# United States Environmental Protection Agency
# Region 7
# Total Maximum Daily Load
# For Total Suspended Solids,
# Total Nitrogen and Total Phosphorus

## Piper Creek (MO_1444)
## Polk County, Missouri

for William A. Spratlin
Director
Water, Wetlands and Pesticides Division

11-1-10
Date

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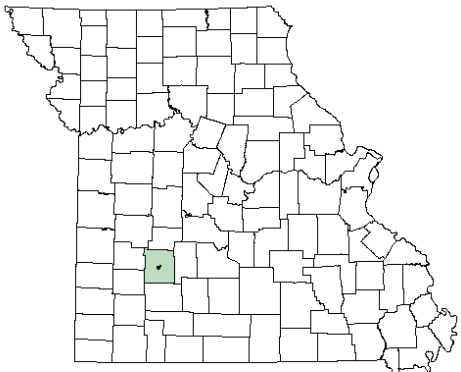
**Total Maximum Daily Load (TMDL)**
**For Piper Creek (Town Branch)**
**303(d) Listed Pollutants: Organic Sediment and Unknown**

**Name:** Piper Creek (Town Branch)[1]


State map showing location of watershed

**Location:** Near the city of Bolivar in Polk County, Missouri

**Hydrologic Unit Code (HUC):** 10290107-0303

**Water Body Identification (WBID):** 1444[2]

**Missouri Stream Class:** Class P[3]

**Designated Beneficial Uses:**
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Human Health Protection (Fish Consumption)
- Whole Body Contact Recreation – Category B (CSR, 2009)

**Size of Classified Segment:** 7.5 miles

**Size of Impaired Segment:** 7.5 miles

**Location of Classified Segment:** From State Highway 83 in Bolivar, Missouri, to the confluence of Piper Creek with the Pomme De Terre River (approximately from 93º 24' 16.93" West, 37º 36' 1.45" North to 93º 24' 18.16" West, 37º 40' 45.36" North).

**Location of Impaired Segment:** From State Highway 83 in Bolivar, Missouri, to the confluence of Piper Creek with the Pomme De Terre River (approximately from 93º 24' 16.93" West, 37º 36' 1.45" North to 93º 24' 18.16" West, 37º 40' 45.36" North).

**Impaired Use:** Protection of Warm Water Aquatic Life

**Pollutants:** Organic Sediment and Unknown

**Identified Source on 303(d) List:** City of Bolivar Wastewater Treatment Facility (WWTF)[4] and Unknown

**TMDL Priority Ranking:** High

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[1] The water body is named "Town Branch" in Missouri water quality standards (WQS) Table H (10 Code of State Regulations (CSR) 20-7.031) and referred to as Piper Creek (Town Branch) in the 2008 303(d) List.
[2] WBIDs are usually assigned to one segment of a classified stream; however, WBID #1444 includes Town Branch as well as a segment of Piper Creek. Town Branch is the receiving stream for Bolivar WWTF and is a tributary of Piper Creek. Throughout this TMDL, the name Piper Creek will be used.
[3] Streams that maintain permanent flow even in drought periods. See Missouri WQS 10 CSR 20-7.031 (1)(F).
[4] Missouri State Operating Permit No. MO0022373. The state permitting system is Missouri's program for administering the National Pollutant Discharge Elimination System (NPDES) program.

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# LIST OF ACRONYMS

| | |
|---|---|
| Σ | Sum |
| µg | Micrograms |
| µg/L | Micrograms per Liter |
| µgN/L | Micrograms of Nitrogen per Liter |
| µgP/L | Micrograms of Phosphorus per Liter |
| AFO | Animal Feeding Operation |
| BI | Biotic Index |
| BMPs | Best Management Practices |
| BOD | Biochemical Oxygen Demand |
| CAFO | Concentrated Animal Feeding Operation |
| CBOD | Carbonaceous Biochemical Oxygen Demand |
| $CBOD_5$ | Carbonaceous Biochemical Oxygen Demand (5-Day) |
| CFR | Code of Federal Regulations |
| cfs | Cubic Feet per Second |
| cms | Cubic Meters per Second |
| CSR | Code of State Regulation |
| CWA | Clean Water Act |
| Deg C | Temperature in Degrees Celsius |
| DO | Dissolved Oxygen |
| e.g. | For Example |
| EDU | Ecological Drainage Unit |
| EPA | United States Environmental Protection Agency |
| EPTT | Ephemeroptera/ Plecoptera/ Trichoptera Taxa |
| FC | Fecal Coliform |
| GIS | Geographic Information System |
| HUC | Hydrologic Unit Code |
| km | Kilometer |
| LA | Load Allocation |
| Lbs/day | Pounds per day |
| LC | Loading Capacity |
| LDC | Load Duration Curve |
| m | Meters |
| m/s | Meters per Second |
| MDC | Missouri Department of Conservation |
| MDNR | Missouri Department of Natural Resources |
| mg | Milligrams |
| mg/L | Milligrams per Liter |
| MGD | Million Gallons per Day |
| MO | Missouri |
| MoRAP | Missouri Resource Assessment Partnership |
| MOS | Margin of Safety |
| MS4 | Municipal Separate Storm Sewer System |
| MSDIS | Missouri Spatial Data Information Service |

**List of Acronyms (continued)**

| | |
|---|---|
| MSOPS | Missouri State Operating Permitting System |
| NA | Not Applicable |
| NASS | National Agricultural Statistics Service |
| NBOD | Nitrogenous Biochemical Oxygen Demand |
| $NH_3$-N | Ammonia Nitrogen |
| $NO_2$-N | Nitrite Nitrogen |
| $NO_3$-N | Nitrate Nitrogen |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| O&G | Oil and Grease |
| ºC | Temperature in Degrees Celsius |
| PBIAS | Percent Bias Statistic |
| PCS | Permit Compliance System |
| RMSE | Root Mean Square Error Statistic |
| SDI | Shannon Diversity Index |
| SOD | Sediment Oxygen Demand |
| SWPPP | Storm Water Pollution Prevention Plan |
| TKN | Total Kjeldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| TR | Taxa Richness |
| TRC | Total Residual Chlorine |
| TROP | Total Recoverable Oil Petroleum |
| TSS | Total Suspended Solids |
| URS | URS Group Inc. |
| U.S. | United States |
| USDA | United States Department of Agriculture |
| USDI | United States Department of the Interior |
| VSS | Volatile Suspended Solids |
| WBID | Water Body Identification |
| WET | Whole Effluent Toxicity |
| WLA | Wasteload Allocation |
| WQS | Water Quality Standards |
| WWTF | Wastewater Treatment Facility |
| WWTP | Wastewater Treatment Plant |

# 1 INTRODUCTION

The Piper Creek Total Maximum Daily Load (TMDL) is being established in accordance with Section 303(d) of the Clean Water Act (CWA). The water quality limited segment is included on the United States (U.S.) Environmental Protection Agency (EPA) approved Missouri 2008 303(d) List and is identified as impaired due to organic sediment and unknown pollutants. This report addresses the Piper Creek impairment by establishing total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) TMDLs in accordance with Section 303(d) of the CWA. EPA is establishing this TMDL to meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001.

During 2003-2004, the Missouri Department of Natural Resources (MDNR) conducted a water quality study aimed at assessing macroinvertebrate populations and characterizing biochemical oxygen demand (BOD), TSS and volatile suspended solids (VSS) concentrations in portions of Town Branch (a tributary to Piper Creek) and Piper Creek. The objective of this study was to determine if the macroinvertebrate community and water quality of Town Branch and Piper Creek were being affected by a wastewater discharge (city of Bolivar wastewater treatment facility (WWTF)). This study was followed by a second study in 2005 in which additional sediment and organic solids assessment in Town Branch and Piper Creek were performed. These studies concluded that both point and nonpoint sources contribute to impaired aquatic life conditions in these water bodies.

Section 303(d) of the CWA and Federal Chapter 40 of Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated beneficial uses under technology-based controls for pollutants of concern. The TMDL process quantitatively assesses the impairment factors so that states can establish water-quality based controls to reduce pollutants and restore and protect the quality of their water resources. The purpose of a TMDL is to determine the maximum amount of a pollutant (the load) that a water body can assimilate without exceeding the water quality standards (WQS) for that pollutant. WQS are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant loading capacity (LC) necessary to meet the Missouri WQS established for each water body based on the relationship between pollutant sources and in-stream water quality conditions. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA) and a margin of safety (MOS). The WLA is the portion of the allowable load that is allocated to point sources. The LA is the portion of the allowable load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with linking pollutant load to the water quality impairment. This is often associated with model assumptions and data limitations.

The goal of the TMDL program is to restore impaired designated beneficial uses to water bodies. Thus, reduction strategies for point and nonpoint sources and implementation of source controls throughout the watershed will be necessary to restore the protection of warm water aquatic life use in Piper Creek. In addition to establishing a TMDL for Piper Creek, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information and detailed analysis of water quality, flow

data and comparison to a reference stream condition in the same ecoregion or ecological drainage unit (EDU) in which Piper Creek is located.

Section 2 of this report provides background information on the Piper Creek watershed and Section 3 describes the water quality problems. Section 4 describes potential sources of concern and Section 5 presents the applicable WQS. Section 6 describes the modeling and technical approach used to develop the TMDL. Sections 7 to 11 present the LC, WLA, LA, MOS and seasonal variation. Sections 12 to 14 present the follow-up monitoring plan, reasonable assurances and public participation. A summary of the administrative record is presented in Section 15. Appendix A summarizes the available water quality data. Appendix B presents QUAL2K modeling conducted to support this TMDL. Methods and data used in the load duration curve (LDC) modeling are presented in Appendix C – Appendix E.

# 2 BACKGROUND

This section of the report provides information on Piper Creek and its watershed.

## 2.1 The Setting

Town Branch and Piper Creek are located in Polk County within the Middle Pomme de Terre River watershed in southwest Missouri. Town Branch flows northeast through the city of Bolivar into Piper Creek. Piper Creek then flows northwest into Pomme de Terre River, which is part of the Osage River Basin that flows into the Missouri River. The Piper Creek impaired watershed covers an area of approximately 37 square miles with a combined stream distance of approximately eight miles.

Portions of Piper Creek and Town Branch are listed as impaired due to exceedances of Missouri's general water quality criteria for protection of warm water aquatic life and natural biological aquatic communities. Both streams were placed on the 303(d) list under the name "Piper Creek" due to observations of objectionable solids downstream of the city of Bolivar WWTF. Piper Creek remains as an impaired water body on the consolidated 2008 Missouri 303(d) List due to organic sediments and unknown pollutants and sources.

The EPA-approved 2008 303(d) List of impaired waters identifies the impaired segments of Piper Creek (Town Branch) at a length of 7.5 miles. Due to the increased accuracy of Geographic Information System (GIS) data layers for analysis over previous methods of stream length measurements, the stream length used in the TMDL analysis does not correspond exactly to the length shown in the 2008 303(d) List. The descriptive start and end point of each segment remains the same. This TMDL addresses the impaired segment in its entirety. Based on such improved estimates using GIS, the impaired segment is approximately eight miles in length, originating on Town Branch at Highway 83 and continuing northeast to the confluence of Piper Creek and the Pomme de Terre River (Figure 1). The elevation of the watershed ranges from approximately 1260 to 870 feet (USDI, 1997). The channel averages approximately 21.5 feet wide based on measurements at four monitoring locations and the average stream gradient is 0.004 feet/feet or 0.4 percent.

## 2.2 Physiographic Location, Geology and Soils

The Piper Creek watershed is located within the Springfield Plateau, a region within the Ozark Natural Division. The Ozark Natural Division is a physiographic section of the Ozark Highland Province. The geology of the watershed is dominated by Jefferson City-Cotter dolomite and includes a small area of Mississippian limestone. Movement of water from the surface to subsurface is minimal throughout most of the watershed. This is due to the stony red clay residue overlying much of the Jefferson City-Cotter and the presence of thin shale units within the formation (MDC, 2009).

Table 1 and Figure 2 provide a summary of soil types in the impaired Piper Creek watershed. Soil data for the Piper Creek watershed is from Natural Resources Conservation Service (2009) soil maps and data. The upland soils along Piper Creek are primarily of the Hoberg-Bona-Creldon Association with a slope range of 1 to 15 percent. The Hoberg silt loam is gently sloping (2 to 5 percent), very deep, well-drained soil found on summits and shoulder slopes, with a fragipan layer. The Bona gravelly silt loam has similar characteristics to the Hoberg, but it can be strongly sloping (3 to 15 percent) and is also found on back slopes. The Creldon silt loam also has similar characteristics, but it is nearly level and is found on summits only. The bottom-land soil is the Sturkie-Moniteau-Horsecreek Association, with a slope of 0 to 2 percent built from alluvium. The Sturkie silt loam is found in the flood plain. This very deep, nearly level soil is well drained with moderate permeability and is frequently flooded. Horsecreek silt loam has the same characteristics, but is found on the stream terrace. Moniteau silt loam is similar to Horsecreek, but is poorly drained and has moderately slow permeability. Lower Piper Creek runs through the Viraton-Ocie-Gatewood soil association. This association is found on ridges and hills with a slope range of 2 to 35 percent. These silt loams are deep and moderately well drained.

The soils hydrologic group relates to the rate at which surface water enters the soil profile, which in turn affects the amount of water that enters the stream as direct runoff. The dominant soil type C, covers approximately 73 percent of the watershed. Group C includes sandy clay loam soils that have a moderately fine to fine structure. These soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water. Soil type B covers approximately 18 percent of the Piper Creek watershed. Group B includes silt loam and loam which have moderate infiltration rates. These soils consist of well drained soils with moderately fine to moderately coarse textures. Approximately 5 percent of soils in the impaired watershed are categorized as Group D. Group D soils include clay loam, silty clay loam, sandy clay, silty clay or clay. This soil group has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material (Purdue Research Foundation, 2009).

## 2.3 Rainfall and Climate

Two weather stations are within or close to the Piper Creek watershed (Figure 3). Both stations record daily precipitation, maximum and minimum temperature, snowfall and snow depth. Figure 3 provides a summary of rainfall and climate data for Station 230789 (Bolivar 1

NE, Missouri) based on 30-year totals (1971 – 2000) (NOAA, 2009). The annual average precipitation and temperature over the 30-year period is 45.5 inches and 55.5 degrees Fahrenheit, respectively. These nearby weather stations will provide useful information for simulating stream temperature which impacts the growth of algae, decay of carbonaceous biochemical oxygen demand (CBOD), transformations of nutrients and solubility of dissolved oxygen (DO).

**Table 1. Piper Creek Watershed Soils Breakdown (NRCS, 2009)**

| Soil Type | Hydrologic Soil Group | Acres | Percent |
|---|---|---|---|
| Bona gravelly silt loam | B | 509 | 2% |
| Peridge silt loam | B | 425 | 2% |
| Pomme silt loam | B | 1,361 | 6% |
| Racket silt loam | B | 1,484 | 6% |
| Sturkie silt loam | B | 265 | 1% |
| Wanda silt loam | B | 299 | 1% |
| **(Subtotal B soil group)** | **B** | **4,344** | **18%** |
| Alsup gravelly silt loam | C | 587 | 2% |
| Barden silt loam | C | 672 | 3% |
| Basehor fine sandy loam | C | 395 | 2% |
| Bolivar loam | C | 2,501 | 11% |
| Creldon silt loam | C | 2,969 | 13% |
| Goodson gravelly silt loam | C | 237 | 1% |
| Goss gravelly silt loam | C | 377 | 2% |
| Hoberg silt loam | C | 2,152 | 9% |
| Mano-Ocie complex | C | 798 | 3% |
| Ocie-Gatewood complex | C | 1,452 | 6% |
| Plato silt loam | C | 610 | 3% |
| Viraton silt loam | C | 4,587 | 19% |
| **(Subtotal C soil group)** | **C** | **17,337** | **73%** |
| Glensted silt loam | D | 315 | 1% |
| Hartville silt loam | D | 501 | 2% |
| Sacville silty clay loam | D | 253 | 1% |
| **(Subtotal D soil group)** | **D** | **1,069** | **5%** |
| Other[5] | B/C/D | 1,002 | 4% |

[5] Other soil types that make up less than one percent of the total watershed area include: Alsup silt loam (C), Blueye-Moko complex (D), Bolivar fine sandy loam (C), Cedargap gravelly silt loam (B), Goodson silt loam (C), Goss very cobbly silt loam (C), Goss-Moko complex (C), Horsecreek silt loam (B), Humansville silt loam (B), Liberal silt loam (C), McGirk silt loam (D), Moko-Rock outcrop complex (D), Moniteau silt loam (C/D), Sowcoon silt loam (D) and Wilderness gravelly silt (C).

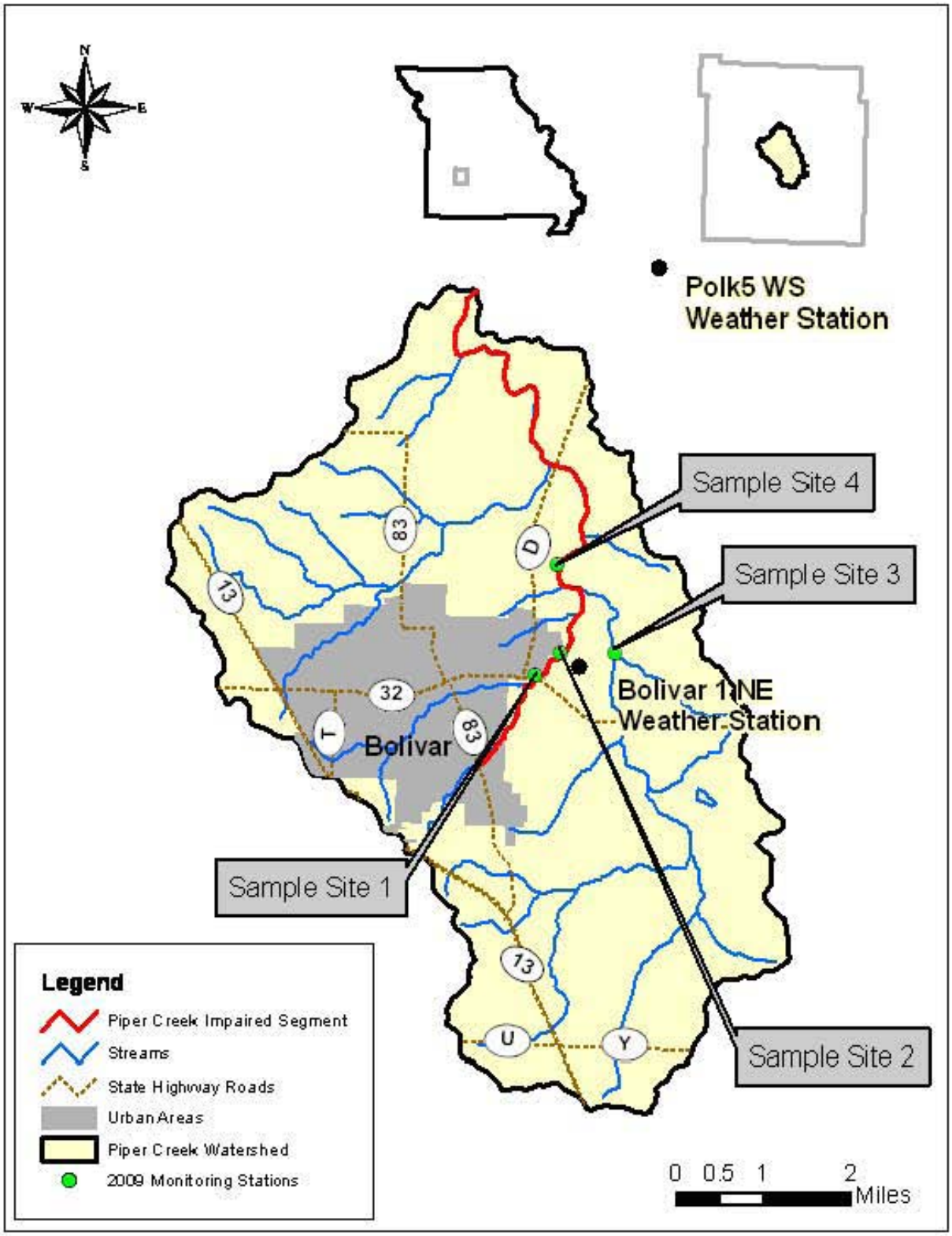


**Figure 1. Location of Piper Creek Watershed with Weather Stations**

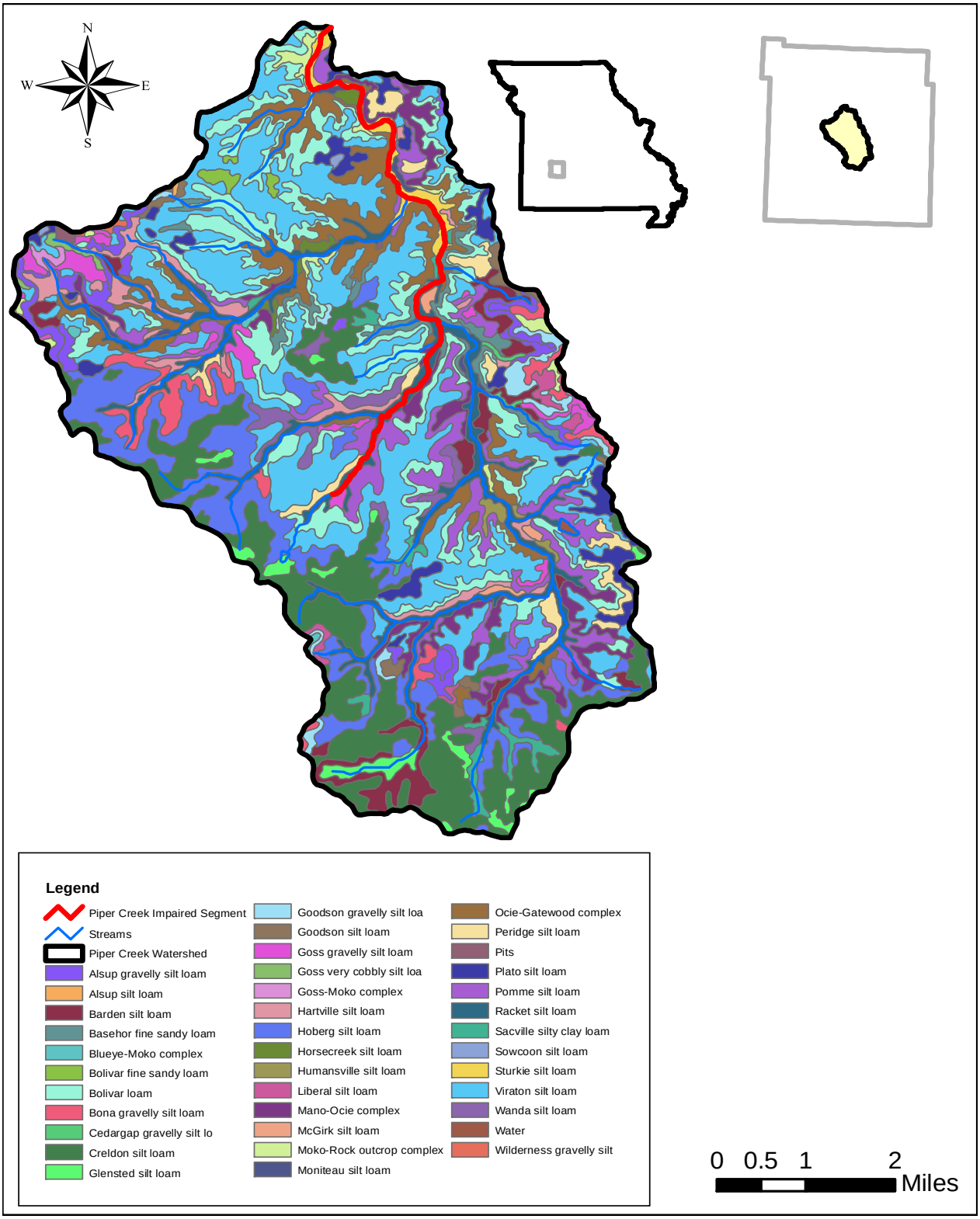


**Figure 2. Piper Creek Watershed Soils**

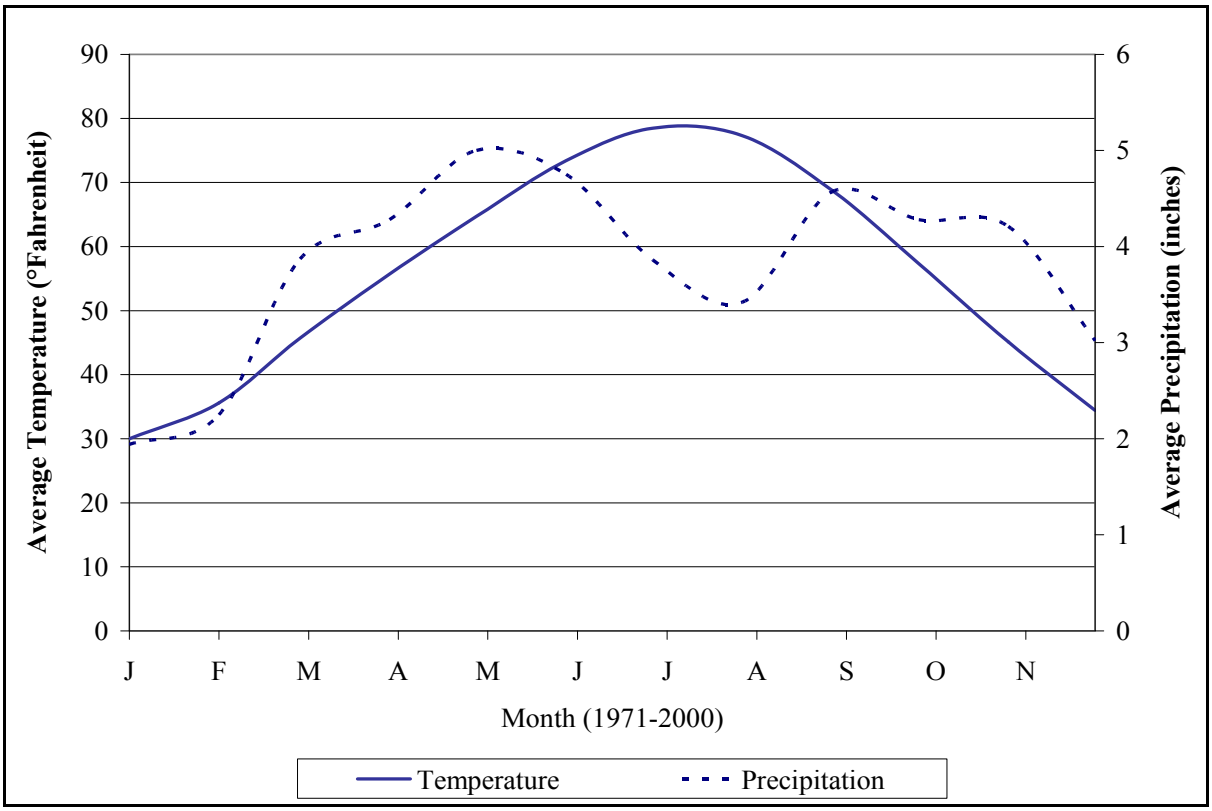


**Figure 3. Thirty-Year Monthly Temperature and Precipitation Averages for Station 230789 (Bolivar, Missouri) (NOAA, 2009)**

## 2.4 Population

According to the United States Census Bureau, the 2000 population for the city of Boliver was 9,143 (U.S. Census Bureau, 2000). The urban population of the watershed can be estimated by multiplying the percent of urban area (city of Bolivar) that is within the watershed and the individual population of the urban area. The urban population of the Piper Creek watershed is approximately 8,968.

The rural population of the watershed can be estimated based on the proportion of the watershed compared to Polk County. Polk County covers an area of 641.86 square miles and has a population of 26,992. The rural population in Polk County is approximately 15,218 (total county population minus population of Aldrich, Bolivar, Fair Play, Flemington, Halfway, Humansville, Morrisville and Pleasant Hope) and the rural county area is 630.33 square miles (total county area minus 11.53 square miles county urban area). The Piper Creek watershed rural area was estimated to be 758 persons; calculated by dividing the rural watershed area (31.4 square miles) by the Polk County rural area (630.33) and multiplying the product by the Polk County rural population (15,218 persons).

The total estimated population of the Piper Creek watershed is approximately 9,715. An overall population density for the Piper Creek watershed was calculated to be 263 persons per square mile (9,715 persons divided by 37 square miles).

## 2.5 Land Use and Land Cover

The land use and land cover of the Piper Creek watershed is shown in Figure 4 and summarized in Table 2 (MoRAP, 2005). The primary land uses/land covers are grassland (62.7 percent) and forest (12.6 percent) with impervious cover and low intensity urban areas occupying 7.1 percent and 6.7 percent of the watershed area, respectively. The remaining categories comprise less than seven percent of the watershed area.

**Table 2. Land Use/Land Cover in the Piper Creek Impaired Watershed (MoRAP, 2005)**

| Land Use/Land Cover | Watershed Area | | Percent of Watershed Area |
|---|---|---|---|
| | Acres | Square Miles | |
| Impervious[6] | 1,682 | 2.6 | 7.1 |
| High Intensity Urban[7] | 91 | 0.1 | 0.4 |
| Low Intensity Urban[8] | 1,597 | 2.5 | 6.7 |
| Barren or Sparsely Vegetated | 171 | 0.3 | 0.7 |
| Cropland | 960 | 1.5 | 4.0 |
| Grassland | 14,887 | 23.3 | 62.7 |
| Forest | 2,993 | 4.7 | 12.6 |
| Herbaceous[9] | 1,214 | 1.9 | 5.1 |
| Wetland | 26 | 0.0 | 0.1 |
| Open Water | 130 | 0.2 | 0.6 |
| **Total** | **23,751** | **37.1** | **100** |

Note: MoRAP = Missouri Resource Assessment Partnership

[6] Impervious land use includes non-vegetated, impervious surfaces including areas dominated by streets, parking lots and buildings (MoRAP, 2005)
[7] High Intensity Urban land use includes vegetated urban environments with a high density of buildings (MoRAP, 2005).
[8] Low Intensity Urban land use includes vegetated urban environments with a low density of buildings (MoRAP 2005).
[9] Herbaceous land use includes open woodland and woody shrubland (including young woodland) with less than 60% vegetated cover (MoRAP 2005).

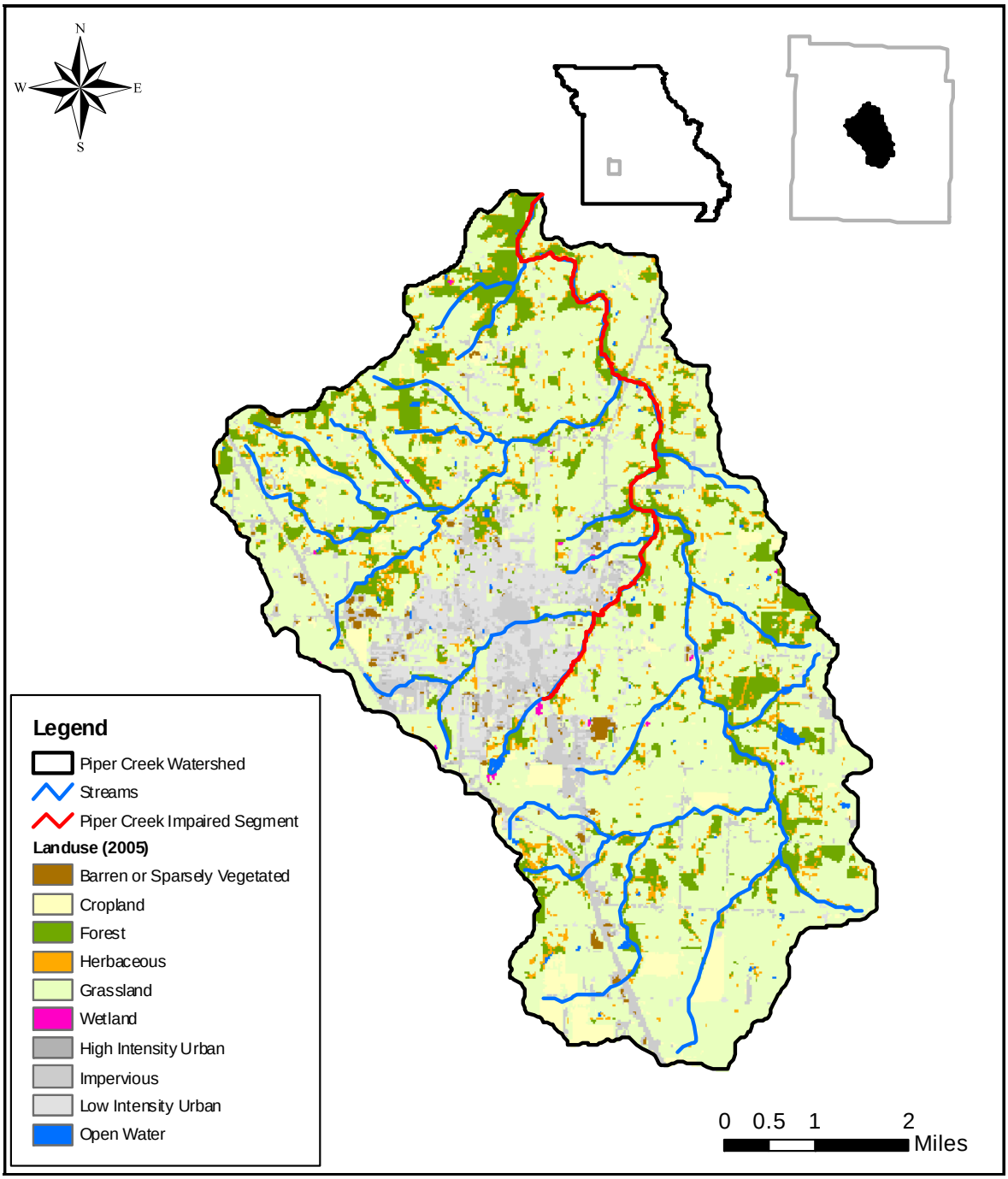


**Figure 4. Land Use/Land Cover in the Piper Creek Impaired Watershed (MoRAP, 2005)**

# 3 DEFINING THE PROBLEM

A TMDL is needed for Piper Creek because it is not meeting Missouri's general criteria pertaining to the protection of aquatic life (10 CSR 20-7.031). The stream was placed on the Missouri 303(d) List of impaired waters because it showed an accumulation of objectionable

solids downstream from the Bolivar WWTF in 1993 (MDNR, 2005). A two-year study of the deposition of solids in Town Branch and Piper Creek was conducted by MDNR beginning in 2003. The portion of the study that characterized impacts related to sediment deposition and organic solids was completed in 2004. The results of this study do not indicate VSS impairment due to the treatment plant. However, the bioassessment portion of the study indicated that the aquatic community was partly impaired due to the WWTF. The study reported heavy growth of algae both upstream and downstream of the facility indicating the WWTF was not the only source of the impairment (MDNR, 2005). The 2008 303(d) List reports Piper Creek (Town Branch) as being impaired by organic sediment and unknown pollutants.

The study described above was comprised of three intensive field studies in the Piper Creek (Town Branch) watershed: a 2003-2004 biological assessment study (MDNR 2004a) and sediment deposition and organic solids evaluations in March - May 2004 and 2005 - 2006 (MDNR 2004b, MDNR 2006). The purpose of the 2003 - 2004 biological assessment study was to characterize the relative importance of the city of Bolivar WWTF to biological conditions in the stream. This characterization was determined through bioassessment, habitat and water quality monitoring at four locations in the watershed and one regional control station (Dry Creek). The Dry Creek #1 station is an unimpaired, regional control station with a watershed size and land use characteristics similar to the Town Branch/ Piper Creek watershed. The purpose of the 2005-2006 study was to evaluate the impact of fine organic solids, originating at the city of Bolivar WWTF, on Town Branch and Piper Creek (MDNR 2006). These studies provide a strong basis for understanding and quantifying impairment from sources in these water bodies.

An underlying assumption in interpreting metric values based on macroinvertebrate communities is that a healthy macroinvertebrate community is a reflection of healthy stream conditions. Mean and standard deviation values for taxa richness (TR), Ephemeroptera/ Plecoptera/Trichoptera Taxa (EPTT), Biotic Index (BI), Shannon Diversity Index (SDI), percent Ephemeroptera, percent Plecoptera, percent Trichoptera and percent composition of the dominant macroinvertebrate families from the Piper Creek, Town Branch and small regional control stations are presented in Appendix A. Taxa richness, EPTT, SDI, percent Ephemeroptera and percent Trichoptera were much higher and BI was much lower at the small regional control stations than the control and test stations at Piper Creek and Town Branch. Both the control and test stations for Piper Creek and Town Branch did not have macroinvertebrate communities comparable to the small regional control stations based on community composition and stream condition index (SCI) scores. Mayflies were in higher abundance at the small regional control stations while chironomids, tubificid worms and planarians were more abundant at the Piper Creek and Town Branch stations. Caenidae, Heptageniidae, Isonychiidae, Psephenidae and Arachnoidea were the more abundant families at the small regional control stations while Elmidae, Planariidae, Chironomidae and Tubificidae were more abundant in the Piper Creek and Town Branch stations. These macroinvertebrate abundances indicate that water quality tolerant species pre-dominate the stream biology.

Spring 2004 data showed that TR, EPTT, percent Ephemeroptera, percent Plecoptera and percent Trichoptera were much higher at Dry Fork #1 than the sampling stations on Town Branch and Piper Creek (Appendix A). Taxa richness, EPTT, percent Ephemeroptera, percent

Plecoptera and percent Trichoptera were very low at the Town Branch and Piper Creek sampling stations except for percent Ephemeroptera at Piper Creek #2. No stoneflies were present at the Town Branch sampling stations. Chironomids were more abundant at Town Branch/Piper Creek sampling stations than Dry Fork #1. Chironomids were especially high in abundance at the Town Branch sampling stations. *Cricotopus/Orthocladius*, *Polypedilum convictum* group and *Dicrotendipes* made up much of the chironomid abundance at the Town Branch stations. *Cricotopus/Orthocladuis*, *Polypedilum* convictum group and *Eukiefferiella* made up for most of the chironomid abundance at Piper Creek. Elmid beetles, primarily *Stenelmis*, were abundant at all of the sampling stations. Tubificid worms were fairly abundant at the sampling stations except at Town Branch #2. Planariidae was much more abundant at the two test stations below the Bolivar WWTF discharge (Town Branch #1 and Piper Creek #1). The results of this spring study also indicate water quality tolerant species exist in the stream and dominate Town Branch/Piper Creek.

Primary conclusions of these studies are as follows:

**Town Branch**

- Evidence of nutrient enrichment (excess algae growth) was present both above and below the WWTF discharge suggesting that both point and nonpoint sources are contributors to biological impairment.
- Town Branch was characterized as having poor habitat; sedimentation was high, pools composed a very small percentage of the sample reach and substrate was very poor for macroinvertebrates. Downstream of the WWTF, epifaunal substrate[10], bank vegetative protection and riparian zone were characterized as poor or marginal.
- The mean sediment deposition value above and below the WWTF discharge was found, on average, to be 78 percent and 90 percent, respectively.
- Most of the effects of nutrient enrichment appeared to be due to the WWTF. In 2003, all macroinvertebrate metrics at stations downstream of the WWTF showed a decline compared to stations upstream of the WWTF.
- The importance of VSS as a contributor to impairment was assessed in both studies. The 2003 - 2004 study found other factors such as habitat, sediment deposition and nutrient enrichment to be greater contributors to impairment than VSS while the 2005 - 2006 study found evidence of significant VSS impairment. The 2005 - 2006 study concluded that "fine sediment percent cover estimations and sediment characterization analysis of this study do show evidence of significant VSS impairment of Town Branch by the Bolivar WWTP" [Wastewater Treatment Plant], and that "the notable differences during [the 2003 - 2004 and 2005 - 2006] survey periods between the two Town Branch sites indicate the Bolivar WWTP as a significant source of impairment."

**Piper Creek**

- The upstream control sample location showed evidence of poor to marginal habitat. Sediment deposition, bank vegetative protection and riparian zone width scored in either

[10] Epifanual substrate is material on the creek bed used by organisms that live on the material.

the poor or marginal scoring category. The influence of adjacent pasture land on erosion and sedimentation was noted.

- The macroinvertebrate community appears to recover between the downstream Town Branch monitoring location and the downstream Piper Creek monitoring location. Water quality, riparian conditions and instream habitat improved at the downstream Piper Creek monitoring location. At this location below the confluence of Town Branch and Piper Creek, sediment deposition was low (17 - 18 percent sediment coverage).

In July 2009 and August 2009, two 48-hour WLA studies were conducted on Piper Creek during summer ambient or low-flow conditions. The 48-hour studies consisted of the collection of one early morning (e.g., 05:00 - 07:30 AM) and one early afternoon (e.g., 12:00 - 2:30 PM) grab sample at each of the four sampling locations (Figure 5), over a consecutive two-day period. The first WLA study was conducted during July 15 - 16, 2009, while the second WLA study was conducted on August 19 - 20, 2009. A detailed summary of monitoring activities conducted during these periods is provided in a separate report (EPA, 2009a). Results from the monitoring are provided in Table 3 through Table 6 and are discussed in this section.

In both of the 48-hour sampling events, temperature and DO generally displayed lower values in the early morning and higher values in the afternoon. The pH readings at all locations throughout both sampling events ranged from 7.73 to 9.20. These values are consistent with those typically expected for a surface water body. Ammonia was below the laboratory detection reporting limit for all samples. Concentrations of nitrate+nitrite ($NO_3$+$NO_2$), total kjeldahl nitrogen (TKN), total nitrogen (TN) (calculated by adding the $NO_3$+$NO_2$ and the TKN concentrations), total phosphorous (TP) and $CBOD_5$ during both of the WLA events were lowest at the sample location upstream of the WWTF with the exception of TKN on July 15, $NO_3$+$NO_2$ on July 16, TKN on August 19 and TKN and $NO_3$+$NO_2$ on August 20. In most cases, the concentrations of all of these analytes were highest at the two locations immediately below the WWTF and the concentrations decreased with an increase in distance downstream. This indicates that the nutrients during these sampling events likely originated from the Bolivar WWTF.

The studies (MDNR, 2004a; MDNR, 2004b; MDNR, 2006; and EPA, 2009a) conducted on Piper Creek (Town Branch) identify several pollutants that may be leading to the impairment of aquatic life. The pollutants include:

- Nutrients (TN and TP) from nonpoint and point sources that may contribute to excessive algae growth above and below the Bolivar WWTF;
- Sediment (TSS) from nonpoint and point sources that may contribute to sedimentation and poor substrate habitat and;
- Low DO caused by decaying organic solids, as measured by $CBOD_5$, high consumption of oxygen from decaying matter on the streambed below the Bolivar WWTF and physical factors associated with low reaeration rates.

Based on this assessment, TMDLs for Piper Creek (Town Branch) will be calculated for TSS, TN, TP and CBOD.

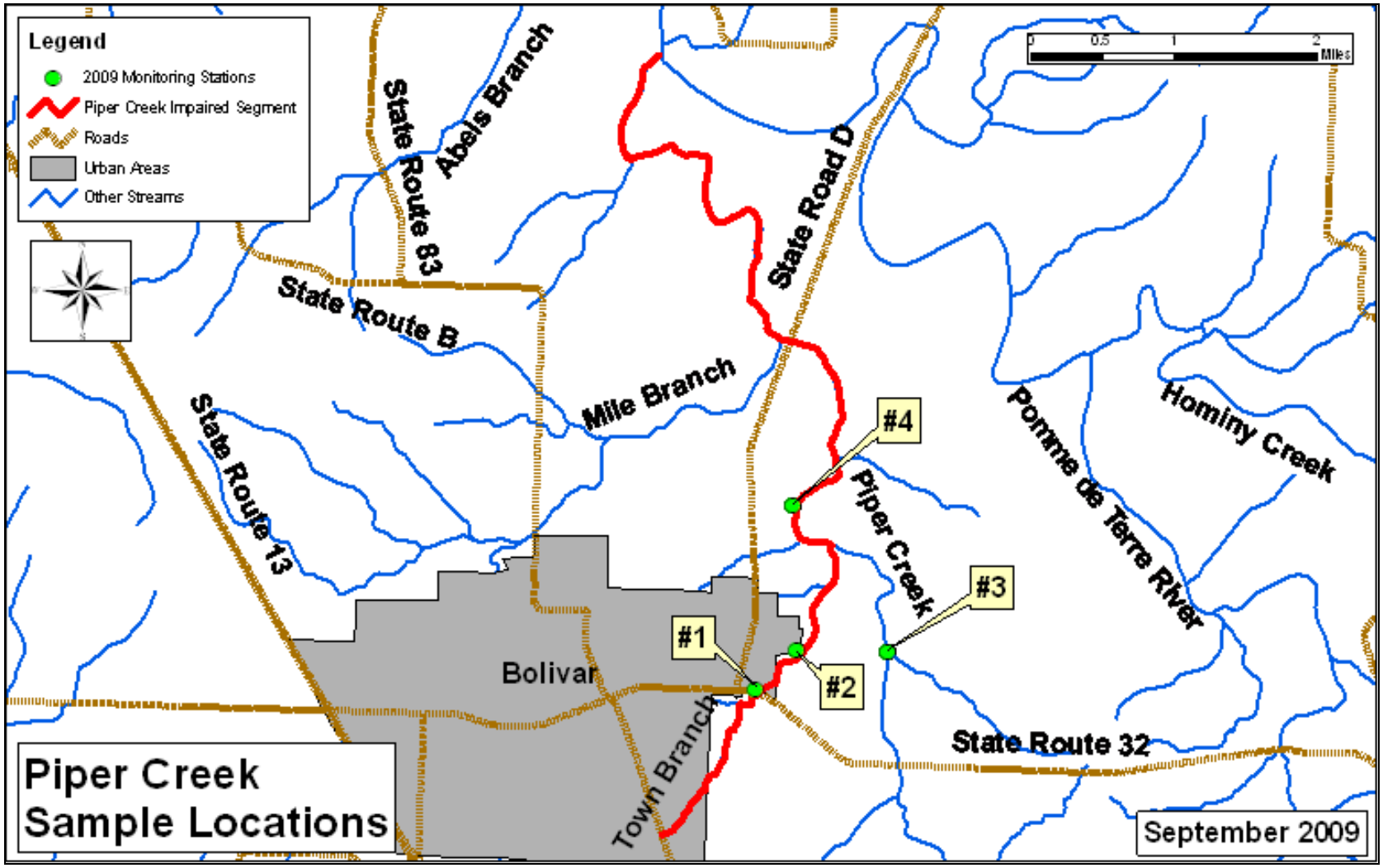


**Figure 5. Location of July 2009 and August 2009 Sampling Sites**

## Table 3. Summary of Piper Creek Water Quality Data Collected on July 15, 2009

| Sampling Location | Time | Flow (cms) | Velocity (m/sec) | $CBOD_5$ (mg/L) | $NH_3$ Nitrogen (mg/L) | TKN Nitrogen (mg/L) | $NO_2$+$NO_3$ Nitrogen (mg/L) | DO (mg/L) | pH | Temp. (°C) | TP (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6:15 AM | 0.275 | 0.496 | 2.500 | < 0.500 | 0.611 | 1.080 | 7.730 | 7.990 | 22.510 | 0.059 |
| 1 | 1:00 PM | 0.116 | 0.273 | 1.800 | < 0.500 | 0.912 | 1.160 | 9.820 | 8.430 | 24.310 | 0.042 |
| 2 | 7:25 AM | 0.297 | 0.399 | 2.200 | < 0.500 | 0.602 | 2.080 | 7.370 | 8.230 | 22.890 | 0.840 |
| 2 | 1:50 PM | 0.199 | 0.316 | 1.600 | < 0.500 | 0.495 | 2.645 | 8.340 | 8.470 | 25.050 | 1.230 |
| 3 | 8:50 AM | 0.057 | 0.006 | 2.100 | < 0.500 | 1.211 | 0.520 | 7.080 | 8.260 | 23.980 | 0.120 |
| 3 | 2:50 PM | 0.108 | 0.012 | 2.600 | < 0.500 | 1.385 | 0.610 | 9.200 | 8.340 | 26.910 | 0.117 |
| 4 | 9:00 AM | 0.359 | 0.166 | 2.000 | < 0.500 | 0.787 | 1.610 | 7.900 | 8.500 | 23.540 | 0.530 |
| 4 | 3:20 PM | 0.433 | 0.201 | 1.100 | < 0.500 | 1.159 | 1.690 | 9.170 | 8.680 | 25.900 | 0.660 |

Notes: cms = cubic meters per second; m/sec = meters per second; mg/L = milligrams per liter; $CBOD_5$ = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; $NO_2$+$NO_3$ = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature in degrees Celsius; TP = Total Phosphorus

## Table 4. Summary of Piper Creek Water Quality Data Collected on July 16, 2009

| Sampling Location | Time | Flow (cms) | Velocity (m/sec) | $CBOD_5$ (mg/L) | $NH_3$ Nitrogen (mg/L) | TKN Nitrogen (mg/L) | $NO_2$+$NO_3$ Nitrogen (mg/L) | DO (mg/L) | pH | Temp. (°C) | TP (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5:20 AM | 0.050 | 0.156 | 1.000 | < 0.500 | 0.142 | 1.700 | 7.930 | 8.460 | 21.860 | 0.035 |
| 1 | 1:00 PM | 0.044 | 0.141 | 0.700 | < 0.500 | 0.270 | 1.795 | 11.680 | 8.910 | 23.960 | 0.035 |
| 2 | 6:15 AM | 0.101 | 0.211 | 0.700 | < 0.500 | 1.026 | 3.480 | 7.590 | 8.490 | 23.200 | 1.365 |
| 2 | 2:20 PM | 0.103 | 0.214 | 1.100 | < 0.500 | 0.709 | 4.170 | 8.600 | 8.660 | 25.600 | 1.910 |
| 3 | 7:50 AM | 0.021 | 0.002 | 1.400 | < 0.500 | 0.622 | 0.580 | 5.450 | 8.420 | 24.360 | 0.077 |
| 3 | 3:20 PM | 0.016 | 0.002 | 1.400 | < 0.500 | 1.355 | 0.550 | 6.550 | 8.410 | 25.110 | 0.071 |
| 4 | 8:20 AM | 0.306 | 0.162 | 1.300 | < 0.500 | 0.735 | 2.040 | 8.490 | 8.780 | 24.340 | 0.770 |
| 4 | 3:30 PM | 0.204 | 0.115 | 1.200 | < 0.500 | 0.758 | 2.160 | 9.550 | 9.200 | 26.840 | 0.750 |

Notes: cms = cubic meters per second; m/sec = meters per second; mg/L = milligrams per liter; $CBOD_5$ = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; $NO_2$+$NO_3$ = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature in degrees Celsius; TP = Total Phosphorus

## Table 5. Summary of Piper Creek Water Quality Data Collected on August 19, 2009

| Sampling Location | Time | Flow (cms) | Velocity (m/sec) | $CBOD_5$ (mg/L) | $NH_3$ Nitrogen (mg/L) | TKN Nitrogen (mg/L) | $NO_2$+$NO_3$ Nitrogen (mg/L) | DO (mg/L) | pH | Temp. (°C) | TP (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5:20 AM | 0.033 | 0.120 | 1.100 | < 0.500 | 2.944 | 1.650 | 6.810 | 8.030 | 18.710 | 0.024 |
| 1 | 1:00 PM | 0.046 | 0.146 | 2.100 | < 0.500 | 1.384 | 1.900 | 10.390 | 8.400 | 21.690 | 0.024 |
| 2 | 6:15 AM | 0.075 | 0.166 | 1.600 | < 0.500 | 7.000 | 6.000 | 6.190 | 7.920 | 19.960 | 0.630 |
| 2 | 1:30 PM | 0.122 | 0.217 | 2.400 | < 0.500 | 1.319 | 6.700 | 8.740 | 8.340 | 22.780 | 0.694 |
| 3 | 6:50 AM | 0.029 | 0.004 | 1.900 | < 0.500 | 0.496 | 0.325 | 2.670 | 7.710 | 20.450 | 0.090 |
| 3 | 2:05 PM | --- | --- | 1.600 | < 0.500 | 0.366 | 0.260 | 3.680 | 7.750 | 21.400 | 0.039 |
| 4 | 8:15 AM | 0.166 | 0.099 | 0.850 | < 0.500 | 0.668 | 3.550 | 6.400 | 8.130 | 20.140 | 0.360 |
| 4 | 3:05 PM | 0.185 | 0.103 | 2.100 | < 0.500 | 1.237 | 3.500 | 10.130 | 8.750 | 23.120 | 0.340 |

Notes: cms = cubic meters per second; m/sec = meters per second; mg/L = milligrams per liter; $CBOD_5$ = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; $NO_2$+$NO_3$ = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature in degrees Celsius; TP = Total Phosphorus. Values denoted --- were too small to measure or compute.

**Table 6. Summary of Piper Creek Water Quality Data Collected on August 20, 2009**

| Sampling Location | Time | Flow (cms) | Velocity (m/sec) | $CBOD_5$ (mg/L) | $NH_3$ Nitrogen (mg/L) | TKN Nitrogen (mg/L) | $NO_2$+$NO_3$ Nitrogen (mg/L) | DO (mg/L) | pH | Temp. (°C) | TP (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5:15 AM | 0.029 | 0.105 | 1.500 | < 0.500 | 0.985 | 1.960 | 6.840 | 8.020 | 19.360 | 0.021 |
| 1 | 1:00 PM | 0.027 | 0.097 | 1.300 | < 0.500 | 0.827 | 1.780 | 10.950 | 8.340 | 21.980 | 0.019 |
| 2 | 5:50 AM | 0.072 | 0.163 | 1.100 | < 0.500 | 0.847 | 6.300 | 5.700 | 7.950 | 20.650 | 0.550 |
| 2 | 1:45 PM | 0.091 | 0.189 | 1.700 | < 0.500 | 0.646 | 8.400 | 7.840 | 8.210 | 23.000 | 0.670 |
| 3 | 7:05 AM | 0.103 | 0.012 | 1.300 | < 0.500 | 0.768 | 0.257 | 2.770 | 7.730 | 21.030 | 0.033 |
| 3 | 2:20 PM | 0.001 | 0.000 | 1.500 | < 0.500 | 2.973 | 0.255 | 4.900 | 7.710 | 22.160 | 0.029 |
| 4 | 8:15 AM | 0.165 | 0.105 | 1.200 | < 0.500 | 1.067 | 4.000 | 6.560 | 8.090 | 20.740 | 0.400 |
| 4 | 3:05 PM | 0.199 | 0.105 | 1.400 | < 0.500 | 0.614 | 3.600 | 10.110 | 8.770 | 23.520 | 0.330 |

Notes: cms = cubic meters per second; m/sec = meters per second; mg/L = milligrams per liter; $CBOD_5$ = Carbonaceous Biochemical Oxygen Demand (5 days); TKN = Total Kjeldahl Nitrogen; $NO_2$+$NO_3$ = Nitrite + Nitrate; DO = Dissolved Oxygen; Temp. = Temperature in degrees Celsius; TP = Total Phosphorus

As discussed in Sections 4 and 5, the low DO problem could be due to one or more of the following:

- Excessive loads of decaying organic solids, as measured by BOD.
- Too much algae in the stream as a result of excessive phosphorus or nitrogen loading.
- High consumption of oxygen from decaying matter on the streambed.
- Higher temperatures due to loss of riparian vegetative canopy.

# 4 SOURCE INVENTORY

A source assessment is used to identify and characterize the known and suspected sources contributing to impairment in Piper Creek. For the purpose of this report, sources have been divided into two broad categories: point sources and nonpoint sources. Point sources can be defined as sources, either constant or time transient which occur at a fixed location in a watershed. Nonpoint sources are generally accepted to be diffuse sources not entering a water body at a specific location. Nutrients and oxygen consuming substances from both point and nonpoint sources are considered to be the primary contributors to impairment in Piper Creek. Historic water quality data used to identify and assess sources is presented in Appendix A of this document.

## 4.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. For the purposes of TMDL development, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the Missouri State Operating Permit System (MSOPS). The NPDES and MSOPS programs are the same and for the purposes of this document the term "NPDES" will be used. The following NPDES-regulated entities are included in this source category:

- Municipal and industrial WWTF,
- Concentrated animal feeding operations (CAFOs),
- Storm water runoff from Municipal Separate Storm Sewer Systems (MS4s) and
- General permitted facilities (including storm water runoff from construction and industrial sites).

General permits (as opposed to site specific permits) are issued to activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued to activities that discharge only in response to precipitation events. Point sources in Piper Creek were identified by consulting EPA's Permit Compliance System (PCS) website[11] and Missouri's GIS inventory[12] of storm water and general NPDES-permitted facilities.

Point sources in Piper Creek watershed are listed in Table 7 and shown in Figure 6. Of those listed, five are site specific permits, three are general permits and the remaining twelve are storm water permits. Five permittees are required to monitor and report effluent or storm water concentrations.

[11] www.epa.gov/enviro/html/pcs/index.html
[12] http://msdis.missouri.edu/datasearch/ThemeList.jsp; GIS layers updated May 2009 and June 2009

**Table 7. Permitted Facilities in the Piper Creek Watershed**

| Facility ID | Facility Name | Receiving Stream | Classification/ Description | Discharge Sampling Requirements[1] | Design Flow (MGD)[2] | Permit Expiration Date |
|---|---|---|---|---|---|---|
| MO0022373 | City of Bolivar WWTF | Town Branch | Sewerage system | Unionized $NH_3$, Total $NH_3$, DO, TP, TN, TSS, Temperature, $BOD_5$, pH, Flow, O&G, FC, WET | 2.55 | 2013 |
| MO0097594 | Home Court Advantage, Inc. WWTF | Unnamed Tributary to Mile Branch which flows to Piper Creek | Group Home/ Sewerage Works | Flow, $BOD_5$, TSS, pH, Fecal Coliform, $NH_3$, Temperature and DO (quarterly monitoring) | 0.007 | 2009 |
| MO0116467 | Quail Creek Mobile Home Park WWTF | Unnamed Tributary to Piper Creek | Mobile Home Park/ Sewerage Works | Flow, $BOD_5$, TSS, pH, TP (quarterly monitoring) | 0.01395 | 2010 |
| MO0121754 | Silo Ridge Homeowners Association WWTF | Unnamed Tributary to Piper Creek | Subdivision / Sewerage Works | Flow, $BOD_5$, TSS, pH, Fecal Coliform, TRC, $NH_3$, Temperature, DO (quarterly monitoring) | 0.016830 | 2008 |
| MO0121924 | Karlin Place Subdivision WWTF | Unnamed Tributary to Piper Creek | Commercial Park/ Subdivision/ Sewerage Works | Flow, $BOD_5$, TSS, pH, Fecal Coliform, $NH_3$, Temperature and DO (quarterly monitoring) | 0.021 | 2013 |
| MOG350232 | Carl White Oil Company | Town Branch Tributary | Bulk terminal petroleum station | pH, O&G, TROP, Ethanol, Ethyl Benzene, flow | General Permit | 2012 |
| MOG490247 | Ewing Concrete Materials | Mile Branch Tributary | Crushed and broken limestone | pH, O&G, TSS, Flow, Settleable Solids | General Permit | 2011 |
| MOG490263 | Bolivar Ready Mix & Material | Town Branch Tributary | Crushed and broken limestone | pH, O&G, TSS, Flow, Settleable Solids | General Permit | 2011 |
| MOR109R13 | Industrial Development | Piper Creek Tributary | Heavy Construction | NA | Storm water permit | 2012 |

**Table 7. Permitted Facilities in the Piper Creek Watershed (continued)**

| Facility ID | Facility Name | Receiving Stream | Classification/ Description | Discharge Sampling Requirements | Design Flow (MGD) | Permit Expiration Date |
|---|---|---|---|---|---|---|
| MOR109S12 | Burlington Heights Subdivision | Town Branch Tributary | Heavy Construction | NA | Storm water permit | 2012 |
| MOR109S57 | Monarch Landing | Town Branch | Heavy Construction | NA | Storm water permit | 2012 |
| MOR10A541 | Settler's Village | Town Branch | Heavy Construction | NA | Storm water permit | 2012 |
| MOR10B098 | Walgreen | Town Branch | Heavy Construction | NA | Storm water permit | 2012 |
| MOR10B515 | Stonebridge Estates | Town Branch | Heavy Construction | NA | Storm water permit | 2012 |
| MOR10C027 | ALDI | Town Branch | Heavy Construction | NA | Storm water permit | 2012 |
| MOR10C083 | Highline Village | Town Branch Tributary | Heavy Construction | NA | Storm water permit | 2012 |
| MOR203016 | Tracker Marine | Town Branch | Boat building and repairing | NA | Storm water permit | 2009 |
| MOR240033 | Bolivar Farmers Exchange Fertilizer | Town Branch Tributary | Farm supplies | NA | Storm water permit | 2014 |
| MOR240221 | Hawk Fertilizer | Town Branch Tributary | Farm supplies | NA | Storm water permit | 2014 |
| MOR60A120 | Yeargain Steel & Salvage Yard | Mile Branch Tributary | Motor vehicle parts, used | NA | Storm water permit | 2013 |

[1] Where DO = Dissolved Oxygen, $NH_3$ = Ammonia, BOD = Biochemical Oxygen Demand, TSS = Total Suspended Solids, TN = Total Nitrogen, TP = Total Phosphorus O&G = Oil and Grease, WET = Whole Effluent Toxicity, FC = Fecal Coliform, TRC = Total Residual Chlorine, TROP = Total Recoverable Oil Petroleum; "NA" = Not Applicable. Permits identified as "NA" are storm water or general permits.

[2] MGD = Million Gallons per Day. 1MGD = 1.547229 cubic feet per second (cfs). 1 cfs = 0.6463169 MGD.

The city of Bolivar WWTF (MO0022373) is located in Bolivar, Missouri. The current NPDES permit became effective in April 2008 and expires in April 2013. The facility was designed to accommodate a population of 25,365 people with a design flow of 2.55 million gallons per day (MGD) and sludge production of 533 dry tons sludge/year. According to the 2008 permit, actual flows average 1.4 MGD. The facility maintains one outfall to Town Branch. Two monitoring locations are specified in the permit. Monitoring location S1 is located on Town Branch at the State Highway 32 Bridge, approximately 340 meters upstream of outfall 001 and monitoring location S2 is located at the Division Street Bridge, approximately 360 yards downstream of outfall 001.

Home Court Advantage, Inc. WWTF (also identified as Hillside Estates on the EPA PCS website) (MO0097594) is located in Bolivar, Missouri, and became effective September 2004 and expired September 2009. The facility was designed to accommodate a population of 70 people with a design flow of 7,000 gallons per day and sludge production of 1.5 dry tons sludge/year. The facility maintains one outfall at Mile Branch, a tributary to Piper Creek.

The Quail Creek Mobile Home Park WWTF (MO0116467) is located on Route 4 in Bolivar, Missouri. This facility maintains one discharge to an unnamed tributary of Piper Creek upstream of the confluence of Town Branch with Piper Creek. The facility was designed to accommodate a population of 186 with a design flow of 13,950 gallons per day (adjusted design flow is 6,999 gallons per day) and sludge production of 3 dry tons/year.

The Silo Ridge Homeowners Association WWTF (MO0121754) is in Bolivar, Missouri. This facility maintains a single discharge to an unnamed tributary of Piper Creek upstream of the confluence of Town Branch with Piper Creek. The facility was designed to accommodate a population of 237 with a design flow of 16,830 gallons per day (adjusted design flow is 4,999 gallons per day) and a design sludge production of 1.66 dry tons/year.

Karlin Place Subdivision WWTF (MO0121924) is located in Bolivar, Missouri. This facility maintains a single discharge to an unnamed tributary of Piper Creek upstream of the confluence of Town Branch with Piper Creek. The facility was designed to accommodate a population of 190 with a design flow of 21,000 gallons per day and a design sludge production of 1.33 dry tons/year.

Of these WWTFs, the city of Bolivar WWTF (MO0022373) is the only point source that discharges directly to the 303(d)-listed portions of Town Branch/Piper Creek.

There are eight storm water permits that are classified as heavy construction, which is designated as land disturbance, including construction or land disturbance greater than one acre. This type of permit authorizes wastewater and storm water discharges with requirements that discharges do not cause an exceedance of the state WQSs (10 CSR 20-7.031) and that the permittee develop and implement a Storm Water Pollution Prevention Plan (SWPPP). Since the permit is for storm water discharges, it will likely have minimal impact on DO concentrations in the stream as the measured DO exceedances occurred during low flow conditions. However, it is possible that these permits may have an impact on organic sediment and sediment oxygen demand (SOD).

Storm water permit MOR203016 (Tracker Marine) is classified as boat building and repairing, which authorizes the discharge of storm water runoff from facilities having Standard Industrial Classification (SIC) codes including 2514, 2522, 2542, 33xx, 34xx, 35xx, 36xx, 37xx and 38xx. In general these codes represent metal, electrical and industrial equipment used for storage and transportation.

Storm water permits MOR240033 (Bolivar Farmers Exchange Fertilizer) and MOR240221 (Hawk Fertilizer) are classified as farm supplies which authorizes the discharge of containment water to waters of the state of Missouri from an agrichemical facility.

Storm water permit MOR60A120 (Yeargain Steel and Salvage Yard) is classified as used motor vehicle parts, which authorizes the discharge of storm water runoff to waters of the state of Missouri from motor vehicle salvage yards and auto/truck recycling operations.

General permits MOG490247 (Ewing Concrete Materials) and MOG490263 (Bolivar Ready Mix and Material) are classified as crushed and broken limestone which authorizes wastewater discharges from limestone and other rock quarries, concrete, glass and asphalt industries.

General permit MOG350232 (Carl White Oil Company) is classified as a bulk terminal petroleum station which authorizes storm water discharges from facilities with above-ground storage capacity totaling more than 20,000 gallons but less than 250,000 gallons of ethanol or biodiesel.

Storm water and general permits shown in Table 7 and discussed in this section will not have a significant impact on Piper Creek water quality during low flow events; however, these sources may contribute nutrients and sediment during runoff events that may impact water quality in the stream.

Illicit straight pipe discharges of household wastes (i.e., a pipe that transports human waste from a household directly to a stream or lake) are also potential point sources in rural areas. These sources are discharged directly into streams or land areas and are different than illicitly connected sewers. There is no specific information on the number of illicit straight pipe discharges of household wastes in the Piper Creek watershed. Leaking or illicitly connected sewers can also be a significant source of pollutant loads within urban areas.

### 4.1.1 Runoff from MS4 Urban Areas

There are no Phase I or Phase II regulated communities within the Piper Creek watershed at this time.

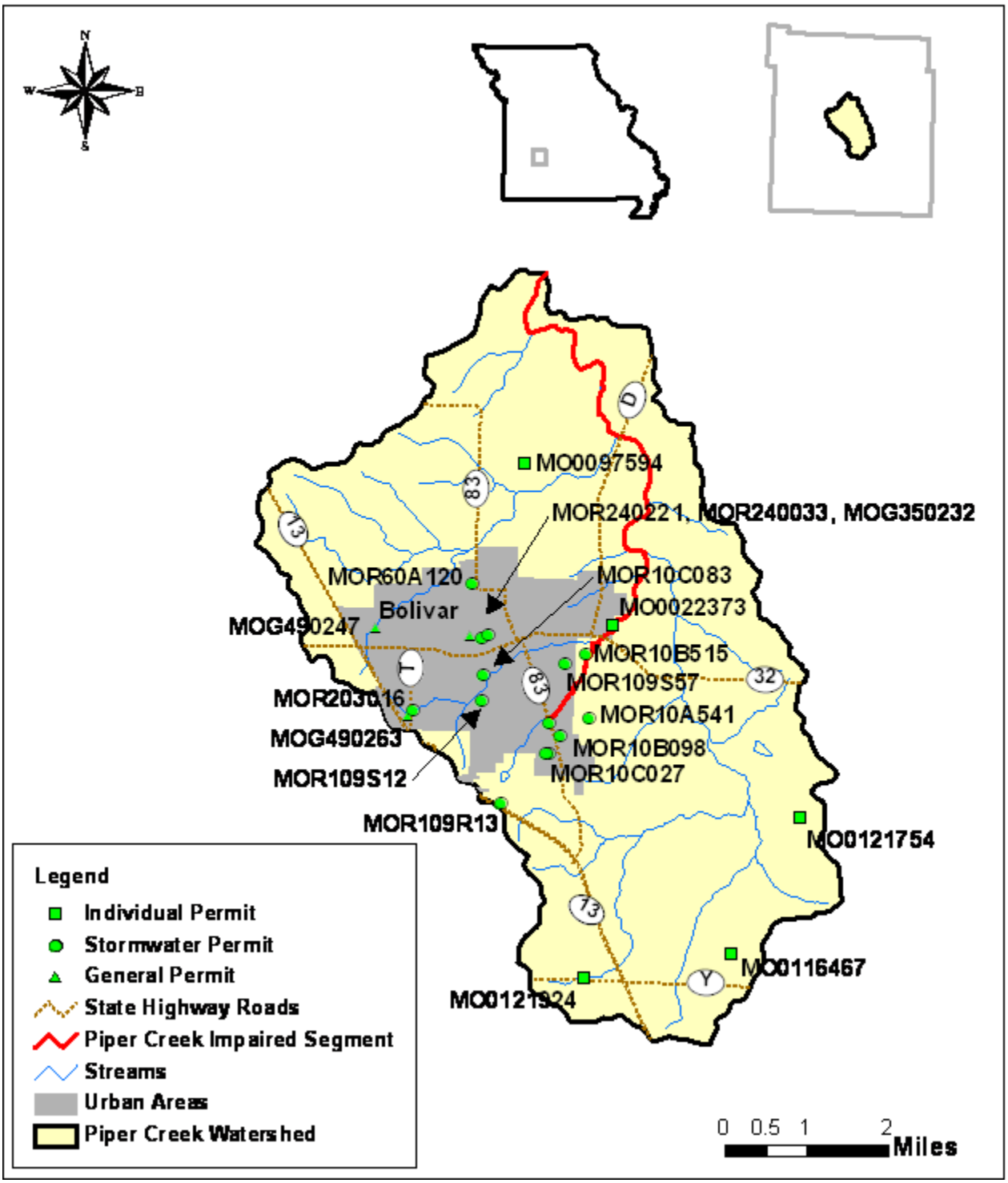


**Figure 6. Location of Permitted Facilities in the Piper Creek Watershed**

## 4.2 Nonpoint Sources

Nonpoint sources include all other categories of pollutant sources not classified as point sources. Potential nonpoint sources contributing to low DO problems in the Piper Creek watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems and various sources associated with riparian habitat conditions. Additional discussion on nonpoint sources is provided in the following sections.

Based on the information before us, the decision to apply discharges associated with unpermitted sources to the LA, as opposed to the WLA for purposes of this TMDL, is acceptable. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by approving these TMDLs with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated sum of the WLA in this TMDL. WLA in addition to that allocated here is not available.

### 4.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients and oxygen consuming substances. Accumulation of nitrogen and phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The 2005 land use/land cover data indicates there are 1.5 square miles of cropland in the watershed, which comprises 4 percent of the entire watershed (Table 2). An assessment of cropland in the riparian buffer of the impaired stream segment showed cropland to be approximately 1 percent ( Table 8).

U.S. Geological Survey (USGS) HUC 8 data taken from the United States Department of Agriculture (USDA) Census of Agriculture (USDA, 2002) were combined with the land cover data for the Piper Creek watershed to estimate approximately 3,122 cattle in the watershed[13]. The cattle are most likely located on the approximately 23.3 square miles of grassland in the watershed; and runoff from these areas can be potential sources of nutrients and oxygen consuming substances. Animals grazing in pasture areas deposit manure directly upon the land surface and even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover, increasing the possibility of erosion and contaminated runoff during a storm event. In addition, when pasture land is not fenced off from the stream, cattle or other livestock may contribute nutrients to the stream while walking in or adjacent to the water body. The low density of cattle in the Piper Creek watershed (84 cattle per square mile) suggests they are unlikely to be a significant source of pollutants. The USDA Census of Agriculture also reports there were 4,915 hogs, 510 sheep, 2,799 horses, 11,798 chickens,

[13] According to the USDA Census of Agriculture there are approximately 56,196 head of cattle and 420.3 square miles of pasture/rangeland in the Pomme De Terre Watershed (HUC 10290107) (USDA, 2002). These two values result in a cattle density of approximately 134 cattle per square mile of grasslands. This density was multiplied by the number of grassland square miles in the Piper Creek watershed to estimate the number of cattle in the watershed.

232,540 turkeys and 43 ducks in the Pomme De Terre Watershed (HUC 10290107) (USDA, 2002). No data are available to estimate the number of these other livestock that might be located in the Piper Creek watershed. Since none of the agricultural operations are CAFOs and the density of cattle is low, it is unlikely that runoff from agricultural areas is a significant source of TSS, TN or TP loads to the watershed.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. At this time, animal feeding operations (AFOs) and unpermitted CAFOs are considered under the LA because we do not currently have enough detailed information to know whether these facilities are required to obtain NPDES permits. This TMDL does not reflect a determination by EPA that such facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved.

Any CAFO that does not obtain a NPDES permit must operate as a no discharge operation. Any discharge from an unpermitted CAFO is a violation of Section 301. It is EPA's position that all CAFOs should obtain a NPDES permit because it provides clarity of compliance requirements, authorization to discharge when the discharges are the result of large precipitation events (e.g., in excess of 25-year and 24-hour frequency/duration) or are from a man-made conveyance.

### 4.2.2 Runoff from Non-MS4 Urban Areas

Storm water runoff from impervious surfaces, high intensity urban areas and low intensity urban areas can also be a source of pollutants. Nutrients, organic matter and sediments from urban storm water runoff can contribute to degraded water quality and impact aquatic life. Excessive nutrients from fertilizers, pet waste and urban wildlife can contribute to nuisance algae and rooted aquatic plants, which may contribute to low DO concentrations. Phosphorus loads from residential areas can be comparable to or higher than loading rates from agricultural areas (Reckhow et al., 1980; Athayde et al., 1983). Organic matter in storm water runoff may originate from failing septic tanks, leaking sewers, yard waste, animal waste and natural organic material. Decomposition of this material consumes oxygen and may reduce DO concentrations in aquatic environments. Storm water runoff from urban areas such as parking lots and buildings is also warmer than runoff from grassy and woodland areas, which can lead to higher temperatures that lower the DO saturation capacity of the stream. Excessive discharge of suspended solids from urban areas may lead to streambed siltation problems and contribute to SOD within streams.

Since approximately 14.2 percent of the Piper Creek watershed is classified as urban and much of this area drains directly to the impaired reach, it is likely that urban storm water runoff contributes to the impairment. This source will be considered in developing the TMDL.

### 4.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters. Failing septic systems release nutrients and pathogens that can reach nearby streams through both runoff and groundwater flows.

The exact number of onsite wastewater treatment systems in the Piper Creek watershed is unknown. However, as discussed in Section 2.4, the estimated rural population in the Piper Creek watershed is approximately 747 persons. Based on this population and on an average density of 2.4 persons per household, there may be approximately 311 systems in the watershed or approximately one septic system for every 64 acres of rural area. Based on aerial imagery, most of the septic systems are thought to be evenly disbursed throughout the rural portion of the watershed located outside the limits of the city of Bolivar. These areas are predominately used for agriculture. No site specific studies have indicated that localized failure of onsite wastewater treatment systems are a problem in the Piper Creek (Town Branch) watershed. EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is between 30 and 50 percent (EPA, 2002). Failing onsite wastewater treatment systems could be a significant source of pollutants if the failure rate is close to the EPA estimate. However, given that the number of septic systems is relatively small (one system per 64 acres of rural land) and that field studies have not identified the presence of failing septic systems in this watershed, this source is not considered a significant source of pollutants at this time.

### 4.2.4 Riparian Habitat Conditions

Riparian[14] (streamside) habitat conditions can have a strong influence on instream DO, TSS, TN and TP. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of nutrients from or by the water column. Therefore, a stream with good riparian habitat is able to moderate higher TSS and nutrient loads than a stream with poor riparian habitat. Riparian buffers can stabilize stream banks and reduce soil erosion. Riparian buffers stabilize the stream banks by providing a root network that helps hold soil in place, reducing instream TSS. In addition, riparian buffers can reduce stream temperatures by providing more shading and thus increase DO carrying capacity in the stream. However, riparian buffers can be the source of undesirable natural material generated in the stream, which may cause low DO problems. For example, leaf fall from vegetation near the water's edge, aquatic plants and drainage from organically rich areas like swamps and bogs are all natural sources of material that consume oxygen.

As indicated in Table 8, approximately half of the land in the Piper Creek 30-meter riparian corridor is classified as forest (MoRAP, 2005). Grassland, including pasture areas, covers approximately one-third of the riparian corridor. Compared to wooded areas, grasslands have the potential to provide much less shading and higher nutrient loads due to livestock activity.

[14] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

**Table 8. Percentage Land Use/Land Cover Within a 30-Meter Riparian Buffer**

| Land Use/Land Cover | Percent of Piper Creek Riparian Area (%)[1] |
|---|---|
| Barren or Sparsely Vegetated | 0.0 |
| Cropland | 1.1 |
| Forest | 48.1 |
| Herbaceous[2] | 9.4 |
| Grassland | 33.4 |
| Wetland | 0.0 |
| High Intensity Urban | 0.4 |
| Impervious | 0.6 |
| Low Intensity Urban | 4.4 |
| Open Water | 2.6 |

[1] Source: MoRAP (2005)
[2] Herbaceous land use includes open woodland and woody shrubland (including young woodland) with less than 60% vegetated cover (MoRAP 2005)

# 5 APPLICABLE WATER QUALITY STANDARDS AND NUMERIC WATER QUALITY TARGETS

Section 303(d) of the CWA and Chapter 40 of the CFR Part 130 require states to develop TMDLs for waters not meeting WQS. The TMDL process quantitatively assesses the impairment factors so that states can establish water-quality based controls to reduce pollutants of concern from both point and nonpoint sources and to restore and protect the quality of their water resources.

Under the CWA, every state must adopt WQS to protect, maintain and improve the quality of the nation's surface waters (US Code Title 33, Chapter 26, Subchapter III [US Code, 2009]). These standards represent a level of water quality that will support the CWA's goal of "fishable/swimmable" waters. Missouri's Surface WQS (10 Code of State Regulation [CSR, 2009] 20-7.031) consist of three components: designated uses, criteria (general and numeric) and an antidegradation policy.

Beneficial or designated uses for Missouri streams are found in the WQS at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (CSR, 2009). Criteria for designated uses are found at 10 CSR 20-7.031, Tables A and B (CSR, 2009)). Missouri's antidegradation policy is outlined at 10 CSR 20-7.031(2) (CSR, 2009).

## 5.1 Designated Beneficial Uses

The designated beneficial uses of Piper Creek (Class P) are:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life

- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation-Category B (CSR, 2009)

The impaired use is the "Protection of Warm Water Aquatic Life." The designated beneficial uses and stream classifications for Missouri may be found in the WQS at 10 CSR 20-7.031(1)(C), (1)(F) and Table H available from the Missouri Secretary of State (CSR, 2009).

## 5.2 Criteria

Missouri's water quality criteria that relate to DO, organic sediment and nutrients are presented in the following sections. The sections also provide brief descriptions of why these parameters are important to water quality, how they are measured and how they are related to other water quality parameters.

### 5.2.1 Dissolved Oxygen

The amount of DO in water is one of the most commonly used indicators of river and stream health. Under extended hypoxic (low DO) or anoxic (no DO) conditions, many higher forms of life are driven off or die. Fish, mussels, macroinvertebrates and all other aquatic life utilize DO to create energy and metabolize food. The WQS for all Missouri streams except cold water fisheries require a daily minimum of 5 milligrams per liter (mg/L) DO (10 CSR 20-7.031 Table A (CSR, 2009)).

DO in streams is affected by several factors including water temperature, the amount of decaying matter (i.e., organic sediment) in the stream, turbulence at the air-water interface and the amount of photosynthesis occurring in plants within the stream. Excessive nitrogen and phosphorus loading to water bodies can also contribute to DO problems because they can accelerate algal growth.

Algae growth in streams is most frequently assessed based on the amount of chlorophyll-a in the water. Algal growth is affected by numerous biotic and abiotic factors including light availability, flow and water velocity, nutrients (particularly nitrogen and phosphorus), grazing and other influences. Algae contribute DO during photosynthesis and consume DO during respiration. This typically results in a net gain of DO during the day and net loss of DO during the night. The breakdown of dead, decaying algae also removes oxygen from water. The most common approach to reducing excessive algal growth involves controls on activities that contribute phosphorus to the water body.

### 5.2.2 Organic Sediment

As previously mentioned, organic sediments can contribute to fluctuating DO concentrations. Decaying matter can come from wastewater effluent, as well as agricultural and urban runoff and is typically measured in-stream as BOD. Decaying matter can also accumulate on the bottom of a stream and cause sediment oxygen demand (SOD). SOD is a combination of all of the oxygen-consuming processes that occur at or just below the sediment/water interface. SOD is partly due to biological processes and partly due to chemical processes. Most of the

SOD at the surface of the sediment is due to the biological decomposition of organic material and the bacterially facilitated nitrification of $NH_3$, while SOD found several centimeters into the sediment is often dominated by the chemical oxidation of species such as iron, manganese and sulfide (Wang, 1980; Walker and Snodgrass, 1986).

High levels of organic sediment can contribute to sludge production along stream beds which smother aquatic invertebrates and fish eggs and cause offensive odors and unsightliness. Missouri's WQS do not include specific numeric criteria for this pollutant, but given the natural effects of excessive organic sediment on aquatic life, Missouri's narrative criteria are applicable [10 CSR 20-7.031(3)(A), (C), (D) and (G)] (CSR, 2009). Included in the narrative criteria are the following requirements:

- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits, or prevent full maintenance of beneficial uses.
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor, or prevent full maintenance of beneficial uses.
- Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life.
- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

There are many quantitative indicators of sediment, such as TSS, turbidity and bedload sediment, which are appropriate to describe sediment in rivers and streams (EPA, 2006). A concentration of TSS was selected to represent the numeric target for this TMDL because it enables the use of the highest quality available data and is included in monitoring data. A detailed discussion of the method used to develop the TSS target is provided in Appendix C.

### 5.2.3 Total Nitrogen and Total Phosphorus

An overabundance of nutrients, in particular nitrogen and phosphorus, is a serious threat to aquatic ecosystems. Excess nutrients support rapid algal growth, also referred to as algal blooms, which will cause significant changes to the water body. This phenomenon is called eutrophication. Eutrophication is the natural aging of lakes or streams caused by nutrient enrichment. Cultural eutrophication is the accelerated aging of the natural condition caused by human activities. Nutrient related water quality issues include the following:

- Proliferation of nuisance algae and the resulting unsightly and harmful bottom deposits;
- Turbidity due to suspended algae and the resulting green color;
- Organic enrichment when algal blooms die off, which perpetuates the cycle of excessive plant growth;
- Low DO caused by extreme swings in oxygen production by over abundant plant life and oxygen depletion resulting from decomposition of algae and other plants, which can have a negative impact on aquatic organisms.

Missouri does not have a numeric criterion for TN and TP in freshwater streams; therefore, targets and LCs are based on EPA-recommended Ecoregion 39 criteria and water quality observations at locations throughout the ecoregion (EPA, 2000). Reference conditions for TN and TP in level III Ecoregion 39 streams are as follows: TN = 0.289 mg/L and TP = 0.007 mg/L. For this TMDL, recommended TN and TP ecoregion criteria are used directly in developing LCs for TN and TP. A detailed discussion of the method used to develop the TN and TP targets is provided in Appendix D of this report.

### 5.3 Antidegradation Policy

Missouri's WQS include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (CSR, 2009).

> Tier 1 – Protects existing in stream uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing in stream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first WQS Regulation.
>
> Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an anti-degradation review consisting of: 1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; 2) full satisfaction of all intergovernmental coordination and public participation provisions; and 3) assurance that the highest statutory and regulatory requirements for point sources and best management practices (BMPs) for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing or beneficial uses.
>
> Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

## 6 MODELING APPROACH

Dissolved Oxygen (DO) in streams is determined by the factors of photosynthetic productivity, respiration (autotrophic and heterotrophic), reaeration and temperature. These factors are influenced by natural and anthropogenic conditions within a watershed. Generally, reaeration is based on the physical properties of the stream and on the capacity of water to hold DO. This capacity is mainly determined by water temperature with colder water having a higher saturation concentration for DO. In a review of variables and their importance in DO modeling, Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Even though the hydrological regime of historic alluvial streams was modified

by changes in land cover and channelization, manipulation of these parameters does not address a pollutant and so is not the goal of a TMDL. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (nitrogen and phosphorus)
- turbidity

An essential component of developing a TMDL is establishing a relationship between the source loadings and the resulting water quality. For this TMDL, two modeling approaches are used. The load duration curve (LDC) method is used to develop TMDLs for TSS, TN and TP under all flow conditions and the QUAL2K model is used to assess DO under low flow conditions. The relationship between the source loadings of CBOD, nutrients ($NH_3$, TN and TP) and algal dynamics on DO is generated by the water quality model QUAL2K (Chapra et al., 2008) under steady low flow conditions.

Since fine particle sized sediment and turbidity are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL establishes an allocation for TSS (see Appendix C for discussion of development of TSS targets). This target was derived based on a reference approach by targeting the 25th percentile of TSS measurements (USGS, non-filterable residue) in the Ozark/Osage geographic region in which Piper Creek is located. To address nutrient levels, the EPA nutrient ecoregion reference concentrations were used. For the Level III 39 Ecoregion where Piper Creek is located, the reference concentration for TN is 0.289 mg/L and the reference concentration for TP is 0.007 mg/L (EPA, 2000). This TMDL will not specifically target chlorophyll as a WLA, but will use a linkage between nutrient concentrations and chlorophyll response to achieve the ecoregion reference concentrations.

## 6.1 Load Duration Curves

The sediment target for this TMDL was derived using a reference approach by targeting the 25th percentile of TSS measurements (USGS, non-filterable residue) in the geographical region in which Piper Creek is located (see Appendix C for a list of sites and data). In this approach, the target for pollutant loading is the 25th percentile of the current EDU condition calculated from all data available within the EDU in which the water body is located. Therefore, the 25th percentile is targeted as the TMDL LDC.

To develop LDCs for TN and TP, a method similar to that used for TSS was employed. First, TN and TP measurements were collected from USGS sites in the vicinity of the impaired stream. These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where this would result in a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. This modeled data was then regressed as instantaneous load versus flow. The resultant regression equation was used to develop the LDC. Allowable pollutant loads were calculated for all flow conditions by multiplying flow by either the EPA-

recommended ecoregion reference concentration or the concentration established using the regional streams, whichever concentration is higher.

To develop the TMDL expression of maximum daily loads, the background discharge at the stream outlet was modified from the traditional approach using synthetic flow estimation. Since the design flow from permitted facilities would overwhelm the background natural low flow, the sum of permitted volumes was added to the derived stream discharge at all percentiles of flow to take into account the increases in flow volume as well as pollutant load. The TMDL curves in the LDCs flatten at low flow because at these lower flows the TMDL target is dominated by the point source flow.

## 6.2 QUAL2K

QUAL2K and its predecessor models have been used extensively for permitting of wastewater treatment discharges and TMDL development across the country. QUAL2K is supported by EPA and is well accepted within the scientific community because of its proven ability to simulate the processes important to DO conditions within streams. QUAL2K is suitable for simulating the hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth and DO dynamics. QUAL2K links plant respiration and photosynthesis as well as other oxygen demanding substances such as CBOD, the nitrification process (which uses oxygen to reduce organic nitrogen to $NH_3$ and then to $NO_3$+$NO_2$) and sediment demands of organic substances to instream oxygen levels.

Flow and water quality data collected on July 15 - 16, 2009, were used to calibrate the QUAL2K model for Piper Creek and data collected on August 19 - 20, 2009, were used to validate the models. Once the QUAL2K model was set up and calibrated for Piper Creek, a series of scenarios were run to evaluate the pollutant load reductions needed to achieve the minimum DO criterion. These results are summarized in Section 7 and a detailed discussion of the QUAL2K model is included in Appendix B.

# 7 CALCULATION OF LOADING CAPACITY

LC is defined as the greatest amount of a pollutant that a water body can assimilate without violating WQS. This load is then divided among the point source (WLA) and nonpoint source (LA) contributions to the stream, with an allowance for an explicit MOS. The MOS accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving water body. If the MOS is implicit, no numeric allowance is necessary. Conceptually, this definition is represented by the equation:

$$LC = \Sigma\ WLAs + \Sigma\ LAs + MOS \qquad \textbf{Equation 1}$$

Where:

LC = Loading Capacity

WLA = Wasteload Allocations (point source)

LA = Load Allocations (nonpoint source)

MOS = Margin of Safety (may be implicit and factored into a conservative WLA or LA or explicit)

The objective of the TMDL is to estimate allowable pollutant loads and to allocate these loads to known pollutant sources within the watershed so appropriate control measures can be implemented and the WQS can be achieved. The WLA and LA are calculated by multiplying the appropriate flow in cubic feet per second (cfs) by the appropriate pollutant concentration in milligrams per liter (mg/L). A conversion factor of 5.395 is used to convert to pounds per day (lbs/day).

Critical conditions are considered when the LC is calculated. DO levels that threaten the integrity of aquatic communities generally occur during low flow periods, so these periods are considered the critical condition. For Class P streams, mixing zones are applicable to all pollutants (with the exception of bacteria) that have specific criteria. Mixing zones are typically based on the 7-day average low flow of a stream with a recurrence interval of 10 years (7Q10) to account for critical low-flow conditions.

In the case of Piper Creek, a mixing zone of one-quarter (¼) of the stream width, cross-sectional area, or volume of flow and a length of ¼ mile is allowed. For modeling purposes, ¼ of the 7Q10 flow was used. The default 7Q10 for Class P streams is 0.1 cfs; thus a mixing zone flow of 0.025 cfs is appropriate for Piper Creek upstream of the facility. For DO targeting purposes, the 5 mg/L minimum DO criterion must be met at one-quarter mile below the facility outfall at 25 percent of the 7Q10 low flow to meet the mixing zone requirements. The applicable mixing zone regulation can be found at 10 CSR 20-7.031(4)(A)4.B.(II). The rationale for limiting the size of mixing zones is three-fold. First, the assumption of rapid and complete mixing is not a conservative assumption. Meaning, many times effluent plumes exist and cause areas of chronically toxic conditions that can extend laterally and longitudinally downstream. Second a zone of passage should be provided so that aquatic organisms may pass by facility outfalls without becoming adversely affected. Third, for antidegradation purposes, the entire assimilative capacity of the water body cannot be allocated to a single discharger.

The mixing zone extends one-quarter mile downstream of the facility and the LC must meet the DO target at the end of this section of the impaired segment. For modeling purposes, model runs were conducted at one-quarter of the 7Q10 low flow to assess LC values one-quarter mile downstream of the Bolivar WWTF and using 7Q10 low flow at distances further than a quarter mile from the Bolivar WWTF. The QUAL2K models predicted that the minimum DO concentration occurs within a quarter mile of the WWTF; thus, critical conditions are controlled by the one-quarter 7Q10 flow. Loads required to meet 5 mg/L DO under one-quarter of the 7Q10 flows were found to also achieve 5 mg/L DO at 7Q10 flows.

The QUAL2K model was calibrated using data collected on July 15 - 16, 2009, and validated using data collected on August 19 - 20, 2009. The August 19 - 20, 2009, models were used to identify the LC since this period represented more critical conditions (i.e., reduced DO and lower flows) than those present during the July 2009 monitoring events. The following steps were taken during the modeling process:

Step 1: Application of the Model to Existing Conditions

This application forms the current condition that is used to evaluate the magnitude of load reductions that are needed to meet WQS. Nonpoint source loads are set equal to the calibrated conditions.

Step 2: Application of the Model to Existing Conditions with Point Sources at Permit Limits

This application forms the baseline condition that will be reduced to meet the allowable load. The Bolivar WWTF was set at its permit limits using the permitted flow and mean daily concentration allowed for in the permit. For pollutants not included in the permit, the observed effluent data were used.

Step 3: Develop and Test Allocation Scenarios

Working from the baseline condition and considering the primary pollutant sources, sample allocation scenarios were developed and applied. For example, if existing BOD or nutrient effluent limits for the Bolivar WWTF in Step 2 are not protective of the instream DO WQS, the QUAL2K model is iteratively run at reduced BOD and nutrient concentrations until compliance with the WQS is met. The difference, between the baseline condition and BOD and nutrient WLA required to achieve the standard, is the percent reduction needed at the facility.

The TMDL, summarized in Table 9, is based on simulating one-quarter of 7Q10 flows in the model using the August 19, 2009, model results. The results are protective (e.g. DO > 5 mg/L) of the mixing zone at one-quarter the 7Q10 flow one-quarter mile downstream of the plant and in the entire impaired reach.

The modeling analysis indicates that a zero percent reduction in $NH_3$, a 82 percent reduction in $BOD_5$ load (from baseline conditions), a 50 percent reduction in SOD and increased effluent aeration to increase DO in the WWTF effluent concentrations to 5 mg/L are needed to achieve a minimum DO of 5 mg/L at locations downstream of the mixing zone.

BOD reductions are deemed necessary to achieve the SOD reduction because most of the SOD at the surface of the sediment is likely due to the biological decomposition of particulate organic material (including algae) discharged by the WWTF that settles downstream of the outfall. Bacterially facilitated nitrification of $NH_3$ is also a likely contributor to SOD.

To meet the targeted nutrient and TSS critical condition targets outlined in this TMDL, the sum of the WLA was calculated by using nutrient ecoregion reference concentrations, the 25th percentile EDU TSS concentrations and the sum of the design flows of permitted facilities in the watershed. The nonpoint sources or LA TMDL targets for TSS, TP and TN were calculated by using nutrient ecoregion reference concentrations, the 25th percentile EDU TSS concentrations and the sum of the headwater and tributary flows. For tributary loading, the ecoregion target for nitrogen (289 micrograms of Nitrogen per Liter [µgN/L] was assigned as 289 µgN/L in the organic nitrogen fraction, based on the assumption that, after implementing the TMDL, nitrogen from nonpoint sources would be largely represented by the organic nitrogen fraction. Similarly, for point source loading, the ecoregion target for nitrogen was assigned as 289 µgN/L ammonia, based on the assumption that ammonia is the primary parameter of concern, with respect to nitrogen, in treated WWTF effluent. For both point and nonpoint sources, the ecoregion criteria target for TP was split 70:30 between organic and inorganic phosphorus fractions[15], respectively, such that the organic phosphorus target was set equal to 4.9 µg/L and the inorganic phosphorus target was set equal to 2.1 µg/L. TP and TN nonpoint source baseline flow conditions were obtained using existing loads sampled on August 19, 2009. The LDCs for the targeted pollutants are depicted in Figure 7, Figure 8 and Figure 9, where the TMDL line represents the total LC of all point and nonpoint sources of pollutants. In these figures, the "Continuous WLA" includes the combined allocation for all five WWTFs that have a permitted design flow (city of Bolivar WWTF, Home Court Advantage, Inc. WWTF, Quail Creek Mobile Home Park WWTF, Silo Ridge Homeowners Association WWTF and Karlin Place Subdivision WWTF). The pollutant allocations under a range of flow conditions are presented in Table 10, Table 11 and Table 12.

[15] Under the natural conditions, a stream would have more organic phosphorus than dissolved phosphorus.

**Table 9. TMDL Summary for Piper Creek at Critical Low Flows**

| Pollutant | Baseline Conditions (based on monthly average limits and design flow) | | | TMDL | | | WLA Percent Reduction | LA Percent Reduction |
|---|---|---|---|---|---|---|---|---|
| | Point Sources | Nonpoint Sources | Total | Point Sources (WLA) | Nonpoint Sources (LA) | Total | | |
| Flow (cfs) | 4.026 | 0.071 | 4.096 | 4.026 | 0.071 | 4.096 | 0 | 0 |
| $BOD_5$ (lb/day) | 654.9 | 1.4 | 656 | 120.5 | 0.5 | 121 | 82 | 63 |
| $NBOD_{ult}$ (lbs/day) | No limit | 2.8 | Not applicable | 136.8 | 1.0 | 137.8 | Not applicable | 65 |
| $NH_3$ (lb/day) | 30 | 0.2 | 30.2 | 30 | 0.1 | 30.1 | 0 | 42 |
| TSS (lbs/day) | 594 | See Note | Not applicable | 192 | 3 | 195 | 68 | See LDC |
| TN (lbs/day) | No limit | 1.1 | Not applicable | 6.3 | 0.1 | 6.4 | Not applicable | See LDC |
| TP (lbs/day) | No limit | 0.02 | Not applicable | 0.15 | 0.003 | 0.15 | Not applicable | See LDC |

Note: The WLA and LA specified in Table 9 results in a minimum DO of 5 mg/L and the effluent is aerated to at least 5.0 mg/L DO. Tributary and headwater nutrient concentrations are set to ecoregion criteria (TN = 0.289 mg/L and TP = 0.007 mg/L). Monthly average permit limits were used for baseline conditions. No TSS data is available in Piper Creek to calculate a baseline condition for nonpoint sources. Point and nonpoint baseline conditions for flow, $BOD_5$, $NBOD_{ult\ [ultimate]}$, $NH_3$, TN and TP are based on QUAL2K modeling results. The point source baseline condition for TSS is based on permitted flow and TSS concentration limits at the WWTFs. Point and nonpoint source TMDL limits for $BOD_5$, $NBOD_{ult}$ and $NH_3$ were obtained from QUAL2K model results. As discussed in Section 7, nitrogen target loading for point sources was based on setting ammonia equal to 289 µgN/L and nonpoint sources was based on setting organic nitrogen equal to 289 µgN/L. Point source TMDL limits are based on the sum of the site specific WWTFs

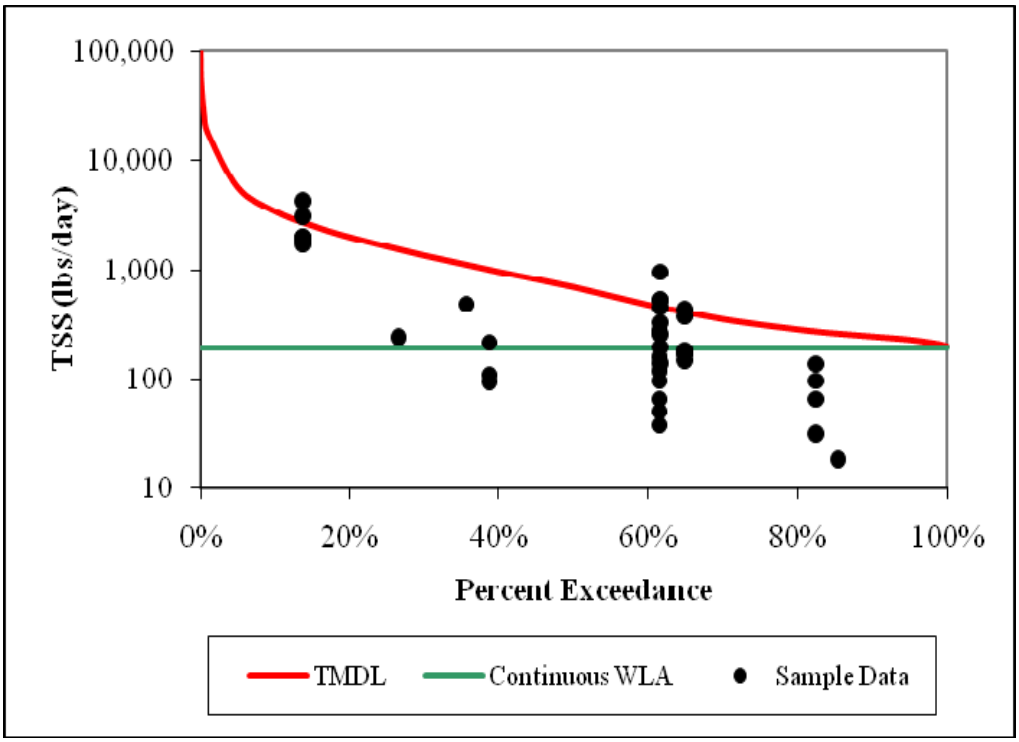


**Figure 7. TSS LDC for Piper Creek at Confluence of Piper Creek with the Pomme De Terre River**

**Table 10. TSS TMDL Under a Range of Flow Conditions in Piper Creek**

| Percent Flow Exceedance | Estimated Flow (cfs) | TMDL (lbs/day) | MOS[1] (lbs/day) | LA Rural (lbs/day) | LA Urban[2] (lbs/day) | WLA Bolivar WWTF (lbs/day) | WLA (other permits) (lbs/day) |
|---|---|---|---|---|---|---|---|
| 95% | 4.9 | 232.5 | -- | 35.1 | 5.8 | 187.3 | 4.3 |
| 90% | 5.2 | 248.4 | -- | 48.7 | 8.1 | 187.3 | 4.3 |
| 70% | 7.5 | 355.8 | -- | 140.9 | 23.3 | 187.3 | 4.3 |
| 50% | 14.8 | 702.8 | -- | 438.6 | 72.6 | 187.3 | 4.3 |
| 30% | 28.7 | 1,360.9 | -- | 1,003.3 | 166.0 | 187.3 | 4.3 |
| 10% | 72.3 | 3,434.6 | -- | 2,782.5 | 460.5 | 187.3 | 4.3 |
| 5% | 119.6 | 5,677.4 | -- | 4,706.8 | 779.0 | 187.3 | 4.3 |

[1] The TSS MOS is implicit.
[2] LA is for low intensity urban area.

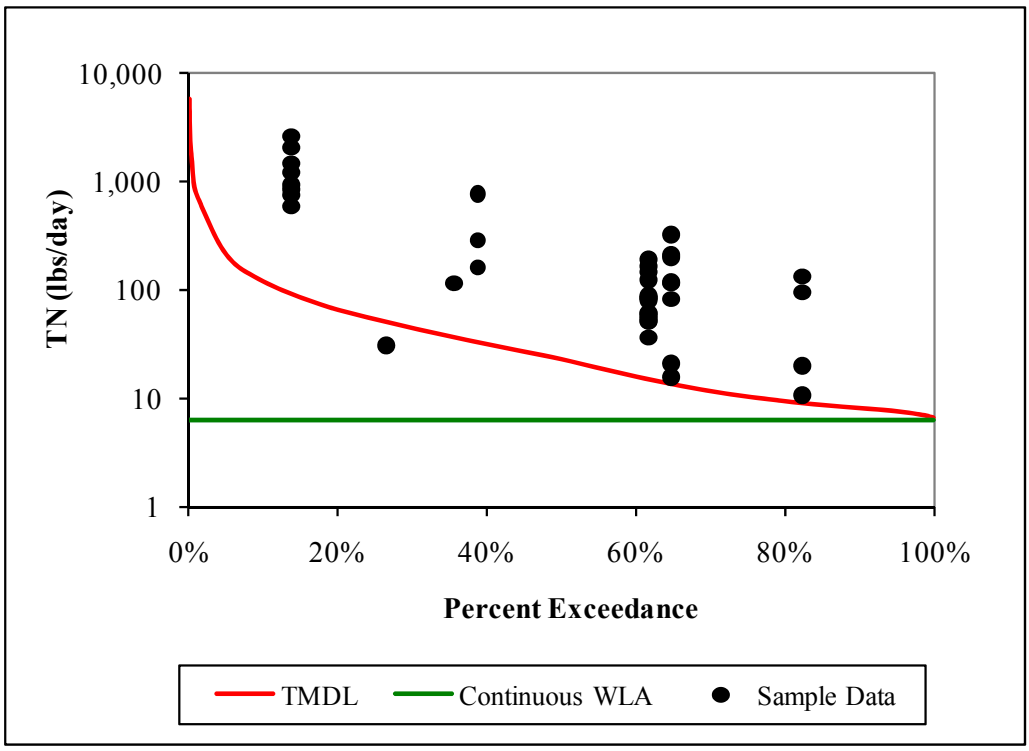


**Figure 8. TN LDC for Piper Creek at Confluence of Piper Creek with the Pomme De Terre River**

**Table 11. TN TMDL Under a Range of Flow Conditions in Piper Creek**

| Percent Flow Exceedance | Estimated Flow (cfs) | TMDL (lbs/day) | MOS[1] (lbs/day) | LA Rural (lbs/day) | LA Urban[2] (lbs/day) | WLA Bolivar WWTF (lbs/day) | WLA (other permits) (lbs/day) |
|---|---|---|---|---|---|---|---|
| 95% | 4.9 | 7.64 | -- | 1.16 | 0.19 | 6.15 | 0.14 |
| 90% | 5.2 | 8.16 | -- | 1.60 | 0.27 | 6.15 | 0.14 |
| 70% | 7.5 | 11.68 | -- | 4.63 | 0.76 | 6.15 | 0.14 |
| 50% | 14.8 | 23.08 | -- | 14.40 | 2.39 | 6.15 | 0.14 |
| 30% | 28.7 | 44.69 | -- | 32.95 | 5.45 | 6.15 | 0.14 |
| 10% | 72.3 | 112.79 | -- | 91.38 | 15.12 | 6.15 | 0.14 |
| 5% | 119.6 | 186.45 | -- | 154.58 | 25.58 | 6.15 | 0.14 |

[1] The TN MOS is implicit.
[2] LA is for low intensity urban area.

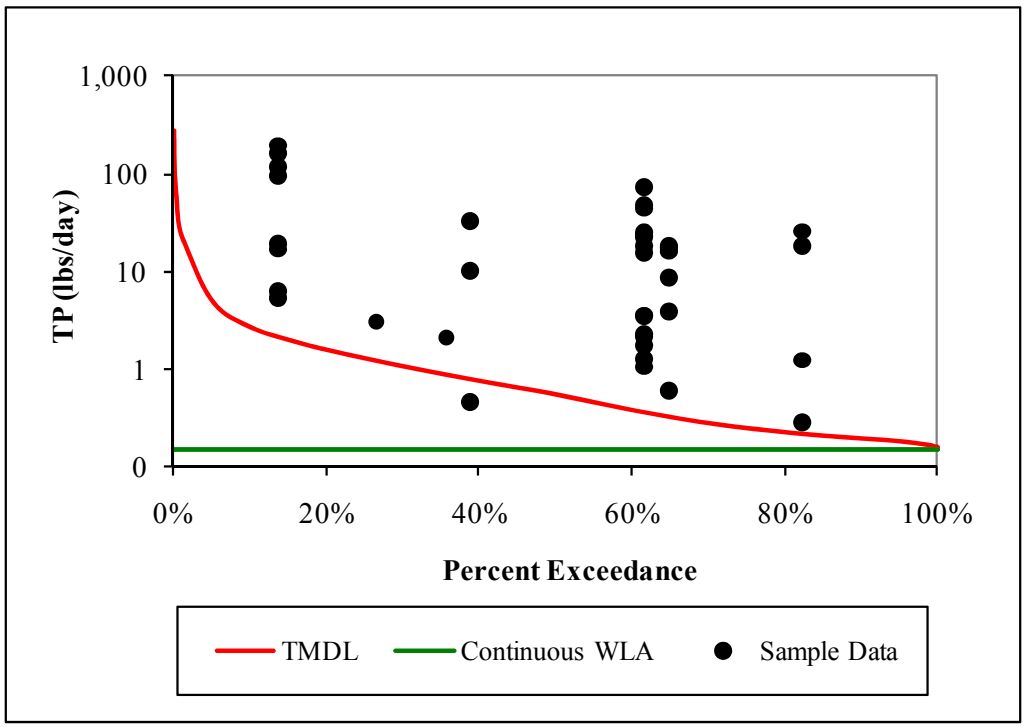


**Figure 9. TP LDC for Piper Creek at Confluence of Piper Creek with the Pomme De Terre River**

**Table 12. TP TMDL Under a Range of Flow Conditions in Piper Creek**

| Percent Flow Exceedance | Estimated Flow (cfs) | TMDL (lbs/day) | MOS[1] (lbs/day) | LA Rural (lbs/day) | LA Urban[2] (lbs/day) | WLA Bolivar WWTF (lbs/day) | WLA (other permits) (lbs/day) |
|---|---|---|---|---|---|---|---|
| 95% | 4.9 | 0.18 | -- | 0.03 | 0.00 | 0.15 | 0.003 |
| 90% | 5.2 | 0.20 | -- | 0.04 | 0.01 | 0.15 | 0.003 |
| 70% | 7.5 | 0.28 | -- | 0.11 | 0.02 | 0.15 | 0.003 |
| 50% | 14.8 | 0.56 | -- | 0.35 | 0.06 | 0.15 | 0.003 |
| 30% | 28.7 | 1.08 | -- | 0.80 | 0.13 | 0.15 | 0.003 |
| 10% | 72.3 | 2.73 | -- | 2.21 | 0.37 | 0.15 | 0.003 |
| 5% | 119.6 | 5.05 | -- | 4.21 | 0.69 | 0.15 | 0.003 |

[1] The TP MOS is implicit.
[2] LA is for low intensity urban area.

# 8 WASTE LOAD ALLOCATION (POINT SOURCE LOADS)

The WLA is the portion of the LC that is allocated to existing and/ or future point sources of pollutants. The sum of design flows of all site specific permitted dischargers with NPDES Permits (Table 7) in the Piper Creek watershed, excluding permitted storm water flows, is 2.61 MGD.

New WLAs for the city of Bolivar WWTF were calculated through the modeling process and are shown in Table 13. The WLA for $BOD_5$ and $NH_3$ were derived from the QUAL2K modeling that resulted in meeting WQS. The WLAs for TN, TP and TSS were derived from the LDCs at low flow, when inputs are set at the facility design flow of 3.95 cfs (2.55 MGD). The other permitted facilities in the watershed each discharge an insignificant volume of effluent compared to the city of Bolivar WWTF, and are unlikely to discharge during the critical low flow periods. Their WLAs therefore remain equal to existing permit limits, which are summarized in Table 14, for the facilities with individual, site specific permits.

**Table 13. WLAs for City of Bolivar WWTF (MO0022373) in the Town Branch/ Piper Creek Watershed**

| Effluent Parameter | Design Flow (MGD) | Existing Permit Limit | | WLA at Design Flow based on QUAL2K modeling | | Percent Reduction |
|---|---|---|---|---|---|---|
| | | Concentration (mg/L) | Load (lbs/day) | Concentration (mg/L) | Load (lbs/day) | |
| $CBOD_5$ | 2.55 | No limit | No limit | 4.03 | 86 | Not applicable |
| $NBOD_5$ | 2.55 | No limit | No limit | 1.17 | 25 | Not applicable |
| TN | 2.55 | No limit | No limit | 0.289 | 6.17 | Not applicable |
| TP | 2.55 | No limit | No limit | 0.007 | 0.15 | Not applicable |
| $NH_3$ | 2.55 | Daily Maximum = 3.7[16] - 8.1[17] Monthly Average = 1.4[18] - 3.1[19] | 30 | 1.4 | 30 | 0 |
| TSS | 2.55 | Weekly Average = 41 Monthly Average = 27 | 575 | 27 | 575 | 0 |

Notes: $CBOD_5$ is calculated using simulated $BOD_5$ divided by 1.29, based on 1998 EPA modeling guidance for NH3 toxicity and DO modeling. $NBOD_5$ is the difference between $BOD_5$ and $CBOD_5$. TN target loading for point sources was based on 289 µgN/L, Ecoregion 39 TN value. TP target loading for point sources was based on 7 µgP/L, Ecoregion 39 TP value.

[16] Represents limits from May 1 – October 31
[17] Represents limits from November 1 – April 30
[18] Represents limits from May 1 – October 31
[19] Represents limits from November 1 – April 30

**Table 14. Existing TSS Permit Limits for Four Small WWTFs in the Town Branch/Piper Creek Watershed**

| Facility ID | Facility Name | Design Flow (MGD)[1] | Existing TSS Permit Limits | |
|---|---|---|---|---|
| | | | Concentration (mg/L) | Load (lbs/day)[2] |
| MO0097594 | Home Court Advantage, Inc. WWTF | 0.007 | Weekly Average = 45<br>Monthly Average = 30 | 1.75 |
| MO0116467 | Quail Creek Mobile Home Park WWTF | 0.01395 | Weekly Average = 110<br>Monthly Average = 70 | 8.15 |
| MO0121754 | Silo Ridge Homeowners Association WWTF | 0.01683 | Weekly Average = 45<br>Monthly Average = 30 | 4.21 |
| MO0121924 | Karlin Place Subdivision WWTF | 0.021 | Weekly Average = 45<br>Monthly Average = 30 | 5.26 |

[1] MGD = Million Gallons per Day
[2] Existing TSS permit limit loads (lbs/day) are based on existing design flow and monthly average limits

# 9 LOAD ALLOCATION (NONPOINT SOURCE LOADS)

The LA includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The LA for the Piper Creek TMDL is for all nonpoint sources of $CBOD_5$, NBOD, TSS, TP and TN, which could include loads from agricultural lands, runoff from urban areas, livestock and failing onsite wastewater treatment systems. The LA also includes runoff from the city of Bolivar, Missouri. The LAs, provided in Table 9, Table 10, Table 11 and Table 12, were calculated based on the total of all headwater and lateral inflow loads used in the QUAL2K model for the allocation scenario model run and LDCs. The LA is intended to allow the DO target to be met at all locations within the stream.

# 10 MARGIN OF SAFETY

A MOS is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

1) Explicit - Reserve a numeric portion of the LC as a separate term in the TMDL.
2) Implicit - Incorporate the MOS as part of the critical conditions for the WLA and LA calculations by making conservative assumptions in the analysis.

An implicit MOS was incorporated into the CBOD and $NH_3$ TMDLs by identifying a LC that achieves a minimum DO concentration of 5 mg/L at the 7Q10 low flow by using conservative modeling assumptions within QUAL2K. The conservative modeling assumptions used for the implicit MOS in the QUAL2K model calibration focused on measured low DO concentrations, critical low flow conditions and DO concentrations under critical low flow

conditions in deriving applicable BOD, CBOD, NBOD, NH3 and TSS targets for the city of Bolivar WWTF.

For TSS, TN and TP, an implicit MOS was incorporated into the TMDL based on conservative assumptions used in the development of the TMDL LDCs. Among the conservative approaches used was to calculate WLAs by targeting the 25th percentile of TSS concentrations in the geographic region in which Piper Creek is located. Another conservative approach was to establish WLAs for the city of Bolivar WWTF under critical low flow conditions when discharge from this facility will dominate the stream flow. The TN and TP targets for this TMDL are also conservative because they are based on the 25th percentile of all TN and TP data gathered from the Subecoregion 39 of Aggregate Nutrient Ecoregion IX. These targets were derived by EPA to represent conditions of surface waters that are minimally impacted by human activities and protective of aquatic life and recreational uses (EPA, 2000). The 25th percentile is considered a surrogate for establishing a reference population of the pristine systems (EPA 2000).

# 11 SEASONAL VARIATION

A TMDL must consider seasonal variation in the derivation of the allocations. DO levels that threaten the integrity of aquatic communities generally occur during low flow periods and warm temperatures, so these periods are considered the critical condition for the DO target. Annual low-flow conditions in Missouri typically occur between July 1 and September 15. In this TMDL report, summer low flow is defined as a 7-day average flow of the 10-year return frequency (7Q10) dry-weather condition. This TMDL addresses seasonal variation and critical conditions by identifying a LC that would be protective of the DO target during the 7Q10 low flow period.

DO in streams is affected by several factors including water temperature, the amount of decaying matter (i.e., organic sediment) in the stream, turbulence at the air-water interface and the amount of photosynthesis occurring in plants within the stream. Organic sediments and SOD can also contribute to fluctuating DO concentrations in the water column. The effects of high nutrient and BOD concentrations on DO swings and low DO conditions (discussed in Section 5.2) are typically amplified under circumstances in which flow is low and water temperature is relatively high (for example, summer months).

The TMDL LDCs for TSS, TN and TP represents flow under all conditions. Because the WLA, LA and TMDL are applicable at all flow conditions, they are also applicable and protective over all seasons. The advantage of the LDC approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

# 12 MONITORING PLAN

TMDL monitoring will be scheduled by MDNR after new effluent limits in the city of Bolivar WWTF permit has gone into effect in 2011 (ammonia) and 2012 (bacteria). In addition, in-stream monitoring is required by the Bolivar WWTF permit as follows: Two sites, one upstream and one downstream of the WWTP outfall, will be sampled quarterly for DO, TSS, TP

and TN. Also, the local watershed group monitors eight sites three times a year. Trained stream team volunteer water quality monitors gather and submit these data to MDNR on a regular basis.

In addition, MDNR will routinely examine physical habitat, water quality, invertebrate and fish community data collected by the Missouri Department of Conservation under its Resource Assessment and Monitoring (RAM) Program. This program randomly samples streams across Missouri on a 5- to 6-year rotating schedule.

As with all of Missouri's TMDLs, if continuing monitoring reveals that WQSs are not being met, the TMDL will be reopened and re-evaluated accordingly.

# 13 REASONABLE ASSURANCES

MDNR has the authority to issue and enforce Missouri State Operating Permits. Inclusion of effluent limits into a state operating permit and requiring that effluent and instream monitoring be reported to MDNR should provide reasonable assurance that instream WQS will be met. Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for WLAs to serve that purpose, they must themselves be stringent enough so that (in conjunction with the water body's other loadings) they meet WQS. This generally occurs when the TMDL's combined nonpoint source LAs and point source WLAs do not exceed the WQS-based LC and there is reasonable assurance that the TMDL's allocations can be achieved. Any discussion of reduction efforts relating to nonpoint sources would be found in the implementation section of the TMDL.

# 14 PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA is providing public notice of this draft TMDL for Piper Creek (Town Branch) on the EPA, Region 7, TMDL website: http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

This water quality limited segment of Piper Creek (Town Branch) in Polk County, Missouri, is included on the EPA-approved 2008 303(d) List for Missouri. This TMDL is being established by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri and EPA is establishing this TMDL at this time to meet the *American Canoe* consent decree milestones. Missouri may submit and EPA may approve a revised or modified TMDL for this water at any time.

Before finalizing EPA established TMDLs (such as this TMDL), the public is notified that a comment period is open on the EPA Region 7 website for at least 30 days. EPA's public notices to comment on draft TMDLs are also distributed via mail and electronic mail to major stakeholders in the watershed or other potentially impacted parties. After the comment period closes, EPA reviews all comments, edits the TMDL as is appropriate, writes a Summary of

Response to Comments and establishes the TMDL. For Missouri TMDLs, groups receiving the public notice announcement include a distribution list provided by MDNR, the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, stream team volunteers, state legislators, County Commissioners, the County Soil and Water Conservation District and potentially impacted cities, towns and facilities. EPA followed this public notice process for this TMDL. Links to active public notices for draft TMDLs, final (approved and established) TMDLs and Summary of Response to Comments are posted on the EPA website: http://www.epa.gov/region07/water/tmdl.htm.

# 15 ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTS

An administrative record on the Piper Creek (Town Branch) TMDL has been assembled and is being kept on file with EPA.

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## Appendices

Appendix A – Historic Piper Creek/Town Branch Water Quality and Sediment Data
Appendix B – Piper Creek QUAL2K Modeling
Appendix C – Development of TSS Targets Using Reference LDCs
Appendix D – Development of Nutrient Targets Using Ecoregion Nutrient Criteria with LDCs
Appendix E – Stream Flow and Water Quality Stations Used to Develop TMDLs in Piper Creek
Appendix F – Supplemental Implementation Plan

# Appendix A –Piper Creek/Town Branch Water Quality and Sediment Data

**Table A-1. Station Number, Legal Location and Descriptive Information for Locations Assessed in the MDNR 2003 - 2004 Bioassessment Study (MDNR, 2004a). Station Numbers are used in Table A-2 through Table A-14**

| Station Number | Location ¼, Section, Township, Range | Description | County |
|---|---|---|---|
| Town Branch #1 | N ½ sec.6, T. 33 N., R. 22 W. | Test-0.5 Miles Downstream of Bolivar WWTF Discharge at 435th Rd Crossing | Polk |
| Town Branch #2 | SW ¼ sec. 6, T. 33 N., R. 22 W. | Control-Directly Upstream of Bolivar WWTF Discharge | Polk |
| Piper Creek #1 | SW ¼ sec. 31, T. 34 N., R. 22 W. | Test-1.7 Miles Downstream of Bolivar WWTF Discharge at 42th Rd Crossing | Polk |
| Piper Creek #2 | NW ¼ sec. 5, T. 33 N., R. 22 W. | Control-Upstream of Town Branch Confluence at 435th Road Crossing | Polk |
| Dry Fork #1 | SW ¼ sec. 35, T. 35 N., R. 23 W. | Regional Control | Polk |

**Table A-2. Summary of Sediment Monitoring in Piper Creek/Town Branch - March 23, 2004**

| Stream | Station | Grid | Sample # | BOD (mg/L) | Mean BOD (not including dup.) | TSS (mg/L) | Mean TSS (not including dup.) | VSS (mg/L) | Mean VSS (not including dup.) | Mean VSS:NVSS Sediment |
|---|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 0411776 | 69 | 69 | 2730 | 2227 | 250 | 300 | 0.16 |
| Town Br. | 1 | Middle | 0411777 | 69 | | 1870 | | 320 | | |
| Town Br. | 1 | Upstream | 0411778 | 69 | | 2080 | | 330 | | |
| Town Br. | 2 | Downstream | 0411773 | 46 | 59 | 1520 | 1767 | 160 | 190 | 0.12 |
| Town Br. | 2 | Middle | 0411774 | 70 | | 2110 | | 250 | | |
| Town Br. | 2 | Upstream | 0411775 | 61 | | 1670 | | 160 | | |
| Piper Cr. | 1 | Downstream | 0411782 | 60 | 62 | 1410 | 961 | 210 | 162 | 0.20 |
| Piper Cr. | 1 | Duplicate (downstream) | 0411783 | 69 | | 2390 | | 250 | | |
| Piper Cr. | 1 | Middle | 0411784 | 48 | | 352 | | 76 | | |
| Piper Cr. | 1 | Upstream | 0411785 | 69 | | 1120 | | 200 | | |
| Piper Cr. | 2 | Downstream | 0411779 | 69 | 62 | 7760 | 6607 | 670 | 545 | 0.09 |
| Piper Cr. | 2 | Middle | 0411780 | 50 | | 860 | | 85 | | |
| Piper Cr. | 2 | Upstream | 0411781 | 67 | | 11200 | | 880 | | |

Source: MDNR (2004b)

BOD = Biological Oxygen Demand, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, NVSS = Nonvolatile Suspended Solids

**Table A-3. Summary of Sediment Monitoring in Piper Creek/Town Branch - May 11, 2004**

| Stream | Station | Grid | Sample # | BOD (mg/L) | Mean BOD (not including dup.) | TSS (mg/L) | Mean TSS (not including dup.) | VSS (mg/L) | Mean VSS (not including dup.) | Mean VSS:NVSS Sediment |
|---|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 0411789 | 80 | 58 | 124000 | 47313.3 | 2930 | 1450 | 0.03 |
| Town Br. | 1 | Duplicate (downstream) | 0411790 | 47 | | 47200 | | 1530 | | |
| Town Br. | 1 | Middle | 0411791 | 53 | | 13200 | | 880 | | |
| Town Br. | 1 | Upstream | 0411792 | 41 | | 4740 | | 540 | | |
| Town Br. | 2 | Downstream | 0411786 | 21 | 38 | 1150 | 1636.7 | 128 | 192 | 0.13 |
| Town Br. | 2 | Middle | 0411787 | 42 | | 1060 | | 128 | | |
| Town Br. | 2 | Upstream | 0411788 | 52 | | 2700 | | 320 | | |
| Piper Cr. | 1 | Downstream | 0411796 | 36 | 36 | 3680 | 10793.3 | 300 | 326.7 | 0.03 |
| Piper Cr. | 1 | Middle | 0411797 | 42 | | 5300 | | 380 | | |
| Piper Cr. | 1 | Upstream | 0411798 | 30 | | 23400 | | 300 | | |
| Piper Cr. | 2 | Downstream | 0411793 | 32 | 34 | 25100 | 19573.3 | 330 | 2366 | 0.14 |
| Piper Cr. | 2 | Middle | 0411794 | 31 | | 1620 | | 176 | | |
| Piper Cr. | 2 | Upstream | 0411795 | 40 | | 32000 | | 1860 | | |

Source: MDNR (2004b)

BOD = Biological Oxygen Demand, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, NVSS = Nonvolatile Suspended Solids

**Table A-4. Summary of Sediment Monitoring in Piper Creek/Town Branch - July 7, 2005**

| Stream | Station | Grid | Sample # | BOD (mg/L) | Mean BOD (not including dup.) | TSS (mg/L) | Mean TSS (not including dup.) | VSS (mg/L) | Mean VSS (not including dup.) | Mean VSS:NVSS Sediment |
|---|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 0502884 | 213 | 268 | 13600 | 13927 | 3000 | 2560 | 0.22 |
| Town Br. | 1 | Middle | 0502885 | 418 | | 20300 | | 3690 | | |
| Town Br | 1 | Upstream | 0502886 | 178 | | 7880 | | 990 | | |
| Town Br. | 2 | Downstream | 0502881 | 37.6 | 106 | 2790 | 6503 | 310 | 715 | 0.12 |
| Town Br. | 2 | Middle | 0502882 | 214 | | 11600 | | 1290 | | |
| Town Br | 2 | Upstream | 0502883 | 67.3 | | 5120 | | 545 | | |
| Piper Cr. | 1 | Downstream | 0502890 | 143 | 147 | 3840 | 5793 | 530 | 723 | 0.14 |
| Piper Cr. | 1 | Duplicate (downstream) | 0502891 | 119 | | 3400 | | 490 | | |
| Piper Cr. | 1 | Middle | 0502892 | 113 | | 5520 | | 530 | | |
| Piper Cr. | 1 | Upstream | 0502893 | 184 | | 8020 | | 1110 | | |
| Piper Cr. | 2 | Downstream | 0502887 | 208 | 208 | 44400 | 40066 | 4580 | 4143 | 0.12 |
| Piper Cr. | 2 | Middle | 0502889 | 210 | | 42800 | | 4270 | | |
| Piper Cr. | 2 | Upstream | 0502888 | 207 | | 33000 | | 3580 | | |

Source: MDNR (2006)

BOD = Biological Oxygen Demand, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, NVSS = Nonvolatile Suspended Solids

**Table A-5. Summary of Sediment Monitoring in Piper Creek/Town Branch - March 6, 2006**

| Stream | Station | Grid | Sample # | BOD (mg/L) | Mean BOD (not including dup.) | TSS (mg/L) | Mean TSS (not including dup.) | VSS (mg/L) | Mean VSS (not including dup.) | Mean VSS:NVSS Sediment |
|---|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 0601256 | 1980 | 1627 | 17600 | 20667 | 5020 | 5147 | 0.33 |
| Town Br. | 1 | Middle | 0601257 | 1490 | | 29800 | | 6840 | | |
| Town Br | 1 | Upstream | 0601258 | 1410 | | 14600 | | 3580 | | |
| Town Br. | 2 | Downstream | 0601259 | 191 | 322 | 4860 | 6293 | 680 | 700 | 0.13 |
| Town Br. | 2 | Middle | 0601260 | 396 | | 6880 | | 740 | | |
| Town Br | 2 | Upstream | 0601261 | 378 | | 7140 | | 680 | | |
| Piper Cr. | 1 | Downstream | 0601250 | 735 | 804 | 7960 | 10420 | 1620 | 2040 | 0.24 |
| Piper Cr. | 1 | Middle | 0601251 | 936 | | 16200 | | 2980 | | |
| Piper Cr. | 1 | Upstream | 0601252 | 741 | | 7100 | | 1520 | | |
| Piper Cr. | 2 | Downstream | 0601253 | 606 | 513 | 22200 | 19533 | 4040 | 3653 | 0.23 |
| Piper Cr. | 2 | Middle | 0601254 | 447 | | 18100 | | 3160 | | |
| Piper Cr. | 2 | Upstream | 0601255 | 487 | | 18300 | | 3760 | | |

Source: MDNR (2006)

BOD = Biological Oxygen Demand, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, NVSS = Nonvolatile Suspended Solids

**Table A-6. Historic Data in Piper Creek and Town Branch. Metric Values and Scores, Using Biological Criteria Database for Stations in Ozark/Osage EDU, Fall 2003**

| Sample #/Station | TR | EPTT | BI | SDI | SCI | Sustainability |
|---|---|---|---|---|---|---|
| 03-18710 | | | | | | |
| Piper Creek #1Value | 62 | 9 | 6.44 | 3.13 | | |
| Piper Creek #1 Score | 3 | 3 | 5 | 3 | 14 | Partial |
| 03-18711 | | | | | | |
| Piper Creek #2 Value | 65 | 3 | 6.93 | 2.97 | | |
| Piper Creek #2 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 03-18712 | | | | | | |
| Town Branch #1 Value | 57 | 7 | 6.78 | 2.86 | | |
| Town Branch #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 03-18713 | | | | | | |
| Town Branch #2 Value | 75 | 9 | 6.44 | 3.00 | | |
| Town Branch #2 Score | 3 | 3 | 5 | 3 | 14 | Partial |

Source: MDNR (2004a)
TR = Taxa Richness, EPTT = Ephemeroptera/Plecoptera/Trichoptera Taxa, BI = Biotic Index, SDI = Shannon Diversity Index

**Table A-7. Historic Data in Piper Creek and Town Branch. Metric Values and Scores, Using Five Small Ozark/Osage EDU Regional Control Stations Data, Fall 2003**

| Sample #/Station | TR | EPTT | BI | SDI | SCI | Sustainability |
|---|---|---|---|---|---|---|
| 03-18710 | | | | | | |
| Piper Creek #1Value | 62 | 9 | 6.44 | 3.13 | | |
| Piper Creek #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 03-18711 | | | | | | |
| Piper Creek #2 Value | 65 | 3 | 6.93 | 2.97 | | |
| Piper Creek #2 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 03-18712 | | | | | | |
| Town Branch #1 Value | 57 | 7 | 6.78 | 2.86 | | |
| Town Branch #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 03-18713 | | | | | | |
| Town Branch #2 Value | 75 | 9 | 6.44 | 3.00 | | |
| Town Branch #2 Score | 3 | 1 | 3 | 3 | 10 | Partial |

Source: MDNR (2004a)
TR = Taxa Richness, EPTT = Ephemeroptera/Plecoptera/Trichoptera Taxa, BI = Biotic Index, SDI = Shannon Diversity Index

**Table A-8. Historic Data in Piper Creek and Town Branch. Metric Values and Scores, Using Biological Criteria Database for Stations in Ozark/Osage EDU, Spring 2004**

| Sample #/Station | TR | EPTT | BI | SDI | SCI | Sustainability |
|---|---|---|---|---|---|---|
| 04-18698 | | | | | | |
| Piper Creek #1 Value | 75 | 10 | 6.10 | 2.96 | | |
| Piper Creek #1 Score | 3 | 1 | 5 | 3 | 12 | Partial |
| 04-18699 | | | | | | |
| Piper Creek #2 Value | 83 | 9 | 6.19 | 2.98 | | |
| Piper Creek #2 Score | 3 | 1 | 5 | 3 | 12 | Partial |
| 04-18700 | | | | | | |
| Town Branch #1 Value | 51 | 4 | 6.92 | 2.06 | | |
| Town Branch #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 04-18701 | | | | | | |
| Town Branch #2 Value | 52 | 5 | 6.20 | 1.62 | | |
| Town Branch #2 Score | 3 | 1 | 3 | 1 | 8 | Partial |

Source: MDNR (2004a)
TR = Taxa Richness, EPTT = Ephemeroptera/Plecoptera/Trichoptera Taxa, BI = Biotic Index, SDI = Shannon Diversity Index

**Table A-9. Historic Data in Piper Creek and Town Branch. Metric Values and Scores, Using Five Small Ozark/Osage EDU Regional Control Stations Data, Spring 2004**

| Sample #/Station | TR | EPTT | BI | SDI | SCI | Sustainability |
|---|---|---|---|---|---|---|
| 04-18698 | | | | | | |
| Piper Creek #1 Value | 75 | 10 | 6.10 | 2.96 | | |
| Piper Creek #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 04-18699 | | | | | | |
| Piper Creek #2 Value | 83 | 9 | 6.19 | 2.98 | | |
| Piper Creek #2 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 04-18700 | | | | | | |
| Town Branch #1 Value | 51 | 4 | 6.92 | 2.06 | | |
| Town Branch #1 Score | 3 | 1 | 3 | 3 | 10 | Partial |
| 04-18701 | | | | | | |
| Town Branch #2 Value | 52 | 5 | 6.20 | 1.62 | | |
| Town Branch #2 Score | 3 | 1 | 3 | 1 | 8 | Partial |

Source: MDNR (2004a)
TR = Taxa Richness, EPTT = Ephemeroptera/Plecoptera/Trichoptera Taxa, BI = Biotic Index, SDI = Shannon Diversity Index

**Table A-10. Piper Creek/Town Branch Test and Control Stations and Small Regional Control Station, Dry Fork #1, Macroinvertebrate Composition per Station, Fall 2003. Values in Bold are the Dominant Macroinvertebrate Families and Taxa for Each Sample**

| Variable-Station | Piper Creek #1 | Piper Creek #2 | Town Branch #1 | Town Branch #2 | Dry Fork #1 |
|---|---|---|---|---|---|
| Macro Sample Number | 03-18710 | 03-18711 | 03-18712 | 03-18713 | 03-18714 |
| TR | 62 | 65 | 57 | 75 | 59 |
| EPTT | 9 | 3 | 7 | 9 | 9 |
| BI | 6.4 | 6.9 | 6.8 | 6.4 | 5.4 |
| SDI | 3.1 | 3.0 | 2.9 | 3.0 | 2.9 |
| % Ephemeroptera | 17.6 | 1.8 | 2.0 | 6.9 | 15.1 |
| % Plecoptera | 0 | 0 | 0 | 0 | 0.1 |
| % Trichoptera | 2.1 | 0.1 | 3.6 | 0.9 | 1.1 |
| % Dominant Macroinvertebrate Families | | | | | |
| *Chironomidae* | **27.4** | **22.6** | **49.7** | **47.0** | **24.6** |
| *Elmidae* | **19.0** | **18.6** | **20.3** | **24.0** | **15.6** |
| *Baetidae* | **10.2** | 0.2 | 0.9 | 2.2 | 0 |
| *Tubificidae* | **6.4** | **13.0** | **7.0** | 1.8 | 3.2 |
| *Heptageniidae* | **6.1** | 0 | 1.0 | **4.2** | 3.5 |
| *Hyalellidae* | 4.9 | **11.4** | 0.1 | 0 | 0 |
| *Corixidae* | 0 | **6.5** | 0 | 0 | 0 |
| *Planaridae* | 5.1 | 6.0 | **8.6** | **4.3** | 0.1 |
| *Hydropsychidae* | 2.1 | 0.1 | **3.5** | 0.4 | 0.3 |
| *Coenagrionidae* | 5.0 | 4.6 | 1.4 | **5.1** | 1.2 |
| *Psephenidae* | 2.1 | 0.3 | 0.3 | 1.6 | **22.2** |
| *Ancylidae* | 4.7 | 0.5 | 0.6 | 1.8 | **10.2** |
| *Caenidae* | 1.3 | 1.7 | 0.1 | 0.6 | **5.7** |
| % Dominant Macroinvertebrate Taxa | | | | | |
| *Stenelmis* | **17.3** | **17.0** | **20.2** | **23.4** | **15.4** |
| *Polypedilum convictum* grp. | **10.8** | **9.4** | **16.3** | **15.0** | 4.4 |
| *Baetis* | **10.1** | 0 | 0.9 | 2.2 | 0 |
| Immature *Tubificidae* | **6.0** | **12.2** | **7.0** | 1.8 | 3.1 |
| *Planaridae* | **5.1** | 6.0 | **8.6** | **4.3** | 0.1 |
| *Hyalella azteca* | 4.9 | **11.4** | 0.1 | 0 | 0 |
| *Corixidae* | 0 | **6.5** | 0 | 0 | 0 |
| *Tanytarsus* | 1.6 | 2.7 | **10.0** | **10.9** | **6.1** |
| *Argia* | 4.3 | 0.4 | 1.2 | **5.0** | 1.2 |
| *Psephenus herricki* | 2.0 | 0.3 | 0 | 1.2 | **22.2** |
| *Ancylidae* | 4.7 | 0.5 | 0.6 | 1.8 | **10.2** |
| *Caenis latipennis* | 1.3 | 1.7 | 0.1 | 0.6 | **5.7** |

Source: MDNR (2004a)
TR = Taxa Richness, EPTT = Ephemeroptera/Plecoptera/Trichoptera Taxa, BI = Biotic Index, SDI = Shannon Diversity Index

**Table A-11. Piper Creek/Town Branch Test and Control Stations and Small Regional Control Station, Dry Fork #1, Macroinvertebrate Composition per Station, Fall 2004. Values in Bold are the Dominant Macroinvertebrate Families and Taxa for Each Sample**

| Variable-Station | Piper Creek #1 | Piper Creek #2 | Town Branch #1 | Town Branch #2 | Dry Fork #1 |
|---|---|---|---|---|---|
| Macro Sample Number | 04-18698 | 04-18699 | 04-18700 | 04-18701 | 04-18697 |
| TR | 75 | 83 | 51 | 52 | 103 |
| EPTT | 10 | 9 | 4 | 5 | 23 |
| BI | 6.1 | 6.2 | 6.9 | 6.7 | 5.5 |
| SDI | 3.0 | 3.0 | 2.1 | 1.6 | 3.4 |
| % Ephemeroptera | 2.9 | 6.1 | 0.6 | 1.7 | 6.4 |
| % Plecoptera | 1.0 | 2.0 | 0 | 0 | 9.6 |
| % Trichoptera | 0.7 | 0.1 | 0.3 | 0.3 | 11.3 |
| % Dominant Macroinvertebrate Families | | | | | |
| *Chironomidae* | **48.8** | **51.9** | **73.1** | **84.3** | **33.6** |
| *Elmidae* | **24.3** | **14.2** | **7.3** | **7.6** | **19.6** |
| *Planariidae* | **5.5** | 1.1 | **7.8** | 0.4 | 0.8 |
| *Pleuroceridae* | **4.0** | 0.3 | 0 | 0 | 0.4 |
| *Tubificidae* | **3.0** | **6.1** | **4.3** | **0.9** | **3.8** |
| *Caenidae* | 1.3 | **5.1** | 0.3 | 0.7 | 2.8 |
| *Coenagrionidae* | 0.9 | **4.9** | 0.8 | 0.4 | 0.2 |
| *Arachnoidea* | 1.2 | 0.2 | **2.0** | 0.4 | 1.0 |
| *Crangonyctidae* | 0.5 | 0.4 | 0.2 | **2.4** | 2.4 |
| *Heptageniidae* | 1.6 | 0.4 | 0.3 | 1.0 | 1.7 |
| *Hydroptilidae* | 0.2 | 0 | 0.3 | 0.2 | **8.1** |
| *Perlidae* | 0.9 | 1.9 | 0 | 0 | **6.4** |
| % Dominant Macroinvertebrate Taxa | | | | | |
| *Stenelmis* | **24.1** | **13.8** | **6.9** | **7.5** | **19.4** |
| *Cricotopus/Orthocladius* | **20.0** | **9.6** | **50.8** | **65.7** | **8.2** |
| *Planariidae* | **5.5** | 1.1 | **7.8** | 0.4 | 0.8 |
| *Polypedilum convictum grp.* | **5.2** | **4.8** | **2.7** | 1.7 | 0.8 |
| *Eukiefferiella* | **4.8** | **22.5** | 0 | 0.2 | **9.8** |
| *Caenis latipennis* | 1.3 | **5.1** | 0.3 | 0 | 2.8 |
| *Dicrotendipes* | 1.8 | 0.3 | **9.6** | **6.0** | 0.3 |
| Immature *Tubificidae* | 2.5 | 4.3 | **4.0** | 0.5 | 2.8 |
| *Hydrobaenus* | 2.1 | 0.7 | 0.3 | **2.7** | 2.0 |
| *Crangonyx* | 0.5 | 0.4 | 0.2 | **2.4** | 2.4 |
| *Perlesta* | 0.9 | 0 | 0 | 0 | **6.3** |
| *Ochrotrichia* | 0 | 0 | 0 | 0 | **5.4** |

Source: MDNR (2004a)

**Table A-12. Piper Creek/Town Branch Test and Control Station Samples and Small Regional Reference Control Station Samples, Mean (SD) Values for Macroinvertebrate Community Composition, Spring Data**

| Variable-Station | Piper Creek/Town Branch Test Stations | Piper Creek/Town Branch Control Stations | Small Regional Reference Control Stations |
|---|---|---|---|
| Sample Size (n) | 2 | 2 | 5 |
| TR | 63.0 (17.0) | 67.5 (21.9) | 104.8 (6.3) |
| EPTT | 7.0 (4.2) | 7.0 (2.8) | 29.2 (3.8) |
| BI | 6.5 (0.6) | 6.5 (0.4) | 5.7 (0.2) |
| SDI | 2.5 (0.6) | 2.3 (1.0) | 3.6 (0.2) |
| % Ephemeroptera | 1.8 (1.7) | 3.9 (3.2) | 23.4 (11.0) |
| % Plecoptera | 0.5 (0.7) | 1.0 (1.4) | 7.9 (4.6) |
| % Trichoptera | 0.5 (0.3) | 0.2 (0.1) | 6.0 (3.5) |
| % Dominant Macroinvertebrate Families | | | |
| *Caenidae* | 0.8 (0.7) | 2.9 (3.1) | 12.8 (10.1) |
| *Heptageniidae* | 0.9 (0.9) | 0.7 (0.4) | 5.2 (3.4) |
| *Tricorythidae* | 0.0 (0.0) | 0.0 (0.0) | 1.8 (2.9) |
| *Siphlonuridae* | 0.0 (0.0) | 0.0 (0.0) | 1.0 (1.2) |
| *Perlidae* | 0.5 (0.7) | 1.0 (1.4) | 2.8 (3.1) |
| *Perlodidae* | 0.0 (0.1) | 0.0 (0.0) | 2.1 (2.3) |
| *Nemouridae* | 0.0 (0.0) | 0.0 (0.0) | 2.0 (1.5) |
| *Hydroptillidae* | 0.2 (0.0) | 0.1 (0.1) | 2.8 (3.1) |
| *Elmidae* | 15.8 (12.0) | 10.9 (4.7) | 6.2 (7.6) |
| *Coenagriondae* | 0.9 (0.1) | 2.7 (3.2) | 0.9 (0.4) |
| *Hyalellidae* | 0.3 (0.2) | 1.8 (2.2) | 2.2 (1.5) |
| *Crangonyctidae* | 0.3 (0.2) | 0.4 (0.0) | 0.9 (0.4) |
| *Pleuroceridae* | 2.0 (2.8) | 0.1 (0.2) | 1.8 (1.4) |
| *Planaridae* | 6.7 (1.6) | 0.7 (0.5) | 0.5 (0.3) |
| *Arachnoidea* | 1.6 (0.6) | 0.3 (0.1) | 4.0 (4.1) |
| *Chironomidae* | 60.9 (17.2) | 68.1 (22.9) | 37.9 (5.1) |
| *Tubificidae* | 3.7 (0.9) | 3.5 (3.7) | 1.3 (1.5) |

Source: MDNR (2004a)

**Table A-13. Piper Creek/Town Branch Test and Control Station Samples and Small Regional Control Station Samples, Mean (SD) Values for Macroinvertebrate Community Composition, Fall Data (MDNR, 2004a)**

| Variable-Station | Piper Creek/Town Branch Test Stations | Piper Creek/Town Branch Control Stations | Small Regional Reference Control Stations |
|---|---|---|---|
| Sample Size (n) | 2 | 2 | 5 |
| TR | 59.5 (3.5) | 70.0 (7.1) | 86.8 (17.9) |
| EPTT | 8.0 (1.4) | 9.0 (4.2) | 20.0 (6.6) |
| BI | 6.6 (0.2) | 6.7 (0.4) | 5.8 (0.3) |
| SDI | 3.0 (0.2) | 3.0 (0.0) | 3.5 (0.4) |
| % Ephemeroptera | 9.8 (11.1) | 4.4 (3.6) | 29.0 (11.1) |
| % Plecoptera | 0.0 (0.0) | 0.0 (0.0) | 0.2 (0.2) |
| % Trichoptera | 2.8 (1.0) | 0.5 (0.6) | 7.6 (4.3) |
| % Dominant Macroinvertebrate Families | | | |
| *Caenidae* | 0.7 (0.8) | 1.1 (0.8) | 12.3 (9.2) |
| *Heptageniidae* | 3.5 (3.6) | 2.1 (3.0) | 6.9 (2.2) |
| *Isonychiidae* | 0.0 (0.0) | 0.0 (0.0) | 3.3 (2.1) |
| *Baetidae* | 5.4 (6.8) | 1.2 (1.5) | 1.4 (1.2) |
| *Hydropsychiidae* | 2.8 (1.0) | 0.2 (0.2) | 3.5 (4.3) |
| *Elmidae* | 19.7 (0.9) | 21.3 (3.8) | 7.9 (4.9) |
| *Psephenidae* | 1.2 (1.3) | 0.9 (0.9) | 7.5 (8.9) |
| *Corixidae* | 0.0 (0.0) | 3.2 (4.6) | 0.0 (0.0) |
| *Coenagrionidae* | 3.2 (2.5) | 4.9 (0.4) | 2.6 (1.3) |
| *Hyalellidae* | 2.5 (3.3) | 5.7 (8.1) | 5.8 (5.7) |
| *Ancylidae* | 2.7 (2.9) | 1.2 (0.9) | 3.3 (4.0) |
| *Planaridae* | 6.9 (2.5) | 5.2 (1.2) | 0.4 (0.6) |
| *Arachnoidea* | 0.1 (0.2) | 0.3 (0.4) | 3.5 (2.8) |
| *Chironomidae* | 38.6 (15.8) | 34.8 (17.2) | 22.9 (9.8) |
| *Tubificidae* | 6.7 (2.5) | 7.4 (7.9) | 1.4 (1.6) |

Source: MDNR (2004a)

**Table A-14. Physicochemical Variables for Piper Creek/Town Branch Study During the Fall 2003 Sampling Season with Outstanding Values Highlighted in Bold. Only Field Measurements were Collected at Dry Fork #1**

| Variable-Station | Piper Creek #1 Test | Piper Creek #2 Control | Town Branch #1 Test | Town Branch #2 Control | Dry Fork #1 Small Regional Control |
|---|---|---|---|---|---|
| *Sample Number* | 03-00823 | 03-00824 | 03-00825 | 03-00826 | 03-00827 |
| Sample Date | 09/24/2003 | 09/24/2003 | 09/24/2003 | 09/24/2003 | 09/25/2003 |
| Sample Time | 1520 | 1400 | 1135 | 0935 | 0935 |
| pH (Standard units) | 8.30 | 7.90 | 7.80 | 8.10 | 7.40 |
| Temperature (ºC) | 21.0 | 23.0 | 21.0 | 18.0 | 16.5 |
| Conductivity (µS) | **675** | 395 | **756** | 534 | 509 |
| DO (mg/L) | 9.80 | 6.25 | 8.30 | 9.45 | 5.20 |
| Discharge (cfs) | 2.55 | 0.11 | 3.09 | 0.45 | 0.02 |
| Turbidity (NTUs) | 7.90 | 14.0 | 4.45 | 10.6 | - |
| $NH_3$-N (mg/L) | 0.03 | 0.03 | 0.03 | 0.03 | - |
| $NO_3 + NO_2$-N (mg/L) | **9.86** | 0.10 | **13.40** | **2.04** | - |
| TKN (mg/L) | 0.06 | 1.02 | 0.55 | 0.05 | - |
| Chloride (mg/L) | **65.5** | 19.4 | **78.8** | 24.5 | - |
| TP (mg/L) | **1.94** | 0.13 | **2.69** | 0.03 | - |

Source: MDNR (2004a)

**Table A-15. Physicochemical Variables for Piper Creek/Town Branch Study During the Spring 2004 Sampling Season with Outstanding Values Highlighted in Bold**

| Variable-Station | Piper Creek #1 Test | Piper Creek #2 Control | Town Branch #1 Test | Town Branch #2 Control | Dry Fork #1 Small Regional Control |
|---|---|---|---|---|---|
| *Sample Number* | 04-11050 | 04-11051 | 04-11052 | 04-11053 | 04-11062 |
| Sample Date | 03/24/2004 | 03/25/2004 | 03/24/2004 | 03/24/2004 | 03/18/2004 |
| Sample Time | 1450 | 1000 | 1125 | 0910 | 1535 |
| pH (Standard units) | 8.52 | 7.68 | 8.31 | 8.35 | 8.28 |
| Temperature (ºC) | 14.0 | 14.5 | 13.5 | 12.5 | 14.0 |
| Conductivity (µS) | 490 | 397 | **681** | 505 | 389 |
| DO (mg/L) | 14.50 | 11.80 | 13.50 | 14.50 | 13.50 |
| Discharge (cfs) | 11.0 | 6.96 | 5.66 | 2.69 | 11.20 |
| Turbidity (NTUs) | 2.01 | 5.75 | 3.41 | 1.79 | 2.50 |
| $NH_3$-N (mg/L) | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| $NO_3 + NO_2$-N (mg/L) | **3.00** | 0.85 | **8.43** | **1.74** | 0.09 |
| TKN (mg/L) | 0.12 | 0.25 | 0.05 | 0.05 | 0.11 |
| Chloride (mg/L) | **30.2** | 15.0 | **58.8** | 22.5 | 11.5 |
| TP (mg/L) | 0.11 | 0.02 | 0.36 | 0.01 | 0.02 |

Source: MDNR (2004a)

**Table A-16. Average Percent Estimated Fine Depositional Cover, Bolivar, MO – March 23, 2004**

| Stream | Station | Grid | Transect 1 | 2 | 3 | 4 | 5 | 6 | Mean % coverage/station (not including duplicate) |
|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 100 | 96 | 60 | 95 | 96 | 60 | 78 |
| Town Br. | 1 | Middle | 32 | 40 | 88 | 90 | 75 | 85 | |
| Town Br. | 1 | Upstream | 100 | 80 | 58 | 10 | 98 | 100 | |
| Town Br. | 2 | Downstream | 1 | 0 | 5 | 1 | 7 | 2 | 67 |
| Town Br. | 2 | Middle | 95 | 100 | 100 | 100 | 100 | 100 | |
| Town Br. | 2 | Upstream | 100 | 100 | 100 | 100 | 99 | 100 | |
| Piper Cr. | 1 | Downstream | 20 | 75 | 50 | 88 | 15 | 20 | 17 |
| Piper Cr. | 1 | Duplicate (downstream) | 100 | 85 | 12 | 5 | 2 | 3 | |
| Piper Cr. | 1 | Middle | 1 | 1 | 1 | 2 | 0 | 2 | |
| Piper Cr. | 1 | Upstream | 12 | 2 | 4 | 2 | 3 | 1 | |
| Piper Cr. | 2 | Downstream | 100 | 97 | 99 | 100 | 100 | 100 | 87 |
| Piper Cr. | 2 | Middle | 100 | 100 | 100 | 100 | 100 | 4 | |
| Piper Cr. | 2 | Upstream | 100 | 80 | 100 | 55 | 85 | 42 | |

Source: MDNR (2004b)

**Table A-17. Average Percent Estimated Fine Depositional Cover, Bolivar, MO - May 11, 2004**

| Stream | Station | Grid | Transect 1 | 2 | 3 | 4 | 5 | 6 | Mean % coverage/station (not including duplicate) |
|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 100 | 100 | 97 | 100 | 100 | 100 | 78 |
| Town Br. | 1 | Duplicate (downstream) | 78 | 100 | 85 | 100 | 98 | 42 | |
| Town Br. | 1 | Middle | 55 | 82 | 32 | 40 | 42 | 80 | |
| Town Br. | 1 | Upstream | 95 | 99 | 95 | 95 | 82 | 10 | |
| Town Br. | 2 | Downstream | 100 | 87 | 96 | 95 | 60 | 98 | 90 |
| Town Br. | 2 | Middle | 60 | 80 | 95 | 100 | 92 | 80 | |
| Town Br. | 2 | Upstream | 100 | 100 | 100 | 82 | 100 | 100 | |
| Piper Cr. | 1 | Downstream | 95 | 1 | 0 | 0 | 2 | 5 | 18 |
| Piper Cr. | 1 | Middle | 0 | 3 | 1 | 5 | 6 | 4 | |
| Piper Cr. | 1 | Upstream | 5 | 30 | 62 | 28 | 25 | 10 | |
| Piper Cr. | 2 | Downstream | 12 | 100 | 12 | 18 | 100 | 90 | 49 |
| Piper Cr. | 2 | Middle | 100 | 12 | 30 | 100 | 3 | 2 | |
| Piper Cr. | 2 | Upstream | 7.5 | 100 | 55 | 82 | 45 | 10 | |

Source: MDNR (2004b)

**Table A-18. Average Percent Estimated Fine Depositional Cover, Bolivar, MO - July 7, 2005**

| Stream | Station | Grid | Transect 1 | 2 | 3 | 4 | 5 | 6 | Mean % coverage/station (not including duplicate) |
|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 88 | 96 | 100 | 48 | 100 | 90 | 86 |
| Town Br. | 1 | Middle | 100 | 100 | 100 | 32 | 50 | 100 | |
| Town Br | 1 | Upstream | 78 | 80 | 90 | 98 | 100 | 100 | |
| Town Br. | 2 | Downstream | 15 | 18 | 5 | 5 | 2 | 45 | 14 |
| Town Br. | 2 | Middle | 8 | 10 | 11 | 6 | 6 | 5 | |
| Town Br | 2 | Upstream | 6 | 14 | 2 | 10 | 5 | 80 | |
| Piper Cr. | 1 | Downstream | 70 | 12 | 4 | 96 | 98 | 60 | 60 |
| Piper Cr. | 1 | Duplicate (downstream) | 32 | 45 | 82 | 38 | 20 | 82 | |
| Piper Cr. | 1 | Middle | 18 | 38 | 75 | 82 | 55 | 75 | |
| Piper Cr. | 1 | Upstream | 12 | 58 | 50 | 90 | 80 | 100 | |
| Piper Cr. | 2 | Downstream | 10 | 78 | 100 | 4 | 80 | 38 | 54 |
| Piper Cr. | 2 | Middle | 48 | 95 | 95 | 78 | 30 | 25 | |
| Piper Cr. | 2 | Upstream | 39 | 80 | 50 | 6 | 95 | 15 | |

Source: MDNR (2006)

**Table A-19. Average Percent Estimated Fine Depositional Cover, Bolivar, MO - March 6, 2006**

| Stream | Station | Grid | Transect 1 | 2 | 3 | 4 | 5 | 6 | Mean % coverage/station (not including duplicate) |
|---|---|---|---|---|---|---|---|---|---|
| Town Br. | 1 | Downstream | 100 | 100 | 100 | 100 | 100 | 100 | 99 |
| Town Br. | 1 | Middle | 100 | 100 | 100 | 100 | 98 | 100 | |
| Town Br | 1 | Upstream | 100 | 100 | 100 | 94 | 100 | 98 | |
| Town Br. | 2 | Downstream | 22 | 15 | 9 | 15 | 10 | 15 | 32 |
| Town Br. | 2 | Middle | 15 | 18 | 20 | 20 | 18 | 35 | |
| Town Br | 2 | Upstream | 60 | 50 | 65 | 68 | 65 | 48 | |
| Piper Cr. | 1 | Downstream | 90 | 95 | 98 | 98 | 98 | 96 | 94 |
| Piper Cr. | 1 | Middle | 99 | 100 | 92 | 98 | 98 | 100 | |
| Piper Cr. | 1 | Upstream | 75 | 88 | 96 | 90 | 78 | 96 | |
| Piper Cr. | 2 | Downstream | 91 | 95 | 100 | 100 | 99 | 100 | 85 |
| Piper Cr. | 2 | Middle | 78 | 91 | 70 | 65 | 76 | 89 | |
| Piper Cr. | 2 | Upstream | 96 | 52 | 70 | 90 | 88 | 84 | |

Source: MDNR (2006)

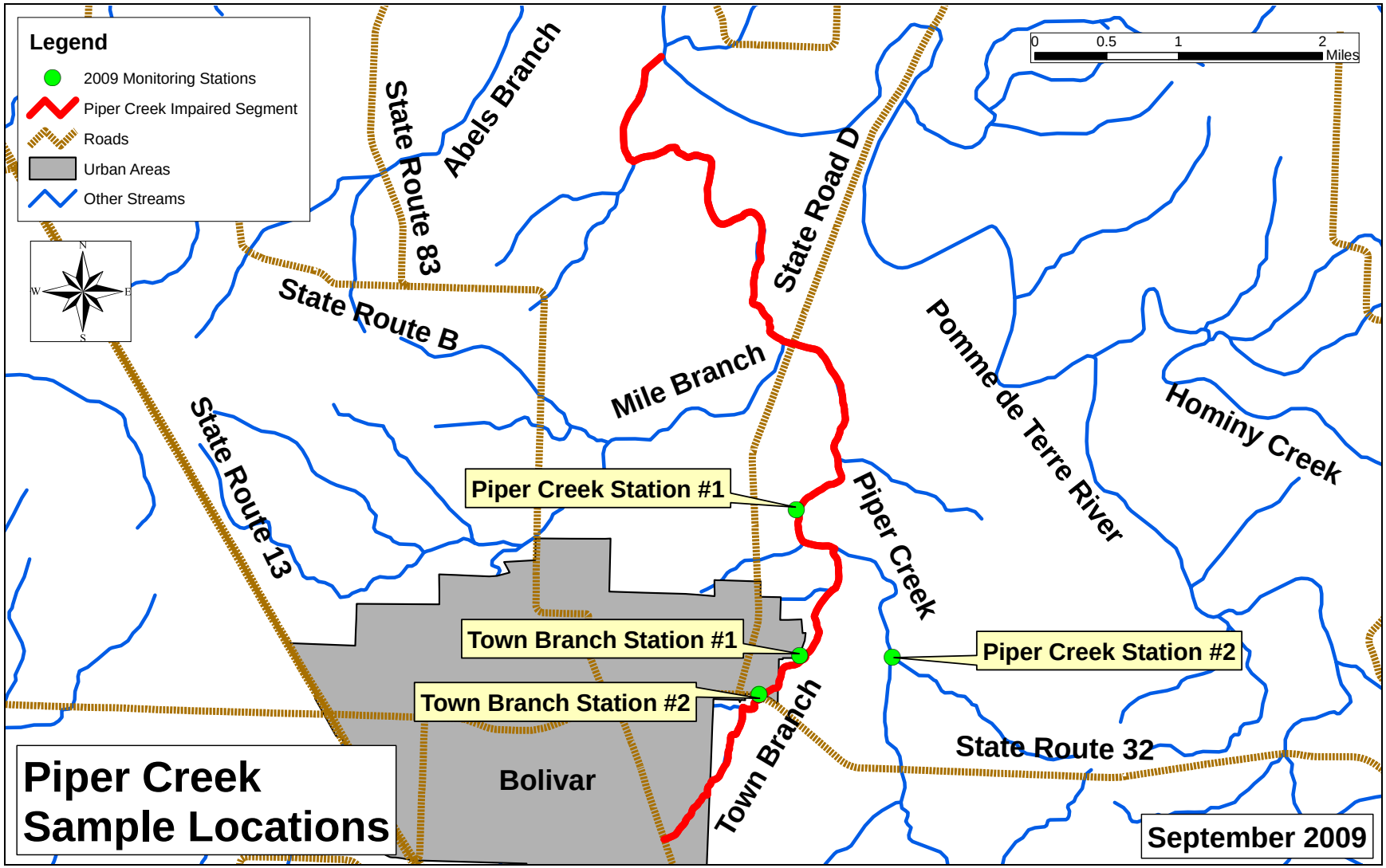


**Figure A-1. Location of Town Branch/Piper Creek 2004 – 2006 Sediment and Water Quality Monitoring Stations**

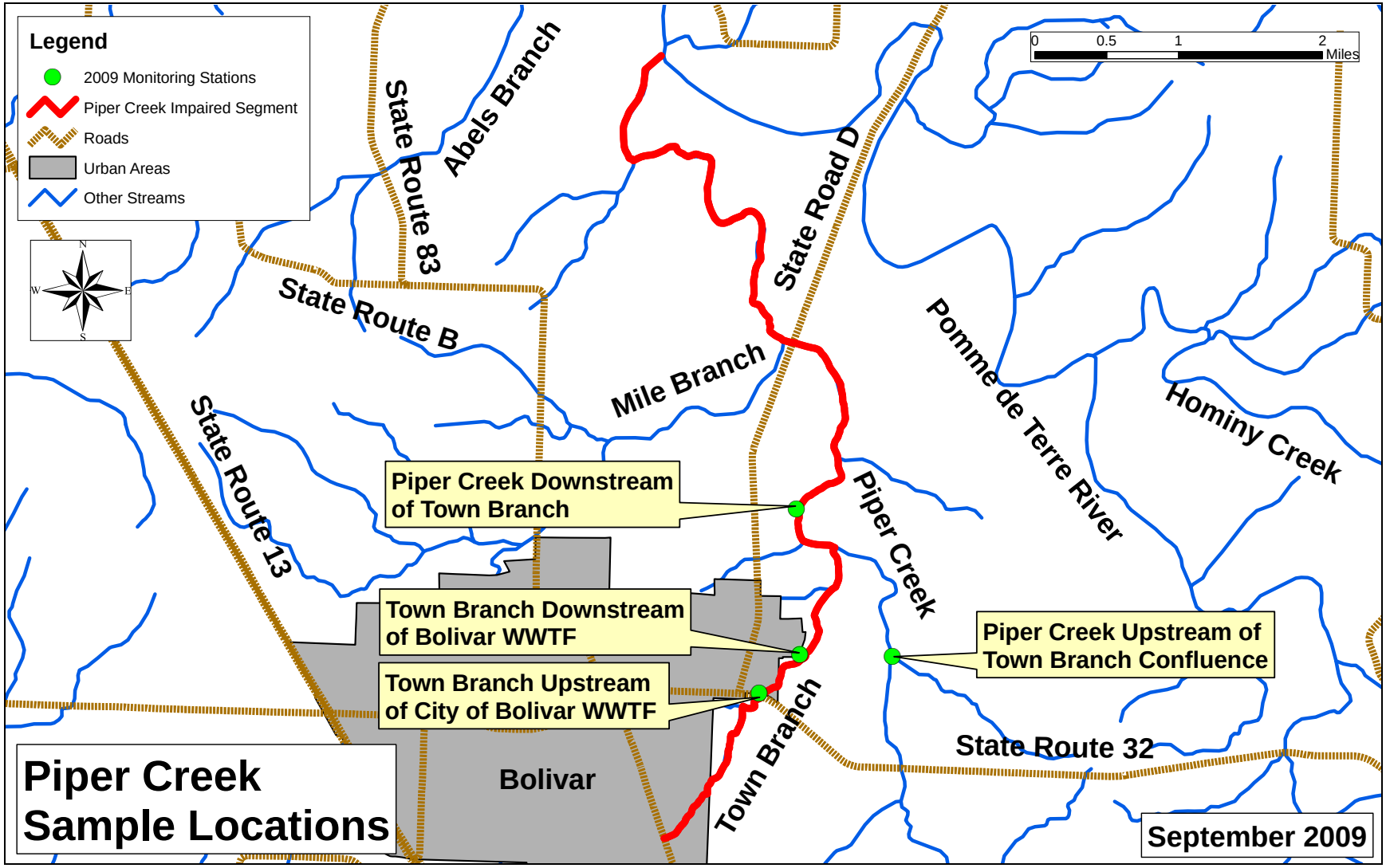


**Figure A-2. Location of Town Branch/Piper Creek 2009 Water Quality Monitoring Stations**

# Appendix B – Piper Creek QUAL2K Modeling

## B.1 Overview of QUAL2K

The QUAL2K water quality model was selected for the development of the Piper Creek DO TMDL. QUAL2K is supported by the EPA and has been used extensively for TMDL development and point source permitting issues across the country, especially for issues related to DO concentrations. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of small rivers and streams. It is a one-dimensional uniform flow model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, nonpoint source loading, tributary flows and incremental inflows and outflows. The processes employed in QUAL2K can address nutrient cycles, algal growth, particulate settling, SOD and DO dynamics.

## B.2 QUAL2K Model Setup

This section describes the process that was used to setup the QUAL2K models for the Piper Creek watershed.

### B.2.1 Stream Segmentation

Figure B-1 and Figure B-2 provide a visual description of the Piper Creek QUAL2K model structure; including locations of monitoring stations, point sources, nonpoint sources and boundaries. The impaired water body segment is divided into four reaches with one tributary simulated as a single reach for a total of five reaches. The lengths of each reach are provided in Table B-1. Reach lengths are based on the location of water quality monitoring stations, stream hydrology, NPDES discharges and point/nonpoint sources. Reaches are further segmented into elements as identified in Table B-1. A consistent element length of approximately 0.16 kilometers was used for all reaches.

As shown in Figure B-1 and B-2, Piper Creek watershed includes several tributaries. Six tributaries enter model reaches between the Reach 1 and Reach 5. The five smaller tributaries were represented in the model as a unique point source and 1.76 kilometers of Piper Creek was modeled (Figure B-1). Average daily flow for each simulated day and tributary was estimated for unknown flows using a drainage area ratio approach. Using measured flow at the four monitoring locations (stations 1, 2, 3 and 4) a watershed average flow/mi$^2$ was calculated for each of the five small tributaries.

The city of Bolivar WWTF, is represented as a point source in Reach 1. The Karlin Place subdivision WWTF, Quail Creek Mobile Home Park WWTF and Silo Ridge Homeowners Association WWTF are represented in Reach 3. The Home Court Advantage, Inc. WWTF is represented in Reach 5.

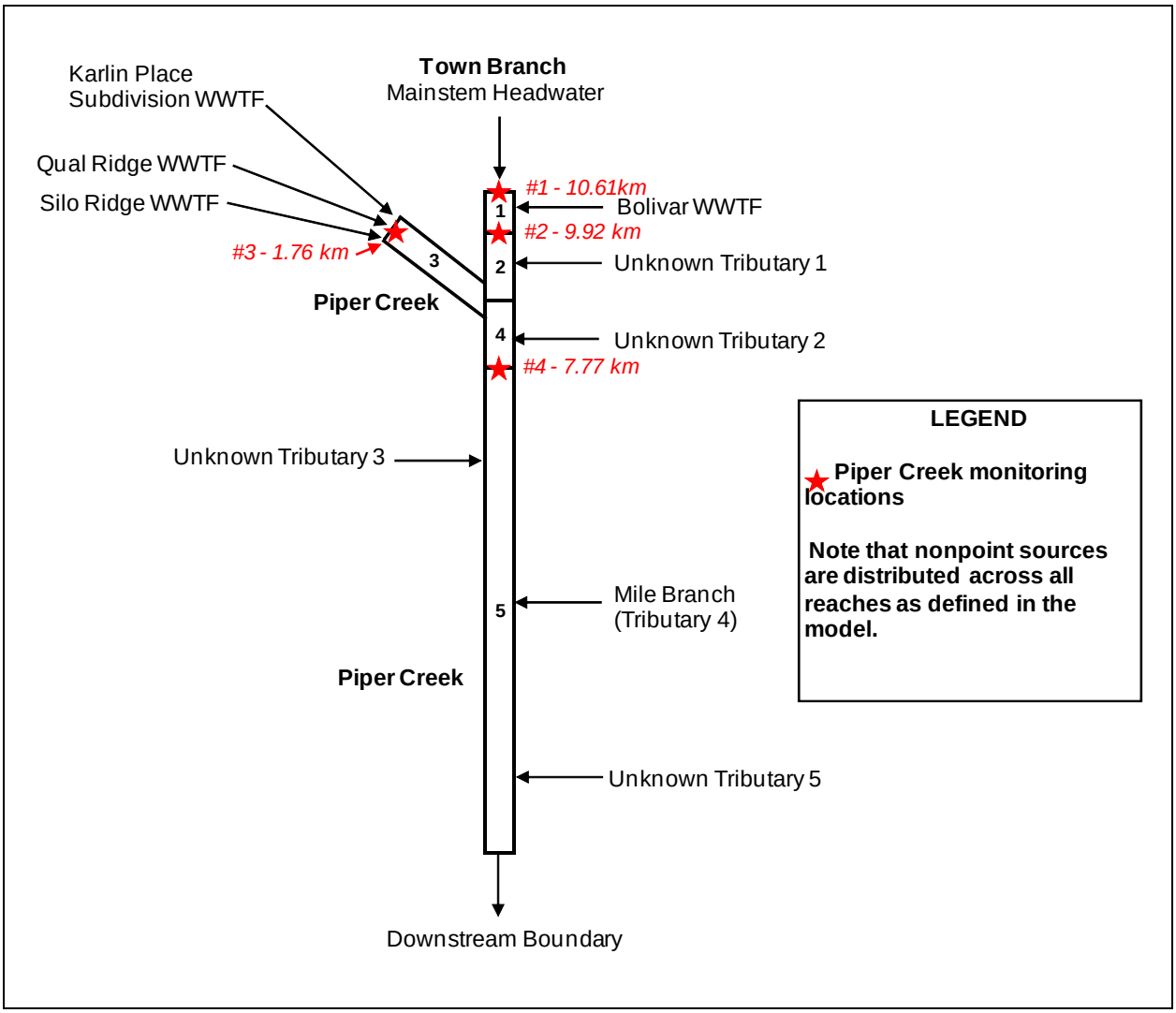


**Figure B-1. Diagram of Piper Creek QUAL2K Stream Model (not to scale)**

**Table B-1. Number of Reaches and Elements Associated with Each Reach in Piper Creek**

| Reach Number | Reach Length (kilometers) | Number of Elements | Element Length (kilometers) |
|---|---|---|---|
| 1 | 0.68 | 4 | 0.16 |
| 2 | 1.48 | 9 | 0.16 |
| 3 | 1.76 | 11 | 0.16 |
| 4 | 0.68 | 4 | 0.16 |
| 5 | 7.77 | 48 | 0.16 |

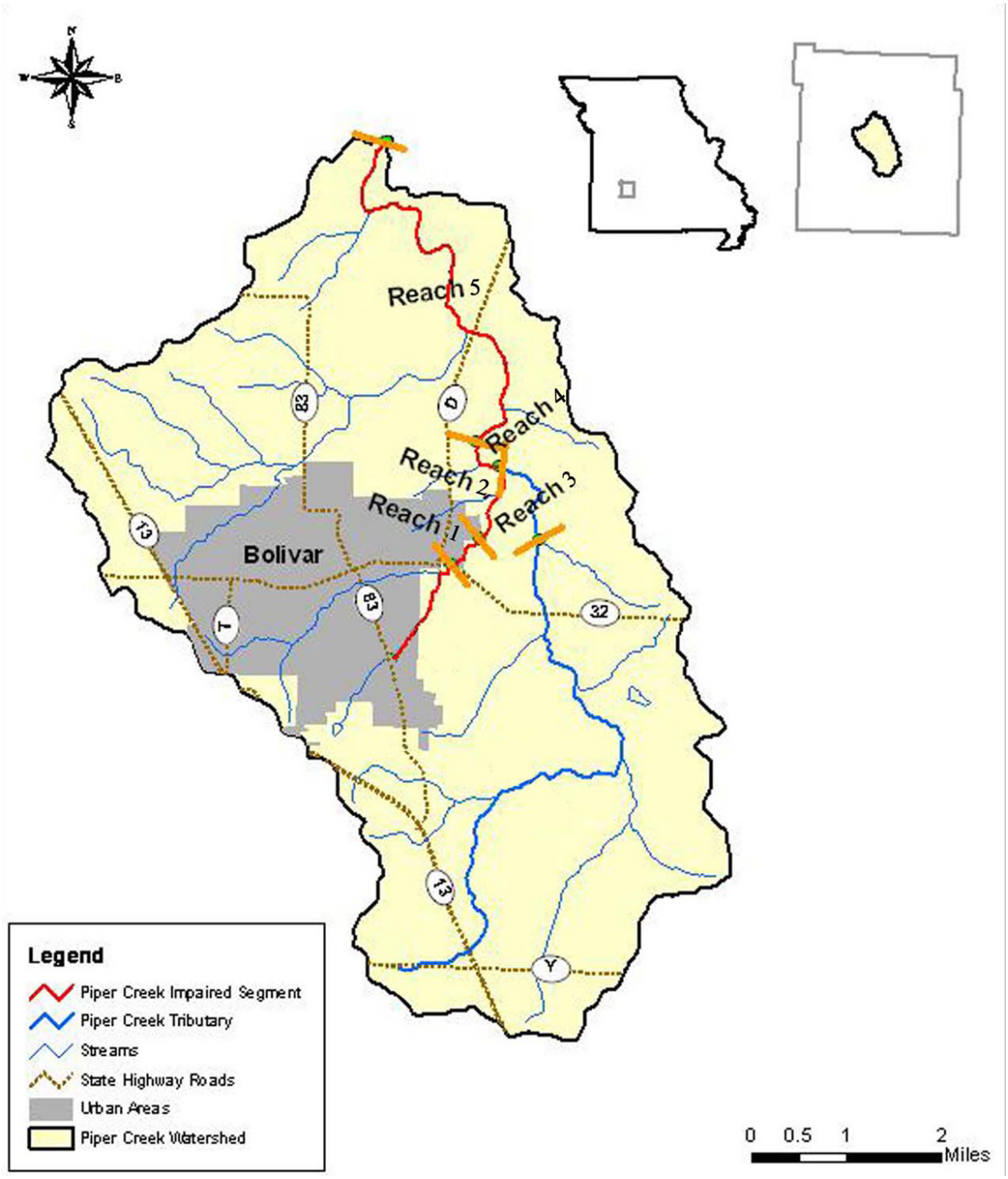


**Figure B-2. Reaches in Piper Creek QUAL2K Model**

### B.2.2 <u>Geometry, Elevation and Weather Data</u>

Measurement of stream velocities, widths and depths were collected at four locations in Piper Creek and were used to calculate flow rates at each location. QUAL2K allows the user to

calculate the flow balance using one of three approaches: weirs, rating curves and Manning equations. For the Piper Creek models, velocity and depth inputs were estimated using rating curves that were developed using Equations 2 and 3.

$$U = aQ^b$$ **Equation 2**

Where,

U = Velocity (m/s)
a = Empirical Coefficient
Q = Flow ($m^3/s$)
b = Empirical Coefficient

$$H = \alpha Q^\beta$$ **Equation 3**

Where,

H = Depth (m)
α = Empirical Coefficient
Q = Flow ($m^3/s$)
β = Empirical Coefficient

$a$, $b$, $\alpha$ and $\beta$ are empirical coefficients that are determined from velocity-discharge and stage-discharge rating curves. Within Q2K the values of velocity and depth are used to estimate reach average cross-sectional area and width by:

$$A_c = \frac{Q}{U}$$ **Equation 4**

Where,

$A_c$ = average cross-sectional area ($m^2$)
Q = flow ($m^3/s$)
U = velocity (m/s)

$$B = \frac{A_c}{H}$$ **Equation 5**

Where,

B = width (m)
$A_c$ = average cross-sectional area ($m^2$)
H = depth (m)

The surface area and volume of the element can then be computed as:

$$A_s = B\Delta x$$ **Equation 6**

Where,

$A_s$ = surface area ($m^2$)
B = width (m)
$\Delta x$ = length of element

$$V = BH\Delta x$$ **Equation 6**

Where,

V = volume ($m^3$)
B = width (m)
H = depth (m)
$\Delta x$ = length of element

The raw data used to generate the rating curve equations used for the QUAL2K model are provided in Table B-2 and the resulting model inputs are provided in Table B-3.

**Table B-2. Stream characteristics for Piper Creek used to develop QUAL2K model hydraulic inputs**

| Time | Site | Date | Width (meters) | Average Depth (meters) | Area (square meters) | Velocity (m/s) | Flow (cms) | Event |
|---|---|---|---|---|---|---|---|---|
| AM | Piper 1 | 07/15/09 | 3.962 | 0.140 | 0.554 | 0.496 | 0.275 | July WLA |
| PM | Piper 1 | 07/15/09 | 3.962 | 0.108 | 0.426 | 0.273 | 0.116 | July WLA |
| AM | Piper 1 | 07/16/09 | 3.962 | 0.081 | 0.322 | 0.156 | 0.050 | July WLA |
| PM | Piper 1 | 07/16/09 | 3.962 | 0.080 | 0.316 | 0.141 | 0.044 | July WLA |
| AM | Piper 1 | 08/19/09 | 3.962 | 0.069 | 0.272 | 0.120 | 0.033 | Aug WLA |
| PM | Piper 1 | 08/19/09 | 3.962 | 0.079 | 0.315 | 0.146 | 0.046 | Aug WLA |
| AM | Piper 1 | 08/20/09 | 3.962 | 0.070 | 0.278 | 0.105 | 0.029 | Aug WLA |
| PM | Piper 1 | 08/20/09 | 3.962 | 0.069 | 0.274 | 0.097 | 0.027 | Aug WLA |
| AM | Piper 2 | 07/15/09 | 4.877 | 0.152 | 0.743 | 0.399 | 0.297 | July WLA |
| PM | Piper 2 | 07/15/09 | 4.877 | 0.129 | 0.629 | 0.316 | 0.199 | July WLA |
| AM | Piper 2 | 07/16/09 | 4.877 | 0.098 | 0.480 | 0.211 | 0.101 | July WLA |
| PM | Piper 2 | 07/16/09 | 4.877 | 0.098 | 0.479 | 0.214 | 0.103 | July WLA |
| AM | Piper 2 | 08/19/09 | 4.572 | 0.099 | 0.451 | 0.166 | 0.075 | Aug WLA |
| PM | Piper 2 | 08/19/09 | 4.572 | 0.122 | 0.560 | 0.217 | 0.122 | Aug WLA |
| AM | Piper 2 | 08/20/09 | 4.572 | 0.096 | 0.440 | 0.163 | 0.072 | Aug WLA |
| PM | Piper 2 | 08/20/09 | 4.572 | 0.106 | 0.485 | 0.189 | 0.091 | Aug WLA |
| AM | Piper 3 | 07/15/09 | 13.411 | 0.685 | 9.185 | 0.006 | 0.057 | July WLA |
| PM | Piper 3 | 07/15/09 | 13.411 | 0.650 | 8.720 | 0.012 | 0.108 | July WLA |
| AM | Piper 3 | 07/16/09 | 13.411 | 0.645 | 8.646 | 0.002 | 0.021 | July WLA |
| PM | Piper 3 | 07/16/09 | 13.411 | 0.645 | 8.650 | 0.002 | 0.016 | July WLA |
| AM | Piper 3 | 08/19/09 | 13.411 | 0.627 | 8.404 | 0.004 | 0.029 | Aug WLA |
| PM | Piper 3 | 08/19/09 | Data not used due velocity measurements of zero | | | | | |
| AM | Piper 3 | 08/20/09 | 13.411 | 0.621 | 8.327 | 0.012 | 0.103 | Aug WLA |
| PM | Piper 3 | 08/20/09 | 13.411 | 0.623 | 8.359 | 0.000 | 0.001 | Aug WLA |
| AM | Piper 4 | 07/15/09 | 10.058 | 0.216 | 2.169 | 0.166 | 0.359 | July WLA |
| PM | Piper 4 | 07/15/09 | 10.058 | 0.214 | 2.154 | 0.201 | 0.433 | July WLA |
| AM | Piper 4 | 07/16/09 | 10.058 | 0.187 | 1.883 | 0.162 | 0.305 | July WLA |
| PM | Piper 4 | 07/16/09 | 10.058 | 0.176 | 1.774 | 0.115 | 0.204 | July WLA |
| AM | Piper 4 | 08/19/09 | 10.058 | 0.166 | 1.670 | 0.099 | 0.166 | Aug WLA |
| PM | Piper 4 | 08/19/09 | 10.058 | 0.178 | 1.792 | 0.103 | 0.185 | Aug WLA |
| AM | Piper 4 | 08/20/09 | 10.058 | 0.156 | 1.573 | 0.105 | 0.165 | Aug WLA |
| PM | Piper 4 | 08/20/09 | 10.058 | 0.165 | 1.659 | 0.120 | 0.199 | Aug WLA |

**Table B-3. Rating Curve QUAL2K Model Inputs**

| Model Reach | Monitoring Location | Velocity | | Depth | |
|---|---|---|---|---|---|
| | | Coefficient | Exponent | Coefficient | Exponent |
| 1 | 1 | 1.2038 | 0.686 | 0.2096 | 0.314 |
| 2 | 2 | 0.8664 | 0.632 | 0.2222 | 0.323 |
| 3 | 3 | 0.1131 | 0.993 | 0.6594 | 0.007 |
| 4 | 4 | 0.3566 | 0.701 | 0.2575 | 0.301 |
| 5 | 4 | 0.3566 | 0.701 | 0.2575 | 0.301 |

Hourly weather data for air temperature, dew point temperature and wind speed were retrieved from the weather underground website[20]. Weather data from the Bolivar, Missouri, Weather Station (KMOBOLIV3) were used because this was the closest station with the

[20]http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KMOBOLIV3&month=7&day=15&year=2009

appropriate data. Table B-3 displays the hourly weather data used for July 15 - 16, 2009, and August 19 - 20, 2009, modeled periods.

**Table B-4. Hourly Weather Data for July 15-16 2009 and August 19 - 20, 2009, from the Bolivar, Missouri, Weather Station (KMOBOLIV3)**

| Date/Time | Air temperature C | Dew point temperature C | Wind speed (meters/second) | Cloud cover |
|---|---|---|---|---|
| **July 15, 2009** | | | | |
| 12:00 AM | 25.4 | 23.2 | 1.84 | 0.0% |
| 1:00 AM | 24.7 | 23.3 | 3.11 | 0.0% |
| 2:00 AM | 24.6 | 23.4 | 2.88 | 0.0% |
| 3:00 AM | 24.6 | 23.2 | 1.20 | 75.0% |
| 4:00 AM | 24.5 | 23.1 | 1.75 | 0.0% |
| 5:00 AM | 23.9 | 22.8 | 1.54 | 0.0% |
| 6:00 AM | 23.8 | 22.9 | 1.09 | 75.0% |
| 7:00 AM | 24.3 | 23.3 | 0.23 | 25.0% |
| 8:00 AM | 26.5 | 24.5 | 0.73 | 25.0% |
| 9:00 AM | 28.0 | 24.9 | 1.97 | 25.0% |
| 10:00 AM | 29.3 | 25.4 | 1.72 | 0.0% |
| 11:00 AM | 30.5 | 25.4 | 1.44 | 0.0% |
| 12:00 PM | 30.4 | 25.6 | 0.98 | 0.0% |
| 1:00 PM | 29.6 | 25.6 | 0.33 | 0.0% |
| 2:00 PM | 29.1 | 25.8 | 0.12 | 25.0% |
| 3:00 PM | 29.3 | 25.3 | 0.55 | 25.0% |
| 4:00 PM | 29.9 | 24.9 | 1.44 | 0.0% |
| 5:00 PM | 30.9 | 24.0 | 0.30 | 0.0% |
| 6:00 PM | 30.9 | 24.9 | 0.00 | 0.0% |
| 7:00 PM | 28.8 | 25.3 | 0.00 | 0.0% |
| 8:00 PM | 27.3 | 24.6 | 0.00 | 0.0% |
| 9:00 PM | 25.7 | 24.2 | 0.00 | 0.0% |
| 10:00 PM | 25.0 | 23.7 | 0.00 | 0.0% |
| 11:00 PM | 24.0 | 23.1 | 0.00 | 0.0% |
| **July 16, 2009** | | | | |
| 12:00 AM | 23.9 | 23.5 | 0.07 | 25.0% |
| 1:00 AM | 24.3 | 23.6 | 0.12 | 25.0% |
| 2:00 AM | 23.7 | 23.2 | 0.06 | 25.0% |
| 3:00 AM | 23.5 | 23.0 | 0.00 | 25.0% |
| 4:00 AM | 23.4 | 22.8 | 0.12 | 25.0% |
| 5:00 AM | 23.2 | 22.7 | 0.34 | 25.0% |
| 6:00 AM | 22.9 | 22.4 | 0.38 | 25.0% |
| 7:00 AM | 23.5 | 22.7 | 0.11 | 25.0% |
| 8:00 AM | 24.3 | 23.6 | 0.40 | 25.0% |
| 9:00 AM | 25.2 | 24.2 | 0.89 | 50.0% |
| 10:00 AM | 26.6 | 24.6 | 0.75 | 75.0% |
| 11:00 AM | 28.0 | 24.9 | 0.47 | 75.0% |

| Date/Time | Air temperature C | Dew point temperature C | Wind speed (meters/second) | Cloud cover |
|---|---|---|---|---|
| 12:00 PM | 29.6 | 25.0 | 0.56 | 75.0% |
| 1:00 PM | 30.5 | 24.7 | 0.78 | 50.0% |
| 2:00 PM | 31.1 | 24.4 | 1.32 | 10.0% |
| 3:00 PM | 25.7 | 22.5 | 1.04 | 75.0% |
| 4:00 PM | 23.0 | 21.9 | 0.77 | 25.0% |
| 5:00 PM | 26.8 | 24.0 | 0.54 | 0.0% |
| 6:00 PM | 27.9 | 24.1 | 0.42 | 0.0% |
| 7:00 PM | 26.4 | 23.3 | 0.63 | 0.0% |
| 8:00 PM | 24.7 | 22.8 | 0.00 | 0.0% |
| 9:00 PM | 23.6 | 21.7 | 0.14 | 0.0% |
| 10:00 PM | 23.0 | 19.8 | 0.36 | 0.0% |
| 11:00 PM | 21.8 | 19.2 | 0.06 | 0.0% |
| **August 19, 2009** | | | | |
| 12:00 AM | 21.0 | 20.2 | 0.00 | 0.0% |
| 1:00 AM | 20.9 | 20.2 | 0.00 | 0.0% |
| 2:00 AM | 20.9 | 20.0 | 0.00 | 0.0% |
| 3:00 AM | 20.7 | 19.8 | 0.00 | 0.0% |
| 4:00 AM | 20.6 | 19.9 | 0.61 | 0.0% |
| 5:00 AM | 21.1 | 20.2 | 1.66 | 0.0% |
| 6:00 AM | 21.2 | 20.3 | 1.42 | 0.0% |
| 7:00 AM | 21.4 | 20.4 | 0.80 | 0.0% |
| 8:00 AM | 22.4 | 21.1 | 0.35 | 0.0% |
| 9:00 AM | 23.0 | 21.4 | 1.31 | 0.0% |
| 10:00 AM | 23.7 | 21.7 | 1.45 | 0.0% |
| 11:00 AM | 24.5 | 21.4 | 1.82 | 0.0% |
| 12:00 PM | 23.7 | 20.6 | 2.47 | 0.0% |
| 1:00 PM | 21.7 | 19.9 | 1.64 | 0.0% |
| 2:00 PM | 21.0 | 19.2 | 2.47 | 0.0% |
| 3:00 PM | 21.0 | 19.6 | 2.04 | 0.0% |
| 4:00 PM | 20.8 | 19.4 | 0.89 | 0.0% |
| 5:00 PM | 20.4 | 18.9 | 1.53 | 0.0% |
| 6:00 PM | 19.9 | 18.7 | 1.44 | 0.0% |
| 7:00 PM | 19.5 | 18.6 | 1.03 | 0.0% |
| 8:00 PM | 19.2 | 18.0 | 1.10 | 0.0% |
| 9:00 PM | 19.2 | 17.7 | 1.48 | 0.0% |
| 10:00 PM | 19.9 | 18.1 | 1.38 | 0.0% |
| 11:00 PM | 17.3 | 16.4 | 0.96 | 0.0% |
| **August 20, 2009** | | | | |
| 12:00 AM | 17.0 | 16.6 | 2.04 | 0.0% |
| 1:00 AM | 18.1 | 17.8 | 2.09 | 0.0% |
| 2:00 AM | 18.1 | 17.8 | 1.12 | 0.0% |
| 3:00 AM | 18.0 | 17.7 | 2.75 | 0.0% |
| 4:00 AM | 18.0 | 17.6 | 2.12 | 0.0% |
| 5:00 AM | 17.9 | 17.6 | 1.61 | 0.0% |
| 6:00 AM | 17.9 | 17.5 | 0.63 | 0.0% |

| Date/Time | Air temperature C | Dew point temperature C | Wind speed (meters/second) | Cloud cover |
|---|---|---|---|---|
| 7:00 AM | 18.0 | 17.7 | 0.28 | 0.0% |
| 8:00 AM | 18.6 | 18.3 | 0.48 | 0.0% |
| 9:00 AM | 20.0 | 19.3 | 0.97 | 0.0% |
| 10:00 AM | 20.7 | 19.7 | 1.32 | 0.0% |
| 11:00 AM | 21.7 | 20.0 | 1.10 | 0.0% |
| 12:00 PM | 23.1 | 20.3 | 1.23 | 0.0% |
| 1:00 PM | 23.8 | 21.1 | 1.38 | 0.0% |
| 2:00 PM | 24.8 | 21.0 | 1.71 | 0.0% |
| 3:00 PM | 25.3 | 19.0 | 2.04 | 0.0% |
| 4:00 PM | 25.4 | 19.1 | 1.99 | 0.0% |
| 5:00 PM | 25.7 | 17.6 | 1.40 | 0.0% |
| 6:00 PM | 25.4 | 16.4 | 0.92 | 0.0% |
| 7:00 PM | 22.6 | 15.6 | 0.05 | 0.0% |
| 8:00 PM | 19.2 | 18.0 | 1.10 | 0.0% |
| 9:00 PM | 19.2 | 17.7 | 1.48 | 0.0% |
| 10:00 PM | 19.9 | 18.1 | 1.38 | 0.0% |
| 11:00 PM | 17.3 | 16.4 | 0.96 | 0.0% |

### B.2.3 Boundary Conditions

Water quality and stream channel information collected at the most upstream monitoring location were used to specify headwater boundary conditions for most parameters. The following constituents and parameters were based directly on data collected at the most upstream monitoring location (#1): flow, CBOD, nitrate-nitrogen, organic nitrogen, ammonium-nitrogen, organic phosphorus, inorganic phosphorus, pH and rating curve velocity and depth coefficient and exponent inputs. Hourly estimates for temperature and DO were calculated using a polynomial regression on daily measurements. Separate regressions were developed for DO and temperature on each day by utilizing AM and PM samples for each day at monitoring location one. Hourly headwater inputs are provided in Table B-5.

In order to estimate inflows for each of the five small tributaries, the area of each monitoring location was divided by its respective area and all flow/area ratios were averaged to calculate a flow/area ratio for the entire watershed. The drainage area of each tributary was then multiplied by the Piper Creek flow/area ratio to estimate a flow (cfs) for each tributary. Prior to calculating the flow/area ratio for each sample location, the flow contributed by the Bolivar WWTF was subtracted from the monitored flow, as it should have no impact on tributaries draining into Piper Creek. Water quality concentrations for the tributaries were estimated using water quality conditions at sample location #1 (upstream of the Bolivar WWTF) during July and August 2009.

The Piper Creek tributary (Reach 3) was simulated from Sample Site 3 to the confluence with Town Branch. The headwater conditions of this tributary were based directly on data collected at monitoring location 3: flow, CBOD, nitrate-nitrogen, organic nitrogen, ammonium-nitrogen, organic phosphorus, inorganic phosphorus, pH and rating curve velocity and depth

coefficient and exponent inputs. Hourly estimates for temperature and DO were calculated using a polynomial regression on daily measurements. Hourly headwater inputs are provided in Table B-6.

**Table B-5. Piper Creek QUAL2K headwater model input values for Reach 1 for the July 15 - 16, August 25-26, 2009 simulations**

| Constituent | QUAL2K Headwater Model Input values | | | |
|---|---|---|---|---|
| | July 15, 2009 | July 16, 2009 | August 19, 2009 | August 20, 2009 |
| Flow (cms) | 0.198 | 0.048 | 0.040 | 0.028 |
| Temperature (Deg C)[1] | 20.8 – 24.0 | 20.6 – 24.3 | 18.5 – 23.7 | 18.37 – 22.97 |
| DO (mg/L)[1] | 7.3 – 10.0 | 7.9 – 11.7 | 5.5 – 11.7 | 5.9 – 11.1 |
| CBOD Ultimate (mg $O_2$/L) | 10.7 | 4.0 | 7.5 | 6.75 |
| Organic Nitrogen (µg N/L) | 261.0 | 100.0 | 1664.0 | 406.0 |
| NH4-Nitrogen (µg N/L) | 500.0 | 500.0 | 500.0 | 500.0 |
| NO3-Nitrogen (µg N/L) | 1120.0 | 1830.0 | 1775.0 | 1870.0 |
| Organic Phosphorus (µg P/L) | 35.2 | 34.50 | 16.9 | 14.00 |
| Inorganic Phosphorus (µg P/L) | 15.1 | 34.50 | 7.2 | 7.0 |
| Alkalinity (mg $CaCO_3$/L) | 100.0 | 100.00 | 100.0 | 100.00 |
| pH | 8.2 | 8.7 | 8.2 | 8.2 |

[1] Values for temperature and DO vary hourly

**Table B-6. Piper Creek QUAL2K headwater model input values for Reach 3 for the July 15 - 16, and August 25 - 26, 2009 Simulations.**

| Constituent | QUAL2K Headwater Model Input values | | | |
|---|---|---|---|---|
| | July 15, 2009 | July 16, 2009 | August 19, 2009 | August 20, 2009 |
| Flow (cms) | 0.110 | 0.018 | 0.014 | 0.051 |
| Temperature (Deg C)[1] | 22.9 – 28.0 | 24.1 – 25.4 | 20.1 – 21.8 | 20.6 – 22.6 |
| DO (mg/L)[1] | 6.3 – 10.0 | 5.0 – 7.0 | 2.3 – 4.1 | 2.0 – 5.7 |
| CBOD Ultimate (mg $O_2$/L) | 5.5 | 3.3 | 4.1 | 2.3 |
| Organic Nitrogen (µg N/L) | 798.0 | 488.5 | 253.5 | 1370.5 |
| NH4-Nitrogen (µg N/L) | 500.0 | 500.0 | 500.00 | 1000.0 |
| NO3-Nitrogen (µg N/L) | 565.0 | 565.0 | 303.3 | 256.0 |
| Organic Phosphorus (µg P/L) | 83.0 | 51.8 | 51.1 | 21.8 |
| Inorganic Phosphorus (µg P/L) | 35.55 | 22.2 | 21.9 | 72.0 |
| Alkalinity (mg $CaCO_3$/L) | 100.0 | 100.00 | 100.0 | 100.00 |
| pH | 8.30 | 8.42 | 8.2 | 7.7 |

[1] Values for temperature and DO vary hourly

### B.2.4 Point Sources

Point source inputs for the QUAL2K model were obtained from discharge monitoring reports (DMR) provided by MDNR and are summarized in Table B-5. Four point sources were simulated in the model; the Bolivar WWTF which discharges at kilometer 10.31 (between monitoring stations #1 and #2), Home Court Advantage, Inc. WWTF which discharges at kilometer 1.36 (between monitoring location #1 and the end of the Piper Creek impaired segment) and, Karlin Place Subdivision WWTF and Silo Ridge Homeowners Association WWTF which both discharge at kilometer 1.76 on a tributary that enters into the Piper Creek impaired segment (between monitoring location #3 and the confluence of the unimpaired tributary with the Piper Creek impaired segment). Since the model only includes 1.76 of the Piper Creek tributary these point sources are added at the upstream boundary of reach 3. This is a conservative placement of the point sources; however, it has little impact on the model results because the point sources contribute only a small portion of the flow in the tributary (0.0006 cms of 0.110 cms or 0.5 percent of the total flow). The Quail Creek MHP WWTF has a permit to discharge to Piper Creek; however, the DMR showed that the facility had no recoded discharges during the July and August simulation periods.

None of the point sources report organic nitrogen, nitrate, or phosphorus discharge concentrations. These parameters were estimated for the Bolivar WWTP from DMR and instream data. Values estimated for the Bolivar WWTP were used for the other facilities. For other parameters, such as flow, CBOD, $NH_3$ and DO, data from DMR were used.

## Table B-7. Point Source Data Summary

| Facility Name & NPDES | Date | Discharge Point (km)[1] | Flow (cms) | BOD5 (mg/L) | $NH_3$ (µg/L) | Organic N (µg/L) | Nitrate+ Nitrite N (µg/L) | Organic P (µg/L) | Inorganic P (µg/L) | DO (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolivar WWTF[2] | 7/15/2009 | 10.31 | 0.0613 | 22.00 | 130 E | NS | 7,000 E | 2800 E | 1200 E | 2.60 |
| | 7/16/2009 | 10.31 | 0.0570 | 8.50 | 130 E | 1000 E | 5,180 E | 2100 E | 1000 E | 2.60 |
| | 8/19/2009 | 10.31 | 0.0526 | 19.68 | 652.5 E | 1957 E | 10,000 E | 805 E | 345 E | 2.70 |
| | 8/20/2009 | 10.31 | 0.0526 E | 12 | 652.5 E | 652 E | 10,000 E | 805 E | 345 E | 3.70 |
| Karlin Place Subdivision WWTF[3] | 7/15/2009 | 12.69 E | 0.0004 E | 2.36 E | 2600 E | NS | NS | NS | NS | 2.40 E |
| | 7/16/2009 | 12.69 E | 0.0004 E | 2.36 E | 2600 E | NS | NS | NS | NS | 2.40 E |
| | 8/19/2009 | 12.69 E | 0.0004 E | 2.36 E | 2600 E | NS | NS | NS | NS | 2.40 E |
| | 8/20/2009 | 12.69 E | 0.0004 E | 2.36 E | 2600 E | NS | NS | NS | NS | 2.40 E |
| Silo Ridge Homeowners Association WWTF[3] | 7/15/2009 | 7.53 E | 0.0002 E | 4.72 E | NS | NS | NS | 4550 E | 1950 E | NS |
| | 7/16/2009 | 7.53 E | 0.0002 E | 4.72 E | NS | NS | NS | 4550 E | 1950 E | NS |
| | 8/19/2009 | 7.53 E | 0.0002 E | 4.72 E | NS | NS | NS | 4550 E | 1950 E | NS |
| | 8/20/2009 | 7.53 E | 0.0002 E | 4.72 E | NS | NS | NS | 4550 E | 1950 E | NS |
| Home Court Advantage, Inc. WWTF[4] | 7/15/2009 | 1.36 E | 0.0001 E | 6.98 E | NS | NS | NS | 623 E | 267 E | NS |
| | 7/16/2009 | 1.36 E | 0.0001 E | 6.98 E | NS | NS | NS | 623 E | 267 E | NS |
| | 8/19/2009 | 1.36 E | 0.0001 E | 6.98 E | NS | NS | NS | 623 E | 267 E | NS |
| | 8/20/2009 | 1.36 E | 0.0001 E | 6.98 E | NS | NS | NS | 623 E | 267 E | NS |

[1] Discharge location is based on the distance to the end of the stream; The Bolivar WWTF and Home Court Advantage, Inc. WWTF discharge into the impaired segment of Piper Creek; Karlin Place Subdivision WWTF and Silo Ridge Homeowners Association WWTF discharge to a unimpaired tributary entering the Piper Creek impaired segment.

[2] Flow, pH, temperature and DO values reported on daily DMR for each respective day were used as model inputs. Inputs for BOD and ammonia on July 15 and July 16 were based on values reported on July 16, 2009. Inputs for BOD and ammonia on August 19 and August 20 were based on values reported on August 20, 2009. Organic nitrogen, nitrate+nitrite N, organic phosphorus and inorganic phosphorus model inputs were not reported by the Bolivar WWTF DMR. These model inputs were selected based on instream measurements at monitoring location #2. E = Estimated value was estimated based on monitoring conducted on each day.

[3] All values based on September 2009 quarterly DMR.

[4] All values based on July 2008 DMR.

NS = Parameter was not included in the model for this point source.

Organic N is set equal to TKN minus $NH_3$; Inorganic P estimated to be 70 percent of TP and Organic P estimated to be 30 percent of TP based on EPA, 1997.

### B.2.5 Critical Conditions

DO levels that threaten the integrity of aquatic communities generally occur during low flow periods, so these periods are considered the critical condition. For Class P streams, mixing zones are applicable to all pollutants (with the exception of bacteria) that have specific criteria. Mixing zones are typically based on the 7Q10 low flow of the receiving water body to account for critical low-flow conditions. Missouri uses one quarter (1/4) of the 7Q10 for the mixing zone flow. The rationale for limiting the size of mixing zones is three-fold. First, the assumption of rapid and complete mixing is not a conservative assumption. Meaning, many times effluent plumes exist and cause areas of chronically toxic conditions that can extend laterally and longitudinally downstream. Second, state rule requires that a zone of passage be provided so that aquatic organisms may pass by facility outfalls without becoming adversely affected. Third, for antidegradation purposes, the entire assimilative capacity of the water body cannot be allocated to a single discharger.

In the case of Piper Creek, a mixing zone of one-quarter (1/4) of the stream width, cross-sectional area, or volume of flow and a length of ¼ mile is required. For modeling purposes, this means 1/4 of the 7Q10 flow should be the volume of flow available to the facility for mixing and this is the critical flow condition for 1/4 mile downstream of the WWTF discharge. At the default 7Q10 for Class P streams of 0.1 cfs, a mixing zone of 0.025 cfs is the appropriate headwater flow for Piper Creek upstream of the facility. For DO targeting purposes, the 5.0 mg/L minimum DO criteria must be met at ¼ mile below the facility outfall. The applicable mixing zone regulation can be found at 10 CSR 20-7.031(4)(A)4.B.(II) (CSR, 2009). At distances greater than ¼ mile downstream the critical condition is the 7Q10 flow.

The modeling conducted for Piper Creek included both the 7Q10 and mixing zone flow of ¼ of the 7Q10. Since the mixing zone DO requirement is applicable ¼ miles downstream of the discharge and the 7Q10 DO requirements are applicable the entire length of the segment both conditions must be evaluated. The modeling results indicated that the critical DO condition occurred downstream of the mixing zone, thus the 7Q10 flows were used to develop TMDL loads.

Table B-8 presents minimum DO measurements collected on July 15 - 16, 2009, and August 19 - 20, 2009. Of these measurements, DO was found to be lowest during the August morning sampling events. Based on this result, critical conditions are represented in this TMDL through low flow conditions (7Q10 flow) using the August 19, 2009 model.

**Table B-8. Minimum DO (mg/L) Measurement at each Sampling Location**

| Sampling Location | Stream distance (km) | 7/15/2009 | 7/16/2009 | 8/19/2009 | 8/20/2009 |
|---|---|---|---|---|---|
| 1 | 10.61 | 7.73 | 7.93 | 6.81 | 6.84 |
| 2 | 9.93 | 7.37 | 7.59 | 6.19 | 5.7 |
| 3 | 1.76 | 7.08 | 5.45 | 2.67 | 2.77 |
| 4 | 7.77 | 7.9 | 8.49 | 6.4 | 6.56 |

## B.3 Model Calibration

This section of the appendix describes the process that was used to calibrate the QUAL2K model for the Piper Creek watershed and presents the calibration results.

### B.3.1 Flow and Water Depth Simulations

The model was calibrated for flow, stream velocities and depths for the data collected on July 15 - 16, 2009. QUAL2K provides the user with the option to simulate the following flows: boundary headwater flows, point source flows and nonpoint source diffuse flow. In the Piper Creek models, nonpoint sources are grouped with tributary flows that are included in the model as point sources.

Portions of Piper Creek have been identified as a gaining stream. Measured flows between monitoring stations #2 and #4 suggested the presence of water gains that were not otherwise estimated based on watershed area and tributaries or measured at monitoring location #3. For this reason, tributaries 1 and 2 flows were increased to account for flows otherwise not accounted for between monitoring locations #2 and #4. Tributary 1 originates near the city of Bolivar and flows northeast to Town Branch where it joins Town Branch downstream of monitoring location #2 and upstream of the Piper Creek confluence. Tributary 2 originates near the city of Bolivar and flows northeast to Piper Creek where it joins Piper Creek downstream of the Town Branch confluence with Piper Creek and upstream of monitoring location #4. Adjusted flow for both tributaries was determined using a watershed area-weighted approach.

A total of five tributaries are included in the model. Measured flow and concentration data was used for the upstream boundary headwater. Discharges for all WWTFs were included as separate point sources.

Stream velocity, depth and discharge are all critical to the water quality simulation because they influence reaeration, DO, biogeochemical reactions and deposition rates, growth of algal species and the influence of SOD in the stream. Calibration results for flow, depth and velocity are provided for July 15 - 16, 2009, in Figure B-3. A summary of all calibration statistics is provided in Table B-9.

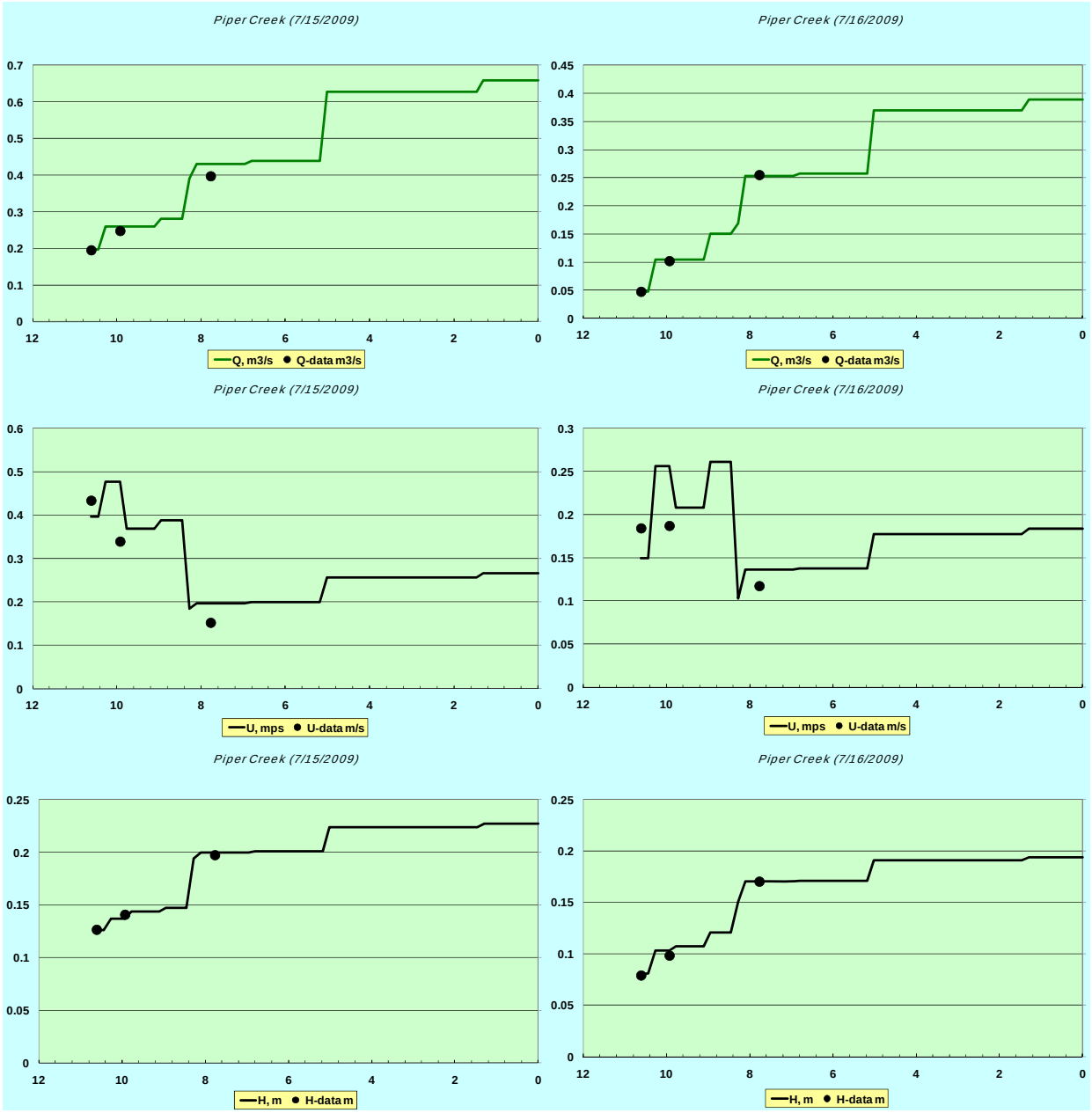


**Figure B-3. Comparisons of observed and simulated flow (Q), velocity (U) and depth (H) in Piper Creek**

### B.3.2 Water Quality Calibration

Calibration consists of the process of adjusting model parameters and the initial estimates of boundary conditions to provide a suitable representation of observed conditions. Calibration is necessary because of the semiempirical nature of water quality models. Although these models are formulated from mass balance principles, most of the kinetic descriptions in the models are empirically derived. These empirical derivations contain a number of coefficients that are usually determined by calibration to data collected in the water body. In addition, there is uncertainty associated with the specification of boundary conditions, point source loads and tributary loads. The boundary conditions and tributary loads might need to be adjusted within the uncertainty bounds of available data to achieve model calibration. Water quality calibration for the Piper Creek QUAL2K model relied on comparison of model predictions to observations at three stations on the mainstem of the system.

Water quality models are often evaluated through visual comparisons, in which the simulated results are plotted against the observed data for the same location and time and are visually evaluated to determine if the model is able to mimic the trend and overall magnitude of the observed conditions. If the model predictions follow the general trend and reproduce the overall magnitude of the observed data, the model is said to represent the dynamics of the system well. The merit of this method is that it is straightforward, taking full advantage of the strength of human intelligence in pattern identification. This method works particularly well when data are limited in quantity and contain significant uncertainty. The limitation of this method is that it relies on the subjective judgment of modelers and lacks quantitative measures to differentiate among sets of calibration result. Because of this, both a visual comparison and quantitative measures were used during the Piper Creek calibration.

BOD is an important calibration parameter because of its influence on DO concentrations. BOD typically consists of two parts: CBOD and NBOD. CBOD is the result of the breakdown of organic carbon molecules such as cellulose and sugars into carbon dioxide and water. NBOD is the result of ammonia oxidation, which is a conversion of ammonia to nitrate in the environment. The consumption of nitrogen usually occurs slower than that of CBOD. CBOD is the oxygen consumed by heterotrophic microbes that utilize the organic matter of the waste in their metabolism. Nitrifying bacteria grow slower than the heterotrophic bacteria, which is one of the reasons why NBOD occurs slower.

The parameter "fast reacting CBOD" was used to simulate CBOD in the models. CBOD5 measurements were adjusted by multiplying each value by the average $CBOD_5$:$CBOD_{ult}$ ratio observed at each station on each of the four days. The $CBOD_5$:$CBOD_{ult}$ ratio was calculated to be 4.71, 6.56, 2.36 and 3.49 at monitoring locations #1, #2, #3 and #4, respectively. This approach to adjusting CBOD model inputs was used for headwater, tributary and WWTF source loads. Headwater and tributary CBOD inputs were adjusted using the ratio 4.71 (similar to monitoring location #1) and the Bolivar WWTF CBOD was adjusted using the ratio 6.56 (similar to monitoring location #2). Given the wide range in calculated $CBOD_5$:$CBOD_{ult}$ ratios, in some cases adjustments were made during calibration to assist in DO fit.

The first order kinetic reaction rates for biogeochemical reactions are influenced from the various flow and chemical conditions in streams. Kinetic rates are a function of different physical and chemical mechanisms such as mixing and turbulence, the particulate and dissolved chemical components ratio, physical settling, biochemical decompositions and sorption by biological slimes on river bottom. In all Piper models, first order reaction rates were selected for the final calibration because they were found to produce the best match to the observed data.

SOD by benthic sediments and organisms can be a large fraction of oxygen consumption in the stream. Benthic sediments can be composed of inorganic minerals and organic material such as leaf litter, particulate and dissolved BOD, detritus from phytoplankton/periphyton and macrophytes. Reduced inorganic and organic materials can exert SOD by diffused oxygen into sediments or oxygen consumption in water column after the inorganic and organic materials are suspended from the sediments. In addition to physical and chemical characteristics of sediments, the impact that SOD has on water column DO can be affected by water depth, stream velocity and water temperature.

SOD is primarily a function of oxidation of dissolved ammonium, methane and decomposition of organic matter by bacteria. Additionally, dissolved hydrogen sulfide and reduced iron and manganese could consume DO once they diffuse into the aerobic sediment layers. The amount of organic matter can be related to SOD consumption.

Organic matter can be described by Redfield ratio, $C_{106}H_{263}O_{110}N_{16}P$. As this ratio suggests, the bacterial conversion (decomposition) of the organic matter can generate the rapidly reactive dissolved N and C species. These species eventually exert SOD from both within sediments and at the interface between water column and sediments. SOD can be measured using the respiration chamber but the method can have high uncertainty and the data was not collected for Piper Creek. SOD values were estimated using the QUAL2K sediment diagenesis routines. Percent bottom SOD coverage was based on the percent fine material identified in the stream reach during the 2009 sampling events.

Benthic algae (periphyton) kinetics also have a marked effect on DO concentrations and diurnal swings (EPA, 1985). Periphyton dynamics were included in model calibration to account for the current observation and historical presence (e.g., Environmental Resources Coalition, 2005) of bottom algae and for the observed diurnal variation in DO. Algal growth, respiration, death and related nutrient kinetics were adjusted within typical ranges reported by the literature (EPA, 1985; Ambrose, 2006) to best match the observed DO variations and nutrient concentrations from the July sampling events.

The "USGS (channel-control)" method was selected to simulate oxygen reaeration. This method was selected after consultation with EPA based on the characteristics of the stream channel and flow conditions. Equations 4 and 5 present formulas for calculating reaeration using the USGS (channel-control) method (Chapra, 2008).

Low flow, $Q < 0.556$ cms (< 19.64 cfs):

$$k_{ah}(20) = 88(US)^{0.313} H^{-0.353}$$ **Equation 4**

High flow, $Q > 0.556$ cms (> 19.64 cfs):

$$k_{ah}(20) = 142(US)^{0.333} H^{-0.66} B_t^{-0.243}$$ **Equation 5**

The final rates used for the Piper Creek calibration are presented in Table B-7. Figures B-4 through B-11 present the results of the model calibration, including temperature, DO, CBOD, TKN, ammonium, nitrate, TN and TP. A visual inspection of the plots indicates that the model predictions follow the general trend and reproduce the overall magnitude of the observed data well.

The quantitative calibration metrics that were used to assess the calibration include the evaluation of average error, residual error, root mean squared error (RMSE), relative error and percent bias. Table B-8 reports the statistical measure and equation for each quantitative calibration metrics used to evaluate the calibration. Table B-9 presents statistical results for calibration model runs for flow, DO, nitrate, TKN and TP.

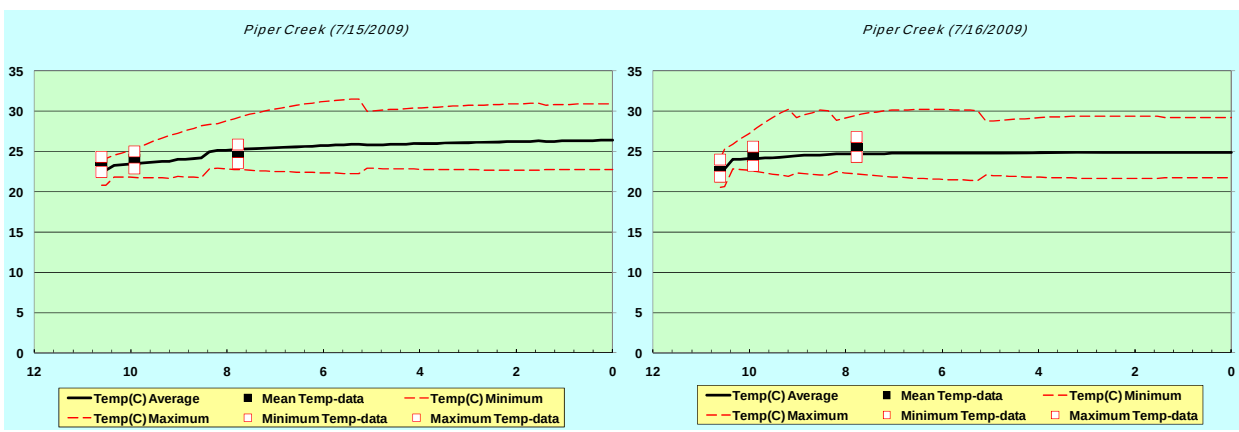


**Figure B-4. Temperature Calibration in Piper Creek**

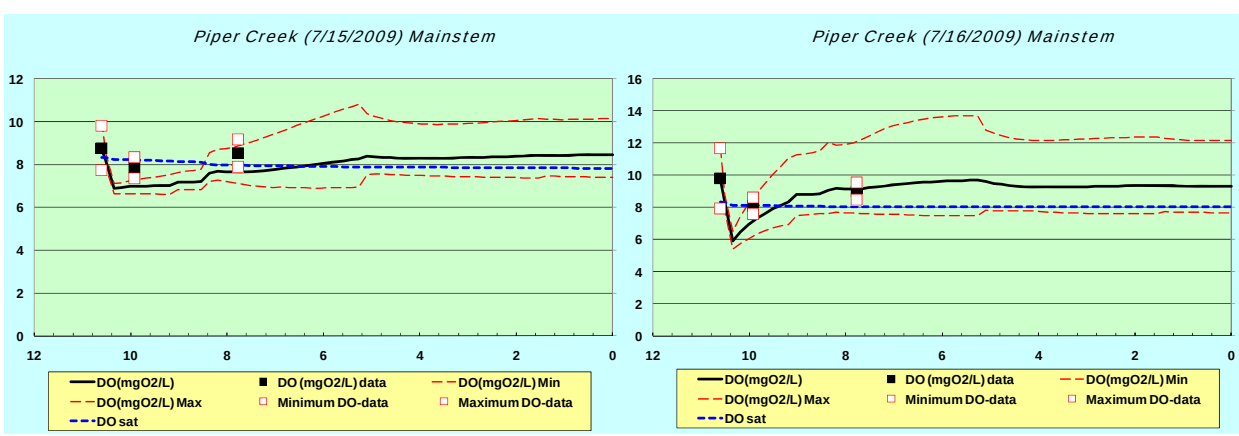


**Figure B-5. DO Calibration in Piper Creek**

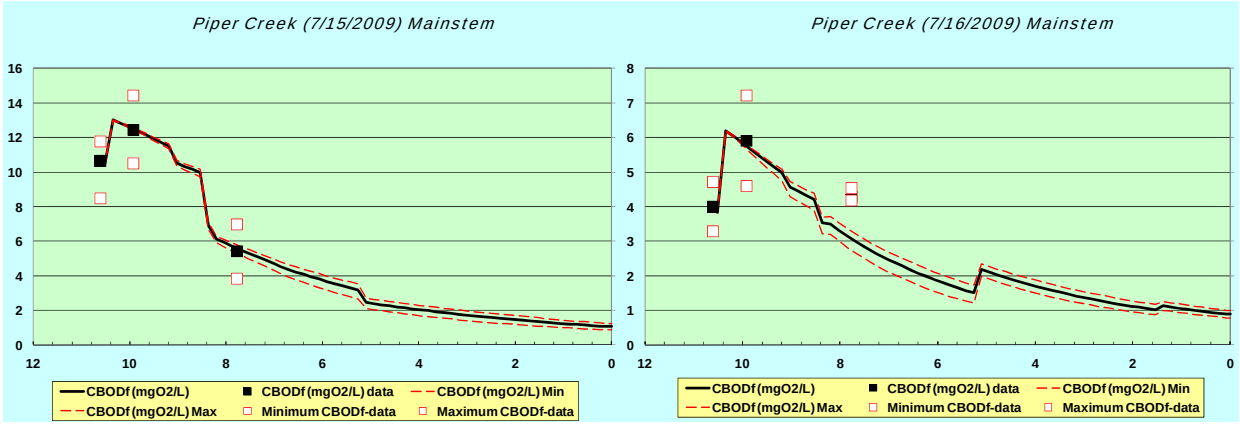


**Figure B-6. CBOD Calibration in Piper Creek**

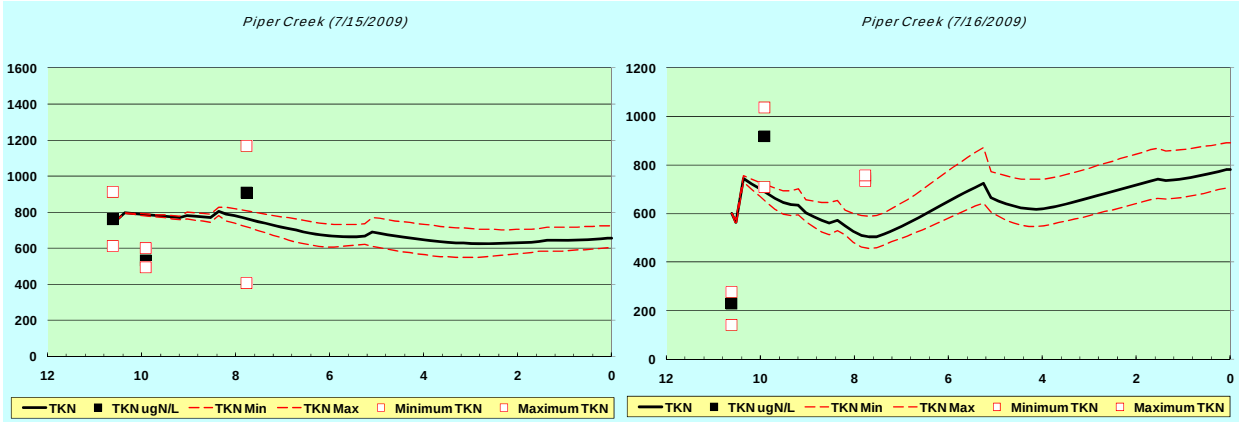


**Figure B-7. TKN Calibration in Piper Creek**

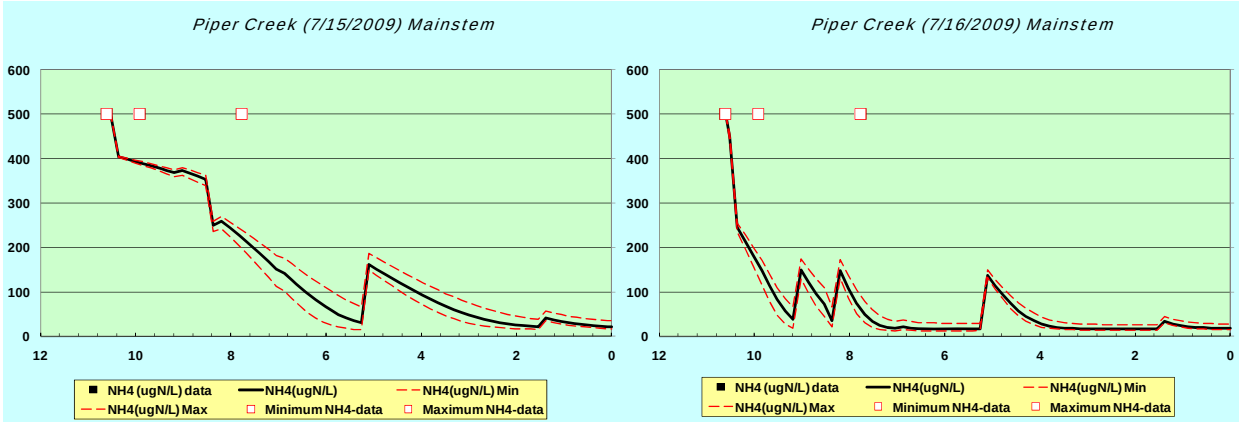


**Figure B-8. Ammonium Calibration in Piper Creek (all measured ammonia was below the detection limit of 500 µg/L)**

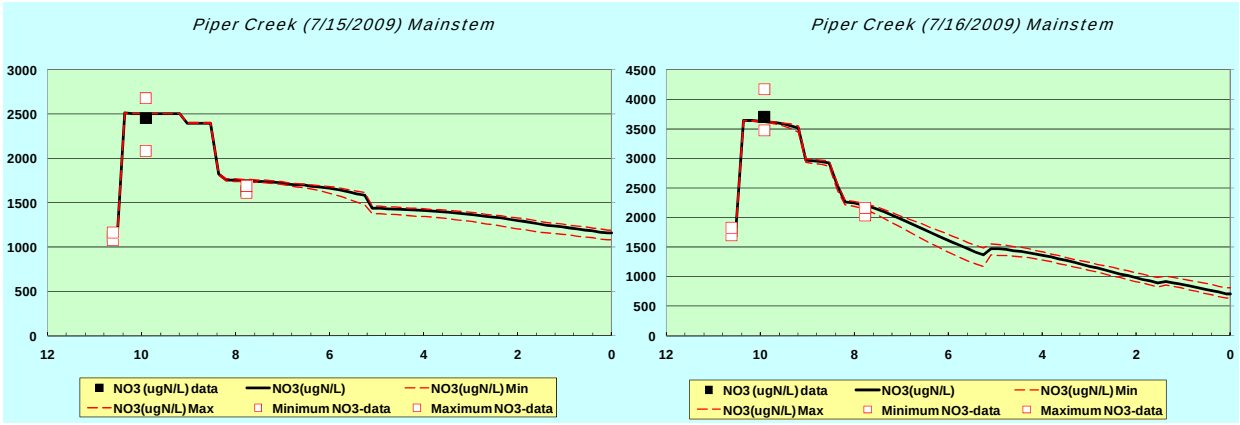


**Figure B-9. Nitrate Calibration in Piper Creek**

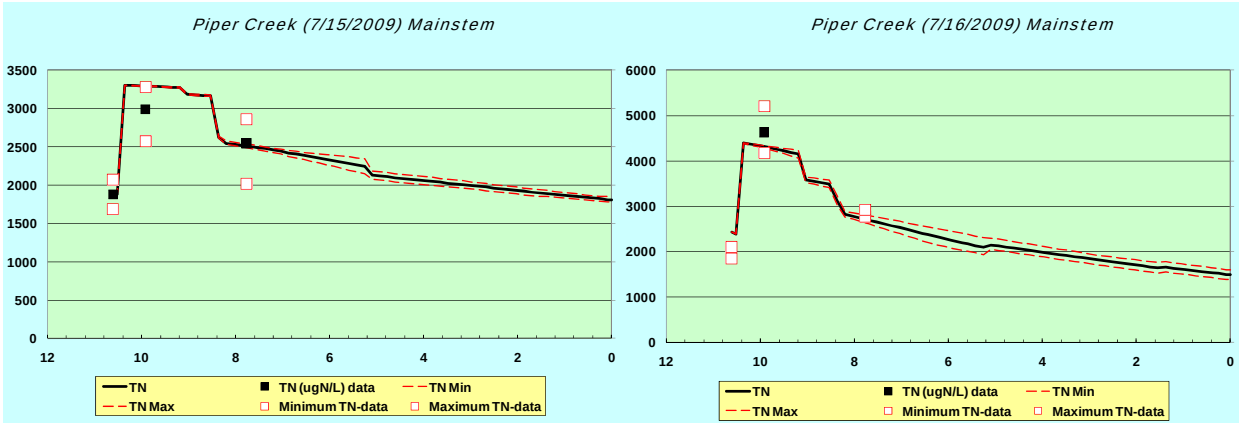


**Figure B-10. Total Nitrogen Calibration in Piper Creek**

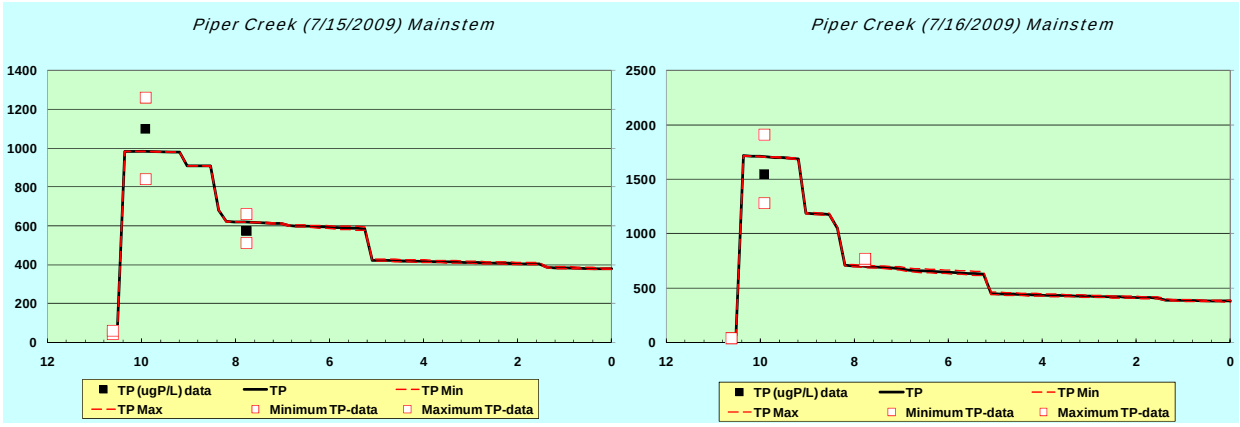


**Figure B-11. Total Phosphorus Calibration in Piper Creek**

## Table B-9. Rates Used for the Piper Creek QUAL2K Calibration

| ***Parameter*** | | ***Units*** | ***Symbol*** |
|---|---|---|---|
| *Stoichiometry:* | | | |
| Carbon | 40 | gC | gC |
| Nitrogen | 7.2 | gN | gN |
| Phosphorus | 1 | gP | gP |
| Dry weight | 100 | gD | gD |
| Chlorophyll | 1 | gA | gA |
| ***Inorganic suspended solids:*** | | | |
| Settling velocity | 1.304 | m/d | $v_i$ |
| ***Oxygen:*** | | | |
| Reaeration model | USGS(channel-control) | | |
| User reaeration coefficient α | 0 | | $\alpha$ |
| User reaeration coefficient β | 0 | | $\beta$ |
| User reaeration coefficient γ | 0 | | $\gamma$ |
| Temp correction | 1.024 | | $\square_a$ |
| Reaeration wind effect | Banks-Herrera | | |
| O2 for carbon oxidation | 2.69 | $gO_2/gC$ | $r_{oc}$ |
| O2 for NH4 nitrification | 4.57 | $gO_2/gN$ | $r_{on}$ |
| Oxygen inhib model CBOD oxidation | Exponential | | |
| Oxygen inhib parameter CBOD oxidation | 0.60 | L/mgO2 | $K_{socf}$ |
| Oxygen inhib model nitrification | Exponential | | |
| Oxygen inhib parameter nitrification | 0.60 | L/mgO2 | $K_{sona}$ |
| Oxygen enhance model denitrification | Exponential | | |
| Oxygen enhance parameter denitrification | 0.60 | L/mgO2 | $K_{sodn}$ |
| Oxygen inhib model phyto resp | Exponential | | |
| Oxygen inhib parameter phyto resp | 0.60 | L/mgO2 | $K_{sop}$ |
| Oxygen enhance model bot alg resp | Exponential | | |
| Oxygen enhance parameter bot alg resp | 0.60 | L/mgO2 | $K_{sob}$ |
| ***Slow CBOD:*** | | | |
| Hydrolysis rate | 0.5 | /d | $k_{hc}$ |
| Temp correction | 1.047 | | $\square_{hc}$ |
| Oxidation rate | 0 | /d | $k_{dcs}$ |
| Temp correction | 1.047 | | $\square_{dcs}$ |
| ***Fast CBOD:*** | | | |
| Oxidation rate | 3 | /d | $k_{dc}$ |
| Temp correction | 1.047 | | $\square_{dc}$ |
| ***Organic N:*** | | | |
| Hydrolysis | 0.1 | /d | $k_{hn}$ |
| Temp correction | 1.07 | | $\square_{hn}$ |
| Settling velocity | 0.2 | m/d | $v_{on}$ |

| ***Parameter*** | | ***Units*** | ***Symbol*** |
|---|---|---|---|
| ***Ammonium:*** | | | |
| Nitrification | 0.1 | /d | $k_{na}$ |
| Temp correction | 1.07 | | $\square_{na}$ |
| ***Nitrate:*** | | | |
| Denitrification | 0.1 | /d | $k_{dn}$ |
| Temp correction | 1.07 | | $\square_{dn}$ |
| Sed denitrification transfer coeff | 0 | m/d | $v_{di}$ |
| Temp correction | 1.07 | | $\square_{di}$ |
| ***Organic P:*** | | | |
| Hydrolysis | 0.1 | /d | $k_{hp}$ |
| Temp correction | 1.07 | | $\square_{hp}$ |
| Settling velocity | 0.1 | m/d | $v_{op}$ |
| ***Inorganic P:*** | | | |
| Settling velocity | 0 | m/d | $v_{ip}$ |
| Inorganic P sorption coefficient | 0.073 | L/mgD | $K_{dpi}$ |
| Sed P oxygen attenuation half sat constant | 1.831 | $mgO_2/L$ | $k_{spi}$ |
| ***Phytoplankton:*** | | | |
| Max Growth rate | 0 | /d | $k_{gp}$ |
| Temp correction | 1.07 | | $\square_{gp}$ |
| Respiration rate | 0.05 | /d | $k_{rp}$ |
| Temp correction | 1.07 | | $\square_{rp}$ |
| Excretion rate | 0.04 | /d | $k_{ep}$ |
| Temp correction | 1.07 | | $\square_{dp}$ |
| Death rate | 0.01 | /d | $k_{dp}$ |
| Temp correction | 1.047 | | $\square_{dp}$ |
| External Nitrogen half sat constant | 100 | ugN/L | $k_{sPp}$ |
| External Phosphorus half sat constant | 40 | ugP/L | $k_{sNp}$ |
| Inorganic carbon half sat constant | 1.30E-05 | moles/L | $k_{sCp}$ |
| Light model | Half saturation | | |
| Light constant | 15 | langleys/d | $K_{Lp}$ |
| Ammonia preference | 25 | ugN/L | $k_{hnxp}$ |
| Subsistence quota for nitrogen | 0.72 | mgN/mgA | $q_{0Np}$ |
| Subsistence quota for phosphorus | 0.1 | mgP/mgA | $q_{0Pp}$ |
| Maximum uptake rate for nitrogen | 72 | mgN/mgA/d | $\square_{mNp}$ |
| Maximum uptake rate for phosphorus | 5 | mgP/mgA/d | $\square_{mPp}$ |
| Internal nitrogen half sat constant | 0.9 | mgN/mgA | $K_{qNp}$ |
| Internal phosphorus half sat constant | 0.13 | mgP/mgA | $K_{qPp}$ |
| Settling velocity | 0 | m/d | $v_a$ |
| ***Bottom Algae:*** | | | |
| Growth model | First-order | | |

| ***Parameter*** | | ***Units*** | ***Symbol*** |
|---|---|---|---|
| Max Growth rate | 0.63 | mgA/m$^2$/d or /d | $C_{gb}$ |
| Temp correction | 1.07 | | $\square_{gb}$ |
| First-order model carrying capacity | 1000 | mgA/m$^2$ | $a_{b,max}$ |
| Respiration rate | 0.02 | /d | $k_{rb}$ |
| Temp correction | 1.07 | | $\square_{rb}$ |
| Excretion rate | 0.09 | /d | $k_{eb}$ |
| Temp correction | 1.07 | | $\square_{db}$ |
| Death rate | 0.05 | /d | $k_{db}$ |
| Temp correction | 1.07 | | $\square_{db}$ |
| External nitrogen half sat constant | 100 | ugN/L | $k_{sPb}$ |
| External phosphorus half sat constant | 40 | ugP/L | $k_{sNb}$ |
| Inorganic carbon half sat constant | 1.30E-05 | moles/L | $k_{sCb}$ |
| Light model | Steele | | |
| Light constant | 190 | langleys/d | $K_{Lb}$ |
| Ammonia preference | 25 | ugN/L | $k_{hnxb}$ |
| Subsistence quota for nitrogen | 0.72 | mgN/mgA | $q_{0N}$ |
| Subsistence quota for phosphorus | 0.1 | mgP/mgA | $q_{0P}$ |
| Maximum uptake rate for nitrogen | 72 | mgN/mgA/d | $\square_{mN}$ |
| Maximum uptake rate for phosphorus | 5 | mgP/mgA/d | $\square_{mP}$ |
| Internal nitrogen half sat constant | 0.9 | mgN/mgA | $K_{qN}$ |
| Internal phosphorus half sat constant | 0.13 | mgP/mgA | $K_{qP}$ |
| ***Detritus (POM):*** | | | |
| Dissolution rate | 0.2 | /d | $k_{dt}$ |
| Temp correction | 1.07 | | $\square_{dt}$ |
| Fraction of dissolution to fast CBOD | 0.50 | | $F_f$ |
| Settling velocity | 0.2 | m/d | $v_{dt}$ |
| ***Pathogens:*** | | | |
| Decay rate | 0.8 | /d | $k_{dx}$ |
| Temp correction | 1.07 | | $k_{dx}$ |
| Settling velocity | 1 | m/d | $\square_{dx}$ |
| Light efficiency factor | 1.00 | | $v_x$ |
| ***pH:*** | | | |
| Partial pressure of carbon dioxide | 347 | ppm | $\square_{path}$ |

## B.4 Model Validation

Typically, the performance of a calibrated model is evaluated through "validation." Model validation is defined as "subsequent testing of a pre-calibrated model to additional field data, usually under different external conditions, to further examine the model's ability to predict future conditions" (EPA, 1997). Its purpose is to ensure that the calibrated model properly assesses all the variables and conditions that can affect model results and demonstrate the ability to predict field observations for periods separate from the calibration effort (Donigian, 2003).

Validation of the Piper Creek model was conducted using the data collected from August 19 - 20, 2009. System rates and coefficients were initially set equal to the values selected in the calibration runs. Comparison of the validation results with measured data provided insight into how the system functioned and provided ideas for how to improve the calibration. Based on this comparison minor adjustments were made to nutrient rates (oxidation, hydrolysis, sorption and settling rates) and bottom algae (growth and respiration rates) in the calibration period models. The adjustments that resulted in improvements during the calibration periods were incorporated into the validation runs. All three models contain the same system rates and coefficients.

Headwater and tributary flows were set equal to the average of morning and afternoon flow measurements on each respective day. Similarly, model inputs for headwater and tributary nutrients, DO, CBOD and pH were also based on average field measurements or calculated based on field measurements (in the case of organic nitrogen, organic phosphorus and inorganic phosphorus) on each respective day. Initial model inputs for air temperature, dew point temperature, wind speed, cloud cover and shade were based on monitoring data. The sediment diagenesis routine was used to estimate SOD. Percent reach with SOD coverage was estimated from sediment characterization data collected during sampling. SOD coverage was set at the percent of stream bottom with sand, silt or clay (Table B-10). The validation results are presented in Figures B-12 to B-20.

**Table B-10. Percent Bottom SOD Coverage**

| ***Reach Number*** | ***Bottom SOD Coverage*** |
|---|---|
| 1 | 6.00% |
| 2 | 6.00% |
| 3 | 2.00% |
| 4 | 10.00% |
| 5 | 10.00% |

**Figure B-12. Validation of observed and simulated flow (Q), velocity (U) and depth (H) in Piper Creek**

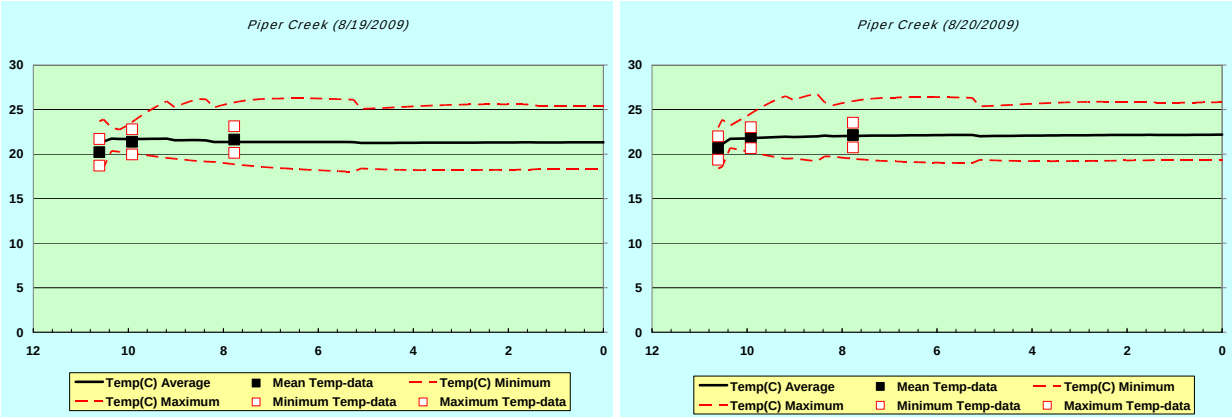


**Figure B-13. Temperature validation in Piper Creek**

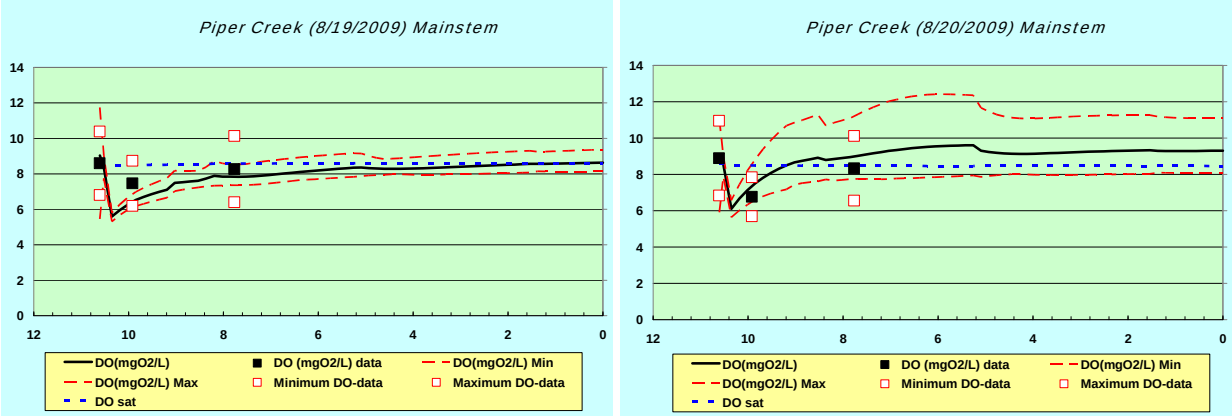


**Figure B-14. DO validation in Piper Creek**

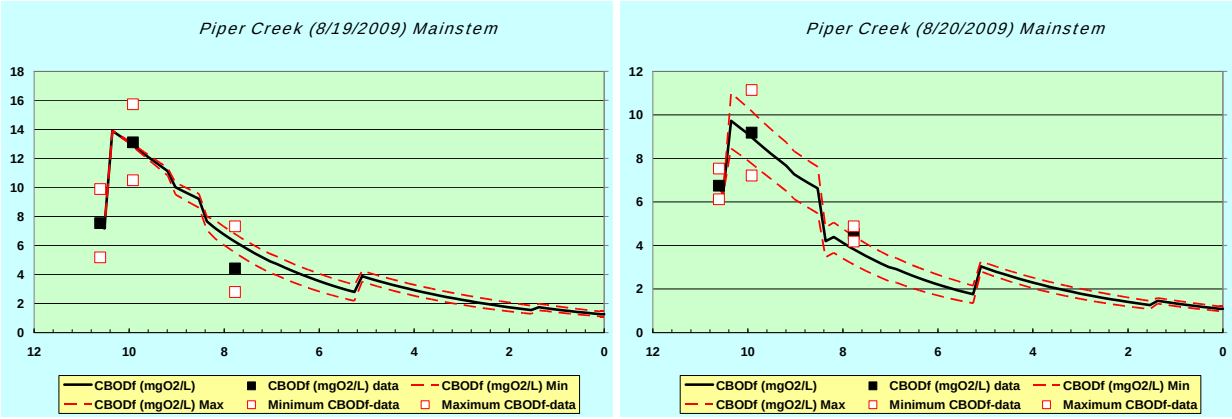


**Figure B-15. CBOD validation in Piper Creek**

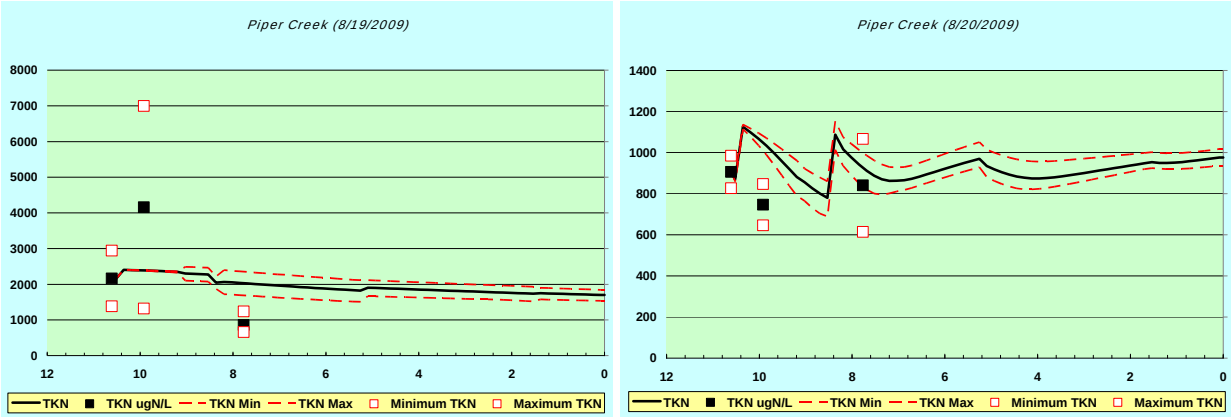


**Figure B-16. TKN validation in Piper Creek**

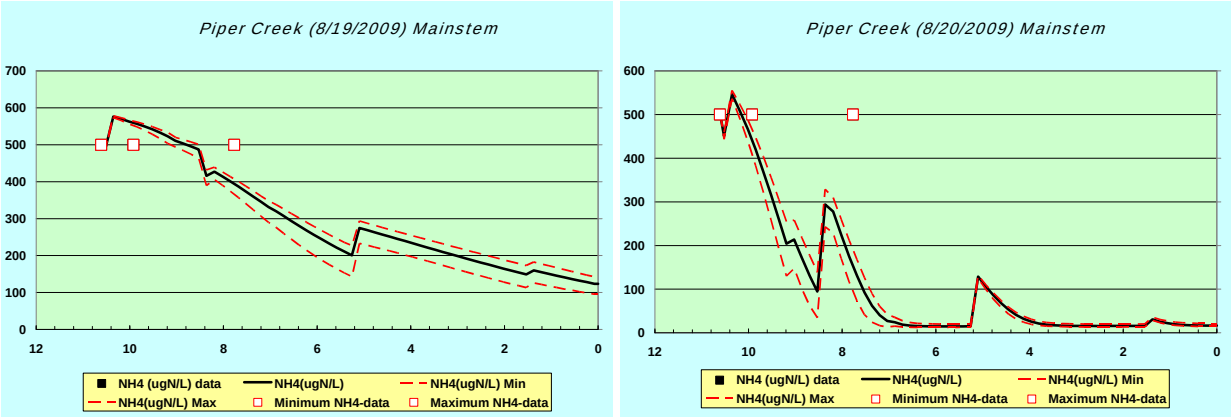


**Figure B-17. Ammonium validation in Piper Creek (all measured ammonia was below the detection limit of 500 µg/L)**

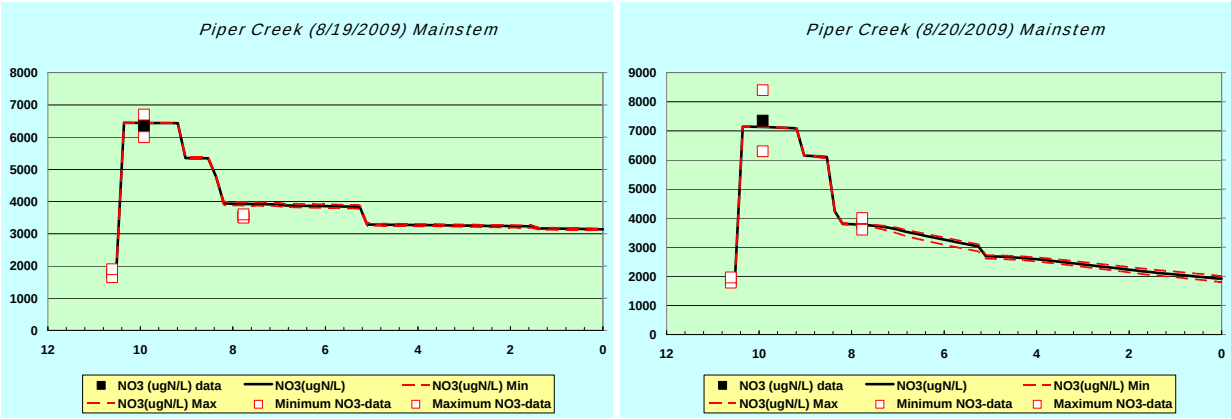


**Figure B-18. Nitrate validation in Piper Creek**

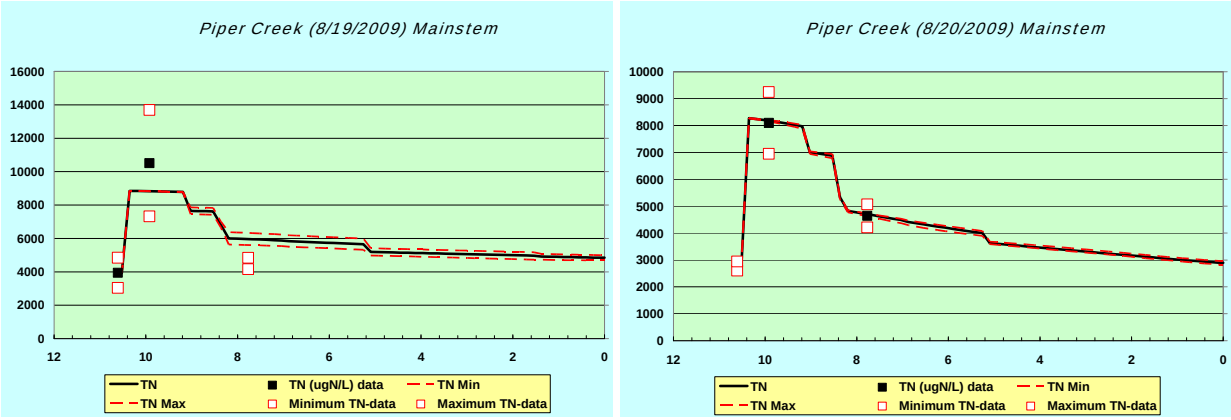


**Figure B-19. Total nitrogen validation in Piper Creek**

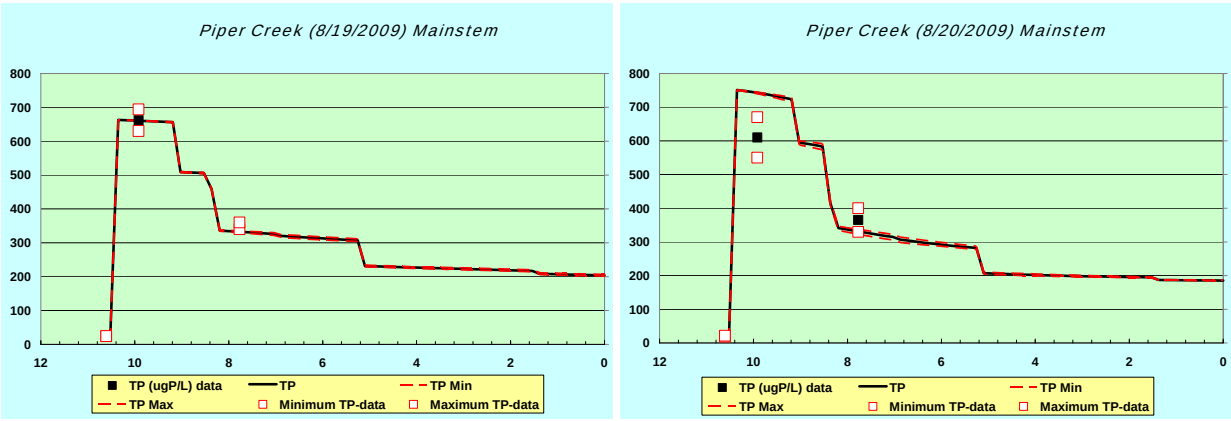


**Figure B-20. Total phosphorus validation in Piper Creek**

## B.5 Model Goodness of Fit Discussion

The calibration and validation periods were assessed visually and statistically. The figures presented above demonstrate that the model follows the same patterns and trends and the measured data and the statistics quantify the differences between the simulated and measured data. The statistics used to evaluate the model are listed in Table B-9 and the statistical comparison between the model results and observed data are included in Table B-10.

The statistics demonstrate that the model results in prediction similar to those measured in the field. Specifically, the following statistics demonstrate a good model fit:

- The RMSE for average DO is near 0.5 mg/L and near 1 mg/L for minimum DO.
- Coefficient of determination ($r^2$) is high for all parameters and suggests a high degree of correlation between the simulated model results and observed water quality data.
- The percent Bias is generally low for all parameters, and for parameters of importance such as DO it is less than 5 percent.

- The bias for minimum DO is negative; thus the calibration and validation are conservative.

The model calibration and validation runs use the same kinetic parameters to achieve a good comparison with measured data. This is supported with a visual and statistical comparison. Based on this comparison the QUAL2K model for Piper Creek is suitable for assessing DO problems and for TMDL development.

**Table B-11. Quantitative Calibration Metrics.**

| Calibration Metric | Equation |
|---|---|
| Root Mean Squared Error (RMSE) | $\sqrt{\frac{\sum(\mathrm{Pr}edicted - Observed)^2}{n-1}}$ |
| Coefficient of determination | $1 - \frac{\sum(Squared\ Errors)}{\sum(Total\ Sum\ of\ Squares)}$ |
| Percent Bias (pBias) | $\frac{\sum(\mathrm{Pr}edicted - Observed)}{\sum Observed} * 100$ |
| Average Error | $\sum_{i=1}^{n} \frac{\lvert Simulated\ Value - Observed\ Value \rvert}{n_{\text{obs}}}$ |
| Residual Error | $\sum_{i=1}^{n} \frac{(Simulated\ Value - Observed\ Value)}{n_{\text{obs}}}$ |
| Relative Error | $\frac{\sum \lvert Simulated\ Value - Observed\ Value \rvert}{\sum Observed} * 100$ |

**Table B-12. Summary statistics for calibration and validation runs**

| Statistic | Model Period | Flow | DO | Min DO | Max DO | TN | TKN | $NO_3$ | TP |
|---|---|---|---|---|---|---|---|---|---|
| **Root Mean Squared Error (RMSE) (mg/L)** | Calibration | 0.02 | 0.66 | 1.63 | 1.80 | 290 | 261 | 84 | 96 |
| | Validation | 0.006 | 0.68 | 2.08 | 2.36 | 1,027 | 959 | 207 | 62 |
| | Entire Period | 0.01 | 0.64 | 1.78 | 2.01 | 720 | 670 | 151 | 77 |
| **Coefficient of determination** | Calibration | 1.00 | 0.92 | 0.81 | 0.77 | 0.93 | 0.05 | 1.00 | 0.98 |
| | Validation | 0.99 | 0.56 | 0.02 | 0.47 | 0.90 | 0.56 | 0.99 | 0.97 |
| | Entire Period | 1.00 | 0.63 | 0.16 | 0.51 | 0.93 | 0.62 | 0.99 | 0.98 |
| **Percent Bias (pBias) (%)** | Calibration | -4.1 | 4.9 | 16.79 | -13.4 | -1.3 | 0.2 | -1.7 | -1.4 |
| | Validation | -1.4 | -0.9 | 18.79 | -20.9 | 0.1 | 2.6 | -0.9 | -3.6 |
| | Entire Period | -3.2 | 2.1 | 17.75 | -17.0 | -0.4 | 1.9 | -1.2 | -2.1 |
| **Average Error (mg/L)** | Calibration | 0.01 | 0.47 | 1.46 | 1.34 | 212 | 210 | 68 | 70 |
| | Validation | 0.003 | 0.55 | 1.51 | 1.85 | 558 | 550 | 124 | 32 |
| | Entire Period | 0.006 | 0.51 | 1.49 | 1.59 | 385 | 380 | 96 | 51 |
| **Residual Error (mg/L)** | Calibration | 0.008 | -0.43 | -1.46 | 1.16 | 36 | -1 | 37 | 9 |
| | Validation | 0.001 | 0.07 | -1.51 | 1.69 | -4 | -42 | 38 | 12 |
| | Entire Period | 0.005 | -0.18 | -1.49 | 1.42 | 16 | -22 | 38 | 11 |
| **Relative Error (%)** | Calibration | 4.3 | 5.5 | 16.79 | 15.4 | 7.5 | 30.7 | 3.2 | 10.3 |
| | Validation | 3.3 | 6.8 | 18.79 | 22.9 | 9.7 | 34.1 | 3.0 | 9.4 |
| | Entire Period | 4.0 | 6.1 | 17.75 | 19.0 | 9.0 | 33.1 | 3.1 | 10.0 |

**References – Appendix B**

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# Appendix C - Development of TSS Targets Using Reference LDCs

## Overview

This procedure is used when a lotic system is placed on the 303(d) list for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the EDU in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record, calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. Selection of these gages is based on location, land use/soil/topography similarities to the Piper Creek watershed and the availability of flow data of sufficient age and duration. From this synthetic record develop a flow duration from which to build a LDC for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL LDC. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the LDC uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This results in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

## Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more).

Figure B-1 shows the application of the approach in the Piper Creek EDU (Ozark/Osage EDU). Watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set of all the gages (Figure C-1, Table C-1). Table C-1 demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

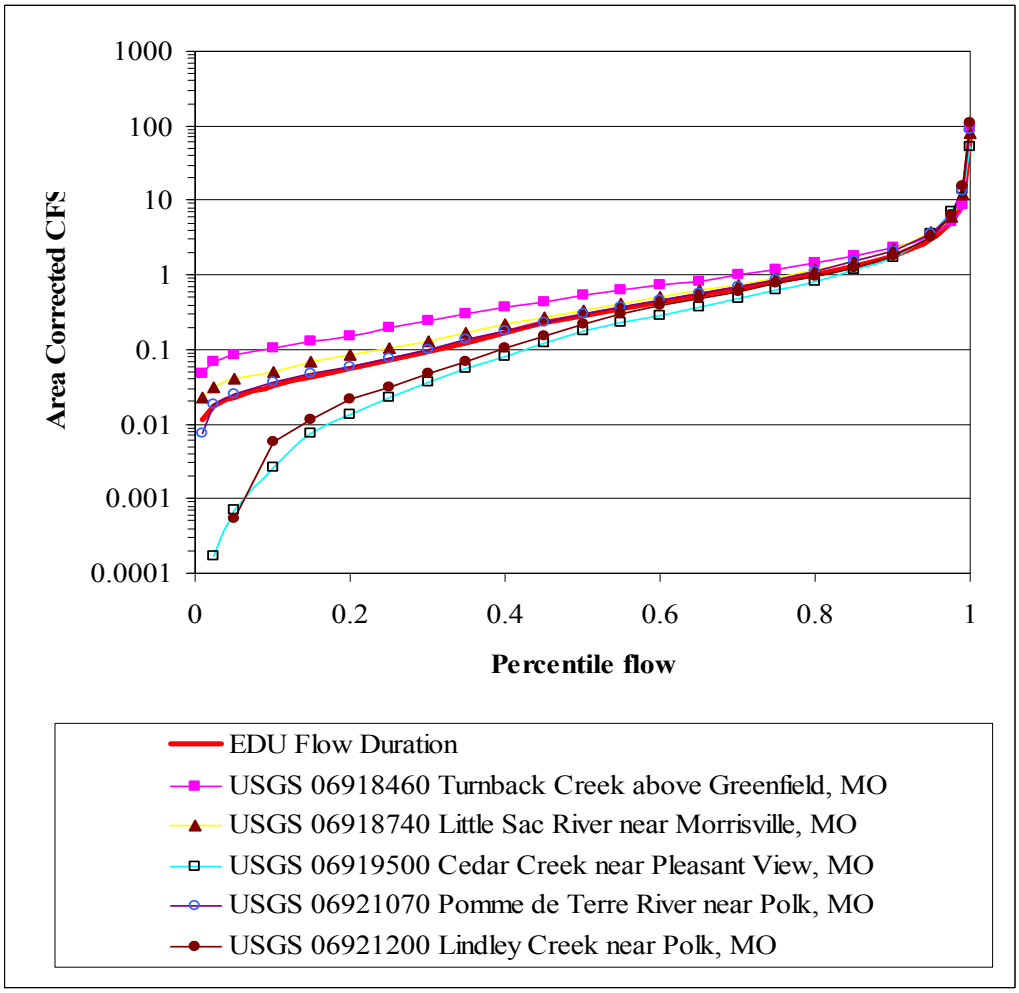


**Figure C-1. Synthetic Flow Development in the Ozark/Osage EDU**

**Table C-1. Stream Flow Stations Used to Estimate Flows in Piper Creek**

| River/Station Name | Data Source | Station Number | Drainage Area ($mi^2$) | Lognormal Nash-Sutcliffe |
|---|---|---|---|---|
| Turnback Creek above Greenfield, MO | USGS | 06918460 | 252 | 97% |
| Little Sac River near Morrisville, MO | USGS | 06918740 | 237 | 100% |
| Cedar Creek near Pleasant View, MO | USGS | 06919500 | 420 | 76% |
| Pomme de Terre River near Polk, MO | USGS | 06921070 | 276 | 98% |
| Lindley Creek near Polk, MO | USGS | 06921200 | 112 | 92% |

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi$^2$/day) and the instantaneous flow (cfs/mi$^2$). Figure C-2 shows the EDU relationship. Further statistical analyses on this relationship are included in Table C-2.

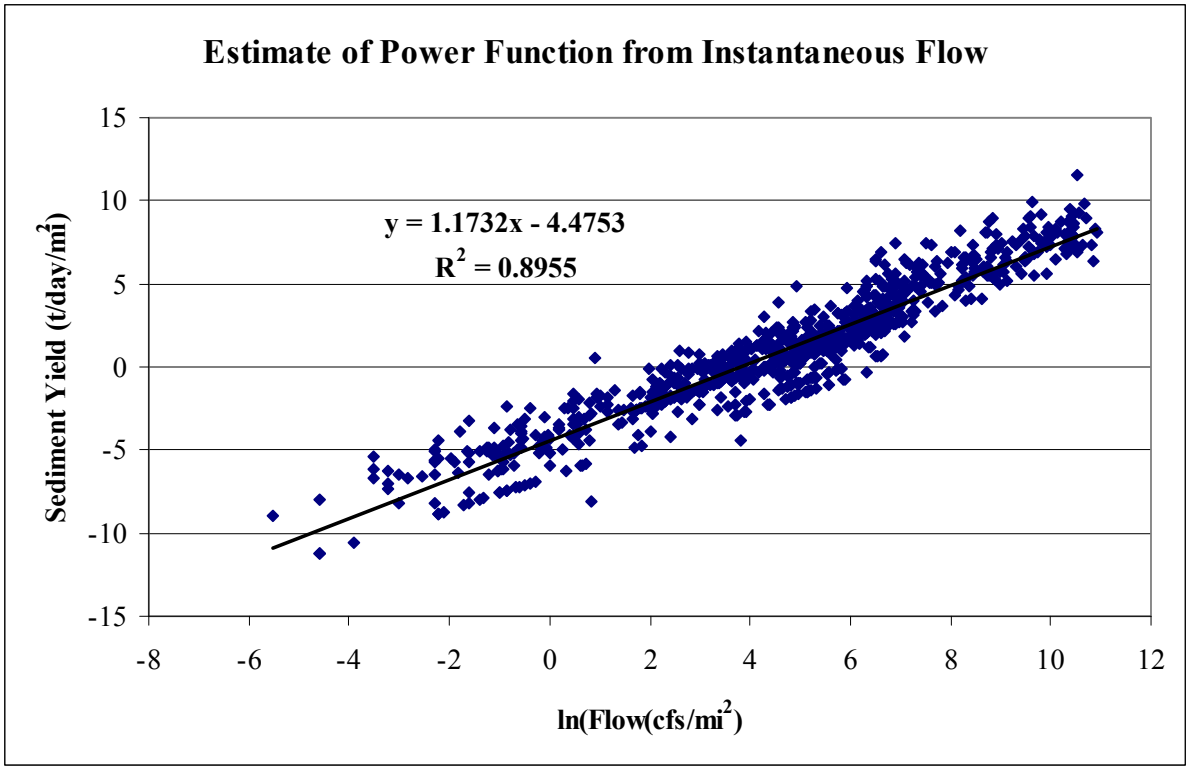


**Figure C-2. Estimate of Power Function from Instantaneous Flow in the Ozark/ Osage EDU**

**Table C-2. Ozark/Osage EDU Flow and Sediment Statistics**

| | | | |
|---|---|---|---|
| m | 1.17321391 | b | -4.475326095 |
| Standard Error (m) | 0.01363522 | Standard Error (b) | 0.076406671 |
| r2 | 0.89549291 | Standard Error (y) | 1.277485554 |
| F | 7403.38182 | DF | 864 |
| SSreg | 12082.0921 | SSres | 1410.02151 |

The standard error of y was used to estimate the 25th percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided $Z_{75}$ statistic times the standard error of (y). The resulting TMDL equation is the following:

**Sediment yield (t/day/mi$^2$) = exp (1.17321391 * ln (flow) -4.475326095)**

A resulting pooled TMDL of all data in the watershed is shown in the following graph:

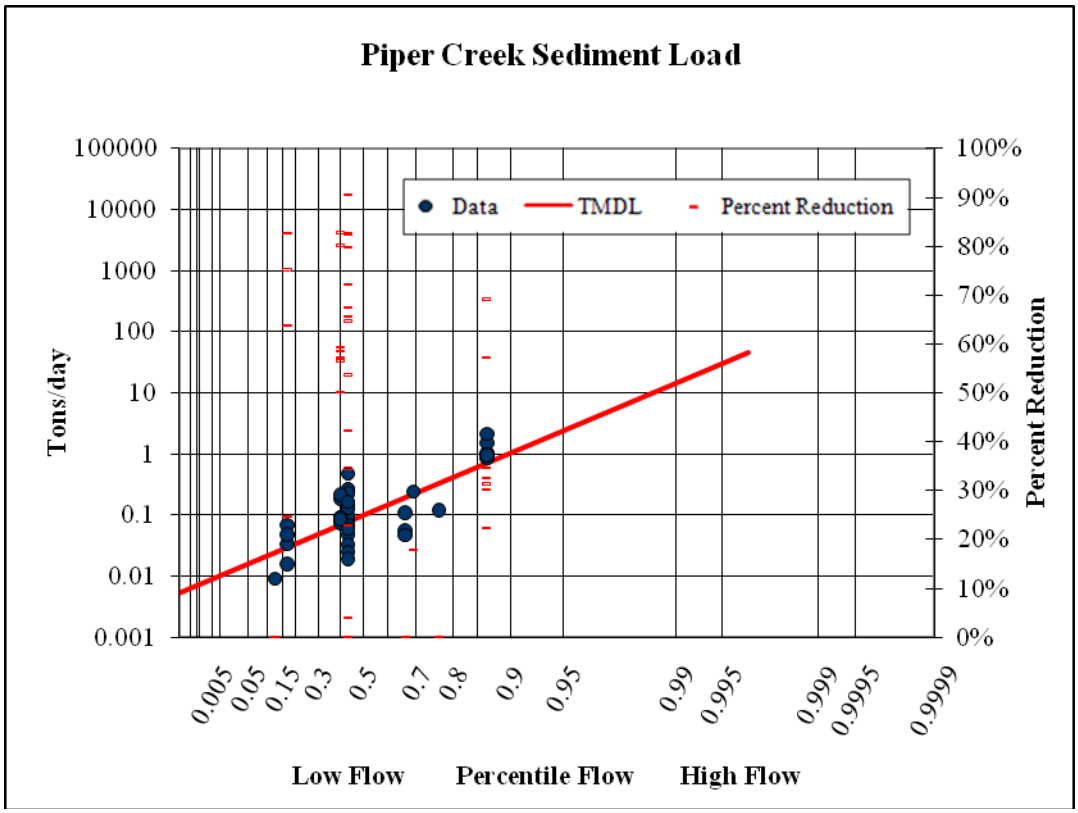


**Figure C-3. TMDL LDC for TSS**

To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.

For Piper Creek the 25th percentile TSS concentration target is 8.8 mg/L. The TMDL, LA and WLA were calculated based on this concentration and the current limits for permitted facilities in the watershed.

For more information contact:

Environmental Protection Agency, Region 7
Water, Wetlands and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, Kansas 66101
Website: http://www.epa.gov/region07/water/tmdl.htm

# Appendix D - Development of Nutrient Targets Using Ecoregion Nutrient Criteria with LDCs

## Overview

This procedure is used when a lotic system is placed on the 303(d) impaired water body list for nutrient pollutants and the designated use being addressed is aquatic life. In cases where EPA-approved state numeric criteria for the impaired stream is not available a reference approach is used. The target for pollutant loading is the EPA recommended ecoregion nutrient criterion for the specific ecoregion in which the water body is located (EPA, 2000). If a flow record for the impaired stream is not available a synthetic flow record is needed. To develop a synthetic flow record a user should calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is contained within the EDU. Selection of these gages is based on location, land use/soil/topography similarities to the Piper Creek watershed and the availability of flow data of sufficient age and duration. From this synthetic record develop a flow duration and build a LDC for the pollutant within the EDU.

See EPA (2000) for more detailed information as to how recommended ecoregion nutrient criteria were developed. This appendix describes how the nutrient criteria (TN and TP) are expressed in this TMDL.

## Methodology

The first step in this procedure is to gather available nutrient data within the ecoregion of interest. These data, along with the instantaneous flow measurement taken at the time of sample collection for the specific date, are required to develop the LDC. Both dates and nutrient concentrations are needed in order to match the measured data used with the synthetic EDU flow record.

Secondly, collect average daily flow data from gages with a variety of drainage areas for a period of time to cover the nutrient record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build the synthetic flow record calculate the Nash-Sutcliffe value to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is then used to develop the LDC for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more).

The following example shows the application of the approach for the Ozark/Osage EDU. Watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set of all the gages (Figure D-1, Table D-1). Table D-1 demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

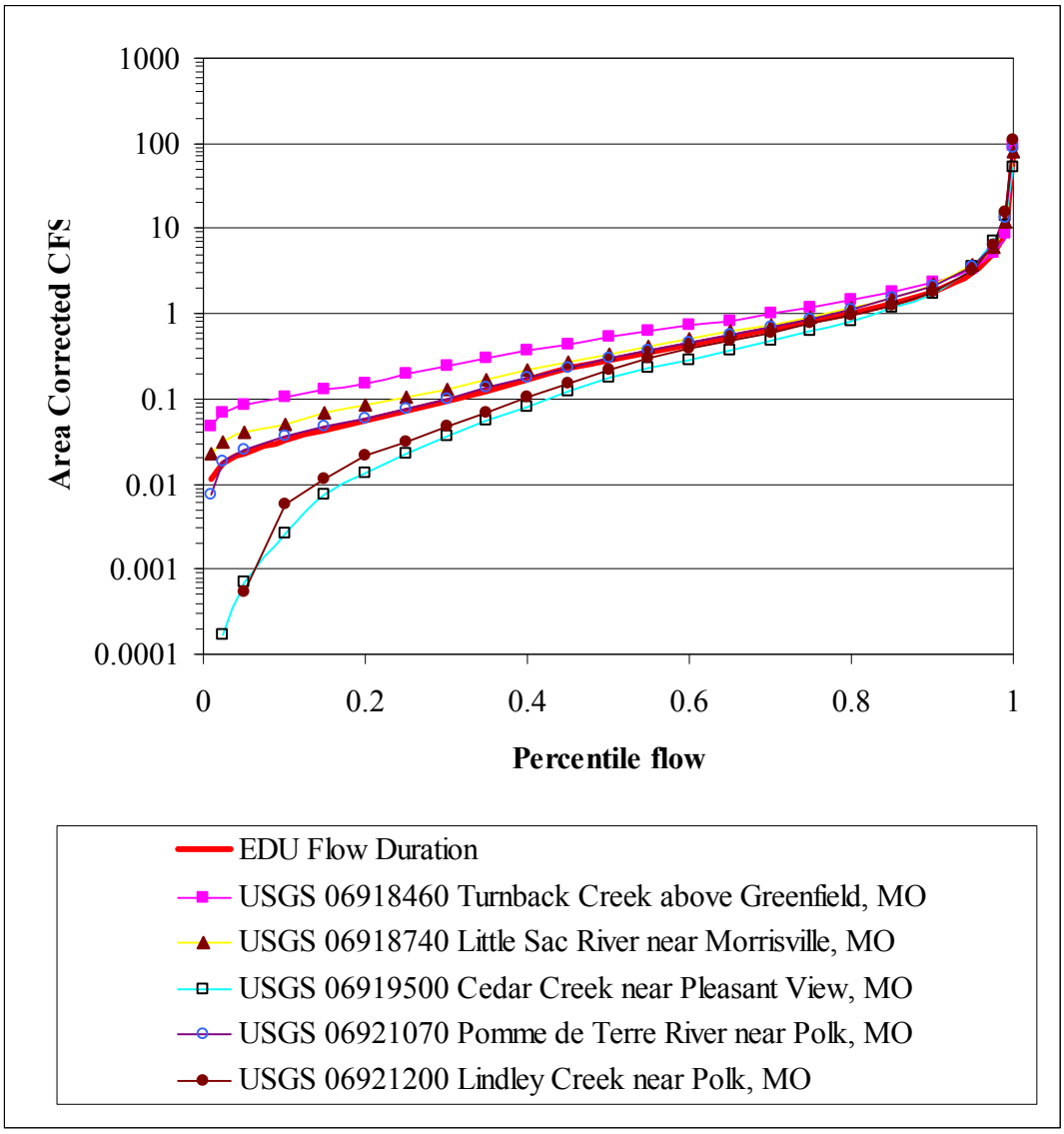


**Figure D-1. Synthetic Flow Development in the Ozark/Osage EDU**

**Table D-1. Stream Flow Stations Used to Estimate Flows in Piper Creek**

| River/Station Name | Data Source | Station Number | Drainage Area ($mi^2$) | Lognormal Nash-Sutcliffe |
|---|---|---|---|---|
| Turnback Creek above Greenfield, MO | USGS | 06918460 | 252 | 97% |
| Little Sac River near Morrisville, MO | USGS | 06918740 | 237 | 100% |
| Cedar Creek near Pleasant View, MO | USGS | 06919500 | 420 | 76% |
| Pomme de Terre River near Polk, MO | USGS | 06921070 | 276 | 98% |
| Lindley Creek near Polk, MO | USGS | 06921200 | 112 | 92% |

The next step was to collect previously measured water quality data from within the ecoregion. Measured TN concentrations are adjusted so their median is equal to the EPA recommended ecoregion TN criterion. This is accomplished by subtracting the difference between the EPA recommended ecoregion TN criterion and the median from the measured data. This results in the data retaining most of its natural variability yet having a median which meets the EPA recommended ecoregion TN criterion. Where this adjustment would result in a negative concentration the minimum measured concentration is substituted. Figure D-2 shows an example of this process where the solid line is the measured distribution of the natural log TN concentration with the natural log flow, and the dashed line represents a data distribution (the adjusted data) which would comply with the EPA recommended ecoregion TN criterion.

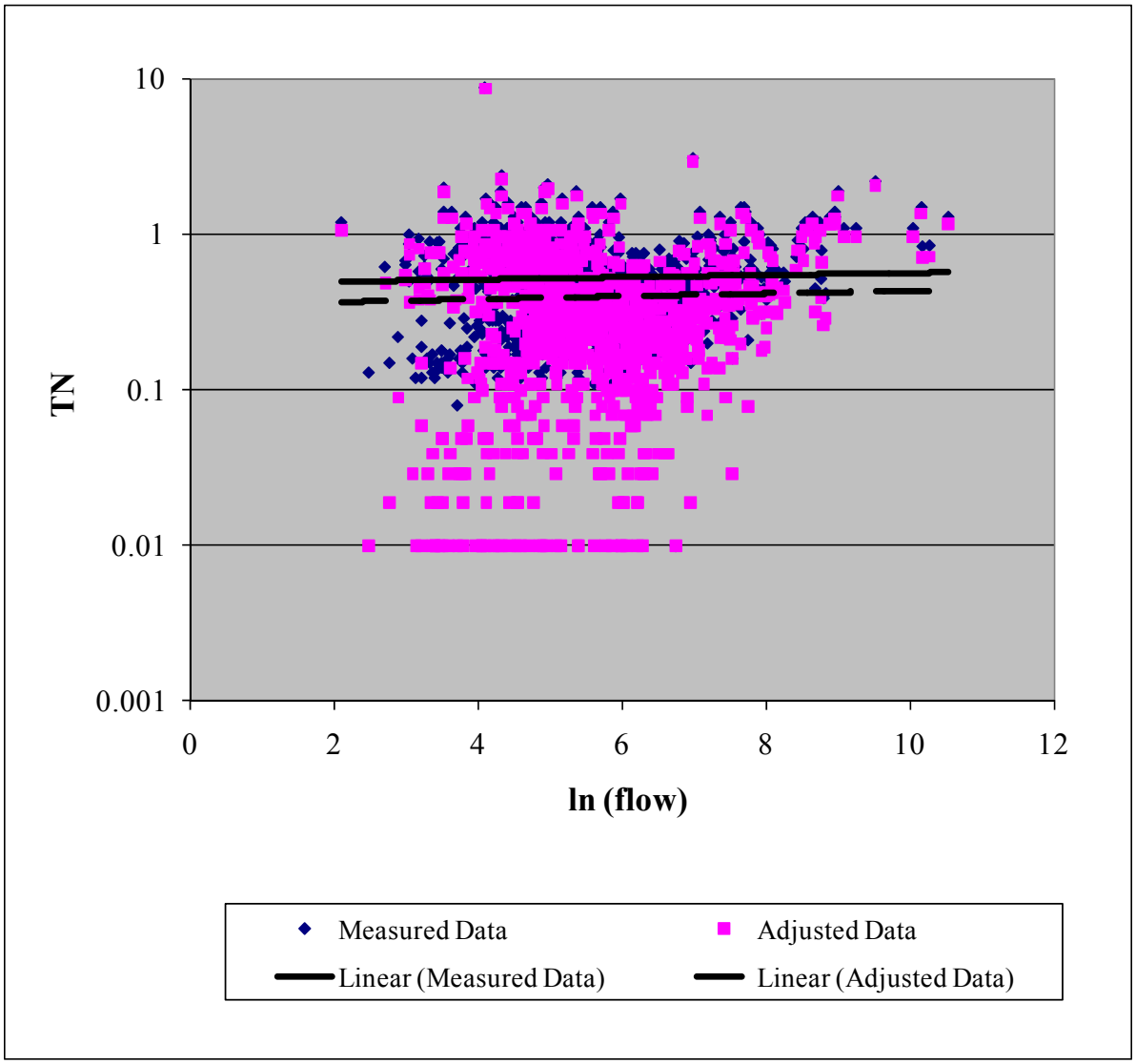


**Figure D-2. Graphic Representation of Data Adjustment in Ozark/Osage EDU**

The next step was to calculate the TN-discharge relationship for the ecoregion using the adjusted data, this is natural log transformed data for the yield (pounds/mi$^2$/day) and the instantaneous flow (cfs/mi$^2$). Figure D-3 shows this relationship for this TMDL.

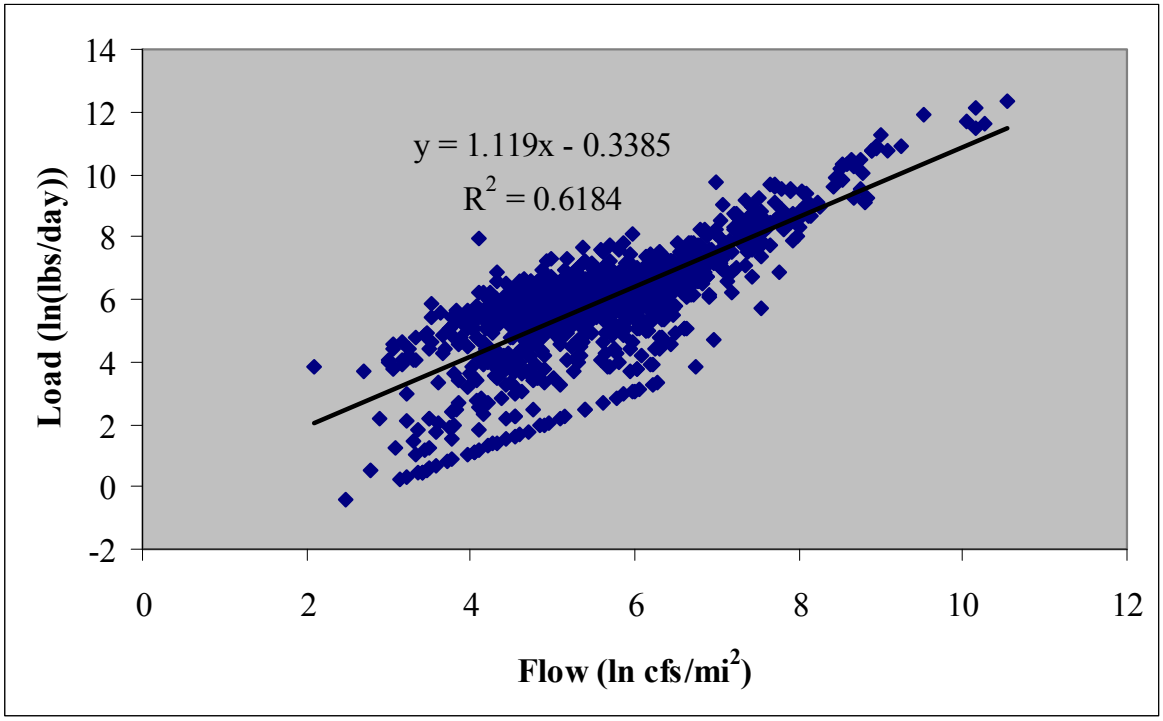


**Figure D-3. Load / Flow Relationship Used to Set LDC TMDL**

This relationship was used to develop a LDC for which the relationship between flow and nutrient distribution is taken into account. In this LDC the targeted concentration is allowed to change at different percentiles of flow exceedance. However, meeting the LDC will result in a water body in which the median concentration is equal to the EPA recommended ecoregion criterion.

To apply this process to a specific watershed entails using the individual watershed data compared to the TMDL curve that has been multiplied by the watershed area (mi$^2$). Data from the impaired segment is then plotted as a load (pounds/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis. These data points do not have to be collected at the segment outlet. The spreadsheet applies an outlet flow (percentile exceedance) to the concentration based on the synthetic flow estimate for the specific date the sample was taken (Figure D-4).

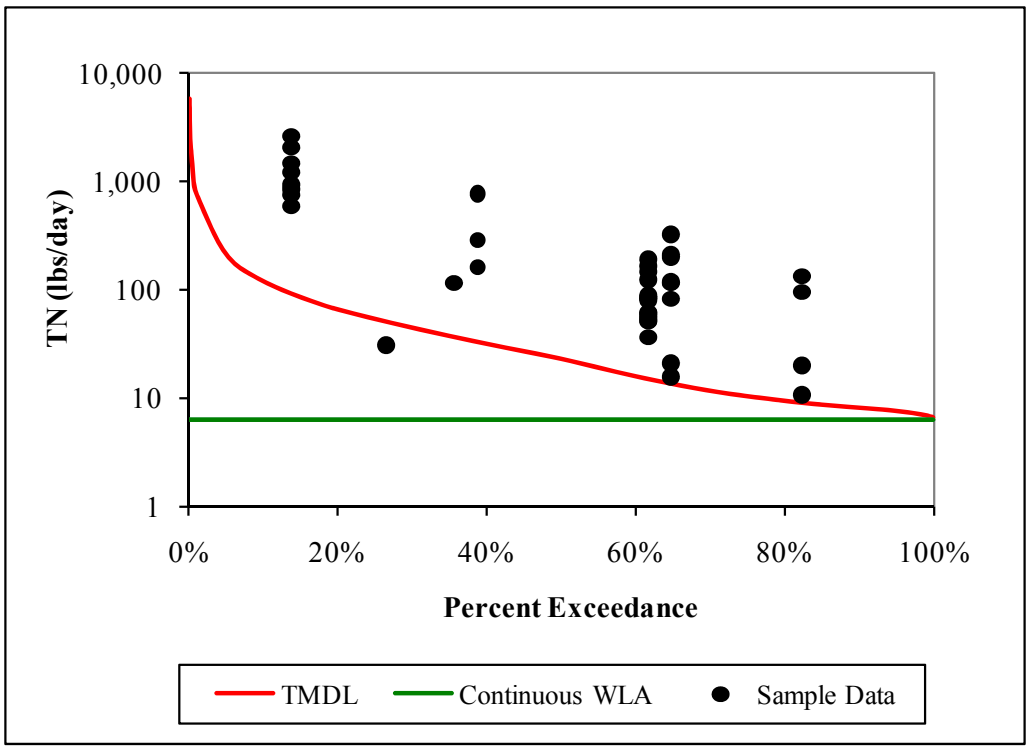


**Figure D-4. Example of TMDL LDC Using This Method**

The resulting LDC with plotted site specific measured data can now be used to target implementation by identifying flows in which TN concentrations are higher than would be expected in a stream meeting the EPA recommended ecoregion TN criterion.

For more information contact:

Environmental Protection Agency, Region 7
Water, Wetlands and Pesticides Division
Total Maximum Daily Load Program
901 North 5th Street
Kansas City, Kansas 66101
Website: http://www.epa.gov/region07/water/tmdl.htm

# Appendix E - Stream Flow and Water Quality Stations Used to Develop TMDLs in the Piper Creek Watershed

**Table E-1. Stations Used to Develop Water Quality Data Targets in Piper Creek**

| USGS Station | Station Name |
|---|---|
| 7010500 | Maramec Spring near St. James, MO |
| 7014000 | Huzzah Creek near Steelville, MO |
| 7014200 | Courtois Creek at Berryman, MO |
| 7014500 | Meramec River near Sullivan, MO |
| 7064400 | Montauk Springs at Montauk, MO |
| 7064440 | Current River at Montauk State Park, MO |
| 7064530 | Welch Spring near Akers, MO |
| 7064555 | Pulltite Spring near Round Spring, MO |
| 7065000 | Round Spring at Round Spring, MO |
| 7065500 | Alley Spring at Alley, MO |
| 7066000 | Jacks Fork at Eminence, MO |
| 7066110 | Jacks Fork above Two River, MO |
| 7066510 | Current River above Powder Mill, MO |
| 7066550 | Blue Spring near Eminence, MO |
| 370857091265901 | Jacks Fork River above Alley Spring, MO |
| 370901091262001 | Alley Spring Below Alley, MO |
| 370905091204001 | Jacks Fork above 2nd Unnamed Hollow below Eminence, MO |
| 371014091201301 | Jacks Fork above Lick Log Hollow below Eminence, MO |
| 371026091183301 | Jacks Fork above Powell Springs above Two Rivers, MO |
| 371054091173501 | Jacks Fork below 3rd Hollow above Two Rivers, MO |

**Table E-2. Water Quality Data Used in TMDL Development**

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370901091262001 | 5/10/1999 | 0.8 | 208 |
| 370901091262001 | 6/22/1999 | 0.85 | 136 |
| 370901091262001 | 11/8/1999 | 0.71 | 89 |
| 370901091262001 | 2/29/2000 | 0.83 | 173 |
| 370901091262001 | 6/6/2000 | 0.64 | 75 |
| 370901091262001 | 6/28/2000 | 0.62 | 99 |
| 370901091262001 | 8/22/2000 | 0.62 | 73 |
| 370901091262001 | 2/22/2001 | 0.85 | 208 |
| 370901091262001 | 3/21/2001 | 0.95 | 123 |
| 370901091262001 | 5/25/2001 | 0.65 | 75 |
| 370901091262001 | 5/27/2001 | 0.65 | 80 |
| 370901091262001 | 8/9/2001 | 0.6 | 69 |
| 370901091262001 | 10/11/2001 | 0.98 | 66 |
| 370901091262001 | 4/2/2002 | 0.76 | 200 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370901091262001 | 5/10/1999 | 0.026 | 208 |
| 370901091262001 | 6/22/1999 | 0.008 | 136 |
| 370901091262001 | 8/10/1999 | 0.015 | 128 |
| 370901091262001 | 11/8/1999 | 0.01 | 89 |
| 370901091262001 | 12/14/1999 | 0.009 | 94 |
| 370901091262001 | 1/18/2000 | 0.009 | 85 |
| 370901091262001 | 2/29/2000 | 0.011 | 173 |
| 370901091262001 | 4/4/2000 | 0.006 | 87 |
| 370901091262001 | 5/10/2000 | 0.006 | 77 |
| 370901091262001 | 5/23/2000 | 0.009 | 80 |
| 370901091262001 | 5/25/2000 | 0.01 | 85 |
| 370901091262001 | 6/6/2000 | 0.011 | 75 |
| 370901091262001 | 6/28/2000 | 0.008 | 99 |
| 370901091262001 | 7/10/2000 | 0.009 | 82 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370901091262001 | 4/30/2002 | 0.59 | 250 |
| 370901091262001 | 5/29/2002 | 0.7 | 293 |
| 370901091262001 | 6/28/2002 | 0.77 | 145 |
| 370901091262001 | 6/29/2002 | 0.79 | 142 |
| 370901091262001 | 10/8/2002 | 1.1 | 89 |
| 370901091262001 | 10/9/2002 | 0.74 | 89 |
| 370901091262001 | 6/2/2003 | 0.71 | 113 |
| 370901091262001 | 6/9/2003 | 0.81 | 117 |
| 370901091262001 | 9/23/2003 | 0.71 | 87 |
| 370901091262001 | 7/13/2004 | 0.31 | 108 |
| 370901091262001 | 9/21/2004 | 0.72 | 88 |
| 6930800 | 2/1/1999 | 0.89 | 3060 |
| 6930800 | 3/16/1999 | 0.92 | 4780 |
| 6930800 | 4/12/1999 | 0.45 | 2900 |
| 6930800 | 5/26/1999 | 0.35 | 1700 |
| 6930800 | 6/24/1999 | 0.42 | 921 |
| 6930800 | 7/12/1999 | 0.44 | 826 |
| 6930800 | 8/12/1999 | 0.32 | 642 |
| 6930800 | 9/2/1999 | 0.27 | 482 |
| 6930800 | 10/5/1999 | 0.47 | 492 |
| 6930800 | 11/16/1999 | 0.25 | 516 |
| 6930800 | 12/8/1999 | 0.36 | 879 |
| 6930800 | 1/13/2000 | 0.6 | 722 |
| 6930800 | 2/9/2000 | 0.31 | 560 |
| 6930800 | 3/13/2000 | 0.49 | 1010 |
| 6930800 | 4/4/2000 | 0.32 | 935 |
| 6930800 | 5/16/2000 | 0.3 | 504 |
| 6930800 | 6/13/2000 | 0.44 | 481 |
| 6930800 | 7/5/2000 | 0.48 | 493 |
| 6930800 | 8/1/2000 | 0.36 | 541 |
| 6930800 | 9/5/2000 | 0.23 | 350 |
| 6930800 | 10/24/2000 | 0.2 | 463 |
| 6930800 | 11/21/2000 | 0.1 | 535 |
| 6930800 | 12/6/2000 | 0.24 | 523 |
| 6930800 | 1/9/2001 | 0.35 | 475 |
| 6930800 | 2/15/2001 | 1.3 | 1570 |
| 6930800 | 3/28/2001 | 0.91 | 894 |
| 6930800 | 4/9/2001 | 0.62 | 1400 |
| 6930800 | 5/3/2001 | 0.32 | 681 |
| 6930800 | 6/13/2001 | 0.43 | 1150 |
| 6930800 | 7/18/2001 | 0.36 | 547 |
| 6930800 | 8/14/2001 | 0.32 | 429 |
| 6930800 | 9/6/2001 | 0.25 | 381 |
| 6930800 | 10/22/2001 | 0.21 | 504 |
| 6930800 | 11/19/2001 | 0.19 | 469 |
| 6930800 | 12/4/2001 | 0.71 | 1820 |
| 6930800 | 1/28/2002 | 0.8 | 1630 |
| 6930800 | 2/13/2002 | 1.5 | 2100 |
| 6930800 | 3/26/2002 | 1.1 | 8780 |
| 6930800 | 4/9/2002 | 0.54 | 2100 |
| 6930800 | 5/20/2002 | 0.84 | 26100 |
| 6930800 | 6/11/2002 | 0.37 | 1670 |
| 6930800 | 7/16/2002 | 0.27 | 729 |
| 6930800 | 8/12/2002 | 0.29 | 547 |
| 6930800 | 9/3/2002 | 0.26 | 598 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370901091262001 | 7/28/2000 | 0.009 | 76 |
| 370901091262001 | 8/11/2000 | 0.009 | 73 |
| 370901091262001 | 8/22/2000 | 0.007 | 73 |
| 370901091262001 | 9/20/2000 | 0.012 | 74 |
| 370901091262001 | 10/4/2000 | 0.009 | 66 |
| 370901091262001 | 11/9/2000 | 0.009 | 79 |
| 370901091262001 | 12/20/2000 | 0.009 | 73 |
| 370901091262001 | 1/24/2001 | 0.01 | 79 |
| 370901091262001 | 2/22/2001 | 0.012 | 208 |
| 370901091262001 | 3/21/2001 | 0.011 | 123 |
| 370901091262001 | 4/25/2001 | 0.011 | 88 |
| 370901091262001 | 5/25/2001 | 0.009 | 75 |
| 370901091262001 | 5/26/2001 | 0.008 | 80 |
| 370901091262001 | 5/26/2001 | 0.01 | 80 |
| 370901091262001 | 5/27/2001 | 0.01 | 80 |
| 370901091262001 | 5/27/2001 | 0.01 | 80 |
| 370901091262001 | 6/7/2001 | 0.01 | 74 |
| 370901091262001 | 8/1/2001 | 0.009 | 64 |
| 370901091262001 | 8/8/2001 | 0.008 | 69 |
| 370901091262001 | 8/8/2001 | 0.009 | 69 |
| 370901091262001 | 8/9/2001 | 0.006 | 69 |
| 370901091262001 | 8/9/2001 | 0.01 | 69 |
| 370901091262001 | 9/18/2001 | 0.009 | 68 |
| 370901091262001 | 10/2/2001 | 0.009 | 66 |
| 370901091262001 | 10/10/2001 | 0.008 | 66 |
| 370901091262001 | 10/10/2001 | 0.009 | 66 |
| 370901091262001 | 10/11/2001 | 0.009 | 66 |
| 370901091262001 | 10/11/2001 | 0.01 | 66 |
| 370901091262001 | 11/20/2001 | 0.002 | 62 |
| 370901091262001 | 4/2/2002 | 0.015 | 200 |
| 370901091262001 | 4/30/2002 | 0.013 | 250 |
| 370901091262001 | 5/29/2002 | 0.021 | 293 |
| 370901091262001 | 6/4/2002 | 0.019 | 226 |
| 370901091262001 | 6/28/2002 | 0.012 | 145 |
| 370901091262001 | 6/29/2002 | 0.012 | 142 |
| 370901091262001 | 7/29/2002 | 0.013 | 118 |
| 370901091262001 | 8/6/2002 | 0.011 | 105 |
| 370901091262001 | 8/7/2002 | 0.012 | 105 |
| 370901091262001 | 10/8/2002 | 0.01 | 89 |
| 370901091262001 | 10/9/2002 | 0.01 | 89 |
| 370901091262001 | 6/2/2003 | 0.011 | 113 |
| 370901091262001 | 6/9/2003 | 0.007 | 117 |
| 370901091262001 | 6/28/2003 | 0.01 | 91 |
| 370901091262001 | 7/26/2003 | 0.009 | 86 |
| 370901091262001 | 8/6/2003 | 0.01 | 86 |
| 370901091262001 | 9/23/2003 | 0.011 | 87 |
| 370901091262001 | 10/8/2003 | 0.01 | 74 |
| 370901091262001 | 6/15/2004 | 0.012 | 127 |
| 370901091262001 | 6/26/2004 | 0.013 | 127 |
| 370901091262001 | 7/13/2004 | 0.009 | 108 |
| 370901091262001 | 8/11/2004 | 0.01 | 103 |
| 370901091262001 | 8/21/2004 | 0.009 | 108 |
| 370901091262001 | 9/21/2004 | 0.012 | 88 |
| 370901091262001 | 10/5/2004 | 0.01 | 85 |
| 370901091262001 | 6/14/2005 | 0.011 | 100 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 6930800 | 10/1/2002 | 0.12 | 498 |
| 6930800 | 11/13/2002 | 0.17 | 547 |
| 6930800 | 12/5/2002 | 0.16 | 547 |
| 6930800 | 1/15/2003 | 0.88 | 952 |
| 6930800 | 2/4/2003 | 0.53 | 631 |
| 6930800 | 3/5/2003 | 1.1 | 2660 |
| 6930800 | 4/8/2003 | 0.44 | 2720 |
| 6930800 | 5/8/2003 | 1.1 | 4900 |
| 6930800 | 6/9/2003 | 0.42 | 952 |
| 6930800 | 7/28/2003 | 0.19 | 475 |
| 6930800 | 9/5/2003 | 1.2 | 5300 |
| 6930800 | 10/29/2003 | 0.17 | 665 |
| 6930800 | 11/21/2003 | 2.2 | 13600 |
| 6930800 | 12/22/2003 | 1.2 | 2410 |
| 6930800 | 1/20/2004 | 1.1 | 5910 |
| 6930800 | 2/4/2004 | 1 | 2730 |
| 6930800 | 3/10/2004 | 1.3 | 5690 |
| 6930800 | 4/20/2004 | 0.28 | 1410 |
| 6930800 | 5/19/2004 | 0.42 | 1680 |
| 6930800 | 6/14/2004 | 0.44 | 864 |
| 6930800 | 7/8/2004 | 0.3 | 787 |
| 6930800 | 9/21/2004 | 0.2 | 481 |
| 6930800 | 10/13/2004 | 0.36 | 467 |
| 6930800 | 11/18/2004 | 1.2 | 1820 |
| 6930800 | 12/10/2004 | 1.4 | 7740 |
| 6930800 | 1/19/2005 | 1.2 | 5130 |
| 6930800 | 2/1/2005 | 1 | 1710 |
| 6930800 | 3/2/2005 | 0.49 | 1990 |
| 6930800 | 4/5/2005 | 0.27 | 1320 |
| 6930800 | 5/23/2005 | 0.31 | 763 |
| 6930800 | 6/9/2005 | 0.47 | 580 |
| 6930800 | 7/7/2005 | 0.28 | 484 |
| 6930800 | 8/1/2005 | 0.23 | 344 |
| 6930800 | 8/11/2005 | 0.27 | 343 |
| 6930800 | 9/1/2005 | 0.3 | 473 |
| 6930800 | 10/13/2005 | 0.17 | 554 |
| 6930800 | 11/22/2005 | 1 | 1340 |
| 6930800 | 12/20/2005 | 0.49 | 611 |
| 6930800 | 1/10/2006 | 0.28 | 117 |
| 6930800 | 2/6/2006 | 0.31 | 1180 |
| 6930800 | 3/22/2006 | 0.78 | 1660 |
| 6930800 | 4/25/2006 | 0.35 | 943 |
| 6930800 | 5/8/2006 | 1 | 5860 |
| 6930800 | 6/6/2006 | 0.31 | 871 |
| 6930800 | 7/5/2006 | 0.3 | 481 |
| 6930800 | 8/1/2006 | 0.27 | 463 |
| 6930800 | 9/7/2006 | 0.25 | 424 |
| 6930800 | 10/4/2006 | 0.23 | 404 |
| 6930800 | 11/2/2006 | 0.22 | 637 |
| 6930800 | 12/11/2006 | 1.5 | 2200 |
| 6930800 | 1/23/2007 | 1.3 | 7240 |
| 6930800 | 2/7/2007 | 1 | 1680 |
| 6930800 | 3/14/2007 | 0.4 | 1300 |
| 6930800 | 4/25/2007 | 0.45 | 3360 |
| 6930800 | 5/8/2007 | 0.32 | 2930 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370901091262001 | 7/5/2005 | 0.01 | 94 |
| 370901091262001 | 8/9/2005 | 0.009 | 88 |
| 6930800 | 3/16/1999 | 0.03 | 4780 |
| 6930800 | 4/12/1999 | 0.03 | 2900 |
| 6930800 | 7/12/1999 | 0.04 | 826 |
| 6930800 | 10/5/1999 | 0.04 | 492 |
| 6930800 | 4/4/2000 | 0.03 | 935 |
| 6930800 | 6/13/2000 | 0.04 | 481 |
| 6930800 | 7/5/2000 | 0.04 | 493 |
| 6930800 | 8/1/2000 | 0.05 | 541 |
| 6930800 | 4/9/2001 | 0.03 | 1400 |
| 6930800 | 6/13/2001 | 0.03 | 1150 |
| 6930800 | 8/14/2001 | 0.03 | 429 |
| 6930800 | 12/4/2001 | 0.03 | 1820 |
| 6930800 | 3/26/2002 | 0.07 | 8780 |
| 6930800 | 5/20/2002 | 0.13 | 26100 |
| 6930800 | 3/5/2003 | 0.02 | 2660 |
| 6930800 | 5/8/2003 | 0.09 | 4900 |
| 6930800 | 6/9/2003 | 0.03 | 952 |
| 6930800 | 9/5/2003 | 0.11 | 5300 |
| 6930800 | 11/21/2003 | 0.3 | 13600 |
| 6930800 | 12/22/2003 | 0.03 | 2410 |
| 6930800 | 1/20/2004 | 0.07 | 5910 |
| 6930800 | 2/4/2004 | 0.02 | 2730 |
| 6930800 | 3/10/2004 | 0.05 | 5690 |
| 6930800 | 6/14/2004 | 0.02 | 864 |
| 6930800 | 7/8/2004 | 0.03 | 787 |
| 6930800 | 10/13/2004 | 0.04 | 467 |
| 6930800 | 11/18/2004 | 0.05 | 1820 |
| 6930800 | 12/10/2004 | 0.1 | 7740 |
| 6930800 | 1/19/2005 | 0.04 | 5130 |
| 6930800 | 2/1/2005 | 0.03 | 1710 |
| 6930800 | 6/9/2005 | 0.03 | 580 |
| 6930800 | 8/1/2005 | 0.02 | 344 |
| 6930800 | 8/11/2005 | 0.02 | 343 |
| 6930800 | 11/22/2005 | 0.06 | 1340 |
| 6930800 | 3/22/2006 | 0.03 | 1660 |
| 6930800 | 4/25/2006 | 0.03 | 943 |
| 6930800 | 5/8/2006 | 0.12 | 5860 |
| 6930800 | 6/6/2006 | 0.03 | 871 |
| 6930800 | 7/5/2006 | 0.02 | 481 |
| 6930800 | 8/1/2006 | 0.03 | 463 |
| 6930800 | 11/2/2006 | 0.02 | 637 |
| 6930800 | 12/11/2006 | 0.04 | 2200 |
| 6930800 | 1/23/2007 | 0.04 | 7240 |
| 6930800 | 3/14/2007 | 0.02 | 1300 |
| 6930800 | 4/25/2007 | 0.04 | 3360 |
| 6930800 | 5/8/2007 | 0.03 | 2930 |
| 6930800 | 6/4/2007 | 0.02 | 1540 |
| 6930800 | 7/11/2007 | 0.06 | 1360 |
| 6930800 | 9/10/2007 | 0.07 | 1890 |
| 6930800 | 12/4/2007 | 0.03 | 580 |
| 6930800 | 1/9/2008 | 0.31 | 8130 |
| 6930800 | 2/6/2008 | 0.11 | 7290 |
| 6930800 | 3/18/2008 | 0.21 | 25800 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 6930800 | 6/4/2007 | 0.5 | 1540 |
| 6930800 | 7/11/2007 | 0.63 | 1360 |
| 6930800 | 8/16/2007 | 0.22 | 487 |
| 6930800 | 9/10/2007 | 0.81 | 1890 |
| 6930800 | 10/17/2007 | 0.24 | 542 |
| 6930800 | 11/19/2007 | 0.17 | 557 |
| 6930800 | 12/4/2007 | 0.23 | 580 |
| 6930800 | 1/9/2008 | 1.9 | 8130 |
| 6930800 | 2/6/2008 | 1.3 | 7290 |
| 6930800 | 3/18/2008 | 1.5 | 25800 |
| 6930800 | 4/2/2008 | 1.1 | 22900 |
| 6930800 | 5/14/2008 | 0.52 | 6400 |
| 6930800 | 6/3/2008 | 0.42 | 2470 |
| 6930800 | 7/31/2008 | 0.44 | 1000 |
| 6930800 | 8/4/2008 | 0.36 | 1080 |
| 6930800 | 9/3/2008 | 0.37 | 874 |
| 6930800 | 10/16/2008 | 0.31 | 1160 |
| 6930800 | 11/4/2008 | 0.26 | 927 |
| 6930800 | 12/1/2008 | 0.36 | 795 |
| 6930800 | 1/26/2009 | 0.66 | 787 |
| 6930800 | 2/2/2009 | 0.54 | 825 |
| 6930800 | 3/16/2009 | 0.27 | 1560 |
| 6930800 | 4/6/2009 | 0.55 | 3230 |
| 6930800 | 5/18/2009 | 0.79 | 6440 |
| 6930800 | 6/1/2009 | 0.21 | 2320 |
| 6930800 | 7/6/2009 | 0.46 | 1150 |
| 6930800 | 8/17/2009 | 0.38 | 625 |
| 6930800 | 9/2/2009 | 0.49 | 592 |
| 6930800 | 10/5/2009 | 0.46 | 856 |
| 6930800 | 11/2/2009 | 1.3 | 37400 |
| 371054091173501 | 11/10/1999 | 0.37 | 169 |
| 371054091173501 | 12/16/1999 | 0.47 | 276 |
| 371054091173501 | 3/2/2000 | 0.72 | 470 |
| 371054091173501 | 4/6/2000 | 0.45 | 241 |
| 371054091173501 | 5/12/2000 | 0.36 | 146 |
| 371054091173501 | 5/25/2000 | 0.58 | 225 |
| 371054091173501 | 6/8/2000 | 0.48 | 177 |
| 371054091173501 | 6/30/2000 | 0.3 | 250 |
| 371054091173501 | 7/12/2000 | 0.4 | 171 |
| 371054091173501 | 7/26/2000 | 0.31 | 165 |
| 371054091173501 | 8/9/2000 | 0.43 | 132 |
| 371054091173501 | 8/21/2000 | 0.35 | 128 |
| 371054091173501 | 12/12/2000 | 0.42 | 195 |
| 371054091173501 | 1/24/2001 | 0.41 | 186 |
| 371054091173501 | 2/21/2001 | 0.63 | 475 |
| 371054091173501 | 4/25/2001 | 0.34 | 235 |
| 371054091173501 | 5/26/2001 | 0.33 | 218 |
| 371054091173501 | 5/27/2001 | 0.31 | 193 |
| 371054091173501 | 5/27/2001 | 0.33 | 193 |
| 371054091173501 | 8/1/2001 | 0.33 | 150 |
| 371054091173501 | 8/8/2001 | 0.33 | 122 |
| 371054091173501 | 8/8/2001 | 0.35 | 122 |
| 371054091173501 | 8/9/2001 | 0.36 | 122 |
| 371054091173501 | 8/9/2001 | 0.37 | 122 |
| 371054091173501 | 9/19/2001 | 0.33 | 125 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 6930800 | 4/2/2008 | 0.13 | 22900 |
| 6930800 | 5/14/2008 | 0.03 | 6400 |
| 6930800 | 6/3/2008 | 0.03 | 2470 |
| 6930800 | 7/31/2008 | 0.03 | 1000 |
| 6930800 | 8/4/2008 | 0.02 | 1080 |
| 6930800 | 9/3/2008 | 0.02 | 874 |
| 6930800 | 1/26/2009 | 0.04 | 787 |
| 6930800 | 2/2/2009 | 0.02 | 825 |
| 6930800 | 4/6/2009 | 0.02 | 3230 |
| 6930800 | 5/18/2009 | 0.06 | 6440 |
| 6930800 | 7/6/2009 | 0.03 | 1150 |
| 6930800 | 9/2/2009 | 0.03 | 592 |
| 6930800 | 10/5/2009 | 0.03 | 856 |
| 6930800 | 11/2/2009 | 0.21 | 37400 |
| 371054091173501 | 3/2/2000 | 0.005 | 470 |
| 371054091173501 | 5/12/2000 | 0.004 | 146 |
| 371054091173501 | 5/25/2000 | 0.014 | 225 |
| 371054091173501 | 6/8/2000 | 0.005 | 177 |
| 371054091173501 | 6/30/2000 | 0.004 | 250 |
| 371054091173501 | 7/12/2000 | 0.008 | 171 |
| 371054091173501 | 7/26/2000 | 0.005 | 165 |
| 371054091173501 | 8/9/2000 | 0.014 | 132 |
| 371054091173501 | 9/19/2000 | 0.004 | 113 |
| 371054091173501 | 12/12/2000 | 0.003 | 195 |
| 371054091173501 | 1/24/2001 | 0.002 | 186 |
| 371054091173501 | 2/21/2001 | 0.003 | 475 |
| 371054091173501 | 4/25/2001 | 0.004 | 235 |
| 371054091173501 | 5/26/2001 | 0.009 | 218 |
| 371054091173501 | 5/27/2001 | 0.006 | 193 |
| 371054091173501 | 5/27/2001 | 0.006 | 193 |
| 371054091173501 | 8/1/2001 | 0.008 | 150 |
| 371054091173501 | 8/8/2001 | 0.005 | 122 |
| 371054091173501 | 8/8/2001 | 0.006 | 122 |
| 371054091173501 | 8/9/2001 | 0.007 | 122 |
| 371054091173501 | 8/9/2001 | 0.008 | 122 |
| 371054091173501 | 9/19/2001 | 0.006 | 125 |
| 371054091173501 | 10/3/2001 | 0.004 | 110 |
| 371054091173501 | 10/10/2001 | 0.004 | 129 |
| 371054091173501 | 10/10/2001 | 0.004 | 129 |
| 371054091173501 | 10/11/2001 | 0.004 | 129 |
| 371054091173501 | 10/11/2001 | 0.006 | 129 |
| 371054091173501 | 4/3/2002 | 0.005 | 551 |
| 371054091173501 | 5/1/2002 | 0.006 | 728 |
| 371054091173501 | 5/30/2002 | 0.008 | 738 |
| 371054091173501 | 6/5/2002 | 0.005 | 548 |
| 371054091173501 | 6/28/2002 | 0.007 | 310 |
| 371054091173501 | 6/29/2002 | 0.006 | 298 |
| 371054091173501 | 7/30/2002 | 0.006 | 268 |
| 371054091173501 | 8/6/2002 | 0.004 | 226 |
| 371054091173501 | 8/7/2002 | 0.006 | 226 |
| 371054091173501 | 10/8/2002 | 0.004 | 167 |
| 371054091173501 | 10/9/2002 | 0.005 | 167 |
| 371054091173501 | 6/4/2003 | 0.003 | 344 |
| 371054091173501 | 6/28/2003 | 0.006 | 209 |
| 371054091173501 | 7/26/2003 | 0.007 | 185 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371054091173501 | 10/10/2001 | 0.3 | 129 |
| 371054091173501 | 10/10/2001 | 0.49 | 129 |
| 371054091173501 | 10/11/2001 | 0.33 | 129 |
| 371054091173501 | 4/3/2002 | 0.46 | 551 |
| 371054091173501 | 5/1/2002 | 0.31 | 728 |
| 371054091173501 | 5/30/2002 | 0.37 | 738 |
| 371054091173501 | 6/5/2002 | 0.39 | 548 |
| 371054091173501 | 6/28/2002 | 0.48 | 310 |
| 371054091173501 | 6/29/2002 | 0.45 | 298 |
| 371054091173501 | 8/7/2002 | 0.39 | 226 |
| 371054091173501 | 10/9/2002 | 0.38 | 167 |
| 371054091173501 | 6/4/2003 | 0.4 | 344 |
| 371054091173501 | 7/26/2003 | 0.3 | 185 |
| 371054091173501 | 8/6/2003 | 0.35 | 229 |
| 371054091173501 | 9/23/2003 | 0.37 | 210 |
| 371054091173501 | 10/8/2003 | 0.35 | 158 |
| 371054091173501 | 6/15/2004 | 0.42 | 342 |
| 371054091173501 | 6/26/2004 | 0.35 | 266 |
| 371054091173501 | 7/13/2004 | 0.36 | 228 |
| 371054091173501 | 8/11/2004 | 0.37 | 181 |
| 371054091173501 | 8/21/2004 | 0.38 | 184 |
| 371054091173501 | 6/14/2005 | 0.4 | 186 |
| 371054091173501 | 7/6/2005 | 0.38 | 120 |
| 371054091173501 | 8/10/2005 | 0.37 | 149 |
| 371014091201301 | 11/9/1999 | 0.39 | 151 |
| 371014091201301 | 12/15/1999 | 0.51 | 298 |
| 371014091201301 | 1/19/2000 | 0.77 | 173 |
| 371014091201301 | 3/1/2000 | 0.73 | 524 |
| 371014091201301 | 4/5/2000 | 0.46 | 234 |
| 371014091201301 | 5/11/2000 | 0.42 | 138 |
| 371014091201301 | 5/24/2000 | 0.4 | 133 |
| 371014091201301 | 5/25/2000 | 0.4 | 221 |
| 371014091201301 | 6/7/2000 | 0.52 | 168 |
| 371014091201301 | 6/29/2000 | 0.29 | 265 |
| 371014091201301 | 7/11/2000 | 0.4 | 144 |
| 371014091201301 | 7/27/2000 | 0.38 | 143 |
| 371014091201301 | 8/10/2000 | 0.41 | 127 |
| 371014091201301 | 8/22/2000 | 0.42 | 122 |
| 371014091201301 | 10/4/2000 | 0.37 | 111 |
| 371014091201301 | 11/8/2000 | 0.28 | 227 |
| 371014091201301 | 3/21/2001 | 0.64 | 272 |
| 371014091201301 | 4/24/2001 | 0.36 | 226 |
| 371014091201301 | 5/25/2001 | 0.32 | 220 |
| 371014091201301 | 5/26/2001 | 0.33 | 208 |
| 371014091201301 | 5/26/2001 | 0.35 | 208 |
| 371014091201301 | 5/27/2001 | 0.36 | 208 |
| 371014091201301 | 5/27/2001 | 0.38 | 208 |
| 371014091201301 | 6/7/2001 | 0.33 | 192 |
| 371014091201301 | 7/31/2001 | 0.35 | 140 |
| 371014091201301 | 8/8/2001 | 0.4 | 97 |
| 371014091201301 | 8/9/2001 | 0.4 | 97 |
| 371014091201301 | 8/9/2001 | 0.4 | 97 |
| 371014091201301 | 10/2/2001 | 0.33 | 106 |
| 371014091201301 | 10/10/2001 | 0.37 | 109 |
| 371014091201301 | 10/11/2001 | 0.39 | 116 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371054091173501 | 8/6/2003 | 0.009 | 229 |
| 371054091173501 | 9/23/2003 | 0.005 | 210 |
| 371054091173501 | 10/8/2003 | 0.006 | 158 |
| 371054091173501 | 6/15/2004 | 0.007 | 342 |
| 371054091173501 | 6/26/2004 | 0.005 | 266 |
| 371054091173501 | 7/13/2004 | 0.005 | 228 |
| 371054091173501 | 8/11/2004 | 0.008 | 181 |
| 371054091173501 | 8/21/2004 | 0.003 | 184 |
| 371054091173501 | 9/21/2004 | 0.005 | 150 |
| 371054091173501 | 10/5/2004 | 0.004 | 146 |
| 371054091173501 | 6/14/2005 | 0.007 | 186 |
| 371054091173501 | 7/6/2005 | 0.007 | 120 |
| 371054091173501 | 8/10/2005 | 0.007 | 149 |
| 371014091201301 | 11/9/1999 | 0.004 | 151 |
| 371014091201301 | 3/1/2000 | 0.006 | 524 |
| 371014091201301 | 5/11/2000 | 0.006 | 138 |
| 371014091201301 | 5/24/2000 | 0.005 | 133 |
| 371014091201301 | 5/25/2000 | 0.008 | 221 |
| 371014091201301 | 6/7/2000 | 0.01 | 168 |
| 371014091201301 | 6/29/2000 | 0.004 | 265 |
| 371014091201301 | 7/11/2000 | 0.008 | 144 |
| 371014091201301 | 7/27/2000 | 0.006 | 143 |
| 371014091201301 | 8/10/2000 | 0.013 | 127 |
| 371014091201301 | 8/22/2000 | 0.004 | 122 |
| 371014091201301 | 10/4/2000 | 0.005 | 111 |
| 371014091201301 | 11/8/2000 | 0.003 | 227 |
| 371014091201301 | 1/23/2001 | 0.003 | 204 |
| 371014091201301 | 3/21/2001 | 0.005 | 272 |
| 371014091201301 | 4/24/2001 | 0.005 | 226 |
| 371014091201301 | 5/25/2001 | 0.006 | 220 |
| 371014091201301 | 5/26/2001 | 0.006 | 208 |
| 371014091201301 | 5/26/2001 | 0.007 | 208 |
| 371014091201301 | 5/27/2001 | 0.005 | 208 |
| 371014091201301 | 5/27/2001 | 0.009 | 208 |
| 371014091201301 | 6/7/2001 | 0.014 | 192 |
| 371014091201301 | 7/31/2001 | 0.009 | 140 |
| 371014091201301 | 8/8/2001 | 0.012 | 97 |
| 371014091201301 | 8/9/2001 | 0.009 | 97 |
| 371014091201301 | 8/9/2001 | 0.013 | 97 |
| 371014091201301 | 9/18/2001 | 0.005 | 115 |
| 371014091201301 | 10/2/2001 | 0.004 | 106 |
| 371014091201301 | 10/10/2001 | 0.004 | 109 |
| 371014091201301 | 10/10/2001 | 0.009 | 109 |
| 371014091201301 | 10/11/2001 | 0.009 | 116 |
| 371014091201301 | 10/11/2001 | 0.015 | 116 |
| 371014091201301 | 11/21/2001 | 0.004 | 114 |
| 371014091201301 | 4/2/2002 | 0.005 | 590 |
| 371014091201301 | 4/30/2002 | 0.006 | 760 |
| 371014091201301 | 5/29/2002 | 0.007 | 657 |
| 371014091201301 | 6/4/2002 | 0.005 | 488 |
| 371014091201301 | 6/28/2002 | 0.008 | 309 |
| 371014091201301 | 6/29/2002 | 0.009 | 297 |
| 371014091201301 | 7/29/2002 | 0.007 | 266 |
| 371014091201301 | 8/6/2002 | 0.009 | 220 |
| 371014091201301 | 8/7/2002 | 0.007 | 216 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371014091201301 | 10/11/2001 | 0.48 | 116 |
| 371014091201301 | 4/2/2002 | 0.43 | 590 |
| 371014091201301 | 4/30/2002 | 0.28 | 760 |
| 371014091201301 | 5/29/2002 | 0.39 | 657 |
| 371014091201301 | 6/4/2002 | 0.39 | 488 |
| 371014091201301 | 6/28/2002 | 0.5 | 309 |
| 371014091201301 | 6/29/2002 | 0.47 | 297 |
| 371014091201301 | 7/29/2002 | 0.41 | 266 |
| 371014091201301 | 8/6/2002 | 0.42 | 220 |
| 371014091201301 | 8/7/2002 | 0.39 | 216 |
| 371014091201301 | 10/8/2002 | 0.47 | 168 |
| 371014091201301 | 10/9/2002 | 0.48 | 171 |
| 371014091201301 | 6/3/2003 | 0.46 | 308 |
| 371014091201301 | 6/10/2003 | 0.52 | 296 |
| 371014091201301 | 6/28/2003 | 0.41 | 220 |
| 371014091201301 | 7/26/2003 | 0.36 | 170 |
| 371014091201301 | 8/6/2003 | 0.37 | 253 |
| 371014091201301 | 9/23/2003 | 0.4 | 208 |
| 371014091201301 | 10/8/2003 | 0.44 | 157 |
| 371014091201301 | 6/15/2004 | 0.45 | 355 |
| 371014091201301 | 6/26/2004 | 0.39 | 279 |
| 371014091201301 | 7/13/2004 | 0.39 | 223 |
| 371014091201301 | 8/21/2004 | 0.42 | 182 |
| 371014091201301 | 10/5/2004 | 0.4 | 151 |
| 371014091201301 | 6/15/2005 | 0.47 | 179 |
| 371014091201301 | 7/6/2005 | 0.44 | 164 |
| 371014091201301 | 8/10/2005 | 0.43 | 144 |
| 371026091183301 | 6/24/1999 | 0.49 | 267 |
| 371026091183301 | 8/12/1999 | 0.48 | 186 |
| 371026091183301 | 11/10/1999 | 0.39 | 164 |
| 371026091183301 | 12/15/1999 | 0.46 | 298 |
| 371026091183301 | 3/2/2000 | 0.76 | 489 |
| 371026091183301 | 4/5/2000 | 0.45 | 258 |
| 371026091183301 | 5/11/2000 | 0.38 | 144 |
| 371026091183301 | 5/24/2000 | 0.36 | 137 |
| 371026091183301 | 6/7/2000 | 0.45 | 191 |
| 371026091183301 | 6/29/2000 | 0.3 | 246 |
| 371026091183301 | 7/11/2000 | 0.34 | 155 |
| 371026091183301 | 7/27/2000 | 0.37 | 147 |
| 371026091183301 | 8/10/2000 | 0.34 | 133 |
| 371026091183301 | 8/22/2000 | 0.37 | 125 |
| 371026091183301 | 10/4/2000 | 0.33 | 114 |
| 371026091183301 | 12/20/2000 | 0.4 | 164 |
| 371026091183301 | 3/20/2001 | 0.64 | 302 |
| 371026091183301 | 4/24/2001 | 0.37 | 235 |
| 371026091183301 | 5/25/2001 | 0.38 | 235 |
| 371026091183301 | 5/26/2001 | 0.3 | 207 |
| 371026091183301 | 5/26/2001 | 0.33 | 207 |
| 371026091183301 | 5/27/2001 | 0.28 | 207 |
| 371026091183301 | 5/27/2001 | 0.32 | 207 |
| 371026091183301 | 6/7/2001 | 0.31 | 201 |
| 371026091183301 | 7/31/2001 | 0.36 | 147 |
| 371026091183301 | 8/8/2001 | 0.33 | 121 |
| 371026091183301 | 8/8/2001 | 0.43 | 121 |
| 371026091183301 | 8/9/2001 | 0.36 | 121 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371014091201301 | 10/8/2002 | 0.005 | 168 |
| 371014091201301 | 10/9/2002 | 0.007 | 171 |
| 371014091201301 | 6/3/2003 | 0.007 | 308 |
| 371014091201301 | 6/10/2003 | 0.022 | 296 |
| 371014091201301 | 6/28/2003 | 0.006 | 220 |
| 371014091201301 | 7/26/2003 | 0.009 | 170 |
| 371014091201301 | 8/6/2003 | 0.012 | 253 |
| 371014091201301 | 9/23/2003 | 0.005 | 208 |
| 371014091201301 | 10/8/2003 | 0.009 | 157 |
| 371014091201301 | 6/15/2004 | 0.008 | 355 |
| 371014091201301 | 6/26/2004 | 0.006 | 279 |
| 371014091201301 | 7/13/2004 | 0.009 | 223 |
| 371014091201301 | 8/11/2004 | 0.006 | 195 |
| 371014091201301 | 8/21/2004 | 0.003 | 182 |
| 371014091201301 | 9/21/2004 | 0.011 | 135 |
| 371014091201301 | 10/5/2004 | 0.004 | 151 |
| 371014091201301 | 6/15/2005 | 0.011 | 179 |
| 371014091201301 | 7/6/2005 | 0.008 | 164 |
| 371014091201301 | 8/10/2005 | 0.012 | 144 |
| 371026091183301 | 5/12/1999 | 0.004 | 582 |
| 371026091183301 | 8/12/1999 | 0.005 | 186 |
| 371026091183301 | 3/2/2000 | 0.005 | 489 |
| 371026091183301 | 5/24/2000 | 0.005 | 137 |
| 371026091183301 | 6/7/2000 | 0.008 | 191 |
| 371026091183301 | 6/29/2000 | 0.005 | 246 |
| 371026091183301 | 7/11/2000 | 0.007 | 155 |
| 371026091183301 | 7/27/2000 | 0.006 | 147 |
| 371026091183301 | 8/10/2000 | 0.006 | 133 |
| 371026091183301 | 9/20/2000 | 0.005 | 114 |
| 371026091183301 | 10/4/2000 | 0.004 | 114 |
| 371026091183301 | 12/20/2000 | 0.002 | 164 |
| 371026091183301 | 3/20/2001 | 0.006 | 302 |
| 371026091183301 | 4/24/2001 | 0.004 | 235 |
| 371026091183301 | 5/25/2001 | 0.008 | 235 |
| 371026091183301 | 5/26/2001 | 0.007 | 207 |
| 371026091183301 | 5/26/2001 | 0.007 | 207 |
| 371026091183301 | 5/27/2001 | 0.006 | 207 |
| 371026091183301 | 5/27/2001 | 0.006 | 207 |
| 371026091183301 | 6/7/2001 | 0.009 | 201 |
| 371026091183301 | 7/31/2001 | 0.01 | 147 |
| 371026091183301 | 8/8/2001 | 0.005 | 121 |
| 371026091183301 | 8/8/2001 | 0.008 | 121 |
| 371026091183301 | 8/9/2001 | 0.007 | 121 |
| 371026091183301 | 8/9/2001 | 0.01 | 121 |
| 371026091183301 | 9/18/2001 | 0.004 | 118 |
| 371026091183301 | 10/2/2001 | 0.004 | 108 |
| 371026091183301 | 10/10/2001 | 0.005 | 109 |
| 371026091183301 | 10/10/2001 | 0.005 | 109 |
| 371026091183301 | 10/11/2001 | 0.006 | 116 |
| 371026091183301 | 10/11/2001 | 0.006 | 116 |
| 371026091183301 | 11/21/2001 | 0.003 | 119 |
| 371026091183301 | 4/2/2002 | 0.007 | 590 |
| 371026091183301 | 4/30/2002 | 0.006 | 751 |
| 371026091183301 | 5/29/2002 | 0.008 | 657 |
| 371026091183301 | 6/4/2002 | 0.006 | 492 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371026091183301 | 8/9/2001 | 0.38 | 121 |
| 371026091183301 | 9/18/2001 | 0.3 | 118 |
| 371026091183301 | 10/10/2001 | 0.3 | 109 |
| 371026091183301 | 10/11/2001 | 0.33 | 116 |
| 371026091183301 | 10/11/2001 | 0.34 | 116 |
| 371026091183301 | 6/28/2002 | 0.49 | 314 |
| 371026091183301 | 6/29/2002 | 0.45 | 312 |
| 371026091183301 | 7/29/2002 | 0.4 | 249 |
| 371026091183301 | 8/7/2002 | 0.4 | 216 |
| 371026091183301 | 10/8/2002 | 0.4 | 168 |
| 371026091183301 | 10/9/2002 | 0.55 | 171 |
| 371026091183301 | 6/3/2003 | 0.45 | 308 |
| 371026091183301 | 6/10/2003 | 0.43 | 296 |
| 371026091183301 | 6/28/2003 | 0.36 | 220 |
| 371026091183301 | 7/26/2003 | 0.34 | 170 |
| 371026091183301 | 8/6/2003 | 0.35 | 253 |
| 371026091183301 | 9/23/2003 | 0.35 | 208 |
| 371026091183301 | 10/8/2003 | 0.41 | 157 |
| 371026091183301 | 6/15/2004 | 0.43 | 355 |
| 371026091183301 | 6/26/2004 | 0.36 | 279 |
| 371026091183301 | 7/13/2004 | 0.41 | 223 |
| 371026091183301 | 8/11/2004 | 0.39 | 195 |
| 371026091183301 | 8/21/2004 | 0.4 | 182 |
| 371026091183301 | 9/21/2004 | 0.37 | 135 |
| 371026091183301 | 6/15/2005 | 0.42 | 179 |
| 371026091183301 | 7/6/2005 | 0.39 | 164 |
| 371026091183301 | 8/10/2005 | 0.4 | 144 |
| 370857091265901 | 5/10/1999 | 0.24 | 307 |
| 370857091265901 | 6/22/1999 | 0.22 | 82 |
| 370857091265901 | 8/10/1999 | 0.17 | 61 |
| 370857091265901 | 12/14/1999 | 0.37 | 233 |
| 370857091265901 | 2/29/2000 | 0.79 | 359 |
| 370857091265901 | 4/4/2000 | 0.3 | 117 |
| 370857091265901 | 5/10/2000 | 0.22 | 52 |
| 370857091265901 | 5/23/2000 | 0.16 | 42 |
| 370857091265901 | 5/25/2000 | 0.24 | 129 |
| 370857091265901 | 6/6/2000 | 0.22 | 73 |
| 370857091265901 | 6/28/2000 | 0.18 | 123 |
| 370857091265901 | 7/28/2000 | 0.15 | 44 |
| 370857091265901 | 8/11/2000 | 0.16 | 36 |
| 370857091265901 | 8/22/2000 | 0.18 | 33 |
| 370857091265901 | 9/20/2000 | 0.12 | 25 |
| 370857091265901 | 11/9/2000 | 0.18 | 121 |
| 370857091265901 | 2/22/2001 | 0.54 | 328 |
| 370857091265901 | 3/21/2001 | 0.34 | 127 |
| 370857091265901 | 4/25/2001 | 0.2 | 107 |
| 370857091265901 | 5/25/2001 | 0.17 | 102 |
| 370857091265901 | 5/26/2001 | 0.15 | 94 |
| 370857091265901 | 5/26/2001 | 0.17 | 94 |
| 370857091265901 | 5/27/2001 | 0.14 | 85 |
| 370857091265901 | 5/27/2001 | 0.15 | 85 |
| 370857091265901 | 6/7/2001 | 0.15 | 94 |
| 370857091265901 | 8/1/2001 | 0.16 | 45 |
| 370857091265901 | 8/8/2001 | 0.12 | 30 |
| 370857091265901 | 8/8/2001 | 0.18 | 33 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 371026091183301 | 6/28/2002 | 0.005 | 314 |
| 371026091183301 | 6/29/2002 | 0.007 | 312 |
| 371026091183301 | 7/29/2002 | 0.007 | 249 |
| 371026091183301 | 8/6/2002 | 0.005 | 216 |
| 371026091183301 | 8/7/2002 | 0.005 | 216 |
| 371026091183301 | 10/8/2002 | 0.004 | 168 |
| 371026091183301 | 10/9/2002 | 0.006 | 171 |
| 371026091183301 | 6/3/2003 | 0.004 | 308 |
| 371026091183301 | 6/10/2003 | 0.003 | 296 |
| 371026091183301 | 6/28/2003 | 0.007 | 220 |
| 371026091183301 | 7/26/2003 | 0.008 | 170 |
| 371026091183301 | 8/6/2003 | 0.013 | 253 |
| 371026091183301 | 9/23/2003 | 0.004 | 208 |
| 371026091183301 | 10/8/2003 | 0.007 | 157 |
| 371026091183301 | 6/15/2004 | 0.008 | 355 |
| 371026091183301 | 6/26/2004 | 0.005 | 279 |
| 371026091183301 | 7/13/2004 | 0.008 | 223 |
| 371026091183301 | 8/11/2004 | 0.005 | 195 |
| 371026091183301 | 8/21/2004 | 0.005 | 182 |
| 371026091183301 | 9/21/2004 | 0.004 | 135 |
| 371026091183301 | 10/5/2004 | 0.004 | 151 |
| 371026091183301 | 6/15/2005 | 0.007 | 179 |
| 371026091183301 | 7/6/2005 | 0.007 | 164 |
| 371026091183301 | 8/10/2005 | 0.008 | 144 |
| 370905091204001 | 5/11/1999 | 0.006 | 616 |
| 370905091204001 | 6/23/1999 | 0.005 | 239 |
| 370905091204001 | 8/11/1999 | 0.008 | 190 |
| 370905091204001 | 3/1/2000 | 0.006 | 547 |
| 370905091204001 | 5/11/2000 | 0.005 | 142 |
| 370905091204001 | 5/24/2000 | 0.007 | 129 |
| 370905091204001 | 6/7/2000 | 0.007 | 177 |
| 370905091204001 | 7/11/2000 | 0.009 | 155 |
| 370905091204001 | 7/27/2000 | 0.007 | 144 |
| 370905091204001 | 8/10/2000 | 0.006 | 128 |
| 370905091204001 | 8/21/2000 | 0.007 | 124 |
| 370905091204001 | 10/2/2001 | 0.008 | 104 |
| 370905091204001 | 10/10/2001 | 0.007 | 109 |
| 370905091204001 | 10/10/2001 | 0.009 | 109 |
| 370905091204001 | 10/11/2001 | 0.01 | 116 |
| 370905091204001 | 10/11/2001 | 0.018 | 116 |
| 370905091204001 | 11/20/2001 | 0.002 | 112 |
| 370905091204001 | 4/2/2002 | 0.006 | 590 |
| 370905091204001 | 5/29/2002 | 0.008 | 657 |
| 370905091204001 | 6/4/2002 | 0.006 | 488 |
| 370905091204001 | 6/28/2002 | 0.008 | 309 |
| 370905091204001 | 6/29/2002 | 0.009 | 297 |
| 370905091204001 | 7/29/2002 | 0.008 | 266 |
| 370905091204001 | 8/6/2002 | 0.004 | 220 |
| 370905091204001 | 8/7/2002 | 0.007 | 216 |
| 370905091204001 | 10/8/2002 | 0.007 | 161 |
| 370905091204001 | 10/9/2002 | 0.009 | 164 |
| 370905091204001 | 6/3/2003 | 0.007 | 270 |
| 370905091204001 | 6/10/2003 | 0.014 | 263 |
| 370905091204001 | 6/28/2003 | 0.022 | 185 |
| 370905091204001 | 7/26/2003 | 0.009 | 169 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370857091265901 | 8/9/2001 | 0.14 | 33 |
| 370857091265901 | 8/9/2001 | 0.15 | 33 |
| 370857091265901 | 9/18/2001 | 0.13 | 30 |
| 370857091265901 | 4/30/2002 | 0.15 | 382 |
| 370857091265901 | 5/29/2002 | 0.21 | 303 |
| 370857091265901 | 6/4/2002 | 0.23 | 201 |
| 370857091265901 | 6/28/2002 | 0.23 | 99 |
| 370857091265901 | 6/29/2002 | 0.22 | 90 |
| 370857091265901 | 10/8/2002 | 0.11 | 53 |
| 370857091265901 | 10/9/2002 | 0.26 | 54 |
| 370857091265901 | 6/2/2003 | 0.24 | 112 |
| 370857091265901 | 6/9/2003 | 0.2 | 101 |
| 370857091265901 | 8/6/2003 | 0.13 | 128 |
| 370857091265901 | 9/23/2003 | 0.21 | 94 |
| 370857091265901 | 10/8/2003 | 0.18 | 62 |
| 370857091265901 | 6/15/2004 | 0.26 | 162 |
| 370857091265901 | 6/26/2004 | 0.18 | 117 |
| 370857091265901 | 8/21/2004 | 0.16 | 64 |
| 370857091265901 | 6/14/2005 | 0.21 | 75 |
| 370857091265901 | 7/5/2005 | 0.18 | 59 |
| 370857091265901 | 8/9/2005 | 0.13 | 44 |
| 370905091204001 | 5/11/1999 | 0.34 | 616 |
| 370905091204001 | 6/23/1999 | 0.5 | 239 |
| 370905091204001 | 8/11/1999 | 0.52 | 190 |
| 370905091204001 | 11/9/1999 | 0.38 | 154 |
| 370905091204001 | 12/15/1999 | 0.56 | 299 |
| 370905091204001 | 1/19/2000 | 0.45 | 172 |
| 370905091204001 | 3/1/2000 | 0.76 | 547 |
| 370905091204001 | 4/5/2000 | 0.47 | 240 |
| 370905091204001 | 5/24/2000 | 0.41 | 129 |
| 370905091204001 | 6/7/2000 | 0.5 | 177 |
| 370905091204001 | 6/29/2000 | 0.36 | 244 |
| 370905091204001 | 7/27/2000 | 0.46 | 144 |
| 370905091204001 | 8/10/2000 | 0.31 | 128 |
| 370905091204001 | 8/21/2000 | 0.43 | 124 |
| 370905091204001 | 10/2/2001 | 0.41 | 104 |
| 370905091204001 | 10/10/2001 | 0.39 | 109 |
| 370905091204001 | 10/10/2001 | 0.4 | 109 |
| 370905091204001 | 10/11/2001 | 0.37 | 116 |
| 370905091204001 | 4/2/2002 | 0.43 | 590 |
| 370905091204001 | 4/30/2002 | 0.34 | 760 |
| 370905091204001 | 5/29/2002 | 0.36 | 657 |
| 370905091204001 | 6/4/2002 | 0.42 | 488 |
| 370905091204001 | 6/28/2002 | 0.51 | 309 |
| 370905091204001 | 6/29/2002 | 0.46 | 297 |
| 370905091204001 | 7/29/2002 | 0.42 | 266 |
| 370905091204001 | 8/7/2002 | 0.42 | 216 |
| 370905091204001 | 10/8/2002 | 0.47 | 161 |
| 370905091204001 | 10/9/2002 | 0.48 | 164 |
| 370905091204001 | 6/3/2003 | 0.47 | 270 |
| 370905091204001 | 6/10/2003 | 0.5 | 263 |
| 370905091204001 | 6/28/2003 | 0.43 | 185 |
| 370905091204001 | 7/26/2003 | 0.36 | 169 |
| 370905091204001 | 8/6/2003 | 0.35 | 226 |
| 370905091204001 | 9/23/2003 | 0.47 | 201 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370905091204001 | 8/6/2003 | 0.011 | 226 |
| 370905091204001 | 9/23/2003 | 0.006 | 201 |
| 370905091204001 | 10/8/2003 | 0.009 | 151 |
| 370905091204001 | 6/15/2004 | 0.007 | 368 |
| 370905091204001 | 6/26/2004 | 0.005 | 266 |
| 370905091204001 | 7/13/2004 | 0.008 | 216 |
| 370905091204001 | 8/11/2004 | 0.005 | 186 |
| 370905091204001 | 8/21/2004 | 0.005 | 174 |
| 370905091204001 | 9/21/2004 | 0.012 | 147 |
| 370905091204001 | 10/5/2004 | 0.006 | 135 |
| 370905091204001 | 6/14/2005 | 0.008 | 156 |
| 370905091204001 | 7/6/2005 | 0.005 | 164 |
| 370905091204001 | 4/30/2002 | 0.006 | 760 |
| 7066110 | 6/20/1973 | 0.03 | 478 |
| 7066110 | 8/1/1973 | 0.02 | 288 |
| 7066110 | 10/17/1973 | 0.04 | 439 |
| 7066110 | 1/18/1974 | 0.03 | 560 |
| 7066110 | 4/17/1974 | 0.03 | 680 |
| 7066110 | 7/10/1974 | 0.01 | 326 |
| 7066110 | 10/22/1974 | 0.02 | 233 |
| 7066110 | 1/21/1975 | 0.01 | 490 |
| 7066110 | 5/4/1977 | 0.01 | 242 |
| 7066110 | 5/16/1979 | 0.01 | 980 |
| 7066110 | 9/5/1979 | 0.01 | 293 |
| 7066110 | 5/6/1980 | 0.09 | 279 |
| 7066110 | 6/10/1981 | 0.01 | 395 |
| 7066110 | 9/22/1981 | 0.02 | 127 |
| 7066110 | 6/30/1982 | 0.04 | 464 |
| 7066110 | 5/25/1983 | 0.01 | 700 |
| 7066110 | 5/16/1984 | 0.01 | 775 |
| 7066110 | 5/7/1986 | 0.01 | 300 |
| 7066110 | 5/12/1987 | 0.01 | 220 |
| 7066110 | 5/18/1988 | 0.02 | 282 |
| 7066110 | 10/12/1988 | 0.01 | 172 |
| 7066110 | 10/24/1989 | 0.01 | 159 |
| 7066110 | 11/20/1990 | 0.03 | 126 |
| 7066110 | 10/23/1991 | 0.01 | 166 |
| 7066110 | 11/12/1992 | 0.13 | 2200 |
| 7066110 | 12/8/1992 | 0.01 | 344 |
| 7066110 | 1/22/1993 | 0.02 | 1200 |
| 7066110 | 4/7/1993 | 0.05 | 1100 |
| 7066110 | 4/14/1993 | 0.02 | 702 |
| 7066110 | 6/3/1993 | 0.03 | 366 |
| 7066110 | 4/14/1994 | 0.04 | 4140 |
| 7066110 | 10/20/1994 | 0.06 | 251 |
| 7066110 | 5/22/1995 | 0.02 | 680 |
| 7066110 | 8/7/1995 | 0.12 | 262 |
| 7066110 | 10/11/1995 | 0.02 | 189 |
| 7066110 | 4/1/1996 | 0.03 | 1340 |
| 7066110 | 4/7/1997 | 0.03 | 3200 |
| 7066110 | 11/13/2000 | 0.17 | 215 |
| 7066110 | 5/13/2002 | 0.06 | 2400 |
| 7066110 | 2/14/2007 | 0.04 | 2400 |
| 7064555 | 4/3/1973 | 0.007 | 151 |
| 7064555 | 6/18/1973 | 0.04 | 164 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 370905091204001 | 10/8/2003 | 0.45 | 151 |
| 370905091204001 | 6/15/2004 | 0.47 | 368 |
| 370905091204001 | 6/26/2004 | 0.4 | 266 |
| 370905091204001 | 7/13/2004 | 0.42 | 216 |
| 370905091204001 | 8/11/2004 | 0.44 | 186 |
| 370905091204001 | 8/21/2004 | 0.46 | 174 |
| 370905091204001 | 9/21/2004 | 0.5 | 147 |
| 370905091204001 | 6/14/2005 | 0.45 | 156 |
| 370905091204001 | 7/6/2005 | 0.43 | 164 |
| 370905091204001 | 8/10/2005 | 0.46 | 138 |
| 7066110 | 6/20/1973 | 0.37 | 478 |
| 7066110 | 8/1/1973 | 0.45 | 288 |
| 7066110 | 10/17/1973 | 0.58 | 439 |
| 7066110 | 1/18/1974 | 0.39 | 560 |
| 7066110 | 4/17/1974 | 0.46 | 680 |
| 7066110 | 7/10/1974 | 0.46 | 326 |
| 7066110 | 10/22/1974 | 0.35 | 233 |
| 7066110 | 1/21/1975 | 0.48 | 490 |
| 7066110 | 4/15/1975 | 0.53 | 530 |
| 7066110 | 9/23/1976 | 0.3 | 132 |
| 7066110 | 5/4/1977 | 0.53 | 242 |
| 7066110 | 9/22/1977 | 0.69 | 210 |
| 7066110 | 5/11/1978 | 0.53 | 626 |
| 7066110 | 9/13/1978 | 0.56 | 140 |
| 7066110 | 5/16/1979 | 0.29 | 980 |
| 7066110 | 9/5/1979 | 0.34 | 293 |
| 7066110 | 5/6/1980 | 0.54 | 279 |
| 7066110 | 8/27/1980 | 0.73 | 121 |
| 7066110 | 6/10/1981 | 1.7 | 395 |
| 7066110 | 9/22/1981 | 0.6 | 127 |
| 7066110 | 6/30/1982 | 0.76 | 464 |
| 7066110 | 5/25/1983 | 0.6 | 700 |
| 7066110 | 9/14/1983 | 0.6 | 180 |
| 7066110 | 5/16/1984 | 0.7 | 775 |
| 7066110 | 5/15/1985 | 0.6 | 1140 |
| 7066110 | 9/11/1985 | 0.6 | 329 |
| 7066110 | 10/15/1986 | 1.1 | 205 |
| 7066110 | 5/12/1987 | 0.8 | 220 |
| 7066110 | 10/14/1987 | 0.5 | 145 |
| 7066110 | 5/18/1988 | 0.6 | 282 |
| 7066110 | 10/12/1988 | 0.5 | 172 |
| 7066110 | 5/24/1989 | 0.9 | 1380 |
| 7066110 | 11/20/1990 | 0.6 | 126 |
| 7066110 | 11/12/1992 | 0.9 | 2200 |
| 7066110 | 1/22/1993 | 0.52 | 1200 |
| 7066110 | 7/9/1993 | 0.59 | 274 |
| 7066110 | 8/7/1995 | 0.58 | 262 |
| 7066110 | 4/1/1996 | 0.69 | 1340 |
| 7066110 | 11/6/1996 | 0.54 | 123 |
| 7066110 | 6/10/1997 | 0.49 | 410 |
| 7066110 | 1/26/1999 | 0.45 | 530 |
| 7066110 | 3/2/1999 | 0.52 | 390 |
| 7066110 | 4/5/1999 | 0.29 | 860 |
| 7066110 | 6/17/1999 | 0.51 | 220 |
| 7066110 | 8/18/1999 | 0.5 | 196 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064555 | 7/30/1973 | 0.02 | 93 |
| 7064555 | 5/5/1977 | 0.02 | 55 |
| 7064555 | 5/11/1978 | 0.01 | 105 |
| 7064555 | 5/15/1979 | 0.01 | 110 |
| 7064555 | 9/5/1979 | 0.01 | 57 |
| 7064555 | 5/7/1980 | 0.02 | 61 |
| 7064555 | 8/26/1980 | 0.01 | 21 |
| 7064555 | 6/11/1981 | 0.02 | 98 |
| 7064555 | 9/21/1981 | 0.02 | 9.8 |
| 7064555 | 7/1/1982 | 0.05 | 119 |
| 7064555 | 5/26/1983 | 0.02 | 132 |
| 7064555 | 5/15/1984 | 0.01 | 141 |
| 7064555 | 5/6/1986 | 0.01 | 101 |
| 7064555 | 10/14/1986 | 0.01 | 70 |
| 7064555 | 5/11/1987 | 0.01 | 85 |
| 7064555 | 10/13/1987 | 0.01 | 23 |
| 7064555 | 5/17/1988 | 0.02 | 75 |
| 7064555 | 10/11/1988 | 0.01 | 32 |
| 7064555 | 10/23/1989 | 0.01 | 28 |
| 7064555 | 10/22/1991 | 0.02 | 34 |
| 7064555 | 4/13/1993 | 0.04 | 124 |
| 7064555 | 10/19/1993 | 0.03 | 112 |
| 7064555 | 10/10/1995 | 0.04 | 49 |
| 7064555 | 10/1/1996 | 0.18 | 126 |
| 7064530 | 4/2/1973 | 0.004 | 500 |
| 7064530 | 6/18/1973 | 0.02 | 232 |
| 7064530 | 7/30/1973 | 0.03 | 272 |
| 7064530 | 5/5/1977 | 0.03 | 130 |
| 7064530 | 5/12/1978 | 0.01 | 299 |
| 7064530 | 5/15/1979 | 0.01 | 387 |
| 7064530 | 9/4/1979 | 0.01 | 127 |
| 7064530 | 5/8/1980 | 0.03 | 158 |
| 7064530 | 8/26/1980 | 0.01 | 103 |
| 7064530 | 6/11/1981 | 0.19 | 144 |
| 7064530 | 9/21/1981 | 0.02 | 111 |
| 7064530 | 6/29/1982 | 0.05 | 337 |
| 7064530 | 5/24/1983 | 0.01 | 356 |
| 7064530 | 9/15/1983 | 0.01 | 90 |
| 7064530 | 5/15/1984 | 0.01 | 271 |
| 7064530 | 9/18/1984 | 0.01 | 172 |
| 7064530 | 9/10/1985 | 0.01 | 244 |
| 7064530 | 5/6/1986 | 0.01 | 209 |
| 7064530 | 10/14/1986 | 0.01 | 176 |
| 7064530 | 5/11/1987 | 0.01 | 173 |
| 7064530 | 10/13/1987 | 0.01 | 97 |
| 7064530 | 5/17/1988 | 0.02 | 240 |
| 7064530 | 10/11/1988 | 0.01 | 115 |
| 7064530 | 10/23/1989 | 0.01 | 101 |
| 7064530 | 11/19/1990 | 0.01 | 171 |
| 7064530 | 10/22/1991 | 0.01 | 117 |
| 7064530 | 10/19/1994 | 0.18 | 169 |
| 7064530 | 10/10/1995 | 0.02 | 138 |
| 7065500 | 9/23/1976 | 0.01 | 78 |
| 7065500 | 5/10/1978 | 0.01 | 189 |
| 7065500 | 9/5/1979 | 0.01 | 118 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7066110 | 11/1/1999 | 0.41 | 179 |
| 7066110 | 3/20/2000 | 0.66 | 333 |
| 7066110 | 5/8/2000 | 0.43 | 180 |
| 7066110 | 7/17/2000 | 0.4 | 170 |
| 7066110 | 9/11/2000 | 0.35 | 145 |
| 7066110 | 11/13/2000 | 1.2 | 215 |
| 7066110 | 5/10/2001 | 0.39 | 225 |
| 7066110 | 7/17/2001 | 0.29 | 152 |
| 7066110 | 9/4/2001 | 0.31 | 110 |
| 7066110 | 1/22/2002 | 0.51 | 144 |
| 7066110 | 3/5/2002 | 0.4 | 504 |
| 7066110 | 5/13/2002 | 0.5 | 2400 |
| 7066110 | 7/15/2002 | 0.37 | 304 |
| 7066110 | 9/5/2002 | 0.48 | 288 |
| 7066110 | 3/11/2003 | 0.48 | 398 |
| 7066110 | 5/19/2003 | 0.37 | 1170 |
| 7066110 | 7/7/2003 | 0.41 | 271 |
| 7066110 | 9/5/2003 | 0.53 | 761 |
| 7066110 | 11/17/2003 | 0.33 | 340 |
| 7066110 | 1/22/2004 | 0.42 | 853 |
| 7066110 | 5/5/2004 | 0.44 | 1020 |
| 7066110 | 7/6/2004 | 0.35 | 404 |
| 7066110 | 9/7/2004 | 0.42 | 230 |
| 7066110 | 11/22/2004 | 0.54 | 425 |
| 7066110 | 1/25/2005 | 0.62 | 760 |
| 7066110 | 3/15/2005 | 0.45 | 428 |
| 7066110 | 5/19/2005 | 0.37 | 310 |
| 7066110 | 7/18/2005 | 0.38 | 210 |
| 7066110 | 9/1/2005 | 0.33 | 206 |
| 7066110 | 1/4/2006 | 0.5 | 165 |
| 7066110 | 3/1/2006 | 0.34 | 170 |
| 7066110 | 5/8/2006 | 0.29 | 1170 |
| 7066110 | 7/10/2006 | 0.39 | 166 |
| 7066110 | 11/15/2006 | 0.49 | 384 |
| 7066110 | 1/24/2007 | 0.29 | 984 |
| 7066110 | 2/14/2007 | 0.69 | 2400 |
| 7066110 | 4/3/2007 | 0.31 | 440 |
| 7066110 | 5/2/2007 | 0.34 | 530 |
| 7066110 | 6/11/2007 | 0.38 | 282 |
| 7066110 | 7/16/2007 | 0.44 | 206 |
| 7066110 | 9/4/2007 | 0.36 | 162 |
| 7066110 | 5/5/2008 | 0.35 | 650 |
| 7066110 | 7/7/2008 | 0.39 | 340 |
| 7066110 | 10/6/2008 | 0.4 | 230 |
| 7066110 | 1/12/2009 | 0.5 | 250 |
| 7066110 | 3/2/2009 | 0.49 | 322 |
| 7066110 | 5/28/2009 | 0.38 | 613 |
| 7066110 | 7/6/2009 | 0.48 | 310 |
| 7066110 | 9/9/2009 | 0.42 | 334 |
| 7066110 | 10/28/2009 | 0.51 | 1600 |
| 7064555 | 6/18/1973 | 0.76 | 164 |
| 7064555 | 7/30/1973 | 0.63 | 93 |
| 7064555 | 10/15/1973 | 0.68 | 114 |
| 7064555 | 9/24/1976 | 0.51 | 24 |
| 7064555 | 5/5/1977 | 0.67 | 55 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7065500 | 8/27/1980 | 0.01 | 73 |
| 7065500 | 9/22/1981 | 0.01 | 82 |
| 7065500 | 5/16/1984 | 0.01 | 297 |
| 7065500 | 5/7/1986 | 0.01 | 139 |
| 7065500 | 5/12/1987 | 0.01 | 115 |
| 7065500 | 10/25/1989 | 0.01 | 88 |
| 7065500 | 5/30/1991 | 0.01 | 163 |
| 7065500 | 10/16/1973 | 0.02 | 201 |
| 7065500 | 5/4/1977 | 0.02 | 148 |
| 7065500 | 5/16/1979 | 0.02 | 320 |
| 7065500 | 5/6/1980 | 0.02 | 138 |
| 7065500 | 6/10/1981 | 0.02 | 137 |
| 7065500 | 5/25/1983 | 0.02 | 197 |
| 7065500 | 5/18/1988 | 0.02 | 129 |
| 7065500 | 10/12/1988 | 0.02 | 96 |
| 7065500 | 10/22/1991 | 0.02 | 87 |
| 7065500 | 10/10/1995 | 0.02 | 103 |
| 7065500 | 10/8/2002 | 0.02 | 98 |
| 7065500 | 4/4/1973 | 0.021 | 309 |
| 7065500 | 6/19/1973 | 0.03 | 179 |
| 7065500 | 7/31/1973 | 0.03 | 141 |
| 7065500 | 7/10/1974 | 0.03 | 169 |
| 7065500 | 4/14/1993 | 0.03 | 204 |
| 7065500 | 6/30/1982 | 0.04 | 147 |
| 7066550 | 6/21/1973 | 0.03 | 176 |
| 7066550 | 8/1/1973 | 0.02 | 155 |
| 7066550 | 10/17/1973 | 0.02 | 180 |
| 7066550 | 5/4/1977 | 0.01 | 154 |
| 7066550 | 5/16/1979 | 0.01 | 273 |
| 7066550 | 9/5/1979 | 0.01 | 103 |
| 7066550 | 5/6/1980 | 0.03 | 102 |
| 7066550 | 6/10/1981 | 0.01 | 114 |
| 7066550 | 6/30/1982 | 0.04 | 128 |
| 7066550 | 5/25/1983 | 0.02 | 237 |
| 7066550 | 5/16/1984 | 0.01 | 254 |
| 7066550 | 9/11/1985 | 0.01 | 121 |
| 7066550 | 5/12/1987 | 0.01 | 118 |
| 7066550 | 5/18/1988 | 0.02 | 118 |
| 7066550 | 10/12/1988 | 0.01 | 96 |
| 7066550 | 10/23/1991 | 0.01 | 108 |
| 7066550 | 10/20/1994 | 0.02 | 98 |
| 7066550 | 5/23/1995 | 0.03 | 242 |
| 7066550 | 10/2/1996 | 0.02 | 232 |
| 7066550 | 10/7/2002 | 0.02 | 96 |
| 7014000 | 11/23/1993 | 0.03 | 244 |
| 7014000 | 3/11/1994 | 0.02 | 266 |
| 7014000 | 3/11/1994 | 0.02 | 266 |
| 7014000 | 6/23/1994 | 0.02 | 175 |
| 7014000 | 8/29/1994 | 0.09 | 115 |
| 7014000 | 1/13/1995 | 0.03 | 352 |
| 7014000 | 3/20/1995 | 0.02 | 245 |
| 7014000 | 8/7/1995 | 0.02 | 127 |
| 7014000 | 4/9/1996 | 0.02 | 245 |
| 7014000 | 6/24/1996 | 0.02 | 310 |
| 7014000 | 3/10/1997 | 0.03 | 330 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064555 | 9/22/1977 | 0.62 | 15 |
| 7064555 | 5/11/1978 | 0.69 | 105 |
| 7064555 | 9/14/1978 | 1 | 21 |
| 7064555 | 5/15/1979 | 0.48 | 110 |
| 7064555 | 9/5/1979 | 0.66 | 57 |
| 7064555 | 5/7/1980 | 0.9 | 61 |
| 7064555 | 8/26/1980 | 0.87 | 21 |
| 7064555 | 6/11/1981 | 1 | 98 |
| 7064555 | 7/1/1982 | 1 | 119 |
| 7064555 | 5/26/1983 | 0.8 | 132 |
| 7064555 | 9/15/1983 | 0.9 | 49 |
| 7064555 | 5/14/1985 | 0.8 | 153 |
| 7064555 | 9/10/1985 | 0.9 | 77 |
| 7064555 | 10/14/1986 | 1.1 | 70 |
| 7064555 | 5/11/1987 | 0.7 | 85 |
| 7064555 | 10/11/1988 | 0.9 | 32 |
| 7064555 | 10/23/1989 | 0.9 | 28 |
| 7064555 | 5/30/1991 | 0.63 | 115 |
| 7064555 | 5/2/2000 | 0.62 | 26 |
| 7064555 | 5/8/2001 | 0.58 | 24 |
| 7064555 | 5/30/2002 | 0.42 | 150 |
| 7064555 | 10/8/2002 | 0.6 | 33 |
| 7064555 | 5/6/2003 | 0.54 | 113 |
| 7064530 | 6/18/1973 | 0.81 | 232 |
| 7064530 | 7/30/1973 | 0.87 | 272 |
| 7064530 | 10/15/1973 | 0.91 | 284 |
| 7064530 | 9/24/1976 | 0.58 | 65 |
| 7064530 | 5/5/1977 | 0.86 | 130 |
| 7064530 | 9/23/1977 | 0.8 | 75 |
| 7064530 | 5/12/1978 | 1.5 | 299 |
| 7064530 | 9/14/1978 | 1.1 | 113 |
| 7064530 | 5/15/1979 | 0.96 | 387 |
| 7064530 | 9/4/1979 | 1.1 | 127 |
| 7064530 | 5/8/1980 | 0.82 | 158 |
| 7064530 | 8/26/1980 | 1 | 103 |
| 7064530 | 6/11/1981 | 2.1 | 144 |
| 7064530 | 9/21/1981 | 1.1 | 111 |
| 7064530 | 6/29/1982 | 1.2 | 337 |
| 7064530 | 5/24/1983 | 1.4 | 356 |
| 7064530 | 9/15/1983 | 1.1 | 90 |
| 7064530 | 5/15/1984 | 1.4 | 271 |
| 7064530 | 9/10/1985 | 0.9 | 244 |
| 7064530 | 10/14/1986 | 1.7 | 176 |
| 7064530 | 5/11/1987 | 1.2 | 173 |
| 7064530 | 10/13/1987 | 0.9 | 97 |
| 7064530 | 10/11/1988 | 1 | 115 |
| 7064530 | 5/30/1991 | 0.83 | 300 |
| 7064530 | 10/1/1996 | 1.1 | 241 |
| 7065500 | 6/19/1973 | 0.74 | 179 |
| 7065500 | 7/31/1973 | 0.74 | 141 |
| 7065500 | 10/16/1973 | 0.97 | 201 |
| 7065500 | 7/10/1974 | 0.7 | 169 |
| 7065500 | 9/23/1976 | 0.57 | 78 |
| 7065500 | 5/4/1977 | 0.96 | 148 |
| 7065500 | 9/21/1977 | 0.82 | 105 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014000 | 11/15/2000 | 0.078 | 105 |
| 7014000 | 5/9/2002 | 0.06 | 3050 |
| 7014500 | 1/19/1993 | 0.02 | 1450 |
| 7014500 | 4/8/1993 | 0.03 | 2090 |
| 7014500 | 5/19/1993 | 0.08 | 5020 |
| 7014500 | 6/1/1993 | 0.02 | 870 |
| 7014500 | 7/6/1993 | 0.05 | 833 |
| 7014500 | 8/12/1993 | 0.17 | 6830 |
| 7014500 | 9/30/1993 | 0.03 | 3210 |
| 7014500 | 10/6/1993 | 0.02 | 1640 |
| 7014500 | 11/3/1993 | 0.02 | 1070 |
| 7014500 | 12/2/1993 | 0.04 | 1840 |
| 7014500 | 2/14/1994 | 0.03 | 703 |
| 7014500 | 3/1/1994 | 0.04 | 1580 |
| 7014500 | 3/8/1994 | 0.02 | 1190 |
| 7014500 | 5/25/1994 | 0.02 | 1660 |
| 7014500 | 6/23/1994 | 0.02 | 966 |
| 7014500 | 8/31/1994 | 0.02 | 811 |
| 7014500 | 9/12/1994 | 0.02 | 669 |
| 7014500 | 3/22/1995 | 0.02 | 1270 |
| 7014500 | 5/9/1995 | 0.07 | 5890 |
| 7014500 | 6/12/1995 | 0.03 | 4620 |
| 7014500 | 7/18/1995 | 0.02 | 727 |
| 7014500 | 9/11/1995 | 0.02 | 405 |
| 7014500 | 10/3/1995 | 0.03 | 392 |
| 7014500 | 2/27/1996 | 0.02 | 500 |
| 7014500 | 7/24/1996 | 0.02 | 505 |
| 7014500 | 1/14/1997 | 0.02 | 670 |
| 7014500 | 2/5/1997 | 0.02 | 3450 |
| 7014500 | 3/13/1997 | 0.03 | 2230 |
| 7014500 | 4/7/1997 | 0.02 | 3800 |
| 7014500 | 1/19/1999 | 0.04 | 3180 |
| 7014500 | 2/9/1999 | 0.16 | 7760 |
| 7014500 | 4/26/1999 | 0.07 | 4540 |
| 7014500 | 5/20/1999 | 0.04 | 1260 |
| 7014500 | 8/10/1999 | 0.08 | 1380 |
| 7014500 | 10/6/1999 | 0.03 | 267 |
| 7014500 | 11/16/1999 | 0.04 | 302 |
| 7014500 | 6/13/2000 | 0.04 | 274 |
| 7014500 | 8/2/2000 | 0.03 | 242 |
| 7014500 | 11/7/2000 | 0.04 | 322 |
| 7014500 | 7/25/2001 | 0.03 | 226 |
| 7014500 | 3/28/2002 | 0.04 | 3000 |
| 7014500 | 5/23/2002 | 0.03 | 2800 |
| 7014500 | 8/12/2002 | 0.03 | 373 |
| 7014500 | 4/8/2003 | 0.02 | 1870 |
| 7014500 | 5/5/2003 | 0.06 | 2450 |
| 7014500 | 8/6/2003 | 0.03 | 373 |
| 7014500 | 12/17/2003 | 0.02 | 772 |
| 7014500 | 1/21/2004 | 0.02 | 1770 |
| 7014500 | 5/4/2004 | 0.05 | 3140 |
| 7014500 | 9/1/2004 | 0.03 | 642 |
| 7014500 | 11/3/2004 | 0.07 | 1570 |
| 7014500 | 12/14/2004 | 0.02 | 1180 |
| 7014500 | 5/17/2006 | 0.03 | 1710 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7065500 | 5/10/1978 | 1 | 189 |
| 7065500 | 9/13/1978 | 0.77 | 96 |
| 7065500 | 5/16/1979 | 0.62 | 320 |
| 7065500 | 9/5/1979 | 0.79 | 118 |
| 7065500 | 5/6/1980 | 0.86 | 138 |
| 7065500 | 8/27/1980 | 0.68 | 73 |
| 7065500 | 6/10/1981 | 2 | 137 |
| 7065500 | 9/22/1981 | 1 | 82 |
| 7065500 | 6/30/1982 | 1.2 | 147 |
| 7065500 | 5/25/1983 | 1.1 | 197 |
| 7065500 | 9/14/1983 | 1 | 93 |
| 7065500 | 5/16/1984 | 1 | 297 |
| 7065500 | 5/15/1985 | 0.8 | 213 |
| 7065500 | 9/11/1985 | 1.1 | 139 |
| 7065500 | 5/7/1986 | 0.9 | 139 |
| 7065500 | 10/15/1986 | 1.5 | 100 |
| 7065500 | 5/12/1987 | 1.1 | 115 |
| 7065500 | 10/12/1988 | 1.1 | 96 |
| 7065500 | 5/25/1989 | 0.8 | 202 |
| 7065500 | 5/29/2002 | 0.68 | 311 |
| 7065500 | 5/6/2003 | 0.7 | 175 |
| 7065500 | 5/18/2004 | 0.66 | 262 |
| 7065500 | 5/9/2006 | 0.62 | 350 |
| 7066550 | 6/21/1973 | 0.45 | 176 |
| 7066550 | 8/1/1973 | 0.68 | 155 |
| 7066550 | 10/17/1973 | 0.63 | 180 |
| 7066550 | 9/23/1976 | 0.37 | 91 |
| 7066550 | 5/4/1977 | 0.58 | 154 |
| 7066550 | 9/22/1977 | 0.54 | 104 |
| 7066550 | 5/11/1978 | 0.66 | 115 |
| 7066550 | 9/13/1978 | 1 | 93 |
| 7066550 | 5/16/1979 | 0.63 | 273 |
| 7066550 | 9/5/1979 | 0.9 | 103 |
| 7066550 | 5/6/1980 | 0.86 | 102 |
| 7066550 | 8/27/1980 | 0.78 | 92 |
| 7066550 | 6/10/1981 | 1.1 | 114 |
| 7066550 | 9/22/1981 | 1.1 | 116 |
| 7066550 | 6/30/1982 | 1.1 | 128 |
| 7066550 | 5/25/1983 | 1 | 237 |
| 7066550 | 9/14/1983 | 0.9 | 88 |
| 7066550 | 5/16/1984 | 0.9 | 254 |
| 7066550 | 9/11/1985 | 0.6 | 121 |
| 7066550 | 10/15/1986 | 1.2 | 119 |
| 7066550 | 5/12/1987 | 0.6 | 118 |
| 7066550 | 5/29/1991 | 1.9 | 214 |
| 7066550 | 5/7/2001 | 0.43 | 100 |
| 7066550 | 5/28/2002 | 0.65 | 239 |
| 7066550 | 5/9/2006 | 0.31 | 154 |
| 7014000 | 11/23/1993 | 0.48 | 244 |
| 7014000 | 8/7/1995 | 0.39 | 127 |
| 7014000 | 3/4/1999 | 0.36 | 200 |
| 7014000 | 4/8/1999 | 0.28 | 394 |
| 7014000 | 6/14/1999 | 0.36 | 153 |
| 7014000 | 8/19/1999 | 0.73 | 66 |
| 7014000 | 11/15/1999 | 0.25 | 56 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014500 | 4/2/2007 | 0.05 | 2660 |
| 7014500 | 7/10/2007 | 0.02 | 425 |
| 7014500 | 2/6/2008 | 0.02 | 1950 |
| 7014500 | 3/25/2008 | 0.04 | 3270 |
| 7014500 | 4/15/2008 | 0.04 | 3310 |
| 7014500 | 6/3/2008 | 0.02 | 903 |
| 7014500 | 7/22/2008 | 0.02 | 415 |
| 7014500 | 9/2/2008 | 0.03 | 440 |
| 7014500 | 4/20/2009 | 0.18 | 10400 |
| 7014500 | 10/29/2009 | 0.04 | 3870 |
| 7010500 | 11/17/1993 | 0.04 | 1100 |
| 7010500 | 1/20/1994 | 0.02 | 135 |
| 7010500 | 3/8/1994 | 0.03 | 255 |
| 7010500 | 6/23/1994 | 0.03 | 135 |
| 7010500 | 8/29/1994 | 0.02 | 80 |
| 7010500 | 11/3/1994 | 0.04 | 130 |
| 7010500 | 1/13/1995 | 0.02 | 285 |
| 7010500 | 3/22/1995 | 0.05 | 90 |
| 7010500 | 8/8/1995 | 0.02 | 140 |
| 7010500 | 3/5/1996 | 0.18 | 55 |
| 7010500 | 4/10/1996 | 0.04 | 163 |
| 7010500 | 6/25/1996 | 0.03 | 170 |
| 7010500 | 11/13/1996 | 0.02 | 207 |
| 7010500 | 3/10/1997 | 0.04 | 318 |
| 7010500 | 11/16/1999 | 0.05 | 92 |
| 7010500 | 3/14/2000 | 0.03 | 114 |
| 7010500 | 5/17/2000 | 0.04 | 95 |
| 7010500 | 9/14/2000 | 0.04 | 75 |
| 7010500 | 11/8/2000 | 0.05 | 115 |
| 7010500 | 5/14/2001 | 0.04 | 72 |
| 7010500 | 7/20/2001 | 0.04 | 63 |
| 7010500 | 11/2/2001 | 0.04 | 72 |
| 7010500 | 9/5/2002 | 0.03 | 103 |
| 7010500 | 11/13/2002 | 0.03 | 105 |
| 7010500 | 1/14/2003 | 0.03 | 92 |
| 7010500 | 3/4/2003 | 0.02 | 129 |
| 7010500 | 5/5/2003 | 0.04 | 215 |
| 7010500 | 7/30/2003 | 0.03 | 129 |
| 7010500 | 11/10/2003 | 0.03 | 141 |
| 7010500 | 1/6/2004 | 0.03 | 287 |
| 7010500 | 3/15/2004 | 0.04 | 208 |
| 7010500 | 5/5/2004 | 0.03 | 190 |
| 7010500 | 7/27/2004 | 0.03 | 205 |
| 7010500 | 9/2/2004 | 0.02 | 197 |
| 7066000 | 5/11/1999 | 0.068 | 627 |
| 7066000 | 8/11/1999 | 0.004 | 194 |
| 7066000 | 11/8/1999 | 0.006 | 154 |
| 7066000 | 3/1/2000 | 0.004 | 542 |
| 7066000 | 5/24/2000 | 0.005 | 130 |
| 7066000 | 5/25/2000 | 0.01 | 235 |
| 7066000 | 7/11/2000 | 0.004 | 160 |
| 7066000 | 7/27/2000 | 0.004 | 143 |
| 7066000 | 8/10/2000 | 0.005 | 129 |
| 7066000 | 12/20/2000 | 0.002 | 160 |
| 7066000 | 2/21/2001 | 0.005 | 410 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014000 | 1/11/2000 | 0.26 | 92 |
| 7014000 | 3/14/2000 | 0.26 | 100 |
| 7014000 | 5/17/2000 | 0.25 | 47 |
| 7014000 | 7/6/2000 | 0.24 | 76 |
| 7014000 | 9/7/2000 | 0.17 | 29 |
| 7014000 | 11/15/2000 | 0.76 | 105 |
| 7014000 | 3/22/2001 | 0.64 | 110 |
| 7014000 | 5/10/2001 | 0.36 | 66 |
| 7014000 | 7/11/2001 | 0.27 | 37 |
| 7014000 | 11/1/2001 | 0.11 | 57 |
| 7014000 | 1/23/2002 | 0.35 | 70 |
| 7014000 | 3/28/2002 | 0.37 | 469 |
| 7014000 | 5/9/2002 | 0.55 | 3050 |
| 7014000 | 9/3/2002 | 0.3 | 77 |
| 7014000 | 11/12/2002 | 0.19 | 84 |
| 7014000 | 1/13/2003 | 0.47 | 127 |
| 7014000 | 3/3/2003 | 0.34 | 255 |
| 7014000 | 5/6/2003 | 0.28 | 478 |
| 7014000 | 7/29/2003 | 0.31 | 69 |
| 7014000 | 9/11/2003 | 0.28 | 56 |
| 7014000 | 1/8/2004 | 0.38 | 88 |
| 7014000 | 3/17/2004 | 0.43 | 63 |
| 7014000 | 5/5/2004 | 0.31 | 438 |
| 7014000 | 7/27/2004 | 0.28 | 64 |
| 7014000 | 9/2/2004 | 0.28 | 163 |
| 7014000 | 11/9/2004 | 0.28 | 101 |
| 7014000 | 3/1/2005 | 0.28 | 175 |
| 7014000 | 5/18/2005 | 0.22 | 135 |
| 7014000 | 7/6/2005 | 0.23 | 58 |
| 7014000 | 9/7/2005 | 0.28 | 67 |
| 7014000 | 11/22/2005 | 0.38 | 139 |
| 7014000 | 1/10/2006 | 0.28 | 86 |
| 7014000 | 3/21/2006 | 0.43 | 408 |
| 7014000 | 5/9/2006 | 0.24 | 238 |
| 7014000 | 11/8/2006 | 0.24 | 163 |
| 7014000 | 2/14/2007 | 0.46 | 659 |
| 7014000 | 4/2/2007 | 0.28 | 579 |
| 7014000 | 5/22/2007 | 0.24 | 114 |
| 7014000 | 6/5/2007 | 0.26 | 86 |
| 7014000 | 7/13/2007 | 0.24 | 57 |
| 7014000 | 3/24/2008 | 0.54 | 629 |
| 7014000 | 5/19/2008 | 0.18 | 394 |
| 7014000 | 7/21/2008 | 0.28 | 70 |
| 7014000 | 9/2/2008 | 0.28 | 81 |
| 7014000 | 10/27/2008 | 0.14 | 141 |
| 7014000 | 5/26/2009 | 0.15 | 494 |
| 7014000 | 7/21/2009 | 0.24 | 221 |
| 7014000 | 10/27/2009 | 0.46 | 255 |
| 7014500 | 1/19/1993 | 0.82 | 1450 |
| 7014500 | 5/19/1993 | 0.81 | 5020 |
| 7014500 | 7/6/1993 | 0.67 | 833 |
| 7014500 | 11/3/1993 | 0.35 | 1070 |
| 7014500 | 3/1/1994 | 0.64 | 1580 |
| 7014500 | 3/21/1994 | 0.34 | 854 |
| 7014500 | 8/31/1994 | 0.68 | 811 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7066000 | 3/21/2001 | 0.004 | 242 |
| 7066000 | 4/24/2001 | 0.004 | 218 |
| 7066000 | 5/25/2001 | 0.006 | 215 |
| 7066000 | 5/26/2001 | 0.003 | 202 |
| 7066000 | 5/26/2001 | 0.006 | 202 |
| 7066000 | 5/27/2001 | 0.003 | 190 |
| 7066000 | 5/27/2001 | 0.003 | 186 |
| 7066000 | 6/6/2001 | 0.007 | 211 |
| 7066000 | 7/31/2001 | 0.005 | 136 |
| 7066000 | 8/8/2001 | 0.004 | 112 |
| 7066000 | 8/8/2001 | 0.005 | 112 |
| 7066000 | 8/9/2001 | 0.005 | 116 |
| 7066000 | 8/9/2001 | 0.008 | 116 |
| 7066000 | 9/18/2001 | 0.003 | 112 |
| 7066000 | 10/2/2001 | 0.003 | 104 |
| 7066000 | 10/10/2001 | 0.002 | 109 |
| 7066000 | 10/10/2001 | 0.007 | 109 |
| 7066000 | 10/11/2001 | 0.003 | 116 |
| 7066000 | 10/11/2001 | 0.004 | 116 |
| 7066000 | 11/20/2001 | 0.002 | 112 |
| 7066000 | 4/2/2002 | 0.005 | 590 |
| 7066000 | 4/30/2002 | 0.006 | 760 |
| 7066000 | 5/29/2002 | 0.009 | 657 |
| 7066000 | 6/4/2002 | 0.005 | 488 |
| 7066000 | 6/28/2002 | 0.006 | 309 |
| 7066000 | 6/29/2002 | 0.01 | 297 |
| 7066000 | 7/29/2002 | 0.006 | 266 |
| 7066000 | 8/6/2002 | 0.004 | 220 |
| 7066000 | 8/7/2002 | 0.004 | 216 |
| 7066000 | 10/8/2002 | 0.005 | 161 |
| 7066000 | 10/9/2002 | 0.004 | 164 |
| 7066000 | 6/3/2003 | 0.003 | 270 |
| 7066000 | 6/9/2003 | 0.019 | 263 |
| 7066000 | 6/28/2003 | 0.004 | 185 |
| 7066000 | 7/26/2003 | 0.005 | 169 |
| 7066000 | 8/6/2003 | 0.005 | 226 |
| 7066000 | 9/23/2003 | 0.004 | 201 |
| 7066000 | 10/8/2003 | 0.004 | 151 |
| 7066000 | 6/15/2004 | 0.01 | 368 |
| 7066000 | 6/26/2004 | 0.005 | 266 |
| 7066000 | 7/13/2004 | 0.005 | 216 |
| 7066000 | 8/11/2004 | 0.002 | 186 |
| 7066000 | 8/21/2004 | 0.003 | 174 |
| 7066000 | 9/21/2004 | 0.005 | 147 |
| 7066000 | 10/5/2004 | 0.004 | 125 |
| 7066000 | 6/14/2005 | 0.005 | 150 |
| 7066000 | 7/5/2005 | 0.005 | 127 |
| 7066000 | 8/9/2005 | 0.005 | 142 |
| 7065000 | 4/3/1973 | 0.013 | 158 |
| 7065000 | 6/19/1973 | 0.04 | 60 |
| 7065000 | 7/31/1973 | 0.02 | 48 |
| 7065000 | 10/16/1973 | 0.02 | 71 |
| 7065000 | 5/5/1977 | 0.04 | 28 |
| 7065000 | 5/16/1979 | 0.01 | 118 |
| 7065000 | 9/5/1979 | 0.01 | 40 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014500 | 9/12/1994 | 0.41 | 669 |
| 7014500 | 10/12/1994 | 0.41 | 480 |
| 7014500 | 4/24/1995 | 0.44 | 3490 |
| 7014500 | 5/9/1995 | 0.45 | 5890 |
| 7014500 | 6/12/1995 | 0.92 | 4620 |
| 7014500 | 7/5/1995 | 0.42 | 1260 |
| 7014500 | 7/18/1995 | 0.48 | 727 |
| 7014500 | 9/11/1995 | 0.4 | 405 |
| 7014500 | 10/3/1995 | 0.3 | 392 |
| 7014500 | 1/9/1996 | 0.56 | 500 |
| 7014500 | 1/22/1996 | 0.7 | 1440 |
| 7014500 | 4/16/1996 | 0.48 | 1470 |
| 7014500 | 5/22/1996 | 0.46 | 1450 |
| 7014500 | 7/24/1996 | 0.51 | 505 |
| 7014500 | 10/7/1996 | 0.6 | 592 |
| 7014500 | 12/5/1996 | 0.56 | 2460 |
| 7014500 | 2/5/1997 | 0.59 | 3450 |
| 7014500 | 4/7/1997 | 0.57 | 3800 |
| 7014500 | 6/17/1997 | 0.54 | 2220 |
| 7014500 | 7/9/1997 | 0.27 | 812 |
| 7014500 | 1/19/1999 | 0.85 | 3180 |
| 7014500 | 2/9/1999 | 1.3 | 7760 |
| 7014500 | 3/24/1999 | 0.37 | 1800 |
| 7014500 | 4/26/1999 | 0.72 | 4540 |
| 7014500 | 5/20/1999 | 0.24 | 1260 |
| 7014500 | 6/29/1999 | 0.42 | 1170 |
| 7014500 | 7/21/1999 | 0.24 | 381 |
| 7014500 | 8/10/1999 | 0.95 | 1380 |
| 7014500 | 9/9/1999 | 0.28 | 272 |
| 7014500 | 10/6/1999 | 1.5 | 267 |
| 7014500 | 11/16/1999 | 0.16 | 302 |
| 7014500 | 12/8/1999 | 0.25 | 494 |
| 7014500 | 1/11/2000 | 0.16 | 517 |
| 7014500 | 2/8/2000 | 0.22 | 338 |
| 7014500 | 3/15/2000 | 0.22 | 662 |
| 7014500 | 4/4/2000 | 0.2 | 576 |
| 7014500 | 6/13/2000 | 0.59 | 274 |
| 7014500 | 7/5/2000 | 0.27 | 288 |
| 7014500 | 1/24/2001 | 0.16 | 333 |
| 7014500 | 2/15/2001 | 0.6 | 895 |
| 7014500 | 3/27/2001 | 0.35 | 489 |
| 7014500 | 4/18/2001 | 0.4 | 1000 |
| 7014500 | 5/14/2001 | 0.23 | 324 |
| 7014500 | 6/13/2001 | 0.21 | 523 |
| 7014500 | 7/25/2001 | 0.28 | 226 |
| 7014500 | 8/14/2001 | 0.23 | 355 |
| 7014500 | 9/6/2001 | 0.19 | 175 |
| 7014500 | 12/5/2001 | 0.34 | 673 |
| 7014500 | 1/23/2002 | 0.3 | 312 |
| 7014500 | 2/12/2002 | 0.66 | 821 |
| 7014500 | 3/28/2002 | 0.53 | 3000 |
| 7014500 | 4/10/2002 | 0.29 | 1860 |
| 7014500 | 5/23/2002 | 0.53 | 2800 |
| 7014500 | 6/20/2002 | 0.26 | 729 |
| 7014500 | 7/30/2002 | 0.24 | 419 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7065000 | 5/7/1980 | 0.03 | 31 |
| 7065000 | 6/9/1981 | 0.03 | 34 |
| 7065000 | 9/23/1981 | 0.01 | 20 |
| 7065000 | 7/1/1982 | 0.06 | 38 |
| 7065000 | 5/24/1983 | 0.02 | 100 |
| 7065000 | 5/17/1984 | 0.01 | 52 |
| 7065000 | 5/6/1986 | 0.01 | 58 |
| 7065000 | 10/14/1986 | 0.02 | 34 |
| 7065000 | 5/11/1987 | 0.01 | 52 |
| 7065000 | 5/17/1988 | 0.02 | 38 |
| 7065000 | 10/11/1988 | 0.01 | 21 |
| 7065000 | 10/22/1991 | 0.01 | 25 |
| 7065000 | 4/14/1993 | 0.04 | 214 |
| 7065000 | 10/21/1993 | 0.1 | 47 |
| 7065000 | 5/23/1995 | 0.02 | 82 |
| 7065000 | 10/1/1996 | 0.08 | 65 |
| 7064440 | 4/2/1973 | 0.013 | 253 |
| 7064440 | 6/18/1973 | 0.04 | 139 |
| 7064440 | 7/30/1973 | 0.04 | 107 |
| 7064440 | 10/15/1973 | 0.01 | 152 |
| 7064440 | 1/18/1974 | 0.04 | 160 |
| 7064440 | 4/17/1974 | 0.04 | 204 |
| 7064440 | 7/9/1974 | 0.03 | 146 |
| 7064440 | 10/21/1974 | 0.13 | 109 |
| 7064440 | 1/22/1975 | 0.04 | 153 |
| 7064440 | 4/15/1975 | 0.01 | 165 |
| 7064440 | 9/24/1976 | 0.03 | 64 |
| 7064440 | 5/6/1977 | 0.07 | 74 |
| 7064440 | 9/23/1977 | 0.03 | 45 |
| 7064440 | 5/12/1978 | 0.02 | 155 |
| 7064440 | 9/14/1978 | 0.02 | 58 |
| 7064440 | 5/15/1979 | 0.01 | 181 |
| 7064440 | 9/4/1979 | 0.04 | 90 |
| 7064440 | 5/8/1980 | 0.03 | 76 |
| 7064440 | 8/26/1980 | 0.03 | 62 |
| 7064440 | 6/9/1981 | 0.09 | 75 |
| 7064440 | 9/21/1981 | 0.03 | 52 |
| 7064440 | 6/29/1982 | 0.06 | 114 |
| 7064440 | 5/24/1983 | 0.01 | 172 |
| 7064440 | 9/13/1983 | 0.01 | 90 |
| 7064440 | 5/15/1984 | 0.02 | 181 |
| 7064440 | 9/18/1984 | 0.01 | 100 |
| 7064440 | 5/14/1985 | 0.01 | 196 |
| 7064440 | 9/10/1985 | 0.02 | 125 |
| 7064440 | 5/6/1986 | 0.02 | 130 |
| 7064440 | 10/14/1986 | 0.02 | 113 |
| 7064440 | 5/11/1987 | 0.02 | 114 |
| 7064440 | 10/13/1987 | 0.03 | 77 |
| 7064440 | 5/17/1988 | 0.02 | 116 |
| 7064440 | 10/11/1988 | 0.03 | 82 |
| 7064440 | 5/23/1989 | 0.02 | 221 |
| 7064440 | 10/23/1989 | 0.02 | 76 |
| 7064440 | 11/19/1990 | 0.01 | 90 |
| 7064440 | 5/30/1991 | 0.01 | 167 |
| 7064440 | 10/22/1991 | 0.03 | 81 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014500 | 8/12/2002 | 0.39 | 373 |
| 7014500 | 9/3/2002 | 0.3 | 411 |
| 7014500 | 11/14/2002 | 0.15 | 411 |
| 7014500 | 12/2/2002 | 0.11 | 351 |
| 7014500 | 1/14/2003 | 0.32 | 580 |
| 7014500 | 2/4/2003 | 0.29 | 388 |
| 7014500 | 3/4/2003 | 0.4 | 1050 |
| 7014500 | 4/8/2003 | 0.39 | 1870 |
| 7014500 | 5/5/2003 | 0.6 | 2450 |
| 7014500 | 6/9/2003 | 0.28 | 621 |
| 7014500 | 7/30/2003 | 0.29 | 351 |
| 7014500 | 8/6/2003 | 0.28 | 373 |
| 7014500 | 9/4/2003 | 0.46 | 626 |
| 7014500 | 10/20/2003 | 0.14 | 396 |
| 7014500 | 12/17/2003 | 0.41 | 772 |
| 7014500 | 1/21/2004 | 0.48 | 1770 |
| 7014500 | 2/9/2004 | 0.3 | 766 |
| 7014500 | 3/2/2004 | 0.23 | 506 |
| 7014500 | 4/20/2004 | 0.28 | 637 |
| 7014500 | 5/4/2004 | 0.54 | 3140 |
| 7014500 | 6/1/2004 | 0.24 | 784 |
| 7014500 | 7/19/2004 | 0.26 | 358 |
| 7014500 | 9/1/2004 | 0.53 | 642 |
| 7014500 | 10/14/2004 | 0.27 | 367 |
| 7014500 | 11/3/2004 | 0.67 | 1570 |
| 7014500 | 12/14/2004 | 0.47 | 1180 |
| 7014500 | 1/3/2005 | 0.31 | 465 |
| 7014500 | 2/2/2005 | 0.6 | 877 |
| 7014500 | 3/10/2005 | 0.24 | 754 |
| 7014500 | 4/5/2005 | 0.17 | 760 |
| 7014500 | 5/4/2005 | 0.15 | 1050 |
| 7014500 | 6/8/2005 | 0.37 | 386 |
| 7014500 | 7/25/2005 | 0.2 | 353 |
| 7014500 | 8/17/2005 | 0.39 | 896 |
| 7014500 | 9/1/2005 | 0.22 | 283 |
| 7014500 | 10/12/2005 | 0.17 | 381 |
| 7014500 | 11/9/2005 | 0.21 | 581 |
| 7014500 | 12/5/2005 | 0.33 | 760 |
| 7014500 | 1/9/2006 | 0.23 | 425 |
| 7014500 | 2/7/2006 | 0.16 | 620 |
| 7014500 | 3/6/2006 | 0.2 | 415 |
| 7014500 | 4/12/2006 | 0.17 | 742 |
| 7014500 | 5/17/2006 | 0.49 | 1710 |
| 7014500 | 6/14/2006 | 0.29 | 420 |
| 7014500 | 7/20/2006 | 0.22 | 214 |
| 7014500 | 9/5/2006 | 0.19 | 206 |
| 7014500 | 10/11/2006 | 0.12 | 222 |
| 7014500 | 11/7/2006 | 0.14 | 401 |
| 7014500 | 12/4/2006 | 0.7 | 1910 |
| 7014500 | 1/8/2007 | 0.33 | 522 |
| 7014500 | 2/15/2007 | 0.59 | 1690 |
| 7014500 | 3/13/2007 | 0.22 | 642 |
| 7014500 | 4/2/2007 | 0.55 | 2660 |
| 7014500 | 5/21/2007 | 0.2 | 648 |
| 7014500 | 6/5/2007 | 0.53 | 565 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064440 | 4/14/1992 | 0.01 | 122 |
| 7064440 | 9/30/1992 | 0.03 | 100 |
| 7064440 | 4/29/1993 | 0.02 | 173 |
| 7064440 | 10/21/1993 | 0.02 | 122 |
| 7064440 | 10/19/1994 | 0.02 | 91 |
| 7064440 | 5/22/1995 | 0.03 | 164 |
| 7064440 | 10/10/1995 | 0.07 | 98 |
| 7064440 | 5/8/2001 | 0.03 | 53 |
| 7064440 | 10/3/2001 | 0.03 | 48 |
| 7064440 | 10/9/2002 | 0.02 | 71 |
| 7064440 | 10/7/2004 | 0.03 | 51 |
| 7064440 | 5/8/2006 | 0.02 | 120 |
| 7066510 | 6/20/1973 | 0.03 | 1560 |
| 7066510 | 8/1/1973 | 0.02 | 1240 |
| 7066510 | 1/18/1974 | 0.03 | 1820 |
| 7066510 | 4/17/1974 | 0.03 | 2420 |
| 7066510 | 7/10/1974 | 0.02 | 1260 |
| 7066510 | 10/22/1974 | 0.02 | 850 |
| 7066510 | 1/21/1975 | 0.01 | 1870 |
| 7066510 | 5/4/1977 | 0.01 | 928 |
| 7066510 | 9/22/1977 | 0.01 | 738 |
| 7066510 | 5/16/1979 | 0.01 | 3000 |
| 7066510 | 9/5/1979 | 0.01 | 894 |
| 7066510 | 5/6/1980 | 0.01 | 798 |
| 7066510 | 6/10/1981 | 0.01 | 1190 |
| 7066510 | 9/22/1981 | 0.01 | 462 |
| 7066510 | 6/30/1982 | 0.04 | 1150 |
| 7066510 | 5/25/1983 | 0.02 | 2240 |
| 7066510 | 9/14/1983 | 0.04 | 680 |
| 7066510 | 5/12/1987 | 0.01 | 985 |
| 7066510 | 5/18/1988 | 0.02 | 932 |
| 7066510 | 10/12/1988 | 0.01 | 639 |
| 7066510 | 10/23/1991 | 0.01 | 659 |
| 7066510 | 4/13/1993 | 0.03 | 3500 |
| 7066510 | 5/23/1995 | 0.05 | 2400 |
| 7066510 | 10/7/2002 | 0.02 | 1000 |
| 7061600 | 1/13/2009 | 0.02 | 136 |
| 7061600 | 8/10/1995 | 0.01 | 248 |
| 7061600 | 9/8/2009 | 0.02 | 280 |
| 7061600 | 2/15/1994 | 0.01 | 360 |
| 7061600 | 2/12/2007 | 0.03 | 370 |
| 7061600 | 3/22/1995 | 0.02 | 416 |
| 7061600 | 7/11/1995 | 0.02 | 565 |
| 7061600 | 5/7/2008 | 0.03 | 735 |
| 7061600 | 1/29/2006 | 0.04 | 1140 |
| 7061600 | 5/21/2003 | 0.02 | 1320 |
| 7061600 | 11/18/2003 | 0.17 | 6280 |
| 7061600 | 5/14/2002 | 0.06 | 6630 |
| 7061600 | 5/11/2006 | 0.07 | 6830 |
| 7061600 | 4/12/1994 | 0.17 | 28800 |
| 7064400 | 9/24/1976 | 0.01 | 51 |
| 7064400 | 5/6/1977 | 0.03 | 60 |
| 7064400 | 5/12/1978 | 0.01 | 112 |
| 7064400 | 5/15/1979 | 0.01 | 140 |
| 7064400 | 9/4/1979 | 0.02 | 70 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014500 | 7/10/2007 | 0.25 | 425 |
| 7014500 | 8/13/2007 | 0.33 | 214 |
| 7014500 | 9/5/2007 | 0.13 | 218 |
| 7014500 | 10/23/2007 | 0.2 | 278 |
| 7014500 | 11/5/2007 | 0.11 | 274 |
| 7014500 | 1/24/2008 | 0.57 | 396 |
| 7014500 | 2/6/2008 | 0.62 | 1950 |
| 7014500 | 3/25/2008 | 0.81 | 3270 |
| 7014500 | 4/15/2008 | 0.58 | 3310 |
| 7014500 | 5/21/2008 | 0.22 | 1710 |
| 7014500 | 6/3/2008 | 0.28 | 903 |
| 7014500 | 7/22/2008 | 0.36 | 415 |
| 7014500 | 8/5/2008 | 0.2 | 425 |
| 7014500 | 9/2/2008 | 0.33 | 440 |
| 7014500 | 10/28/2008 | 0.13 | 430 |
| 7014500 | 11/13/2008 | 0.2 | 559 |
| 7014500 | 12/8/2008 | 0.31 | 363 |
| 7014500 | 1/20/2009 | 0.37 | 363 |
| 7014500 | 2/3/2009 | 0.19 | 460 |
| 7014500 | 3/23/2009 | 0.16 | 548 |
| 7014500 | 4/20/2009 | 1.1 | 10400 |
| 7014500 | 6/1/2009 | 0.35 | 1580 |
| 7014500 | 7/21/2009 | 0.24 | 815 |
| 7014500 | 8/24/2009 | 0.28 | 614 |
| 7014500 | 9/2/2009 | 0.22 | 543 |
| 7014500 | 10/29/2009 | 0.5 | 3870 |
| 7010500 | 11/17/1993 | 0.78 | 1100 |
| 7010500 | 8/8/1995 | 0.93 | 140 |
| 7010500 | 11/13/1996 | 0.88 | 207 |
| 7010500 | 6/19/1997 | 0.76 | 384 |
| 7010500 | 11/16/1999 | 0.87 | 92 |
| 7010500 | 1/12/2000 | 0.88 | 102 |
| 7010500 | 5/17/2000 | 0.72 | 95 |
| 7010500 | 7/5/2000 | 0.64 | 79 |
| 7010500 | 9/14/2000 | 0.84 | 75 |
| 7010500 | 11/8/2000 | 0.77 | 115 |
| 7010500 | 1/9/2001 | 0.89 | 58 |
| 7010500 | 3/27/2001 | 1 | 104 |
| 7010500 | 5/14/2001 | 0.75 | 72 |
| 7010500 | 7/20/2001 | 0.76 | 63 |
| 7010500 | 9/6/2001 | 0.66 | 72 |
| 7010500 | 11/2/2001 | 0.75 | 72 |
| 7010500 | 1/28/2002 | 0.87 | 77 |
| 7010500 | 5/21/2002 | 0.6 | 411 |
| 7010500 | 7/29/2002 | 0.88 | 135 |
| 7010500 | 9/5/2002 | 0.91 | 103 |
| 7010500 | 11/13/2002 | 0.47 | 105 |
| 7010500 | 1/14/2003 | 0.89 | 92 |
| 7010500 | 5/5/2003 | 0.7 | 215 |
| 7010500 | 7/30/2003 | 0.92 | 129 |
| 7010500 | 9/4/2003 | 0.84 | 123 |
| 7010500 | 1/6/2004 | 0.78 | 287 |
| 7010500 | 3/15/2004 | 0.89 | 208 |
| 7010500 | 5/5/2004 | 0.63 | 190 |
| 7010500 | 9/2/2004 | 0.96 | 197 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064400 | 8/26/1980 | 0.01 | 43 |
| 7064400 | 6/9/1981 | 0.02 | 64 |
| 7064400 | 9/21/1981 | 0.01 | 46 |
| 7064400 | 6/29/1982 | 0.07 | 106 |
| 7064400 | 5/24/1983 | 0.01 | 132 |
| 7064400 | 9/13/1983 | 0.05 | 70 |
| 7064400 | 5/15/1984 | 0.01 | 123 |
| 7064400 | 9/18/1984 | 0.01 | 77 |
| 7064400 | 5/14/1985 | 0.05 | 151 |
| 7064400 | 9/10/1985 | 0.02 | 95 |
| 7064400 | 5/6/1986 | 0.01 | 102 |
| 7064400 | 10/14/1986 | 0.02 | 83 |
| 7064400 | 5/11/1987 | 0.01 | 8.2 |
| 7064400 | 10/13/1987 | 0.02 | 61 |
| 7064400 | 5/17/1988 | 0.02 | 93 |
| 7064400 | 10/11/1988 | 0.02 | 68 |
| 7064400 | 10/23/1989 | 0.02 | 62 |
| 7064400 | 5/30/1991 | 0.01 | 132 |
| 7064400 | 10/22/1991 | 0.02 | 69 |
| 7064400 | 4/29/1993 | 0.02 | 92 |
| 7064400 | 10/21/1993 | 0.02 | 70 |
| 7064400 | 10/19/1994 | 0.04 | 78 |
| 7064400 | 10/10/1995 | 0.03 | 81 |
| 7014200 | 11/23/1993 | 0.04 | 240 |
| 7014200 | 8/7/1995 | 0.02 | 45 |
| 7014200 | 4/9/1996 | 0.02 | 140 |
| 7014200 | 6/24/1996 | 0.02 | 47 |
| 7014200 | 3/10/1997 | 0.03 | 240 |
| 7014200 | 8/19/1999 | 0.03 | 68 |
| 7014200 | 11/15/2000 | 0.09 | 39 |
| 7014200 | 5/9/2002 | 0.07 | 3250 |
| 7014200 | 2/14/2007 | 0.04 | 264 |

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7066000 | 5/11/1999 | 0.37 | 627 |
| 7066000 | 6/23/1999 | 0.5 | 227 |
| 7066000 | 8/11/1999 | 0.59 | 194 |
| 7066000 | 11/8/1999 | 0.35 | 154 |
| 7066000 | 12/15/1999 | 0.45 | 305 |
| 7066000 | 3/1/2000 | 0.75 | 542 |
| 7066000 | 4/5/2000 | 0.46 | 241 |
| 7066000 | 5/25/2000 | 0.36 | 235 |
| 7066000 | 6/7/2000 | 0.41 | 172 |
| 7066000 | 6/29/2000 | 0.34 | 245 |
| 7066000 | 7/27/2000 | 0.4 | 143 |
| 7066000 | 8/10/2000 | 0.36 | 129 |
| 7066000 | 8/22/2000 | 0.41 | 127 |
| 7066000 | 9/19/2000 | 0.4 | 113 |
| 7066000 | 2/21/2001 | 0.63 | 410 |
| 7066000 | 3/21/2001 | 0.6 | 242 |
| 7066000 | 5/25/2001 | 0.33 | 215 |
| 7066000 | 5/26/2001 | 0.31 | 202 |
| 7066000 | 5/26/2001 | 0.34 | 202 |
| 7066000 | 5/27/2001 | 0.22 | 186 |
| 7066000 | 5/27/2001 | 0.33 | 190 |
| 7066000 | 6/6/2001 | 0.29 | 211 |
| 7066000 | 7/31/2001 | 0.34 | 136 |
| 7066000 | 8/8/2001 | 0.32 | 112 |
| 7066000 | 8/8/2001 | 0.34 | 112 |
| 7066000 | 8/9/2001 | 0.34 | 116 |
| 7066000 | 8/9/2001 | 0.38 | 116 |
| 7066000 | 10/11/2001 | 0.35 | 116 |
| 7066000 | 10/11/2001 | 0.36 | 116 |
| 7066000 | 4/2/2002 | 0.44 | 590 |
| 7066000 | 4/30/2002 | 0.26 | 760 |
| 7066000 | 5/29/2002 | 0.37 | 657 |
| 7066000 | 6/28/2002 | 0.49 | 309 |
| 7066000 | 6/29/2002 | 0.31 | 297 |
| 7066000 | 8/7/2002 | 0.38 | 216 |
| 7066000 | 10/8/2002 | 0.44 | 161 |
| 7066000 | 6/3/2003 | 0.46 | 270 |
| 7066000 | 6/9/2003 | 0.46 | 263 |
| 7066000 | 6/28/2003 | 0.4 | 185 |
| 7066000 | 7/26/2003 | 0.35 | 169 |
| 7066000 | 8/6/2003 | 0.32 | 226 |
| 7066000 | 9/23/2003 | 0.37 | 201 |
| 7066000 | 10/8/2003 | 0.39 | 151 |
| 7066000 | 6/15/2004 | 0.46 | 368 |
| 7066000 | 6/26/2004 | 0.42 | 266 |
| 7066000 | 8/21/2004 | 0.44 | 174 |
| 7066000 | 9/21/2004 | 0.45 | 147 |
| 7066000 | 7/5/2005 | 0.39 | 127 |
| 7066000 | 8/9/2005 | 0.46 | 142 |
| 7065000 | 6/19/1973 | 0.47 | 60 |
| 7065000 | 7/31/1973 | 0.53 | 48 |
| 7065000 | 10/16/1973 | 0.5 | 71 |
| 7065000 | 9/22/1976 | 0.28 | 25 |
| 7065000 | 5/5/1977 | 0.51 | 28 |
| 7065000 | 9/22/1977 | 0.94 | 24 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7065000 | 5/11/1978 | 0.47 | 39 |
| 7065000 | 9/13/1978 | 0.73 | 26 |
| 7065000 | 5/16/1979 | 0.5 | 118 |
| 7065000 | 9/5/1979 | 0.51 | 40 |
| 7065000 | 5/7/1980 | 0.89 | 31 |
| 7065000 | 8/26/1980 | 0.64 | 20 |
| 7065000 | 6/9/1981 | 2 | 34 |
| 7065000 | 9/23/1981 | 0.68 | 20 |
| 7065000 | 7/1/1982 | 1.4 | 38 |
| 7065000 | 5/24/1983 | 0.8 | 100 |
| 7065000 | 9/13/1983 | 0.7 | 34 |
| 7065000 | 5/17/1984 | 0.7 | 52 |
| 7065000 | 5/16/1985 | 0.5 | 97 |
| 7065000 | 9/11/1985 | 0.7 | 43 |
| 7065000 | 5/6/1986 | 0.5 | 58 |
| 7065000 | 10/14/1986 | 1.4 | 34 |
| 7065000 | 5/11/1987 | 0.9 | 52 |
| 7065000 | 10/11/1988 | 0.5 | 21 |
| 7065000 | 5/23/1989 | 0.8 | 179 |
| 7065000 | 5/8/2001 | 0.54 | 27 |
| 7065000 | 5/29/2002 | 0.5 | 153 |
| 7065000 | 5/5/2003 | 0.45 | 53 |
| 7065000 | 5/18/2004 | 0.5 | 88 |
| 7065000 | 5/10/2006 | 0.42 | 250 |
| 7064440 | 6/18/1973 | 1.2 | 139 |
| 7064440 | 7/30/1973 | 0.97 | 107 |
| 7064440 | 10/15/1973 | 0.93 | 152 |
| 7064440 | 1/18/1974 | 0.66 | 160 |
| 7064440 | 4/17/1974 | 0.79 | 204 |
| 7064440 | 7/9/1974 | 0.86 | 146 |
| 7064440 | 10/21/1974 | 0.84 | 109 |
| 7064440 | 1/22/1975 | 0.82 | 153 |
| 7064440 | 4/15/1975 | 0.84 | 165 |
| 7064440 | 9/24/1976 | 0.9 | 64 |
| 7064440 | 5/6/1977 | 1.1 | 74 |
| 7064440 | 9/23/1977 | 0.91 | 45 |
| 7064440 | 5/12/1978 | 0.9 | 155 |
| 7064440 | 9/14/1978 | 1.2 | 58 |
| 7064440 | 5/15/1979 | 0.55 | 181 |
| 7064440 | 9/4/1979 | 0.89 | 90 |
| 7064440 | 5/8/1980 | 2.4 | 76 |
| 7064440 | 8/26/1980 | 1 | 62 |
| 7064440 | 6/9/1981 | 1.9 | 75 |
| 7064440 | 9/21/1981 | 1.1 | 52 |
| 7064440 | 6/29/1982 | 1.1 | 114 |
| 7064440 | 5/24/1983 | 1 | 172 |
| 7064440 | 9/13/1983 | 1.3 | 90 |
| 7064440 | 5/15/1984 | 1 | 181 |
| 7064440 | 5/14/1985 | 0.9 | 196 |
| 7064440 | 5/6/1986 | 1 | 130 |
| 7064440 | 10/14/1986 | 1.3 | 113 |
| 7064440 | 5/11/1987 | 1.3 | 114 |
| 7064440 | 10/11/1988 | 1.1 | 82 |
| 7064440 | 5/23/1989 | 1.3 | 221 |
| 7064440 | 4/29/1993 | 0.86 | 173 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064440 | 5/29/1996 | 0.79 | 182 |
| 7064440 | 10/6/1999 | 0.96 | 96 |
| 7064440 | 5/3/2000 | 0.87 | 72 |
| 7064440 | 5/8/2001 | 0.79 | 53 |
| 7064440 | 10/3/2001 | 0.58 | 48 |
| 7064440 | 5/30/2002 | 0.56 | 189 |
| 7064440 | 10/9/2002 | 0.85 | 71 |
| 7064440 | 5/7/2003 | 0.64 | 151 |
| 7064440 | 10/7/2003 | 0.79 | 57 |
| 7064440 | 5/17/2004 | 0.62 | 186 |
| 7064440 | 10/7/2004 | 0.82 | 51 |
| 7064440 | 5/25/2005 | 0.83 | 80 |
| 7064440 | 5/8/2006 | 0.59 | 120 |
| 7066510 | 6/20/1973 | 0.38 | 1560 |
| 7066510 | 8/1/1973 | 0.5 | 1240 |
| 7066510 | 10/17/1973 | 0.52 | 1480 |
| 7066510 | 1/18/1974 | 0.34 | 1820 |
| 7066510 | 4/17/1974 | 0.49 | 2420 |
| 7066510 | 7/10/1974 | 0.46 | 1260 |
| 7066510 | 10/22/1974 | 0.01 | 850 |
| 7066510 | 1/21/1975 | 0.16 | 1870 |
| 7066510 | 4/15/1975 | 0.58 | 1880 |
| 7066510 | 9/23/1976 | 0.25 | 533 |
| 7066510 | 5/4/1977 | 0.36 | 928 |
| 7066510 | 9/22/1977 | 0.49 | 738 |
| 7066510 | 5/11/1978 | 0.51 | 2050 |
| 7066510 | 9/13/1978 | 0.58 | 532 |
| 7066510 | 5/16/1979 | 0.38 | 3000 |
| 7066510 | 9/5/1979 | 0.42 | 894 |
| 7066510 | 5/6/1980 | 0.48 | 798 |
| 7066510 | 8/27/1980 | 0.35 | 441 |
| 7066510 | 6/10/1981 | 1.4 | 1190 |
| 7066510 | 9/22/1981 | 0.59 | 462 |
| 7066510 | 6/30/1982 | 0.97 | 1150 |
| 7066510 | 5/25/1983 | 1.4 | 2240 |
| 7066510 | 9/14/1983 | 0.8 | 680 |
| 7066510 | 5/16/1984 | 0.6 | 2350 |
| 7066510 | 5/15/1985 | 0.6 | 2480 |
| 7066510 | 9/11/1985 | 0.7 | 1080 |
| 7066510 | 5/7/1986 | 0.5 | 1290 |
| 7066510 | 10/15/1986 | 3.1 | 1080 |
| 7066510 | 5/12/1987 | 0.7 | 985 |
| 7066510 | 5/29/1991 | 0.66 | 1750 |
| 7066510 | 5/1/2000 | 0.32 | 600 |
| 7066510 | 5/7/2001 | 0.38 | 720 |
| 7066510 | 10/7/2002 | 0.37 | 1000 |
| 7066510 | 5/5/2003 | 0.43 | 2500 |
| 7066510 | 10/6/2003 | 0.32 | 552 |
| 7066510 | 5/17/2004 | 0.33 | 2100 |
| 7066510 | 5/24/2005 | 0.31 | 713 |
| 7066510 | 5/8/2006 | 0.31 | 2800 |
| 7061600 | 4/12/1994 | 0.85 | 28800 |
| 7061600 | 11/2/1999 | 0.13 | 172 |
| 7061600 | 1/10/2000 | 0.39 | 316 |
| 7061600 | 7/24/2000 | 0.21 | 121 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7061600 | 9/14/2000 | 0.12 | 99 |
| 7061600 | 1/16/2001 | 0.21 | 599 |
| 7061600 | 3/12/2001 | 0.58 | 271 |
| 7061600 | 5/8/2001 | 0.38 | 164 |
| 7061600 | 7/16/2001 | 0.18 | 95 |
| 7061600 | 9/4/2001 | 0.13 | 93 |
| 7061600 | 5/14/2002 | 0.39 | 6630 |
| 7061600 | 9/5/2002 | 0.12 | 163 |
| 7061600 | 3/10/2003 | 0.29 | 329 |
| 7061600 | 5/21/2003 | 0.2 | 1320 |
| 7061600 | 7/7/2003 | 0.19 | 203 |
| 7061600 | 9/2/2003 | 0.26 | 468 |
| 7061600 | 11/18/2003 | 1.2 | 6280 |
| 7061600 | 5/5/2004 | 0.22 | 1000 |
| 7061600 | 11/23/2004 | 0.27 | 374 |
| 7061600 | 1/25/2005 | 0.34 | 444 |
| 7061600 | 3/15/2005 | 0.19 | 136 |
| 7061600 | 5/16/2005 | 0.13 | 322 |
| 7061600 | 9/6/2005 | 0.12 | 133 |
| 7061600 | 11/2/2005 | 0.21 | 501 |
| 7061600 | 1/4/2006 | 0.38 | 203 |
| 7061600 | 1/29/2006 | 0.34 | 1140 |
| 7061600 | 2/2/2006 | 0.24 | 802 |
| 7061600 | 2/13/2006 | 0.25 | 305 |
| 7061600 | 3/7/2006 | 0.24 | 225 |
| 7061600 | 4/18/2006 | 0.17 | 268 |
| 7061600 | 5/11/2006 | 0.42 | 6830 |
| 7061600 | 6/20/2006 | 0.17 | 191 |
| 7061600 | 7/12/2006 | 0.18 | 204 |
| 7061600 | 8/3/2006 | 0.17 | 134 |
| 7061600 | 10/23/2006 | 0.25 | 287 |
| 7061600 | 11/13/2006 | 0.34 | 348 |
| 7061600 | 12/19/2006 | 0.38 | 422 |
| 7061600 | 1/4/2007 | 0.23 | 614 |
| 7061600 | 3/29/2007 | 0.29 | 866 |
| 7061600 | 4/3/2007 | 0.21 | 990 |
| 7061600 | 9/10/2007 | 0.5 | 1020 |
| 7061600 | 5/7/2008 | 0.17 | 735 |
| 7061600 | 10/7/2008 | 0.14 | 110 |
| 7061600 | 3/3/2009 | 0.28 | 430 |
| 7061600 | 5/26/2009 | 0.15 | 497 |
| 7061600 | 7/6/2009 | 0.18 | 312 |
| 7061600 | 9/8/2009 | 0.18 | 280 |
| 7061600 | 10/27/2009 | 0.39 | 936 |
| 7064400 | 7/9/1974 | 1 | 101 |
| 7064400 | 9/23/1975 | 0.82 | 42 |
| 7064400 | 9/24/1976 | 0.84 | 51 |
| 7064400 | 5/6/1977 | 1 | 60 |
| 7064400 | 9/23/1977 | 0.82 | 42 |
| 7064400 | 5/12/1978 | 0.89 | 112 |
| 7064400 | 9/14/1978 | 1 | 51 |
| 7064400 | 5/15/1979 | 0.67 | 140 |
| 7064400 | 9/4/1979 | 1 | 70 |
| 7064400 | 5/8/1980 | 8.8 | 60 |
| 7064400 | 8/26/1980 | 1.1 | 43 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7064400 | 6/9/1981 | 1.6 | 64 |
| 7064400 | 9/21/1981 | 1.3 | 46 |
| 7064400 | 6/29/1982 | 1.5 | 106 |
| 7064400 | 5/24/1983 | 1.6 | 132 |
| 7064400 | 9/13/1983 | 1.5 | 70 |
| 7064400 | 5/15/1984 | 1.2 | 123 |
| 7064400 | 5/14/1985 | 0.9 | 151 |
| 7064400 | 9/10/1985 | 1.2 | 95 |
| 7064400 | 10/14/1986 | 1.6 | 83 |
| 7064400 | 5/11/1987 | 1.2 | 8.2 |
| 7064400 | 10/13/1987 | 1.7 | 61 |
| 7064400 | 10/11/1988 | 1.2 | 68 |
| 7064400 | 10/6/1999 | 1.1 | 75 |
| 7064400 | 5/3/2000 | 0.89 | 61 |
| 7064400 | 5/30/2002 | 0.5 | 155 |
| 7064400 | 5/7/2003 | 0.63 | 111 |
| 7064400 | 5/17/2004 | 0.62 | 113 |
| 7064400 | 5/8/2006 | 0.59 | 90 |
| 7014200 | 8/7/1995 | 0.29 | 45 |
| 7014200 | 6/24/1996 | 0.52 | 47 |
| 7014200 | 6/19/1997 | 0.29 | 313 |
| 7014200 | 3/4/1999 | 0.24 | 88 |
| 7014200 | 4/8/1999 | 0.21 | 359 |
| 7014200 | 6/14/1999 | 0.19 | 90 |
| 7014200 | 8/19/1999 | 0.31 | 68 |
| 7014200 | 3/14/2000 | 0.14 | 68 |
| 7014200 | 5/17/2000 | 0.16 | 27 |
| 7014200 | 7/6/2000 | 0.19 | 25 |
| 7014200 | 9/7/2000 | 0.13 | 12 |
| 7014200 | 11/15/2000 | 0.75 | 39 |
| 7014200 | 3/22/2001 | 0.32 | 60 |
| 7014200 | 5/10/2001 | 0.16 | 43 |
| 7014200 | 7/11/2001 | 0.22 | 18 |
| 7014200 | 11/1/2001 | 0.13 | 29 |
| 7014200 | 1/23/2002 | 0.19 | 47 |
| 7014200 | 3/28/2002 | 0.17 | 328 |
| 7014200 | 5/9/2002 | 0.62 | 3250 |
| 7014200 | 7/30/2002 | 0.15 | 31 |
| 7014200 | 9/3/2002 | 0.14 | 32 |
| 7014200 | 11/12/2002 | 0.14 | 57 |
| 7014200 | 1/13/2003 | 0.27 | 97 |
| 7014200 | 3/3/2003 | 0.17 | 150 |
| 7014200 | 5/6/2003 | 0.16 | 441 |
| 7014200 | 9/11/2003 | 0.14 | 61 |
| 7014200 | 1/8/2004 | 0.21 | 210 |
| 7014200 | 3/17/2004 | 0.2 | 114 |
| 7014200 | 5/5/2004 | 0.16 | 289 |
| 7014200 | 7/27/2004 | 0.17 | 37 |
| 7014200 | 9/2/2004 | 0.18 | 46 |
| 7014200 | 11/9/2004 | 0.17 | 68 |
| 7014200 | 1/4/2005 | 0.15 | 61 |
| 7014200 | 3/1/2005 | 0.15 | 117 |
| 7014200 | 7/6/2005 | 0.16 | 22 |
| 7014200 | 9/7/2005 | 0.15 | 16 |
| 7014200 | 11/22/2005 | 0.24 | 82 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| USGS Gage | Sample Date | TN (mg/L) | Flow (cfs) |
|---|---|---|---|
| 7014200 | 3/21/2006 | 0.29 | 311 |
| 7014200 | 5/9/2006 | 0.16 | 162 |
| 7014200 | 11/8/2006 | 0.14 | 75 |
| 7014200 | 2/14/2007 | 0.34 | 264 |
| 7014200 | 4/2/2007 | 0.15 | 414 |
| 7014200 | 5/22/2007 | 0.12 | 72 |
| 7014200 | 6/5/2007 | 0.18 | 43 |
| 7014200 | 7/10/2007 | 0.15 | 28 |
| 7014200 | 3/24/2008 | 0.32 | 355 |
| 7014200 | 7/21/2008 | 0.17 | 80 |
| 7014200 | 10/27/2008 | 0.08 | 41 |
| 7014200 | 5/26/2009 | 0.28 | 73 |
| 7014200 | 7/21/2009 | 0.12 | 23 |
| 7014200 | 9/1/2009 | 0.13 | 36 |
| 7014200 | 10/27/2009 | 0.31 | 228 |

| USGS Gage | Sample Date | TP (mg/L) | Flow (cfs) |
|---|---|---|---|

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | L. Sac R. @Walnut Grove | 10/2/1984 | 4 | 14 |
| USGS | L. Sac R. @Walnut Grove | 11/5/1984 | 3 | 136 |
| USGS | L. Sac R. @Walnut Grove | 12/4/1984 | 14 | 80 |
| USGS | L. Sac R. @Walnut Grove | 1/10/1985 | 4 | 160 |
| USGS | L. Sac R. @Walnut Grove | 2/19/1985 | 8 | 135 |
| USGS | L. Sac R. @Walnut Grove | 3/18/1985 | 8 | 225 |
| USGS | L. Sac R. @Walnut Grove | 4/15/1985 | 20 | 220 |
| USGS | L. Sac R. @Walnut Grove | 5/21/1985 | 14 | 84 |
| USGS | L. Sac R. @Walnut Grove | 6/11/1985 | 113 | 660 |
| USGS | L. Sac R. @Walnut Grove | 8/5/1985 | 12 | 50 |
| USGS | L. Sac R. @Walnut Grove | 9/9/1985 | 1 | 35 |
| USGS | L. Sac R. @Walnut Grove | 10/8/1985 | 14 | 120 |
| USGS | L. Sac R. @Walnut Grove | 11/12/1985 | 2 | 40 |
| USGS | L. Sac R. @Walnut Grove | 12/6/1985 | 1 | 320 |
| USGS | L. Sac R. @Walnut Grove | 1/7/1986 | 1 | 120 |
| USGS | L. Sac R. @Walnut Grove | 2/10/1986 | 2 | 100 |
| USGS | L. Sac R. @Walnut Grove | 10/3/1988 | 6 | 33 |
| USGS | L. Sac R. @Walnut Grove | 11/1/1988 | 7 | 32 |
| USGS | L. Sac R. @Walnut Grove | 12/6/1988 | 6 | 114 |
| USGS | L. Sac R. @Walnut Grove | 1/3/1989 | 10 | 275 |
| USGS | L. Sac R. @Walnut Grove | 2/7/1989 | 3 | 88 |
| USGS | L. Sac R. @Walnut Grove | 3/9/1989 | 4 | 195 |
| USGS | L. Sac R. @Walnut Grove | 4/3/1989 | 7 | 290 |
| USGS | L. Sac R. @Walnut Grove | 5/9/1989 | 1 | 72 |
| USGS | L. Sac R. @Walnut Grove | 6/6/1989 | 13 | 88 |
| USGS | L. Sac R. @Walnut Grove | 7/17/1989 | 0.499 | 42 |
| USGS | L. Sac R. @Walnut Grove | 8/3/1989 | 15 | 88 |
| USGS | L. Sac R. @Walnut Grove | 9/5/1989 | 10 | 48 |
| USGS | L. Sac R. @Walnut Grove | 10/10/1989 | 0.499 | 50 |
| USGS | L. Sac R. @Walnut Grove | 11/6/1989 | 0.499 | 48 |
| USGS | L. Sac R. @Walnut Grove | 12/4/1989 | 3 | 48 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | L. Sac R. @Walnut Grove | 1/8/1990 | 13 | 42 |
| USGS | L. Sac R. @Walnut Grove | 2/6/1990 | 11 | 100 |
| USGS | L. Sac R. @Walnut Grove | 3/5/1990 | 194 | 98 |
| USGS | L. Sac R. @Walnut Grove | 4/4/1990 | 0.499 | 166 |
| USGS | L. Sac R. @Walnut Grove | 5/10/1990 | 16 | 190 |
| USGS | L. Sac R. @Walnut Grove | 6/4/1990 | 6 | 195 |
| USGS | L. Sac R. @Walnut Grove | 1/26/1994 | 14 | 74 |
| USGS | L. Sac R. @Walnut Grove | 6/28/1994 | 8 | 22 |
| USGS | L. Sac R. @Walnut Grove | 1/10/1995 | 6 | 21 |
| USGS | L. Sac R. @Walnut Grove | 6/29/1995 | 14 | 120 |
| USGS | L. Sac R. @Walnut Grove | 1/16/1996 | 7 | 28 |
| USGS | L. Sac R. @Walnut Grove | 6/18/1996 | 37 | 76 |
| COEKC | Sac R. nr. Dadeville | 4/14/1993 | 25 | 370 |
| COEKC | Sac R. nr. Dadeville | 3/16/1994 | 14 | 440 |
| COEKC | Sac R. nr. Dadeville | 4/13/1994 | 127 | 3020 |
| COEKC | Sac R. nr. Dadeville | 5/10/1994 | 36 | 1200 |
| COEKC | Sac R. nr. Dadeville | 6/16/1994 | 33 | 185 |
| COEKC | Sac R. nr. Dadeville | 7/12/1994 | 16 | 70 |
| COEKC | Sac R. nr. Dadeville | 8/16/1994 | 18 | 39 |
| COEKC | Sac R. nr. Dadeville | 9/7/1994 | 25 | 130 |
| COEKC | Sac R. nr. Dadeville | 10/11/1994 | 11 | 174 |
| COEKC | Sac R. nr. Dadeville | 11/21/1994 | 47 | 1120 |
| USGS | L. Sac R. @Walnut Grove | 11/3/1999 | 0.499 | 6.2 |
| USGS | L. Sac R. @Walnut Grove | 1/11/2000 | 2 | 20 |
| USGS | L. Sac R. @Walnut Grove | 5/24/2000 | 33 | 13 |
| USGS | L. Sac R. @Walnut Grove | 7/26/2000 | 4.99 | 106 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 1/30/2001 | 6 | 0.9 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 1/30/2001 | 2 | 1.3 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 1/30/2001 | 6 | 5 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 1/30/2001 | 4 | 8.4 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 1/30/2001 | 8 | 1.2 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 1/30/2001 | 6 | 0.1 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 2/19/2001 | 8 | 0.3 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 2/19/2001 | 2 | 0.05 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 2/19/2001 | 2 | 0.3 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 2/19/2001 | 4 | 0.5 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 27) | 2/19/2001 | 1 | 0.1 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 3/24/2001 | 8 | 0.4 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 3/24/2001 | 20 | 0.9 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 3/24/2001 | 25 | 0.1 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 1/30/2001 | 76 | 13.3 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 1/30/2001 | 260 | 2.5 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 1/30/2001 | 4 | 15.3 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 2/19/2001 | 8 | 9.6 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 2/19/2001 | 4 | 0.8 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 2/19/2001 | 6 | 4.4 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 2/19/2001 | 4 | 0.4 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 3/24/2001 | 28 | 2.6 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 3/24/2001 | 28 | 1.8 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 3/24/2001 | 10 | 1.2 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 3/24/2001 | 1 | 0.2 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 4/16/2001 | 4 | 0.46 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 4/16/2001 | 3 | 0.95 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 4/16/2001 | 6 | 0.04 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 5/22/2001 | 8 | 0.04 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 5/22/2001 | 42 | 0.11 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 5/22/2001 | 14 | 0.11 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 5/22/2001 | 0.499 | 0.43 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 5/22/2001 | 6.45 | 0.08 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 5/22/2001 | 25.6 | 0.03 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 6/5/2001 | 0.499 | 0.11 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 6/5/2001 | 0.499 | 0.27 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 6/5/2001 | 0.499 | 0.12 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 6/5/2001 | 0.499 | 0.37 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 6/5/2001 | 0.499 | 0.37 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 6/5/2001 | 0.499 | 0.02 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 27) | 6/5/2001 | 0.499 | 0.42 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 4/16/2001 | 7 | 3.88 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 4/16/2001 | 12 | 0.19 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 4/16/2001 | 23 | 1.32 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 4/16/2001 | 23 | 2.74 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 4/16/2001 | 5 | 0.88 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 5/22/2001 | 12 | 3.23 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 5/22/2001 | 16 | 0.03 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 5/22/2001 | 19 | 0.56 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 5/22/2001 | 22 | 1.45 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 5/22/2001 | 10 | 0.2 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 6/5/2001 | 0.499 | 2.1 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 6/5/2001 | 58 | 0.03 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 6/5/2001 | 0.499 | 0.76 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 6/5/2001 | 0.0499 | 2.32 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 6/5/2001 | 0.499 | 0.6 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 11/6/2001 | 13 | 0.01 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 11) | 12/17/2001 | 0.499 | 0.01 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 12/17/2001 | 0.499 | 0.11 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 12/17/2001 | 0.499 | 0.01 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 11/6/2001 | 18 | 0.04 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 12/17/2001 | 9 | 0.58 |
| USGS | Sac R. nr. Dadeville | 5/24/1994 | 96 | 1510 |
| USGS | Sac R. nr. Dadeville | 9/20/1994 | 34 | 44 |
| USGS | Sac R. nr. Dadeville | 5/23/1995 | 107 | 380 |
| USGS | Brush Creek ab Green Spring | 9/21/1994 | 3 | 0.39 |
| USGS | Brush Creek ab Green Spring | 5/23/1995 | 21 | 62 |
| USGS | Brush Creek ab Green Spring | 5/25/1994 | 15 | 13 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | L. Sac R. @Walnut Grove | 11/29/2000 | 4.99 | 9.2 |
| USGS | L. Sac R. @Walnut Grove | 1/17/2001 | 4.99 | 38 |
| USGS | L. Sac R. @Walnut Grove | 5/23/2001 | 23 | 29 |
| USGS | Sac R. nr. Dadeville | 10/14/1986 | 5 | 353 |
| USGS | Sac R. nr. Dadeville | 11/5/1986 | 0.499 | 207 |
| USGS | Sac R. nr. Dadeville | 12/2/1986 | 6 | 148 |
| USGS | Sac R. nr. Dadeville | 1/5/1987 | 1 | 114 |
| USGS | Sac R. nr. Dadeville | 2/2/1987 | 5 | 253 |
| USGS | Sac R. nr. Dadeville | 3/2/1987 | 24 | 1010 |
| USGS | Sac R. nr. Dadeville | 4/7/1987 | 6 | 277 |
| USGS | Sac R. nr. Dadeville | 5/19/1987 | 28 | 103 |
| USGS | Sac R. nr. Dadeville | 6/9/1987 | 32 | 51 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 2/20/2003 | 24 | 2.6 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 3/25/2003 | 13 | 0.56 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 2/20/2003 | 12 | 2.8 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 3/25/2003 | 4 | 1.8 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 2/20/2003 | 10 | 1.6 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 3/25/2003 | 1.99 | 2.2 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 3/25/2003 | 4 | 2.1 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 3/25/2003 | 1.99 | 0.4 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 3/25/2003 | 7 | 1.7 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 3/25/2003 | 8 | 0.15 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 2/20/2003 | 1.99 | 0.35 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 3/25/2003 | 1.99 | 0.36 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 3/25/2003 | 5 | 0.53 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 3/25/2003 | 1.99 | 0.38 |
| Murphy | Trib to Cynthia Cr. US of Murphy OOP (Site 26) | 3/25/2003 | 8 | 0.06 |
| MDNR | Stockton Br. 0.1 mi ab. WWTP | 6/24/2003 | 9 | 0.25 |
| MDNR | Stockton WWTP effluent | 6/24/2003 | 70 | 0.2 |
| MDNR | Stockton Br. 40 yds. bl. WWTP | 6/24/2003 | 19 | 0.45 |
| MDNR | Stockton Br. 1.7 mi bl. WWTP | 6/24/2003 | 30 | 0.33 |
| USGS | L. Sac R. @Walnut Grove | 10/4/2001 | 4.99 | 8.1 |
| USGS | L. Sac R. @Walnut Grove | 11/26/2001 | 20 | 22 |
| USGS | L. Sac R. @Walnut Grove | 12/10/2001 | 4.99 | 18 |
| USGS | L. Sac R. @Walnut Grove | 1/8/2002 | 4.99 | 36 |
| USGS | L. Sac R. @Walnut Grove | 2/12/2002 | 4.99 | 78 |
| USGS | L. Sac R. @Walnut Grove | 3/13/2002 | 4.99 | 78 |
| USGS | L. Sac R. @Walnut Grove | 4/15/2002 | 16 | 111 |
| USGS | L. Sac R. @Walnut Grove | 5/20/2002 | 18 | 526 |
| USGS | L. Sac R. @Walnut Grove | 6/19/2002 | 4.9 | 51 |
| USGS | L. Sac R. @Walnut Grove | 7/22/2002 | 18 | 24 |
| USGS | L. Sac R. @Walnut Grove | 8/27/2002 | 4.99 | 26 |
| USGS | L. Sac R. @Walnut Grove | 9/11/2002 | 10 | 8 |
| USGS | Sac R. nr. Dadeville | 10/8/1985 | 15 | 30 |
| USGS | Sac R. nr. Dadeville | 11/12/1985 | 1 | 54 |
| USGS | Sac R. nr. Dadeville | 12/6/1985 | 1 | 679 |
| USGS | Sac R. nr. Dadeville | 1/7/1986 | 2 | 230 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Sac R. nr. Dadeville | 2/10/1986 | 1 | 202 |
| USGS | Sac R. nr. Dadeville | 3/20/1986 | 4 | 234 |
| USGS | Sac R. nr. Dadeville | 4/8/1986 | 480 | 749 |
| USGS | Sac R. nr. Dadeville | 5/13/1986 | 40 | 97 |
| USGS | Sac R. nr. Dadeville | 6/3/1986 | 106 | 72 |
| USGS | Sac R. nr. Dadeville | 7/9/1986 | 20 | 32 |
| USGS | Sac R. nr. Dadeville | 8/4/1986 | 24 | 32 |
| USGS | Sac R. nr. Dadeville | 9/16/1986 | 57 | 16 |
| USGS | Sac R. nr. Dadeville | 10/2/1984 | 5 | 22 |
| USGS | Sac R. nr. Dadeville | 11/5/1984 | 11 | 400 |
| USGS | Sac R. nr. Dadeville | 12/4/1984 | 8 | 258 |
| USGS | Sac R. nr. Dadeville | 1/10/1985 | 7 | 566 |
| USGS | Sac R. nr. Dadeville | 2/19/1985 | 15 | 386 |
| USGS | Sac R. nr. Dadeville | 3/18/1985 | 16 | 361 |
| USGS | Sac R. nr. Dadeville | 4/15/1985 | 18 | 560 |
| USGS | Sac R. nr. Dadeville | 5/21/1985 | 24 | 171 |
| USGS | Sac R. nr. Dadeville | 6/11/1985 | 74 | 533 |
| USGS | Sac R. nr. Dadeville | 7/10/1985 | 24 | 69 |
| USGS | Sac R. nr. Dadeville | 8/5/1985 | 11 | 37 |
| USGS | Sac R. nr. Dadeville | 9/9/1985 | 10 | 60 |
| USGS | Sac R. nr. Dadeville | 11/10/1983 | 16 | 265 |
| USGS | Sac R. nr. Dadeville | 12/6/1983 | 5 | 389 |
| USGS | Sac R. nr. Dadeville | 1/3/1984 | 0.499 | 131 |
| USGS | Sac R. nr. Dadeville | 2/6/1984 | 0.99 | 101 |
| USGS | Sac R. nr. Dadeville | 3/5/1984 | 120 | 1560 |
| USGS | Sac R. nr. Dadeville | 4/2/1984 | 42 | 674 |
| USGS | Sac R. nr. Dadeville | 5/8/1984 | 19 | 752 |
| USGS | Sac R. nr. Dadeville | 6/5/1984 | 33 | 84 |
| USGS | Sac R. nr. Dadeville | 7/10/1984 | 0.99 | 136 |
| USGS | Sac R. nr. Dadeville | 8/6/1984 | 12 | 29 |
| USGS | Sac R. nr. Dadeville | 9/11/1984 | 12 | 29 |
| USGS | L. Sac R. @Walnut Grove | 10/18/1983 | 22 | 40 |
| USGS | L. Sac R. @Walnut Grove | 11/10/1983 | 1 | 50 |
| USGS | L. Sac R. @Walnut Grove | 12/6/1983 | 2 | 194 |
| USGS | L. Sac R. @Walnut Grove | 1/3/1984 | 5 | 40 |
| USGS | L. Sac R. @Walnut Grove | 2/6/1984 | 0.99 | 40 |
| USGS | L. Sac R. @Walnut Grove | 3/5/1984 | 45 | 895 |
| USGS | L. Sac R. @Walnut Grove | 4/2/1984 | 17 | 250 |
| USGS | L. Sac R. @Walnut Grove | 5/8/1984 | 5 | 100 |
| USGS | L. Sac R. @Walnut Grove | 6/5/1984 | 21 | 28 |
| USGS | L. Sac R. @Walnut Grove | 7/10/1984 | 23 | 40 |
| USGS | L. Sac R. @Walnut Grove | 8/6/1984 | 12 | 30 |
| USGS | L. Sac R. @Walnut Grove | 9/11/1984 | 14 | 30 |
| USGS | L. Sac R. @Walnut Grove | 10/15/2002 | 4.99 | 8.4 |
| USGS | L. Sac R. @Walnut Grove | 11/4/2002 | 4.99 | 15 |
| USGS | L. Sac R. @Walnut Grove | 12/9/2002 | 4.99 | 10 |
| USGS | L. Sac R. @Walnut Grove | 1/22/2003 | 4.99 | 47 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | L. Sac R. @Walnut Grove | 2/11/2003 | 4.99 | 6.2 |
| USGS | L. Sac R. @Walnut Grove | 3/18/2003 | 4.99 | 56 |
| USGS | L. Sac R. @Walnut Grove | 4/15/2003 | 10 | 26 |
| USGS | L. Sac R. @Walnut Grove | 5/14/2003 | 30 | 128 |
| USGS | L. Sac R. @Walnut Grove | 6/17/2003 | 10 | 196 |
| USGS | L. Sac R. @Walnut Grove | 7/8/2003 | 23 | 20 |
| USGS | L. Sac R. @Walnut Grove | 8/21/2003 | 13 | 8.3 |
| USGS | L. Sac R. @Walnut Grove | 9/8/2003 | 4.99 | 19 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 4/28/2003 | 6 | 0.98 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 4/28/2003 | 0.499 | 1.88 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 4/28/2003 | 22 | 0.53 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 5/29/2003 | 12 | 0.1 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 14) | 5/29/2003 | 11 | 0.05 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 5/29/2003 | 0.499 | 1.89 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 16) | 5/29/2003 | 0.499 | 0.51 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 13) | 6/19/2003 | 24 | 0.1 |
| Murphy | Trib to Wilkey Cr. US of Murphy OOP (Site 15) | 6/19/2003 | 7 | 1.2 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 4/28/2003 | 5 | 1 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 4/28/2003 | 4 | 0.16 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 4/28/2003 | 0.499 | 0.25 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 4/28/2003 | 4 | 1.5 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 4/28/2003 | 10 | 0.29 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 4/28/2003 | 11 | 0.14 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 5/29/2003 | 0.499 | 0.67 |
| Murphy | Trib to Cynthia Cr. @ Murphy OOP (Site 20) | 5/22/2003 | 8 | 0.29 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 5/22/2003 | 7 | 0.34 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 5/22/2003 | 0.499 | 1.4 |
| Murphy | Trib. to McCarty Cr. DS of Murphy OOP (Site 28) | 5/22/2003 | 14 | 0.1 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 5/22/2003 | 5 | 0.34 |
| Murphy | Wilkey Cr. @ Murphy OOP (Site 17) | 6/19/2003 | 9 | 0.33 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 22) | 6/19/2003 | 48 | 1.6 |
| Murphy | Cynthia Cr. DS of Murphy OOP (Site 23) | 6/19/2003 | 81 | 0.43 |
| Murphy | Trib to Cynthia Cr. DS of Murphy OOP (Site 32) | 6/19/2003 | 47 | 0.17 |
| USGS | L. Sac R. @Walnut Grove | 10/15/2003 | 4.99 | 9.1 |
| USGS | L. Sac R. @Walnut Grove | 11/5/2003 | 4.99 | 21 |
| USGS | L. Sac R. @Walnut Grove | 12/9/2003 | 4.99 | 21 |
| USGS | L. Sac R. @Walnut Grove | 1/20/2004 | 4.99 | 203 |
| USGS | L. Sac R. @Walnut Grove | 2/9/2004 | 4.99 | 73 |
| USGS | L. Sac R. @Walnut Grove | 3/11/2004 | 10 | 194 |
| USGS | L. Sac R. @Walnut Grove | 4/19/2004 | 17 | 37 |
| USGS | L. Sac R. @Walnut Grove | 5/12/2004 | 18 | 71 |
| USGS | L. Sac R. @Walnut Grove | 6/7/2004 | 16 | 22 |
| USGS | L. Sac R. @Walnut Grove | 7/19/2004 | 15 | 9.1 |
| USGS | L. Sac R. @Walnut Grove | 8/24/2004 | 14 | 9.4 |
| USGS | L. Sac R. @Walnut Grove | 9/13/2004 | 10 | 7.8 |
| MDNR | Brush Cr. 6.2 mi.bl. Humansville WWTP | 7/6/2005 | 8 | 3.14 |
| MDNR | Brush Cr. 2.9 mi.bl. Humansville WWTP | 7/6/2005 | 10 | 1.76 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| MDNR | Brush Cr. 1.8 mi.bl. Humansville WWTP | 7/6/2005 | 9 | 2.19 |
| MDNR | Brush Cr. 0.2 mi.bl. Humansville WWTP | 7/6/2005 | 7 | 1.59 |
| MDNR | Brush Cr. 0.3 mi.ab. Humansville WWTP | 7/6/2005 | 2.499 | 0.82 |
| MDNR | Panther Cr. @Hwy 13 | 7/5/2005 | 12 | 0.56 |
| MDNR | Sadler Br. At Hwy N | 7/5/2005 | 5 | 0.44 |
| MDNR | Brush Cr. 1.8 mi.bl. Humansville WWTP | 7/19/2005 | 6 | 0.96 |
| MDNR | Brush Cr. 2.9 mi.bl. Humansville WWTP | 7/19/2005 | 5 | 0.57 |
| MDNR | Brush Cr. 6.2 mi.bl. Humansville WWTP | 7/19/2005 | 8 | 0.75 |
| MDNR | Panther Cr. @Hwy 13 | 7/19/2005 | 12 | 0.004 |
| MDNR | Brush Cr. 0.3 mi.ab. Humansville WWTP | 7/19/2005 | 9 | 0.44 |
| MDNR | Sadler Br. At Hwy N | 7/19/2005 | 10 | 0.3 |
| MDNR | Brush Cr. 0.2 mi.bl. Humansville WWTP | 7/19/2005 | 8 | 0.56 |
| USGS | L. Sac R. @Walnut Grove | 10/25/2004 | 4.99 | 12 |
| USGS | L. Sac R. @Walnut Grove | 11/16/2004 | 4.99 | 81 |
| USGS | L. Sac R. @Walnut Grove | 12/14/2004 | 4.99 | 130 |
| USGS | L. Sac R. @Walnut Grove | 1/20/2005 | 4.99 | 233 |
| USGS | L. Sac R. @Walnut Grove | 2/8/2005 | 4.99 | 42 |
| USGS | L. Sac R. @Walnut Grove | 3/29/2005 | 4.99 | 80 |
| USGS | L. Sac R. @Walnut Grove | 4/11/2005 | 10 | 186 |
| USGS | L. Sac R. @Walnut Grove | 5/24/2005 | 45 | 7.3 |
| USGS | L. Sac R. @Walnut Grove | 6/14/2005 | 23 | 14 |
| USGS | L. Sac R. @Walnut Grove | 7/27/2005 | 21 | 52 |
| USGS | L. Sac R. @Walnut Grove | 8/9/2005 | 12 | 8.8 |
| USGS | L. Sac R. @Walnut Grove | 9/19/2005 | 18 | 19 |
| USGS | L. Sac R. @Walnut Grove | 10/24/2005 | 4.99 | 6.1 |
| USGS | L. Sac R. @Walnut Grove | 11/29/2005 | 4.99 | 14 |
| USGS | L. Sac R. @Walnut Grove | 12/12/2005 | 4.99 | 13 |
| USGS | L. Sac R. @Walnut Grove | 1/17/2006 | 15 | 16 |
| USGS | L. Sac R. @Walnut Grove | 2/14/2006 | 4.99 | 8.9 |
| USGS | L. Sac R. @Walnut Grove | 3/20/2006 | 4.99 | 5.6 |
| USGS | L. Sac R. @Walnut Grove | 4/18/2006 | 4.99 | 10 |
| USGS | L. Sac R. @Walnut Grove | 5/23/2006 | 29 | 74 |
| USGS | L. Sac R. @Walnut Grove | 6/19/2006 | 4.99 | 7 |
| USGS | L. Sac R. @Walnut Grove | 7/27/2006 | 11 | 10 |
| USGS | L. Sac R. @Walnut Grove | 8/29/2006 | 20 | 21 |
| USGS | L. Sac R. @Walnut Grove | 9/18/2006 | 50 | 65 |
| USGS | L. Sac R. @Walnut Grove | 10/24/2006 | 4.99 | 6.7 |
| USGS | L. Sac R. @Walnut Grove | 11/15/2006 | 4.99 | 14 |
| USGS | L. Sac R. @Walnut Grove | 12/11/2006 | 4.99 | 5.6 |
| USGS | L. Sac R. @Walnut Grove | 1/22/2007 | 10 | 317 |
| USGS | L. Sac R. @Walnut Grove | 2/26/2007 | 4.99 | 30 |
| USGS | L. Sac R. @Walnut Grove | 3/5/2007 | 4.99 | 17 |
| USGS | L. Sac R. @Walnut Grove | 4/17/2007 | 4.99 | 254 |
| USGS | L. Sac R. @Walnut Grove | 5/8/2007 | 4.99 | 88 |
| USGS | L. Sac R. @Walnut Grove | 6/25/2007 | 4.99 | 28 |
| USGS | L. Sac R. @Walnut Grove | 7/23/2007 | 12 | 6.1 |
| USGS | L. Sac R. @Walnut Grove | 8/7/2007 | 4.99 | 18 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | L. Sac R. @Walnut Grove | 9/17/2007 | 4.99 | 54 |
| USGS | L. Sac R. @Walnut Grove | 10/16/2007 | 4.99 | 16 |
| USGS | L. Sac R. @Walnut Grove | 11/6/2007 | 4.99 | 10 |
| USGS | L. Sac R. @Walnut Grove | 12/17/2007 | 4.99 | 9 |
| USGS | L. Sac R. @Walnut Grove | 1/22/2008 | 4.99 | 14 |
| USGS | L. Sac R. @Walnut Grove | 2/13/2008 | 4.99 | 218 |
| USGS | L. Sac R. @Walnut Grove | 3/17/2008 | 4.99 | 59 |
| USGS | L. Sac R. @Walnut Grove | 4/22/2008 | 4.99 | 80 |
| USGS | L. Sac R. @Walnut Grove | 5/27/2008 | 4.99 | 41 |
| USGS | L. Sac R. @Walnut Grove | 6/3/2008 | 15 | 31 |
| USGS | L. Sac R. @Walnut Grove | 7/22/2008 | 4.99 | 5.6 |
| USGS | L. Sac R. @Walnut Grove | 8/4/2008 | 4.99 | 12 |
| USGS | L. Sac R. @Walnut Grove | 9/16/2008 | 4.99 | 255 |
| USGS | Pomme de Terre R. nr. Polk | 11/3/1999 | 7 | 9.7 |
| USGS | Pomme de Terre R. nr. Polk | 5/22/2000 | 4.99 | 16 |
| USGS | Pomme de Terre R. nr. Polk | 1/11/1999 | 0.499 | 170 |
| USGS | Pomme de Terre R. nr. Polk | 7/12/1999 | 6 | 58 |
| USGS | Pomme de Terre R. nr. Polk | 11/4/1997 | 5 | 19 |
| USGS | Pomme de Terre R. nr. Polk | 1/8/1998 | 12 | 546 |
| USGS | Pomme de Terre R. nr. Polk | 7/13/1998 | 23 | 105 |
| USGS | Pomme de Terre R. nr. Polk | 11/4/1996 | 2 | 222 |
| USGS | Pomme de Terre R. nr. Polk | 1/22/1997 | 8 | 416 |
| USGS | Pomme de Terre R. nr. Polk | 6/24/1997 | 19 | 27 |
| USGS | Pomme de Terre R. nr. Polk | 8/12/1997 | 28 | 43 |
| USGS | Pomme de Terre R. nr. Polk | 11/7/1995 | 9 | 8.3 |
| USGS | Pomme de Terre R. nr. Polk | 1/16/1996 | 0.499 | 40 |
| USGS | Pomme de Terre R. nr. Polk | 6/19/1996 | 9 | 35 |
| USGS | Pomme de Terre R. nr. Polk | 8/5/1996 | 0.499 | 11 |
| USGS | Pomme de Terre R. nr. Polk | 11/23/1994 | 44 | 475 |
| USGS | Pomme de Terre R. nr. Polk | 1/11/1995 | 4 | 66 |
| USGS | Pomme de Terre R. nr. Polk | 6/29/1995 | 56 | 1660 |
| USGS | Pomme de Terre R. nr. Polk | 8/24/1995 | 26 | 10 |
| USGS | Pomme de Terre R. nr. Polk | 5/25/1994 | 45 | 129 |
| USGS | Pomme de Terre R. nr. Polk | 9/21/1994 | 11 | 9.1 |
| USGS | Pomme de Terre R. nr. Polk | 11/24/1993 | 4 | 257 |
| USGS | Pomme de Terre R. nr. Polk | 1/27/1994 | 28 | 461 |
| USGS | Pomme de Terre R. nr. Polk | 5/28/1994 | 20 | 27 |
| USGS | Pomme de Terre R. nr. Polk | 11/17/1992 | 0.499 | 183 |
| USGS | Pomme de Terre R. nr. Polk | 1/12/1993 | 20 | 536 |
| USGS | Pomme de Terre R. nr. Polk | 3/10/1993 | 8 | 331 |
| USGS | Pomme de Terre R. nr. Polk | 5/5/1993 | 25 | 337 |
| USGS | Pomme de Terre R. nr. Polk | 7/27/1993 | 19 | 56 |
| USGS | Pomme de Terre R. nr. Polk | 9/28/1993 | 18 | 1040 |
| USGS | Pomme de Terre R. nr. Polk | 11/27/2000 | 4.99 | 20 |
| USGS | Pomme de Terre R. nr. Polk | 5/23/2001 | 16 | 100 |
| USGS | Pomme de Terre R. nr. Polk | 11/26/2001 | 4.99 | 38 |
| USGS | Pomme de Terre R. nr. Polk | 1/9/2002 | 4.99 | 78 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Pomme de Terre R. nr. Polk | 3/13/2002 | 4.99 | 212 |
| USGS | Pomme de Terre R. nr. Polk | 5/20/2002 | 17 | 630 |
| USGS | Pomme de Terre R. nr. Polk | 7/22/2002 | 12 | 12 |
| USGS | Pomme de Terre R. nr. Polk | 9/9/2002 | 4.99 | 9.7 |
| USGS | Pomme de Terre R. nr. Polk | 10/8/1985 | 7 | 7.9 |
| USGS | Pomme de Terre R. nr. Polk | 11/12/1985 | 1 | 28 |
| USGS | Pomme de Terre R. nr. Polk | 12/3/1985 | 1 | 761 |
| USGS | Pomme de Terre R. nr. Polk | 1/7/1986 | 1 | 95 |
| USGS | Pomme de Terre R. nr. Polk | 2/10/1986 | 4 | 348 |
| USGS | Pomme de Terre R. nr. Polk | 11/5/1984 | 4 | 307 |
| USGS | Pomme de Terre R. nr. Polk | 12/4/1984 | 9 | 150 |
| USGS | Pomme de Terre R. nr. Polk | 1/11/1985 | 4 | 268 |
| USGS | Pomme de Terre R. nr. Polk | 2/19/1985 | 34 | 959 |
| USGS | Pomme de Terre R. nr. Polk | 3/18/1985 | 11 | 420 |
| USGS | Pomme de Terre R. nr. Polk | 4/15/1985 | 8 | 451 |
| USGS | Pomme de Terre R. nr. Polk | 5/21/1985 | 13 | 80 |
| USGS | Pomme de Terre R. nr. Polk | 6/11/1985 | 43 | 974 |
| USGS | Pomme de Terre R. nr. Polk | 7/9/1985 | 3 | 58 |
| USGS | Pomme de Terre R. nr. Polk | 8/5/1985 | 9 | 15 |
| USGS | Pomme de Terre R. nr. Polk | 9/9/1985 | 20 | 16 |
| USGS | Pomme de Terre R. nr. Polk | 11/10/1983 | 13 | 275 |
| USGS | Pomme de Terre R. nr. Polk | 12/6/1983 | 6 | 536 |
| USGS | Pomme de Terre R. nr. Polk | 1/3/1984 | 2 | 114 |
| USGS | Pomme de Terre R. nr. Polk | 2/6/1984 | 0.99 | 104 |
| USGS | Pomme de Terre R. nr. Polk | 3/5/1984 | 72 | 1540 |
| USGS | Pomme de Terre R. nr. Polk | 4/2/1984 | 11 | 481 |
| USGS | Pomme de Terre R. nr. Polk | 5/8/1984 | 6 | 238 |
| USGS | Pomme de Terre R. nr. Polk | 6/5/1984 | 16 | 47 |
| USGS | Pomme de Terre R. nr. Polk | 7/10/1984 | 24 | 74 |
| USGS | Pomme de Terre R. nr. Polk | 8/6/1984 | 8 | 7.5 |
| USGS | Pomme de Terre R. nr. Polk | 9/11/1984 | 21 | 31 |
| USGS | Pomme de Terre R. nr. Polk | 11/4/2002 | 4.99 | 11 |
| USGS | Pomme de Terre R. nr. Polk | 1/23/2003 | 4.99 | 17 |
| USGS | Pomme de Terre R. nr. Polk | 3/18/2003 | 4.99 | 76 |
| USGS | Pomme de Terre R. nr. Polk | 5/14/2003 | 18 | 125 |
| USGS | Pomme de Terre R. nr. Polk | 7/9/2003 | 19 | 11 |
| USGS | Pomme de Terre R. nr. Polk | 9/8/2003 | 4.99 | 13 |
| USGS | Pomme de Terre R. nr. Polk | 11/5/2003 | 10 | 27 |
| USGS | Pomme de Terre R. nr. Polk | 1/20/2004 | 10 | 641 |
| USGS | Pomme de Terre R. nr. Polk | 3/8/2004 | 11 | 674 |
| USGS | Pomme de Terre R. nr. Polk | 5/12/2004 | 12 | 135 |
| USGS | Pomme de Terre R. nr. Polk | 7/19/2004 | 4.99 | 29 |
| USGS | Pomme de Terre R. nr. Polk | 9/13/2004 | 4.99 | 5.2 |
| USGS | Pomme de Terre R. nr. Polk | 11/16/2004 | 4.99 | 221 |
| USGS | Pomme de Terre R. nr. Polk | 1/20/2005 | 4.99 | 377 |
| USGS | Pomme de Terre R. nr. Polk | 3/28/2005 | 4.99 | 256 |
| USGS | Pomme de Terre R. nr. Polk | 5/23/2005 | 11 | 44 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Pomme de Terre R. nr. Polk | 7/27/2005 | 15 | 11 |
| USGS | Pomme de Terre R. nr. Polk | 9/19/2005 | 22 | 62 |
| USGS | Pomme de Terre R. nr. Polk | 11/29/2005 | 4.99 | 19 |
| USGS | Pomme de Terre R. nr. Polk | 1/17/2006 | 4.99 | 31 |
| USGS | Pomme de Terre R. nr. Polk | 3/20/2006 | 4.99 | 38 |
| USGS | Pomme de Terre R. nr. Polk | 5/22/2006 | 56 | 270 |
| USGS | Pomme de Terre R. nr. Polk | 7/12/2006 | 13 | 21 |
| USGS | Pomme de Terre R. nr. Polk | 9/18/2006 | 19 | 1.6 |
| USGS | Pomme de Terre R. nr. Polk | 11/15/2006 | 4.99 | 21 |
| USGS | Pomme de Terre R. nr. Polk | 1/22/2007 | 28 | 1250 |
| USGS | Pomme de Terre R. nr. Polk | 2/27/2007 | 4.99 | 227 |
| USGS | Pomme de Terre R. nr. Polk | 3/5/2007 | 4.99 | 141 |
| USGS | Pomme de Terre R. nr. Polk | 4/17/2007 | 23 | 510 |
| USGS | Pomme de Terre R. nr. Polk | 5/8/2007 | 4.99 | 204 |
| USGS | Pomme de Terre R. nr. Polk | 6/25/2007 | 10 | 143 |
| USGS | Pomme de Terre R. nr. Polk | 7/23/2007 | 4.99 | 43 |
| USGS | Pomme de Terre R. nr. Polk | 9/17/2007 | 4.99 | 59 |
| USGS | Pomme de Terre R. nr. Polk | 11/5/2007 | 4.99 | 15 |
| USGS | Pomme de Terre R. nr. Polk | 1/22/2008 | 4.99 | 100 |
| USGS | Pomme de Terre R. nr. Polk | 3/17/2008 | 4.99 | 236 |
| USGS | Pomme de Terre R. nr. Polk | 5/27/2008 | 4.99 | 404 |
| USGS | Pomme de Terre R. nr. Polk | 7/21/2008 | 4.99 | 85 |
| USGS | Pomme de Terre R. nr. Polk | 9/15/2008 | 69 | 988 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 1/21/1997 | 0.499 | 5.5 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 6/13/1997 | 11 | 124 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 1/30/1996 | 3 | 7.8 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 6/14/1996 | 1 | 5.9 |
| USGS | Coakley Hollow | 4/24/1996 | 1 | 1 |
| USGS | Coakley Hollow | 6/12/1996 | 2 | 0.5 |
| USGS | Coakley Hollow | 8/21/1996 | 0.499 | 0.18 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 1/25/1995 | 2 | 13 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 6/23/1995 | 4 | 20 |
| USGS | Coakley Hollow | 11/15/1994 | 8 | 2 |
| USGS | Coakley Hollow | 4/24/1995 | 6 | 11 |
| USGS | Coakley Hollow | 6/26/1995 | 2 | 1 |
| USGS | Coakley Hollow | 8/30/1995 | 6 | 0.2 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 1/14/1994 | 4 | 9.3 |
| USGS | Big Buffalo Cr. 2 mi. SW of Boylers Mill | 6/9/1994 | 8 | 14 |
| USGS | Coakley Hollow | 11/9/1993 | 0.499 | 0.55 |
| USGS | Coakley Hollow | 6/3/1994 | 6 | 0.32 |
| USGS | Coakley Hollow | 8/25/1994 | 0.499 | 0.2 |
| USGS | Niangua R.@Hwy 64 | 11/15/1999 | 1 | 148 |
| USGS | Niangua R.@Hwy 64 | 5/16/2000 | 4.99 | 150 |
| USGS | Niangua R.@Hwy 64 | 1/19/1999 | 5 | 860 |
| USGS | Niangua R.@Hwy 64 | 6/9/1999 | 1 | 307 |
| USGS | Niangua R.@Hwy 64 | 1/20/1998 | 10 | 390 |
| USGS | Niangua R.@Hwy 64 | 6/8/1998 | 4 | 250 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Dousinbury Cr. @Hwy JJ | 11/15/1996 | 0.1 | 45 |
| USGS | Dousinbury Cr. @Hwy JJ | 2/27/1997 | 0.5 | 110 |
| USGS | Niangua R.@Hwy 64 | 1/22/1997 | 6 | 660 |
| USGS | Niangua R.@Hwy 64 | 6/26/1997 | 8 | 270 |
| USGS | Dousinbury Cr. @Hwy JJ | 11/21/1995 | 31 | 1.6 |
| USGS | Dousinbury Cr. @Hwy JJ | 1/19/1996 | 20 | 51 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/3/1996 | 20 | 21 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/15/1996 | 10 | 88 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/27/1996 | 13 | 5.3 |
| USGS | Dousinbury Cr. @Hwy JJ | 7/24/1996 | 19 | 2.2 |
| USGS | Dousinbury Cr. @Hwy JJ | 8/19/1996 | 44 | 0.67 |
| USGS | Niangua R.@Hwy 64 | 1/31/1996 | 0.499 | 170 |
| USGS | Hahatonka Spring | 12/5/1995 | 0.499 | 79 |
| USGS | Hahatonka Spring | 4/25/1996 | 9 | 250 |
| USGS | Hahatonka Spring | 6/12/1996 | 2 | 124 |
| USGS | Hahatonka Spring | 8/21/1996 | 0.499 | 124 |
| USGS | Dousinbury Cr. @Hwy JJ | 10/4/1994 | 10 | 2.3 |
| USGS | Dousinbury Cr. @Hwy JJ | 10/31/1994 | 3 | 4.3 |
| USGS | Dousinbury Cr. @Hwy JJ | 12/6/1994 | 10 | 13 |
| USGS | Dousinbury Cr. @Hwy JJ | 1/9/1995 | 3 | 4 |
| USGS | Dousinbury Cr. @Hwy JJ | 2/6/1995 | 2 | 30 |
| USGS | Dousinbury Cr. @Hwy JJ | 3/8/1995 | 6 | 48 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/3/1995 | 23 | 7.8 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/17/1995 | 336 | 137 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/20/1995 | 20 | 17 |
| USGS | Dousinbury Cr. @Hwy JJ | 7/12/1995 | 35 | 9.3 |
| USGS | Dousinbury Cr. @Hwy JJ | 8/16/1995 | 24 | 3.7 |
| USGS | Niangua R. nr. Windyville | 10/4/1994 | 25 | 38 |
| USGS | Niangua R. nr. Windyville | 11/1/1994 | 8 | 88 |
| USGS | Niangua R. nr. Windyville | 12/6/1994 | 55 | 186 |
| USGS | Niangua R. nr. Windyville | 1/10/1995 | 10 | 101 |
| USGS | Niangua R. nr. Windyville | 2/6/1995 | 5 | 425 |
| USGS | Niangua R. nr. Windyville | 3/9/1995 | 18 | 569 |
| USGS | Niangua R. nr. Windyville | 4/3/1995 | 27 | 123 |
| USGS | Niangua R. nr. Windyville | 5/17/1995 | 33 | 438 |
| USGS | Niangua R. nr. Windyville | 6/20/1995 | 31 | 319 |
| USGS | Niangua R. nr. Windyville | 7/12/1995 | 32 | 164 |
| USGS | Niangua R. nr. Windyville | 8/16/1995 | 42 | 94 |
| USGS | Niangua R.@Hwy 64 | 1/26/1995 | 4 | 747 |
| USGS | Niangua R.@Hwy 64 | 6/30/1995 | 22 | 840 |
| USGS | Hahatonka Spring | 11/15/1994 | 32 | 177 |
| USGS | Hahatonka Spring | 4/24/1995 | 8 | 170 |
| USGS | Hahatonka Spring | 6/26/1995 | 6 | 250 |
| USGS | Hahatonka Spring | 8/29/1995 | 2 | 104 |
| USGS | Dousinbury Cr. @Hwy JJ | 10/5/1993 | 17 | 22 |
| USGS | Dousinbury Cr. @Hwy JJ | 11/15/1993 | 28 | 372 |
| USGS | Dousinbury Cr. @Hwy JJ | 12/6/1993 | 12 | 216 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Dousinbury Cr. @Hwy JJ | 2/7/1994 | 1 | 7.6 |
| USGS | Dousinbury Cr. @Hwy JJ | 2/22/1994 | 655 | 983 |
| USGS | Dousinbury Cr. @Hwy JJ | 3/7/1994 | 16 | 25 |
| USGS | Dousinbury Cr. @Hwy JJ | 3/22/1994 | 14 | 6 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/5/1994 | 2 | 20 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/14/1994 | 6 | 120 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/18/1994 | 5 | 48 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/28/1994 | 279 | 2020 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/11/1994 | 4 | 48 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/16/1994 | 4 | 73 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/26/1994 | 1 | 17 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/2/1994 | 16 | 12 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/9/1994 | 5 | 25 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/14/1994 | 11 | 10 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/22/1994 | 3 | 5.3 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/29/1994 | 18 | 3.2 |
| USGS | Dousinbury Cr. @Hwy JJ | 7/12/1994 | 3 | 1.6 |
| USGS | Dousinbury Cr. @Hwy JJ | 7/25/1994 | 3 | 7.7 |
| USGS | Dousinbury Cr. @Hwy JJ | 8/16/1994 | 2 | 1.8 |
| USGS | Dousinbury Cr. @Hwy JJ | 9/1/1994 | 4 | 21 |
| USGS | Niangua R. nr. Windyville | 10/5/1993 | 10 | 332 |
| USGS | Niangua R. nr. Windyville | 11/15/1993 | 58 | 1720 |
| USGS | Niangua R. nr. Windyville | 12/6/1993 | 13 | 627 |
| USGS | Niangua R. nr. Windyville | 1/4/1994 | 7 | 158 |
| USGS | Niangua R. nr. Windyville | 2/10/1994 | 4 | 160 |
| USGS | Niangua R. nr. Windyville | 3/7/1994 | 21 | 609 |
| USGS | Niangua R. nr. Windyville | 4/5/1994 | 6 | 393 |
| USGS | Niangua R. nr. Windyville | 5/17/1994 | 26 | 840 |
| USGS | Niangua R. nr. Windyville | 6/2/1994 | 13 | 225 |
| USGS | Niangua R. nr. Windyville | 6/14/1994 | 32 | 239 |
| USGS | Niangua R. nr. Windyville | 7/12/1994 | 19 | 44 |
| USGS | Niangua R. nr. Windyville | 8/11/1994 | 11 | 33 |
| USGS | Niangua R. nr. Windyville | 9/7/1994 | 31 | 133 |
| USGS | Hahatonka Spring | 11/5/1993 | 4 | 150 |
| USGS | Hahatonka Spring | 4/6/1994 | 6 | 162 |
| USGS | Hahatonka Spring | 6/7/1994 | 10 | 300 |
| USGS | Hahatonka Spring | 8/25/1994 | 30 | 97 |
| USGS | Dousinbury Cr. @Hwy JJ | 4/21/1993 | 24 | 28 |
| USGS | Dousinbury Cr. @Hwy JJ | 5/20/1993 | 9 | 44 |
| USGS | Dousinbury Cr. @Hwy JJ | 6/14/1993 | 17 | 38 |
| USGS | Dousinbury Cr. @Hwy JJ | 7/7/1993 | 37 | 11 |
| USGS | Dousinbury Cr. @Hwy JJ | 8/25/1993 | 26 | 0.62 |
| USGS | Dousinbury Cr. @Hwy JJ | 9/14/1993 | 90 | 720 |
| USGS | Niangua R. nr. Windyville | 4/21/1993 | 20 | 441 |
| USGS | Niangua R. nr. Windyville | 5/20/1993 | 45 | 638 |
| USGS | Niangua R. nr. Windyville | 6/14/1993 | 86 | 565 |
| USGS | Niangua R. nr. Windyville | 7/8/1993 | 60 | 201 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Niangua R. nr. Windyville | 8/25/1993 | 39 | 20 |
| USGS | Niangua R. nr. Windyville | 9/14/1993 | 343 | 6480 |
| USGS | Niangua R.@Hwy 64 | 11/17/1992 | 0.499 | 364 |
| USGS | Niangua R.@Hwy 64 | 3/11/1993 | 18 | 560 |
| USGS | Niangua R.@Hwy 64 | 5/5/1993 | 27 | 1000 |
| USGS | Niangua R.@Hwy 64 | 9/14/1993 | 396 | 7000 |
| USGS | Niangua R.@Hwy 64 | 11/20/2000 | 4.99 | 119 |
| USGS | Niangua R.@Hwy 64 | 5/24/2001 | 8 | 497 |
| USGS | Niangua R.@Hwy 64 | 10/5/1987 | 3 | 100 |
| USGS | Niangua R.@Hwy 64 | 11/3/1987 | 0.499 | 145 |
| USGS | Niangua R.@Hwy 64 | 12/8/1987 | 9 | 1020 |
| USGS | Niangua R.@Hwy 64 | 2/2/1988 | 4 | 1360 |
| USGS | Niangua R.@Hwy 64 | 3/1/1988 | 14 | 600 |
| USGS | Niangua R.@Hwy 64 | 4/5/1988 | 30 | 1650 |
| USGS | Niangua R.@Hwy 64 | 5/10/1988 | 0.499 | 260 |
| USGS | Niangua R.@Hwy 64 | 6/10/1988 | 1 | 340 |
| USGS | Niangua R.@Hwy 64 | 7/12/1988 | 9 | 180 |
| USGS | Niangua R.@Hwy 64 | 8/2/1988 | 4 | 160 |
| USGS | Niangua R.@Hwy 64 | 9/6/1988 | 32 | 135 |
| USGS | Niangua R.@Hwy 64 | 10/14/1986 | 10 | 840 |
| USGS | Niangua R.@Hwy 64 | 11/5/1986 | 3 | 490 |
| USGS | Niangua R.@Hwy 64 | 12/2/1986 | 0.499 | 80 |
| USGS | Niangua R.@Hwy 64 | 1/5/1987 | 1 | 250 |
| USGS | Niangua R.@Hwy 64 | 2/2/1987 | 4 | 460 |
| USGS | Niangua R.@Hwy 64 | 3/2/1987 | 31 | 1460 |
| USGS | Niangua R.@Hwy 64 | 4/7/1987 | 3 | 432 |
| USGS | Niangua R.@Hwy 64 | 5/19/1987 | 1 | 190 |
| USGS | Niangua R.@Hwy 64 | 6/9/1987 | 4 | 150 |
| USGS | Niangua R.@Hwy 64 | 7/7/1987 | 0.499 | 80 |
| USGS | Niangua R.@Hwy 64 | 8/4/1987 | 3 | 147 |
| USGS | Niangua R.@Hwy 64 | 9/1/1987 | 1 | 125 |
| USGS | Niangua R.@Hwy 64 | 11/1/2001 | 4.99 | 147 |
| USGS | Niangua R.@Hwy 64 | 1/22/2002 | 4.99 | 171 |
| USGS | Niangua R.@Hwy 64 | 3/18/2002 | 4.99 | 376 |
| USGS | Niangua R.@Hwy 64 | 5/21/2002 | 18 | 1160 |
| USGS | Niangua R.@Hwy 64 | 7/29/2002 | 4.99 | 165 |
| USGS | Niangua R.@Hwy 64 | 9/9/2002 | 4.99 | 140 |
| USGS | Niangua R.@Hwy 64 | 10/8/1985 | 6 | 270 |
| USGS | Niangua R.@Hwy 64 | 11/12/1985 | 1 | 145 |
| USGS | Niangua R.@Hwy 64 | 12/3/1985 | 10 | 1900 |
| USGS | Niangua R.@Hwy 64 | 1/7/1986 | 1 | 265 |
| USGS | Niangua R.@Hwy 64 | 2/10/1986 | 6 | 680 |
| USGS | Niangua R.@Hwy 64 | 3/18/1986 | 4 | 260 |
| USGS | Niangua R.@Hwy 64 | 4/8/1986 | 14 | 6300 |
| USGS | Niangua R.@Hwy 64 | 5/13/1986 | 29 | 310 |
| USGS | Niangua R.@Hwy 64 | 6/5/1986 | 153 | 1250 |
| USGS | Niangua R.@Hwy 64 | 7/7/1986 | 6 | 225 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Niangua R.@Hwy 64 | 8/4/1986 | 3 | 135 |
| USGS | Niangua R.@Hwy 64 | 9/16/1986 | 3 | 150 |
| USGS | Niangua R.@Hwy 64 | 10/2/1984 | 1 | 125 |
| USGS | Niangua R.@Hwy 64 | 11/5/1984 | 5 | 753 |
| USGS | Niangua R.@Hwy 64 | 12/4/1984 | 6 | 360 |
| USGS | Niangua R.@Hwy 64 | 1/11/1985 | 2 | 605 |
| USGS | Niangua R.@Hwy 64 | 2/19/1985 | 14 | 1050 |
| USGS | Niangua R.@Hwy 64 | 3/18/1985 | 13 | 1050 |
| USGS | Niangua R.@Hwy 64 | 4/15/1985 | 7 | 1130 |
| USGS | Niangua R.@Hwy 64 | 5/21/1985 | 3 | 340 |
| USGS | Niangua R.@Hwy 64 | 6/11/1985 | 107 | 3280 |
| USGS | Niangua R.@Hwy 64 | 7/9/1985 | 2 | 300 |
| USGS | Niangua R.@Hwy 64 | 8/5/1985 | 0.499 | 175 |
| USGS | Niangua R.@Hwy 64 | 9/9/1985 | 1 | 174 |
| USGS | Niangua R.@Hwy 64 | 10/18/1983 | 0.499 | 125 |
| USGS | Niangua R.@Hwy 64 | 11/10/1983 | 5 | 540 |
| USGS | Niangua R.@Hwy 64 | 12/6/1983 | 7 | 1100 |
| USGS | Niangua R.@Hwy 64 | 1/3/1984 | 1 | 185 |
| USGS | Niangua R.@Hwy 64 | 2/6/1984 | 1 | 200 |
| USGS | Niangua R.@Hwy 64 | 3/5/1984 | 184 | 6290 |
| USGS | Niangua R.@Hwy 64 | 4/2/1984 | 6 | 860 |
| USGS | Niangua R.@Hwy 64 | 5/8/1984 | 1 | 700 |
| USGS | Niangua R.@Hwy 64 | 6/5/1984 | 6 | 95 |
| USGS | Niangua R.@Hwy 64 | 7/10/1984 | 3 | 271 |
| USGS | Niangua R.@Hwy 64 | 8/6/1984 | 2 | 135 |
| USGS | Niangua R.@Hwy 64 | 9/11/1984 | 7 | 200 |
| USGS | Niangua R.@Hwy 64 | 10/6/1982 | 2 | 122 |
| USGS | Niangua R.@Hwy 64 | 12/16/1982 | 0.499 | 550 |
| USGS | Niangua R.@Hwy 64 | 2/8/1983 | 0.499 | 345 |
| USGS | Niangua R.@Hwy 64 | 3/15/1983 | 1 | 320 |
| USGS | Niangua R.@Hwy 64 | 4/5/1983 | 38 | 1840 |
| USGS | Niangua R.@Hwy 64 | 5/3/1983 | 24 | 2200 |
| USGS | Niangua R.@Hwy 64 | 6/6/1983 | 12 | 590 |
| USGS | Niangua R.@Hwy 64 | 7/5/1983 | 5 | 40 |
| USGS | Niangua R.@Hwy 64 | 8/9/1983 | 14 | 174 |
| USGS | Niangua R.@Hwy 64 | 9/22/1983 | 5 | 112 |
| USGS | Niangua R.@Hwy 64 | 11/13/2002 | 4.99 | 151 |
| USGS | Niangua R.@Hwy 64 | 1/14/2003 | 4.99 | 160 |
| USGS | Niangua R.@Hwy 64 | 3/11/2003 | 4.99 | 256 |
| USGS | Niangua R.@Hwy 64 | 5/28/2003 | 4.99 | 160 |
| USGS | Niangua R.@Hwy 64 | 7/17/2003 | 12 | 153 |
| USGS | Niangua R.@Hwy 64 | 9/8/2003 | 4.99 | 110 |
| USGS | Niangua R.@Hwy 64 | 11/25/2003 | 4.99 | 280 |
| USGS | Niangua R.@Hwy 64 | 1/22/2004 | 4.99 | 510 |
| USGS | Niangua R.@Hwy 64 | 3/11/2004 | 56 | 534 |
| USGS | Niangua R.@Hwy 64 | 5/24/2004 | 4.99 | 627 |
| USGS | Niangua R.@Hwy 64 | 7/7/2004 | 4.99 | 179 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Niangua R.@Hwy 64 | 9/21/2004 | 4.99 | 113 |
| USGS | Niangua R.@Hwy 64 | 11/17/2004 | 4.99 | 283 |
| USGS | Niangua R.@Hwy 64 | 1/18/2005 | 4.99 | 760 |
| USGS | Niangua R.@Hwy 64 | 3/21/2005 | 4.99 | 325 |
| USGS | Niangua R.@Hwy 64 | 5/23/2005 | 4.99 | 153 |
| USGS | Niangua R.@Hwy 64 | 7/25/2005 | 4.99 | 137 |
| USGS | Niangua R.@Hwy 64 | 9/19/2005 | 12 | 261 |
| USGS | Niangua R.@Hwy 64 | 11/29/2005 | 4.99 | 146 |
| USGS | Niangua R.@Hwy 64 | 1/17/2006 | 4.99 | 146 |
| USGS | Niangua R.@Hwy 64 | 3/20/2006 | 4.99 | 160 |
| USGS | Niangua R.@Hwy 64 | 5/22/2006 | 4.99 | 184 |
| USGS | Niangua R.@Hwy 64 | 7/24/2006 | 4.99 | 139 |
| USGS | Niangua R.@Hwy 64 | 9/18/2006 | 4.99 | 113 |
| USGS | Niangua R.@Hwy 64 | 11/2/2006 | 4.99 | 150 |
| USGS | Niangua R.@Hwy 64 | 1/24/2007 | 4.99 | 1000 |
| USGS | Niangua R.@Hwy 64 | 2/27/2007 | 4.99 | 300 |
| USGS | Niangua R.@Hwy 64 | 3/5/2007 | 4.99 | 261 |
| USGS | Niangua R.@Hwy 64 | 4/17/2007 | 15 | 1140 |
| USGS | Niangua R.@Hwy 64 | 5/9/2007 | 4.99 | 283 |
| USGS | Niangua R.@Hwy 64 | 6/25/2007 | 4.99 | 267 |
| USGS | Niangua R.@Hwy 64 | 7/23/2007 | 4.99 | 130 |
| USGS | Niangua R.@Hwy 64 | 9/17/2007 | 4.99 | 160 |
| USGS | Niangua R.@Hwy 64 | 11/5/2007 | 4.99 | 39 |
| USGS | Niangua R.@Hwy 64 | 1/22/2008 | 4.99 | 165 |
| USGS | Niangua R.@Hwy 64 | 3/17/2008 | 12 | 372 |
| USGS | Niangua R.@Hwy 64 | 5/27/2008 | 4.99 | 433 |
| USGS | Niangua R.@Hwy 64 | 7/21/2008 | 4.99 | 296 |
| USGS | Niangua R.@Hwy 64 | 9/15/2008 | 112 | 12900 |
| USGS | Osage R. bl. St. Thomas | 11/8/1999 | 10 | 564 |
| USGS | Osage R. bl. St. Thomas | 5/3/2000 | 6 | 1430 |
| USGS | Osage R. bl. St. Thomas | 1/6/1999 | 10 | 7130 |
| USGS | Osage R. bl. St. Thomas | 5/27/1999 | 23 | 54900 |
| USGS | Osage R. bl. St. Thomas | 11/7/1997 | 6 | 1090 |
| USGS | Osage R. bl. St. Thomas | 5/19/1998 | 14 | 11000 |
| UE | Osage R. bl. St. Thomas | 7/17/2001 | 16.9 | 13100 |
| UE | Osage R. bl. St. Thomas | 8/14/2001 | 8.8 | 708 |
| UE | Osage R. bl. St. Thomas | 8/30/2001 | 19.8 | 13200 |
| UE | Osage R. bl. St. Thomas | 6/22/2001 | 10.4 | 24200 |
| UE | Osage R. bl. St. Thomas | 7/31/2001 | 22 | 15900 |
| UE | Osage R. bl. St. Thomas | 9/13/2001 | 8 | 1420 |
| USGS | L. Tavern Cr. nr mouth | 5/19/1994 | 4 | 38 |
| USGS | L. Tavern Cr. nr mouth | 8/31/1994 | 5 | 14 |
| USGS | L. Tavern Cr. nr mouth | 5/30/1995 | 18 | 82 |
| USGS | Osage R. bl. St. Thomas | 11/10/1993 | 14 | 32400 |
| USGS | Osage R. bl. St. Thomas | 3/15/1994 | 20 | 13200 |
| USGS | Osage R. bl. St. Thomas | 3/24/1993 | 63 | 4600 |
| USGS | Osage R. bl. St. Thomas | 5/18/1993 | 36 | 31200 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Osage R. bl. St. Thomas | 7/21/1993 | 11 | 30400 |
| USGS | Osage R. bl. St. Thomas | 9/30/1993 | 64 | 44800 |
| USGS | Osage R. bl. St. Thomas | 11/14/1990 | 4 | 663 |
| USGS | Osage R. bl. St. Thomas | 1/9/1991 | 5 | 4000 |
| USGS | Osage R. bl. St. Thomas | 3/7/1991 | 7 | 1450 |
| USGS | Osage R. bl. St. Thomas | 5/6/1991 | 48 | 4500 |
| USGS | Osage R. bl. St. Thomas | 7/15/1991 | 7 | 625 |
| USGS | Osage R. bl. St. Thomas | 9/6/1991 | 11 | 960 |
| USGS | Osage R. bl. St. Thomas | 1/19/1990 | 4 | 800 |
| USGS | Osage R. bl. St. Thomas | 3/20/1990 | 29 | 34700 |
| USGS | Osage R. bl. St. Thomas | 5/7/1990 | 27 | 34800 |
| USGS | Osage R. bl. St. Thomas | 7/9/1990 | 71 | 31600 |
| USGS | Osage R. bl. St. Thomas | 11/1/1988 | 11 | 666 |
| USGS | Osage R. bl. St. Thomas | 1/10/1989 | 20 | 8550 |
| USGS | Osage R. bl. St. Thomas | 5/17/1989 | 7 | 804 |
| USGS | Osage R. bl. St. Thomas | 7/18/1989 | 221 | 788 |
| USGS | Osage R. bl. St. Thomas | 9/15/1989 | 35 | 14400 |
| USGS | Osage R. bl. St. Thomas | 11/21/2000 | 4.99 | 556 |
| USGS | Osage R. bl. St. Thomas | 5/2/2001 | 13 | 676 |
| USGS | Osage R. bl. St. Thomas | 10/18/1974 | 62 | 7740 |
| USGS | Osage R. bl. St. Thomas | 11/21/1974 | 44 | 17800 |
| USGS | Osage R. bl. St. Thomas | 12/19/1974 | 110 | 14500 |
| USGS | Osage R. bl. St. Thomas | 1/20/1975 | 30 | 8780 |
| USGS | Osage R. bl. St. Thomas | 2/13/1975 | 38 | 31000 |
| USGS | Osage R. bl. St. Thomas | 3/13/1975 | 62 | 35000 |
| USGS | Osage R. bl. St. Thomas | 4/17/1975 | 40 | 9080 |
| USGS | Osage R. bl. St. Thomas | 5/13/1975 | 54 | 6610 |
| USGS | Osage R. bl. St. Thomas | 6/4/1975 | 69 | 10100 |
| USGS | Osage R. bl. St. Thomas | 7/23/1975 | 20 | 4080 |
| USGS | Osage R. bl. St. Thomas | 8/29/1975 | 63 | 24700 |
| USGS | Osage R. bl. St. Thomas | 9/24/1975 | 46 | 5020 |
| USGS | Osage R. bl. St. Thomas | 11/6/1987 | 60 | 771 |
| USGS | Osage R. bl. St. Thomas | 1/14/1988 | 23 | 16800 |
| USGS | Osage R. bl. St. Thomas | 3/3/1988 | 35 | 17900 |
| USGS | Osage R. bl. St. Thomas | 5/9/1988 | 24 | 9250 |
| USGS | Osage R. bl. St. Thomas | 7/15/1988 | 24 | 2390 |
| USGS | Osage R. bl. St. Thomas | 9/7/1988 | 7 | 890 |
| USGS | Osage R. bl. St. Thomas | 11/19/1986 | 4 | 51400 |
| USGS | Osage R. bl. St. Thomas | 1/15/1987 | 15 | 6360 |
| USGS | Osage R. bl. St. Thomas | 3/12/1987 | 15 | 32700 |
| USGS | Osage R. bl. St. Thomas | 5/15/1987 | 7 | 7950 |
| USGS | Osage R. bl. St. Thomas | 7/9/1987 | 14 | 8080 |
| USGS | Osage R. bl. St. Thomas | 9/10/1987 | 6 | 2490 |
| USGS | Osage R. bl. St. Thomas | 11/7/2001 | 18 | 6190 |
| USGS | Osage R. bl. St. Thomas | 1/9/2002 | 10 | 7280 |
| USGS | Osage R. bl. St. Thomas | 3/7/2002 | 4.99 | 4420 |
| USGS | Osage R. bl. St. Thomas | 5/8/2002 | 152 | 43700 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Osage R. bl. St. Thomas | 7/15/2002 | 105 | 992 |
| USGS | Osage R. bl. St. Thomas | 9/3/2002 | 11 | 740 |
| USGS | Osage R. bl. St. Thomas | 11/15/1985 | 64 | 34200 |
| USGS | Osage R. bl. St. Thomas | 1/16/1986 | 29 | 4890 |
| USGS | Osage R. bl. St. Thomas | 3/4/1986 | 7 | 9150 |
| USGS | Osage R. bl. St. Thomas | 5/8/1986 | 20 | 6200 |
| USGS | Osage R. bl. St. Thomas | 7/18/1986 | 25 | 21800 |
| USGS | Osage R. bl. St. Thomas | 9/2/1986 | 2 | 1170 |
| UE | Osage R. bl. St. Thomas | 5/31/2001 | 18.6 | 3700 |
| UE | Osage R. bl. St. Thomas | 5/31/2001 | 18.6 | 3700 |
| USGS | Osage R. bl. St. Thomas | 11/16/1984 | 26 | 5800 |
| USGS | Osage R. bl. St. Thomas | 1/18/1985 | 16 | 31700 |
| USGS | Osage R. bl. St. Thomas | 3/15/1985 | 29 | 53000 |
| USGS | Osage R. bl. St. Thomas | 5/10/1985 | 6 | 15500 |
| USGS | Osage R. bl. St. Thomas | 7/19/1985 | 29 | 1980 |
| USGS | Osage R. bl. St. Thomas | 9/19/1985 | 68 | 2790 |
| USGS | Osage R. bl. St. Thomas | 10/28/1975 | 28 | 1110 |
| USGS | Osage R. bl. St. Thomas | 11/13/1975 | 122 | 554 |
| USGS | Osage R. bl. St. Thomas | 12/18/1975 | 208 | 14900 |
| USGS | Osage R. bl. St. Thomas | 1/14/1976 | 35 | 1970 |
| USGS | Osage R. bl. St. Thomas | 2/4/1976 | 19 | 5750 |
| USGS | Osage R. bl. St. Thomas | 3/19/1976 | 9 | 3200 |
| USGS | Osage R. bl. St. Thomas | 4/8/1976 | 11 | 3490 |
| USGS | Osage R. bl. St. Thomas | 5/17/1976 | 374 | 3680 |
| USGS | Osage R. bl. St. Thomas | 6/17/1976 | 8 | 1380 |
| USGS | Osage R. bl. St. Thomas | 7/19/1976 | 16 | 875 |
| USGS | Osage R. bl. St. Thomas | 8/19/1976 | 47 | 552 |
| USGS | Osage R. bl. St. Thomas | 9/28/1976 | 54 | 1470 |
| USGS | Osage R. bl. St. Thomas | 11/18/1976 | 21 | 1670 |
| USGS | Osage R. bl. St. Thomas | 12/13/1976 | 61 | 803 |
| USGS | Osage R. bl. St. Thomas | 1/12/1977 | 25 | 5810 |
| USGS | Osage R. bl. St. Thomas | 2/4/1977 | 65 | 521 |
| USGS | Osage R. bl. St. Thomas | 3/4/1977 | 1 | 742 |
| USGS | Osage R. bl. St. Thomas | 4/15/1977 | 64 | 957 |
| USGS | Osage R. bl. St. Thomas | 5/13/1977 | 25 | 706 |
| USGS | Osage R. bl. St. Thomas | 6/16/1977 | 55 | 1180 |
| USGS | Osage R. bl. St. Thomas | 7/7/1977 | 107 | 39100 |
| USGS | Osage R. bl. St. Thomas | 8/11/1977 | 192 | 6060 |
| USGS | Osage R. bl. St. Thomas | 9/15/1977 | 128 | 4660 |
| USGS | Osage R. bl. St. Thomas | 10/6/1977 | 93 | 2290 |
| USGS | Osage R. bl. St. Thomas | 11/4/1977 | 61 | 12300 |
| USGS | Osage R. bl. St. Thomas | 12/15/1977 | 64 | 4050 |
| USGS | Osage R. bl. St. Thomas | 1/23/1978 | 91 | 550 |
| USGS | Osage R. bl. St. Thomas | 2/23/1978 | 60 | 4910 |
| USGS | Osage R. bl. St. Thomas | 3/16/1978 | 58 | 20300 |
| USGS | Osage R. bl. St. Thomas | 4/12/1978 | 160 | 31800 |
| USGS | Osage R. bl. St. Thomas | 5/25/1978 | 92 | 34100 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Osage R. bl. St. Thomas | 6/22/1978 | 133 | 1310 |
| USGS | Osage R. bl. St. Thomas | 7/13/1978 | 96 | 1730 |
| USGS | Osage R. bl. St. Thomas | 8/10/1978 | 36 | 1380 |
| USGS | Osage R. bl. St. Thomas | 10/19/1978 | 209 | 1200 |
| USGS | Osage R. bl. St. Thomas | 12/14/1978 | 76 | 8400 |
| USGS | Osage R. bl. St. Thomas | 2/7/1979 | 52 | 11000 |
| USGS | Osage R. bl. St. Thomas | 3/22/1979 | 151 | 7530 |
| USGS | Osage R. bl. St. Thomas | 6/14/1979 | 189 | 18100 |
| USGS | Osage R. bl. St. Thomas | 7/12/1979 | 206 | 14200 |
| USGS | Osage R. bl. St. Thomas | 10/12/1979 | 8 | 560 |
| USGS | Osage R. bl. St. Thomas | 11/8/1979 | 357 | 1800 |
| USGS | Osage R. bl. St. Thomas | 12/12/1979 | 358 | 660 |
| USGS | Osage R. bl. St. Thomas | 2/22/1980 | 77 | 7300 |
| USGS | Osage R. bl. St. Thomas | 3/27/1980 | 67 | 6800 |
| USGS | Osage R. bl. St. Thomas | 4/29/1980 | 77 | 920 |
| USGS | Osage R. bl. St. Thomas | 6/12/1980 | 71 | 3900 |
| USGS | Osage R. bl. St. Thomas | 9/10/1980 | 68 | 2200 |
| USGS | Osage R. bl. St. Thomas | 10/23/1980 | 58 | 780 |
| USGS | Osage R. bl. St. Thomas | 11/25/1980 | 2 | 590 |
| USGS | Osage R. bl. St. Thomas | 12/16/1980 | 24 | 2300 |
| USGS | Osage R. bl. St. Thomas | 1/20/1981 | 22 | 570 |
| USGS | Osage R. bl. St. Thomas | 2/24/1981 | 44 | 2400 |
| USGS | Osage R. bl. St. Thomas | 3/26/1981 | 114 | 866 |
| USGS | Osage R. bl. St. Thomas | 4/22/1981 | 50 | 1770 |
| USGS | Osage R. bl. St. Thomas | 5/28/1981 | 495 | 15400 |
| USGS | Osage R. bl. St. Thomas | 6/24/1981 | 1070 | 37500 |
| USGS | Osage R. bl. St. Thomas | 7/28/1981 | 18 | 13500 |
| USGS | Osage R. bl. St. Thomas | 8/18/1981 | 11 | 4340 |
| USGS | Osage R. bl. St. Thomas | 11/12/1981 | 4 | 5600 |
| USGS | Osage R. bl. St. Thomas | 1/12/1982 | 28 | 15000 |
| USGS | Osage R. bl. St. Thomas | 3/25/1982 | 46 | 25500 |
| USGS | Osage R. bl. St. Thomas | 5/18/1982 | 71 | 13400 |
| USGS | Osage R. bl. St. Thomas | 9/15/1982 | 45 | 3700 |
| USGS | Osage R. bl. St. Thomas | 11/29/1983 | 39 | 20400 |
| USGS | Osage R. bl. St. Thomas | 1/12/1984 | 41 | 6730 |
| USGS | Osage R. bl. St. Thomas | 3/16/1984 | 42 | 22900 |
| USGS | Osage R. bl. St. Thomas | 5/18/1984 | 48 | 35100 |
| USGS | Osage R. bl. St. Thomas | 7/27/1984 | 28 | 2020 |
| USGS | Osage R. bl. St. Thomas | 11/16/1982 | 19 | 4000 |
| USGS | Osage R. bl. St. Thomas | 1/24/1983 | 16 | 800 |
| USGS | Osage R. bl. St. Thomas | 3/31/1983 | 63 | 16000 |
| USGS | Osage R. bl. St. Thomas | 7/25/1983 | 25 | 4750 |
| USGS | Osage R. bl. St. Thomas | 9/7/1983 | 313 | 660 |
| USGS | Osage R. bl. St. Thomas | 11/12/2002 | 19 | 562 |
| USGS | Osage R. bl. St. Thomas | 1/13/2003 | 4.99 | 568 |
| USGS | Osage R. bl. St. Thomas | 3/10/2003 | 4.99 | 676 |
| USGS | Osage R. bl. St. Thomas | 5/27/2003 | 4.99 | 820 |

| Org | Site Name | Date | TSS (mg/L) | Inst. Flow (cfs) |
|---|---|---|---|---|
| USGS | Osage R. bl. St. Thomas | 7/14/2003 | 14 | 3450 |
| USGS | Osage R. bl. St. Thomas | 9/3/2003 | 25 | 6110 |
| USGS | Osage R. bl. St. Thomas | 11/24/2003 | 15 | 955 |
| USGS | Osage R. bl. St. Thomas | 1/13/2004 | 8 | 12400 |
| USGS | Osage R. bl. St. Thomas | 3/8/2004 | 38 | 29000 |
| USGS | Osage R. bl. St. Thomas | 5/25/2004 | 47 | 21900 |
| USGS | Osage R. bl. St. Thomas | 7/6/2004 | 4.99 | 2200 |
| USGS | Osage R. bl. St. Thomas | 9/20/2004 | 17 | 992 |
| USGS | Osage R. bl. St. Thomas | 11/29/2004 | 10 | 37200 |
| USGS | Osage R. bl. St. Thomas | 1/26/2005 | 11 | 36800 |
| USGS | Osage R. bl. St. Thomas | 3/9/2005 | 4.99 | 20500 |
| USGS | Osage R. bl. St. Thomas | 5/2/2005 | 4.99 | 1160 |
| USGS | Osage R. bl. St. Thomas | 7/13/2005 | 14 | 8470 |
| USGS | Osage R. bl. St. Thomas | 9/1/2005 | 24 | 20300 |
| USGS | Osage R. bl. St. Thomas | 11/3/2005 | 4.99 | 1070 |
| USGS | Osage R. bl. St. Thomas | 1/3/2006 | 4.99 | 648 |
| USGS | Osage R. bl. St. Thomas | 3/6/2006 | 4.99 | 956 |
| USGS | Osage R. bl. St. Thomas | 5/4/2006 | 81 | 27300 |
| USGS | Osage R. bl. St. Thomas | 7/6/2006 | 11 | 529 |
| USGS | Osage R. bl. St. Thomas | 9/5/2006 | 30 | 769 |
| USGS | Maries R. 3 mi. W of Freeburg | 8/10/2006 | 4 | 0.5 |
| USGS | Osage R. bl. St. Thomas | 11/2/2006 | 4.99 | 449 |
| USGS | Osage R. bl. St. Thomas | 1/23/2007 | 20 | 4660 |
| USGS | Osage R. bl. St. Thomas | 2/6/2007 | 21 | 6030 |
| USGS | Osage R. bl. St. Thomas | 3/13/2007 | 26 | 1200 |
| USGS | Osage R. bl. St. Thomas | 4/24/2007 | 16 | 34500 |
| USGS | Osage R. bl. St. Thomas | 5/8/2007 | 15 | 36600 |
| USGS | Osage R. bl. St. Thomas | 6/5/2007 | 23 | 31000 |
| USGS | Osage R. bl. St. Thomas | 7/11/2007 | 12 | 49900 |
| USGS | Osage R. bl. St. Thomas | 9/10/2007 | 15 | 6980 |
| USGS | Osage R. bl. St. Thomas | 11/20/2007 | 14 | 1440 |
| USGS | Osage R. bl. St. Thomas | 1/10/2008 | 38 | 3740 |
| USGS | Osage R. bl. St. Thomas | 3/27/2008 | 15 | 29100 |
| USGS | Osage R. bl. St. Thomas | 5/12/2008 | 14 | 41000 |
| USGS | Osage R. bl. St. Thomas | 7/30/2008 | 20 | 32900 |
| USGS | Osage R. bl. St. Thomas | 9/3/2008 | 81 | 20700 |

# Appendix F – Supplemental Implementation Plan

This implementation plan is not a requirement of the Federal CWA. However, the contractor included it as part of the TMDL preparation. EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL. Therefore, this informational plan is included to be used by local professionals, watershed managers and citizens for decision-making support and planning purposes. It should not be considered to be a part of the established Town Branch/Piper Creek TMDL.

The Town Branch/Piper Creek TMDL will be implemented through permit actions and best management practices (BMPs). This approach is based upon recommendations made in the MDNR 2005 - 2006 sediment study report, which are:

- Measures should be taken to upgrade the facilities and/or operation of the Bolivar WWTP to prevent VSS impairment of Town Branch and Piper Creek.

- The city of Bolivar should also provide an adequate buffer between Town Branch and the city's community compost mound. Note: the compost pile was eliminated in spring 2006.

- Measures should also be taken to identify and control nonpoint sources of nutrient input as well as practicing best land management practices.

**Point Source**

The city of Bolivar WWTF's state operating permit (MO0022373) was renewed on April 4, 2008. Effluent limits for TSS, of 41/27 mg/L (weekly/monthly averages) were carried over from the previous permit. New effluent limits for ammonia and bacteria will go into effect in 2011 and 2012, respectively. A schedule of compliance relating to these parameters is included in the operating permit. As mentioned in the monitoring section of the TMDL (Section 8), quarterly instream monitoring for DO, TSS and nutrients upstream and downstream of outfall #001 is required. This will provide additional data with which to assess the impact of the WWTF on Town Branch. Furthermore, the city is under enforcement by EPA to prevent future by-passes and to take action to fix recurring infiltration and inflow problems throughout the sewer's collection system.

Under the Order for Compliance and Consent (OCC), the city of Bolivar has created an electronic Sanitary Sewer Overflow (SSO), Bypass and Basement Tracking System, a Data Management System to collect, organize and analyze all existing and future data regarding the city's sanitary sewer system, a detailed Plan of Action containing a schedule for eliminating SSO events and bypasses and a Continuing Improvement Plan (CIP). The CIP identifies all known short and long term capital investment projects of operation and maintenance activities the city anticipates will be necessary to ensure the current and long term compliance with the city's state operating permit. In the last two and a half years (from Feb 2010), Bolivar has cleaned 26 miles of sewer main (collection lines carrying sewage to the WWTP), video inspected seven miles of

sewer main and made 919 inspections of manholes. In the process, the city has found and repaired many holes, leaks and breaks in the sewer mains and repaired or rebuilt many manholes. The city's goal is to have cleaned all of the sewer mains in five years (there are approximately 70 miles left) and then repeat the process all over again. Collectively, these measures should be adequate to reduce the facility's contribution of organic sediment and nutrients to healthy levels, enabling the stream to meet WQSs.

The state is currently developing nutrient criteria for rivers and streams. When this has been accomplished, the TMDL will be revised to reflect the new criteria for TP and TN. In expectation of these criteria, the nutrient WLAs developed in this TMDL will not be immediately added to the Bolivar WWTF permit. Rather, nutrient monitoring will first be added to the facility operating permit to determine the current nutrient loading from the facility.

**Nonpoint Source**

In April 2005, MDNR started holding public meetings in Boliver to make the local citizens aware of water quality and TMDL issues in Town Branch/Piper Creek. As a result of these meetings, the Bolivar Community Watershed Improvement Group (BCWIG) was organized in November 2005. This group has taken on the responsibility for identifying the sources of nutrients entering Town Branch/Piper Creek and fixing these problems.

Some of the issues the group is addressing are:

- Physical clean-up of the streams
- Lawn care fertilization
- Animal waste
- Sewage infiltration
- Lack of retention and detention of storm water

The group is very actively engaged and regularly meets each month. Some of their activities include:

- Conducting a watershed tour to survey the watershed and figure out the sources/problem areas;
- Resolving the problem with the compost pile. At the June 19, 2006 meeting, the city announced that the compost pile had been eliminated;
- Incorporating as a nonprofit organization;
- Four members have been trained as Volunteer Water Quality Monitors (one at high level 1, two at level 2 and one at CSI level equivalent to DNR professional monitoring) through the Missouri Stream Team Volunteer Water Quality Monitoring Program. With this expertise, the group can gather more data and be able to make better decisions on where to focus time and resources. The group created their own monitoring plan and started collecting data on Town Branch/Piper Creek spring of 2007

- Collecting samples to be analyzed for fecal coliform and ribotyping. The group booked Dr. Andy Carson, a pioneer in ribotyping from the University of Missouri – Columbia, to talk to the group about the DNA testing results and what they mean;
- Manning booths at the local Home and Garden Show in April 2008, 2009 and 2010, handing out over 400 saplings and BCWIG watershed information;
- Organizing a litter pick-up in Town Branch, with city of Bolivar cooperation, in April 2008;
- Hosting a Volunteer WQ Monitoring Introductory Level workshop May 3, 2008;
- Working with the local Boy Scouts to stencil storm drains with "Do not dump. Drains to stream" in July of 2008;

- Organizing and sponsoring an event in conjunction with World Water Monitoring Day with water quality testing demonstrations on Town Branch and Piper Creek and furnishing a lunch for attendees in October, 2008;
- Organizing and presenting a stakeholder's progress update and planning session with MU Water Quality Program facilitators in October, 2009;
- Establishing an education/demonstration planting project along a section of Town Branch;
- July 2010: In cooperation with the NRCS, City of Bolivar, and Springfield/Green County watershed groups, BCWIG sponsored a field workshop in Springfield touring four storm water and urban conservation projects that could be applied to the Town Branch watershed.

As of August 2010, the group is writing their watershed management plan under a 319 grant. They have hired a Certified Public Accountant and are steadily moving ahead with this monumental project. There will be a monitoring component contained in the Watershed Management Plan.