SOUTHWEST MISSOURI WATER QUALITY IMPROVEMENT PROJECT (WQIP)
SAC RIVER BASIN WATER QUALITY GAP ANALYSIS

PREPARED FOR:
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The Science of Water Quality

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ACRONYMS AND ABBREVIATIONS

ab.	above
ACWI	Advisory Committee on Water Information
bl.	below
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
cfu	colony forming units
cfs	cubic feet per second
COE-KCD	Army Corps of Engineers – Kansas City District
CU	City Utilities of Springfield
DNA	deoxyribonucleic acid
DO	Dissolved Oxygen
E.coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EPA STORET	U.S. Environmental Protection Agency STOrage and RETrieval
ERC	Environmental Resource Coalition
F	Fahrenheit
FAPRI	Food and Agricultural Policy Research Institute at the University of Missouri
ft	feet
GIS	Geographic Information System
HUC	Hydrologic Unit Code
MDC	Missouri Department of Conservation
MDCB	Methods and Data Comparability Board
MDNR	Missouri Department of Natural Resources
MEC	Midwest Environmental Consultants Water Resources, Inc.
MSDIS	Missouri Spatial Data Information Service
mg/L	milligram per liter
mL	milliliter
mi.	mile
MS	Microsoft
MSU	Missouri State University
MURPHY	Murphy Family Farms
NAWQA	National Water-Quality Assessment Program
ND	non-detect
n.d.	no date provided
N_2	Nitrogen gas
N_2O	Nitrous Oxide
NO	Nitric Oxide
NO_2	Nitrite
NO_3	Nitrate
NO_3-NO_2	Nitrate plus Nitrite expressed as Nitrogen
NH_4	Ammonium
NH_3-N	Ammonia expressed as Nitrogen
NRCS	Natural Resources Conservation Services

NWIS	National Water Information System
NWQMC	National Water Quality Monitoring Council
Q	discharge or flow
QA/QC	Quality Assurance and Quality Control
SPW	City of Springfield Public Works
sq. mi.	square mile
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen expressed as Nitrogen
TNTC	Too Numerous To Count
TP	Total Phosphorus expressed as Phosphorus
TSS	Total Suspended Solids
WBCR	Whole Body Contact Recreation
WQDE	Water Quality Data Elements
WQIP	Southwest Missouri Water Quality Improvement Project
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant
µg/L	microgram per liter
USGS	U.S. Geological Survey
VSS	Volatile Suspended Solids

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EXECUTIVE SUMMARY

Rapid growth and expansion in southwest Missouri are threatening the water resources this region's population, agriculture, and tourism industry so heavily depend upon. In response to this threat, several watershed groups in southwest Missouri collaborated to secure federal funding for water protection efforts in this region. As a result of this effort, the Environmental Resources Coalition (ERC) received a U.S. Environmental Protection Agency (EPA) grant to develop and manage the Southwest Missouri Water Quality Improvement Project (WQIP), a mult-year, multi-stakeholder effort to address water quality issues in this region. WQIP has initially been tasked with assembling, evaluating, and interpreting existing water quality for several major basins in southwest Missouri. The Sac River Basin is the subject of this report.

The Sac River Basin is 1,969 square miles and includes the north edge of the Springfield area along its southern boundary. Major tributaries of the Sac River include Turnback, Sons, Horse, Cedar, Coon, Turkey, Brush and Bear Creeks, and the Little Sac River. Water quality regulatory issues in the basin include a bacteria total maximum daily load on the Little Sac River, the impairment of Stockton Branch for volatile suspended solids, and the impairment of Brush Creek for low dissolved oxygen.

Water quality data from the Sac River Basin were compiled from multiple collection entities including the Missouri Department of Natural Resources, U.S. Army Corps of Engineers – Kansas City District, City Utilities of Springfield, City of Springfield Public Works, Food and Agricultural Policy Research Institute at the University of Missouri, Murphy Family Farms, and the U.S. Geological Survey. The data were analyzed with relation to total phosphorus, total nitrogen, nitrate plus nitrite as nitrogen, sestonic chlorophyll *a*, *Escherichia coli* (*E. coli*) and fecal coliform. Phosphorus and nitrogen levels were notably elevated in the Sac River above Walnut Grove Brush and in Brush and Turnback Creeks. Significant levels of nitrogen were also observed in the Horse Creek watershed where there is a large concentration of swine operations. Fecal coliform geometric means exceeded Missouri's water quality criterion at two of six stations on the Little Sac River; however, *E. coli* geometric means did not exceed criterion.

Based on a data gap analysis of the existing water quality data in the Sac River Basin, several recommendations were made for WQIP. Formation of a monitoring coordinating board could benefit all the stakeholder entities in WQIP by standardizing sampling designs, quality assurance programs, metadata requirements, and by developing a centralized database to facilitate the sharing of water quality data. Current and historical water quality data are insufficient to address the goals of WQIP; therefore, a new comprehensive water quality monitoring network needs to be designed. Further data analysis and potential special storm water studies are also recommended to better understand non-point source loading issues. WQIP stakeholders are encouraged to participate in the development of regional stream nutrient criteria through stakeholder involvement and further water quality studies. Finally, efforts should be made to incorporate additional existing water quality data into the WQIP database that were not populated at the time of the database's creation.

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1. INTRODUCTION

One of the most important physical and economic attributes of southwestern Missouri is its abundant supply of high quality water resources. A rapidly expanding population, the growing needs of agriculture, and a billion dollar tourism industry are simultaneously highly dependent on these resources and present the greatest threats to the sustained quality of these resources.

The Environmental Resources Coalition (ERC) received a U.S. Environmental Protection Agency (EPA) grant to develop and manage the Southwest Missouri Water Quality Improvement Project (WQIP), a multi-year, multi-stakeholder effort to address water quality issues in this region. The overall purpose of WQIP is to improve water quality while also protecting rural economic development and agricultural interests by providing factual information to facilitate sound regulatory and policy decision making.

ERC selected MEC Water Resources, Inc. (MEC) to assist with the technical aspects of WQIP. One of the first major components of WQIP was to assemble existing water quality data. These data have been collected for various reasons during many years, at many locations, by many different entities. Once compiled, these data were evaluated and interpreted to determine possible data gaps. The database developed through this compilation will also serve as an invaluable resource for future research efforts.

MEC assembled an expert team, including University Ozarks Environmental and Water Resources Institute (OEWRI), and the University Missouri-Columbia to perform the WQIP Data Gap Analysis. This report presents the data gap analysis for the Sac River Basin (hydrologic unit 10290106). The data gap analysis for the Sac River Basin includes a compilation and evaluation of existing data and highlights data gaps to be filled to allow for sound technical and policy decisions to address WQIP objectives.

This report is organized into seven major sections including this introduction:

Section 2. Study Area – a summary of the key characteristics of the Sac River Basin including land use and demographics, point and non-point wastewater discharges, climate, geology, surface water hydrology, and regulatory issues

Section 3. Methods – describes from who and how the data were collected, how the data were managed, and how the data were assessed for use in the data gap analysis

Section 4. Water Quality Summaries and Statistics – provides a summary of the most common water quality parameters of interest including nutrients and bacteria. Various statistical analyses are presented to allow interpretation of the data and to put the data into context.

Section 5. Biological Monitoring – provides a summary of the biological indices and fisheries data that has been collected in the Sac River Basin.

Section 6. Data Gaps – provides an assessment of where data gaps exist in terms of spatial, temporal, hydrological, chemical, and biological coverage of the study area.

Section 7. Recommendations – provides highlights of the key findings of the data gap analysis.

References are also provided. The complete data set is available through ERC by special request.

2. STUDY AREA

The study area description of the Sac River Basin provided below includes the basin characteristics, population and land use, permitted point source discharges, nonpoint sources of pollution, geology and soils, climate and hydrology, and regulatory issues.

2.1 Basin Characteristics

The Sac River Basin (approximately 1,969 mi^2) is located in southwest Missouri draining parts of Barton, Cedar, Christian, Dade, Greene, Hickory, Lawrence, Polk, St. Clair, and Vernon counties (Figure 1). Headwaters to the Sac River originate near northern Springfield. Major tributaries to the Sac River Basin include Little Sac River, Turnback, Sons, Horse, Cedar, Coon, Turkey, Brush, and Bear Creeks. Large sections of the Little Sac and Sac River are inundated by Stockton Reservoir, which covers approximately anywhere from 39 to 60 square miles at normal and flood capacity, respectively. Fellows Lake and McDaniel Lake are two smaller reservoirs located on the Little Sac River upstream of Stockton Reservoir (MDNR, n.d.). Downstream of Stockton dam, near the mouth of basin, the Sac River forms an arm of Truman Reservoir, which on occasion floods the lower portions of Coon Creek, Brush Creek, Turkey Creek, and Cedar Creek (Horton and Hudson, n.d.).

The northern portion of the Springfield metropolitan area in Greene County straddles the Sac and James River Basins. Within the Sac River Basin, the Springfield metropolitan area is drained by Pea Ridge Creek, Spring Branch, and the South Dry Sac, which are all tributaries to the Little Sac River. Other communities of significant size located within the drainage area include Willard, Ash Grove, Walnut Grove, Greenfield, Dadeville, Lockwood, Jerico Springs, Stockton, and Humansville. Republic, Brookline, and Strafford are partially located in headwater areas along the watershed boundary.

2.2 Population and Land Use

Population data from the 2000 census show the highest population density (>500 persons per mi^2) in the basin occurs in north Springfield (Figure 2). Outside of the Springfield area most of the population density in the basin is relatively low, with the exception of population centers such as Republic and El Dorado Springs. However, even within these population centers the density never exceeds 500 persons per mi^2. In general, the population density is less than 100 persons per mi^2 in the eastern half of the basin, whereas the western half has a density of less than 40 persons per mi^2.

Analysis of population change from 1990 to 2000 shows a range of population trends. The mid-portion of the western edge of the basin underwent a population decrease, whereas the majority of the remaining areas experienced an increase in population (Figure 3). Population increases generally ranged from less than 20% to less than 50%. Some of the greatest population increases were in the areas of Strafford, Stockton, Millford, and the area from Humansville south to approximately Willard.

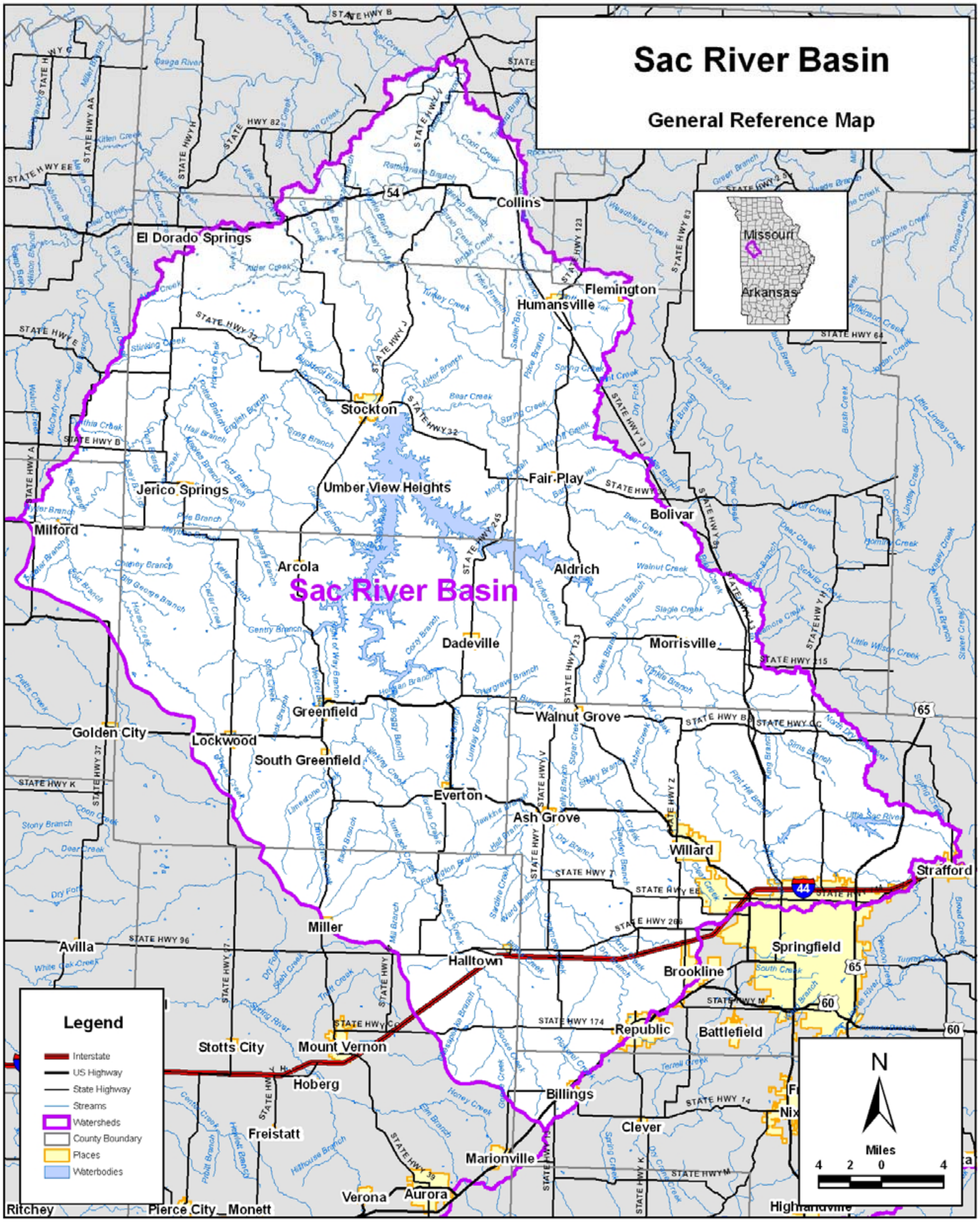

FIGURE 1. Sac River Basin – General Reference

Grassland/pasture and forest dominate land use throughout most of the Sac River Basin (Figure 4). High and low density urban land use is generally limited to relatively small areas near population centers such as Springfield. The headwater areas of the basin are comprised of mainly forest and grassland/pasture land use interspersed with small areas of cropland. Forest land is greatest around and downstream of Stockton Reservoir. Table1 summarizes land use for the basin.

TABLE 1. Sac River Basin Land Use Percentages 2000-2004

Landuse	Percentage
High Density Urban	1
Low Density Urban	1
Barren, Quaries, Lake Shore	1
Cropland	7
Grassland/Pasture	56
Forest	26
Young Forest/shrubland	5
Water	3

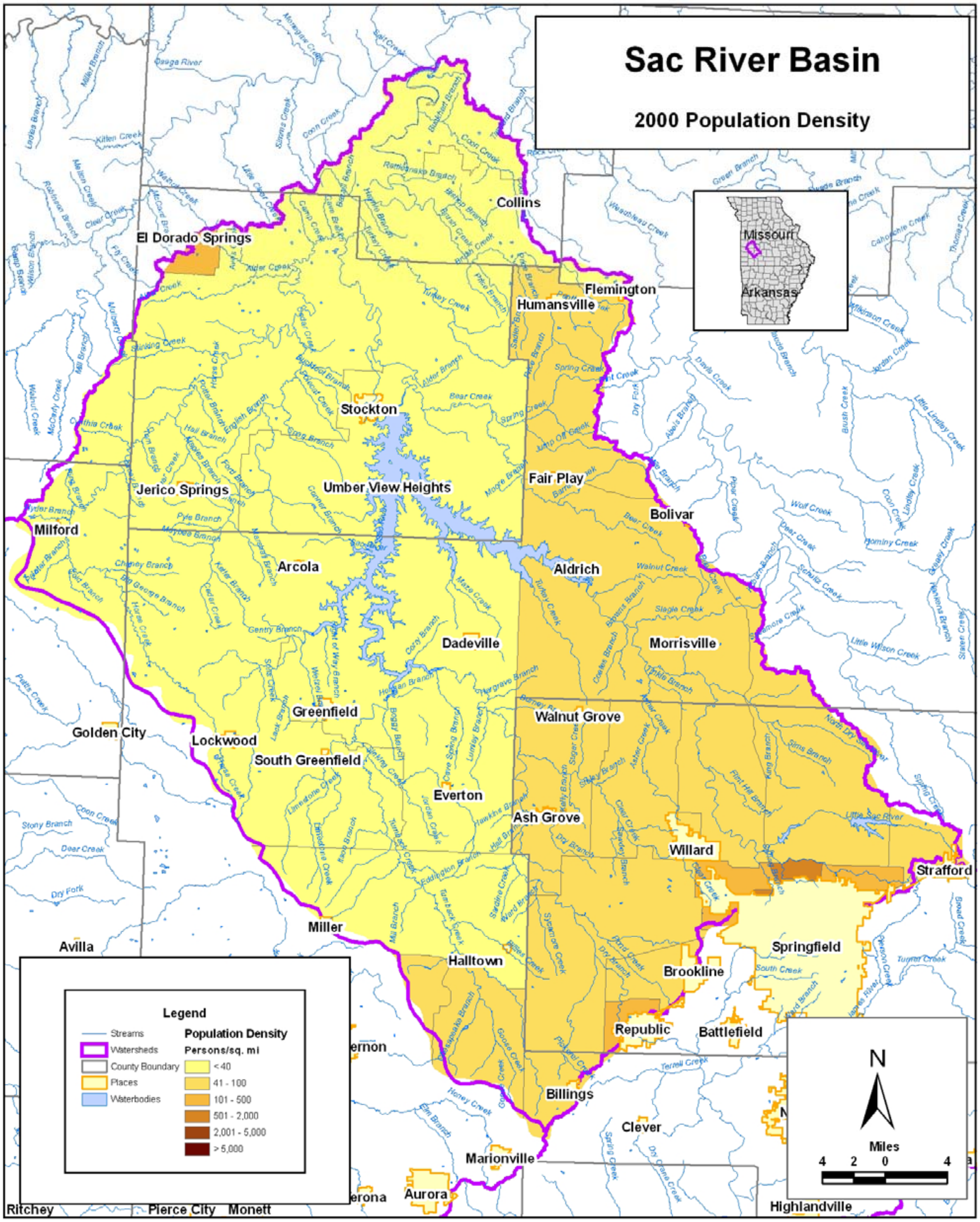

FIGURE 2. Sac River Basin – Population Density (2000)

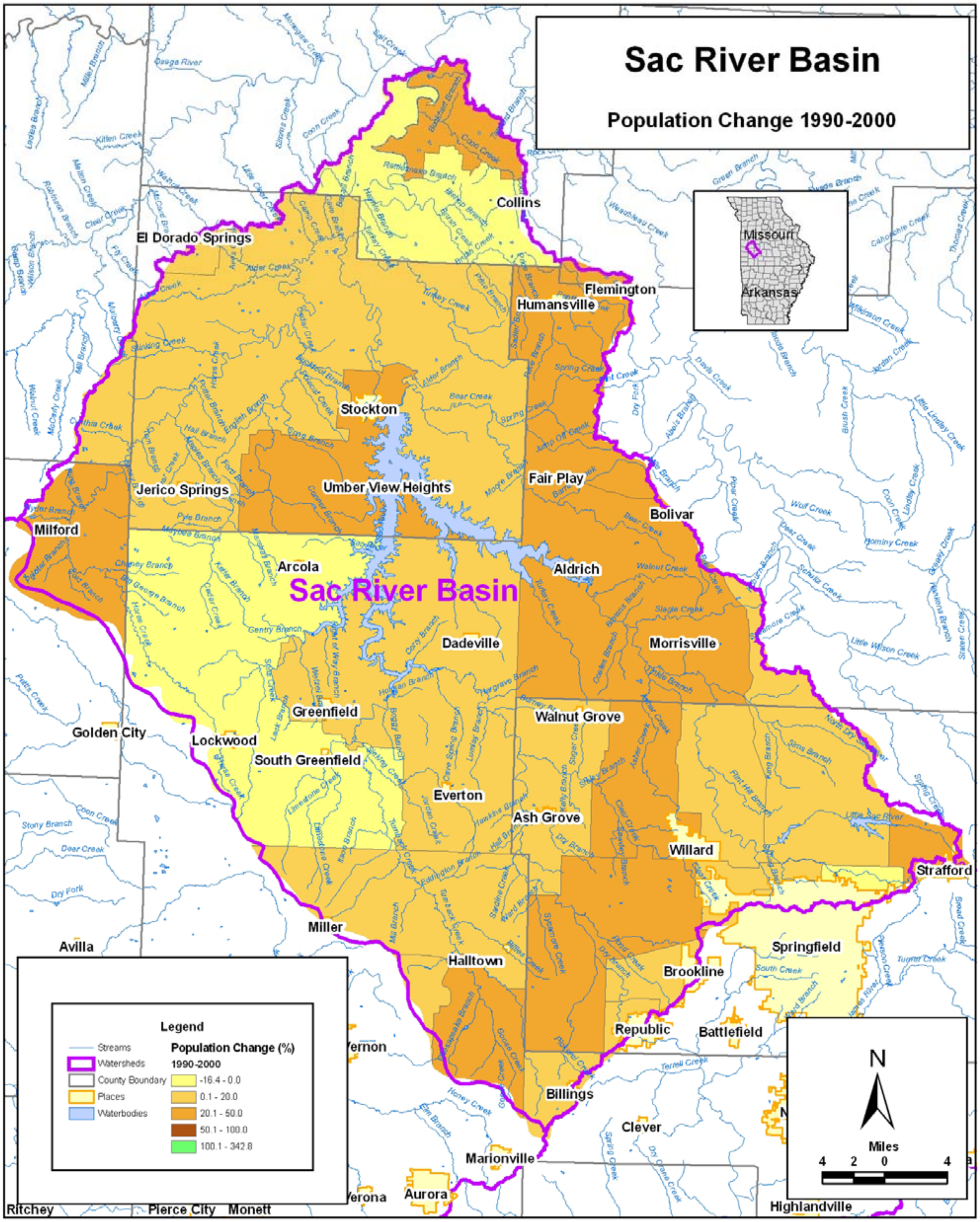

FIGURE 3. Sac River Basin – Population Change (1990 – 2000)

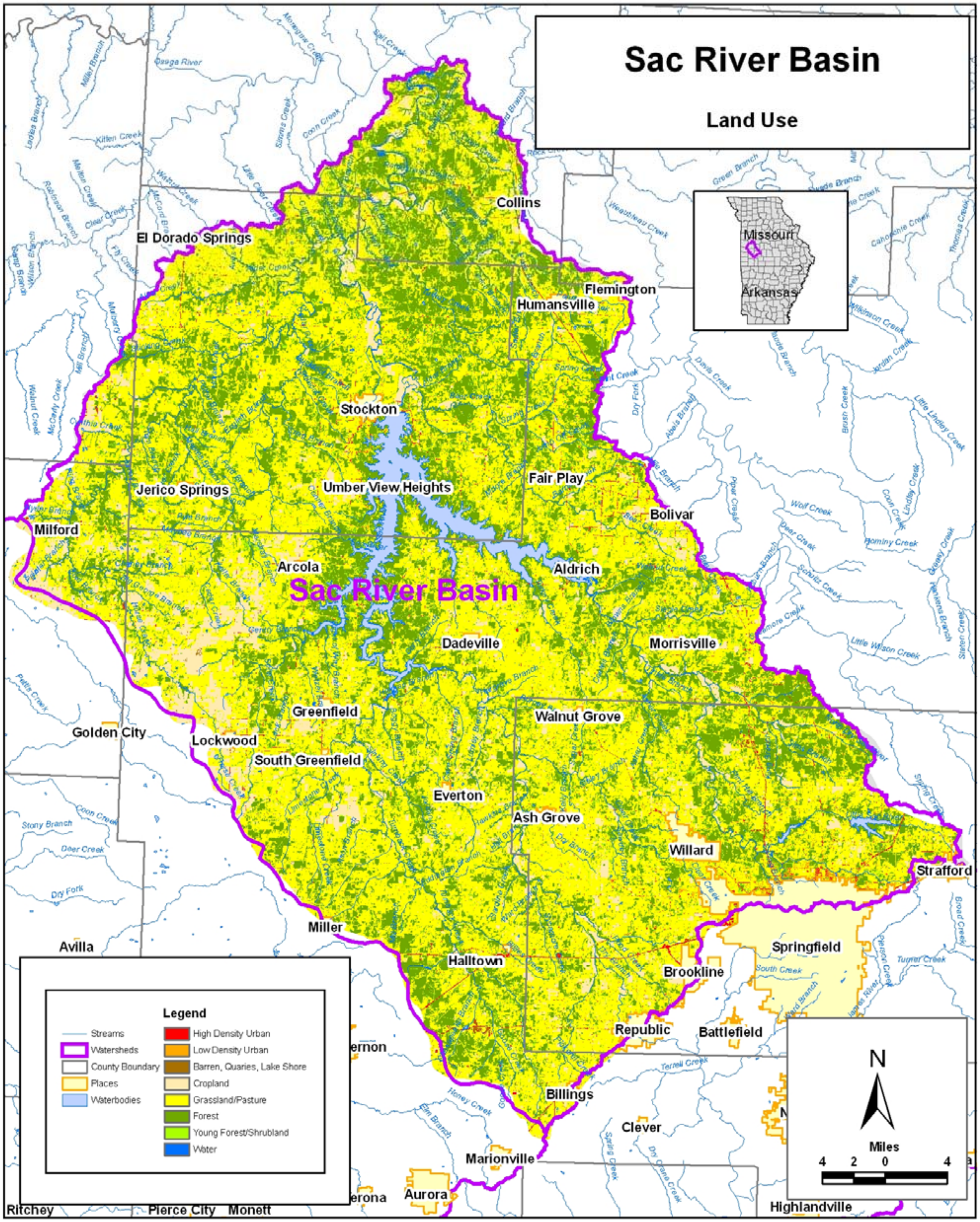

FIGURE 4. Sac River Basin – Land Use

2.3 Permitted Point Source Discharges

Point source discharges may generally be categorized as domestic wastewater or industrial and commercial wastewater. Pollutants from domestic discharges typically include organic matter measured as biological oxygen demand (BOD), suspended solids and ammonia. Domestic discharges are also typically high in nitrogen and phosphorus. Industrial and commercial discharges can include a mix of domestic waste, heavy metals, and man-made organic chemicals. For purposes of discussion, point sources are described below as industrial, non-municipal domestic, municipal, and combined animal feeding operations (CAFOs). Municipal wastewater is typically a mixture of domestic and industrial/commercial wastewater. Since CAFOs are not continuous discharges, they will be discussed separately. This analysis is based on the National Pollutant Discharge Elimination System (NPDES) outfalls spatial dataset accessed from the Missouri Spatial Data Information Service (MSDIS) website.

The Sac River Basin receives continuous discharges from 48 permitted point sources (Table 2 and Figure 5) discharging a combined flow of 14.3 million gallons per day (MGD). The Springfield Northwest WWTP and the Republic WWTP are the two largest discharges to the Sac River Basin accounting for approximately 86% of the total municipal wastewater discharging to the basin. The McDanial Lake hypolimnetic withdrawal system operated by City Utilities of Springfield is the only industrial coded facility in the basin, which has design flow of 3.2 MGD and is permitted for ammonia and total suspended solids. Non-municipal domestic WWTPs account for over half of the WWTPs in the basin but only 2% of the total discharge by point sources.

TABLE 2. Permitted Point Sources in the Sac River Basin

Type	Number	Flow (MGD)*
Industrial	1	3.2
Non-Municipal Domestic	26	0.3
Municipal	21	10.8
Total	**48**	**14.3**

*Million gallons per day

CAFO outfalls are only used to discharge waste under emergency conditions such as spills or breaks of water storage structures resulting from accidents or excessive rain. Animal waste from CAFOs is disposed of through land application, where it can enter water bodies through runoff. Most wastewater from treatment facilities and CAFOs is typically high in nitrogen and phosphorus.

Nineteen CAFOs (1 dairy, 1 turkey, and 17 swine) are located in the Sac River Basin. The estimated annual waste production from these facilities is 91.7 tons (Table 3). Murphy Family Ventures operates 13 of the swine operations, which are concentrated in the northwest part of the basin in the Horse Creek watershed.

TABLE 3. CAFOs in the Sac River Basin

Type	Number	Annual Waste Production (dry tons)*
Dairy	7	5
Swine	17	80.1
Turkey	1	6.6

*Total permitted annual waste

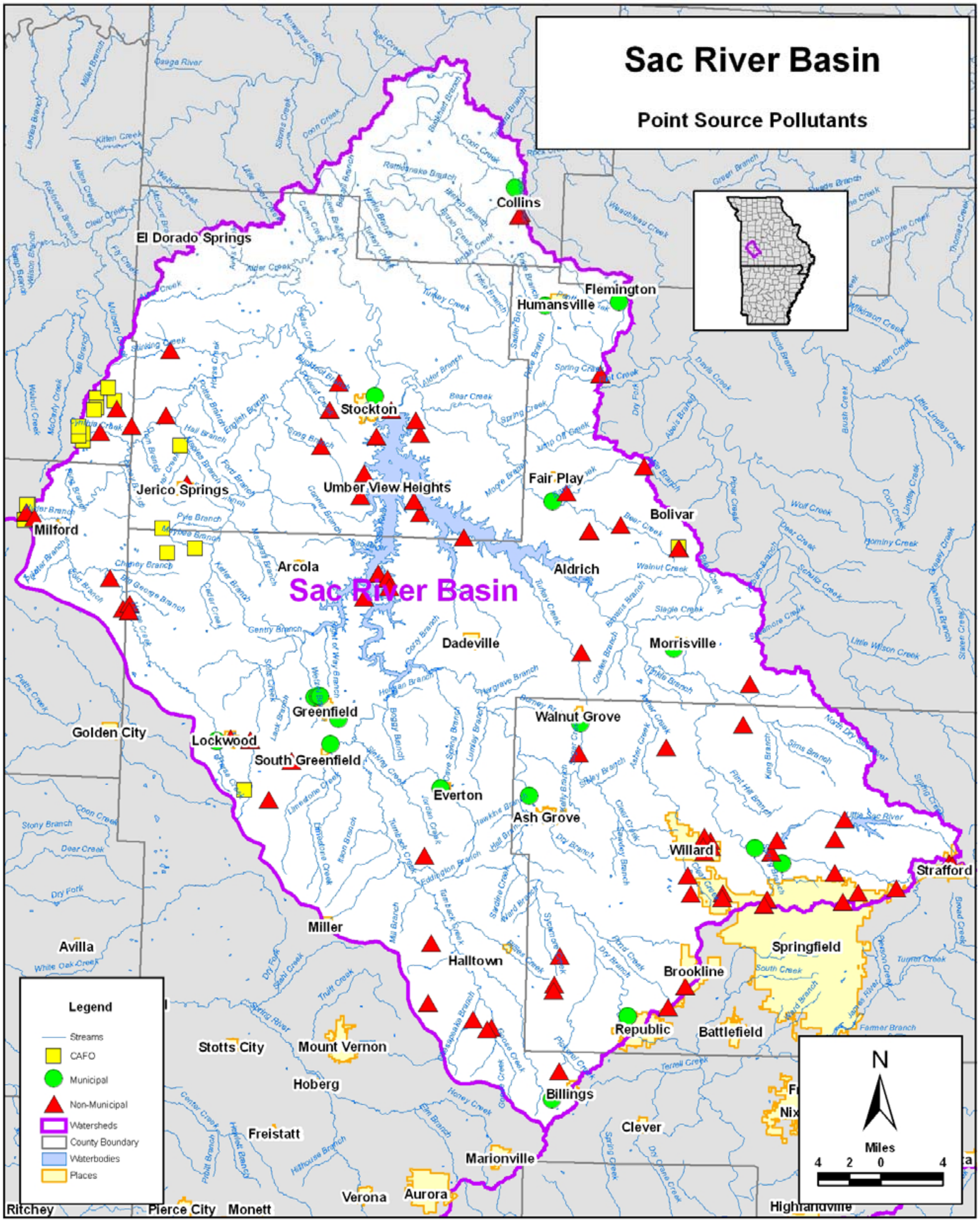

FIGURE 5. Sac River Basin – Point Sources

2.4 Nonpoint Source Pollution

Nonpoint source pollution comes from many diffuse sources rather than from well defined points. It is caused by rainfall or snowmelt moving over and through the ground picking up pollutants along the way. Historical and ongoing potential sources of nonpoint source pollution in the Sac River Basin may include livestock, improperly functioning septic systems, urban runoff, landfills, and abandoned coal mines (MDNR, n.d.).

The karst limestone found in the Sac River Basin makes the groundwater particularly susceptible to nonpoint source pollution. The extremely porous and fractured geology of the area (e.g., sinkholes, fractures, and losing streams) creates conduits between the ground surface and the shallow aquifer. The karst geology and nonpoint source pollution are suspected as being responsible for bacterial contamination of springs within the Little Sac River watershed (Baffaut, 2006).

The Fulbright and Sac River landfills have historically been associated with nonpoint source contamination. Both landfills are located in the upper part of the Sac River Basin and used to accept municipal and industrial waste. The Fulbright and Sac River landfills were in operation from 1962-1969 and 1968-1974, respectively. High concentrations of contaminants were first discovered leaching from the Fulbright landfill in 1978 by a Southwest Missouri State University geology student. In 1981 the industrial solvent trichloroethylene (TCE) was reported nearby in Ritter Springs and Fantastic Caverns. The Fulbright Landfill, along with the Sac River Landfill due to its close proximity, were subsequently placed on the EPA's National Priorities List in 1983. Contaminants of concern at the Fulbright/Sac River Landfills identified by the EPA included arsenic, beryllium, cadmium, chromium, lead, mercury, nickel, zinc, and selected organic compounds (EPA, 2000). A study by Mantei and Foster (1991) suggested the Fulbright Landfill leaches copper, lead, zinc, cadmium, and silver. The study also suggested that the Sac River Landfill leaches cadmium, barium, and silver. In 2000 the EPA determined that no further active remediation was necessary and that human health and the environment were protected. However, surface water, groundwater, and leachate monitoring continues upgradient and downgradient of the two landfills (Smith, 2002).

Mining operations are also a potential nonpoint source concern within the Sac River Basin. Historically, coal, lead, zinc, and iron have been mined throughout the basin. Old mine shafts and mine tailings potentially cause acidic drainage into nearby streams (Horton and Hutson, n.d.). Certain abandoned coal mines in particular have been a concern in the western part of the basin, although they are now believed to only have minimal adverse impacts on water quality (MDNR, n.d.).

2.5 Geology and Soils

The Sac River Basin is divided between the Ozark Highlands and the Osage Plains physiographic regions, the latter being along its western edge. The basin is covered by a layer of loess ranging from less than two feet thick in the uplands region to about four feet in its lower portions. The uplands region of the basin is relatively flat and is characterized by Mississippian aged limestone (Figure 6). Due to the north-facing

Ozark uplift, streams dissect progressively younger strata. Streams in the central portion of the basin dissect Ordovician dolomites. This central area around Stockton Lake is also characterized by hilly terrain. Pennsylvanian aged shale characterizes the most downstream portions of the basin. The southeastern plains are particularly rich in karst limestone features such as springs, caves, sinkholes, and losing streams (Horton and Hutson, n.d.; MDNR, n.d.).

The spatial distribution of soil series associations from both the Ozark Highland and the Osage Plains reflect the geological control in these two regions (Figure 7). A brief description of each soil series landscape position and parent material are described below. This information was obtained from the Natural Resources Conservation Services (NRCS) website at http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdnamequery.cgi. At this website, detailed taxonomic and morphological information for each soil series can be found. Soil characteristics such as drainage characteristics, permeability, and assimilative capacity greatly affect the quantity and quality of surface runoff.

Springfield Plain Soils

53 - Tonti-Goss-Alsup

Alsup series consists of deep, moderately well drained, moderately slowly permeable soils formed in a mantle of colluvium or loess and the underlying residuum from shale or interbedded shale, siltstone, and limestone. They are on summits, side slopes, and foot slopes of uplands. Slopes range from 2 to 35 percent.

Goss series consists of very deep, well drained soils formed in colluvium and residuum weathered from cherty limestone or cherty dolomite and some interbedded shale. These soils are on uplands. Slopes range from 1 to 70 percent.

Tonti series consists of very deep, moderately well drained that formed in residuum from cherty limestone. These nearly level to moderately sloping soils are on uplands of the Ozark Highlands. Slopes range from 1 to 12 percent.

66 - Wilderness-Tonti

Wilderness series consists of very deep, moderately well drained soils that have a fragipan at depths of 15 to about 29 inches. These upland soils formed in colluvium and the underlying residuum from cherty limestone. Permeability is moderate above the fragipan and slow in the fragipan and moderate below the fragipan. Slope gradients range from 2 to 35 percent.

Tonti (see 53 - Tonti-Goss-Alsup association above)

67 - Keeno-Hoberg-Creldon

Keeno series consists of very deep, moderately well drained soils on uplands with a fragipan at depths of 18 to 36 inches. These soils formed in residuum from cherty limestone. Permeability is moderate above the fragipan and slow in the fragipan. Slopes range from 2 to 14 percent.

Hoberg series consists of very deep, moderately well drained soils that have a fragipan. They formed in a thin mantle of loess and the underlying residuum from cherty limestone. Slopes range from 2 to 8 percent. Permeability is moderate above the fragipan, slow in the fragipan and moderate below the fragipan.

Creldon series consists of very deep, moderately well drained soils on uplands that have fragipans at a depth of 18 to 35 inches. These soils formed in a thin mantle of loess, colluvium, and the underlying loamy or clayey cherty residuum weathered from limestone. Permeability is moderately slow above the fragipan and very slow in the fragipan. Slope gradients range from 0 to 9 percent but dominantly are 1 to 3 percent.

68 - Rueter-Moko-Clarksville

Rueter series consists of very deep, somewhat excessively drained soils that formed in colluvium and residuum from cherty limestone on steep side slopes and narrow ridgetops. Slopes range from 3 to 70 percent.

Moko series consists of shallow and very shallow, well drained and somewhat excessively drained soils that formed in loamy colluvium or residuum from limestone or dolostone. They are on dissected uplands in the Ozarks of northern Arkansas and southern Missouri. Slopes range from 3 to 100 percent.

Clarksville series consists of very deep, somewhat excessively drained soils formed in hillslope sediments and the underlying clayey residuum from cherty dolomite or cherty limestone on steep side slopes and narrow ridgetops. Slopes range from 1 to 70 percent.

69 - Verdigris-Hepler-Dapue-Cedargap-Bearthicket

Verdigris series consists of very deep, well drained soils that formed in silty alluvium on floodplains. Slope ranges from 0 to 3 percent.

Hepler series consists of very deep, somewhat poorly drained, moderately slowly permeable soils that formed in silty alluvial sediments. These nearly level to very gently sloping soils are on flood plains. Slope ranges from 0 to 3 percent.

Dapue series consists of very deep, well drained, moderately permeable soils formed in silty alluvium. They are on nearly level flood plains and low stream terraces. Slopes range from 0 to 3 percent.

Cedargap series consists of very deep, well drained soils formed in alluvium with a high content of chert fragments. These soils are on flood plains of small streams near active channels. Slopes range from 0 to 5 percent.

Bearthicket series consists of very deep, well drained soils formed in silty alluvium. These soils are on nearly level flood plains and low stream terraces. Slopes range from 0 to 3 percent.

70 - Maplegrove-Eldorado-Creldon

Maplegrove series consists of very deep, moderately well drained, slowly permeable soils on uplands. These soils formed in a thin mantle of silty loess over a thin mantle of loess over clayey residium. Slope gradient ranges from 1 to 3 percent.

Eldorado series consists of very deep, well drained, moderately permeable soils that formed in residuum weathered from Pennsylvanian age chert limestone. Slope ranges from 1 to 25 percent.

Creldon (see 67 - Keeno-Hoberg-Creldon association above)

85 - Pembroke-Keeno-Eldon-Creldon

Pembroke series consists of very deep, well drained soils formed in a thin silty mantle of loess underlain by older alluvium or residuum of limestone or both. They are on nearly level uplands and karst areas. Slopes commonly range from 0 to 2 percent, but the range allows slopes from 0 to 6 percent.

Keeno (see 67 - Keeno-Hoberg-Creldon association above)

Eldon series consists of very deep, well drained, moderately permeable soils formed in residuum from cherty limestone interbedded with shale and sandstone. These soils are on uplands with slopes ranging from 2 to 25 percent.

Creldon (see 67 - Keeno-Hoberg-Creldon association above)

139 - Secesh-Rueter-Nixa-Clarksville

Secesh series consists of very deep, well drained soils on floodplains, stream terraces, and footslopes. They formed in about 2 feet of loamy alluvium and the underlying cherty residuum or alluvium from limestone and sandstone. Slopes range from 0 to 8 percent.

Rueter (see 68 - Rueter-Moko-Clarksville association above)

Nixa series consists of very deep, moderately well drained, very slowly permeable soils on upland ridgetops and sideslopes of the Ozark Highlands. These nearly level to steep soils formed in colluvium and loamy residuum weathered from cherty limestone. Slopes range from 1 to 35 percent.

Clarksville (see 68 - Rueter-Moko-Clarksville association above)

Cherokee Prairie Soils

74 - Parsons-Barden-Barco

Parsons series consists of very deep somewhat poorly drained soils that formed in material weathered from predominantly clayey alluvium or weathered fissile shales. These nearly level to very gently sloping soils are on broad smooth uplands. Slopes range from 0 to 3 percent.

Barden series consists of very deep, moderately well drained, slowly permeable soils formed in a mantle of loess or other silty material and residuum from shale. These soils are on ridges and upland side slopes and have slopes of 0 to 5 percent.

Barco series consists of moderately deep, well drained soils that formed in residuum from acid sandstone and thin beds of silty and sandy shales. These soils are on uplands and have slopes ranging from 1 to 35 percent.

76 - Hector-Cliquot-Bolivar

Hector series consists of shallow, well drained, moderately rapidly permeable soils that formed in residuum from sandstone bedrock. These soils are on nearly level to moderately steep ridgetops and steep and very steep mountain sides. Slopes range from 2 to 60 percent.

Cliquot series consists of deep, moderately well drained, slowly permeable soils formed in colluvium and the underlying residuum from shale or interbedded shale and sandstone on ridgetops and side slopes. Slope ranges from 3 to 20 percent.

Bolivar series consists of moderately deep, moderately permeable soils that formed in residuum from acid sandstone with thin beds of clayey and sandy shales. These soils are on undulating to gently rolling uplands and have slopes ranging from 1 to 50 percent.

77 - Verdigris-Osage-Lanton

Verdigris (69 - Verdigris-Hepler-Dapue-Cedargap-Bearthicket association above)

Osage series consist of very deep, poorly drained, very slowly permeable soils that formed in thick clayey alluvium. These soils are on flood plains along major streams and have slopes ranging from 0 to 2 percent.

Lanton series consists of very deep, poorly and somewhat poorly drained soils that are dark in the surface layer and to a depth of 24 inches or more. These soils formed in alluvium on flood plains and in depressions. They have moderately slow permeability in the solum and slow permeability in the clayey substratum. Slopes range from 0 to 3 percent.

83 - Goss-Gasconade-Bardley

Goss (see 53 - Tonti-Goss-Alsup association above)

Gasconade series consists of shallow and very shallow, somewhat excessively drained, moderately slowly permeable soils formed in thin clayey layers with a considerable amount of coarse fragments from residuum of the underlying limestone bedrock. These soils are on steep dissected upland landscapes and generally are isolated glade areas. Slope gradients range from 2 to 50 percent.

Bardley series consists of moderately deep, well drained soils that formed in hillslope sediments and the underlying residuum from dolomite interbedded with some limestone and sandstone. These soils are on summits, side slopes, back slopes, and nose slopes of hills and ridges. Slopes range from 2 to 100 percent.

93 - Pit Quarries-Parsons-Opolis-Barden

Parsons (see 74 - Parsons-Barden-Barco association above)

Opolis series consists of very deep, moderately well drained soils that formed in a thin mantle of silty loess over residuum on plains. Slope ranges from 0 to 3 percent.

Barden (see 74 - Parsons-Barden-Barco association above)

Ozark Highland Soils

87 - Viraton-Ocie-Mano

Viraton series consists of very deep, moderately well drained soils that have a fragipan. They formed in loess and the underlying cherty residuum or colluvium from limestone. They are on broad ridges, foot slopes and strath terraces. The permeability is moderate above the fragipan, very slow in the fragipan and moderately slow below the fragipan. Slopes range from 1 to 20 percent.

Ocie series consists of deep, moderately well drained, slowly permeable soils formed in hillslope sediments and the underlying residuum from cherty dolomite or limestone with thin interbedded sandstone. These soils are on upland saddles, benches, and sideslopes. Slopes range from 1 to 35 percent.

Mano series consists of very deep, moderately well drained soils on hills. These soils formed in colluvial sediments from cherty limestone and the underlying residuum from cherty dolomite. Slopes range from 1 to 50 percent.

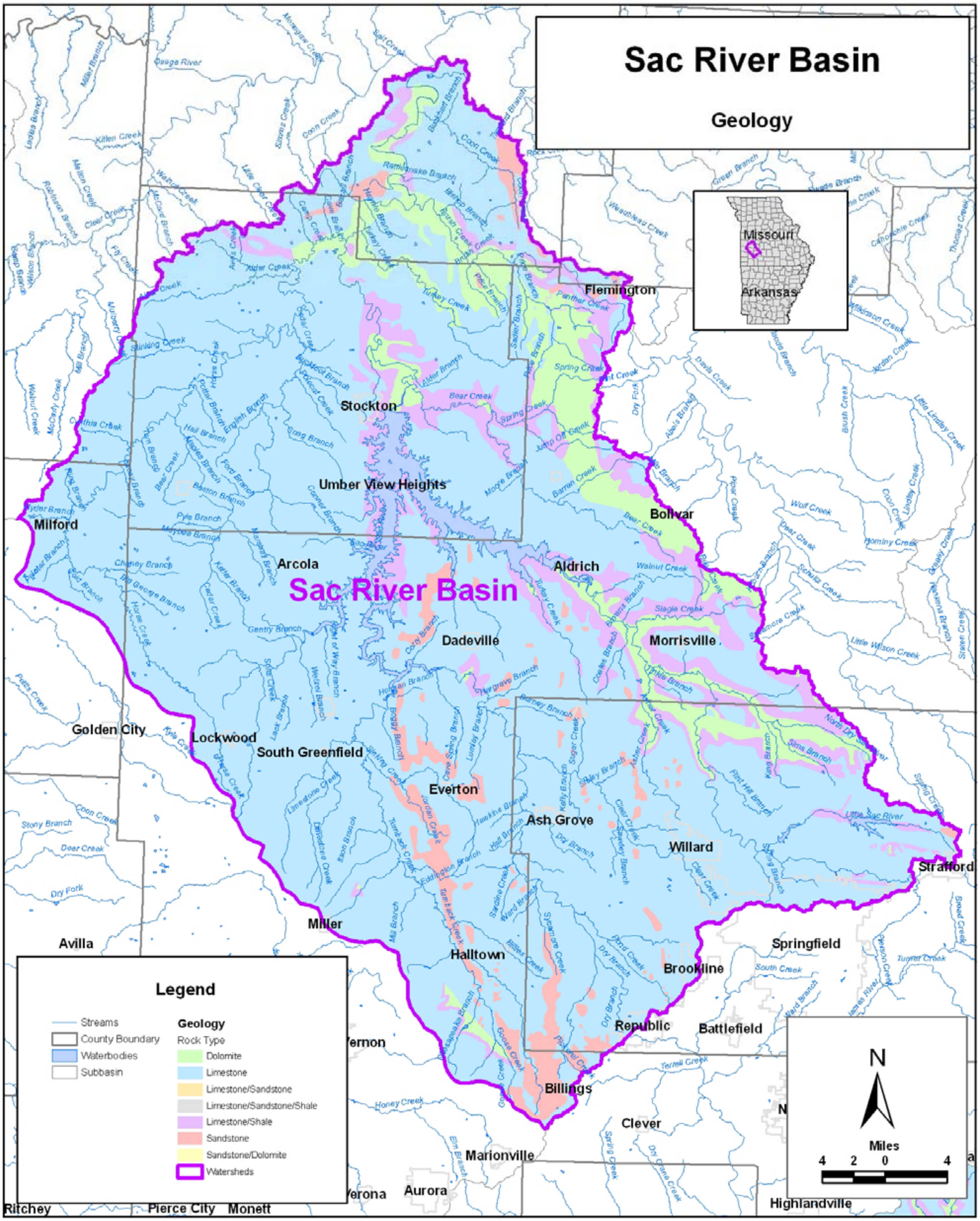

FIGURE 6. Sac River Basin – Geologic Map

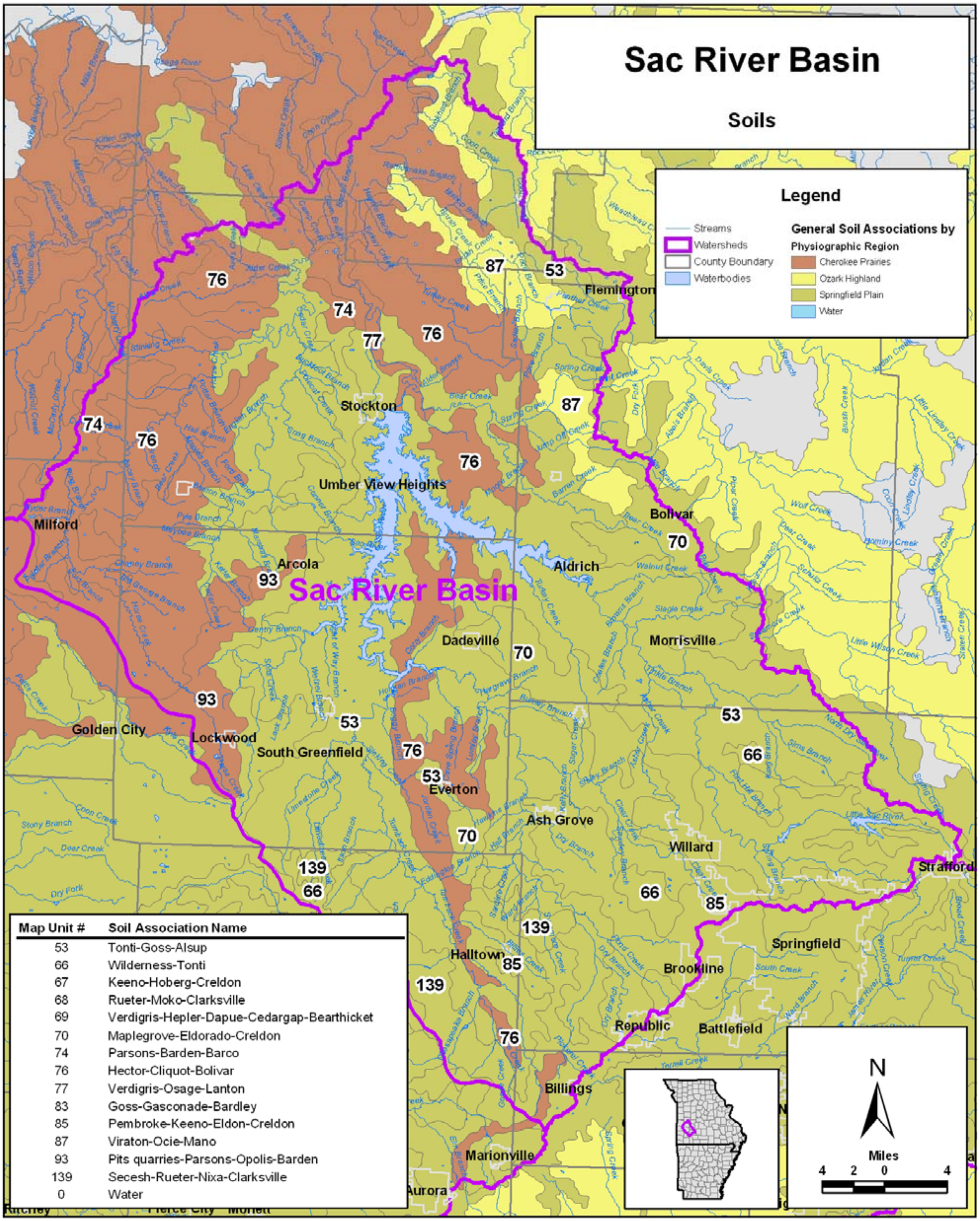

FIGURE 7. Sac River Basin – General Soil Associations

2.6 Climate and Hydrology

Climate for the region is temperate, with an average annual temperature of 57°F and average annual precipitation of 42 inches, based on climate data from Stockton Dam since 1970. Monthly average temperatures (1970-2007) at the Stockton Dam range from approximately 31°F in January to 80°F in July (Figure 8). Monthly average precipitation peaks in late spring with about five inches of rainfall in May and June. Relatively high average rainfall totals also occur in the months of September and October with between 4.2 and 4.3 inches of rainfall. January and February receive the lowest average precipitation totals for the year with around 2 inches of rainfall per month.

The United States Geological Survey (USGS) currently operates seven discharge gaging stations in the basin located on the Sac River (3), Little Sac River (1), Turnback Creek (1), South Fork Dry Sac (1), and Cedar Creek (1) (Figure 9). The Cedar Creek station has approximately 60 years of recorded data and all but one station have at least 30 years of recorded data (Table 4). Monthly mean discharge data from the seven gaging stations show the highest average runoff occurs between April and June corresponding to the spring wet season (Table 5). The lowest average discharges occur between August and October. Median flows along the Sac River increase from 111 cubic feet per second (cfs) near Dadeville to 925 cfs near the bottom of the basin close to Caplinger (Table 7). Peak flows ranged from 14,800 cfs at the Sac River below Stockton to 61,500 cfs at the Sac River near Caplinger (USGS, 2005). It should be noted that flows downstream of Stockton Reservoir (i.e., Sac River below Stockton and near Caplinger) are largely influenced by reservoir releases by the U.S. Army Corps of Engineers (USACE). Flow statistics for the seven discharge gaging stations are summarized in Table 6.

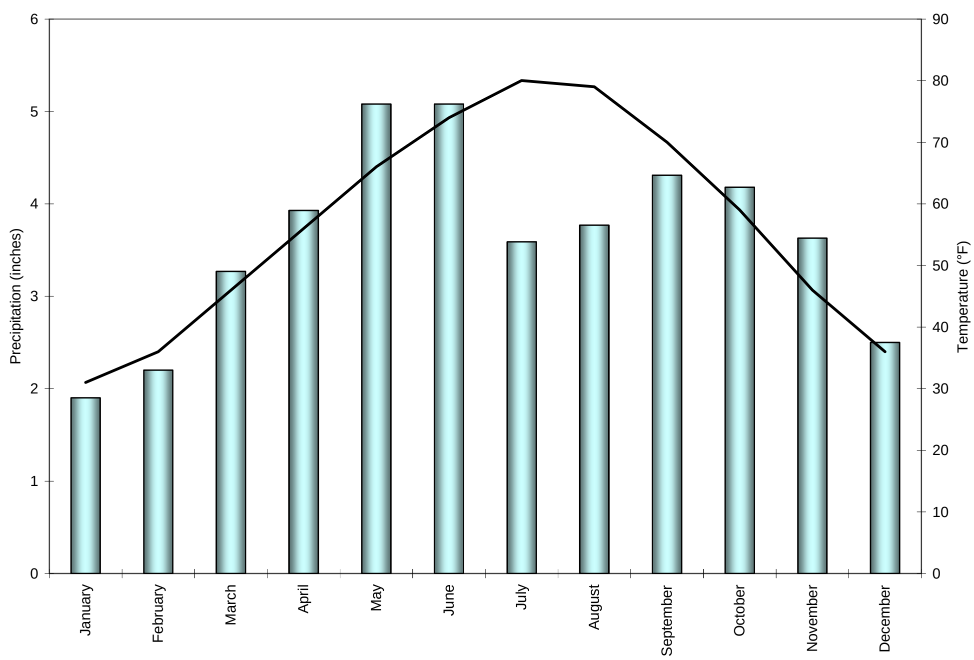

FIGURE 8. Monthly Average Precipitation and Temperature at the Stockton Dam Climate Station

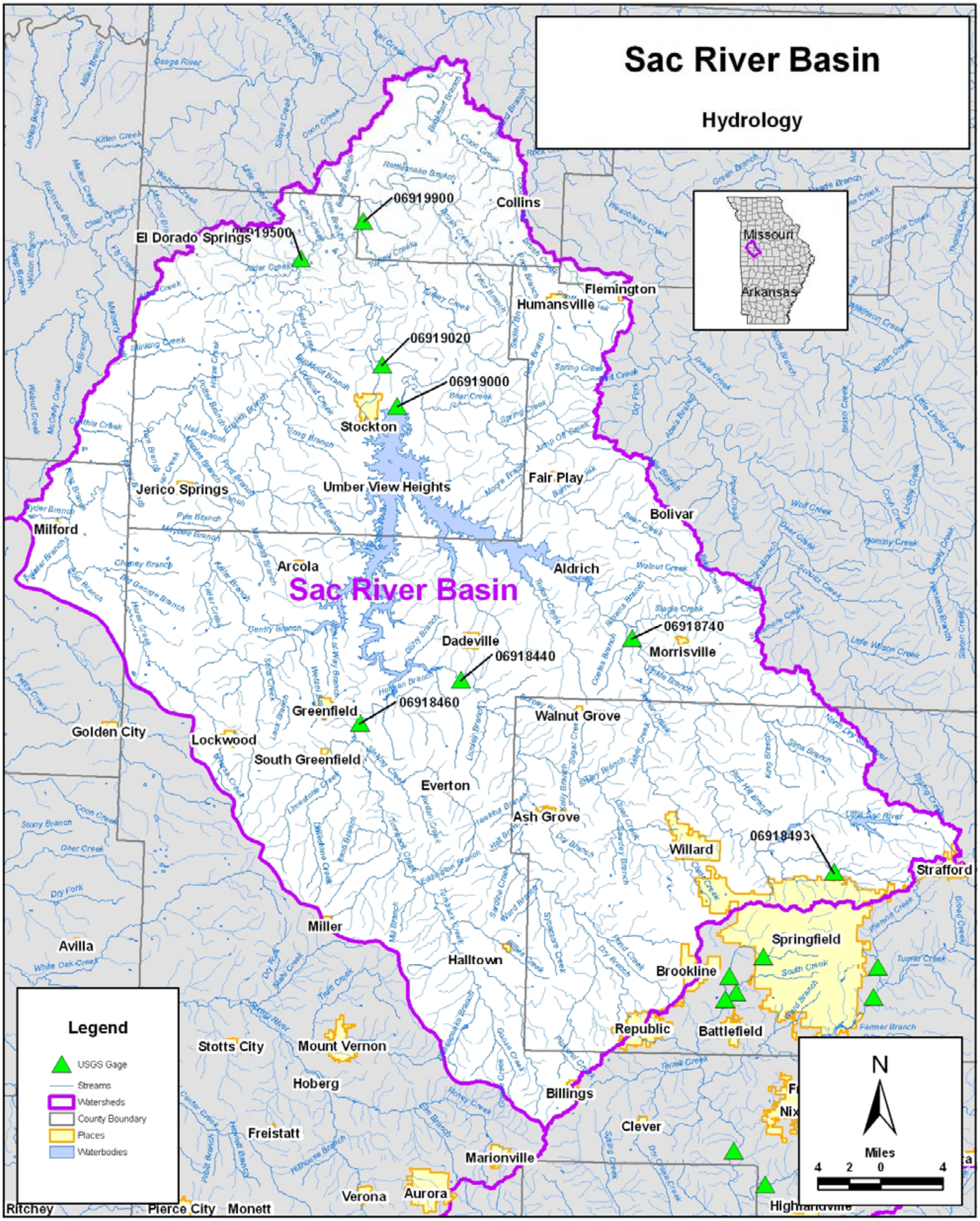

FIGURE 9. Sac River Basin – Hydrologic Gaging Station Locations

TABLE 4. Description of USGS Gaging Stations in the Sac River Basin

Station ID	Station Name	Drainage	Elevation (ft)	Start Year	Years of Record
06918440	Sac River near Dadeville	257	870	1966	39
06918460	Turnback Creek at Greenfield	252	870	1965	40
06918493	S. Dry Sac near Springfield	14	1,185	1996	7
06918740	Little Sac near Morrisville	237	881	1968	37
06919020	Sac River near Stockton (Hwy J)	1,292	750	1973	32
06919500	Cedar Creek near Pleasant View	420	739	1923	60
06919900	Sac River near Caplinger Mills	1,810	721	1974	31

Note: Information on all USGS gages in Missouri can be found at http://waterdata.usgs.gov/mo/nwis/rt.
(Source: USGS, 2005)

TABLE 5. Mean Monthly Discharge for USGS Gaging Stations in the Sac River Basin

Station ID	Station Name	January (cfs)	February (cfs)	March (cfs)	April (cfs)	May (cfs)	June (cfs)	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)	December (cfs)
06918440	Sac River near Dadeville, MO	250	285	419	385	377	207	108	59.3	101	129	282	287
06918460	Turnback Creek above Greenfield, MO	260	312	446	425	384	238	151	84	122	141	299	287
06918493	South Fork Dry Sac River near Springfield, MO	10.1	22.1	27.7	18.5	24.5	9.9	17.1	5.0	4.2	6.2	13.6	10.8
06918740	Little Sac River near Morrisville, MO	249	279	438	392	335	193	81	36	113	116	297	271
06919020	Sac River at Hwy J below Stockton, MO	1190	1,185	1,422	1,673	1,594	1,532	1,188	961	756	590	769	1,125
06919500	Cedar Creek near Pleasant View, MO	277	399	556	538	524	357	221	76	165	185	350	292
06919900	Sac River near Caplinger Mills, MO	1542	1,766	2,164	2,379	2,403	2,020	1,418	1,057	947	1,115	1,370	1,612

Source: USGS, 2005

TABLE 6. Select Flows for USGS Gaging Stations in the Sac River Basin

Station ID	Station Name	Low Q (cfs)	Low Date	90% Q (cfs)	50% Q (cfs)	Mean Q (cfs)	10% Q (cfs)	Max Q (cfs)	Max Date
06918440	Sac River near Dadeville, MO	3.8	8/8/1996	23	111	241	525	36,100	9/25/1993
06918460	Turnback Creek above Greenfield, MO	3.8	8/21/2005	31	127	262	565	44,000	10/1/1986
06918493	South Fork Dry Sac River near Springfield, MO	0	7/15/1997	1.9	5.8	14.1	29	NA*	7/12/2000
06918740	Little Sac River near Morrisville, MO	0.3	9/15/1980	12	80	233	502	29,100	9/25/1993
06919020	Sac River at Hwy J below Stockton, MO	24	3/25/1977	69	536	1,165	3,160	14,800	10/1/1986
06919500	Cedar Creek near Pleasant View, MO	0	-----	1.2	71	327	665	37,000	7/17/1958
06919900	Sac River near Caplinger Mills, MO	33	8/24/1999	95	925	1,648	4,040	61,500	4/12/1994

"-----" = low flow occurred on multiple dates
NA* – not available (flow was not recorded at highest stage)
Q = discharge
Low Q = lowest flow on record
90% Q = 90% of recorded flows exceed this discharge
50% Q = 50% of recorded flows exceed this discharge
Mean Q = average of all recorded flows
10% Q = 10% of recorded flows exceed this discharge
Max Q = maximum flow peak on record
(Source: USGS, 2005)

2.7 Regulatory Issues

Section 303(d) of the federal Clean Water Act (CWA) requires each state to identify those waterbodies not meeting water quality standards. Water quality standards are established by the states and consist of beneficial uses, water quality criteria to protect the beneficial uses, and an antidegradation policy. States must compile and submit their 303(d) List of impaired waterbodies to the EPA for final approval on a biannual basis. The EPA has the authority to approve, reject or modify the list. States are required to establish a total maximum daily loads (TMDL) for those waterbodies on an EPA-approved 303(d) List. A TMDL is a regulatory tool designed to restore the full beneficial uses of a waterbody. By definition a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources (EPA, 2006).

Within the Sac River Basin the following streams are either listed on Missouri's 303(d) List or have a completed TMDL:

- Little Sac River;
- Stockton Branch;
- Brush Creek;
- McDaniel Lake; and
- Fellows Lake

The pollutants identified as responsible for these impairments include bacteria, volatile suspended solids (VSS), low dissolved oxygen, and algae/nutrients.

Bacteria

The Missouri Department of Natural Resources (MDNR) completed a TMDL for bacteria on the Little Sac River on June 30, 2006. The Little Sac River was initially listed as impaired for bacteria during the 1998 303(d) cycle. Missouri currently has bacteria criteria for both fecal coliform and *Escherichia coli* (*E. coli*); however, fecal coliform was the only pollutant identified as causing the impairment. The Little Sac River is designated as a whole body contact recreation (WBCR) Category A water, which has a fecal coliform criteria of 200 colony forming units per 100 milliliter (cfu/100 mL). MDNR plans to remove the fecal coliform criteria in a future rulemaking since *E. coli* is a better indicator of human health risk.

In 2004 the Food and Agricultural Policy Research Institute (FAPRI), a research entity within the University of Missouri system, conducted a study to determine the sources of fecal contamination to the Little Sac River. Although Springfield's Northwest Wastewater Treatment Plant (WWTP) contributes much of the Little Sac River's flow, FAPRI suggested it is a relatively minor source of fecal contamination. Springfield's Northwest WWTP disinfects its effluent by chlorination followed by de-chlorination, resulting in a relatively low fecal concentration. Using DNA source tracking, FAPRI suggested the highest fecal coliform sources come from unknown sources, geese, and humans. During baseflow conditions fecal coliform loadings potentially come from contaminated spring discharges (Baffaut, 2006).

Volatile Suspended Solids

MDNR first listed Stockton Branch as 303(d) impaired for volatile suspended solids (VSS) in 1998. VSS is a measure of organic solids often attributed to wastewater treatment plants. Visual inspections of Stockton Branch during summer low flow conditions in 1988, 1989 and 1993 suggested the presence of excessive suspended algae, excessive deposition of solids and reduced diversity of aquatic invertebrates. MDNR attributed the City of Stockton's five-cell lagoon system as the source of VSS. The city upgraded their wastewater treatment program in 2002, which resulted in improved water conditions. In 2005 the city's permit was issued with new limits in lieu of a TMDL. Ambient stream monitoring has been scheduled for 2009 to determine if the new permit limits have achieved the VSS standard of no noticeable downstream objectionable deposits (MDNR, 2005a).

Low Dissolved Oxygen

Brush Creek was listed in the 2002 and 2004/2006 303(d) lists as impaired for low dissolved oxygen (DO). MDNR attributes low DO in Brush Creek to wastewater high in biochemical oxygen demand (BOD) from the Humansville WWTF. Monitoring by MDNR has documented DO levels below the aquatic life criterion of 5.0 mg/L and impairment to the aquatic life community. However, Humansville began upgrading their wastewater treatment facility in 2004 and MDNR has indicated it plans to issue new permit limits in lieu of completing a TMDL (MDNR, 2004; MDNR, 2007).

Algae/Nutrients

McDaniel and Fellows Lakes serve as the drinking water supply for the City of Springfield; however, taste and odor problems have resulted in their 303(d) listing for algae and nutrients. Complaints about the water from McDaniel Lake go back two decades, whereas there has only been one taste and odor event in Fellows Lake. Taste and odor problems in drinking water are typically problematic of cyanobacteria, which is a specific type of blue-green algae. The production of cyanobacteria is primarily related to nutrients and sunlight (MDNR, 2006; MDNR, 2003).

MDNR attributes most of the nutrient loading in McDaniel Lake to nonpoint agricultural and urban runoff; although urban development is largely replacing agricultural activities in the McDaniel Lake watershed. The McDaniel Lake TMDL completed in 2003 determined that phosphorus loading should be reduced by 40 percent to achieve a chlorophyll-*a* level of 10 micrograms per liter (µg/L). It has been found that the risk for blue-green algae increases exponentially when chlorophyll-*a* exceeds this level. However, the McDaniel Lake TMDL also suggested that controlling algae growth may be considerably more complex than limiting phosphorus levels. McDaniel Lake has very low numbers of zooplankton, which are important for keeping algae levels down. The cause of the low zooplankton numbers is unclear. Furthermore, the withdrawal of water from Fellows and McDaniel Lakes and transfer of water from other watershed further complicates the issue of algae production (MDNR, 2003).

MDNR recently requested that EPA remove Fellows Lake from the 303(d) List for nutrients. Since there has only been one taste and odor event in Fellows Lake and there are no additional data suggesting that it is impaired for nutrients a TMDL does not appear to be necessary. Additionally, since Fellows Lake is part of the McDaniel Lake watershed, the MDNR has contended that measures taken in the watershed to improve McDaniel Lake would also benefit Fellows Lake (MDNR, 2006). EPA approved this request in September 2007 (EPA, 2007).

3. METHODS

Understanding the methods of data collection, management, and analyses is important for interpreting water quality results. MEC compiled and interpreted water quality data from multiple collection entities that used a variety of methods. Data sources used in this report are documented below along with a review of their methodologies and data quality. Methods used by MEC for collecting, storing, and analyzing water quality data are also discussed below. This section is limited to water chemistry and bacteria data. Methods for handling other biological data are discussed in the biological monitoring section.

3.1 Data Collection

MEC compiled water quality data collected in the Sac River Basin from the MDNR and USGS databases in 2006. The MDNR databases include data collected from its own water quality monitoring programs and numerous other state, federal, and municipal sources. Organizations that contributed to the Sac River Basin portion of the MDNR water quality dataset included the U.S. Army Corps of Engineers – Kansas City District (COE-KCD), City Utilities of Springfield (CU), City of Springfield Public Works (SPW), FAPRI, Murphy Family Farms (MURPHY), and the USGS. Although the MDNR included USGS data in its databases, MEC obtained USGS data directly from the USGS National Water Information System (NWIS).

It should be noted that the final analysis of water quality data was limited to a select set of monitoring sites and sample dates. Data management and data assessment issues (discussed in sections 3.2 and 3.3) limited the total number of monitoring sites in the Sac River Basin to 25 (See Figure 10).

Brief descriptions of the programs responsible for collecting the data summarized in this report are presented in the following sections.

Missouri Department of Natural Resources

The MDNR designed their water quality monitoring programs for the following major purposes:

- Characterize background or reference water quality conditions;
- Better understand daily, flow event, and seasonal water quality variations and their underlying processes;
- Characterize aquatic biological communities;
- Assess time trends in water quality;
- Characterize local and regional impacts impacts of point and non-point source discharges on water quality;
- Assess compliance with water quality standards or wastewater permit limits; and
- Support development of strategies to return impaired waters to compliance with water quality standards (MDNR, 2005b).

MDNR uses a combination of a fixed station network, special water quality studies, a toxics monitoring program, a biological monitoring program, fish tissue monitoring, and two volunteer monitoring programs to achieve these goals.

MEC identified 52 MDNR water quality monitoring sites within the Sac River Basin. Water quality parameters collected at these monitoring sites included: temperature, flow, specific conductivity (SC), hardness, alkalinity, turbidity, dissolved oxygen (DO), pH, chlorophyll *a*, total nitrogen as nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorus as phosphorus (TP), ammonia as nitrogen (NH3-N), nitrate plus nitrite as nitrogen (NO_3+NO_2), total suspended solids (TSS), volatile suspended solids (VSS), biochemical oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), fecal coliform, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, dissolved iron, dissolved arsenic, dissolved cadmium, dissolved chromium, dissolved nickel, dissolved lead, and dissolved zinc. The MDNR sample dates ranged from September 1985 to April 2006.

City Utilities of Springfield

Water quality data collected by CU were available from the MDNR database for two monitoring sites in the Sac River Basin. Sample dates ranged from January 2004 to March 2006. Water quality sample parameters measured included temperature, specific conductivity, pH, turbidity, TSS, DO, TP, chlorophyll *a*, NH3-N, NO_3+NO_2, *E. coli*, chloride, sulfate, total copper, total iron, and total manganese,.

City of Springfield Public Works

Water quality data collected by SPW were available from the MDNR database for one monitoring site in the Sac River Basin. Sample dates ranged from January 2001 to January 2004. Water quality sample parameters measured included temperature, flow, DO, pH, NH3-N, fecal coliform, total arsenic, total cadmium, total chromium, total copper, total lead, total nickel, and total zinc.

U.S. Army Corps of Engineers – Kansas City District

According to Corps Engineering Regulations – *Water Quality and Environmental Management for Corps Civil Works Projects*, ongoing water quality monitoring is necessary at all Corps projects. The Kansas City District office is therefore required to develop water quality management objectives for each of its projects to be included in the project's water control plan. Within the Sac River Basin, the COE-KCD manages and routinely collects water quality samples for Stockton Lake.

Water quality data collected by COE-KCD were available from the MDNR database for five monitoring site in the Sac River Basin. Sample dates ranged from July 1991 to August 2002. Water quality sample parameters measured included temperature, flow, DO, pH, turbidity, SC, total dissolved solids (TDS), TSS, VSS, alkalinity, TP, TN, NO_3+NO_2, TKN, NH3-N, chlorophyll a, dissolved iron, dissolved manganese, total manganese, sulfate, and total iron.

Food and Agricultural Policy Research Institute at the University of Missouri

FAPRI is an organization charged with providing objective, quantitative analysis to promote effective agricultural policy. In the mid 1990s FAPRI established a team of analysts to lead the Missouri Water Quality Initiative project. The mission was to quantitatively assess environmental policy in a manner similar to FAPRI's assessment of agricultural policy. Grants from this project have supported extensive water quality monitoring efforts in Missouri.

In 2004 FAPRI conducted a special study to find the sources of fecal contamination to the Little Sac River. Water quality data collected by FAPRI were available from the MDNR database for two monitoring site in the Sac River Basin. Sample dates ranged from December 2003 to August 2004. Water quality sample parameters measured included flow and fecal coliform.

Murphy Family Farms

Murphy Family Farms is a privately owned swine production company with operations in Missouri and North Carolina. In 2000 the Attorney General of Missouri filed a lawsuit against Murphy Family Farms seeking repair of their lagoons in Vernon County. Consequently, MDNR required Murphy Family Farms to conduct water quality sampling in the vicinity of its farms.

Water quality data collected by Murphy Family Farms were available from the MDNR database for 12 monitoring site in the Sac River Basin. Sample dates ranged from January 2001 to June 2003. Water quality sample parameters measured included flow, temperature, pH, TSS, hardness, DO, TP, NO_3+NO_2, NH3-N, and chloride.

U.S. Geological Survey (Water Resource Division)

USGS conducts studies of surface water in cooperation with local and state governments and with other federal agencies in every state. Two significant USGS water quality monitoring efforts include the National Water-Quality Assessment Program (NAWQA) and the National Stream Quality Accounting Network (NASQAN). USGS disseminates their water quality data to the public with the goal of supporting national, regional, state, and local information needs and decisions related to water quality management and policy. Water quality data from USGS were identified for 20 monitoring stations in the Sac River Basin. USGS water quality data in the Sac River Basin ranged from August 1962 to September 2004 and includes over 200 parameter codes[1]. USGS water quality data in the Sac River Basin consists of the following parameter groupings: biological, major inorganics, minor and trace inorganics, nutrients, organics, physical properties, and sediment.

[1] **Parameter codes** are used to identify the water-quality values stored in the data base. Each code is linked to a definition. Parameter-code definitions typically contain information about what was analyzed, what units are associated with the numerical data, and sometimes, how the sample was processed prior to analysis (filtering, for examples). Definitions for each retrieved parameter are provided in the heading of each output.

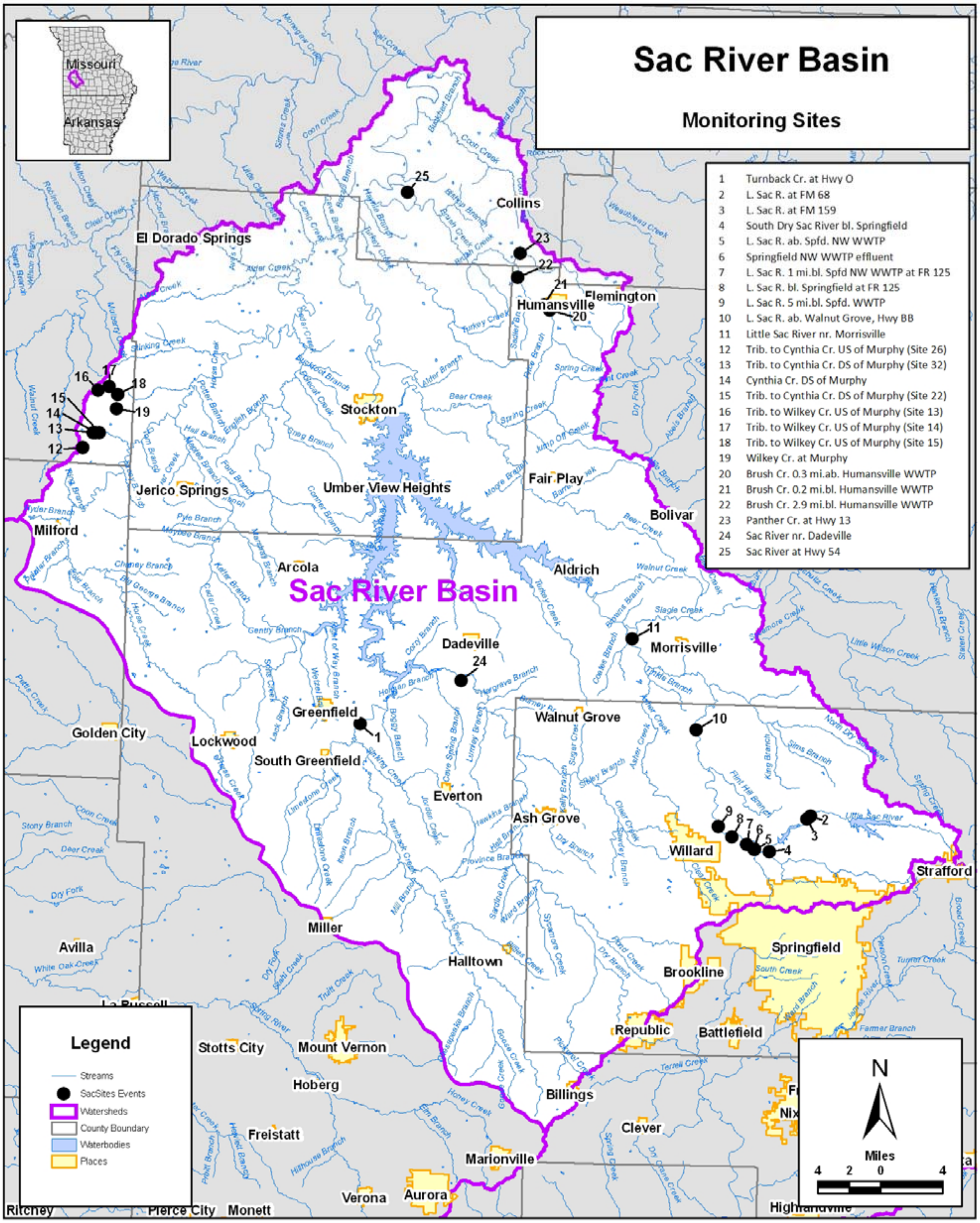

FIGURE 10. Water Quality Monitoring Sites in the Sac River Basin

3.2 Data Management

Water quality data collected from different agencies were stored in a Microsoft (MS) Access™ database. The format selected for the WQIP database is similar to the format used by USGS in the National Water Information System. The water quality data are stored in a single table, such that each record consists of a single monitoring site, sample date, sample time, parameter code, and result value. Other fields stored in this table include the collection entity, alternate site codes, and remark codes. Non-water quality data (e.g., site locations and parameter descriptions) are stored in separate tables.

USGS parameter codes were used where possible to identify water quality parameters in the database. USGS parameter codes clearly indicate the constituent measured and often the method used to measure that constituent. Parameter codes generally were not available from non-USGS data sources. USGS parameter codes were assigned when possible to non-USGS data; however, this was not possible in some instances where sufficient metadata was not readily available. For example, some data did not indicate whether the sample was filtered or unfiltered or the time period for biochemical oxygen demand (5-day or ultimate). MEC assigned an arbitrary generic parameter code if the correct USGS parameter code could not be identified.

Multiple observational data were identified in the WQIP database where possible. Multiple observations occur when more than one observation is stored for the same site and time. This situation typically occurs when QA/QC data are stored along with the observation for that time period. Where multiple observations were known, these data were identified with a remark code. However, all multiple observation data were likely not identified through the screening process.

Analyte concentrations either too low or high are typically censored by laboratories to avoid a false-quantification of a constituent. Typically, analyte concentrations considered too low for laboratory detection limits are reported as not detected (ND). Bacteria samples above the maximum detection limit are typically reported as “too numerous to count” (TNTC). Censored data were identified in the WQIP database in the remark code field.

The WQIP database maintained a primary and secondary value field for the purpose of handling censored data. In general, both the primary and secondary value fields were populated with the laboratory result value unless the value was censored. If the data point was censored, the primary value field was populated with either the minimum detection limit for ND samples or the maximum detection limits for TNTC samples. Where laboratory detection limits were not available for ND samples, a value of zero was entered in the primary value field. The secondary value field was populated with one-half the detection limit for ND samples, and double the maximum detection limit for TNTC samples. The secondary value field was used for purposes of generating water quality statistics.

Within the MDNR databases ND samples are reported as values slightly less than one half the detection limit (e.g. a detection limit of 0.3 would be reported as 0.1499). MDNR reported TNTC samples as twice the maximum detection limit. In both cases, the MDNR did not assign descriptors to ND or TNTC samples. MEC made no attempt to identify non-detect and TNTC samples originating from the MDNR databases.

The WQIP database includes a spatial table to identify the location of the water quality sampling sites. The spatial table includes the site code, site description, latitude, longitude, and 8-digit USGS Hydrologic Unit Code (HUC). The USGS and MDNR databases provided the site codes, descriptions, and geographic coordinates associated with the water quality data. In some instances, data with geographic coordinates were not available. These records were maintained in the database, but were not used for data analysis.

The spatial information provided by MDNR and USGS databases appeared questionable for some sites. For example, the geographic coordinates did not always plot in the HUC indicated by the MDNR and USGS databases. In these instances, the HUC codes were reassigned to their plotted position. In other instances the plotted position of a site did not agree with the site description. If the geographic coordinates could not be trusted, data from that site were not used for data analysis.

MEC attempted to identify co-located monitoring sites so the water quality data could be pooled for purposes of data analysis[2]. The criteria for identifying co-located monitoring sites were primarily based on best professional judgment. Sites were combined if two or more sites plotted in relatively close proximity. Monitoring sites were not considered to be co-located if the sites straddled a tributary or a point source. Co-located sites are identified in the database by use of a consistent alternate site number. The site number is the key identifier used in the database to relate a site to its water quality data and metadata.

3.3 Data Assessment

Methods of data assessment in terms of data source quality, selection of parameters and periods of interest, methods of analysis, and data limitations are discussed below.

3.3.1 Data Quality Assessment

When evaluating the quality and relevance of existing water quality and other data as part of the Data Gap Analysis project, MEC used five general assessment factors. This approach was based on U.S. Environmental Protection Agency Science Policy Council's "A Summary of General Assessment Factors for Evaluating Quality of Scientific and Technical Information", June 2003 (EPA 100/B-03/001) (EPA, 2003a). The five factors are:

1. Soundness - the extent to which scientific and technical procedures, measure, methods or models employed to generate the data are reasonable, and consistent with, the intended application of the data.

[2] Only co-located sites with "data of interest" were identified. The methods for selecting the "data of interest" are described in the data assessment section.

2. Applicability and Utility – the extent to which the data is relevant to our intended use, which is to substitute for acquiring all new data to assess water quality in southwest Missouri.
3. Clarity and Completeness – the degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented.
4. Uncertainty and Variability – the extent to which the qualitative and quantitative uncertainty and variability in the data are evaluated and characterized.
5. Evaluation and Review – the extent of independent verification, validation, and peer review of the data, procedures, measures, methods or models.

A checklist was developed to rate the suitability of existing data (Figure 11). While most, if not all, data collected during the project will be available through the WQIP database, the data were attributed with the collection entity. In this manner, the data user can determine which data are suitable for inclusion in their particular study or data presentation.

Source of Data:	Source Information Reviewed by/with:			
Brief Description of Data (period of record, general location, parameters, etc.)				
Factor 1 Soundness	YES	NO	UNKNOWN	COMMENTS
Were documented standard operating procedures employed to collect, analyze and report the data? Were samples collected, analyzed and reported by trained personnel? Were the methods used to collect and analyze the samples appropriate for our intended use of the data (e.g., were detection limits low enough)?				
Factor 2 Applicability and Utility				
Has the data been collected within the past 5 years? Are complementary data present (e.g., flow, hardness for metals)? Are the sample collection locations geo-referenced or can they be georeferenced easily?				
Factor 3 – Clarity and Completeness				
Is an approved Quality Assurance Plan available? Are field notes and chain of custody forms available?				
Factor 4 – Uncertainty and Variability				
Have adequate numbers and types of field and laboratory quality control samples been collected, analyzed and reported? Have data uncertainty and variability been addressed and this evaluation documented?				
Factor 5 – Evaluation and Review				
Have the data been verified, validated and or peer reviewed? Is the review documented?				
SCORE				

FIGURE 11. Data Suitability Rating Sheet

The checklist was based on the five factors described above. Within each factor, several objective questions (listed below) were asked and if all of the responses were affirmative, the data received a one point credit for that factor. Therefore, the data sources received scores of 0 to 5, with 5 as the highest score. Data sources also received partial credit (0.5 points) if they met most of the requirements for a factor.

Factor 1 – Soundness

- Were documented standard operating procedures employed to collect, analyze and report the data?
- Were samples collected, analyzed and reported by trained personnel?
- Were the methods used to collect and analyze the samples appropriate for our intended use of the data (e.g., were detection limits low enough)?

Factor 2 – Applicability and Utility

- Have the data been collected within the past 5 years?
- Are complementary data present (e.g., flow, hardness for metals)?
- Are the sample collection locations geo-referenced or can they be georeferenced easily?

Factor 3 – Clarity and Completeness

- Is an approved Quality Assurance Plan available?
- Are field notes and chain of custody forms available?

Factor 4 – Uncertainty and Variability

- Have adequate numbers and types of field and laboratory quality control samples been collected, analyzed and reported?
- Have data uncertainty and variability been addressed and this evaluation documented?

Factor 5 – Evaluation and Review

- Have the data been verified, validated and or peer reviewed?
- Is the review documented?

Most of the data included in the database are from the USGS and MDNR, which both received a score of 5. For other organizations' data included in the MDNR database it was not possible to assess the data in this manner. Data received directly from other entities were evaluated and the received the following average ratings:

City Utilities of Springfield	4.5
City of Springfield Public Works	4.5
U.S. Army Corp of Engineers – Kansas City District	3.5
FAPRI	3.5
Murphy Family Farms	

These ratings do not infer that the data received from these entities are not accurate. It simply limits the data's usefulness in certain applications that require rigorous quality assurance/quality control documentation.

3.3.2 Parameters of Interest

All readily available water quality data from the Sac River Basin were compiled into the WQIP database, which consists of hundreds of water quality parameters. However, for purposes of this report the assessment was limited to the following five parameters:

- Total Phosphorus as Phosphorus (TP),
- Total Nitrogen as Nitrogen (TN),
- Nitrate plus Nitrite as Nitrogen ($NO_3 + NO_2$),
- Chlorophyll *a*, and
- *E. coli*.

The WQIP project workgroup selected the five water quality parameters listed above, since they represent direct or indirect indications of threats to the water quality resources of southwest Missouri. *E. coli* was selected for analysis over fecal coliform based on EPA recommendations. EPA epidemiological studies indicate *E. coli* is a better predictor of acute gastrointestinal illness for freshwater recreation than fecal coliform. However, limited analysis of fecal coliform is presented in this report since it has been identified as causing bacteria impairment to the Little Sac River.

3.3.3 Periods of Interest

MEC limited data analysis to those water quality sample stations with a minimum of ten samples during selected periods of record. In the "first cut" of water quality data, MEC identified only those stations with at least ten samples over the entire period of record. MEC's "final cut" of sample stations was based on those sites with a minimum of 10 samples for any of the five selected parameters after the period of interest was selected.

The periods of interest were selected on a parameter-by-parameter basis and were based on a variety of factors. Ideally, data analyses would be performed with data collected from all monitoring sites at the same dates, times, and frequency. However, this is not possible for a multitude of reasons. Therefore, reasonable attempts were made to select a period of interest most representative of all monitoring sites' sampling history.

Analysis of TP was limited to sampling dates on or after October 1, 1992. Although TP data dates as far back as 1983, it is not until 1993 that a significant number of the monitoring stations appear to begin sampling for TP (Figure 12). Therefore, the period of record was set to the beginning of the 1993 hydrologic water year (i.e., October 1, 1992).

Analysis of TN and $NO_3 + NO_2$ was limited to sampling dates on or after October 1, 1992. $NO_3 + NO_2$ data were available in the Sac River Basin as far back as 1983, however TN data were only been available since 1993 (Figures 13 and 14). The period of record was set to the beginning of the 1993 hydrologic water year (i.e., October 1, 1992) to correspond with the TP period of record and since that is approximately when most nutrient sampling appears to have begun in the Sac River Basin.

Analysis of sestonic chlorophyll *a* was limited to sampling dates on or after October 1, 2003. Only two sestonic chlorophyll *a* monitoring stations were available for the Sac River Basin and their periods of records were concurrent (Figure 15). Sampling at the two monitoring stations began on January 28, 2004. The period of interest for sestonic chlorophyll *a* was set as the beginning of the 2004 water year (i.e., October 1, 2003).

Analysis of bacteria data was limited to sampling dates on or after July 22, 1999. The earliest available *E. coli* data are from October 4, 1999 (Figure 16). Although fecal coliform data are available from as early as 1983, most fecal coliform sampling efforts appear to begin July 22, 1999 (Figure 17). Therefore, the period of interest for bacteria (*E. coli* and fecal coliform) was set to July 22, 1999.

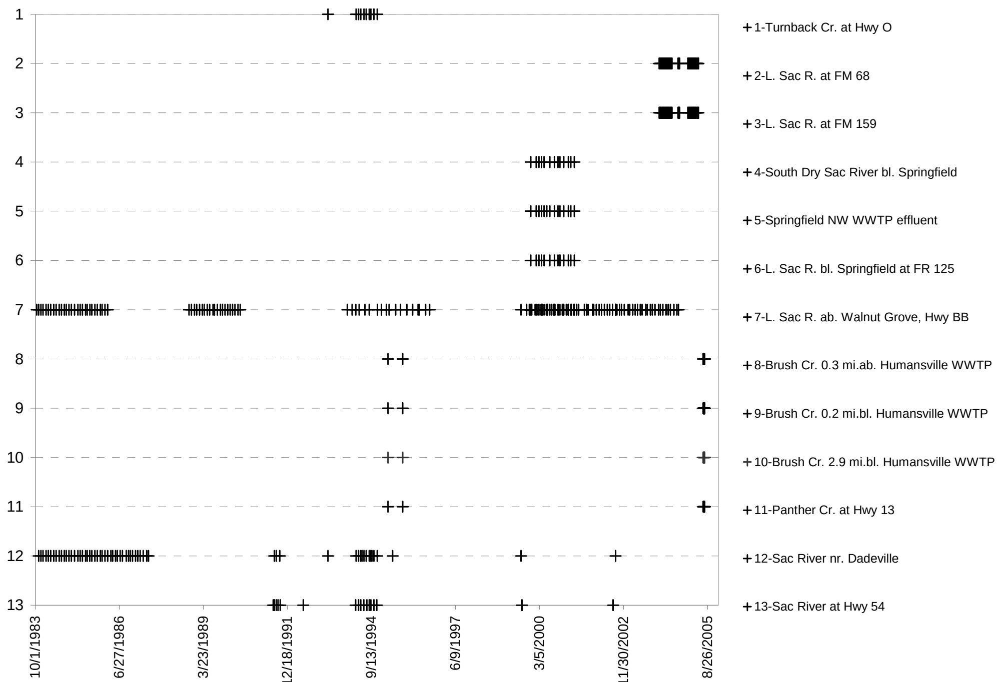

FIGURE 12. Total Phosphorus Sampling Frequency and Period of Record in the Sac River Basin

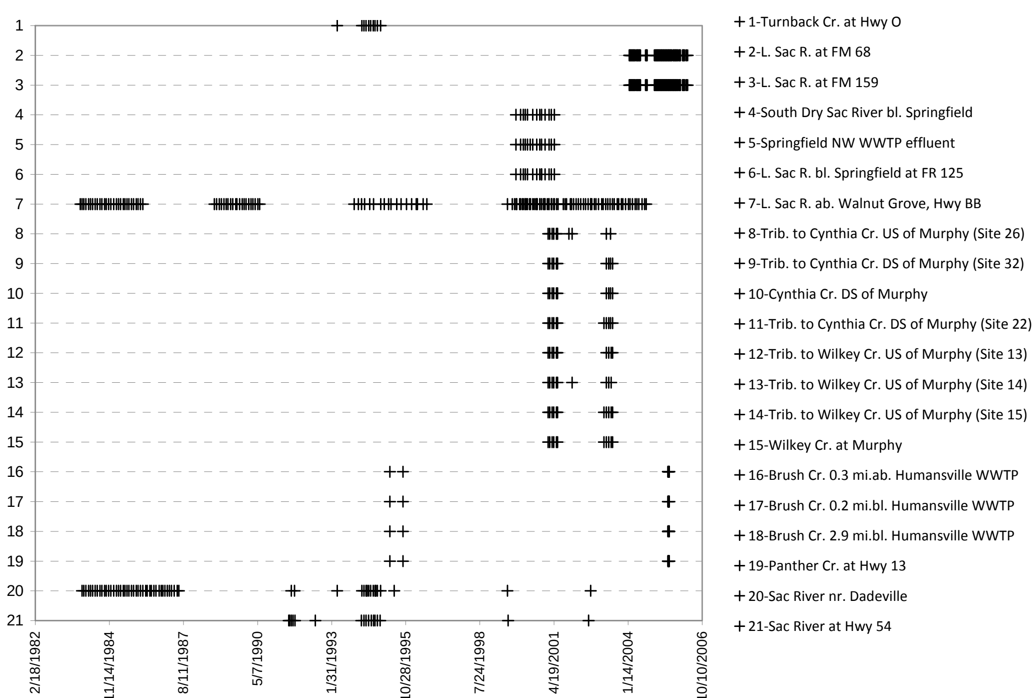

FIGURE 13. Nitrate plus Nitrite Sampling Frequency and Period of Record in the Sac River Basin

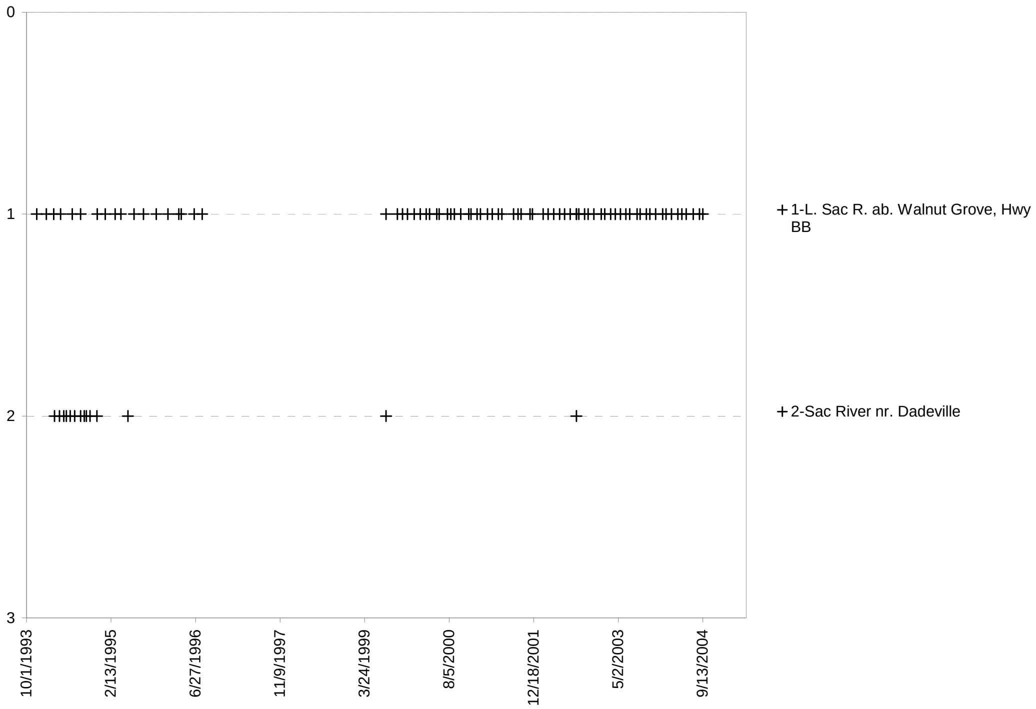

FIGURE 14. Total Nitrogen Sampling Frequency and Period of Record in the Sac River Basin

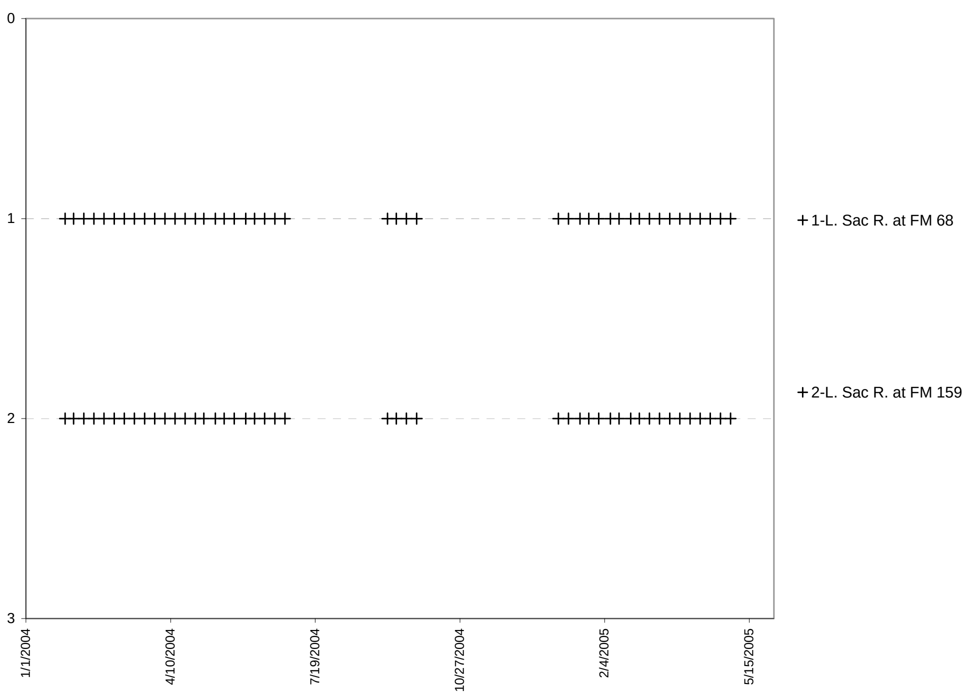

FIGURE 15. Sestonic Chlorophyll *a* Sampling Frequency and Period of Record in the Sac River Basin

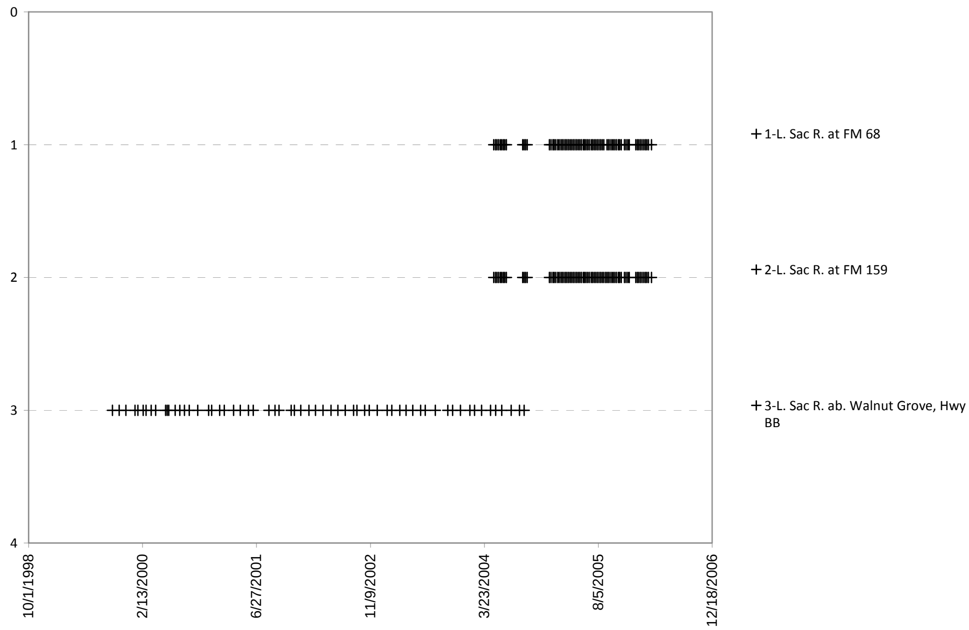

FIGURE 16. *E. coli* Sampling Frequency and Period of Record in the Sac River Basin

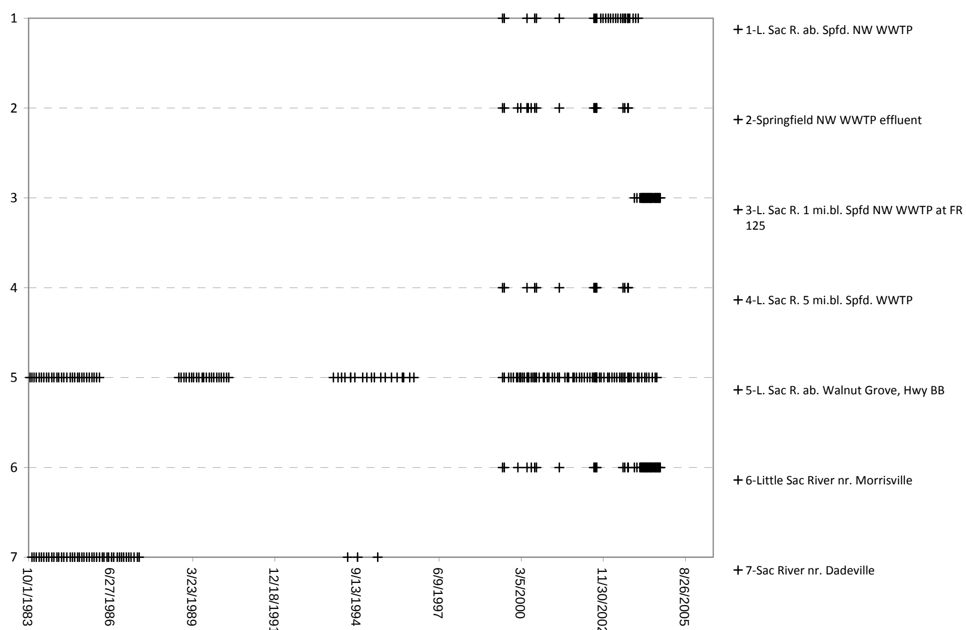

FIGURE 17. Fecal coliform sampling Frequency and Period of Record in the Sac River Basin

3.3.4 Data Analysis

Water quality data in the Sac River Basin were analyzed with the purposes of characterizing stream water quality and directing future monitoring efforts through the identification of data gaps. Data analysis methods presented in this document include statistical summary tables, time series graphs, boxplots, bar charts, and maps. Software used as part of the data analysis included MS Access™, MS Excel™, Grapher™, and ArcGIS™. Data results are displayed in the tables and figures in order of upstream to downstream with the caveat that all Sac River sites are listed subsequent to other monitoring sites (see Figure 10 for site ordering).

TN values were based on direct analytical determination or the combined sum of individual forms such as organic nitrogen, ammonia, nitrite, and nitrate. Therefore, some TN values were calculated prior to data analysis by summing TKN (organic nitrogen plus ammonia) and NO_3+NO_2 values for each site after grouping by the smallest temporal scale available (i.e., either by date or time). Not all samples were attributed with a collection time, but all samples were attributed with a collection date. Where multiple TKN and NO_3+NO_2 component values existed for a given day and were not attributed with a collection time, the component values were averaged prior to summing.

Multiple closely related analytical measurements of NO_3+NO_2 were available with their own parameter codes. Rather than select a single parameter code to represent NO_3+NO_2, we chose to aggregate the various related parameter codes. NO_3+NO_2 data analyzed in this report includes filtered NO_3+NO_2, unfiltered NO_3+NO_2, nitrate added to nitrite where they were analyzed separately, and nitrate where nitrite was unavailable. In most surface waters, nitrite is only available in trace amounts. We assumed that nitrate samples are reasonably representative of NO_3+NO_2 levels. A review of the database supported this assumption that nitrite levels were very low or below detection limits.

3.3.5 Data Limitations

The data analyses presented in this report are based on data with certain limitations, which potentially hinder its interpretation and use. Some data limitations are inherent to most water quality data and are described below as statistical limitations. Other data limitations originate from data gaps and lack of data comparability.

Statistical limitations of water quality data potentially include nonnormality, seasonality, and serial correlation. Water quality data tends to be more right skewed than normally distributed; however, the statistical distribution of the WQIP water quality data was not analyzed. Seasonality is a characteristic of water quality data that reflects known cycles in the data and may impact any statistical procedure which assumes a stationary time series. Serial correlation is the redundancy of information that may result from samples being taken too close together temporally relative to the time period of interest. Serial correlation implies samples are not independent and potentially could mask the true population variance. Although not necessary for the purposes of this report, more rigorous statistical analyses of the data should be utilized to address these statistical limitations.

The National Water Quality Monitoring Council (NWQMC)[3] cites the lack of commonly accepted data elements as a significant limitation in the secondary use of water quality data. A lack of common water quality data elements (WQDE)[4] limits the comparability, sharing, and value of water quality data. The Methods and Data Comparability Board (MDCB), a Workgroup under the NWQMC, formed a WQDE Workgroup in 1999 specifically to address this issue. The Workgroup developed a minimal set of WQDE needed to serve most, if not all, secondary uses of the respective types of data and to make an informed assessment regarding data comparability (NWQMC, 2006). The recommended WQDE, including information on detection limits and sample times, are largely lacking from the WQIP database. The lack of WQDE potentially limits the value of the data analyses presented in this report.

In addition to a lack of WQDE (i.e., "core metadata"), other data gaps limit the interpretation of the water quality data. For example, flow data, which is largely lacking, is typically necessary for a proper analysis of water quality data, since water quality varies during different flow regimes. The issue of lack of WQDE and other data gaps are discussed in further detail in Section 6.0.

[3] The NWQMC was formed in 1997 as the permanent successor to the Intergovernmental Task Force on Monitoring Water Quality (ITFM). The NWQMC reports to the Advisory Committee on Water Information (ACWI), convened by the Department of the Interior under the Federal Committee of Water Information (FACA).

[4] The NWQMC considers WQDE to be the "core metadata" necessary to allow data comparability assessments.

4. WATER QUALITY SUMMARIES AND STATISTICS

A discussion and characterization of nutrients, suspended chlorophyll *a* and *E. coli* in the Sac River Basin are presented below. Basic summary statistics including sample count, geometric means (hereinafter referred to as geomean), minimum, maximum, standard deviation and percentiles are provided for each parameter in a table format. A graduated symbol map, boxplot comparisons, and a bar graph ordered by geomeans are also presented for each parameter. For most parameters a single station was chosen for each parameter to depict long-term trend analysis using a bar graph of annual geomeans.

4.1 Nutrients and Algal Biomass

Cultural eutrophication (the adverse effects of excess nutrient inputs) of surface water is an issue confronting the State of Missouri as well as the rest of the nation. Approximately 10 percent of all waters listed on Missouri's 2002 303(d) list are considered impaired due to nutrients. The effects of cultural eutrophication can include the following (MDNR, 2005c):

- Proliferation of nuisance algae and the resulting unsightly and harmful bottom deposits;
- Turbidity due to suspended algae and the resulting unsightly green color;
- Dissolved oxygen depletion resulting from decomposition of overabundant algae and other plants that can have a negative impact on aquatic life; and
- Organic enrichment when algal blooms die off, which perpetuates the cycle of excessive plant growth.

Nutrient impairment may be gauged by two general categories – causal and response variables. TP and TN are typically the causal variables of interest, since limnologists consider them to be the most essential parameters for nutrient enrichment. Two early indicator response variables of system enrichment include chlorophyll *a* and some measure of turbidity (MDNR, 2005c; EPA, 2000b). A discussion of causal (TP, TN, NO_2+NO_3) and response (chlorophyll *a*) variables observed in the Sac River Basin is summarized below.

4.1.1 Phosphorus

Phosphorus is a naturally occurring nutrient found in streams and rivers and is essential to all forms of life. Minimal levels of phosphorus are important for maintaining the ecological health and regulating the autotrophic[1] state in lotic[2] ecosystems. Excessive levels of phosphorus have been linked to eutrophication and increased production of autotrophs (e.g., algae). Although phosphorus is generally regarded as the most common cause of eutrophication in reservoirs, lakes and streams; Dodds (2006) cautions against making this assumption a priori for any particular stream.

[1] The autotrophic state is the gross primary production during lighted periods. An autotroph is an organism that produces organic matter from carbon dioxide using either light or reactions of inorganic compounds as a source of energy.
[2] Lotic refers to flowing water.

Phosphorus occurs in a variety of molecular forms in the environment, but is rarely found in volatile states. Phosphates bind strongly to most soils and sediment, therefore surface waters receive most of their phosphorus from surface flows. The dominant form of phosphorus found in aquatic ecosystems is the pentavalent form. Among the pentavalent forms of phosphorus, only orthophosphate may be assimilated by autotrophs. Other forms of phosphorus may be chemically or enzymatically hydrolyzed to orthophosphate under appropriate conditions (Correll, 1999).

Phosphorus may be discharged to aquatic systems from both point and non-point sources. Historically, point sources such as wastewater treatment outfalls have been considered the most significant sources of phosphorus. However, the influence of non-point sources has taken on greater significance as treatment technologies have improved. Agricultural runoff of field fertilizers and animal manure, as well as runoff from residential and commercial fertilized lawns are commonly recognized non-point sources of phosphorus (Correll, 1999; Dodds *et al.*, 1998). Non-point sources may be responsible for greater than 90% of phosphorus loading in about one-third of US streams and rivers (Newman, 1996).

Baseline nutrient levels vary based on regional differences in geology, topography, and land uses (Dodds, 2006). The EPA has suggested an appropriate TP reference condition for the Level III Ozark Highlands Ecoregion (inclusive of the Sac River Basin) is 6.6 µg/L[3] (EPA, 2000b). However, the Regional Technical Assistance Group (RTAG) for EPA Region 7 has recommended in draft a TP benchmark of 75 µg/L for all Region 7 states (email correspondence with Gary Welker – EPA Region 7 Nutrient Regional Coordinator – 2/20/2007). The RTAG recommendation is supported by Dodds *et al.* (1998), which suggests the threshold between mesotrophic and eutrophic rivers is characterized by a TP level of 75 µg/L.

A trend analysis was conducted using data from the Little Sac River above Walnut Grove water quality station (hereinafter referred to as the Walnut Grove station). The Walnut Grove station had the most complete long-term phosphorus recordset of any station in the Sac River Basin. Annual geomean TP levels at the Walnut Grove station indicate phosphorus levels in the Little Sac River decreased significantly beginning around 1990 (Figure 18). From 1983 to 1990 annual TP geomeans ranged from about 250 µg/L to 450 µg/L. TP annual geomeans for years with available data subsequent to 1990 ranged from about 60 µg/L to 125 µg/L. The Walnut Grove station is located about 13 miles downstream of the Springfield Northwest WWTF. The observed decrease in phosphorus concentrations corresponds to upgrades at the Springfield Northwest WWTF that allowed biological phosphorus removal (personal correspondence, Randy Lyman, Environmental Compliance Officer, City of Springfield).

[3] This value is based on the 25th percentile of EPA's entire nutrient database for level III ecoregion 39.

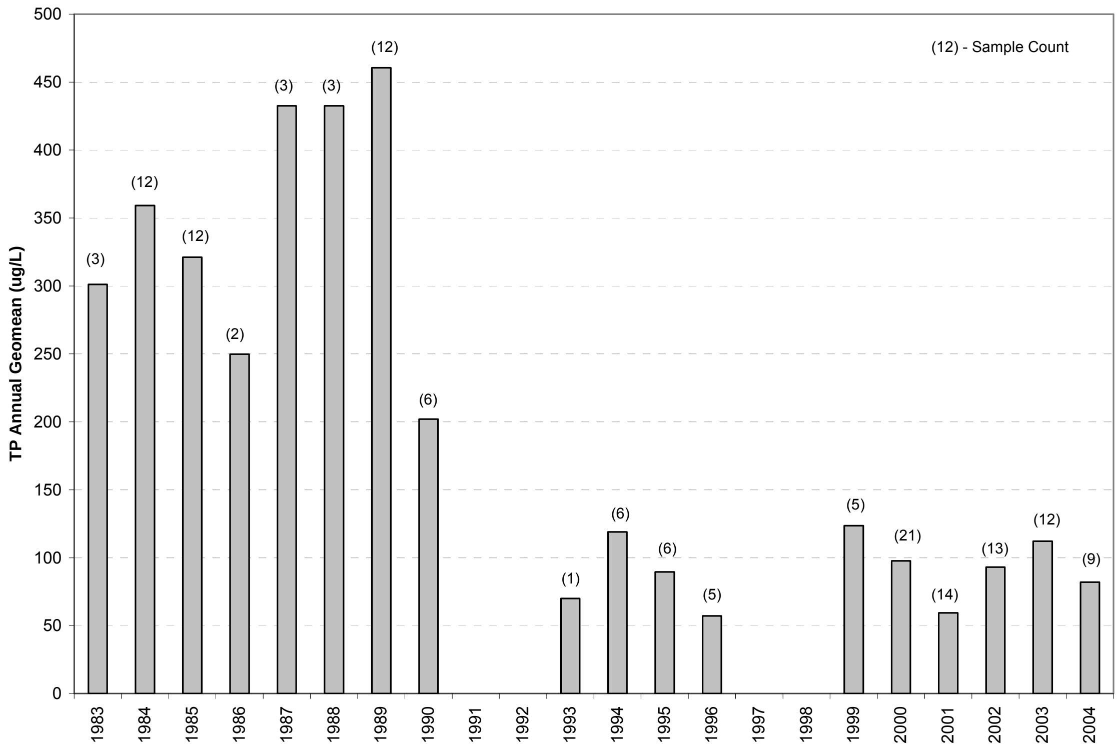

FIGURE 18. Total Phosphorus Annual Geometric Means Measured in the Little Sac River above Walnut Grove Station

TP geomeans were above the Dodds *et al.* (1998) recommended threshold of 75 µg/L at several monitoring stations throughout the Sac River Basin (Table 7). Figure 19 suggests TP loading may be originating from multiple areas within the basin. The greatest loading appears to be from the Springfield Northwest WWTF effluent where the TP geomean was 285 µg/L. A boxplot comparison of TP values suggest TP levels within the Little Sac River drop downstream of the Springfield Northwest WWTF, but not to levels observed upstream of the facility (Figure 20). The Little Sac River above Walnut Grove had a TP geomean of 89 µg/L (i.e., greater than the recommended threshold); however, it is unclear whether sources other than the Springfield Northwest WWTF may be contributing to this elevated level. The TP geomean at the Brush Creek station located approximately 0.2 miles downstream of the Humansville WWTF was 194 µg/L , which is significantly greater than all other observed instream TP geomeans (Figure 21). TP geomeans 0.3 miles above and 2.9 miles below the Humansville WWTF were 39 µg/L and 58 µg/L, respectively; strongly suggesting the Humansville WWTF is a significant source of TP loading to Brush Creek. The Turnback Creek station had a TP geomean of 91 µg/L. TP levels in Turnback Creek may be impacted by the Greenfield Southeast WWTF, which is located less than two miles upstream of the Turnback Creek station. The Sac River station near Dadeville had a TP geomean of 81 µg/L. The only other Sac River station with TP data is located downstream Stockton Lake, which had a TP geomean less than the 75 µg/L threshold.

TABLE 7. Selected Statistics for the Sac River Basin – Total Phosphorus

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles 10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
1411/4.9	Turnback Cr. at Hwy O	4/14/1993	11/21/1994	10	75	115	91	30	270	82	48	53	177	216
1388/0.3	L. Sac R. at FM 68	1/28/2004	5/9/2005	46	20	22	20	10	70	12	10	10	30	30
1388/0.8	L. Sac R. at FM 159	1/28/2004	5/9/2005	46	20	31	25	10	80	19	10	20	40	60
6918495	South Dry Sac River bl. Springfield	11/22/1999	4/24/2001	13	10	17	15	10	40	10	10	10	20	30
1381/33.3	Springfield NW WWTP effluent	11/22/1999	4/24/2001	14	200	848	285	80	5,000	1,677	119	160	270	3,310
6918525	L. Sac R. bl. Springfield at FR 125	11/22/1999	4/24/2001	14	80	124	70	10	720	179	16	62	88	185
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	11/30/1993	9/13/2004	92	85	156	89	10	1,300	198	30	40	200	397
1372/0.3	Brush Cr. 0.3 mi.ab. Humansville WWTP	3/28/1995	7/21/2005	10	40	43	39	20	90	19	25	32	48	54
1371/3.8	Brush Cr. 0.2 mi.bl. Humansville WWTP	3/28/1995	7/21/2005	11	280	251	194	25	440	133	50	185	320	390
1371/1.1	Brush Cr. 2.9 mi.bl. Humansville WWTP	3/28/1995	7/21/2005	10	55	63	58	25	110	25	48	50	67	101
1373/0.9	Panther Cr. at Hwy 13	3/28/1995	7/21/2005	10	55	50	47	25	90	20	29	32	60	63
6918440	Sac River nr. Dadeville	4/14/1993	8/27/2002	15	80	101	81	20	300	74	40	55	125	184
1343/9.2	Sac River at Hwy 54	3/8/1994	7/29/2002	11	70	88	57	10	350	95	20	30	105	130

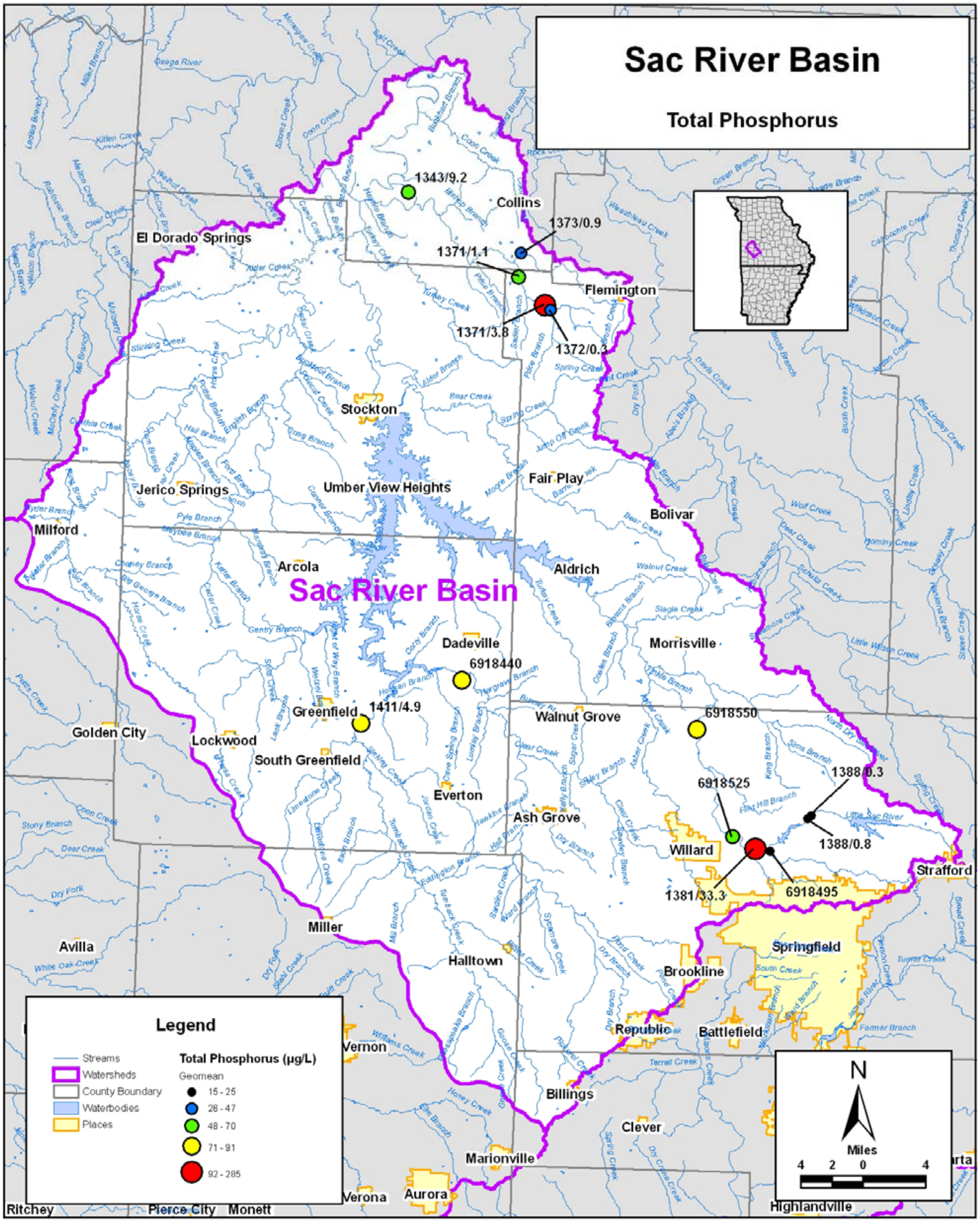

FIGURE 19. Total Phosphorus Geometric Means at Select Monitoring Stations in the Sac River Basin

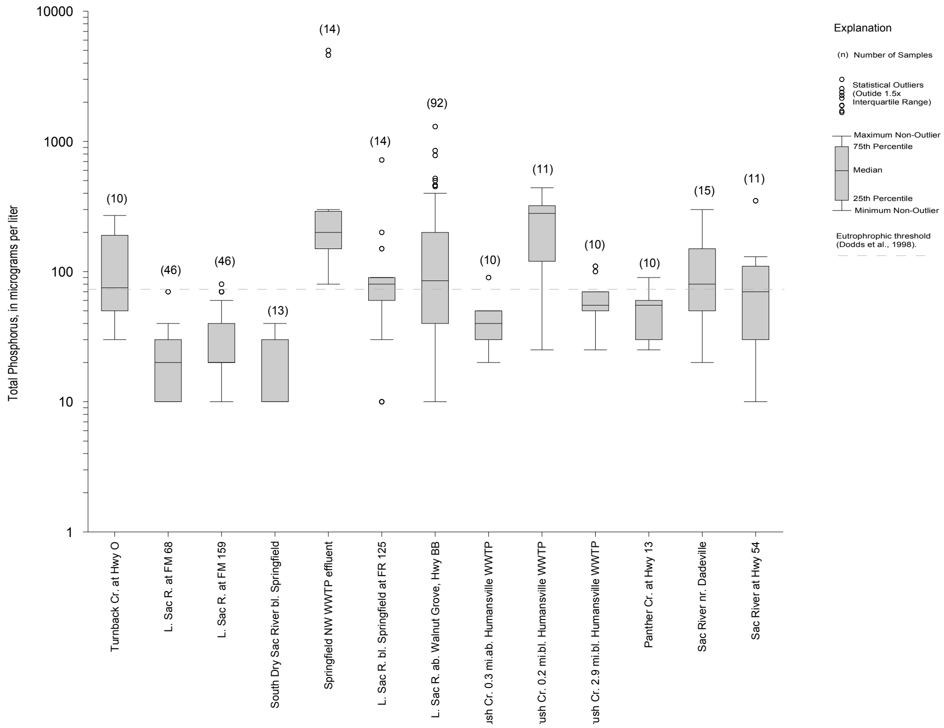

FIGURE 20. Box Plot of Total Phosphorus in the Sac River Basin (April 14, 1993 to September 21, 2005) Compared to Eutrophication Threshold

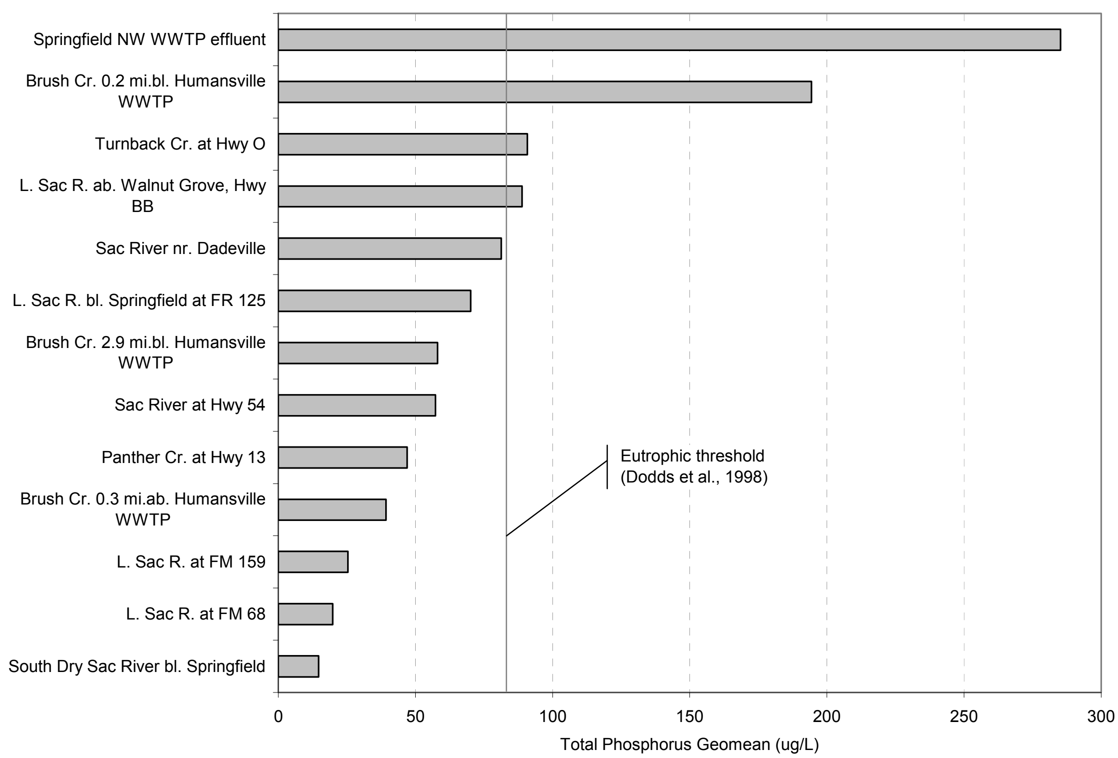

FIGURE 21. Total Phosphorus Geometric Means in the Sac River Basin (4/14/1993 – 7/21/2005)

4.1.2 Nitrogen

Like phosphorus, nitrogen is a found in variety of chemical forms and is an essential nutrient for living organisms. Nitrogen may be present in the air, water, soil, rocks, plants, and animals. The chemical forms of nitrogen include organic nitrogen compounds, nitrogen gas (N_2), ammonia (NH_3), ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrous oxide (N_2O), and nitric oxide (NO). Reactive nitrogen[4] is biologically the most important form of nitrogen. Although most nitrogen is not in a reactive form, nitrogen migrates throughout the environment and changes chemical forms in what is commonly termed the nitrogen cycle (Driscoll *et al.*, 2003; Seelig and Nowatzki, 2001).

Microorganisms may utilize nitrogen in its organic form as an energy source in a process referred to as mineralization. The process of mineralization transforms organic nitrogen to inorganic nitrogen in two steps. The first step is ammonification, whereby microorganisms extract energy from organic nitrogen and release NH_4 as a byproduct. Nitrification is the second step, in which *nitrosomas* bacteria convert the NH_4 into NO_2 and *nitrobacter* bacteria convert the NO_2 into NO_3. Conversion of NO_2 to NO_3 typically occurs more readily than conversion of NH_4 to NO_3; therefore, NO_3 concentrations typically far exceed those of NO_2. The opposite of mineralization is immobilization, whereby microorganisms convert inorganic nitrogen into its organic form (Seelig and Nowatzki, 2001).

In a symbiotic relationship with nitrogen fixing bacteria, some plants are capable of extracting elemental nitrogen gas (N_2) from the atmosphere and converting it into a NH_3, where it may be readily assimilated into organic nitrogen. A microbial process called denitrification releases nitrogen from decomposing plant matter back into the atmosphere. Denitrification converts NO_3 to the gaseous forms of N_2O and elemental N_2. Nitrogen may also be volatilized to the atmosphere as NH_3 during ammonification. The loss of nitrogen to the atmosphere is a natural mechanism that helps protect water resources from excessive levels of nitrogen (Seelig and Nowatzki, 2001).

Anthropogenic activities have effectively increased the delivery of nitrogen to water bodies. Although a variety of pathways exist for reactive nitrogen to enter aquatic systems, surface runoff from agricultural and urban areas is one of the most cited. Stormwater runoff from lawns, agricultural fields, golf courses, parks and gardens often contains relatively high concentrations of nitrogen and may reach streams in its highly soluble form (i.e., NO_3) or absorbed to soil particles as the positively charged NH_4. Industrial discharges and municipal wastewater effluents also contribute significant levels of nitrogen to stream systems as point sources (Driscoll *et al.*, 2003; Seelig and Nowatzki).

The EPA has suggested an appropriate TN reference condition for the Level III Ozark Highlands Ecoregion (inclusive of the Sac River Basin) is 379 µg/L[5] (EPA, 2000b).

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[4] Reactive nitrogen refers to all forms of nitrogen that are readily available to biota (largely ammonia, ammonium and nitrate).

[5] This value is based on the 25th percentile of EPA's entire nutrient database for level III ecoregion 39.

However, the RTAG for EPA Region 7 has recommended in draft a TN benchmark of 900 µg/L for all Region 7 states (email correspondence with Gary Welker – EPA Region 7 Nutrient Regional Coordinator – 2/20/2007). Dodds *et al.* (1998) suggests the mesotrophic and eutrophic TN thresholds for streams are 700 µg/L and 1,500 µg/L, respectively. Eutrophic thresholds are typically not expressed in terms of NO_3+NO_2; however, Missouri has applied a criterion for NO_3-N of 10,000 µg/L for surface waters designated as a drinking water supply (Carnahan, 2005).

4.1.2.1 Total Nitrogen

No apparent temporal trend for TN exists based on annual geomean concentrations at the Walnut Grove water quality station on the Little Sac River (Figure 22). Although annual TN geomean values varied between years, the data did not indicate any upward or downward trends over the observed period of record. The available TN period of record for the Walnut Grove station spanned from 1993 to 2004; however, no TN data are available from 1997 and 1998.

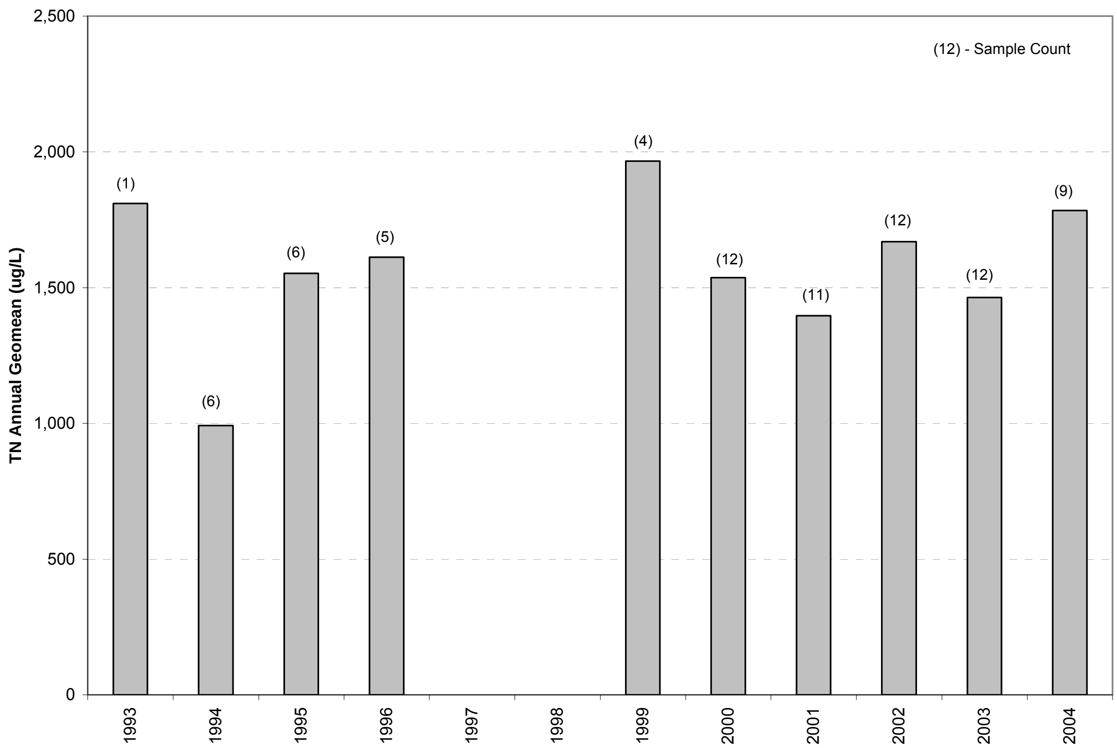

FIGURE 22. Total Nitrogen Annual Geometric Means Measured in the Little Sac River above Walnut Grove Station

Only two water quality stations were available for TN analysis from the Sac River Basin. The two stations include the Little Sac River above Walnut Grove and the Sac River near Dadeville, both of which are located upstream of Stockton Reservoir (Figure 23). TN geomeans at both stations exceeded the Dodds *et al.* (1998) recommended threshold value of 1,500 µg/L. The Walnut Grove and Dadeville stations had TN geomeans of

1,527 µg/L and 1,633 µg/L, respectively (Table 8). A boxplot comparison of the two stations indicates they have a relatively similar distribution of data (Figure 24).

TABLE 8. Selected Statistics for the Sac River Basin – Total Nitrogen

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles 10th (µg/L)	25th (µg/L)	75th (µg/L)	90th (µg/L)
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	11/30/1993	9/13/2004	78	1,690	1,615	1,527	110	3,160	447	1,150	1,282	1,880	2,065
6918440	Sac River nr. Dadeville	4/14/1993	8/27/2002	15	1,600	1,671	1,633	1,300	2,700	397	1,300	1,350	1,855	2,100

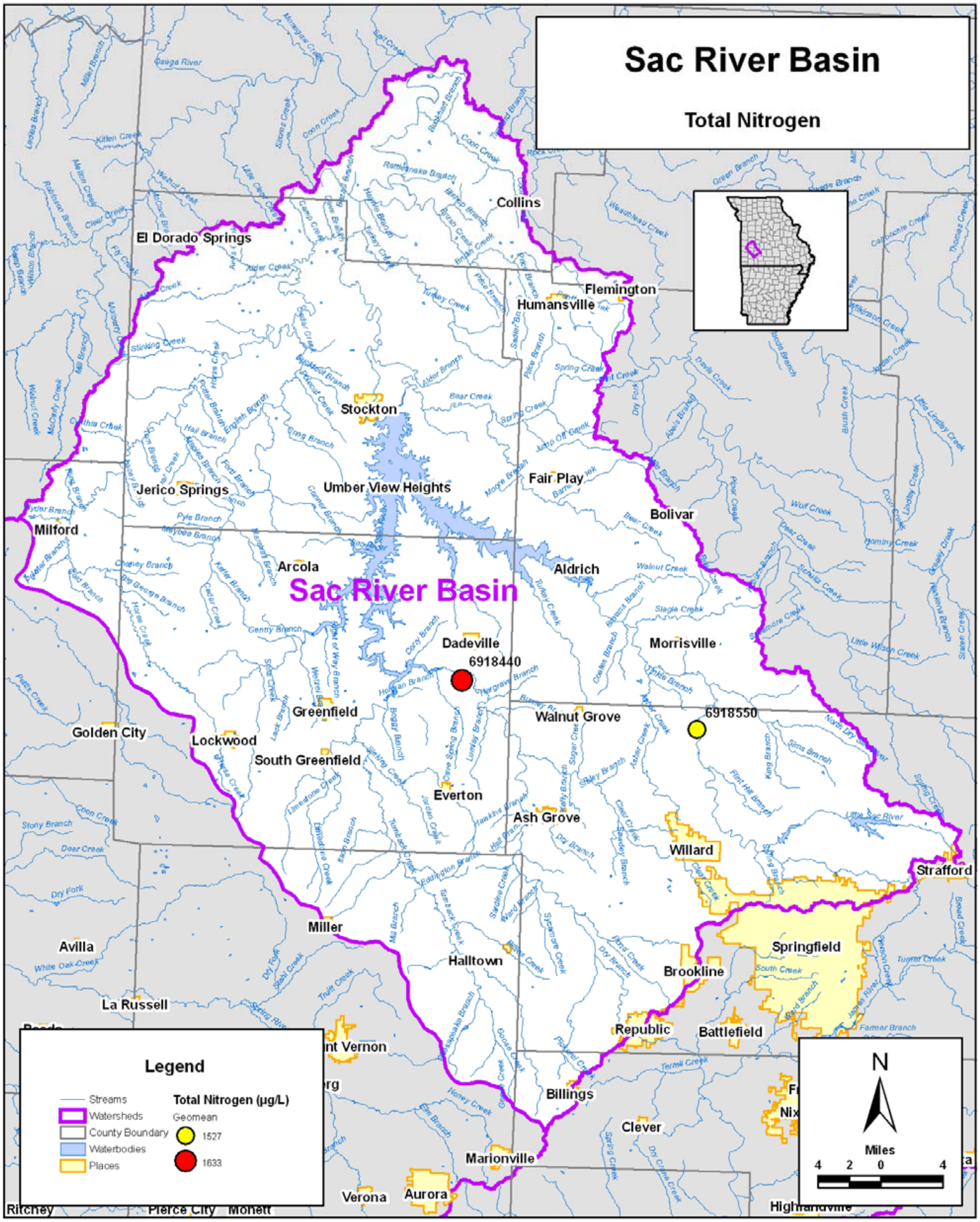

FIGURE 23. Total Nitrogen Geometric Means at Select Monitoring Stations in the Sac River Basin

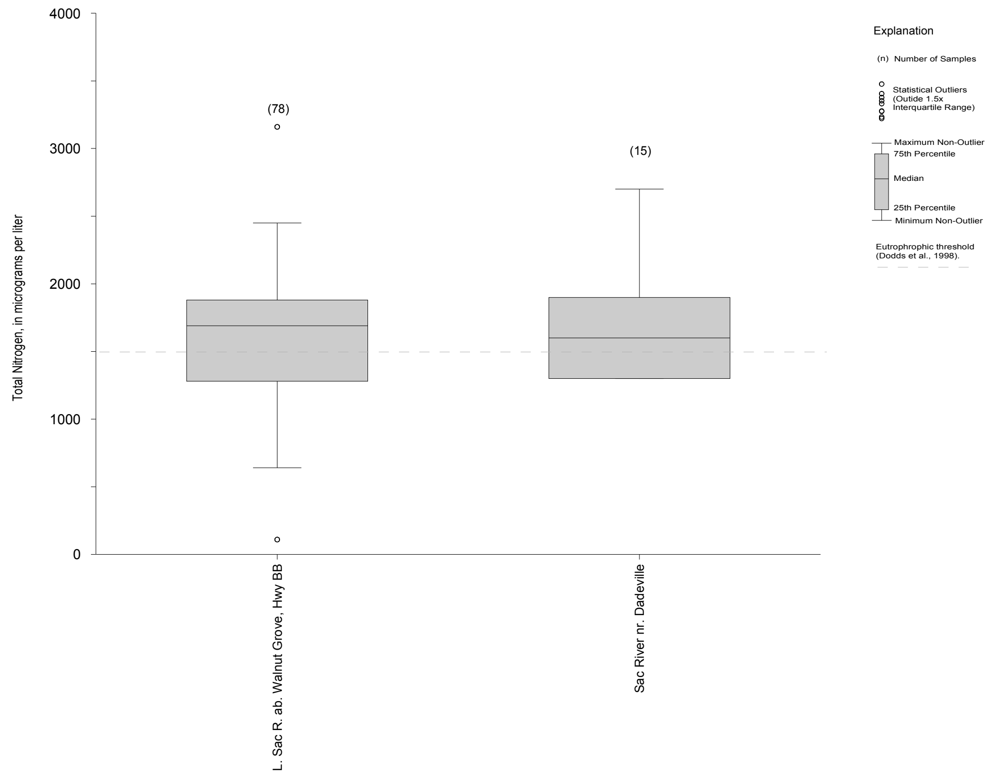

FIGURE 24. Box Plot of Total Nitrogen in the Sac River Basin (April 14, 1993 to September 13, 2004) Compared to Eutrophication Threshold

4.1.2.2 Nitrate plus Nitrite Nitrogen

The annual NO_2+NO_3 geomean concentrations at the Walnut Grove water quality station suggest nitrate levels dropped in the early 1990s (Figure 25). The drop in NO_2+NO_3 levels appears to mimic decreases in phosphorus observed around the same, which corresponds to upgrades at the Springfield Northwest WWTF. The available NO_2+NO_3 period of record for the Walnut Grove station spanned from 1983 to 2004; however, no NO_2+NO_3 data were available from 1987, 1991-1992, and 1997-1998.

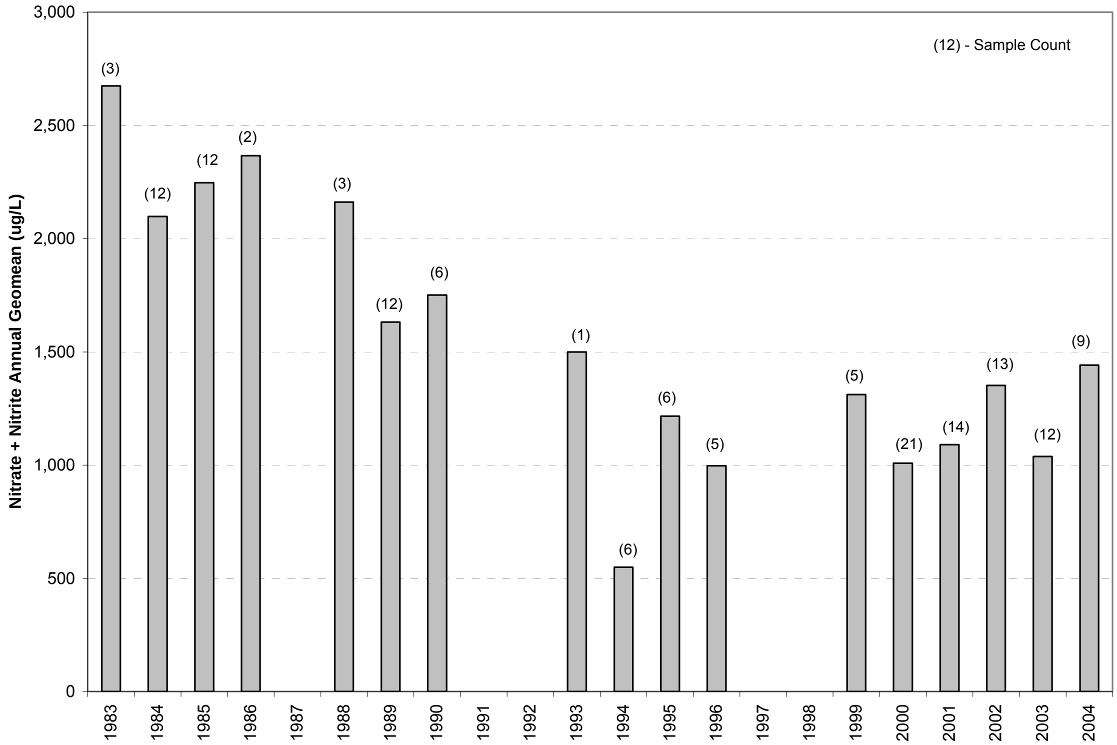

FIGURE 25. Nitrate plus Nitrite Nitrogen Annual Geometric Means Measured in the Little Sac River above Walnut Grove Station

Instream NO_2+NO_3 geomeans varied widely throughout the Sac River Basin ranging from 26 µg/L to 2,356 µg/L (Table 9), suggesting multiple nitrate loading sources. The highest observed instream NO_2+NO_3 levels were in the northeast section of the basin in the vicinity of Murphy Family Farms, which operates large scale swine production facilities (Figure 26). Sites on Wilkey Creek, Cynthia Creek, and tributaries thereof, identified as at or downstream of Murphy Family Farms had geomeans ranging from 1,010 µg/L to 2,356 µg/L. Boxplot depictions of these stations indicate NO_2+NO_3 loadings from Murphy Farms are highly variable (Figure 27).

NO_2+NO_3 levels on the Little Sac River appear to be largely influenced by the Springfield Northwest WWTF, which had an effluent NO_2+NO_3 geomean of 4,147 µg/L. NO_2+NO_3 geomeans on the Little Sac River ranged from 320 µg/L to 427 µg/L upstream of the WWTF to 1,095 µg/L to 2,264 µg/L downstream of the WWTF. Water quality stations upstream of the WWTF are ranked near the middle with regards to NO_2+NO_3 geomeans, suggesting nitrate loading sources other than the WWTF may be present (Figure 28). Since no other significant point sources are located upstream of the Springfield Northwest WWTF, nonpoint sources may be contributing to nitrate loading in the Little Sac River.

Evidence of other NO_2+NO_3 loading sources is found throughout the basin. The Turnback Creek station had a relatively high NO_2+NO_3 geomean of 1,046 µg/L. This station is located approximately two miles downstream of the Greenfield Southeast

WWTF. No other stations were available in Turnback Creek, so the source of the NO_2+NO_3 loading is unclear. Relatively high levels of NO_2+NO_3 were also observed at the South Dry Sac River station and the Sac River near Dadeville station (i.e., 1,201 μg/L and 1,372 μg/L, respectively). The sources of nitrate loading at the South Dry Sac River and Dadeville stations are also unclear. The Humansville WWTF appears to have a slight impact on NO_2+NO_3 levels in Brush Creek. The NO_2+NO_3 geomean in Brush Creek increases from 184 μg/L 0.3 miles above the WWTF to 235 μg/L 0.2 miles below the WWTF.

The least impacted water quality stations were Panther Creek at Highway 13 and the Sac River at Highway 54, which had a NO_2+NO_3 geomeans of 26 μg/L and 47 μg/L, respectively. Panther Creek is a headwater stream in the lower Sac River Basin, with no apparent loading sources. The Sac River at Highway 54 station is located near the mouth of the basin. The relatively low NO_2+NO_3 levels at this downstream location may be indicative of Stockton Lake acting as a nitrogen sink.

TABLE 9. Selected Statistics for the Sac River Basin – Nitrate plus Nitrite Nitrogen

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles 10th (µg/L)	Percentiles 25th (µg/L)	Percentiles 75th (µg/L)	Percentiles 90th (µg/L)
1411/4.9	Turnback Cr. at Hwy O	4/14/1993	11/21/1994	10	1,130	1,094	1,046	430	1,500	288	790	1,123	1,185	1,347
1388/0.3	L. Sac R. at FM 68	1/28/2004	3/27/2006	83	400	595	427	5	2,220	482	170	250	825	1,280
1388/0.8	L. Sac R. at FM 159	1/28/2004	3/27/2006	84	265	508	320	5	2,210	493	116	178	698	1,243
6918495	South Dry Sac River bl. Springfield	11/22/1999	4/24/2001	13	1,100	1,279	1,201	640	2,300	488	814	920	1,500	1,980
1381/33.3	Springfield NW WWTP effluent	11/22/1999	4/24/2001	14	6,350	5,366	4,147	130	8,100	2,349	2,650	3,400	7,075	7,340
6918525	L. Sac R. bl. Springfield at FR 125	11/22/1999	4/24/2001	14	2,100	2,393	2,264	1,300	5,000	926	1,660	2,025	2,450	3,360
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	11/30/1993	9/13/2004	92	1,300	1,243	1,095	10	2,810	467	661	895	1,567	1,727
1348/26/4.5/1.4	Trib. to Cynthia Cr. US of Murphy (Site 26)	1/30/2001	5/22/2003	10	50	152	72	20	890	268	47	50	50	323
1348/26/4.2/0.1	Trib. to Cynthia Cr. DS of Murphy (Site 32)	1/30/2001	6/19/2003	10	1,375	1,900	1,010	50	4,980	1,768	248	500	2,793	4,548
1348/26/3.9	Cynthia Cr. DS of Murphy	1/30/2001	6/19/2003	10	2,250	2,631	2,184	800	7,120	1,837	1,124	1,415	2,852	4,294
1348/26/3.4/0.1	Trib. to Cynthia Cr. DS of Murphy (Site 22)	1/30/2001	6/19/2003	11	1,050	1,773	1,027	50	5,690	1,727	420	630	2,465	3,800
1348/23/4.3/1.7	Trib. to Wilkey Cr. US of Murphy (Site 13)	1/30/2001	6/19/2003	10	335	861	271	50	2,490	1,073	50	50	1,815	2,436
1348/23/4.3/1.3	Trib. to Wilkey Cr. US of Murphy (Site 14)	1/30/2001	5/29/2003	10	125	1,025	235	30	5,060	1,645	48	50	1,368	2,747
1348/23/4.3/1.1	Trib. to Wilkey Cr. US of Murphy (Site 15)	1/30/2001	6/19/2003	11	600	973	452	50	2,850	1,061	50	200	1,710	2,400
1348/23/3.5	Wilkey Cr. at Murphy	1/30/2001	6/19/2003	11	2,470	3,721	2,356	300	11,540	3,432	700	1,280	5,050	7,470
1372/0.3	Brush Cr. 0.3 mi.ab. Humansville WWTP	3/28/1995	7/21/2005	10	220	210	184	25	280	72	173	200	255	271
1371/3.8	Brush Cr. 0.2 mi.bl. Humansville WWTP	3/28/1995	7/21/2005	11	200	259	235	120	450	117	140	170	370	380
1371/1.1	Brush Cr. 2.9 mi.bl. Humansville WWTP	3/28/1995	7/21/2005	10	90	98	89	25	140	36	66	82	127	140
1373/0.9	Panther Cr. at Hwy 13	3/28/1995	7/21/2005	10	27	52	26	5	290	85	5	20	37	83
6918440	Sac River nr. Dadeville	4/14/1993	8/27/2002	15	1,360	1,389	1,372	1,100	1,850	231	1,146	1,205	1,500	1,724
1343/9.2	Sac River at Hwy 54	3/8/1994	7/29/2002	11	60	128	47	5	400	143	10	10	260	270

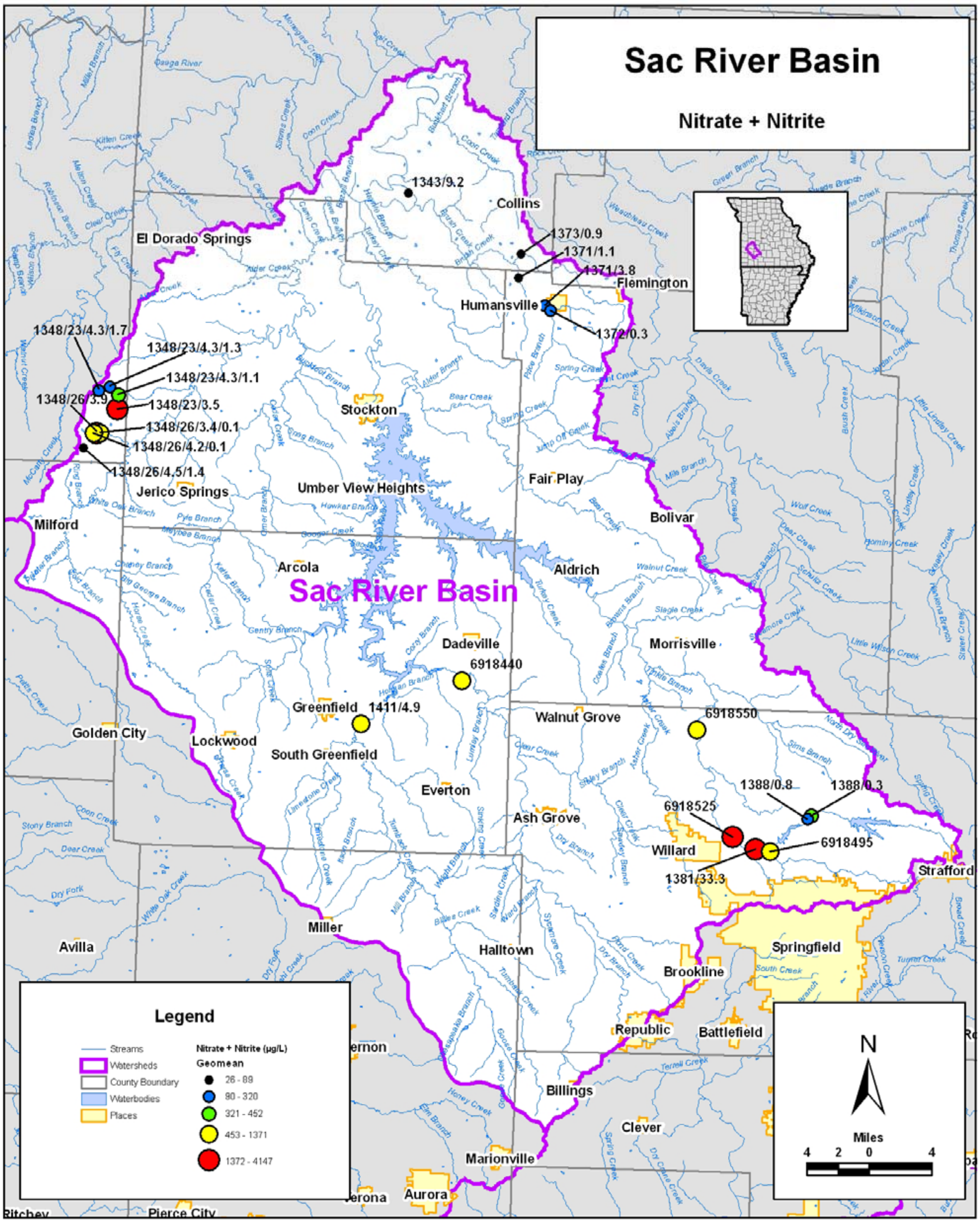

FIGURE 26. Nitrate plus Nitrite Nitrogen Geometric Means at Select Stations in the Sac River Basin

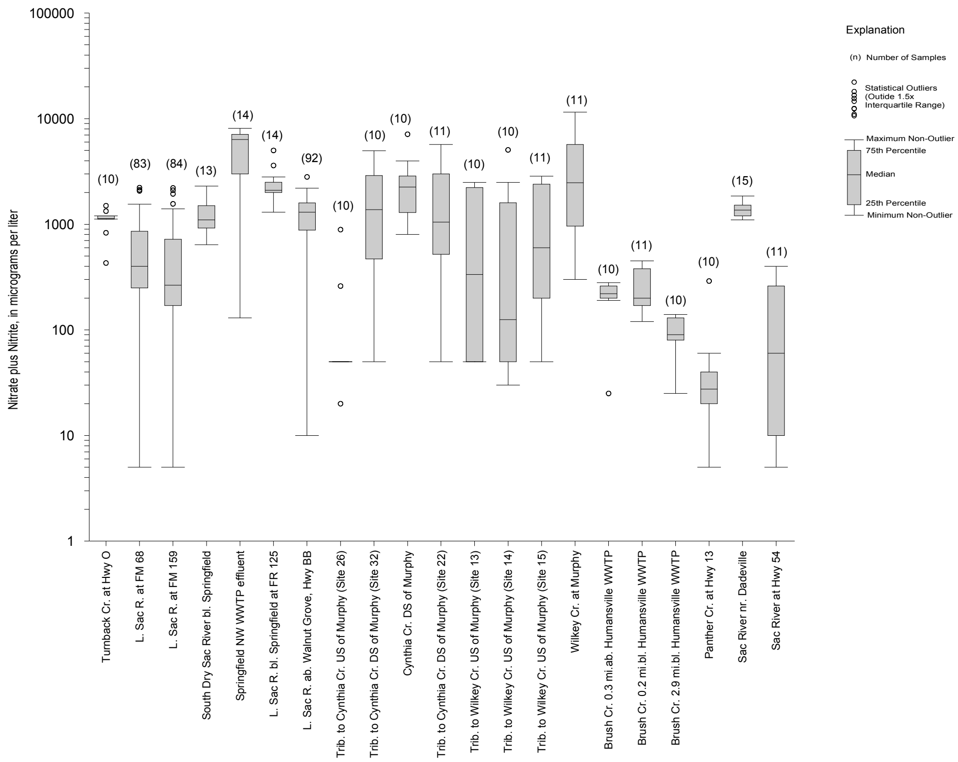

FIGURE 27. Box Plot of Nitrate plus Nitrite Nitrogen in the Sac River Basin (April 14, 1993 to July 21, 2005)

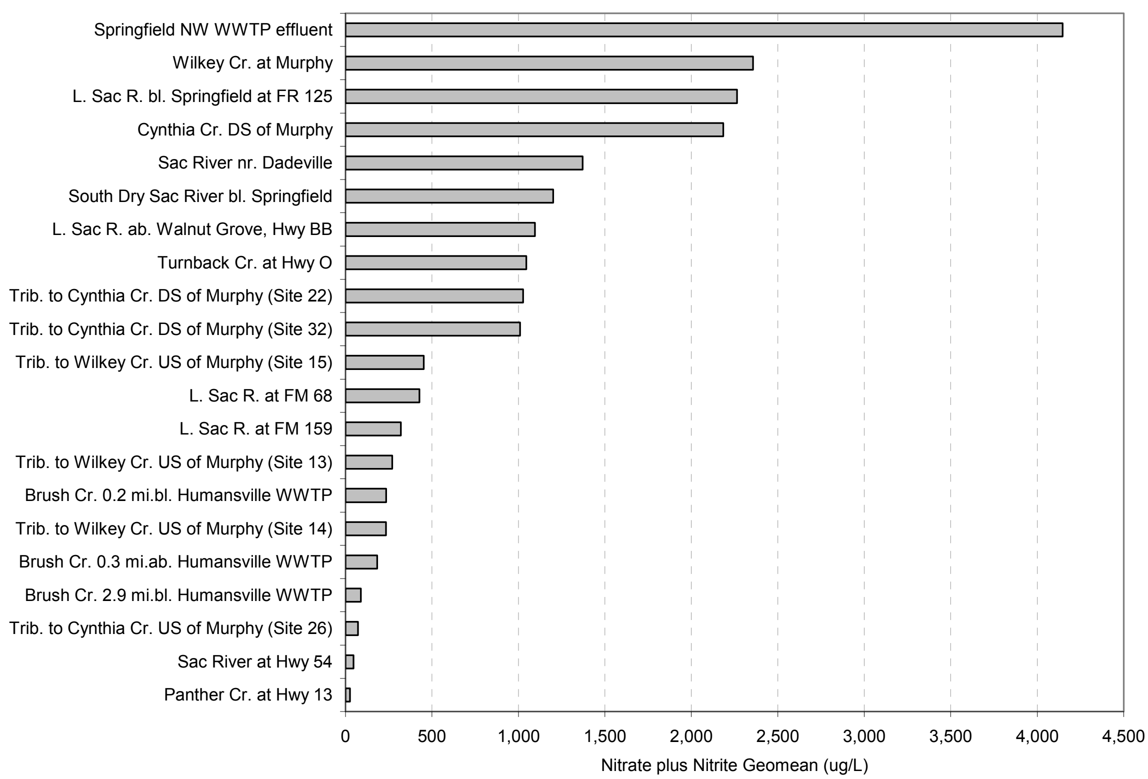

FIGURE 28. Nitrite plus Nitrate Nitrogen Geometric Means in the Sac River Basin (4/14/1993 – 7/21/2005)

The concept of nutrient limitation is considered key to understanding eutrophic systems. According to Leibig's Law of Minimum the least available element or nutrient relative to a primary producer's requirements limits its growth. Under reasonable growth conditions, algae have relatively well defined elemental and nutrient requirements. As algae grow, these organisms take up nutrients from the water in proportion to these requirements. A comparison of nutrient levels in water to algal cell stoichiometry is one method to determine the limiting nutrient. Typically, mass TN:TP ratios less than 10 are considered nitrogen-limiting and TN:TP ratios greater than 20 are considered phosphorus-limiting (Smith *et al.*, 1999).

Although TN:TP ratios offer a "firstcut" at identifying the growth limitation factor, Michaelis-Menton kinetics suggest nutrients do not always limit algal growth. The Michaelis-Menton model suggests that at high nutrient concentrations, the algal growth rate is independent of the available nutrient supply. At nutrient levels approximately 5 times the half-saturation constant (k_s) (i.e., the nutrient concentration at which the algal growth rate is one-half its maximum value) algal growth is no longer limited by nutrients and becomes constant. At such high nutrient concentrations other factors such as light limit algal growth (Chapra, 1997). Literature values of k_s constants for phosphorus and nitrogen vary widely. However, EPA suggests typical k_s constants for phosphorus range from 0.5-30 µg/L and that the k_s constant for nitrogen is 25 µg/L (EPA, 1985).

TN:TP ratio calculations were limited to those stations with TN and TP data available from the same dates, since TN:TP ratios were calculated by site and date. TN:TP ratios were then averaged over all dates by site. In order to provide a more thorough analysis of TN:TP ratios in the Sac River Basin, sample counts less than 10 were included. TN:TP ratios are presented in Table 10.

An analysis of TN:TP ratios suggests the limiting nutrient varies throughout the Sac River Basin, if nutrients are in fact limiting. Downstream of the Humansville WWTF in Brush Creek the limiting nutrient appears to be nitrogen where the TN:TP ratio is 4.8 (Table 10). Since nitrogen and phosphorus appear to be co-limiting upstream of the Humansville WWTF, the Humansville WWTF may be a significant phosphorous loading source. The Little Sac River above Walnut Grove and the Sac River near Dadeville appear to be phosphorus limited. However, both of these stations have relatively high levels of phosphorus and nitrogen as discussed previously. Panther Creek at Highway 13 and the Sac River at Highway 54 have TN:TP ratios indicating co-limiting nutrients. These two stations have relatively low nitrogen and phosphorus levels, suggesting they may be representative of natural background conditions.

An analysis of Michaelis-Menton kinetics suggests nutrients may be the limiting growth factor in some streams but is not in others. Although TN:TP ratios suggest Brush Creek below the Humansville WWTF may be nitrogen limited, both phosphorus and nitrogen geomeans exceed 5 times their k_s value. Therefore, conditions in Brush Creek below the Humansville WWTF do not appear nutrient limited and may potentially be eutrophic. Michaelis-Menton kinetics appear to confirm that conditions in the Little Sac River above Walnut Grove and the Sac River near Dadeville are phosphorus limited. At these locations the nitrogen geomean exceeds 5 times their k_s value; however, phosphorus geomeans do not. Panther Creek and the Sac River at Highway 54 are well below five times the k_s values for phosphorus and nitrogen, further suggesting these locations may be representative of natural background conditions.

TABLE 10. TN:TP Ratios for Monitoring Sites in the Sac River Basin

Site Number	Station Name	TN:TP (Average)	Count	Period of Record
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	28.2	78	11/30/1993-9/13/2004
1372/0.3	Brush Cr. 0.3 mi.ab. Humansville WWTP	13.8	8	7/5/2005-7/21/2005
1371/3.8	Brush Cr. 0.2 mi.bl. Humansville WWTP	4.8	9	7/5/2005-7/21/2005
1371/1.1	Brush Cr. 2.9 mi.bl. Humansville WWTP	9.0	8	7/5/2005-7/21/2005
1373/0.9	Panther Cr. at Hwy 13	9.7	8	7/5/2005-7/21/2005
6918440	Sac River nr. Dadeville	24.2	15	4/14/1993-8/27/2002
1343/9.2	Sac River at Hwy 54	10.0	2	8/10/1999-7/29/2002

4.1.4 Algal Biomass

Limnologists consider chlorophyll *a* to be an early indicator response variable to excessive nutrient loading. Chlorophyll *a* is a photosynthetic pigment found in periphyton (i.e., benthic algae) and phytoplankton (i.e., sestonic algae) and may be used as a measure of algal biomass. Excessive levels of chlorophyll *a* may indicate the presence of cultural eutrophication (EPA 2000b; Smith *et al.*, 1999). However, factors other than nutrients can govern chlorophyll *a* concentrations, such as light intensity and invertebrate grazing (Hessen *et al.*, 2002).

Although no criterion currently exists for chlorophyll *a*, suggested benchmarks for sestonic (i.e., in the water column) and benthic (i.e., attached to substrate) algae are available. Dodds *et al.* (1998) suggested that the mesotrophic and eutrophic boundaries are represented by sestonic chlorophyll *a* concentrations of 10 and 30 μg/L, respectively. EPA Region 7 RTAG has recommended in draft that sestonic chlorophyll *a* values not exceed 8.0 μg/L for all streams in Region 7 states. The Dodds *et al.* (1998) suggested mesotrophic and eutrophic boundaries for benthic chlorophyll *a* are 20 and 70 milligrams per square meter (mg/m^2), respectively. EPA Region 7 RTAG has recommended in draft that benthic chlorophyll *a* concentrations not exceed 40 mg/m^2 for all Region 7 states (email correspondence with Gary Welker – EPA Region 7 Nutrient Regional Coordinator – 2/20/2007).

Sestonic chlorophyll *a* data were only available from two stations in the Little Sac River (Figure 29). The chlorophyll *a* geomean concentrations at these two sites ranged from 2.6 to 3.5 μg/L (Table 11 and Figure 30), which are below the EPA Region 7 RTAG draft stream level of 8.0 μg/L. No benthic algae data were available for the Sac River Basin. The relatively low sestonic chlorophyll *a* levels observed at these two sites may be explained by the relatively low phosphorus and nitrate levels also found at these sites (see Tables 7 and 9).

TABLE 11. Selected Statistics for the Sac River Basin - Sestonic Chlorophyll *a*

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (µg/L)	Mean (µg/L)	Geomean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Std.Dev. (µg/L)	Percentiles 10th (µg/L)	Percentiles 25th (µg/L)	Percentiles 75th (µg/L)	Percentiles 90th (µg/L)
1388/0.3	L. Sac R. at FM 68	1/28/2004	5/2/2005	45	2.1	4.6	2.6	1.0	45.0	9.4	1.2	1.2	4.6	9.7
1388/0.8	L. Sac R. at FM 159	1/28/2004	5/2/2005	45	2.3	6.7	3.5	1.0	45.0	11.1	1.2	1.2	8.2	28.1

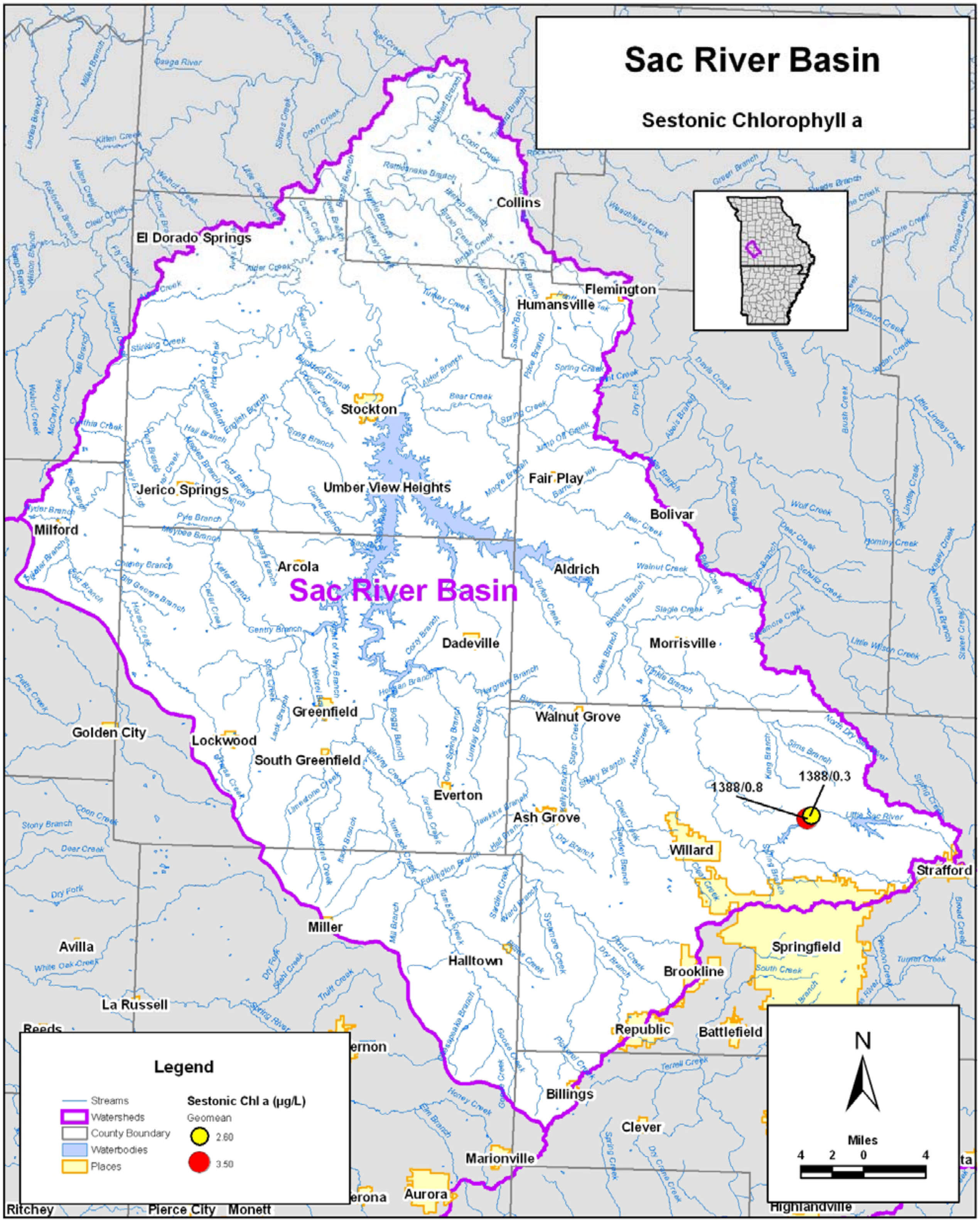

FIGURE 29. Sestonic Chlorophyll *a* Geometric Means at Select Stations in the Sac River Basin

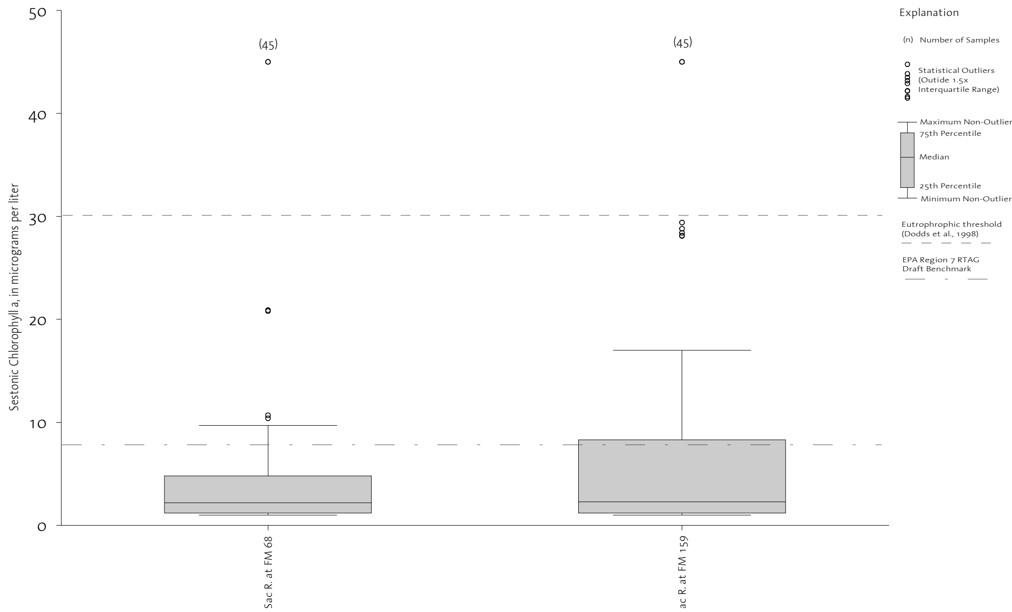

FIGURE 30. Box Plot of Sestonic Chlorophyll *a* in the Sac River Basin (January 28, 2004 to May 2, 2005) Compared to Eutrophication Threshold and EPA Region 7 RTAG Draft Benchmark

4.2 Bacteria

Historically, fecal coliform have been used as indicator organisms for evaluating the microbiological suitability of recreation waters. Only recently has *E. coli* been included in Missouri's water quality standards. Although *E. coli* are generally not harmful, their presence in water is considered by EPA to be a better indicator of pathenogenic contamination than fecal coliform. The EPA conducted a series of epidemiological studies that examined the relationship between swimming-associated illnesses and the microbiological quality of the waters used by recreational bathers, prior to releasing its recommended criteria in 1986 (EPA, 2003b). Based on these EPA studies, the MDNR developed *E. coli* criteria for Missouri's recreational waters. The MDNR designated *E. coli* whole body contact recreation (WBCR) criteria of 126 cfu/100 mL and 548 cfu/100 mL for Category A and B waters[6], respectively. The MDNR fecal coliform criterion is set at 200 cfu/100 mL for WBCR Category A waters. Fecal coliform has no Category B criterion. The *E. coli* and fecal coliform water quality criteria are expressed as a recreational season (April 1 – October 31) geomean. Fecal coliform criteria are set to be phased out of Missouri's water quality standards by January 1, 2009. With the exception of the upper reaches, most of the Sac River, Little Sac River, Turnback Creek, and Cedar Creek have Category A whole body contact use designations. The remaining classified streams in the Sac River Basin are designated for Category B whole body contact recreation (Carnahan, 2005). Although, bacteria criteria apply only to the recreational season, the analysis presented below is based on data collected year round.

[6] Category A applies to those water segments that have been established by the property owner as public swimming areas allowing full and free access by the public for swimming purposes and waters with existing whole body contact recreational use(s). Category B applies to waters designated for whole body contact recreation not contained in Category A.

The primary purpose of this bacteria summary is to provide a general analysis of available data and not to analyze for compliance with water quality standards.

Annual fecal coliform geomean concentrations were analyzed for the Walnut Grove station for any temporal trends. *E. coli* was not analyzed for temporal trends due to its relatively short period of record. No apparent trend appears for fecal coliform levels at the Walnut Grove station (Figure 31). The available fecal coliform period of record for the Walnut Grove station spanned from 1983 to 2004; however, no fecal coliform data were available for 1987, 1991-1992, and 1997-1998.

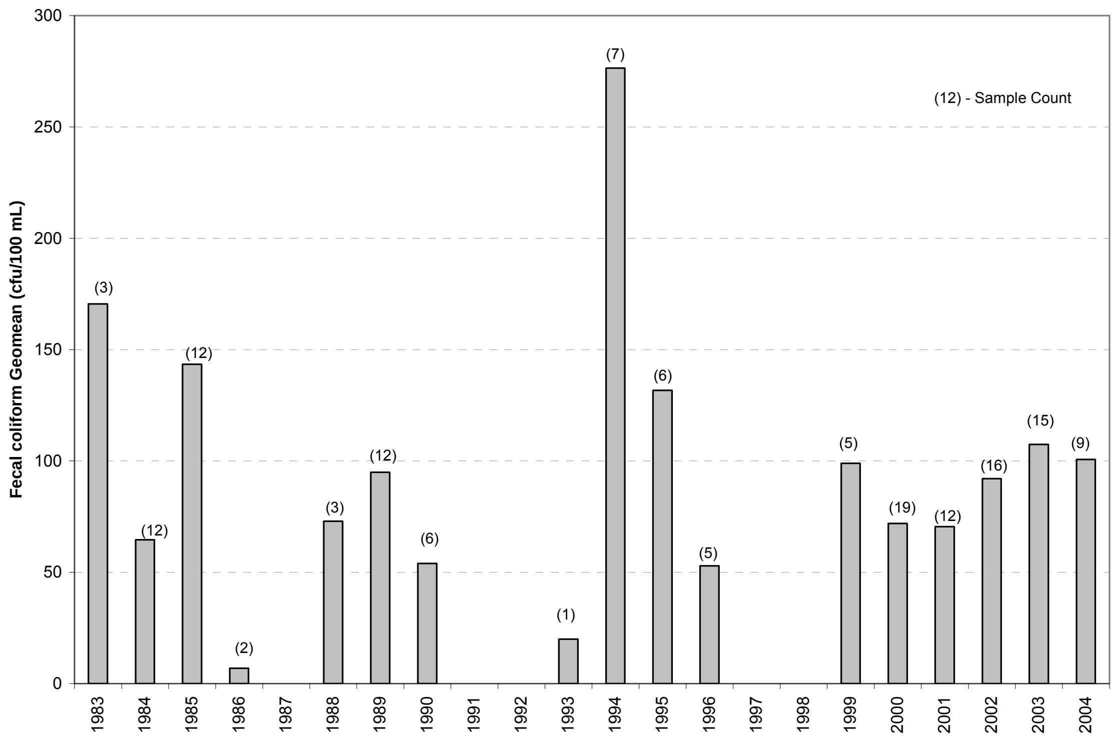

FIGURE 31. Fecal coliform Annual Geometric Means Measured in the Little Sac River above Walnut Grove Station

Bacteria data within the Sac River Basin are limited to water quality stations on the Little Sac River, which has been 303(d) listed as impaired for bacteria by the MDNR (Figures 32 and 33). The *E. coli* data show relatively low concentrations (i.e., less than WBCR-A *E. coli* criterion of 126 cfu/100 mL) upstream of McDaniel Lake and above Walnut Grove (Table 12 and Figure 34). However, fecal coliform data 1 mile below the Springfield Northwest WWTF and near Morrisville appear elevated (i.e., greater than the WBCR-A fecal coliform criterion of 200 cfu/100 mL) (Table 13 and Figure 35). The fecal coliform geomean increases from 137 to 478 cfu/100 mL from upstream to 1 mile downstream of the Springfield Northwest WWTF. Effluent from the WWTF has a geomean of only 48 cfu/100 mL suggesting the WWTF is not causing the increase in fecal coliform levels. The presence of cattle and septic tanks downstream of the WWTF may explain this increase.

A recently completed TMDL on the Little Sac River suggests bacterial sources are varied and difficult to pinpoint. Relative contributions from various sources may depend on precipitation and flow conditions. During baseflow conditions bacteria loadings may be dominated by springs located in the upper part of the watershed or from direct inputs such as cattle in the stream and illegal discharges. Urban runoff, particularly from the Pea Ridge Creek watershed, and contributions from geese and livestock may dominate bacteria loadings during times of high precipitation and flow (Baffaut, 2006).

TABLE 12. Selected Statistics for the Sac River Basin - *E. coli*

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (cfu/100mL)	Geomean (cfu/100mL)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Std.Dev. (cfu/100mL)	Percentiles 10th (cfu/100mL)	25th (cfu/100mL)	75th (cfu/100mL)	90th (cfu/100mL)
1388/0.3	L. Sac R. at FM 68	5/3/2004	3/27/2006	72	103	104	12	1,300	229	40	60	163	272
1388/0.8	L. Sac R. at FM 159	5/3/2004	3/27/2006	73	76	70	1	1,554	239	13	34	140	242
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	10/4/1999	9/13/2004	62	57	42	1	1,500	223	3	19	130	179

TABLE 13. Selected Statistics for the Sac River Basin – Fecal coliform

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (cfu/100mL)	Geomean (cfu/100mL)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Std.Dev. (cfu/100mL)	Percentiles 10th (cfu/100mL)	25th (cfu/100mL)	75th (cfu/100mL)	90th (cfu/100mL)
1381/33.4	L. Sac R. ab. Spfd. NW WWTP	5/16/2000	1/29/2004	28	145	137	4	2,195	519	27	100	278	527
1381/33.3	Springfield NW WWTP effluent	1/24/2000	9/30/2003	16	42	48	4	4,100	1,342	5	6	81	1,150
1381/32.3	L. Sac R. 1 mi.bl. Spfd NW WWTP at FR 125	12/15/2003	10/26/2004	37	390	478	37	14,800	3,528	114	260	850	2,380
1381/28.3	L. Sac R. 5 mi.bl. Spfd. WWTP	5/16/2000	9/30/2003	12	189	158	12	420	128	64	107	223	410
6918550	L. Sac R. ab. Walnut Grove, Hwy BB	10/4/1999	9/13/2004	74	120	87	2	1,600	280	14	34	200	282
6918740	Little Sac River nr. Morrisville	1/25/2000	10/26/2004	51	240	269	11	8,000	1,719	63	136	475	1,732

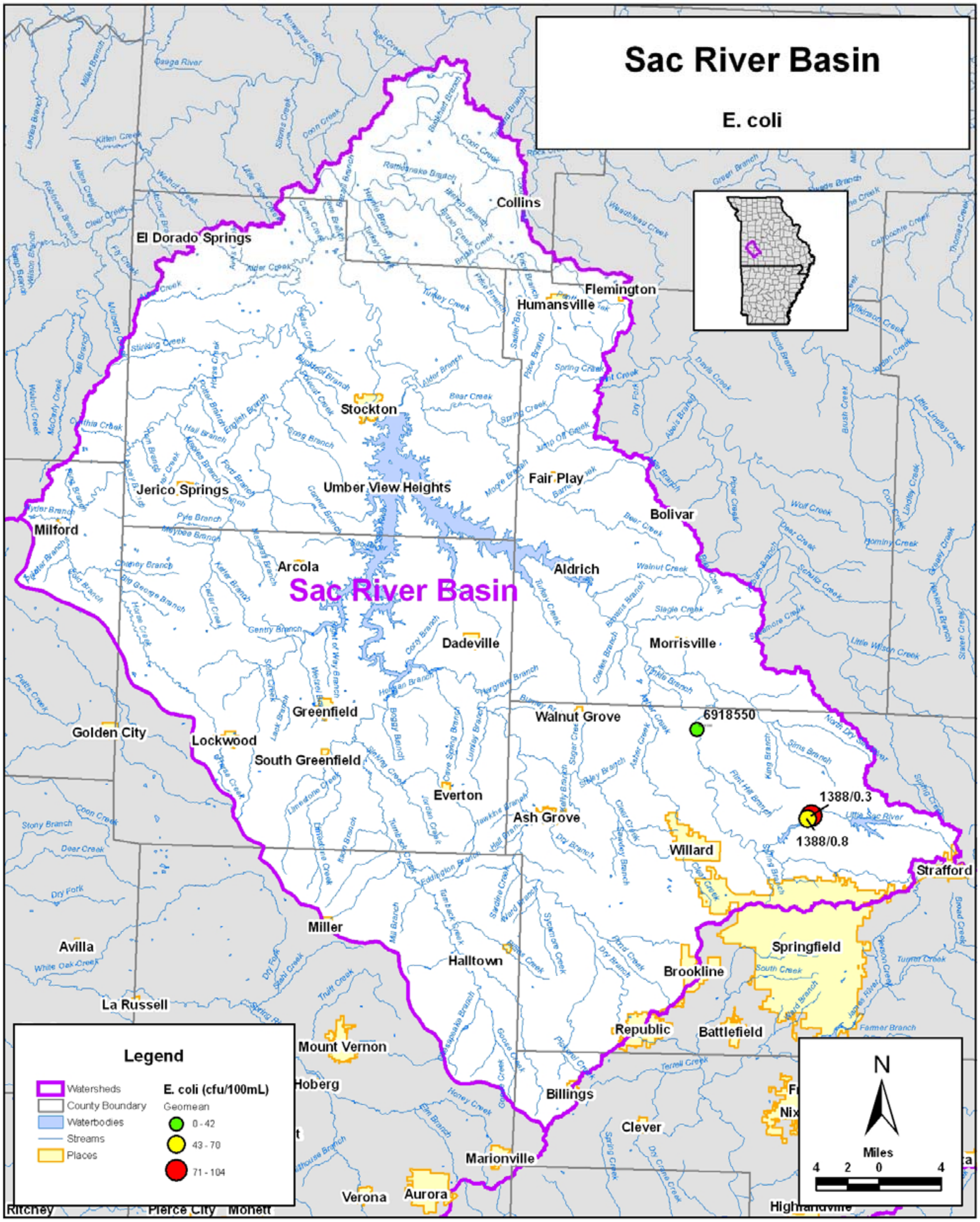

FIGURE 32. *E. coli* Geometric Means at Select Stations in the Sac River Basin

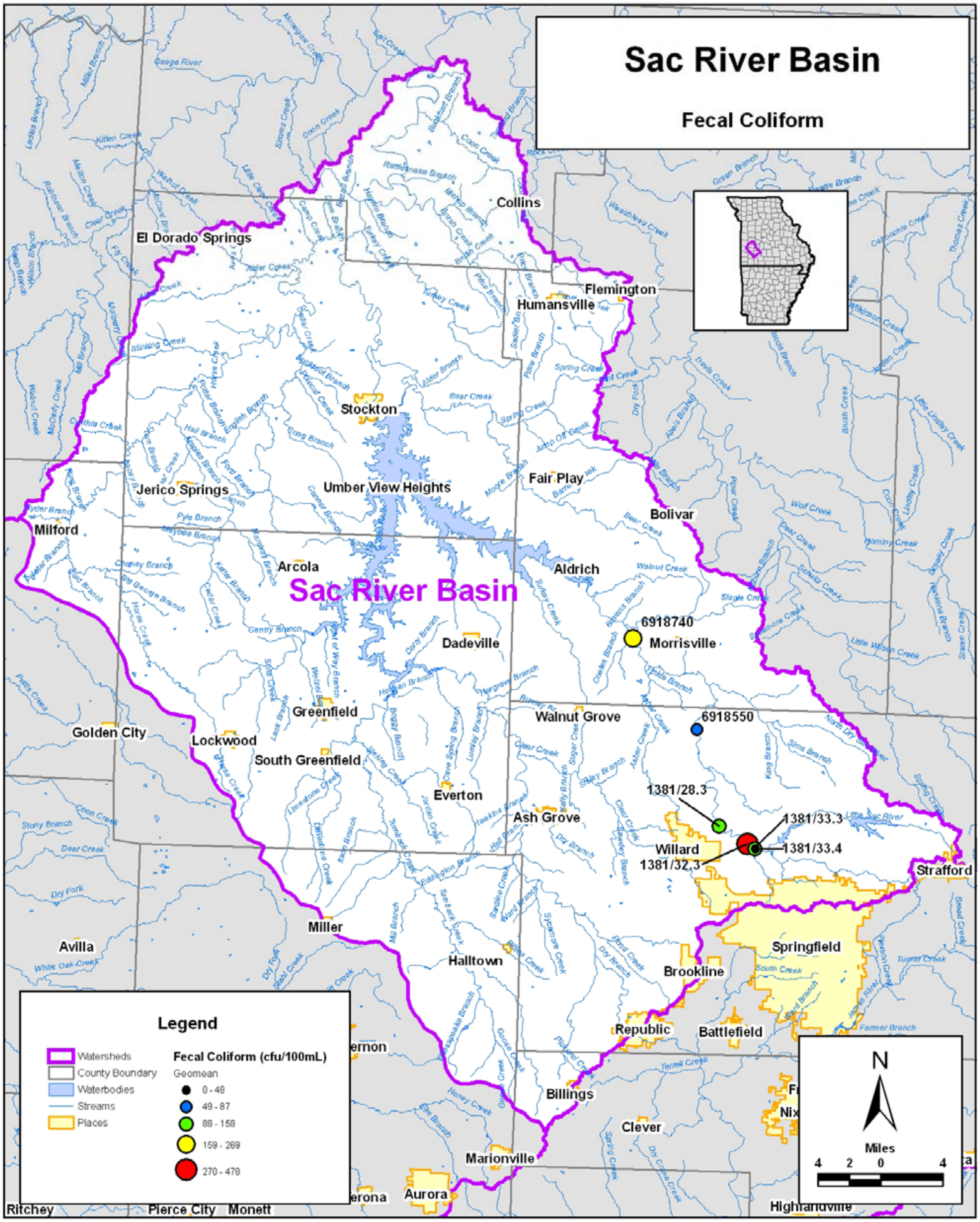

FIGURE 33. Fecal coliform Geometric Means at Select Stations in the Sac River Basin

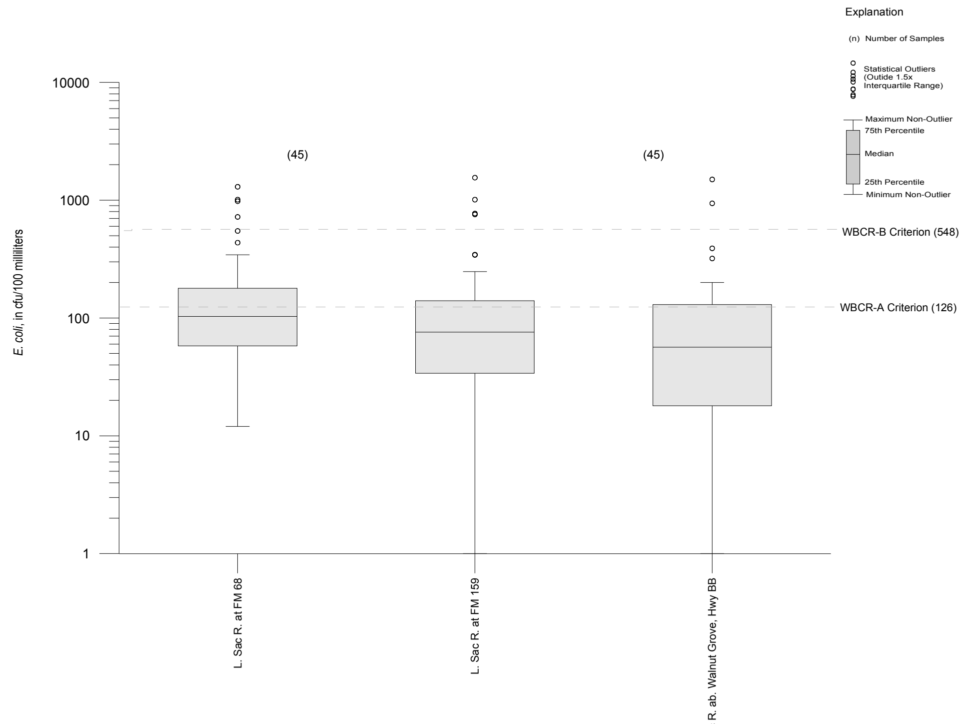

FIGURE 34. Box Plot of *E. coli* in the Sac River Basin (October 4, 1999 to October 26, 2006) Compared to Whole Body Contact Recreational Use Criteria

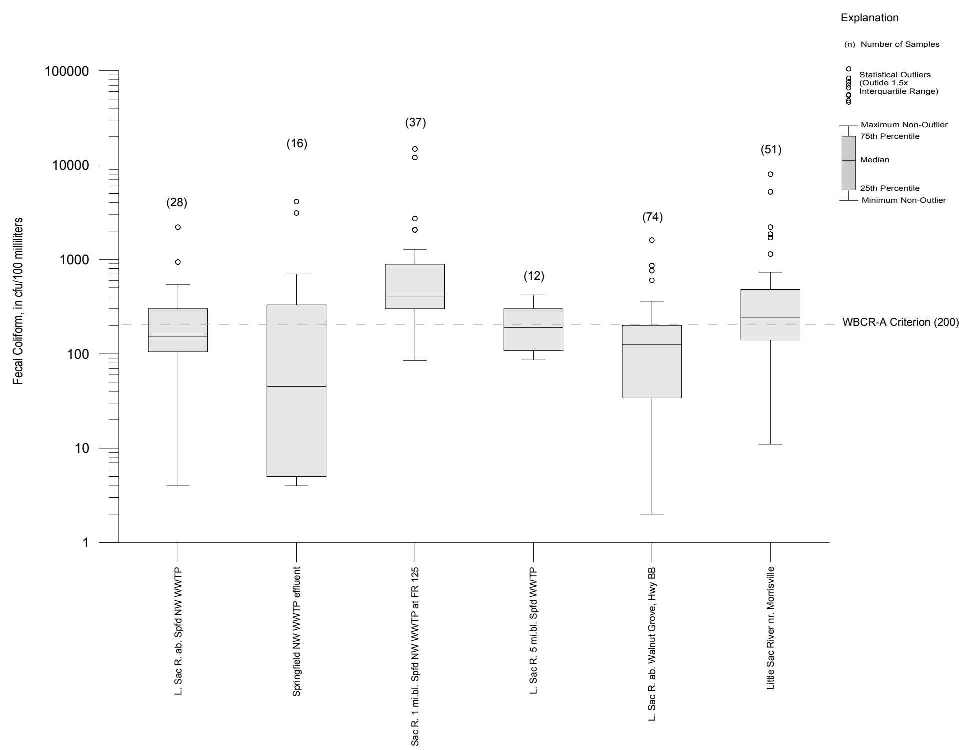

FIGURE 35. Box Plot of Fecal coliform in the Sac River Basin (October 4, 1999 to March 27, 2006) Compared to Whole Body Contact Recreational Use Criteria

5. BIOLOGICAL MONITORING

Various biological (fish and macroinvertebrate) studies have been conducted in the Sac River Basin since at least the 1940s. Recent notable monitoring efforts in the Sac River Basin include fish collections made by the Missouri Department of Conservation's (MDC) Southwest Regional staff during the later 1990s, a macroinvertebrate study by Randy Sarver of the MDNR during the mid 1990s (Horton and Hutson, n.d.), and ongoing studies as part of Missouri's overall aquatic biological assessment program.

Eighty-nine species of fish have been identified in the Sac River Basin, but fifteen of these species have not been collected since 1983 (Horton and Hutson, n.d.). The ghost shiner, bluestripe darter, gilt darter, least darter, and blacknose shiner are believed to be extirpated from the basin. Population declines are thought to be a result of habitat loss (Pflieger, 1997, as cited in Horton and Hutson, n.d.). Other missing species are not necessarily absent or in decline in the Sac River Basin. The absence of some larger fish from recent collections (e.g., longnose gar, mooneye, gravel chub, spotted sucker, river redhorse, and Ozark bass) may simply be a result of the sampling method. These larger fish commonly avoid seine hauls, which was the primary sampling method of recent collections. The absence of chestnut and southern brook lampreys from recent sampling efforts may be due to their short adult life spans and difficulty in collecting (Horton and Hutson, n.d.).

The Niangua darter, a federally threatened species, is considered evidence of good water quality and healthy, diverse plant and animal communities. The Niangua darter has been found in the Little Sac River, Bear Creek, and Brush Creek watersheds. However, for many years the Brush Creek population of Niangua darters was believed to be extirpated. In 1997 MDC found 10 young-of-the-year and several adult Niangua darters at a conservation area in Brush Creek, suggesting a viable and reproducing population. MDC attributes the success of the Niangua darter to cooperative efforts with private landowners to manage stream-side property for better water quality and fish habitat (MDC, 1997).

Macroinvertebrate assemblages represent another measure of water quality. They are a good indicator of stream health since they have limited migration patterns and represent a broad range of pollution tolerances. Several metrics are used to assess macroinvertebrates; however, one of the more common ones is the Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa index. The EPT taxa represent the majority of pollutant intolerant species. Generally, declining or low counts of EPT taxa are indicative of stream perturbation (Barbour *et al.*, 1999).

Extensive aquatic macroinvertebrate studies were conducted by the MDNR at multiple sites on the Little Sac River, Clear Creek, Turnback Creek, Brush Creek, and Bear Creek in 1995 and 1996. Over twice the number of EPT taxa were collected from Clear Creek, Turnback Creek, and Brush Creek than from the Little Sac River or Bear Creek (Table 14). The count of Plecoptera in the Little Sac River and Bear Creek were also particularly low (i.e., zero and two, respectively). These EPT taxa counts may suggest that the Little Sac

River and Bear Creek have some perturbation issues. However, this represents only a cursory analysis based on summary data provided by MDC (n.d.). The MDC (n.d.) data provided no indication of taxa richness and did not account for seasonality.

TABLE 14. EPT Taxa Counts from the 1995-1996 Sac River Basin Macroinvertebrate Study

Sample Site	Macroinvertebate Order			Sum
	Ephemeroptera	Plecoptera	Trichoptera	
Little Sac River	15	0	3	18
Clear Creek	25	13	17	55
Turnback Creek	27	12	20	59
Brush Creek	26	13	24	63
Bear Creek	15	2	8	25

Notes:

Little Sac River samples collected from two sites on April 2-3, 1996 and September 19, 1996.

Clear Creek samples collected from two sites on April 3, 1996 and September 18, 1996.

Turnback Creek samples collected from two sites on April 4, 1996 and September 18, 1996.

Brush Creek samples collected from four sites on March 30-31, 1995 and six sites on

Bear Creek samples collected from three sites on September 20-21, 1995.

Source: Randy Sarver of the MDNR as cited at http://mdc.mo.gov/fish/watershed/sac/biotic/340bct22.htm.

Ongoing and future monitoring activities in the Sac River Basin are scheduled as part of Missouri's overall aquatic biological assessment program, which is a multi-agency collaborative effort between the MDC, MDNR, the University of Missouri-Columbia, and the EPA. MDC's Resource Assessment and Monitoring (RAM) Program and MDNR's biological criteria development program are two key components to this collaborative effort (EPA, 2002).

The MDC RAM Program includes a combination of targeted reference sites and randomly selected sites. The RAM Program is responsible for sampling fish and macroinvertebrates along with performing physical habitat assessments. The MDNR is responsible for sampling macroinvertebrates at 30% of the sites. The program operates on a five year cycle with statewide random sites collected for one year and random sites in priority watersheds collected for four years (EPA, 2002). Within the Sac River Basin there are eight RAM sites that have been surveyed from 1994 to 2002 which are identified in Figure 36.

The MDNR biological criteria development program began in 1992 as an approach for defining impaired waters. Development of biological criteria requires extensive sampling at multiple reference sites throughout the state. The MDNR has identified 63 biocriteria reference streams, which represent some the least impacted streams in the state. Three of these biocriteria reference streams are located within the Sac River Basin: Cedar Creek, Horse Creek, and Turnback Creek (Figure 36).

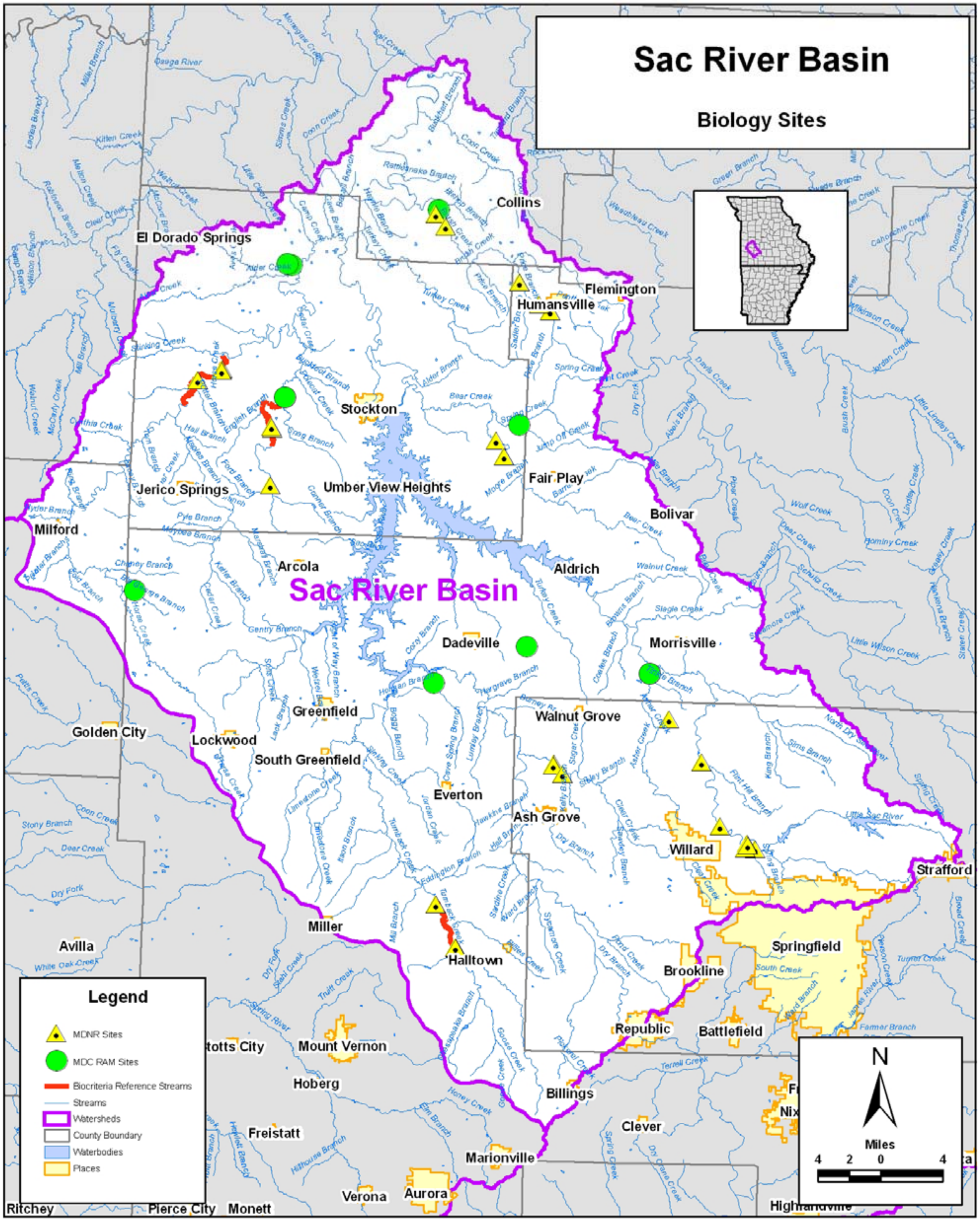

FIGURE 36. Biological Monitoring Sites in the Sac River Basin

6. DATA GAPS

A data gap is defined here as a lack of information necessary to meet the goals of the WQIP. Within the Spring River Basin water quality data have been collected by various agencies for various purposes. However, the existing ambient data does not necessarily provide the information needed to address the broader goals of water quality researchers, managers and policy makers, or the WQIP. The information needs of the WQIP are defined by the following goals:

- Characterize regional background or reference water quality conditions;
- Characterize regional and seasonal water quality and flow variations and their underlying processes;
- Assess regional and temporal trends in water quality;
- Characterize the impacts of point and non-point source discharges on water quality; and
- Provide water quality information to:
    - Better understand the effects of land uses and use changes on water quality,
    - Measure effectiveness of watershed management programs,
    - Support development of management strategies to return impaired waters to compliance with water quality standards.

This section of the report identifies data deficiencies, or data gaps, for meeting the goals of the WQIP within the Sac River Basin. Data gap issues discussed below include spatial gaps, temporal gaps, parameter gaps, detection limit gaps, metadata gaps, and unincorporated data. The data gap analyses presented below primarily address the issues of excessive nutrients and bacteria. It should be noted that although this parameter gap analysis is limited to the 25 selected sampling stations, it is not limited to the periods of record or minimum sample sizes used in the data analysis section.

6.1 Spatial Gaps

Based on the information needs of the WQIP described above, the water quality monitoring network in the Sac River Basin should be extensive consisting of both baseline and impact stations. Baseline stations account for natural or near-natural effects and trends and are located where there are likely minimal effects of point or non-point sources. These provide information regarding regional background or reference water quality conditions, provide a baseline for monitoring watershed management programs, and are located to monitor effects of land use changes. Impact stations are located downstream of present, and possible future, pollution sources. Multiple potential pollution sources exist throughout the entire basin (e.g., improperly functioning septic systems, urban runoff, agricultural runoff, abandoned mines, and wastewater treatment facilities).

The distribution of existing sampling stations in the Sac River Basin is insufficient to address the goals of the WQIP. Water quality data in the Sac River Basin was compiled from 25 sampling stations (see Figure 10 in Section 3.1). The greatest concentration of stations appears in the upper Little Sac River, Brush Creek, and in the Horse Creek watersheds (Table 16). The majority of watersheds within the Sac River Basin lack the water quality data to sufficiently characterize baseline conditions or potential pollutant sources. The goals of the WQIP are very broad and most sampling efforts to date appear to address only a few localized issues.

TABLE 15. Count of Monitoring Stations in Watersheds of the Sac River Basin

Watershed	Water Quality Monitoring Stations[1]
Little Sac River	10
Turnback Creek	1
Sons Creek	0
Bear Creek	0
Cedar Creek[2]	0
Horse Creek	8
Turkey Creek	0
Brush Creek	4
Sac River[3]	2

Notes:

[1] Stations are limited to those with parameters of interest and that are identified in Section 3.

[2] Excluding the Horse Creek subwatershed

[3] Stations are limited to those in the Sac River (i.e., not the entire Sac River watershed)

Although no Cedar Creek data were available for this report, it should be noted that significant data collection efforts were conducted in Cedar Creek during the summer of 2006 as part of ERC's Ecological and Water Resources Assessment Project (EWRAP). Data collected in Cedar Creek included dissolved oxygen, nutrients, benthic and sestonic algae, and BOD.

Determining the appropriate distribution for sample stations for the various goals of the WQIP is complex. Although not explicitly stated, an overall goal of the WQIP is to detect, isolate and identify sources of pollution. Stream ordering is an effective procedure for addressing this goal. This procedure effectively defines a water quality network with equal spatial coverage of the basin's water quality. Such an approach potentially necessitates a large number of sample stations. Addressing some of the more specific goals (e.g., assessing trends and management strategies) potentially requires fewer more targeted sample stations, but also requires greater knowledge of water quality conditions and pollutant sources. Designing a robust monitoring network may require a systematic approach to first better identify issues to help target long-term sampling locations.

Although the Sac River Basin is not fully characterized for water quality, several issues are known to exist and should be considered as part of an overall monitoring strategy. Areas with well documented water quality issues are listed below.

- Little Sac Watershed
    - 303(d) listed for bacteria

    - Nonpoint pollution sources (e.g., septic tanks and urban runoff)
    - Fulbright/Sac River landfills

- Horse Creek Watershed
    - Murphy Farms/high density of CAFOs

- Stockton Branch
    - VSSs downstream of Stockton's WWTF

- Brush Creek
    - 303(d) listed for low dissolved oxygen
    - Humansville WWTF

However, this list is not meant to imply that other areas do not require monitoring. As discussed above, further monitoring is needed throughout the basin to better target other potential loading sources.

6.2 Temporal Gaps

Temporal gaps refer to water quality data characterized by a period of record or sampling frequency insufficient for purposes of addressing information needs. The information needs of the WQIP goals potentially require long-term monitoring, short-term intensive studies, seasonal data and potential storm event sampling. Temporal characteristics of sampling stations in the Sac River Basin are discussed below.

There is a lack of long-term monitoring data within the Sac River Basin. Long-term monitoring data could help address any of the WQIP goals; however, it is most critical for addressing regional and temporal trends. The only clear long-term monitoring station is the Little Sac River above Walnut Grove, which has data dating back to 1983 (Figure 37). A small number of other stations also have data from the 1980s and early 1990s, but were collected too infrequently to clearly depict any trends. Several stations along the Little Sac River have the potential to produce valuable long-term monitoring data if monitoring efforts continue on a more regular and frequent basis. However, it is unclear whether these monitoring efforts in the Little Sac River are continuing or have ceased. Regardless, long-term monitoring data is lacking throughout most all watersheds within the basin.

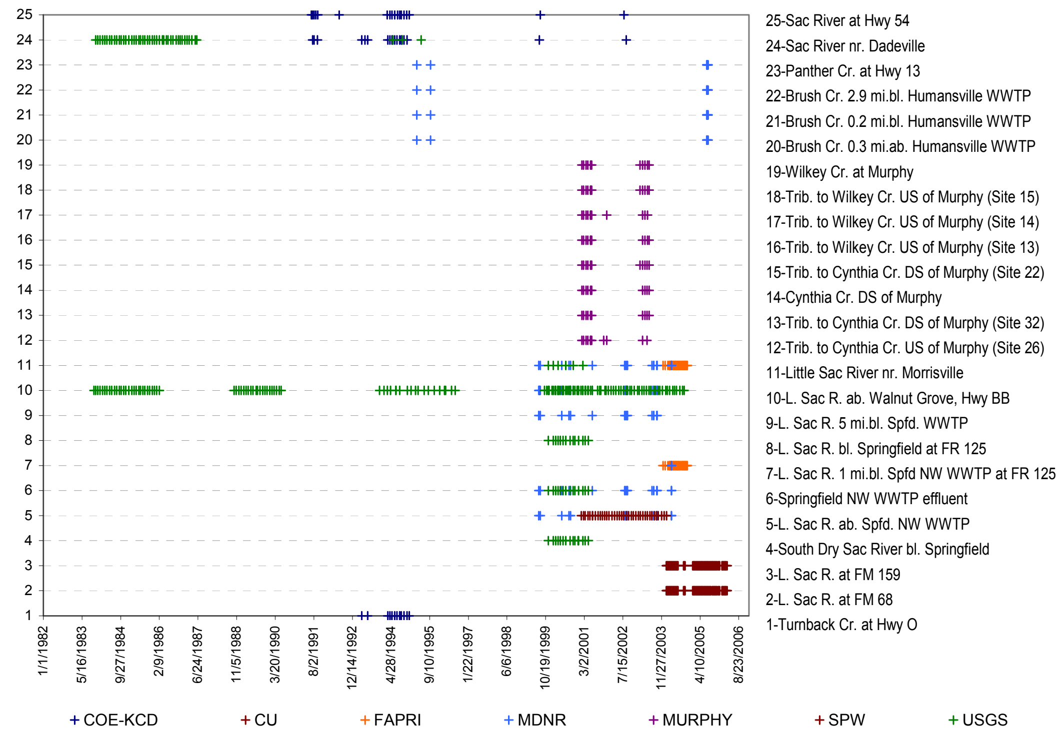

FIGURE 37. Monitoring Visits by Collection Entity from 1982 to 2006

Many of the WQIP goals do not necessarily require long-term data but may be addressed by short-term studies. Short-term studies are defined here as generally less than a season but may be repeated over multiple years. They can be effective for characterizing reference conditions or impacts from pollutant sources. Available data suggest short-term studies have been conducted in the Horse Creek watershed, in Brush Creek, in Turnback Creek and in the Little Sac River watershed (Figure 37). However, more short-term studies are needed to better understand existing loading sources and reference conditions throughout the basin.

The observed sampling frequency in the Sac River Basin varies by site and collection entity, but generally appears suitable for the information goals of the WQIP (note that this statement only refers to sampling frequency and does not address other factors such as duration, season, consistency, or spatial coverage). Although determining sampling frequency is typically based on the judgment of the monitoring system designer, some general rules do apply. Typically smaller streams with greater maximum to minimum flow ratios require sampling at a greater frequency than larger rivers. Tighter sampling frequencies (i.e., at least once a week) may also be called for during short-term intensive surveys, or for monitoring bacteria levels at known recreational areas. Monthly sampling, however, is considered adequate for characterizing water quality over a long time period. With the exception of some noticeable monitoring gaps (i.e., several months or greater) most sites appeared to have been monitored at least monthly.

Analysis of non-point issues may require special storm event studies. Sites sampled at a consistent frequency over a sufficiently long period of time should yield a representative set of storm water runoff samples. However, as previously discussed there is little long-term data within the Sac River Basin. Furthermore, it is unclear which water quality samples in the WQIP database were taken during runoff conditions. Only the USGS water quality samples are specifically attributed for runoff conditions. USGS samples represent only a fraction of the available water quality data. Furthermore, the available water quality data represents only a fraction of the basin. Therefore, special storm event studies are necessary to characterize non-point issues.

The temporal analysis of sampling frequency presented in Figure 37 also suggests opportunities exist for different collection entities to work collaboratively. It appears that sampling schedules are overlapping in some instances. Different agencies are sampling some of the same streams at the same time for different purposes. With some coordination and sharing of duties, sampling efforts may be able to be reduced.

6.3 Parameter Gaps

A parameter gap is a dataset characterized by missing or inappropriate water quality variables to address the issues of interest. Water quality data compiled for the WQIP were collected for a variety of interests, which do not necessarily address the issues of excessive nutrients and bacteria (i.e., the primary issues identified by the WQIP workgroup). Although numerous parameters could conceivably be measured to address these issues, this parameter gap analysis is limited to TP, TN, $NO_3 + NO_2$, chlorophyll *a*, *E. coli*, and flow.

Nutrient sample coverage is limited to a small number of areas within the Sac River Basin. Even within the already limited number of monitoring stations in the Sac River Basin, nutrient data are only available from a select number of stations. TP data are available for sample stations in the Little Sac River and Brush Creek watersheds plus two sites on the Sac River and one site on Turnback Creek. $NO_3 + NO_2$ data are available from the same sample stations plus sites located within a subwatershed of Horse Creek. TN data are limited to one site on the Sac River and one site on the Little Sac River. The limited number of nutrient sample stations means the Sac River Basin is largely uncharacterized for nutrients.

Chlorophyll *a* data are lacking from the Sac River Basin. Although excessive algal growth is the primary concern with excessive nutrification, chlorophyll *a* data (i.e., a measure of algal growth) are considerably more limited than nutrient data. Suspended chlorophyll *a* data are primarily available from a few sites on the Little Sac River. It is also available from four sites in the Brush Creek watershed and one site on the Sac River, but is extremely limited in sample size at these locations (i.e., sample counts range from one to five). No benthic algae data were found for the Sac River Basin.

Bacteria data (i.e., *E. coli* or fecal coliform) are primarily only available for the Little Sac River, which is 303(d) listed for bacteria. Whereas bacteria data are available for nine stations in and on (i.e., Springfield NW WWTF effluent) the Little Sac River, only six other stations have bacteria data. Of these six stations, only one station has more than four bacteria samples; which is located on the Sac River. The other five stations include three sites on Brush Creek, one site on Panther Creek and one site on the South Dry Sac River.

In general there is a need for greater characterization of bacteria in the Sac River Basin, but characterization of *E. coli* is particularly lacking. Although *E. coli* has replaced fecal coliform as the designated indicator organism in Missouri's water quality standards, there is considerably less data for it. Only three sites within the Little Sac River are characterized by at least five *E coli* samples (note that bacteria compliance requires a minimum of five samples to calculate the geometric mean due to its variability). Future bacteria monitoring efforts should focus on collecting *E. coli* data.

Better efforts at characterizing flow conditions during monitoring events are needed in the future. Although flow measurements are important for interpreting water quality data, flows were only recorded during about 50% of the site visits in the Sac River Basin (Table 16). Flow values allow for a more robust analysis of water quality data. For example, periods of high flow are typically associated with stormwater runoff; which can cause increases in nutrient and bacteria levels. Springs and groundwater may be the dominant pollutant sources during low flow conditions. Flow data are also critical for understanding loadings (mass per time). It should be noted, as discussed in Section 2.6, there are seven USGS gaging stations in the Sac River Basin. Potentially discharge data from these USGS gaging stations could be used in analyzing existing ambient water quality data in the Sac River Basin.

Finally, the general lack of parameter characterization found throughout the Sac River Basin may simply be addressed in the future by collecting additional parameters during site visits. Available water quality data to date indicates only a few parameters of interest are sampled for during site visits. An analysis of site visits suggests the most frequently sampled parameter is $NO_3 + NO_2$; however, on average this parameter is only sampled for 76% of the time (Table 16). Although it varies by site, TP on average is only sampled for 46% of the time. TN, bacteria, and chlorophyll *a* are sampled for less than 20% of the time on average. Sampling agencies could better address the goals of the WQIP by collecting multiple parameters during site visits.

TABLE 16. Percent of Time Parameters were Collected During Site Visits

Station Name	Total Visits	TP	TN	NO_3+NO_2	*E. coli*	Fecal coliform	Suspened Chlorophyll *a*	Flow
Turnback Cr. at Hwy O	12	83%	0%	83%	0%	0%	0%	0%
L. Sac R. at FM 68	86	53%	0%	97%	84%	0%	52%	0%
L. Sac R. at FM 159	87	53%	0%	97%	84%	0%	52%	0%
South Dry Sac River bl. Springfield	15	87%	0%	87%	27%	27%	0%	87%
L. Sac R. ab. Spfd. NW WWTP	54	0%	0%	0%	0%	56%	0%	69%
Springfield NW WWTP effluent	31	45%	0%	45%	13%	58%	0%	0%
L. Sac R. 1 mi.bl. Spfd NW WWTP at FR 125	37	0%	0%	0%	0%	100%	0%	0%
L. Sac R. bl. Springfield at FR 125	15	93%	0%	93%	27%	27%	0%	80%
L. Sac R. 5 mi.bl. Spfd. WWTP	14	0%	0%	0%	0%	100%	0%	0%
L. Sac R. ab. Walnut Grove, Hwy BB	158	90%	49%	90%	39%	92%	1%	88%
Little Sac River nr. Morrisville	60	12%	0%	12%	3%	88%	0%	62%
Trib. to Cynthia Cr. US of Murphy (Site 26)	11	9%	0%	91%	0%	0%	0%	82%
Trib. to Cynthia Cr. DS of Murphy (Site 32)	10	10%	0%	100%	0%	0%	0%	100%
Cynthia Cr. DS of Murphy	10	10%	0%	100%	0%	0%	0%	100%
Trib. to Cynthia Cr. DS of Murphy (Site 22)	11	18%	0%	100%	0%	0%	0%	100%
Trib. to Wilkey Cr. US of Murphy (Site 13)	11	9%	0%	91%	0%	0%	0%	64%
Trib. to Wilkey Cr. US of Murphy (Site 14)	11	9%	0%	91%	0%	0%	0%	82%
Trib. to Wilkey Cr. US of Murphy (Site 15)	12	17%	0%	92%	0%	0%	0%	92%
Wilkey Cr. at Murphy	11	18%	0%	100%	0%	0%	0%	100%
Brush Cr. 0.3 mi.ab. Humansville WWTP	12	83%	67%	83%	0%	17%	33%	17%
Brush Cr. 0.2 mi.bl. Humansville WWTP	11	100%	82%	100%	0%	18%	45%	18%
Brush Cr. 2.9 mi.bl. Humansville WWTP	10	100%	80%	100%	0%	20%	40%	20%
Panther Cr. at Hwy 13	14	71%	57%	71%	0%	14%	29%	14%
Sac River nr. Dadeville	65	95%	23%	94%	5%	72%	2%	95%
Sac River at Hwy 54	18	94%	11%	94%	0%	0%	0%	0%
Total of all stations	**786**	**46%**	**15%**	**76%**	**11%**	**28%**	**10%**	**51%**

6.4 Detection Limit Gaps

A detection limit gap is defined here to mean a dataset characterized by insufficient detection levels. Where laboratory detection limits exceed ambient conditions, water quality data are difficult to interpret. Although laboratory methods have fixed detection limits, laboratory methods in some instances may be altered to lower detection limits (e.g., longer path lengths in spectrophotometric tests). The purpose of this analysis is to identify where such laboratory methods may need to be adjusted.

To conduct this detection limit gap analysis, assumptions were made regarding detection limits that were not used for the water quality summary and statistics portion of the report. As previously discussed (see Section 3.2) data sources did not always provide laboratory detection limits. In particular, the MDNR database utilizes a protocol for reporting laboratory non-detects to ease the end use of the data for statistical analysis. Reasonable attempts were made to determine MDNR non-detect values, but only for purposes of this detection limit gap analysis. It also should be noted that some detection limits are presented as "0" by some sources. This does not mean to imply that 0 is the true laboratory detection limit; it only means a laboratory value was identified as a non-detectable, but no detection limit was provided. It should also be noted that this data gap analysis was performed on the entire available period of record, and not on the period of interest selected in Section 3.3.

Phosphorus detection limits generally appear sufficient for characterizing TP levels in the Sac River Basin. Although some phosphorus limits are relatively high (e.g., 50 to 100 µg/L), the percent of samples below the detection limit is generally low (Table 17). Therefore, with the exception of the Murphy sites, the relatively high detection limits likely do not skew the mean concentrations. The sites located in the subwatershed of Horse Creek that were sampled by Murphy do have significant detection limit issues.

Most all sites sampled by Murphy have 100% of there samples below the detection limit of 100 µg/L (note that the eutrophic threshold is often considered to be 75 µg/L). However, the small sample counts (i.e., two or less) suggest Murphy is not continuing to sample these sites.

TABLE 17. Total Phosphorus Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
COE-KCD	Turnback Cr. at Hwy O	10	0	0%	NA
CU	L. Sac R. at FM 68	46	0	0%	NA
CU	L. Sac R. at FM 159	46	0	0%	NA
USGS	South Dry Sac River bl. Springfield	13	8	62%	20(8)
USGS	Springfield NW WWTP effluent	14	0	0%	NA
USGS	L. Sac R. bl. Springfield at FR 125	14	2	14%	20(2)
COE-KCD	L. Sac R. ab. Walnut Grove, Hwy BB	2	0	0%	NA
USGS	L. Sac R. ab. Walnut Grove, Hwy BB	140	13	9%	20(5), 50(1), 60(7)
USGS	Little Sac River nr. Morrisville	7	1	14%	20(1)
MURPHY	Trib. to Cynthia Cr. US of Murphy (Site 26)	1	1	100%	100(1)
MURPHY	Trib. to Cynthia Cr. DS of Murphy (Site 32)	1	1	100%	100(1)
MURPHY	Cynthia Cr. DS of Murphy	1	1	100%	100(1)
MURPHY	Trib. to Cynthia Cr. DS of Murphy (Site 22)	2	2	100%	100(2)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 13)	1	1	100%	100(1)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 14)	1	1	100%	100(1)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 15)	2	1	50%	100(1)
MURPHY	Wilkey Cr. at Murphy	2	2	100%	100(2)
MDNR	Brush Cr. 0.3 mi.ab. Humansville WWTP	10	2	20%	50(1), 100(1)
MDNR	Brush Cr. 0.2 mi.bl. Humansville WWTP	11	1	9%	50(1)
MDNR	Brush Cr. 2.9 mi.bl. Humansville WWTP	10	2	20%	50(1), 100(1)
MDNR	Panther Cr. at Hwy 13	10	2	20%	50(1), 100(1)
COE-KCD	Sac River nr. Dadeville	15	0	0%	NA
USGS	Sac River nr. Dadeville	47	3	6%	100(3)
COE-KCD	Sac River at Hwy 54	17	0	0%	NA

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

Detection limits, with few exceptions, do not appear to be a significant issue for TN or $NO_3 + NO_2$ samples. MEC identified only one TN sample below laboratory detection limits (Table 18). However, it should be noted that this discussion of TN detection limits only concerns directly reported TN values (i.e., not MEC calculated TN values). With the exception of the Murphy sites, $NO_3 + NO_2$ detection limits are relatively low (50 µg/L or less) and do not appear to be an issue (Table 19). The $NO_3 + NO_2$ detection limit for most of the Murphy sites is 100 µg/L, which represents anywhere from 9 to 70% of the samples collected. Since most of the Murphy sites are relatively impacted by nutrient loadings and do not represent reference conditions, this likely has little effect on the calculated mean $NO_3 + NO_2$ values.

TABLE 18. Total Nitrogen Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
COE-KCD	L. Sac R. ab. Walnut Grove, Hwy BB	2	0	0%	NA
MDNR	Brush Cr. 0.3 mi.ab. Humansville WWTP	8	0	0%	NA
MDNR	Brush Cr. 0.2 mi.bl. Humansville WWTP	9	0	0%	NA
MDNR	Brush Cr. 2.9 mi.bl. Humansville WWTP	8	0	0%	NA
MDNR	Panther Cr. at Hwy 13	8	0	0%	NA
COE-KCD	Sac River nr. Dadeville	11	0	0%	NA
COE-KCD	Sac River at Hwy 54	2	1	50%	120(1)

TABLE 19. Nitrate plus Nitrite Nitrogen Sample Results Reported Below Detection Limit

Agency	Station Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit[1]
COE-KCD	Turnback Cr. at Hwy O	10	0	0%	NA
CU	L. Sac R. at FM 68	83	1	1%	0(1)
CU	L. Sac R. at FM 159	84	1	1%	0(1)
USGS	South Dry Sac River bl. Springfield	13	0	0%	NA
USGS	Springfield NW WWTP effluent	14	0	0%	NA
USGS	L. Sac R. bl. Springfield at FR 125	14	0	0%	NA
COE-KCD	L. Sac R. ab. Walnut Grove, Hwy BB	2	0	0%	NA
USGS	L. Sac R. ab. Walnut Grove, Hwy BB	140	1	1%	20(1)
USGS	Little Sac River nr. Morrisville	7	1	14%	20(1)
MURPHY	Trib. to Cynthia Cr. US of Murphy (Site 26)	10	7	70%	100(7)
MURPHY	Trib. to Cynthia Cr. DS of Murphy (Site 32)	10	1	10%	100(1)
MURPHY	Cynthia Cr. DS of Murphy	10	0	0%	NA
MURPHY	Trib. to Cynthia Cr. DS of Murphy (Site 22)	11	1	9%	100(1)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 13)	10	4	40%	100(4)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 14)	10	4	40%	100(4)
MURPHY	Trib. to Wilkey Cr. US of Murphy (Site 15)	11	2	18%	100(2)
MURPHY	Wilkey Cr. at Murphy	11	0	0%	NA
MDNR	Brush Cr. 0.3 mi.ab. Humansville WWTP	10	1	10%	50(1)
MDNR	Brush Cr. 0.2 mi.bl. Humansville WWTP	11	0	0%	NA
MDNR	Brush Cr. 2.9 mi.bl. Humansville WWTP	10	1	10%	50(1)
MDNR	Panther Cr. at Hwy 13	10	3	30%	10(2), 50(1)
COE-KCD	Sac River nr. Dadeville	14	0	0%	NA
USGS	Sac River nr. Dadeville	47	0	0%	NA
COE-KCD	Sac River at Hwy 54	17	7	41%	0(1), 10(5), 20(1)

Notes: [1]Detection limit reported in ug/L followed by the count in ( ) at that detection limit (e.g., 20(2)) means 2 samples with a laboratoy detection limit of 20 ug/L. NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

6.5 Metadata Gaps

Metadata are data that provide information about sample collection and analysis. Properly documented metadata describe where, when, how, why, and by who samples were collected and processed. Metadata also describe the conditions under which samples were collected (e.g., baseflow, weather, etc.). In order to increase the sharing and value of water quality data, the NWQMC recommends water quality collection entities, at a minimum, report metadata for the following seven categories of WQDE for chemical and microbiological analytes:

1. Contact;
2. Results;
3. Reason for Sampling;
4. Data/Time;
5. Location;
6. Sample Collection; and
7. Sample Analysis.

Water quality data compiled for WQIP contained significant metadata gaps. MDNR's databases (i.e., the primary source of WQIP's data) are compilations of data collected by multiple collection entities. Therefore, metadata gaps discussed here do not necessarily imply who is responsible for the missing metadata. Further investigation would be required to determine whether the metadata gaps discussed below originate from the original data sources.

Contact

The collection entity contact information was generally either provided for, or was readily attainable by MEC. However, the NWQMC also recommends laboratory contact information be provided. Laboratory contact information is potentially necessary for analysis clarification but generally was not available.

Results

The results data element is intended to characterize the analyte and the analytical result value. The NWQMC recommends collection entities use a common analyte identifier taken from an authoritative list (e.g., USGS or EPA STORET Parameter Code). Most collection entities appear to group their data into generic parameter categories. For example the category "TP" is not as specific as the USGS parameter codes for total phosphorus, which indicate the analytical method. Selection of an appropriate analyte identifier may require some verification with a laboratory, but allows for greater data comparability and analysis.

Reason for Sampling

The reason for sampling was generally not available. Some of the recommended reason categories provided by the NWQMC include reconnaissance, trend analysis, storm event, research, and regulatory benchmark. Documenting the reason for sampling may imply critical information to the end user of the water quality data. For example, storm event samples may imply very different, unique conditions compared to permit compliance samples.

Date/Time

Although sample collection dates were available, sample times were frequently not available. Sample times can be critical in data analysis, particularly where analyte concentrations fluctuate on a diurnal basis.

Location

The location data element recommended by the NWQMC characterizes more than the geographic coordinates of the sampling site. The location data element includes such information as station type, accuracy and method of determining the geographic coordinates, and stream stage. The station type denotes how to characterize a sampling site (e.g., ambient stream, storm sewer, outfall site). Generally not much information was available regarding sample sites beyond the geographic coordinates. However, in some instances even the geographic coordinates were not readily available. Unless a sample collection site can be spatially located, the water quality data are of little use. MEC identified three sampling sites in the Sac River Basin with no geographic coordinates. Station names from these sites provide an indication as to their approximate locations, but this is not sufficient for a thorough data analysis.

These three sites were not included in this reports analysis of available water quality. Spatial information for these sites potentially may be found with further investigation.

Sample Collection

The sample collection data element includes metadata on several aspects of sampling including sample type, sample identification, and collection method. Examples of sample type include routine, field blank and field replicate. Documenting the sample type can assure proper and consistent analysis of water quality data. A sample identification number can help facilitate potential questions between a researcher and the laboratory. The collection method (e.g., grab, integrated depth) allows for a more robust analysis of the water quality data. Generally, no sample collection metadata are available in the current WQIP database.

Sample Analysis

Sample analysis data elements are important to fully characterize the results of the water quality data. Accuracy, precision, and other QA/QC notes contribute to the confidence and interpretation of the data; however, they generally were not available. Two notable data elements missing from the water quality data were the detection level measure and type. The detection level measure describes the quantity of analyte below which the sample analysis equipment will not detect the analyte accurately. Examples of detection level types include method detection level, estimated detection level, practical quantification limit, and limit of detection.

6.6 Unincorporated Data

Not all available water quality data from the Sac River basin compiled by MEC were incorporated into the WQIP database at the time of the writing of this report. Although reasonable efforts were made to incorporate available data, some data sources were identified too late and/or were too difficult to incorporate with a reasonable amount of effort. Continuing efforts should be made to incorporate all water quality data into the WQIP database.

7. RECOMMENDATIONS

The overall purpose of WQIP is to improve water quality while also protecting rural economic development and agricultural interests by providing factual information to facilitate sound regulatory and policy decision making. Based on an analysis of existing water quality data, the following categories of recommendations are suggested in support of this purpose:

- Monitoring coordinating board;
- Comprehensive monitoring network;
- Non-point source loading issues;
- Special studies in support of nutrient criteria development; and
- Continue to populate database with historical data.

Monitoring Coordinating Board

The creation of a monitoring coordinating board would help achieve the goals of WQIP in a more effective and efficient manner. The opportunity exists for the multiple water quality collection entities in southwest Missouri to collaborate more closely under the direction of a centralized monitoring coordinating board. The monitoring coordinating board should standardize sampling designs, quality assurance programs, metadata requirements, and develop a centralized database to facilitate the sharing of water quality data. With some synchronization of monitoring programs and better sharing of water quality data, redundant efforts could be eliminated and existing monitoring resources could be leveraged better.

The monitoring coordinating board should be responsible for developing a recommended minimum quality assurance program. Developing quality assurance programs can be a resource intensive effort for individual collection entities. However, by collaborating through a monitoring coordinating board, resources needed to develop a quality assurance program could be minimized. Additionally, a standardized quality assurance program would increase the value of the water quality data.

The Methods and Data Comparability Board (MDCB) of the National Water Quality Monitoring Council (NWQMC) recommends a minimum set of “core metadata”, or water quality data elements (WQDE), necessary for maximizing data comparability and usefulness. Based on the available water quality data, few of the necessary WQDE appear to be documented by most of the collection entities in the Sac River Basin. The monitoring coordinating board should recommend which WQDE elements should be required for all water quality monitoring programs in southwest Missouri. It may not be necessary to adopt all the recommendations of the NWQMC, but the consistent use of at least some “core metadata” would greatly enhance the value of the water quality data. The NWQMC recommendations on WQDE can be found at the Advisory Committee on Water Information website (http://acwi.gov/methods/).

The monitoring coordinating board should maintain all water quality data from the various collection entities in a central database. To facilitate the development and updating of a central database and the sharing of water quality data, a common data storage format should be used by all collection entities. The actual storage software (i.e., spreadsheet or database program) is not as critical as the format of the data. By utilizing common protocols the transfer and utilization of shared data could be simplified. The format should accommodate the recommended WQDE of the NWQMC and the principles of good database design. For example, result values should be maintained in a numeric column separate from any remarks. The format should also accommodate the storage of censored data (e.g., less than laboratory detection limits). Methods of storing censored data values (e.g., use half the detection limit) by data collection entities are irrelevant as long as the detection limit and censored remark are clearly identified. Ultimately, developing an effective and robust common data storage format will increase the value of the data for all entities.

Comprehensive Monitoring Network

A comprehensive monitoring network should be designed for the Sac River Basin to address the goals of WQIP. Water quality throughout much of the basin remains uncharacterized and more sample stations are needed to detect, isolate and identify known and potential sources of pollution. The information goals of WQIP should be carefully considered in developing the network design. Since the goals of WQIP are broad and extensive, monitoring locations should be spaced throughout all the major watersheds in the basin. Initial monitoring effort should continue for at least two years. Long-term monitoring stations should be established and more targeted monitoring should occur at the end of this two year period. The exact location of the sampling sites needs to be guided by information goals. For example, if the goal is to measure the effectiveness of watershed management programs then such programs need to be clearly defined in order to properly locate the sampling stations. Information goals are also important for determining the appropriate variables to measure and the frequency and duration at which to measure them. In summary, the historical and current sample stations found throughout the Sac River Basin do not fully address the WQIP goals. A well designed monitoring network that clearly addresses the goals of the WQIP is needed.

Non-Point Source Loading Issues

One of the primary goals of WQIP is to characterize the impacts of point and non-point source discharges on water quality. Characterizing point and non-point source influences requires water quality data collected during multiple flows during both baseflow and runoff conditions. USGS data are well attributed with flows and flow conditions, but much of the remaining WQIP data lack any flow characterization. Where lacking, flow attributes may be derived from USGS gaging stations in close proximity or historical precipitation data. Efforts should be made to characterize as much of the WQIP data as possible with flow attributes. Load duration curves and relationships between runoff conditions and parameter levels should then be analyzed based on flow attributes. Where available data are insufficient to characterize non-point loadings, special storm event studies may be necessary.

Special Studies in Support of Nutrient Criteria Development

In 2005, MDNR mutually agreed with the EPA to develop region specific nutrient criteria for water bodies in the State of Missouri. MDNR has placed first priority on developing lake and reservoir nutrient criteria, which likely will be proposed in 2008. Stakeholder group involvement in the development of stream nutrient criteria will commence in 2008 and it is anticipated that criteria will be effective by 2010.

WQIP can serve an integral role in assuring appropriate stream nutrient criteria are developed for the southwest Missouri area. Appropriate nutrient criteria development will require stakeholder participation and significant data analysis. WQIP already consists of multiple stakeholders and has consolidated a significant amount of nutrient data. WQIP stakeholders are encouraged to participate in the stream nutrient criteria stakeholder meetings beginning next year. Significant data analysis, however, is still necessary for the development of nutrient criteria. As part of this data analysis, MDNR recommends the following (MDNR, 2005d):

- Develop load duration curves to evaluate loading across multiple flow regimes;
- Develop regression lines for response variables, such as sestonic and benthic chlorophyll, and turbidity based on the causal variables of total nitrogen and total phosphorus; and
- Evaluate potential correlations between stream order and nutrient data (causal and response).

As discussed in this report, there are relatively little nutrient data available for the Sac River Basin. Where nutrient data are available, they are likely insufficient for all the data analysis methods recommended by MDNR. Additional causal (nutrient) and response (algae) data from various flow regimes are necessary. Currently available data from the Sac River Basin has little to no paired causal and response variables and flow conditions are generally lacking. WQIP should therefore design and implement special nutrient water quality studies with the goal of supporting the development of technically sound nutrient criteria.

Continue to Populate Database with Historical Data

Much water quality data in the Sac River Basin have not been incorporated into the WQIP database due to a lack of common metadata and suitable data storage format. Also, additional water quality data were received after the cutoff date for this analysis. Efforts should be made to add any currently unincorporated water quality data to the database. If collection entities choose to collaborate on monitoring efforts, utilize common core metadata, and a suitable data storage format, future updates to the database should require less effort.

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