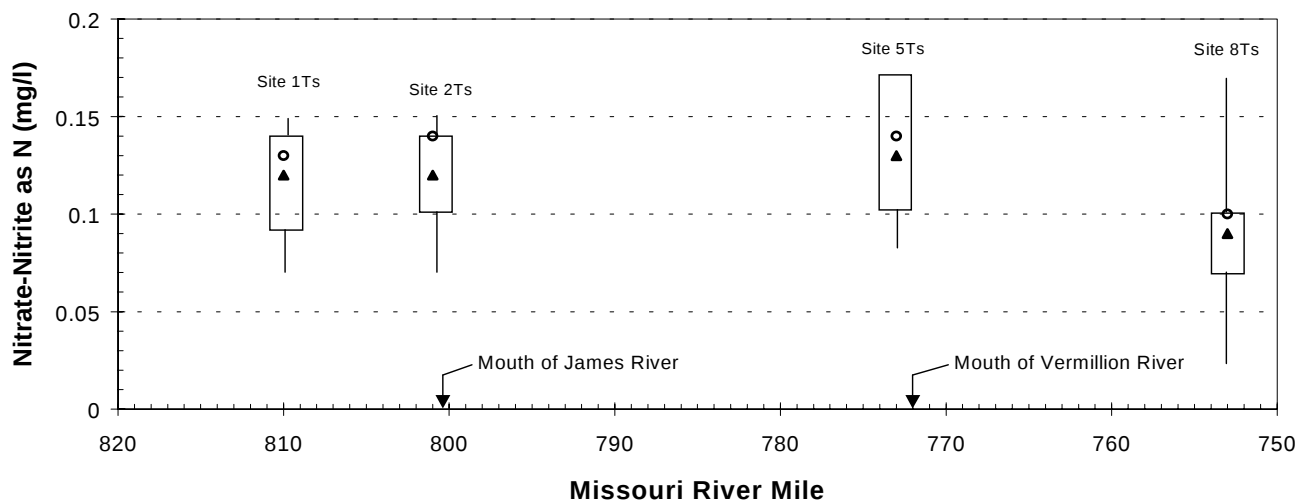
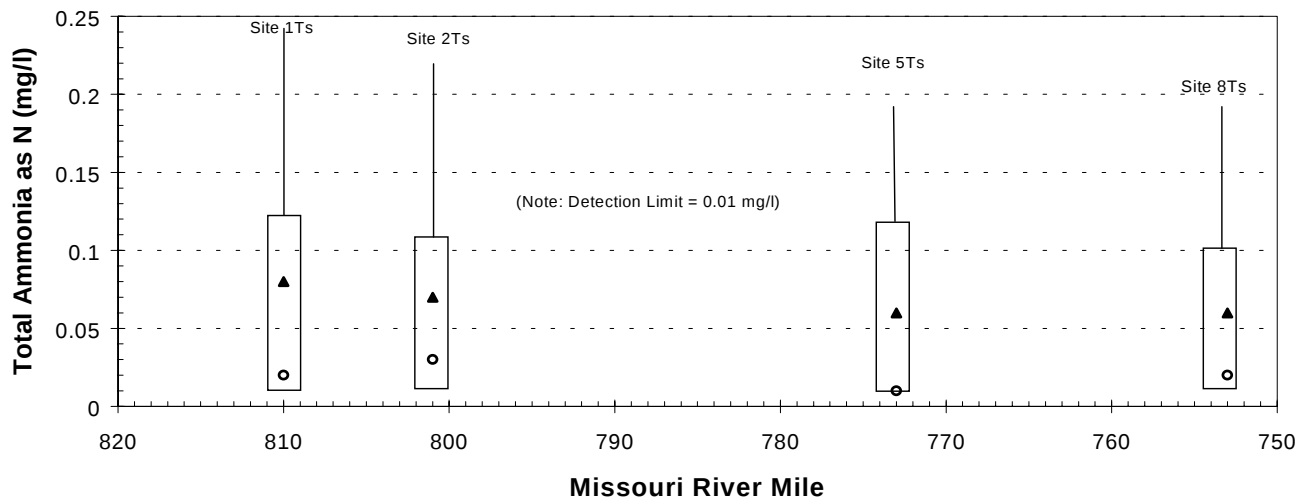
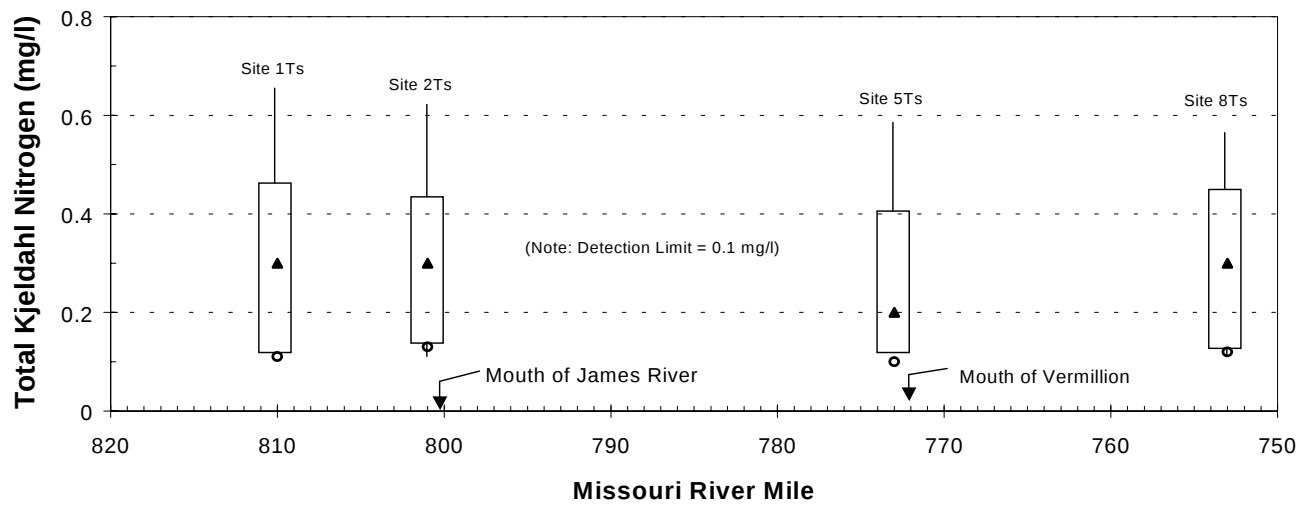


Figure 9. (Continued.)

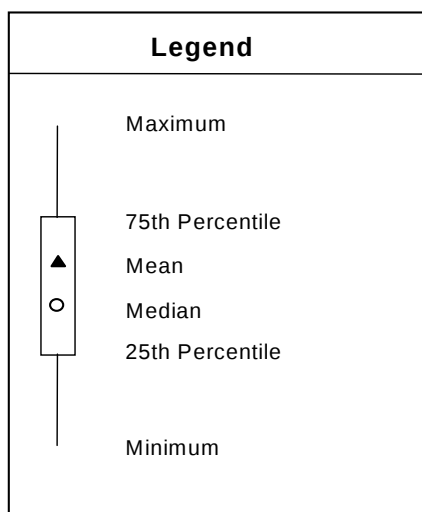
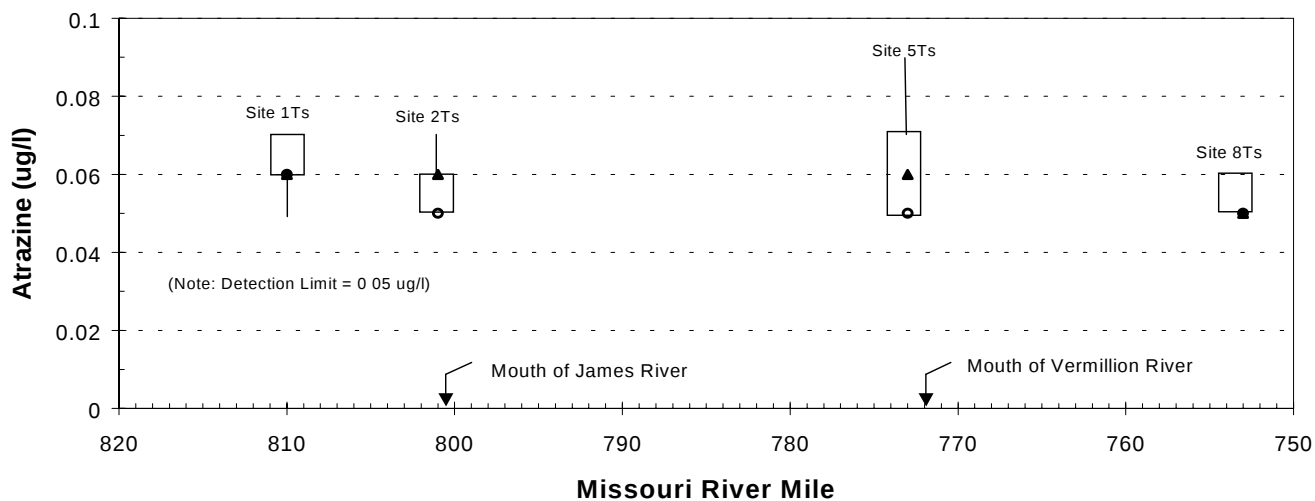
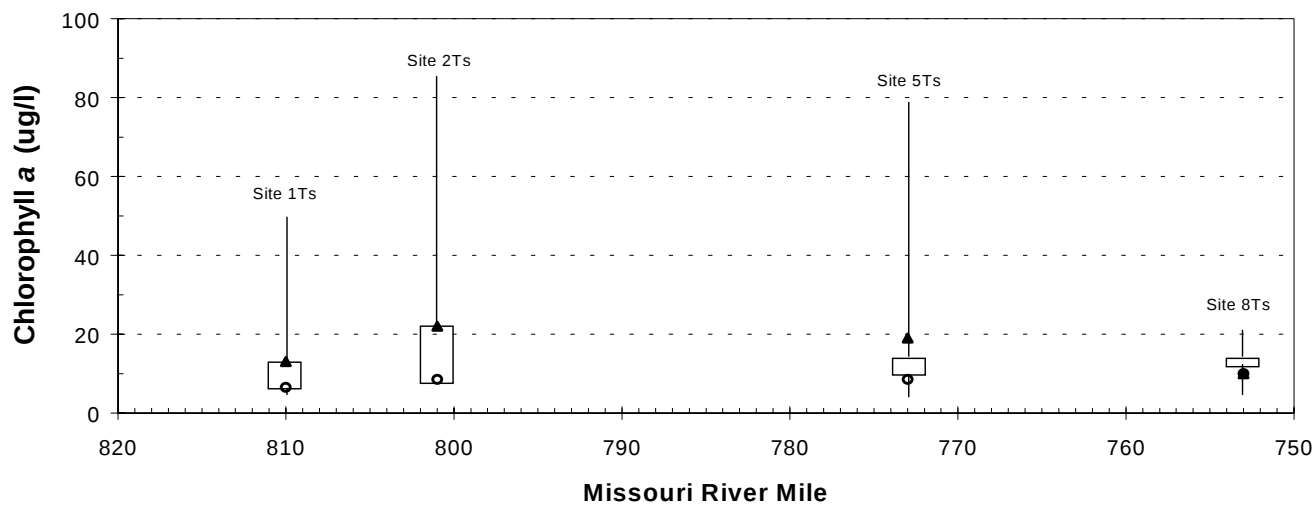


Figure 9. (Continued.)

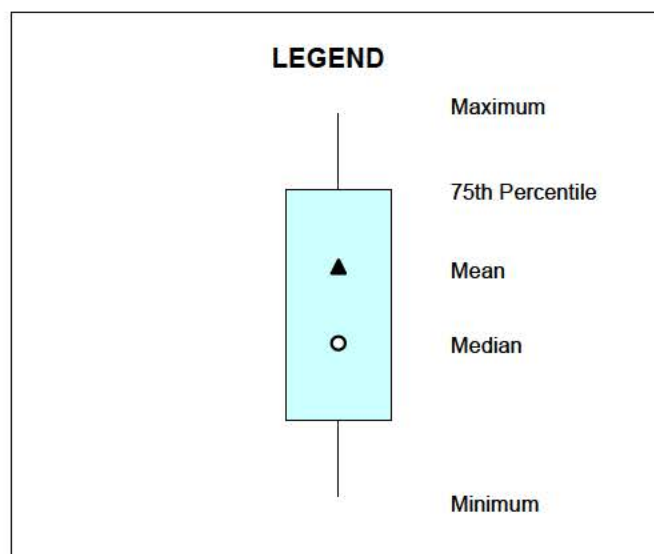
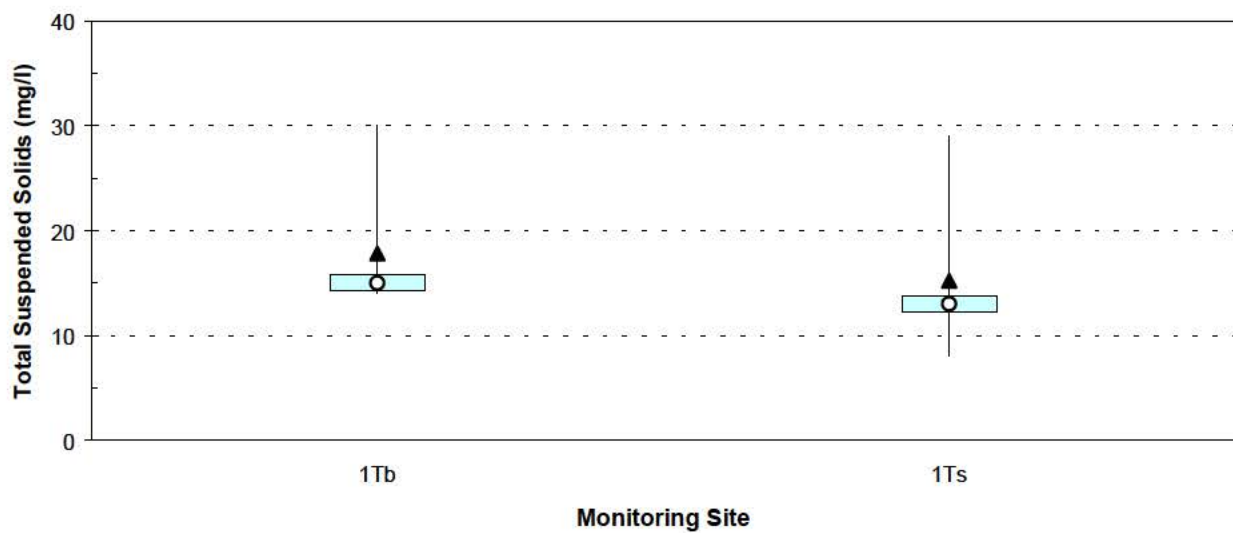
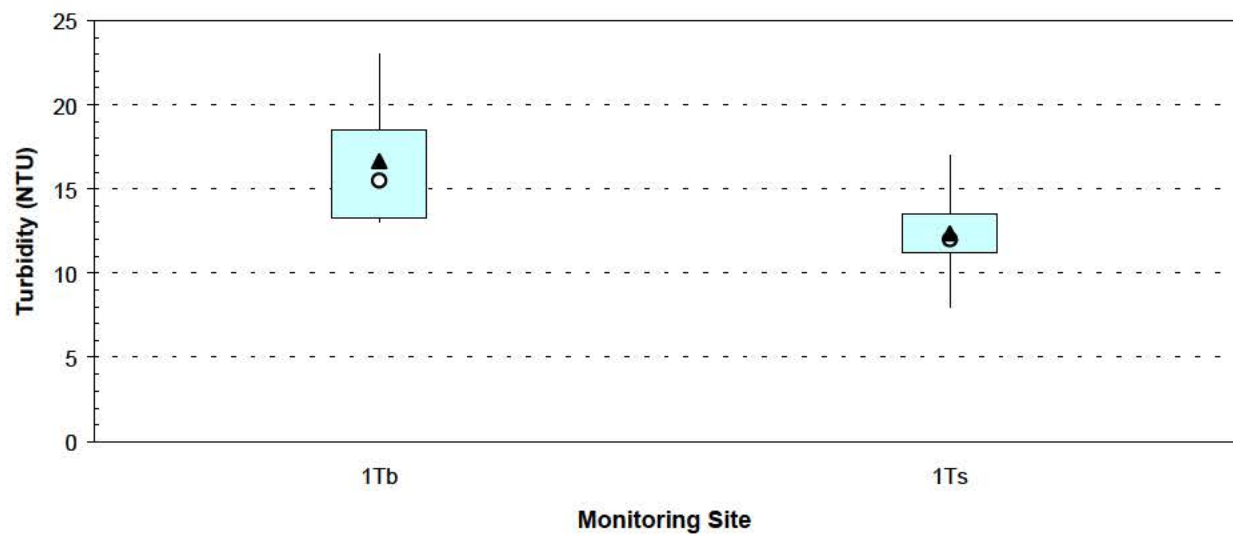


Figure 10. Boxplots of turbidity and total suspended solids levels for the near-bottom and near-surface thalweg samples collected at monitoring location 1.

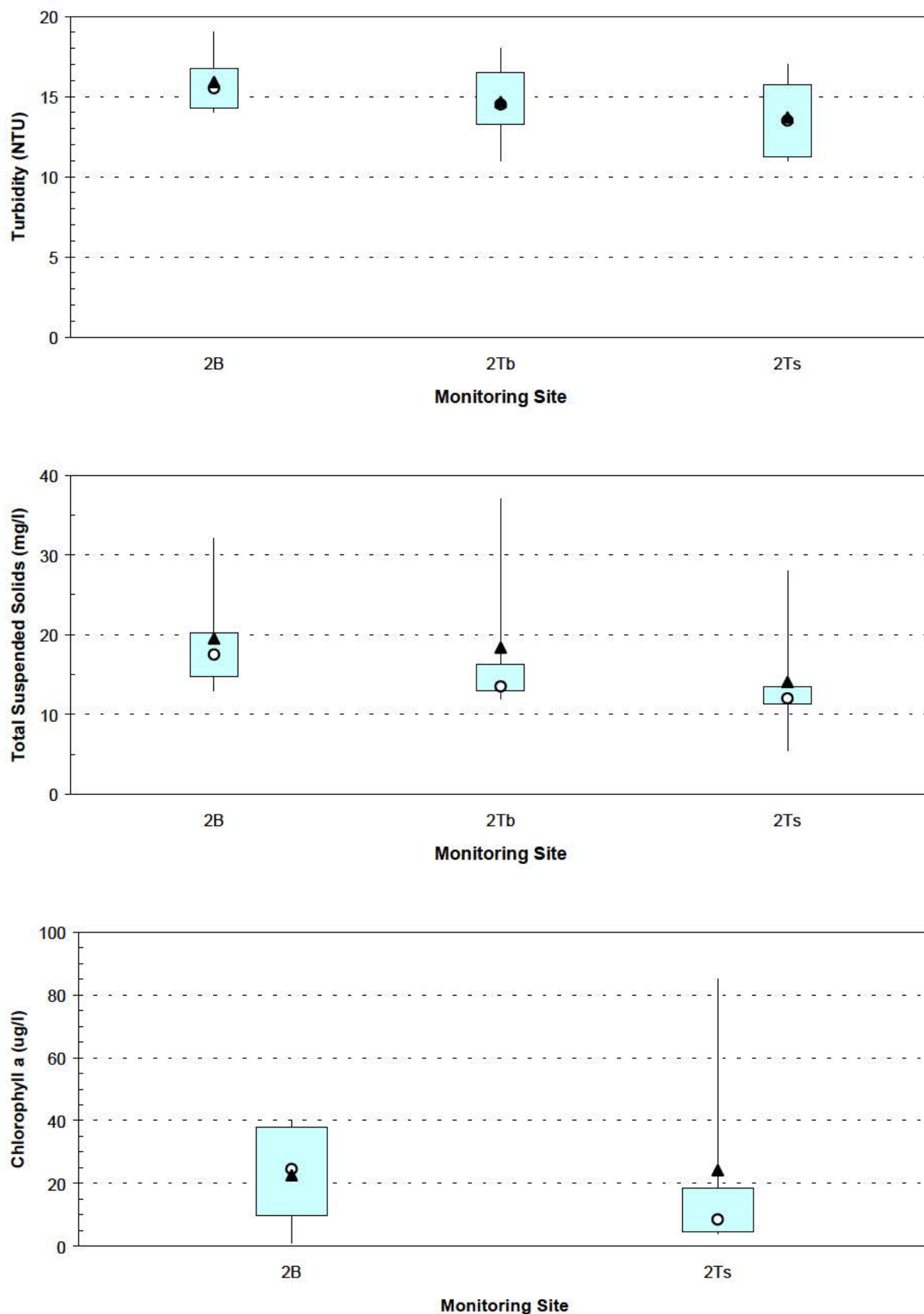


Figure 11. Boxplots of turbidity, total suspended solids, and chlorophyll a levels for the backwater and near-bottom and near-surface thalweg samples collected at monitoring location 2.

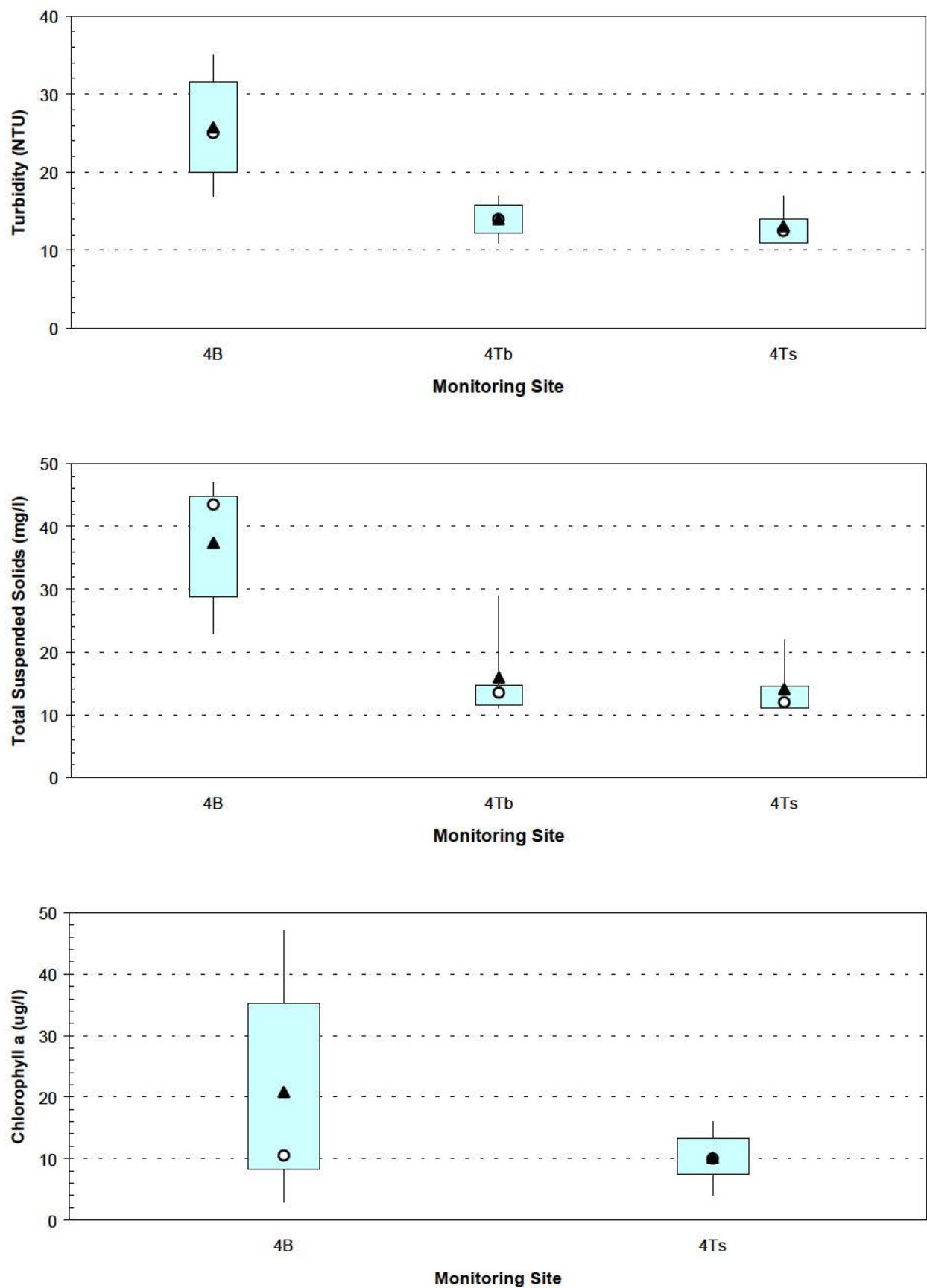


Figure 12. Boxplots of turbidity, total suspended solids, and chlorophyll a levels for the backwater and near-bottom and near-surface thalweg samples collected at monitoring location 4.

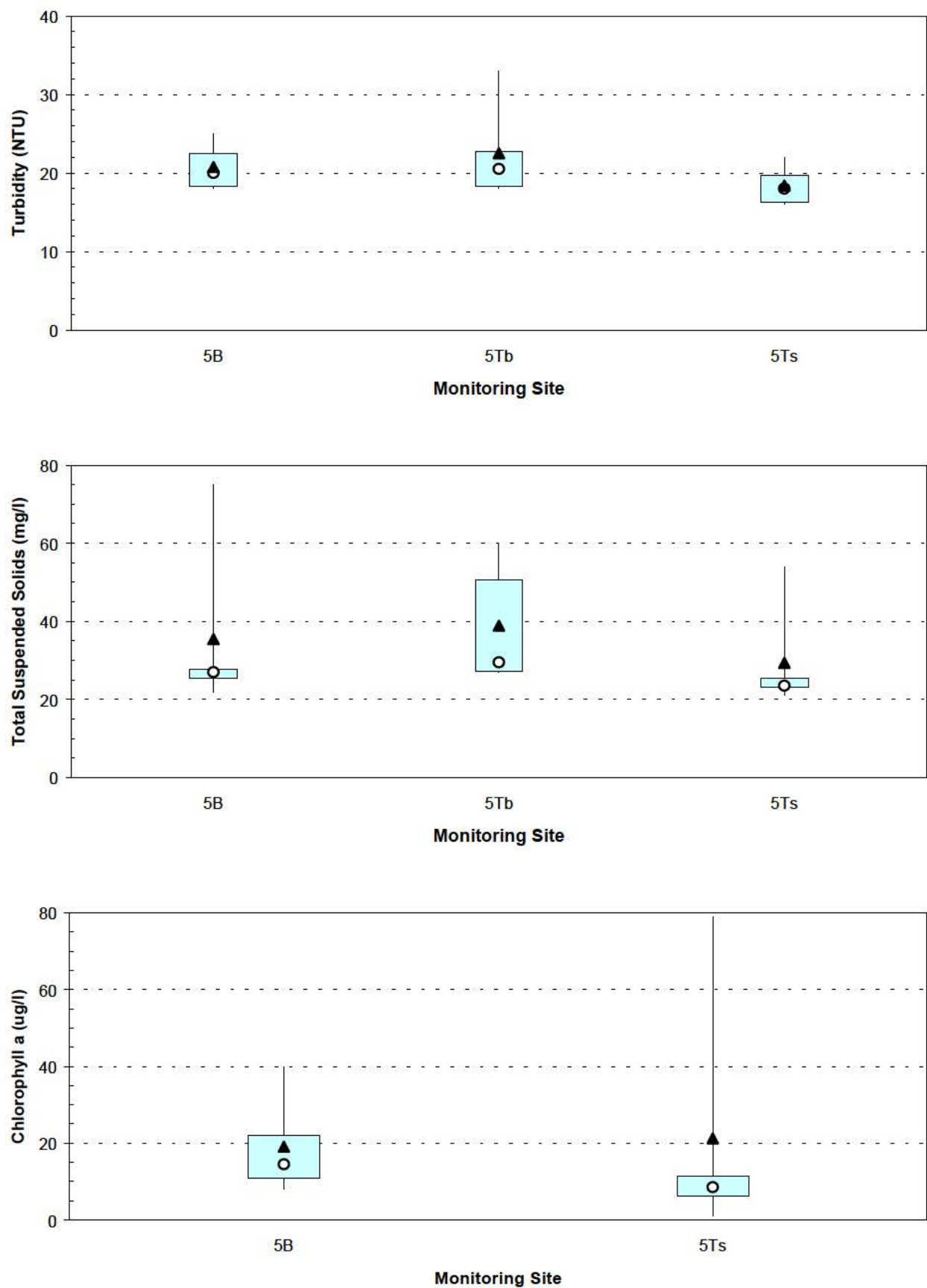


Figure 13. Boxplots of turbidity, total suspended solids, and chlorophyll *a* levels for the backwater and near-bottom and near-surface thalweg samples collected at monitoring location 5.

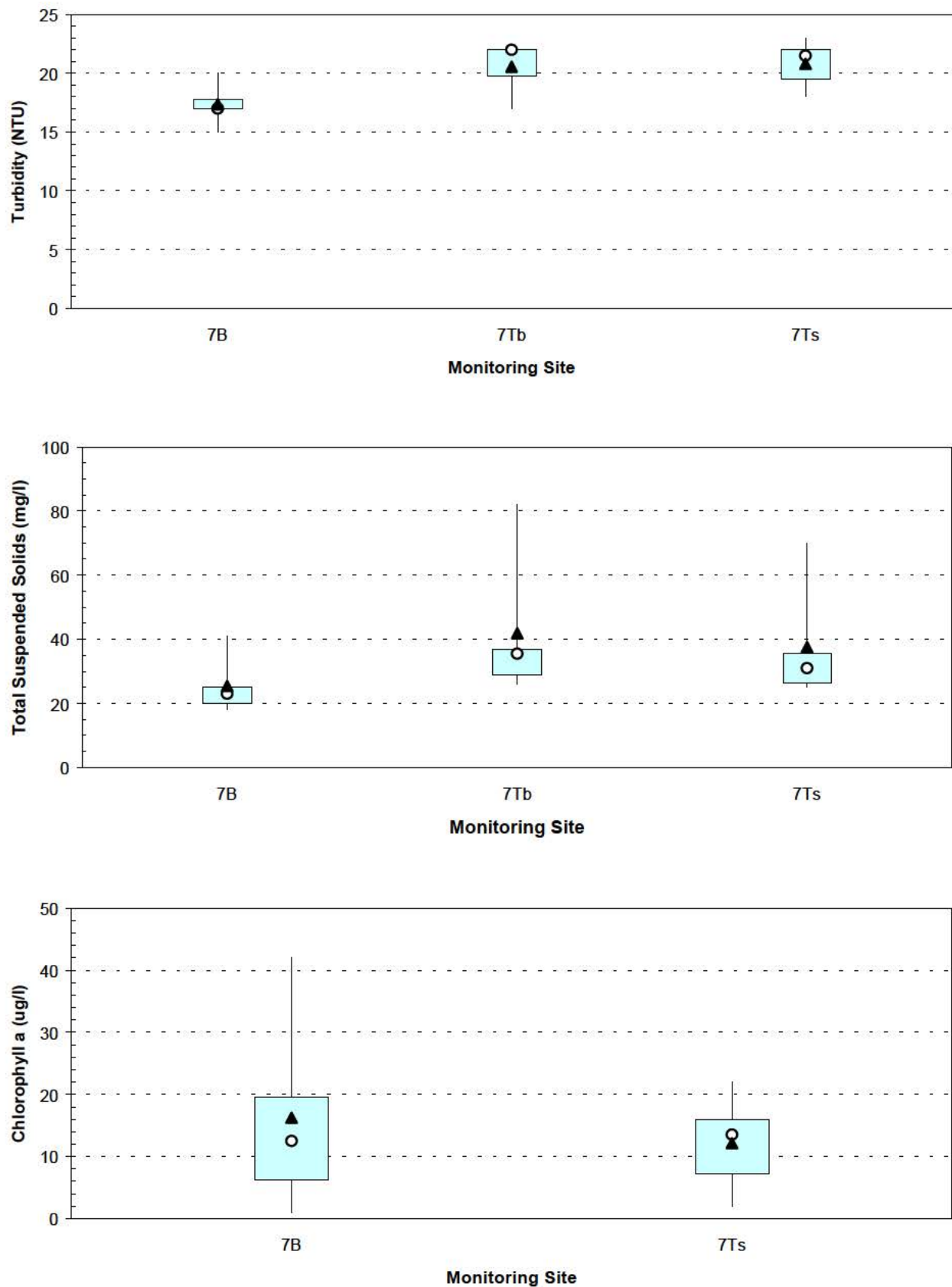


Figure 14. Boxplots of turbidity, total suspended solids, and chlorophyll *a* levels for the backwater and near-bottom and near-surface thalweg samples collected at monitoring location 7.

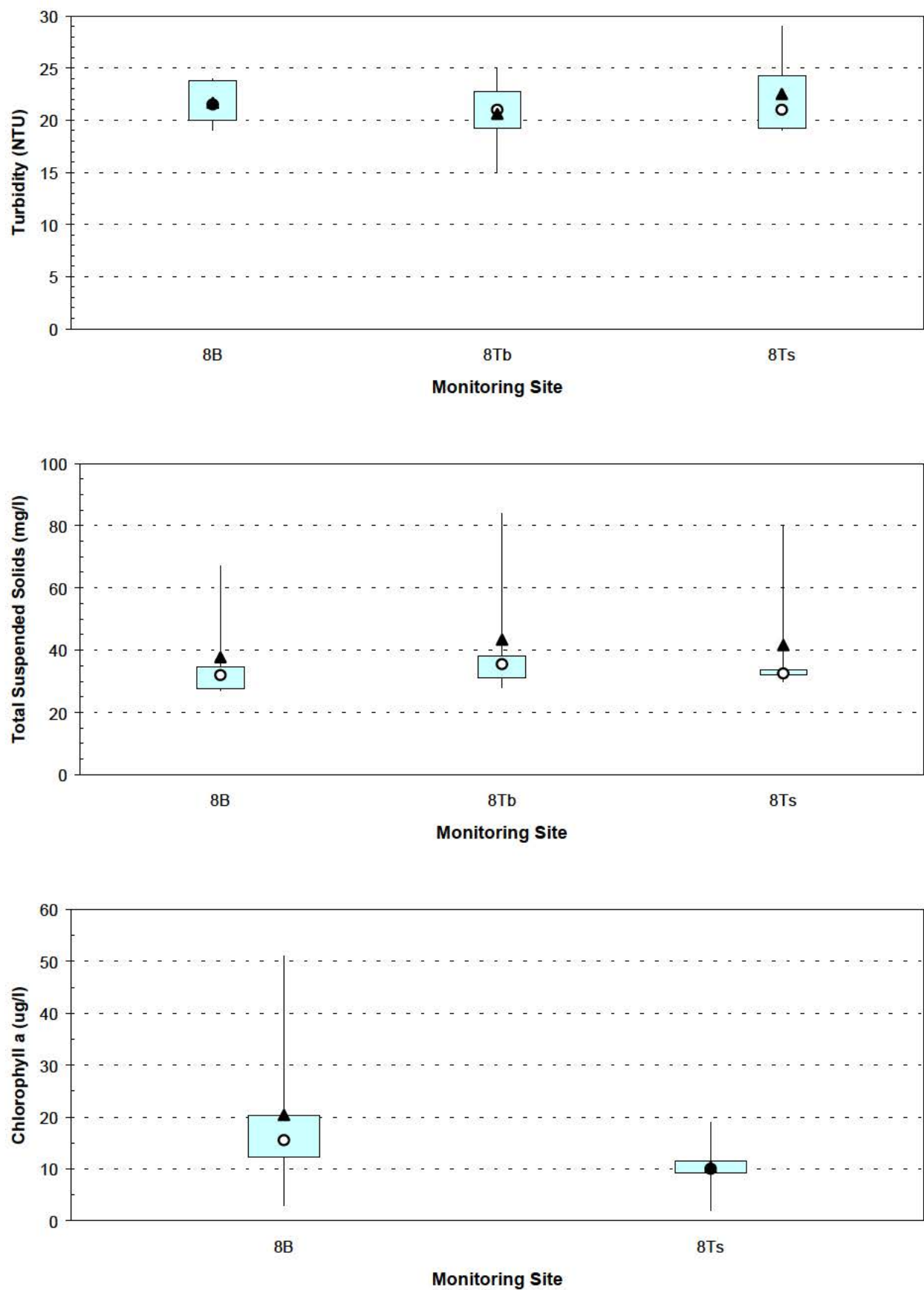


Figure 15. Boxplots of turbidity, total suspended solids, and chlorophyll a levels for the backwater and near-bottom and near-surface thalweg samples collected at monitoring location 8.



Plate 16. Area near the mouth of the James River as it enters a side channel of the Missouri River as depicted in a 1997 orthophoto of the area.