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

PREPARED FOR:
Environmental Resource Coalition
3118 Emerald Lane
Jefferson City, Missouri 65109

October 2007

PREPARED BY:
MEC Water Resources, Inc.
1123 Wilkes Boulevard, Suite 400
Columbia, Missouri 65201

Ozarks Environmental Water Resources Institute, Missouri State University
Temple Hall 328
901 South National Avenue
Springfield, Missouri 65897

(page intentionally left blank)

TABLE OF CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ACWI	Advisory Committee on Water Information
asl	above sea level
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CCHD	Christian County Health Department
cfu	colony forming units
cfs	cubic feet per second
CU	Springfield City Utilities
DNR	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
ft.	feet
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LMVP	Lakes of Missouri Volunteer Monitoring Program
MDC	Missouri Department of Conservation
MDCB	Methods and Data Comparability Board
MDNR	Missouri Department of Natural Resources
MEC	Midwest Environmental Consultants Water Resources, Inc.
MS	Microsoft
MSU	Missouri State University
mi.	mile
NAWQA	National Water-Quality Assessment Program
nd	non-detect
NO_2	Nitrite
NO_3	Nitrate
NO_3-N	Nitrate expressed as Nitrogen
NH_4	Ammonium
NH_3	Ammonia
NRCS	Natural Resources Conservation Services
NWIS	National Water Information System
NWQMC	National Water Quality Monitoring Council
PAH	Polycyclic Aromatic Hydrocarbon
QA/QC	Quality Assurance and Quality Control
SCHD	Stone County Health Department
SPMD	Semipermeable Membrane Device
SPW	Springfield Public Works
sq. mi.	square mile
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen

TNTC	Too Numerous To Count
TP	Total Phosphorus
TSS	Total Suspended Solids
VOC	Volatile Organic Compounds
WBC	Whole Body Contact
WBCR	Whole Body Contact Recreation
WCO	Watershed Committee of the Ozarks
WQDE	Water Quality Data Elements
WWTP	Wastewater Treatment Plant
μg/L	microgram per liter
mg/L	milligram per liter
mL	milliliter
N_2	Nitrogen gas
N_2O	Nitrous Oxide
NO	Nitric Oxide
UMC	University of Missouri at Columbia
USGS	U.S. Geological Survey
VSS	Volatile Suspended Solid

(page intentionally left blank)

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 James River Basin is the subject of this report.

The James River Basin is 1,455 square miles and includes the Springfield metropolitan area along its northern boundary. Major tributaries of the James River include Flat, Finley, Crane, Wilson, and Pearson Creeks. Existing water quality regulatory issues in the James River Basin include a nutrient total maximum daily load (TMDL) on the James River, the impairment of Wilson and Pearson Creeks for unknown toxicity, and the impairment of Pearson Creek for bacteria.

Water quality data from the James River Basin were compiled from multiple collection entities including the Missouri Department of Natural Resources (MDNR), Christian County Health Department (CCHD), Stone County Health Department (SCHD), Lakes of Missouri Volunteer Program (LMVP), Missouri State University (MSU), University of Missouri – Columbia (UMC), Springfield City Utilities, City of Springfield Public Works, the and U.S. Geological Survey (USGS). Water quality data were analyzed with relation to total phosphorus (TP), total nitrogen (TN), nitrate plus nitrite nitrogen ($NO_3 + NO_2$), and sestonic and benthic chlorophyll *a*. Nutrient levels are generally greatest downstream the major urban areas of Springfield, Nixa, and Ozark. However, significant improvements in phosphorus levels appear subsequent to the phosphorus removal upgrades to the Springfield Southwest Wastewater Treatment Facility (WWTF) in 2001. Bacteria levels are greatest downstream of the City of Springfield in Wilson Creek, but were only observed to exceed the applicable water quality criterion in Pearson Creek.

Based on a data gap analysis of the existing water quality data in the James 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. Further data analysis and potential special storm water studies are recommended to better understand non-point source loading issues. WQIP is encouraged to participate in the development of regional stream nutrient criteria through stakeholder involvement and further water quality studies. Toxicity issues are known to exist in the James River Basin; however, further research is necessary to fully characterize its sources and extent of impact. 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.

(page intentionally left blank)

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 James River basin (hydrologic unit 11010002), the most studied watershed in southwest Missouri. The data gap analysis for the James 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 James River Basin including land use and demographics, point and non-point wastewater discharges, climate, geology, and surface water hydrology

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 James 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 James River Basin provided below describes the basin characteristics, population and land use, point sources and permitted discharges, geology and soils, and climate and hydrology.

2.1 Basin Characteristics

The James River Basin (1,455 mi^2) is located in southwest Missouri draining Webster, Greene, Christian, Stone, Barry and small portions of Lawrence and Douglas counties (Figure 1). The headwaters begin in eastern Webster County (≈1,716 feet asl) flowing 155 miles to the confluence with the White River near Kimberling City in southern Stone County (Table 1). Below the town of Galena, the James River forms one of the major arms of Table Rock Lake, contributing 15% of the surface area and 30% of the flow to the reservoir (Knowlton and Jones, 1989). Major tributary drainage areas include: Flat Creek (314 mi^2), Finley Creek (277 mi^2), Crane Creek (160 mi^2), Wilson Creek (84 mi^2) and Pearson Creek (23 mi^2) (Kiner and Vitello, 1997).

The Springfield metropolitan area in Greene County is located along the northern boundary of the middle James River Basin and is drained from west to east by Wilson Creek, Ward Branch, Galloway Creek, and Pearson Creek. The fast growing communities of Nixa and Ozark are located in the lower Finley Creek Watershed in Christian County. Other communities of significant size located within the drainage area are: Battlefield (Wilson Creek), Cassville (Flat Creek), Crane (Crane Creek), and Galena (James River). The communities of Highlandville, Marshfield, Reeds Spring, Republic, Seymour, Sparta, Spokane, and Strafford, are all partially located in headwater areas along the watershed boundary.

Table 1. Characteristics of Major Tributaries of the James River

Watershed	Drainage Area (mi^2)	Length (mi)	Headwaters Elevation (ft)	Elevation (ft) at Mouth
James River	1,455	155	1,716	915*
Major Tributaries				
Flat Creek	314	53	1,568	915*
Finley Creek	277	53	1,621	1,020
Crane Creek	160	25	1,421	961
Wilson Creek	84	19	1,385	1,070
Pearson Creek	23	12	1,470	1,158

*Powerpool elevation of Table Rock Lake

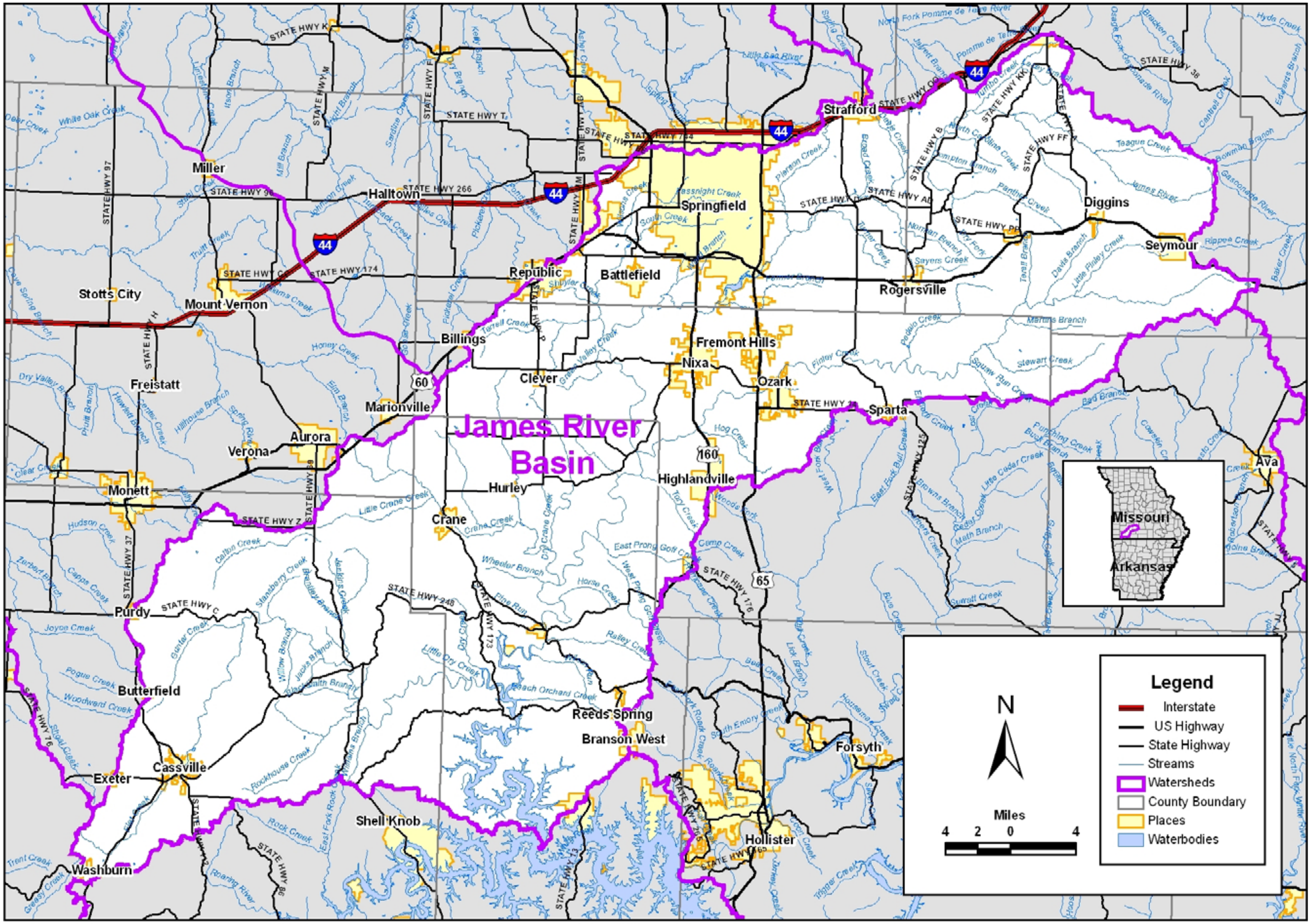

FIGURE 1. James River Basin – General Reference

2.2 Population and Land Use

Population data from the 2000 census show the highest population density (>5,000 persons per mi^2) in the basin occurs in downtown Springfield (Figure 2). Density decreases moving away from center city with the lowest population density being found in the lower basin. Deviating from this trend, locally high population densities are found near the James River Arm of Table Rock Lake and around Cassville in western Barry County.

Analysis of population change from 1990 to 2000 shows a trend of decreasing population in downtown Springfield to > 100% increase in the unincorporated areas of Greene County and around the cities of Nixa and Ozark in Christian County (Figure 3). A significant population increase (>50%) also occurred close to Table Rock Lake near the cities of Reeds Spring and Branson West.

High and Low Density Urban land use dominates the areas around Springfield, Nixa and Ozark (Figure 4). The headwater areas of the basin are comprised of mainly forest and grassland/pasture land use interspersed with small areas of cropland. The western sections of the basin are comprised of mostly agricultural land uses with pasture/grassland being the most prominent. The lower sections around the lake are dominated by forest land cover with several small high density urban clusters. Table 2 summarizes land use for the basin.

TABLE 2. James River Basin Land Use Percentages 2000-2004

Land Use Description	Area (sq. mi.)	% of Total
High Density Urban	45	3
Low Density Urban	60	4
Barren	14	1
Cropland	42	3
Grassland	757	52
Forest	445	31
Young Forest/Shrubland	70	5
Water	22	1
Total	**1,455**	**100**

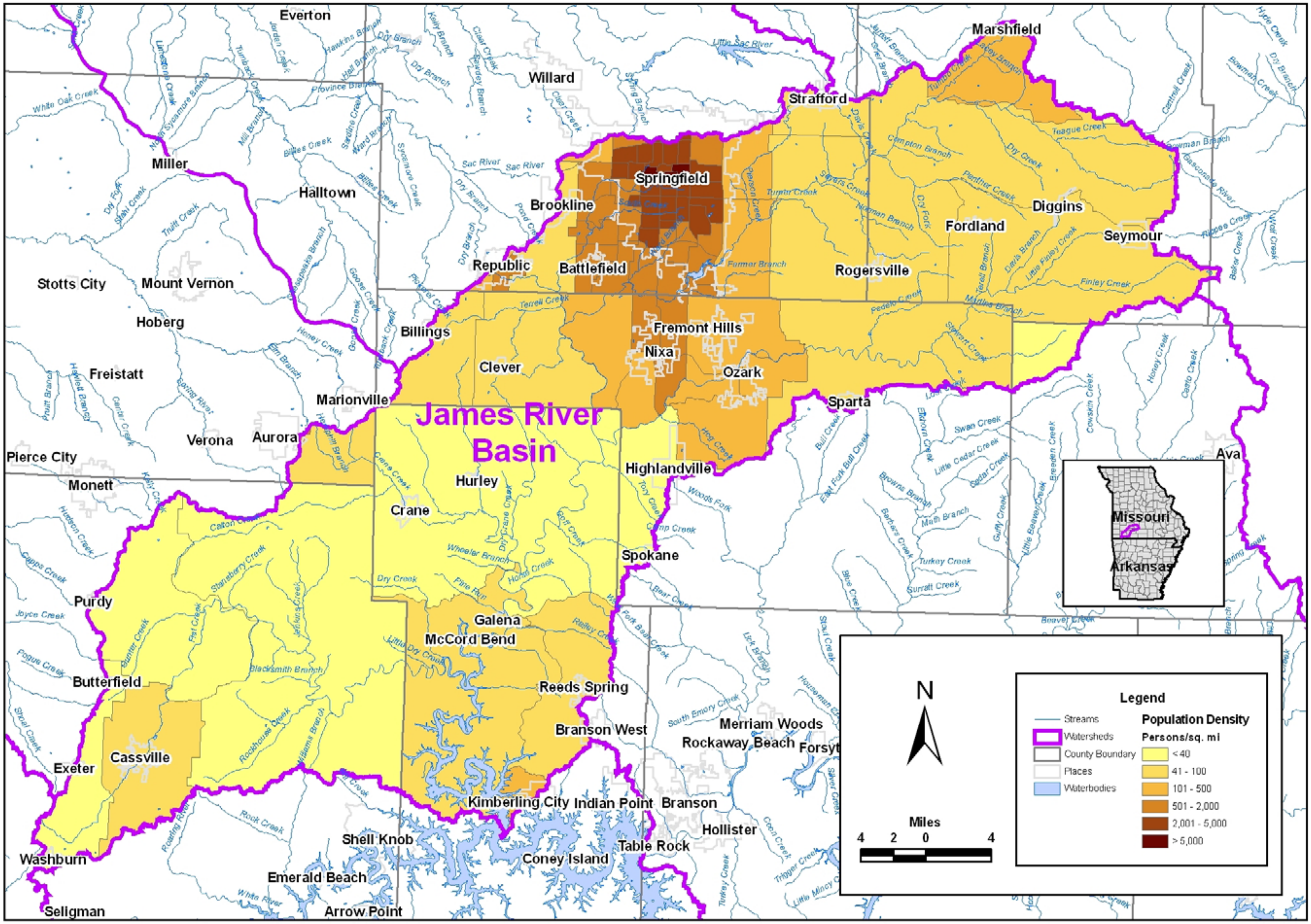

FIGURE 2. James River Basin – Population Density (2000)

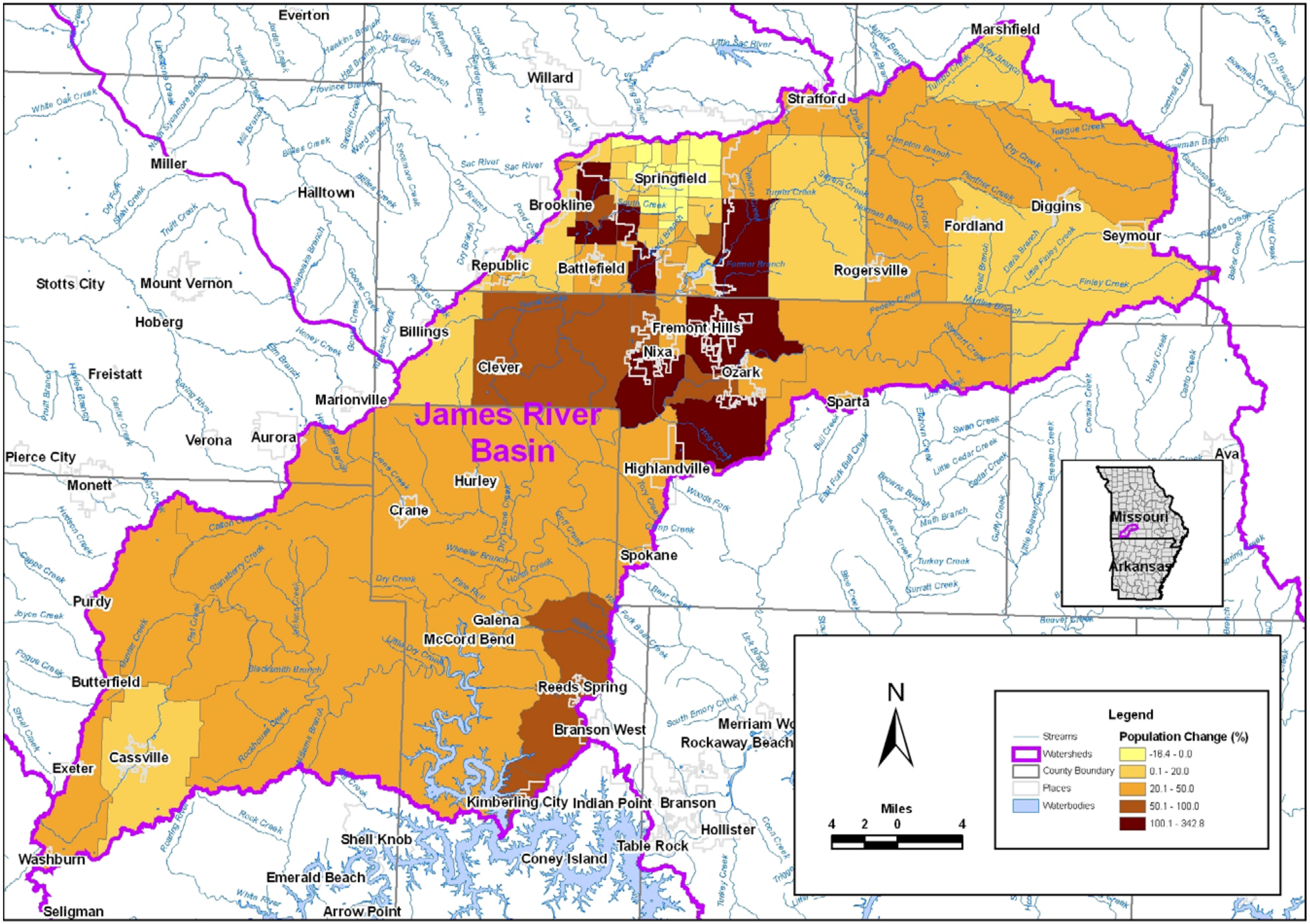

FIGURE 3. James River Basin – Population Change (1990 – 2000)

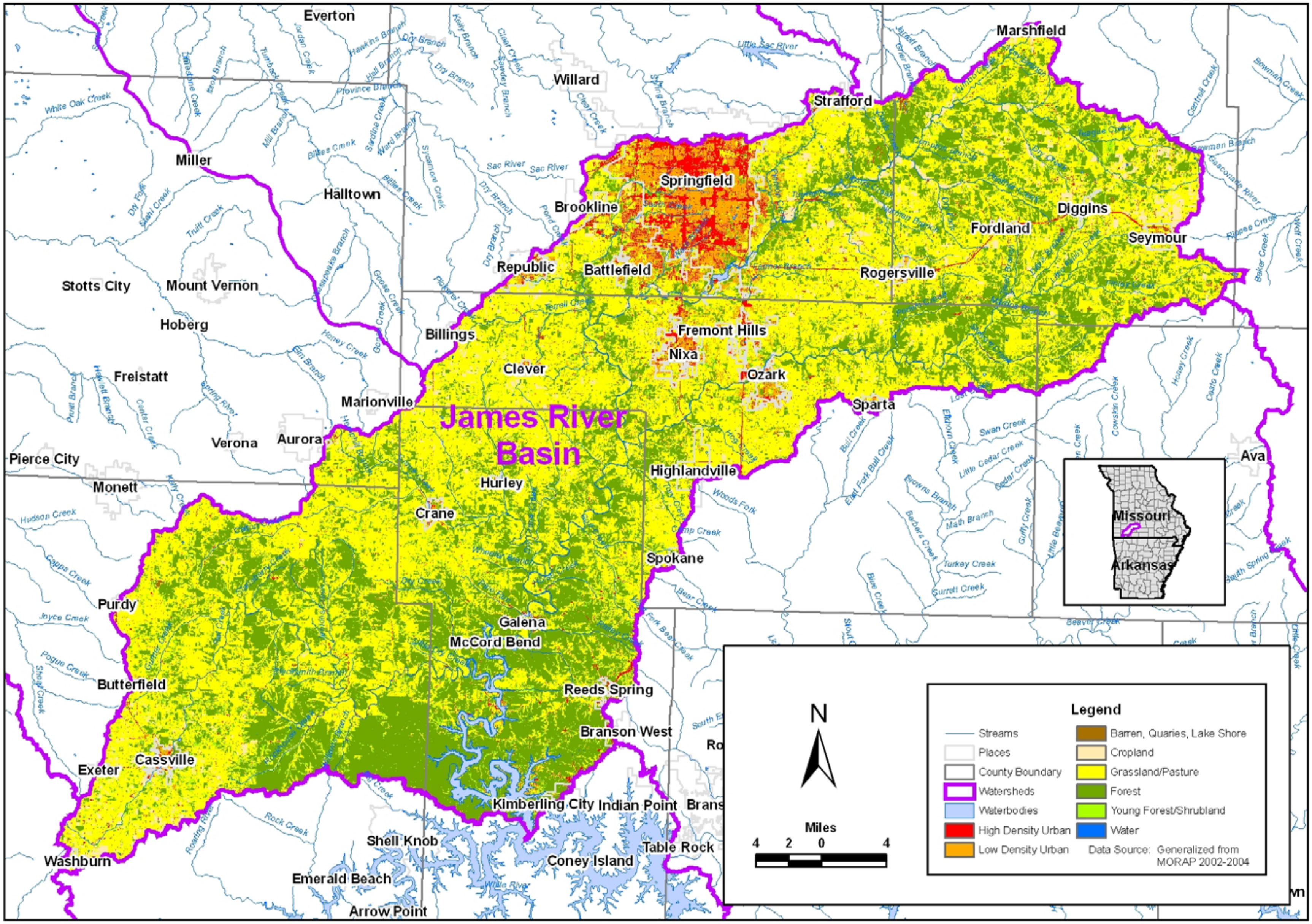

FIGURE 4. James River Basin – Land Use

2.3 Point Sources and Permitted Dischargers

The James River Basin receives nutrient discharges from 65 permitted point sources (as of December 2006). A large number of non-municipal domestic wastewater treatment plants (WWTPs) (37) are clustered around Table Rock Lake and in the urbanized region near Springfield and the surrounding towns (Figure 5). There are only 6 industrial point sources for nutrients within the basin that collectively yield nearly the same total discharge as the 37 non-municipal WWTPs combined (Table 3). However, non-municipal domestic WWTPs and industrial facilities contribute only 3% of the total discharge by point sources within the basin. The vast majority of the total discharge (97%) is contributed by the relatively large municipal WWTPs. The largest single point source is the City of Springfield's Southwest Treatment Plant, which accounts for approximately 50% of the permitted point source discharge to the basin.

A significant number of small turkey (5) and poultry (17) confined animal feeding operations (CAFOs) are located in the James River Basin, mainly in the southwest corner near Cassville in the Flat Creek watershed. While there are over three times as many poultry operations within the basin, the five turkey operations are permitted to produce over 60% of the total tons of dry waste produced by CAFOs in the basin (Table 4).

TABLE 3. Permitted Point Sources in the James River Basin

Type	Number	Discharge (MGD)*
Industrial	6	1.07
Non-Municipal Domestic	37	0.83
Municipal	22	64.32
Total	**65**	**66.22**

*Million gallons per day (based on design flow)

TABLE 4. Confined Animal Feeding Operations in the James River Basin

Type	Number	Annual Waste Production (dry tons)*
Poultry	17	24.5
Turkey	5	37.5
Total	**22**	**62**

*Total permitted annual waste

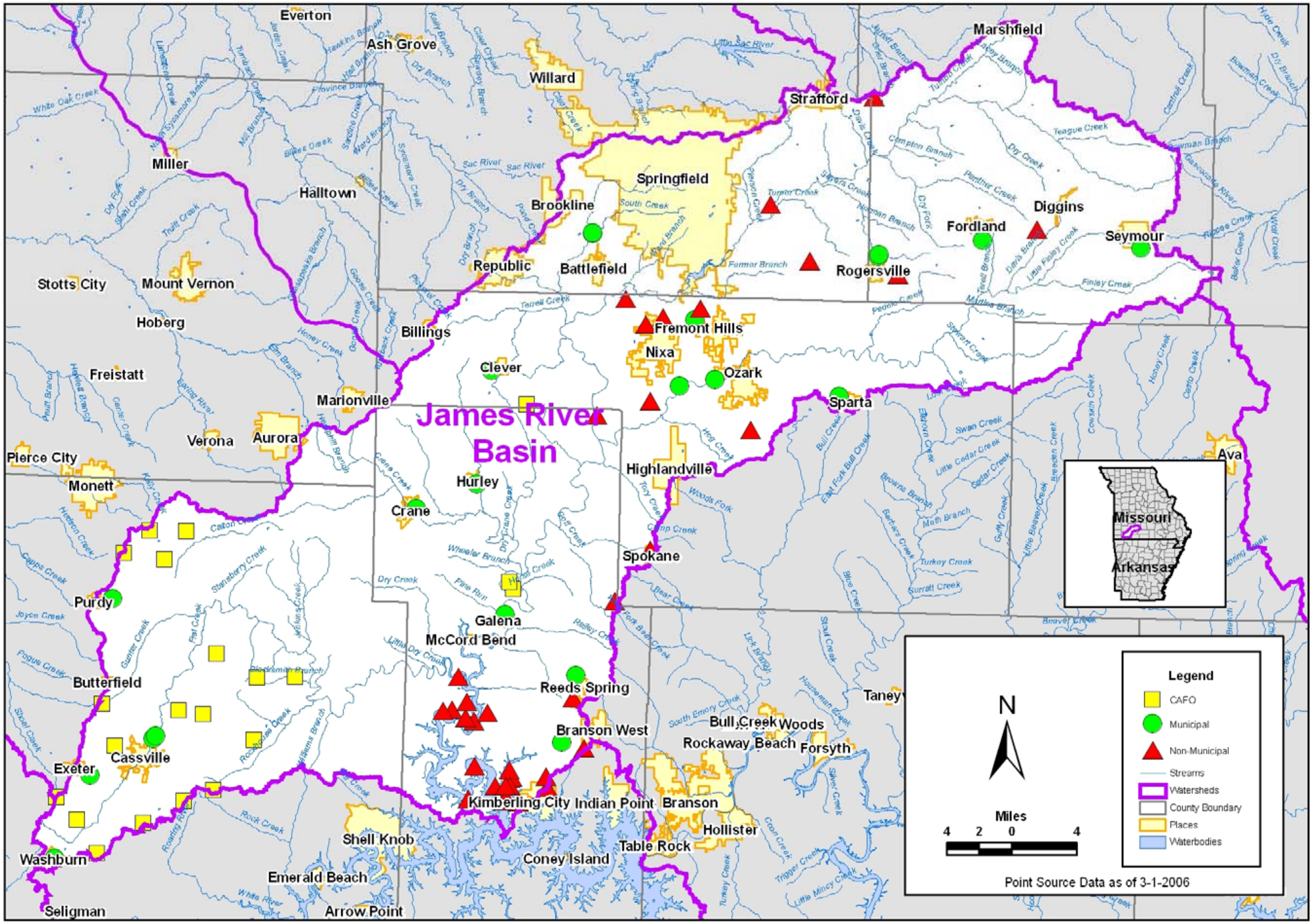

FIGURE 5. James River Basin – Point Sources

2.4 Geology and Soils

The James River Basin covers two Ozark Plateaus physiographic regions, the Springfield Plain and the Ozark Highlands of Missouri and Arkansas. Both physiographic regions are underlain by limestone, dolomite, and shale bedrock (Aldrich and Meinert, 1994) (Figure 6). These bedrock units are of differing ages with the Ozark Highlands (Ordovician) being older and more dissected than the Springfield Plain (Mississippian) (Adamski et al., 1995). Karst topography accounts for the numerous springs, losing streams, and sinkholes, common to the region, which act as a conduit between surface runoff and groundwater (Petersen et al., 1998). These geologic attributes affect the natural quantity and quality of water resources in the James River Basin.

The spatial distribution of soil series associations from both the Springfield Plain and Ozark Highland within James River Basin 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.

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)

102 - Nixa-Jay-Clarksville-Captina

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.

Jay The Jay series consists of very deep, moderately well drained, slowly permeable soils that formed in loamy material overlying siltstone or cherty

limestone. These nearly level to gently sloping soil are on uplands on the Ozark Highlands. Slopes range from 1 to 8 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.

Captina series consists of very deep, moderately well drained soils on nearly level to moderately sloping uplands and old stream terraces of the Ozark Highlands. They formed in a thin mantle of silty material and the underlying colluvium and residuum weathered from limestone, cherty limestone and dolomite, or siltstone. Slopes range from 1 to 15 percent.

Ozark Highland Soils

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 (see 102 - Nixa-Jay-Clarksville-Captina association above)

86 - Ocie-Mano-Gatewood-Alred

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.
Gatewood series consists of moderately deep, moderately well drained soils of the uplands. They formed in gravelly hillslope sediments and the underlying residuum from cherty limestone or dolomite and shale. Slope gradients range from 1 to 60 percent.

Alred series consists of very deep, well drained soils formed in cherty hillslope sediments and the underlying clayey residuum. These soils are on moderately sloping to very steep uplands. Slopes range from 1 to 60 percent.

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 (see 86 - Ocie-Mano-Gatewood-Alred association above)

Mano (see 86 - Ocie-Mano-Gatewood-Alred association above)

91 - Ocie-Moko-Gatewood

Ocie (see 86 - Ocie-Mano-Gatewood-Alred association above)

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

Gatewood (see 86 - Ocie-Mano-Gatewood-Alred association above)

140 - Wilderness-Viraton

Wilderness (see 66 - Wilderness-Tonti association above)

Viraton (see 87 - Viraton-Ocie-Mano association above)

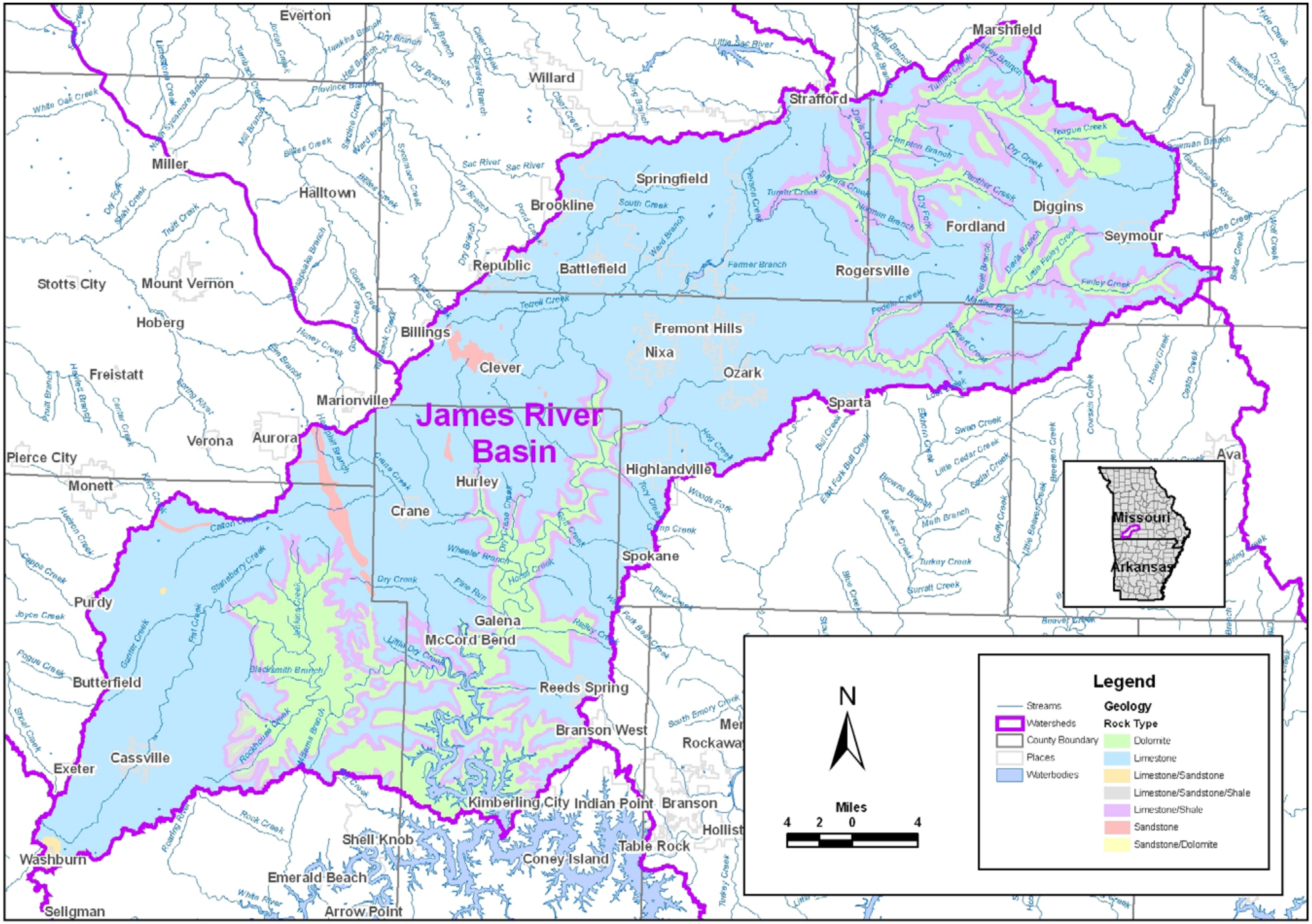

FIGURE 6. James River Basin – Geologic Map

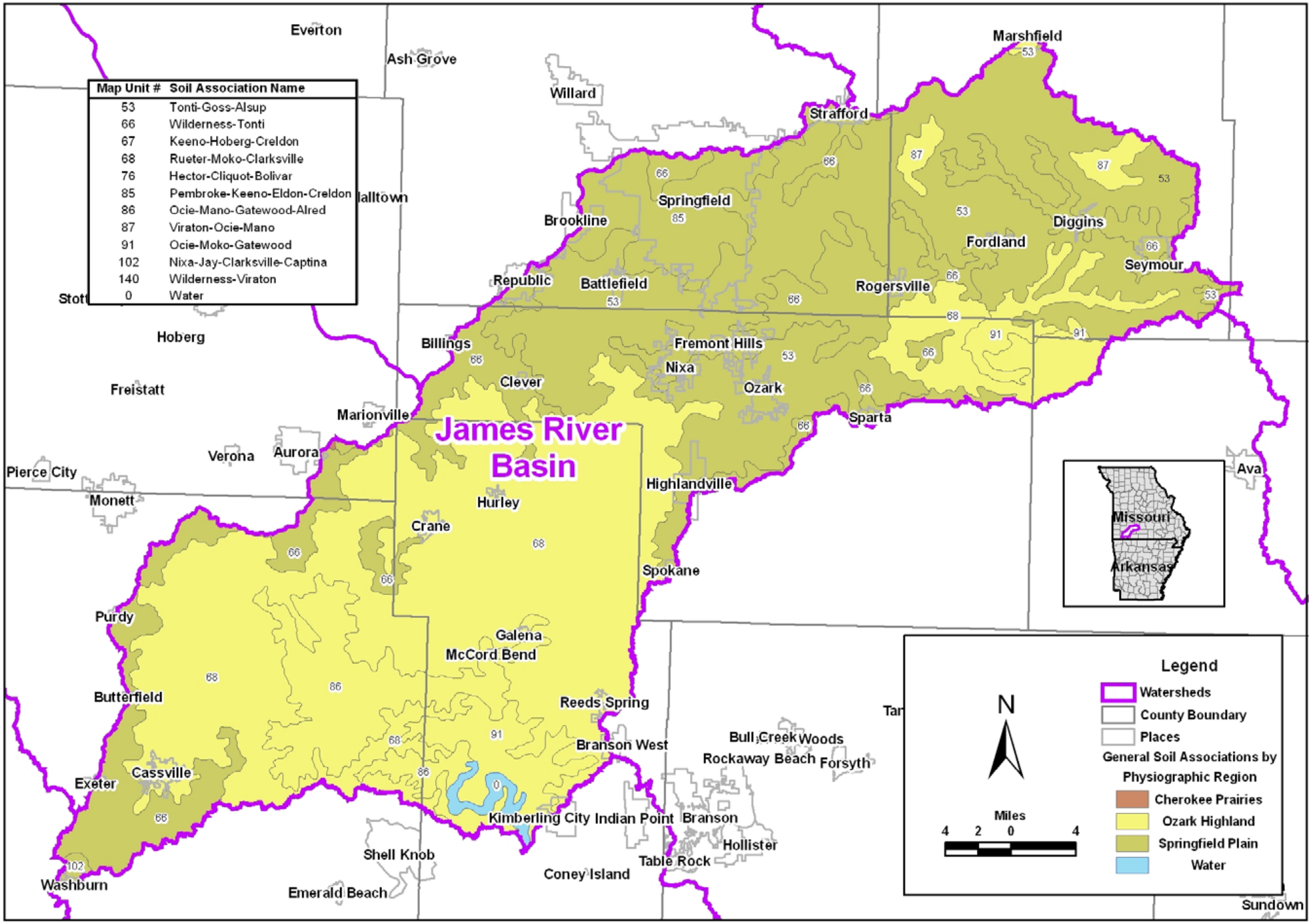

FIGURE 7. James River Basin – General Soil Associations

2.5 Climate and Hydrology

Climate for the region is considered temperate, with an average annual temperature of 59°F and average annual precipitation of 40 inches (Adamski et al., 1995). Thirty year monthly average temperatures at the Springfield Regional Airport range from approximately 30°F in January to near 80°F in July (Figure 8). Monthly average precipitation starts to rise in late winter and peaks in late spring with 4.5 to 5 inches of rainfall in May and June. Relatively high average rainfall totals also occur in the months of September and November with between 4.5 and 5 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) operates 9 discharge gaging stations in the basin located on the James River (3), Wilson Creek (3), Finley Creek (1), Pearson Creek (1), and South Creek (1) (Figure 9 and Table 5). James River stations at Galena and Springfield have more than 50 years of recorded data, while 4 of the 9 stations have less than 10 years of record, and the remaining 3 have between 12 and 17 years of record. Recordings at these gage stations are not necessarily continuous throughout the corresponding periods of record.

Monthly mean discharge data from the 9 gaging stations show the highest average runoff occurs between March and May corresponding to the spring wet season (Table 6). The lowest average discharges occur between July and October. Stations that do not follow this pattern are found in the Wilson Creek watershed, which is highly urbanized and influenced by wastewater treatment plant discharge. Additionally, only short periods of record are available for the Wilson Creek watershed stations.

Hydrology in the region is primarily controlled by karst features such as sinkholes, springs and losing/gaining sections of stream. The linkages among these features contribute to the ephemeral and intermittent properties of most Ozark streams as well as inter-basin water transfer. An important distinction however is that flow for the gages at Wilson Creek near Brookline (07052152) and James River near Boaz (07052200) are highly influenced by releases from the City of Springfield's Southwest Treatment Plant (design flow is 65.8 cfs). This is especially true during low flow periods where wastewater discharges contribute a high proportion of the flow below Springfield. The 90% exceedance flow (i.e., the flow at which all other flows exceed it 90% of the time) for Wilson Creek increases from 0 cfs above the plant to 34 cfs below the plant. The 34 cfs at the gage at Brookline is over half the flow recorded at Boaz (67 cfs) for the 90% exceedance discharge.

Flood records from these gages show the highest floods on record for the two longest continually recording gages along the James River were during the floods of 1993 (Table 7). Peak flow during the 1993 floods was approximately 41,000 cfs and 73,000 cfs at the Springfield and Galena gages, respectively. While three stations with non-continuous periods of record were established, they were not recording in 1993. The highest floods on record for the non-continually recording and recently established stations resulted from locally intense storm events in July 2000 and May 2002.

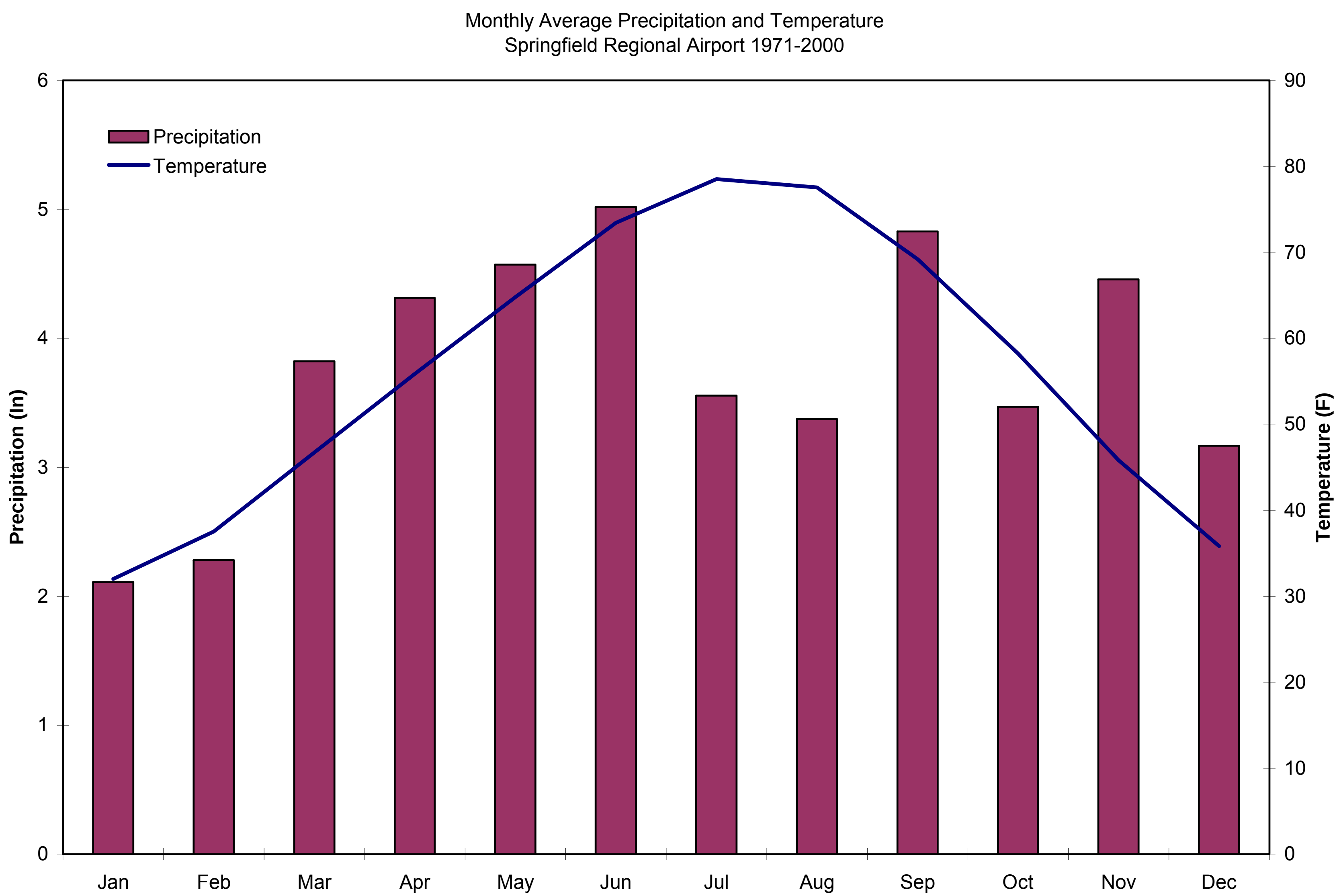

FIGURE 8. Monthly Average Precipitation and Temperature at the Springfield, Missouri Regional Airport

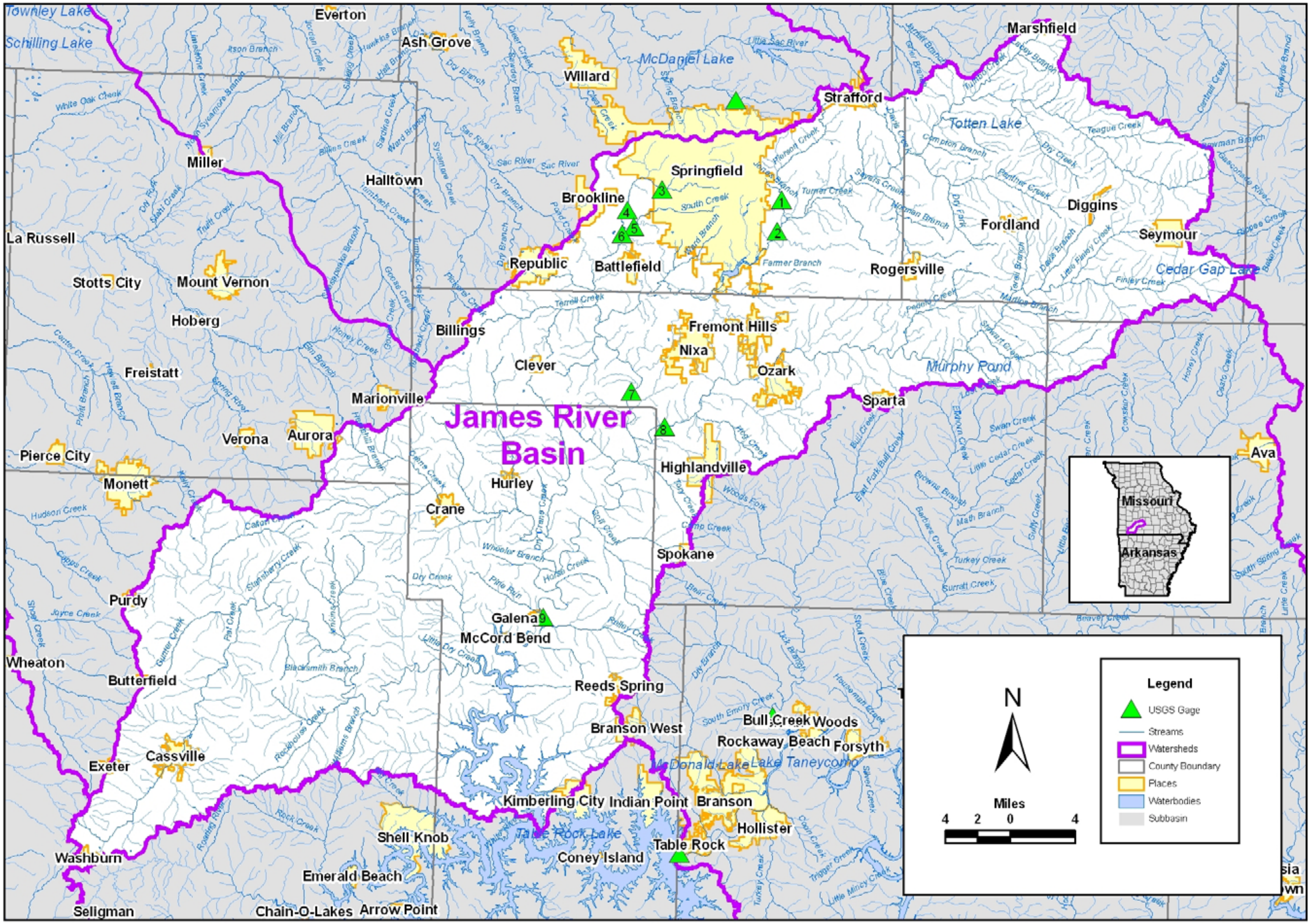

FIGURE 9. James River Basin – Hydrologic Gaging Station Locations

TABLE 5. Description of USGS Gaging Stations in the James River Basin

Station ID	Station Name	Drainage Area (mi^2)	Elevation (ft)	Start Year	Years of Record
07050690	Pearson Creek near Springfield, MO	21	1,201	1999	6
07050700	James River near Springfield, MO	246	1,143	1955	50
07052000	Wilson Creek at Springfield, MO	17.8	1,201	1932	17
07052100	Wilson Creek near Springfield, MO	31.4	1,150	1972	17
07052120	South Creek near Springfield, MO	10.5	1,146	1998	7
07052152	Wilson Creek near Brookline, MO	44.6	1,130	2001	4
07052200	James River near Boaz, MO	462	1,035	1972	12
07052345	Finley Creek below Riverdale, MO	261	1,140	2001	4
07052500	James River at Galena, MO	987	921	1921	84

* Information on all USGS gages in Missouri can be found at http://waterdata.usgs.gov/mo/nwis/rt

TABLE 6. Mean Monthly Discharge for USGS Gaging Stations in the James 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)
07050690	Pearson Creek near Springfield, MO	34	28	29	22	34	15	19	9	7	6	14	21
07050700	James River near Springfield, MO	229	274	409	420	398	187	102	37	104	90	241	280
07052000	Wilson Creek at Springfield, MO	21	19	22	22	29	29	19	11	32	13	18	14
07052100	Wilson Creek near Springfield, MO	17	16	31	27	36	26	18	10	13	15	23	15
07052120	South Creek near Springfield, MO	3	6	13	7	14	2	6	3	2	9	2	5
07052152	Wilson Creek near Brookline, MO	87	56	68	66	102	54	49	46	50	43	58	61
07052200	James River near Boaz, MO	525	529	1,064	820	809	396	274	143	246	197	630	463
07052345	Finley Creek below Riverdale, MO	373	265	390	413	617	105	76	55	40	34	142	287
07052500	James River at Galena, MO	941	1,130	1,521	1,758	1,617	1,133	580	385	411	473	856	959

TABLE 7. Select Flows for USGS Gaging Stations in the James 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
07050690	Pearson Creek near Springfield, MO	1.4	9/7/2002	3.1	9.3	20	40	2,200	7/12/2000
07050700	James River near Springfield, MO	0.1	9/16/1956	12	73	231	496	41,100	9/25/1993
07052000	Wilson Creek at Springfield, MO	0.31	9/29/2004	3	8.6	18.5	37	6,750	7/12/2000
07052100	Wilson Creek near Springfield, MO	0	-----	0	5.8	20.8	44	5,480	7/12/2000
07052120	South Creek near Springfield, MO	0	-----	0	0	6.18	6.9	NA	7/12/2000
07052152	Wilson Creek near Brookline, MO	1	4/13/2004	34	44	62	85	NA	5/8/2002
07052200	James River near Boaz, MO	35	9/19/2002	67	238	508	1,070	21,700	5/8/2002
07052345	Finley Creek below Riverdale, MO	10.92	8/28/2003	24	90	210	433	21,400	5/8/2002
07052500	James River at Galena, MO	10	9/20/1954	121	426	979	2,130	73,200	9/25/1993

"-----" = low flow occurred on multiple dates
NA – not available (flow was not calculated for this 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

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

- James River;
- Wilson Creek; and
- Pearson Creek.

The pollutants identified as responsible for these impairments include nutrients, unknown toxicity, bacteria, and mercury.

Nutrients

In 1998 the State of Missouri 303(d) listed three segments of the James River as impaired for nutrients, which extend from its headwaters to Table Rock Lake. The MDNR cited phosphorus from sewage treatment plants, and runoff of phosphorus and nitrogen from urban and agricultural non-point sources as being of particular concern in the James River. Elevated nutrient levels, particularly phosphorus, in the James River have also been attributed to causing decreased clarity in Table Rock Lake (MDNR, 2004a).

The EPA approved the James River TMDL in May 2001, which is to be completed in two phases. Phase I of the TMDL includes the implementation of phosphorus removal efforts at select wastewater discharge facilities. The Springfield Southwest Wastewater Treatment Plant, which has been cited as the most significant nutrient loading source, completed its phosphorus removal upgrades in March 2001. Phosphorus removal upgrades at all other facilities are to be completed by November 2007. Phase II of the James River TMDL primarily addresses the reduction of non-point nutrient loadings (MDNR, 2001).

Unknown Toxicity

The State of Missouri lists Wilson and Pearson Creeks as impaired for unknown toxicity. Evidence of toxicity in Wilson Creek includes a low diversity of fish and aquatic

invertebrates based on sampling conducted by the Missouri Department of Conservation and biologists at City Utilities of Springfield. The National Park Service also found evidence of toxicity in Wilson Creek based on direct toxicity testing in 1989 (MDNR, 2004b). Evidence of toxicity in Pearson Creek comes from long term monitoring by biologists at City Utilities of Springfield, which indicates significant reductions in the number of aquatic invertebrate species between the 1960s and 1990s (MDNR, 2004c).

A USGS toxicity investigation on Wilson and Pearson Creeks suggests urban derived contaminants are contributing to toxicity issues (Richards and Johnson, 2002). The predominant contaminants found in the study included polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs); however, these compounds were detected below water quality standards. Toxicity tests of semipermeable membrane device (SPMD) dialysates also indicated the presence of genotoxins[1], which Richards and Johnson (2002) largely attribute to PAHs and VOCs. PAHs and VOCs are likely derived from petroleum products or combustion sources, which are commonly washed off of parking lots and roadways during storms. Richards and Johnson (2002) also suggest the low concentrations of pesticides and pesticide metabolites that were detected during the study probably compound the genotoxicity issues.

MDNR is currently proposing the removal of Wilson and Pearson Creeks from the 2004/2006 303(d) List for unknown toxicity (MDNR, 2006a). Although evidence of toxicity exists in Wilson and Pearson Creeks, MDNR considers the data insufficient for impairment listing purposes based on latest methodology for the development of 303(d) Lists. MDNR considers waters to be impaired by toxics if there are two or more exceedances of toxic criterion values in a three year period (MDNR, 2006b; MDNR, 2006c).

Bacteria

The State of Missouri is proposing the addition of Pearson Creek to the 2004/2006 303(d) List for bacteria. Evidence of bacteria impairment includes an *Escherichia coli* (*E. coli*) geomean of 493 cfu/100 mL in Pearson Creek (MDNR, 2006d). Pearson Creek is designated as a whole body contact recreation (WBCR) Category A water, which has an *E. coli* criterion of 126 cfu/100 mL. No other streams in the James River Basin are currently 303(d) listed or proposed for 303(d) listing based on bacteria.

Mercury

The issue of mercury impairment is considerably more complex than most other pollutants. Atmospheric deposition from sources outside the State of Missouri is considered the primary source of mercury in Missouri streams. Therefore, the MDNR is currently addressing the issue of mercury contamination on a state-wide basis as

[1] Genotoxins are chemicals than can induce deoxyribonucleic acid (DNA) damage in cells that may result in lethality, mutagenesis, and carcinogenesis.

opposed to a waterbody-by-waterbody approach. A combined network of 55 sampling stations throughout the state suggests mercury levels in fish are sufficient to raise health concerns related to fish consumption on 13 waterbodies. However, MDNR acknowledges that mercury contamination is likely more prevalent than what current data suggests (MDNR, 2006a).

The James River was 303(d) listed in 2002 based on mercury levels in fish tissue; however, MDNR is currently recommending the removal of the James River from the 2004/2006 303(d) List for mercury. Existing data in the James River does not meet MDNR's latest 303(d) listing criterion, which requires the 60% upper confidence limit to exceed the fish tissue mercury criterion of 0.30 mg/kg (MDNR, 2006c; MDNR, 2006e).

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 James River Basin from Missouri Department of Natural Resources (MDNR) and USGS databases in June 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 MDNR water quality dataset included the Christian County Health Department (CCHD), Stone County Health Department (SCHD), Lakes of Missouri Volunteer Monitoring Program (LMVP), Missouri State University under the supervision of Dr. Robert T. Pavlowski (MSU), University of Missouri - Columbia under the supervision of Dr. John R. Jones (UMC), Springfield City Utilities (CU), City of Springfield Public Works (SPW), and USGS. Although the MDNR included USGS data in its databases, MEC obtained USGS data directly from the USGS National Water Information System (NWIS). Additionally, benthic algae data was obtained directly from MSU since it was absent from the MDNR database.

The geographic coordinates for monitoring sites within James River Basin were collected concurrently with the water quality data. However, not all monitoring sites with water quality data are discussed in this report. Data management and data assessment issues (discussed in Sections 3.2 and 3.3) limited the total number of monitoring sites in the James River Basin to 42. Figure 10 depicts the 42 water quality monitoring stations in the James River Basin.

Brief descriptions of the collection 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, 2005a).

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 17 MDNR water quality monitoring sites within the James River Basin. Water quality parameters collected at these monitoring sites included: temperature, flow, specific conductivity (SC), dissolved oxygen (DO), pH, total nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ammonia (NH3-N), total suspended solids (TSS), biochemical oxygen demand (BOD)[2], carbonaceous biochemical oxygen demand (CBOD), fecal coliform, *Escherichia coli* (*E. coli*), and chloride. The MDNR sample dates ranged from February 2000 to September 2005.

Christian County Health Department

The CCHD samples recreational waters weekly from Memorial Day through Labor Day in collaboration with the Missouri Department of Conservation (MDC) throughout Christian County. Water quality sampling is performed monthly in the fall, winter, and spring. Water quality samples collected by the CCHD in the James River Basin were available from June 1997 to May 2006 from seven monitoring sites. The CCHD agency analyzed these samples for *E. coli* bacteria.

Stone County Health Department

Water quality data collected by SCHD were available from the MDNR database for 7 monitoring sites in the James River Basin. Sample dates ranged from June 1999 to September 2004. The SCHD agency analyzed these samples for *E. coli* bacteria.

Lakes of Missouri Volunteer Program

The LMVP volunteers have been collecting water quality samples primarily from lakes and some streams from around the state since 1992. The goals of the LMVP are:

1. To determine the current water quality of Missouri's lakes based on productivity or trophic state;
2. To monitor for changes in water quality over time; and
3. To educate the public about lake ecology and water quality issues.

[2] The time period for BOD (e.g., 5-day or ultimate) was not specified.

Stream samples collected by the LMVP in the James River Basin were available from April 2004 to July 2005 from three stream monitoring sites. Water quality sample parameters measured included temperature, TN, TP, and TSS.

Missouri State University

Water quality data collected by MSU were available from the MDNR database for 11 monitoring sites in the James River Basin. Sample dates ranged from July 2001 to August 2003. Water quality sample parameters measured included temperature, flow, turbidity, specific conductivity, DO, pH, TN, nitrate plus nitrite, TP, TSS, and chlorophyll *a* (sestonic and benthic).

University of Missouri – Columbia

Water quality data collected by UMC were available from the MDNR database from one site (James River west of Nixa) within the James River Basin. Sample dates from this James River site ranged from July 1999 to December 2003. Water quality sample parameters measured included specific conductivity, TN, TP, alkalinity, volatile suspended solids (VSS), and chlorophyll *a*.

Springfield City Utilities

Water quality data collected by CU were available from the MDNR database for 8 monitoring sites in the James River Basin. Sample dates ranged from January 1985 to December 1998. Water quality sample parameters measured included temperature, specific conductivity, pH, nitrate plus nitrite, TP, TSS, alkalinity, and fecal coliform.

City of Springfield Public Works

Water quality data collected by SPW were available from the MDNR database for 19 monitoring sites in the James River Basin. Sample dates ranged from July 1992 to January 2004. Water quality sample parameters measured included temperature, flow, specific conductivity, DO, pH, TN, TKN, nitrate plus nitrite, TP, orthophosphate, ammonia, and fecal coliform.

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 119 monitoring stations in the James River Basin. USGS water quality data in the James River Basin ranged from December 1937 to September 2004 and includes over 500

parameter codes[3]. USGS water quality data in the James River Basin consists of the following parameter groupings: biological, major inorganics, minor and trace inorganics, nutrients, organics, physical properties, radiochemicals, and sediment.

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 the 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.

[3] **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).

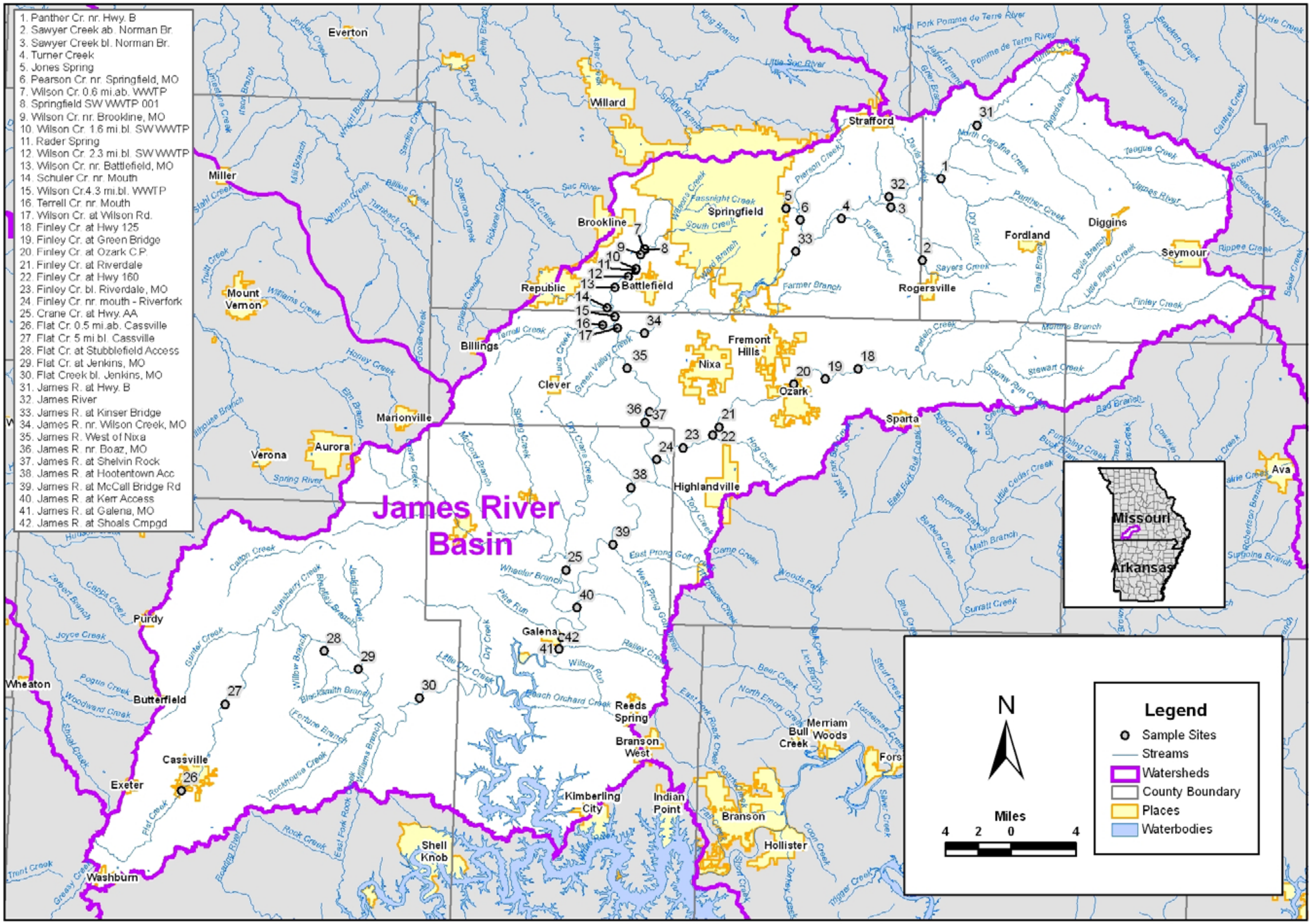

FIGURE 10. Water Quality Monitoring Sites in the James River Basin

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 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 was 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[4]. 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.

[4] 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.

3.3.1 Data Quality

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. 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
University of Missouri Limnology Department	4.5
Missouri State University	4.5
Greene County Health Department	2.5
Christian County Health Department	2.0
Stone County Health Department	1.6

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

3.3.3 Periods of Interest

MEC limited data analysis to water quality sample stations with a minimum of 10 samples for any of the five selected water quality parameters. This "first cut" resulted in 42 candidate sample stations (Figure 10). Based on water quality data from the 42 sample stations, MEC selected an appropriate period of interest for data analysis. MEC's "final cut" of sample stations was based on those with a minimum of 10 samples for any of the five selected parameters for the selected period of interest.

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. Consideration was also given for dates of significant changes in loading in the watershed.

Analysis of TP was limited to sampling dates on or after October 1, 2000. Although Figure 12 indicates TP sampling efforts in the James River Basin appeared to increase around 1993, the Springfield Southwest Wastewater Treatment Plant (WWTP) completed a phosphorus removal upgrades in March 2001. Therefore, the period of interest was set as the beginning of the March 2001 hydrologic water year (i.e., October 1, 2000). Based on this selected period of interest, MEC eliminated the Turner Creek and Sawyer Creek below Norman Branch monitoring stations from consideration for TP analysis.

Analysis of TN and $NO_3 + NO_2$ was limited to sampling dates on or after October 1, 1992. Some limited nitrogen sampling was present in the James River Basin as far back as 1973, however most TN and $NO_3 + NO_2$ sampling apparently began around 1993 (Figures 13 and 14). Therefore, the period of interest for these parameters was therefore set as the beginning of the 1993 hydrologic water year (i.e., October 1, 1992).

Based on this selected period of interest, MEC eliminated the Turner Creek and Sawyer Creek below Norman Branch monitoring stations from consideration for $NO_3 + NO_2$ analysis.

Analysis of sestonic and benthic chlorophyll *a* was limited to sampling dates on or after October 1, 2000. Eleven of the 12 sestonic chlorophyll *a* monitoring stations in the James River Basin began sampling in July 2001 (Figure 15). Since chlorophyll *a* is a response variable to nutrient loading, the 2001 phosphorus removal upgrades to the Springfield Southwest WWTP were also taken into consideration. Therefore, the period of interest for sestonic chlorophyll *a* was set as the beginning of the 2001 hydrologic water year (i.e., October 1, 2000). Where benthic chlorophyll *a* was collected, it was collected concurrent with sestonic chlorophyll *a*; therefore, the period of interest for benthic chlorophyll a was also set as the beginning of the 2001 hydrologic water year (i.e., October 1, 2000).

Analysis of *E. coli* was limited to sampling dates on or after June 19, 1997. With the exception of a small number of samples at one station dating back to 1994, all available *E. coli* samples occur on or after June 19, 1997 (Figure 16).

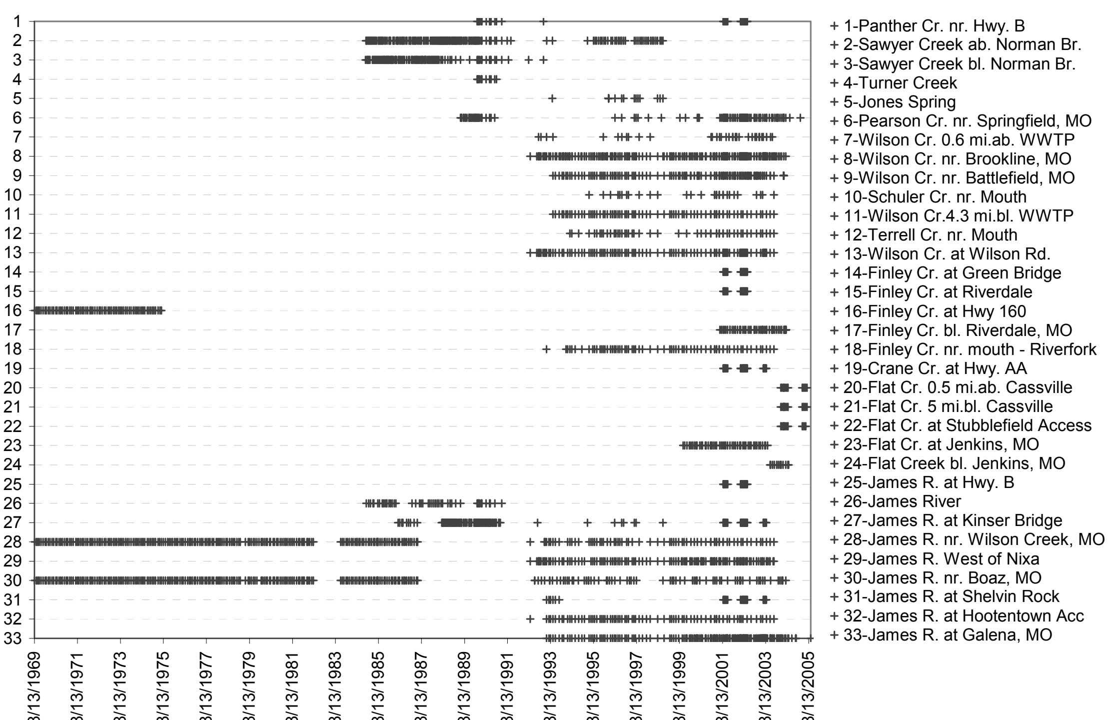

FIGURE 12. Total Phosphorus Sampling Frequency and Period of Record in the James River Basin

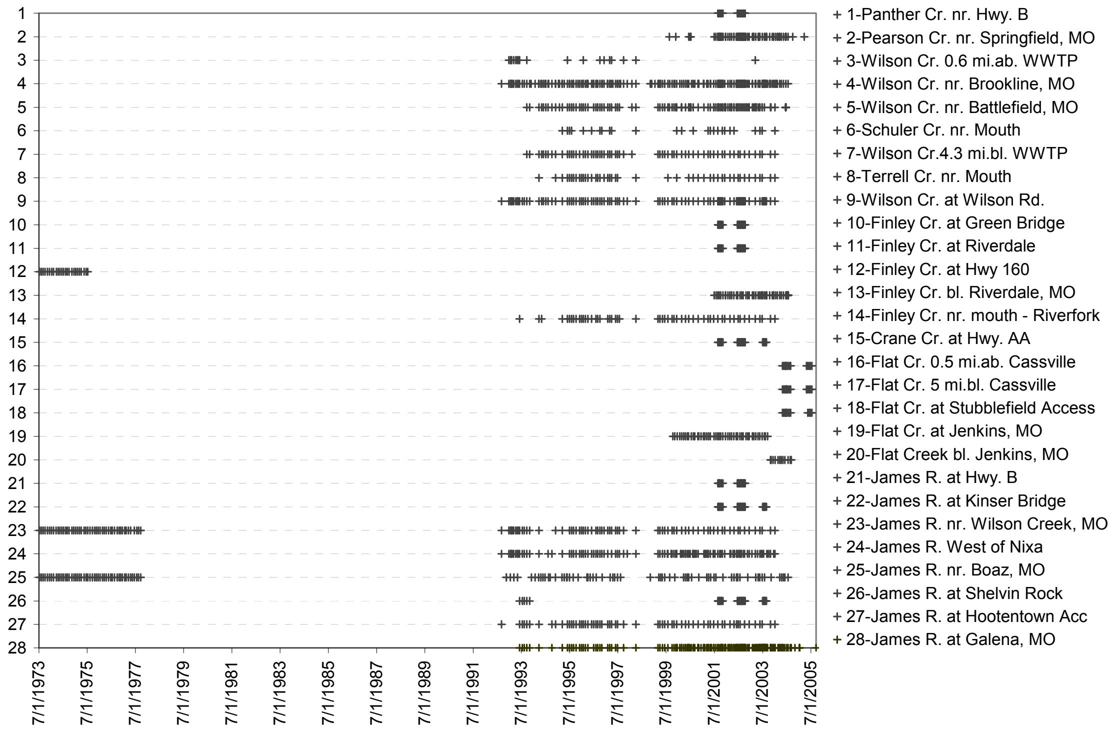

FIGURE 13. Total Nitrogen Sampling Frequency and Period of Record in the James River Basin

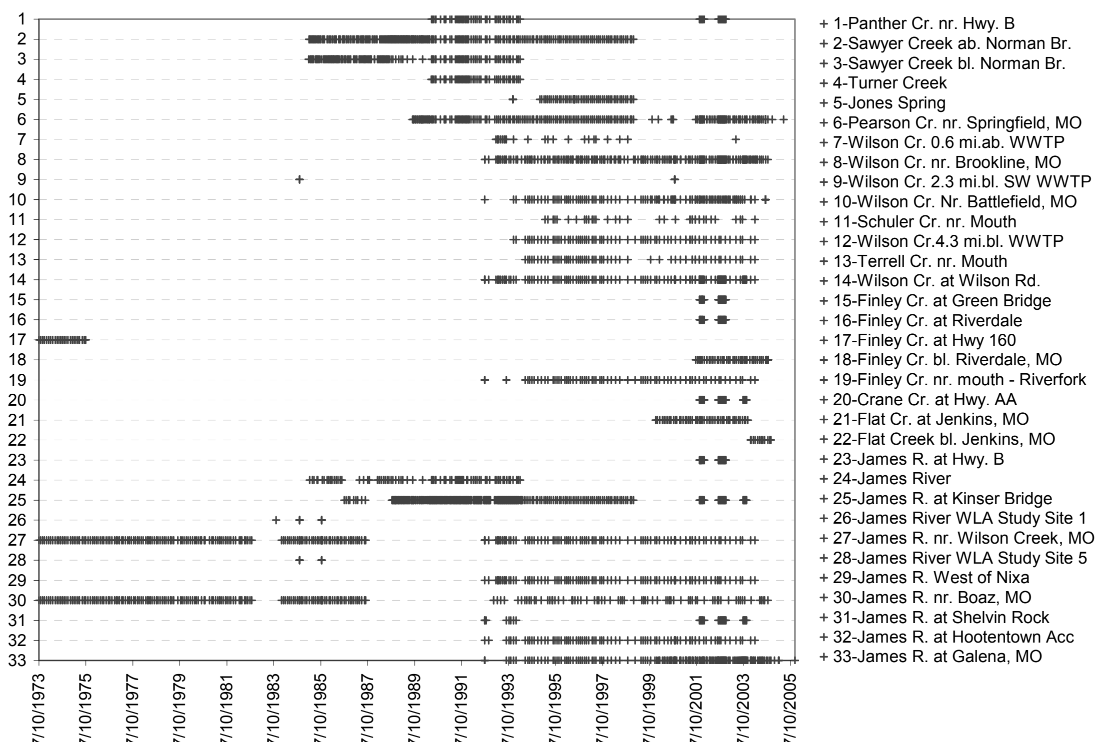

FIGURE 14. Nitrate plus Nitrite Sampling Frequency and Period of Record in the James River Basin

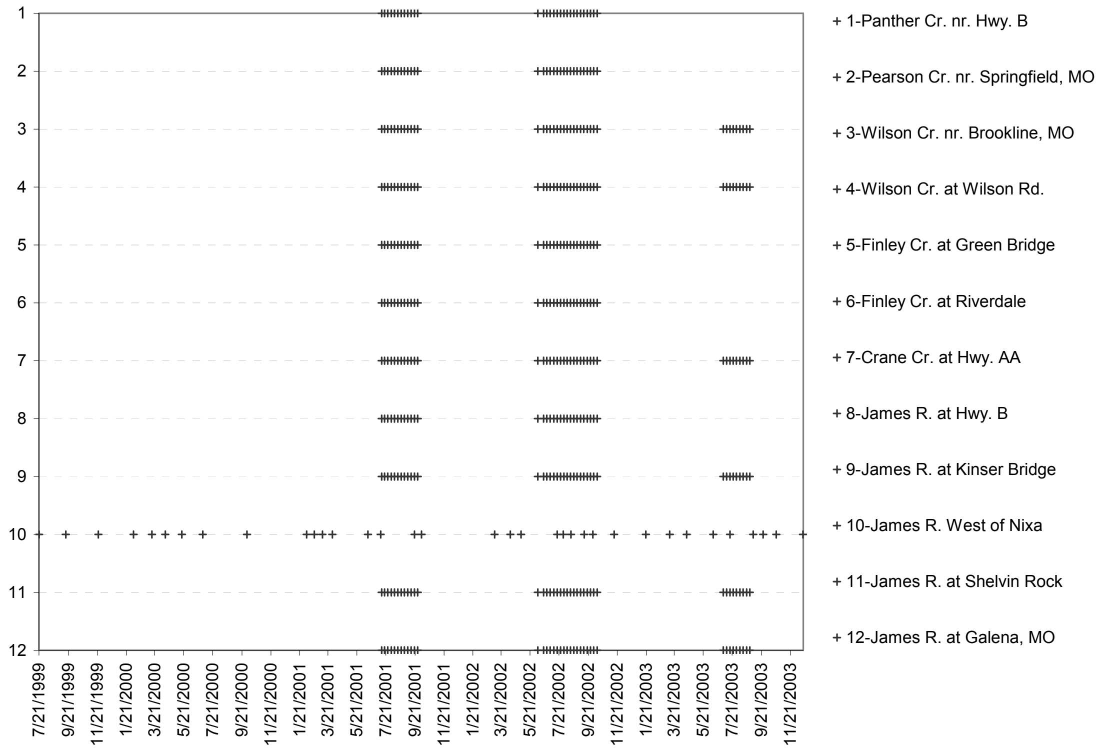

FIGURE 15. Suspended Chlorophyll *a* Sampling Frequency and Period of Record in the James River Basin

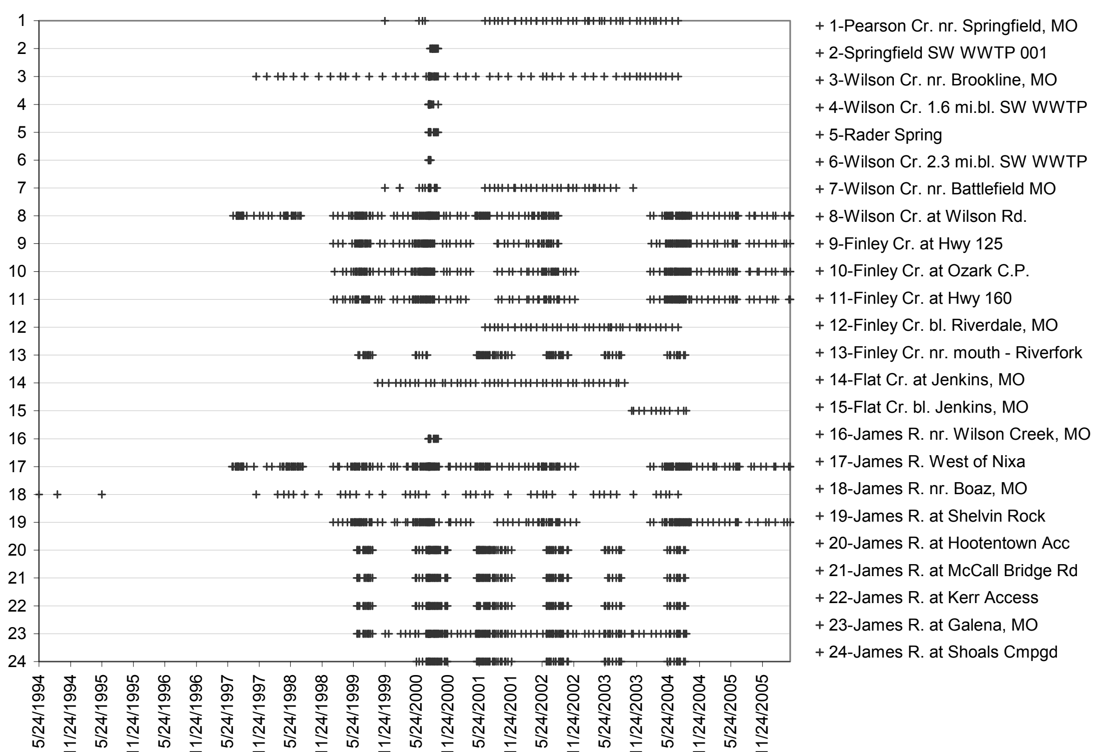

FIGURE 16. *E. coli* Sampling Frequency and Period of Record in the James River Basin

3.3.4 Data Analysis

Water quality data in the James 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 James 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.

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)[5] 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)[6] limits the comparability,

[5] 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).

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

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.

4. WATER QUALITY SUMMARIES AND STATISTICS

A discussion and characterization of nutrients, suspended chlorophyll *a* and *E. coli* in the James River Basin are presented below. Basic summary statistics including sample count, 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[7] are considered impaired due to nutrients. The effects of cultural eutrophication can include the following (MDNR, 2005b):

- 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, 2005b; EPA, 2000). A discussion of causal (TP, TN, NO_2+NO_3) and response (chlorophyll *a*) variables observed in the James 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[8] state in lotic[9] 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

[7] Section 303(d) of the Clean Water Act and its accompanying regulations (CFR Part 130 Section 7) requires each state to identify waterbodies (i.e., lakes, reservoirs, rivers, streams, and wetlands) with impaired beneficial uses which require load allocations, waste load allocations, and total maximum daily loads.
[8] 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.
[9] Lotic refers to flowing water.

common cause of eutrophication in reservoirs, lakes and streams; Dodds *et al.* (2006) cautions against making this assumption a priori for any particular stream.

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 James River Basin) is 6.6 µg/L[10] (EPA, 2000). 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 MDNR also recommends that the in-stream TP level for the James River should not exceed 75 µg/L (MDNR, 2001). The RTAG and MDNR recommendations are 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.

Phosphorus reduction efforts by the City of Springfield are evident in annual geomean TP levels at the James River near Boaz water quality station. The James River near Boaz station is located approximately 13.5 miles downstream from the Springfield Southwest WWTP and represents one the most complete long-term TP monitoring stations in the James River Basin. Figure 17 illustrates that TP levels at the Boaz station have been declining since the early 1970s. A significant decrease in TP levels coincides with the completion of phosphorus removal upgrades to the Springfield Southwest WWTP in 2001.

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

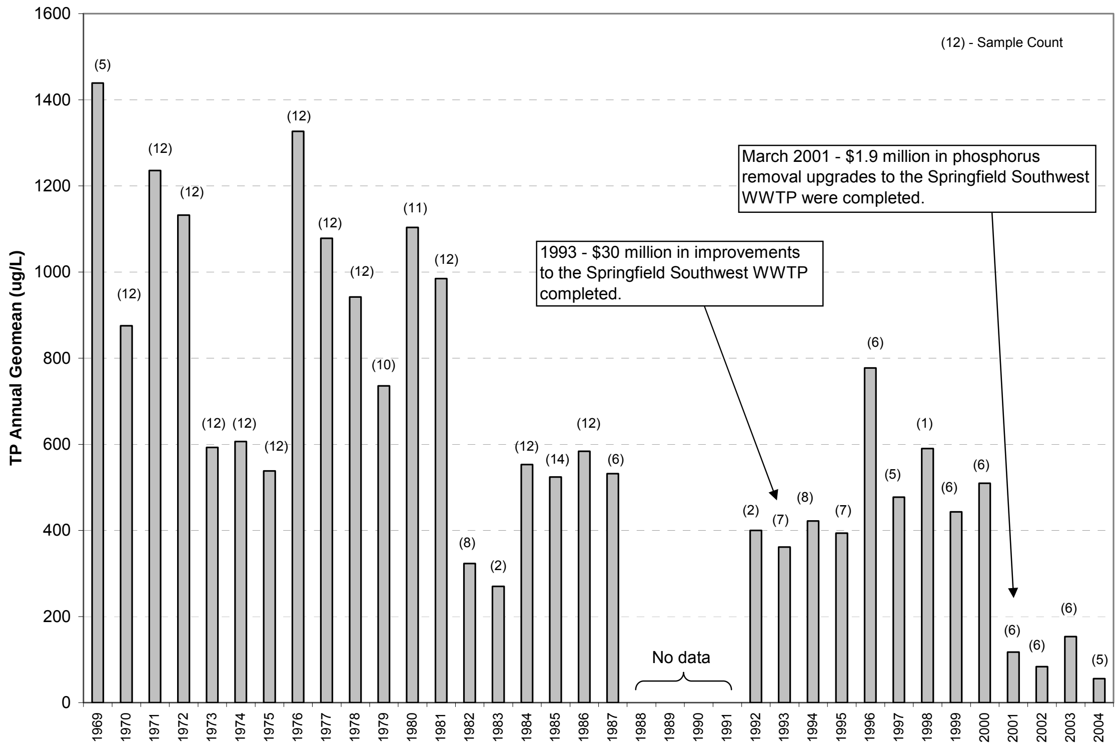

FIGURE 17. Total Phosphorus Annual Geomeans Measured in the James River at the Boaz Station

Wilson Creek had the highest observed TP geomeans in the James River Basin, with values ranging from 165 μg/L above the Springfield's Southwest WWTP to 343 μg/L approximately 4 miles below the plant (Table 8 and Figure 18). The elevated levels of TP in Wilson Creek are likely due to its close downstream proximity to the Springfield metro area and the Springfield Southwest WWTP effluent. TP geomeans in the James River were lowest upstream of the Wilson Creek confluence and the Springfield city limits, where geomeans ranged from 20 μg/L to 38 μg/L. TP geomeans in James River ranged from 103 μg/L to 162 μg/L downstream of the Wilson Creek. TP geomeans along the Finley Creek branch of the James River increased from 14 μg/L upstream of Ozark to 265 μg/L downstream of Ozark. TP geomeans along Flat Creek increased from 24 μg/L upstream of Cassville to 55 μg/L downstream of Cassville. TP geomeans were generally the lowest along Panther Creek, Pearson Creek, Crane Creek, and Flat Creek, where geomeans ranged from 21 μg/L to 55 μg/L.

A boxplot comparison of TP values further illustrates that phosphorus levels increase near major urban areas (e.g., Springfield, Nixa, and Ozark) (Figure 19). Eleven of the 27 water quality monitoring stations in the James River Basin, which were largely outside the influence of urban areas, had interquartile TP ranges below the Dodds *et al.* (1998) eutrophic threshold value of 75 μg/L. Figure 20 illustrates that the James River at Galena water quality station (the most downstream James River station with TP values) is ranked near the middle of all James River Basin stations with regards to TP geomeans.

TABLE 8. Selected Statistics for the James 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)	Percentiles 25th (µg/L)	Percentiles 75th (µg/L)	Percentiles 90th (µg/L)
2368/0.7	Panther Cr. nr. Hwy. B	8/22/2001	10/9/2002	28	42	43	40	15	106	18	26	36	47	57
7050690	Pearson Cr. nr. Springfield, MO	6/27/2001	3/24/2005	85	40	67	48	18	430	77	20	30	60	126
2375/7.3	Wilson Cr. 0.6 mi.ab. WWTP	1/29/2001	12/3/2003	24	165	202	165	30	580	125	72	125	300	327
7052152	Wilson Cr. nr. Brookline, MO	10/27/2000	7/22/2004	98	341	410	346	67	2,862	366	211	262	430	543
7052160	Wilson Cr. Nr. Battlefield, MO	10/30/2000	6/17/2004	68	275	453	315	60	2,460	508	145	178	415	1,031
3368/0.1	Schuler Cr. nr. Mouth	3/29/2001	1/2/2004	16	102	118	88	20	400	95	25	68	140	200
2375/2.4	Wilson Cr.4.3 mi.bl. WWTP	10/30/2000	1/2/2004	25	300	506	343	140	3,340	679	160	170	380	1,000
2376/0.7	Terrell Cr. nr. Mouth	10/30/2000	1/2/2004	23	190	197	156	20	550	133	92	110	216	345
2375/1.0	Wilson Cr. at Wilson Rd.	10/30/2000	1/2/2004	63	210	259	222	60	1,481	191	136	165	317	369
2352/13.6	Finley Cr. at Green Bridge	8/22/2001	10/9/2002	27	17	18	14	2	79	15	4	13	21	24
2352/4.0	Finley Cr. at Riverdale	8/22/2001	10/9/2002	28	244	251	235	101	460	89	148	189	309	370
7052345	Finley Cr. bl. Riverdale, MO	6/27/2001	7/25/2004	55	130	151	114	20	790	124	40	70	200	278
2352/0.3	Finley Cr. nr. mouth - Riverfork	10/30/2000	1/2/2004	25	260	271	190	25	1,130	243	52	130	300	472
2381/0.9	Crane Cr. at Hwy. AA	8/22/2001	8/27/2003	36	38	39	37	17	61	11	27	32	45	54
2397/2.8	Flat Cr. 0.5 mi.ab. Cassville	4/25/2004	7/17/2005	14	23	24	24	18	37	4	21	22	26	28
2387/37.1	Flat Cr. 5 mi.bl. Cassville	4/25/2004	7/17/2005	15	60	58	55	32	87	19	36	40	71	82
2387/23.7	Flat Cr. at Stubblefield Access	4/25/2004	6/26/2005	13	29	36	32	15	102	22	24	27	35	52
7052800	Flat Cr. at Jenkins, MO	10/23/2000	9/15/2003	36	30	36	32	20	180	26	20	30	40	40
7052820	Flat Creek bl. Jenkins, MO	10/27/2003	9/7/2004	12	20	22	21	20	40	6	20	20	20	20
2365/19.7	James R. at Hwy. B	8/22/2001	10/9/2002	28	22	24	20	1	57	13	13	17	29	41
2365/2.3	James R. at Kinser Bridge	8/22/2001	8/27/2003	37	37	43	38	14	151	26	23	28	49	67
7051600	James R. nr. Wilson Creek, MO	10/30/2000	1/2/2004	25	160	182	143	25	550	124	44	120	210	327
2362/8.1	James R. West of Nixa	10/1/2000	1/2/2004	54	144	392	158	25	10,740	1,447	67	87	239	324
7052250	James R. nr. Boaz, MO	11/8/2000	7/21/2004	24	115	119	103	30	300	64	43	70	153	184
2362/2.6	James R. at Shelvin Rock	8/22/2001	8/27/2003	36	141	146	140	77	231	39	95	120	174	195
2347/27.4	James R. at Hootentown Acc	10/30/2000	1/2/2004	26	188	209	162	25	757	156	65	110	253	290
7052500	James R. at Galena, MO	10/23/2000	9/16/2005	138	105	158	110	20	2,100	220	40	79	150	252

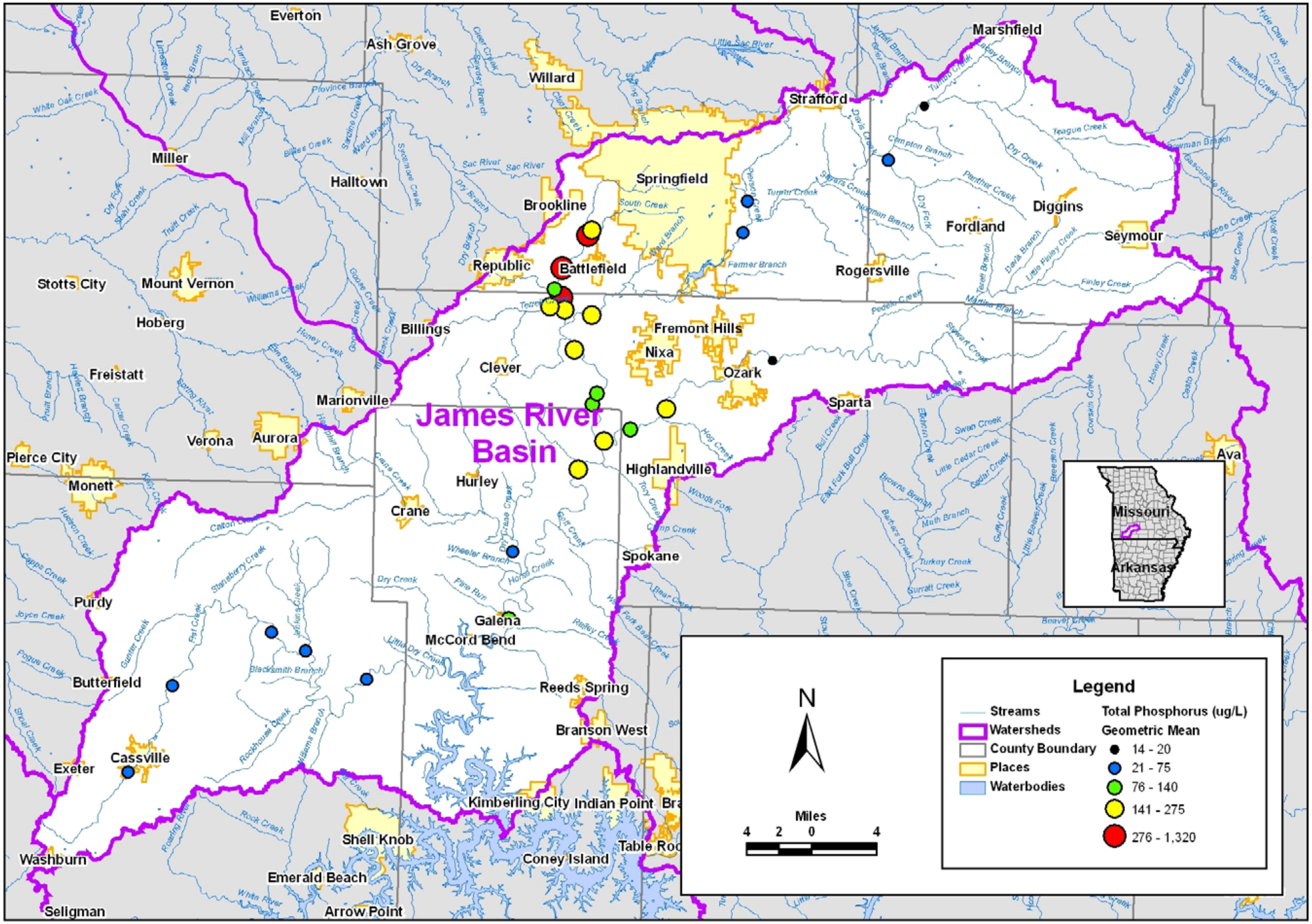

FIGURE 18. Total Phosphorus Geometric Means at Select Monitoring Stations in the James River Basin

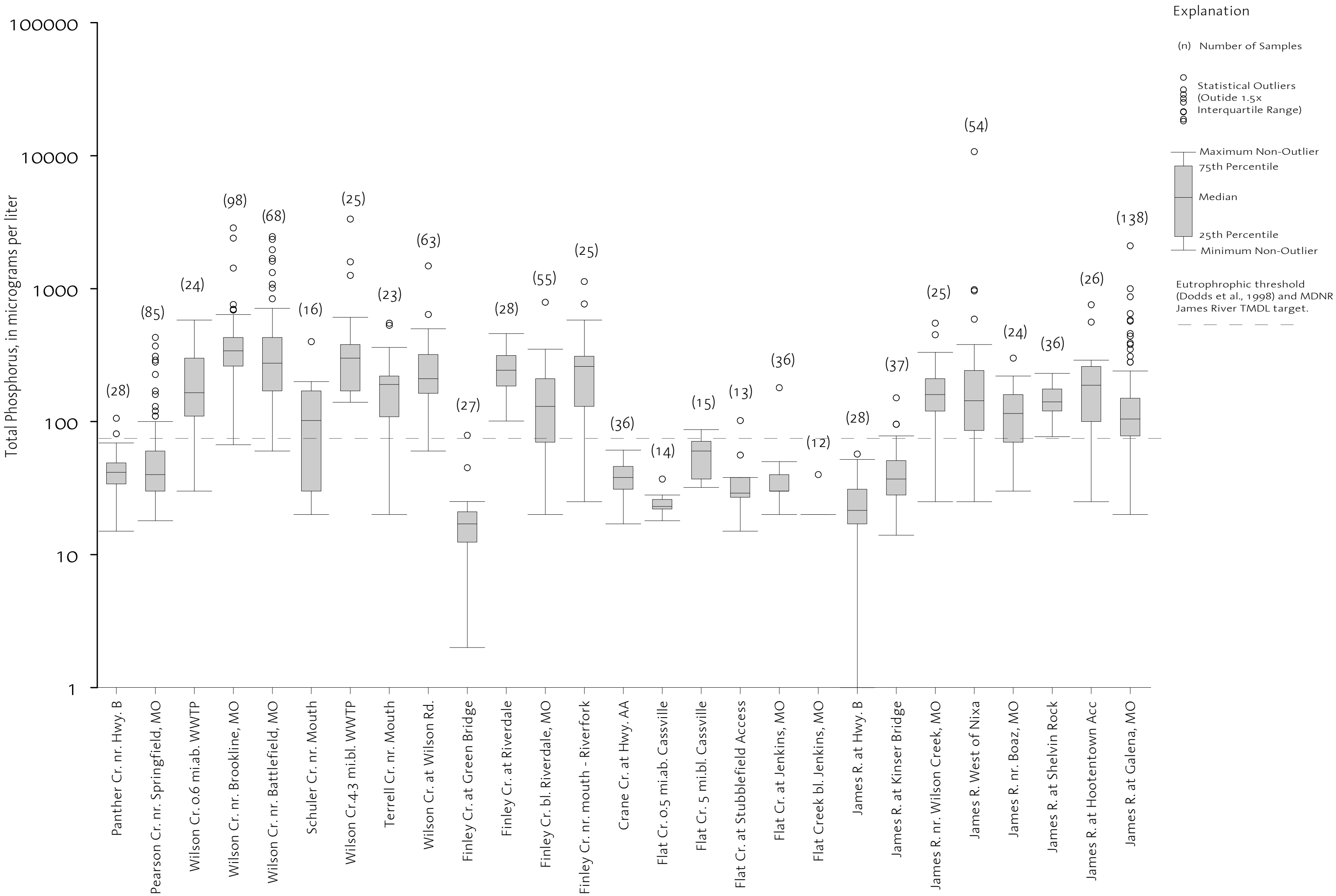

FIGURE 19. Box Plot of Total Phosphorus in the James River Basin (October 1, 1992 to September 16, 2005) Compared to Eutrophication Threshold and MDNR James River TMDL Target

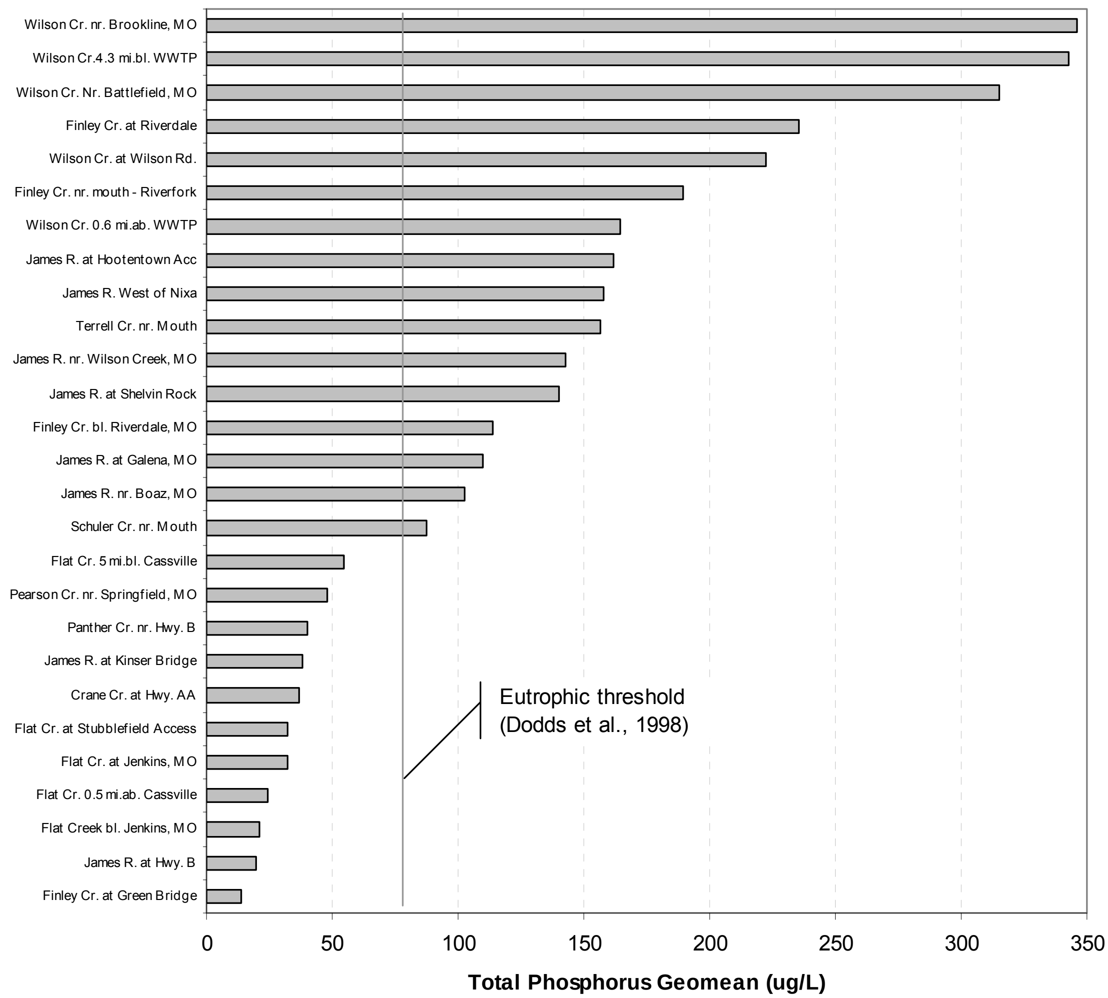

FIGURE 20. Total Phosphorus Geomeans in the James River Basin (10/1/2000 – 9/16/2005)

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[11] 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

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

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 James River Basin) is 379 µg/L[12] (EPA, 2000). 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). Additionally, MDNR recommends that the in-stream TN level for the James River should not exceed 1,500 µg/L (MDNR, 2001). 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 NO3-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 James River near Boaz water quality station (Figure 21). 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

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

record for the Boaz station spanned from 1973 to 2004; however, no TN data are available from 1978 through 1991.

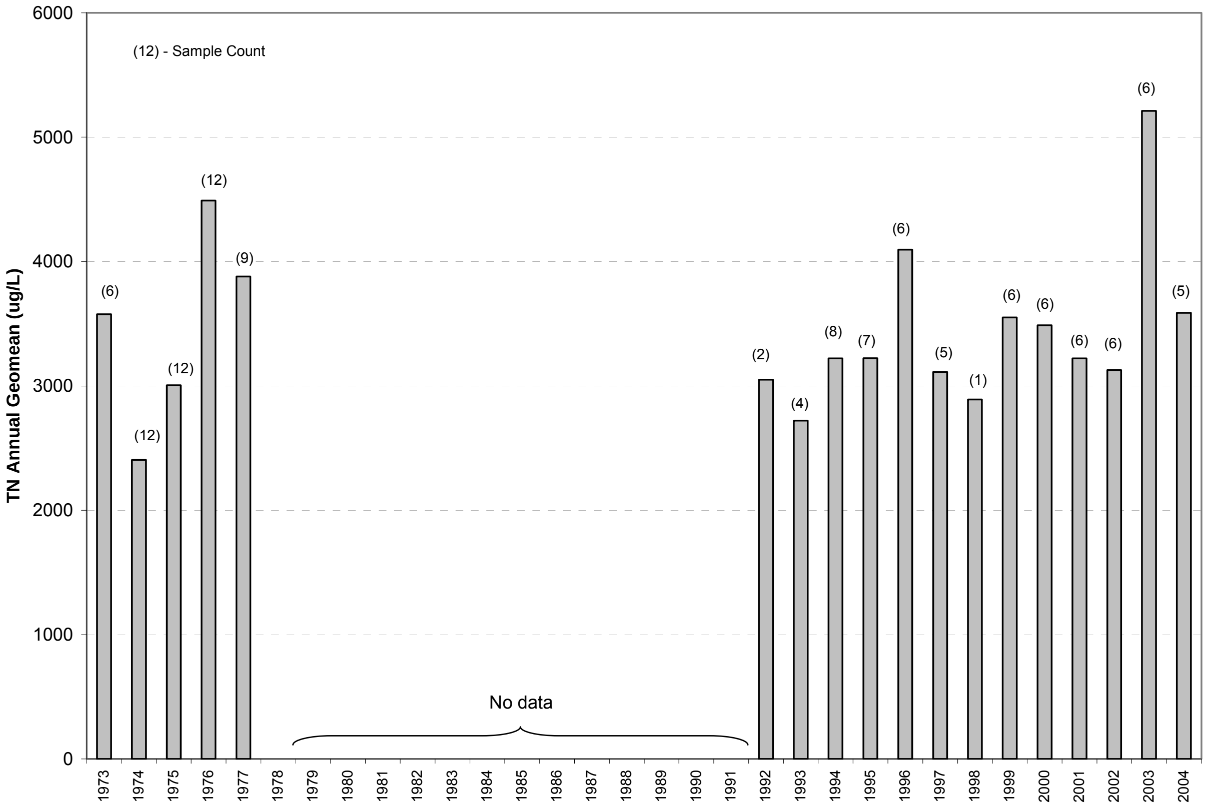

FIGURE 21. Total Nitrogen Annual Geomeans Measured in the James River at the Boaz Station

As with phosphorus, the highest levels of TN geomeans in the James River Basin were observed in Wilson Creek. TN geomeans in Wilson Creek ranged from 3,005 μg/L above the Springfield's Southwest WWTP to 10,867 μg/L at the Brookline station (Table 9 and Figure 22). The elevated TN levels at the Brookline station and its relatively close proximity to the Southwest WWTP indicates that wastewater effluent increases nitrogen levels within Wilson Creek and the James River. TN geomeans along the James River ranged from 346 μg/L at its most upstream station to 4,127 μg/L at Shelvin Rock. Along the Finley Creek, TN geomeans increased from 635 μg/L upstream of Ozark to 2,185 μg/L just below Ozark at Riverdale. TN geomeans were generally the lowest along Panther Creek, Flat Creek, Finley Creek and the upper reaches of the James River.

A boxplot comparison of TN values suggests most water quality samples collected in the James River Basin exceed the Dodds *et al.* (1998) eutrophic threshold value of 1,500 μg/L (Figures 23 and 24). Only four of the 27 water quality monitoring stations in the James River Basin had interquartile ranges below the suggested eutrophic threshold value. The greatest concentrations of TN were observed in the vicinity of Springfield, Nixa, and Ozark; however, TN levels outside the influence of urban areas were also largely above the Dodds *et al.* (1998) eutrophic threshold.

TABLE 9. Selected Statistics for the James 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)
2368/0.7	Panther Cr. nr. Hwy. B	8/22/2001	10/9/2002	28	632	2,023	693	193	20,280	5,094	265	331	857	1,516
7050690	Pearson Cr. nr. Springfield, MO	8/18/1999	3/24/2005	89	2,590	2,973	2,694	1,450	20,240	2,302	1,859	2,350	3,000	3,290
2375/7.3	Wilson Cr. 0.6 mi.ab. WWTP	12/22/1992	3/13/2003	19	2,930	3,466	3,005	1,580	13,440	2,596	2,024	2,155	3,580	4,594
7052152	Wilson Cr. nr. Brookline, MO	12/22/1992	7/22/2004	189	10,500	12,682	10,867	356	97,500	10,293	6,792	8,580	13,910	17,740
7052160	Wilson Cr. Nr. Battlefield, MO	9/21/1993	6/17/2004	116	6,575	7,945	6,858	780	32,170	4,771	3,800	4,970	9,768	12,350
3368/0.1	Schuler Cr. nr. Mouth	3/10/1995	1/2/2004	26	2,773	3,368	2,909	1,550	17,180	2,940	2,065	2,218	3,186	3,848
2375/2.4	Wilson Cr.4.3 mi.bl. WWTP	9/21/1993	1/2/2004	65	7,020	9,839	7,601	2,630	114,320	13,828	3,702	5,690	10,710	14,466
2376/0.7	Terrell Cr. nr. Mouth	3/24/1994	1/2/2004	46	3,150	4,947	3,643	1,320	35,010	5,815	2,125	2,503	4,010	11,530
2375/1.0	Wilson Cr. at Wilson Rd.	12/22/1992	1/2/2004	114	7,198	9,541	7,456	1,200	91,780	10,772	3,735	5,488	9,335	13,317
2352/13.6	Finley Cr. at Green Bridge	8/22/2001	10/9/2002	28	548	1,465	635	258	17,250	3,472	280	375	678	1,714
2352/4.0	Finley Cr. at Riverdale	8/22/2001	10/9/2002	28	1,951	3,481	2,185	205	24,040	5,634	1,460	1,767	2,282	2,854
7052345	Finley Cr. bl. Riverdale, MO	6/27/2001	7/25/2004	55	1,690	1,725	1,693	1,120	2,760	343	1,352	1,495	1,895	2,158
2352/0.3	Finley Cr. nr. mouth - Riverfork	6/4/1993	1/2/2004	56	1,635	3,388	2,054	740	30,800	5,587	1,062	1,455	2,288	5,170
2381/0.9	Crane Cr. at Hwy. AA	8/22/2001	8/27/2003	36	2,296	3,033	2,453	1,550	19,450	3,479	1,862	1,981	2,478	2,680
2397/2.8	Flat Cr. 0.5 mi.ab. Cassville	4/25/2004	7/17/2005	14	2,590	2,616	2,612	2,410	2,960	159	2,445	2,495	2,673	2,826
2387/37.1	Flat Cr. 5 mi.bl. Cassville	4/25/2004	7/17/2005	15	2,000	2,031	2,011	1,570	2,810	306	1,672	1,920	2,110	2,346
2387/23.7	Flat Cr. at Stubblefield Access	4/25/2004	7/17/2005	13	1,800	2,039	1,925	1,210	3,750	770	1,264	1,530	2,140	3,190
7052800	Flat Cr. at Jenkins, MO	10/12/1999	9/15/2003	48	1,740	1,755	1,674	990	3,510	555	1,067	1,358	1,963	2,568
7052820	Flat Creek bl. Jenkins, MO	10/27/2003	9/7/2004	12	1,485	1,376	1,085	80	2,520	684	611	1,018	1,730	2,066
2365/19.7	James R. at Hwy. B	8/22/2001	10/9/2002	27	298	1,244	346	68	16,750	3,516	111	177	432	775
2365/2.3	James R. at Kinser Bridge	8/22/2001	8/27/2003	37	1,172	2,060	1,234	501	23,120	4,121	665	859	1,318	1,680
7051600	James R. nr. Wilson Creek, MO	12/22/1992	1/2/2004	71	1,700	4,044	2,052	490	36,720	7,195	800	1,155	2,260	9,970
2362/8.1	James R. West of Nixa	12/22/1992	1/2/2004	112	3,670	4,870	4,086	1,560	29,680	3,819	2,102	2,765	5,703	8,144
7052250	James R. nr. Boaz, MO	11/17/1992	7/21/2004	68	3,090	3,795	3,451	1,750	13,640	1,942	2,170	2,508	4,638	6,052
2362/2.6	James R. at Shelvin Rock	6/4/1993	8/27/2003	41	3,927	4,750	4,127	2,100	22,430	3,547	2,540	3,146	5,039	5,894
2347/27.4	James R. at Hootentown Acc	6/4/1993	1/2/2004	64	2,925	4,429	3,361	810	30,260	4,968	1,970	2,395	3,823	6,824
7052500	James R. at Galena, MO	6/4/1993	9/16/2005	184	2,308	2,886	2,442	670	27,050	2,869	1,661	1,948	2,805	3,449

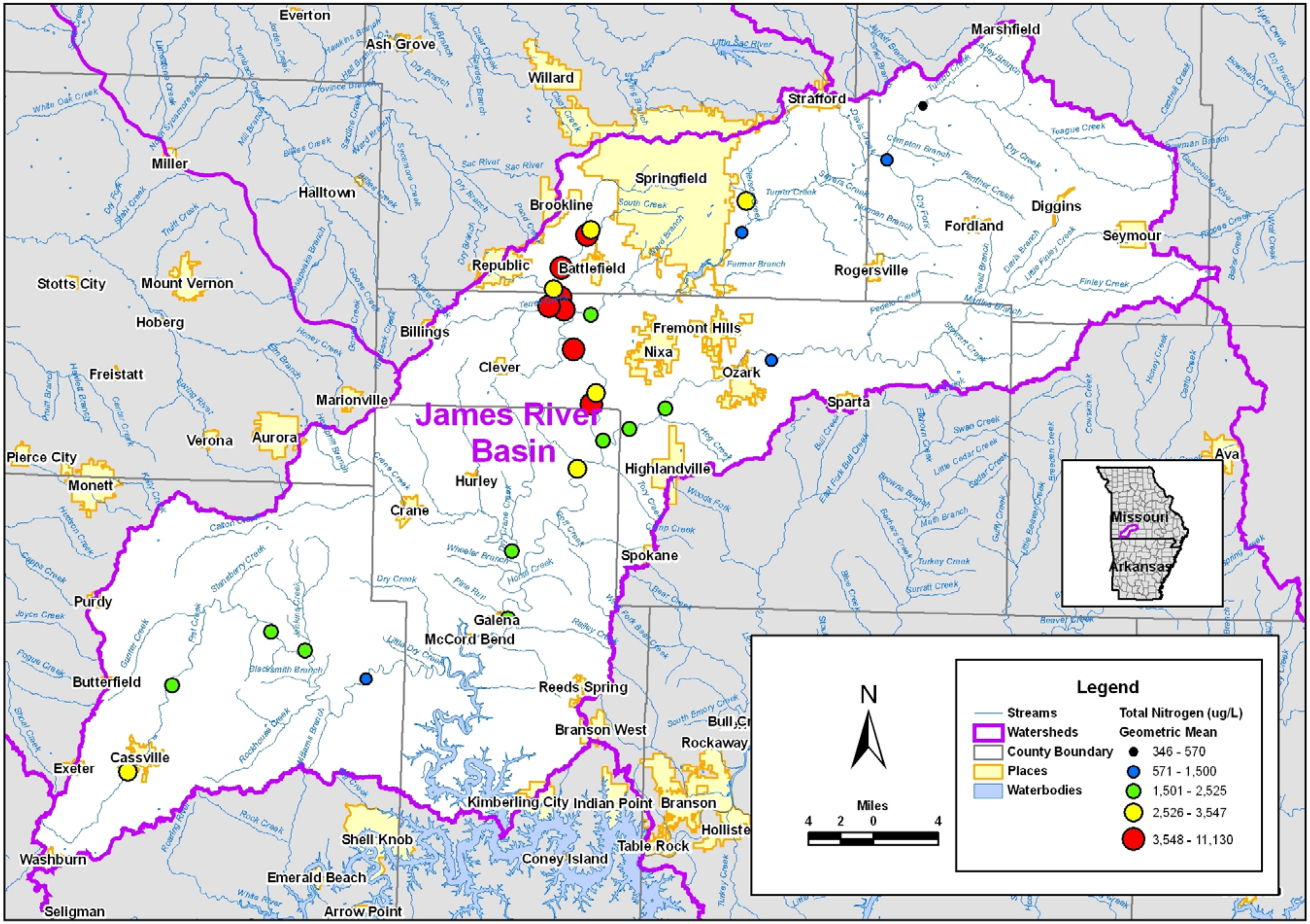

FIGURE 22. Total Nitrogen Geometric Means at Select Monitoring Stations in the James River Basin

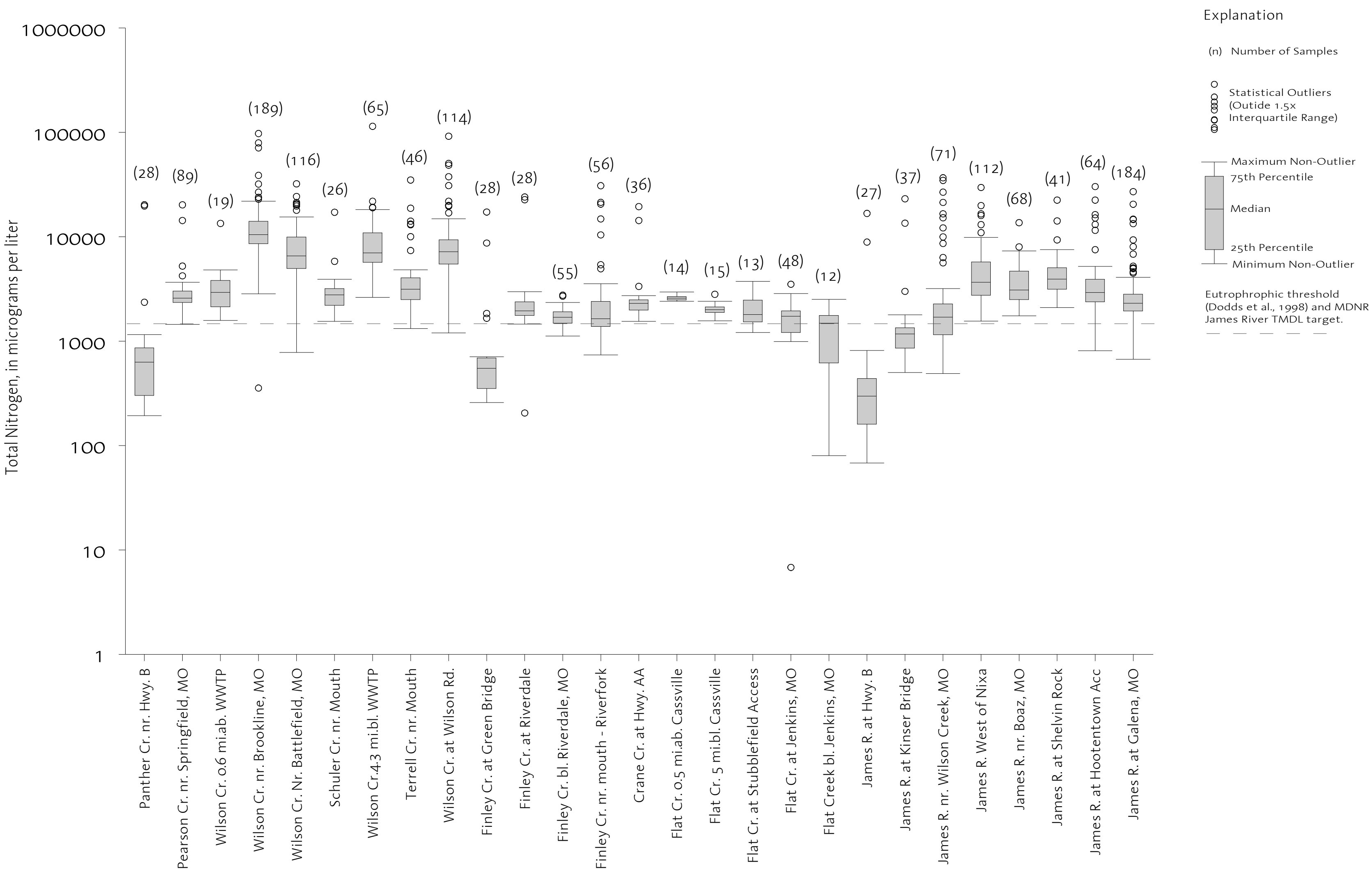

FIGURE 23. Box Plot of Total Nitrogen in the James River Basin (October 1, 1992 to September 16, 2005) Compared to Eutrophication Threshold and MDNR James River TMDL Target

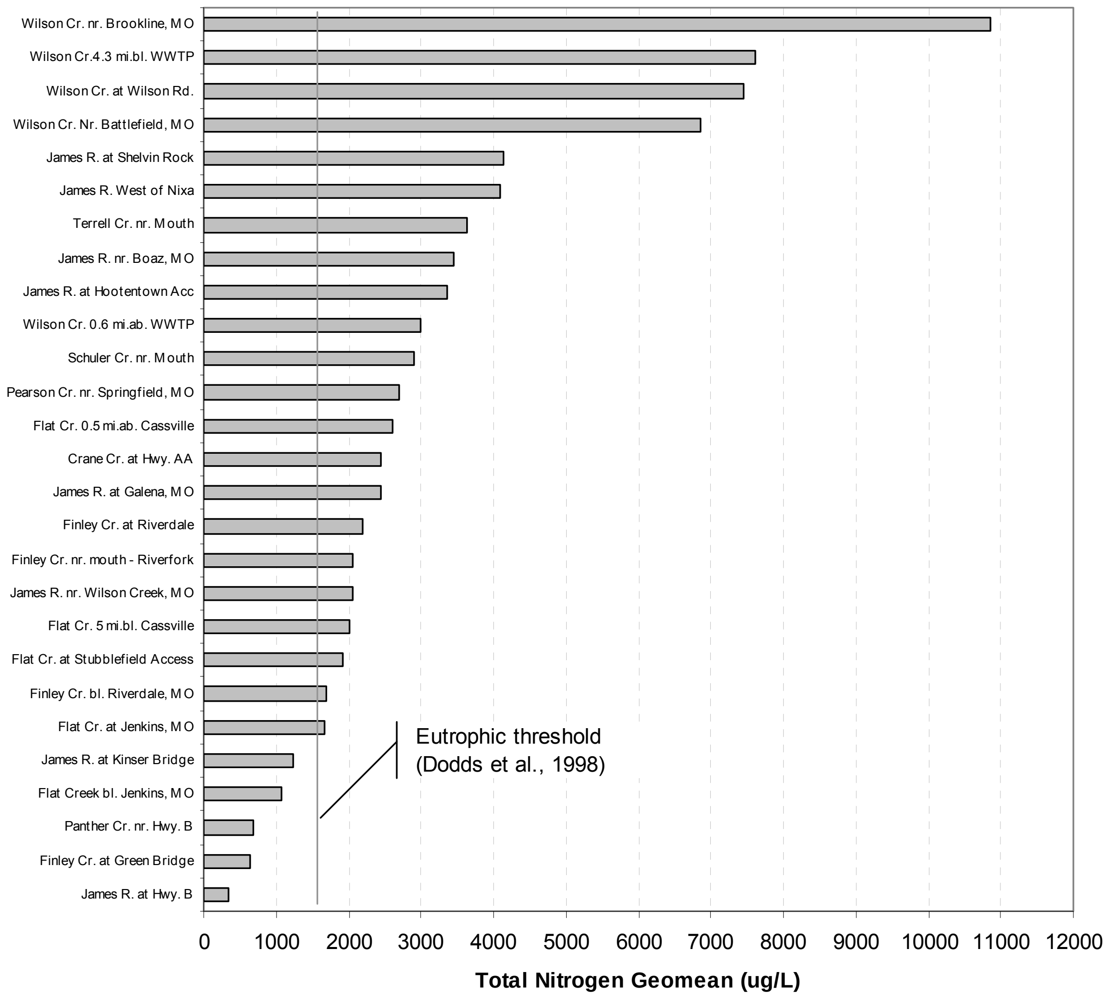

FIGURE 24. Total Nitrogen Geomeans in the James River Basin (10/1/1992 – 9/16/2005)

4.1.2.2 Nitrate plus Nitrite Nitrogen

The annual NO_2+NO_3 geomean concentrations at the James River near Boaz water quality station suggest no obvious trend (Figure 25). The data appears to be highly variable with periods of spiking where NO_2+NO_3 annual geomean values jumped over 1,000 µg/L in 1978, 1980 and 2003. The available NO_2+NO_3 period of record for the Boaz station spanned from 1973 to 2004, however no NO_2+NO_3 data were available from 1988 through 1991.

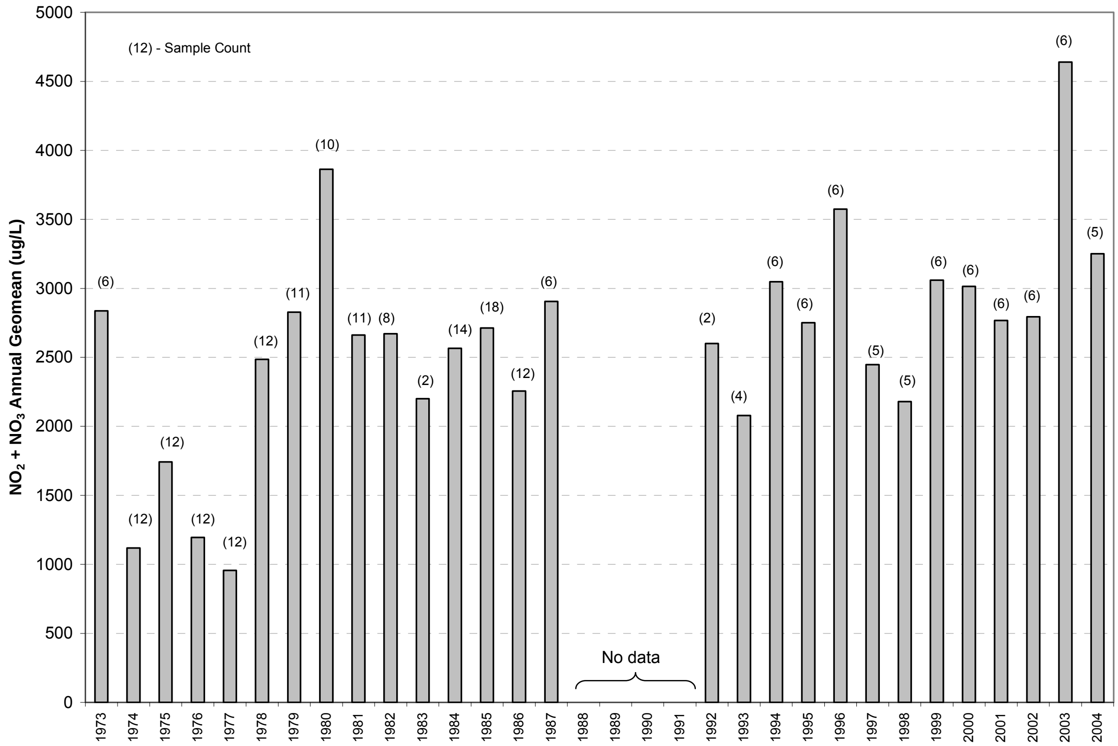

FIGURE 25. Nitrate plus Nitrite Nitrogen Annual Geomeans in the James River at the Boaz Station

The spatial patterns observed with the NO_2+NO_3 data closely mimicked the TN data. As with TN, the highest levels of NO_2+NO_3 were observed in Wilson Creek where geomeans in Wilson Creek ranged from 1,784 µg/L above the Springfield's Southwest WWTP to 8,230 µg/L at the Brookline station (Table 10 and Figure 26). NO_2+NO_3 geomeans along the James River ranged from 132 µg/L at its most upstream station to 3,904 µg/L at Shelvin Rock. Along the Finley Branch, NO_2+NO_3 geomeans increased from 510 µg/L upstream of Ozark to 2,185 µg/L just below Ozark at Riverdale. NO_2+NO_3 geomeans were generally the lowest along Panther Creek, Flat Creek, Finley Creek and the upper reaches of the James River.

Concentrations of NO_2+NO_3 trend upward in the James River as water flows from the Highway B station to the West of Nixa station (Figure 27). The West of Nixa station is located approximately 2.2 miles downstream from the Wilson Creek confluence. Wilson Creek had the four highest ranking water quality stations in terms of NO_3+NO_2 geomean concentrations (Figure 28). Downstream of the West of Nixa station, NO_3+NO_2 levels in the James River appear to initially level out and then decline slightly before reaching the Galena station.

TABLE 10. Selected Statistics for the James River Basin – Nitrate plus Nitrite Nitrogen

Site Number	Station Name	BeginDate	EndDate	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)
2368/0.7	Panther Cr. nr. Hwy. B	12/14/1992	10/9/2002	41	620	1667	598	10	21320	4392	200	310	930	1308
SRC090	Sawyer Creek ab. Norman Br.	12/14/1992	11/2/1998	72	2608	2708	2540	736	5820	961	1679	2041	3153	3891
SRC330	Sawyer Creek bl. Norman Br.	12/14/1992	1/5/1994	13	1169	1242	1177	717	1888	413	761	838	1657	1688
TNC130	Turner Creek	12/7/1992	1/3/1994	14	3135	3145	3106	2484	4202	524	2582	2650	3403	3828
JNS000	Jones Spring	9/13/1993	11/2/1998	76	2877	2747	2604	154	4046	695	1789	2297	3228	3535
7050690	Pearson Cr. nr. Springfield, MO	12/7/1992	3/24/2005	162	2312	2498	2293	1030	25380	2080	1704	1945	2609	2905
2375/7.3	Wilson Cr. 0.6 mi.ab. WWTP	12/22/1992	3/13/2003	23	1800	2020	1784	500	6770	1232	1134	1440	2165	2598
7052152	Wilson Cr. nr. Brookline, MO	12/22/1992	7/22/2004	210	8765	9885	8230	450	80800	7960	4306	6470	11600	15000
7052160	Wilson Cr. Nr. Battlefield, MO	9/21/1993	6/17/2004	130	5845	6260	5382	90	19400	3164	3002	4298	8157	10610
3368/0.1	Schuler Cr. nr. Mouth	1/26/1995	1/2/2004	36	2640	2618	2484	1080	5775	888	1720	1885	3063	3615
2375/2.4	Wilson Cr.4.3 mi.bl. WWTP	9/21/1993	1/2/2004	75	6190	8203	6273	960	114000	12812	3218	4610	8730	10620
2376/0.7	Terrell Cr. nr. Mouth	3/24/1994	1/2/2004	63	2690	3111	2708	310	12830	1979	1744	2215	3410	4206
2375/1.0	Wilson Cr. at Wilson Rd.	12/22/1992	1/2/2004	131	5730	7323	5728	680	89500	8952	2950	4425	8201	10110
2352/13.6	Finley Cr. at Green Bridge	8/22/2001	10/9/2002	27	440	1393	510	180	16440	3435	190	220	625	1504
2352/4.0	Finley Cr. at Riverdale	8/22/2001	10/9/2002	28	1890	3529	2185	710	25110	6110	1460	1603	2270	2589
7052345	Finley Cr. bl. Riverdale, MO	6/27/2001	7/25/2004	55	1320	1413	1373	870	2550	354	1028	1115	1635	1858
2352/0.3	Finley Cr. nr. mouth - Riverfork	6/4/1993	1/2/2004	74	1195	1269	1154	100	2930	514	663	920	1588	1818
2381/0.9	Crane Cr. at Hwy. AA	8/22/2001	8/27/2003	36	2135	2907	2328	1450	19460	3445	1677	1864	2430	2645
7052800	Flat Cr. at Jenkins, MO	10/12/1999	9/15/2003	48	1670	1637	1553	850	3420	545	958	1208	1890	2296
7052820	Flat Creek bl. Jenkins, MO	10/27/2003	9/7/2004	12	1400	1293	939	30	2420	669	533	943	1648	1949
2365/19.7	James R. at Hwy. B	8/22/2001	10/9/2002	27	100	777	132	0	15100	2877	22	60	250	732
JMR075	James River	12/14/1992	1/5/1994	13	757	776	711	314	1244	318	417	516	1076	1160
2365/2.3	James R. at Kinser Bridge	11/30/1992	8/27/2003	154	1050	1288	1014	300	24340	2236	594	788	1265	1561
7051600	James R. nr. Wilson Creek, MO	12/22/1992	1/2/2004	92	1110	2101	1156	100	36000	5199	651	803	1615	2072
2362/8.1	James R. West of Nixa	12/22/1992	1/2/2004	95	3090	3810	3145	390	19100	2561	1530	2220	4970	6970
7052250	James R. nr. Boaz, MO	11/17/1992	7/21/2004	73	2640	3309	2940	1100	13000	1874	1800	2200	3980	5508
2362/2.6	James R. at Shelvin Rock	6/4/1993	8/27/2003	41	3990	4617	3904	1640	22340	3533	2140	2730	5092	7550
2347/27.4	James R. at Hootentown Acc	6/4/1993	1/2/2004	86	2430	2734	2476	460	8070	1255	1570	1958	3288	3995
7052500	James R. at Galena, MO	6/4/1993	9/16/2005	212	1955	2097	1916	80	14550	1154	1271	1600	2280	3015

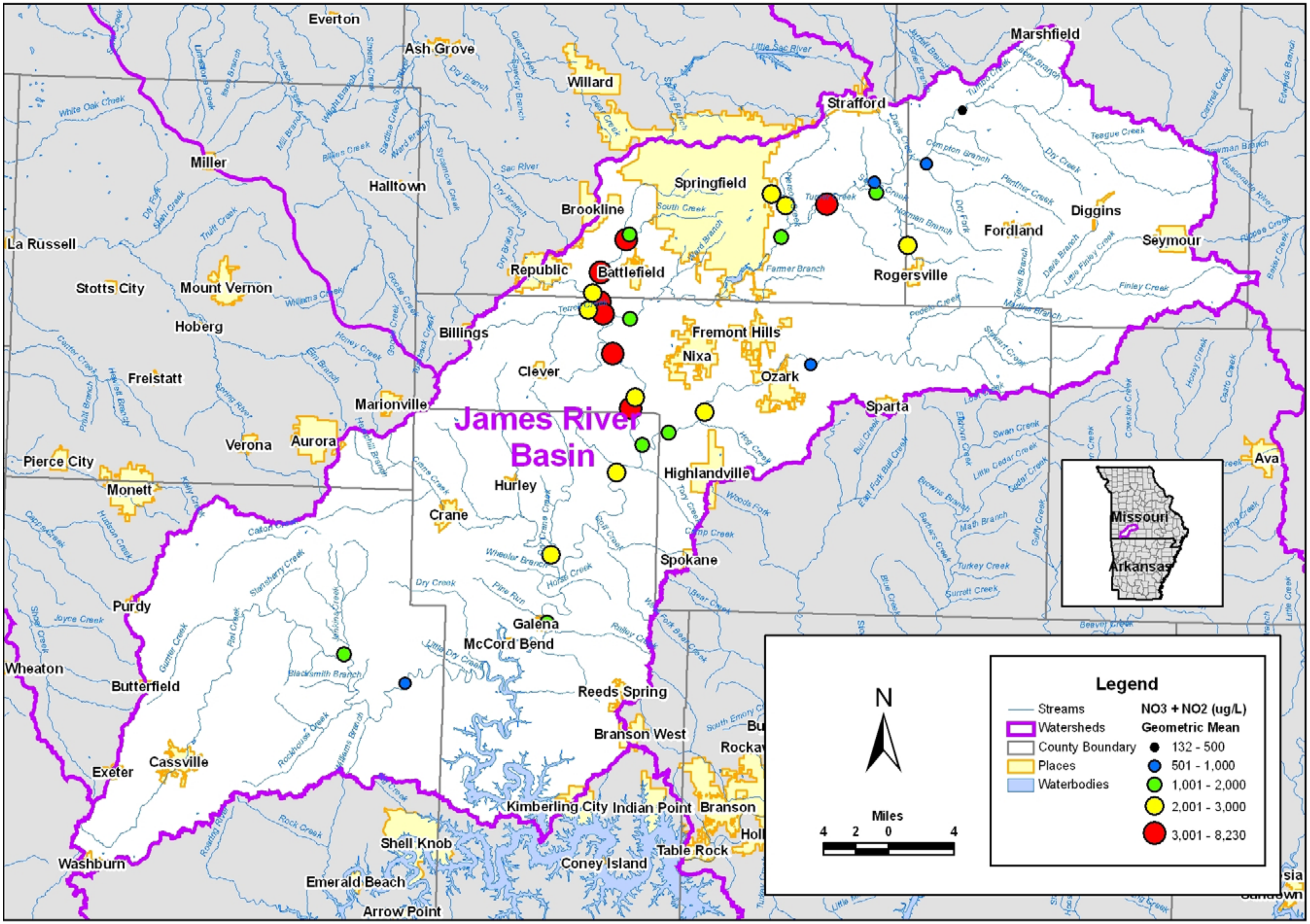

FIGURE 26. Nitrate plus Nitrite Nitrogen Geometric Means at Select Stations in the James River Basin

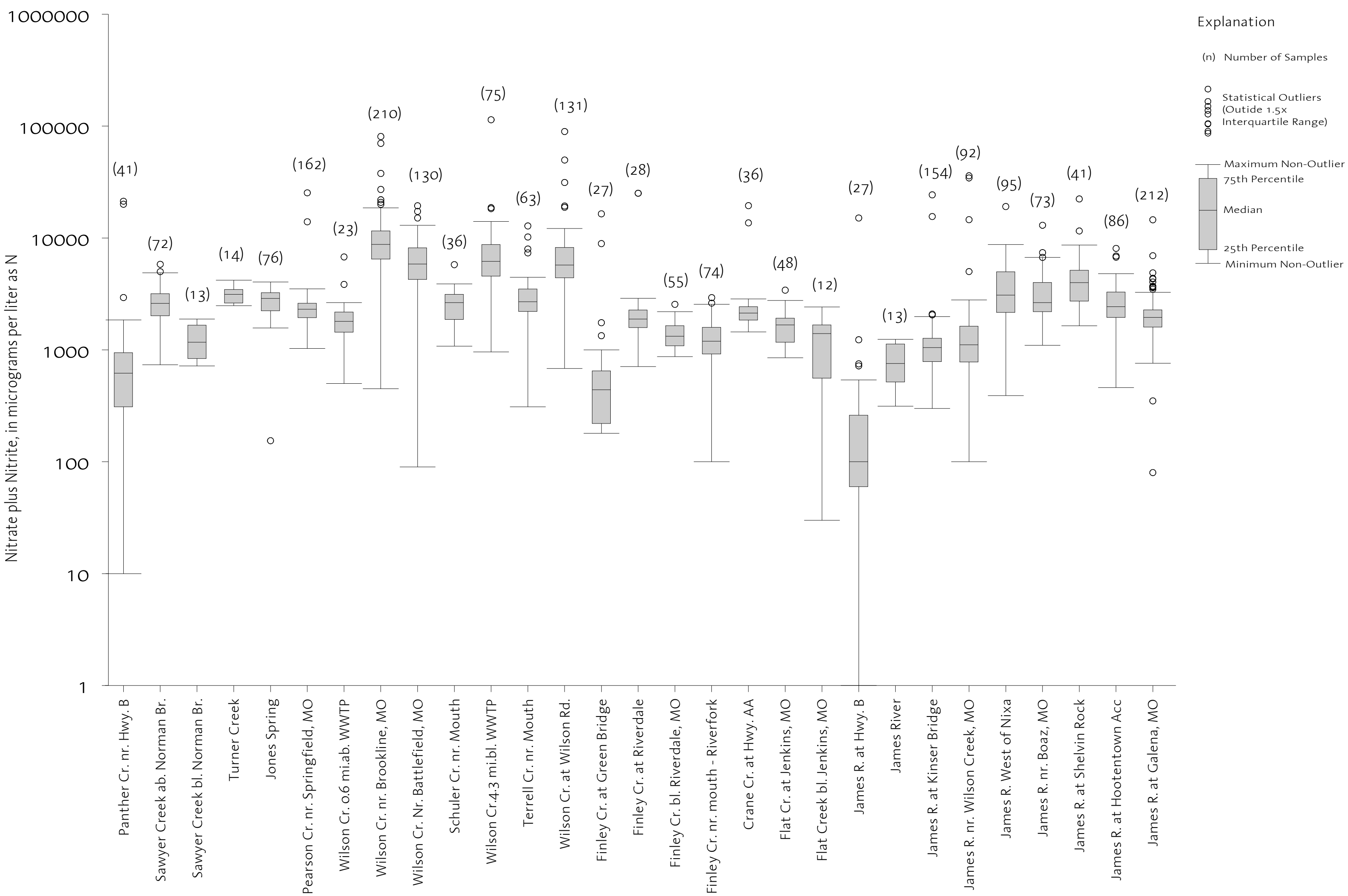

FIGURE 27. Box Plot of Nitrate plus Nitrite Nitrogen in the James River Basin (October 1, 1992 to September 16, 2005)

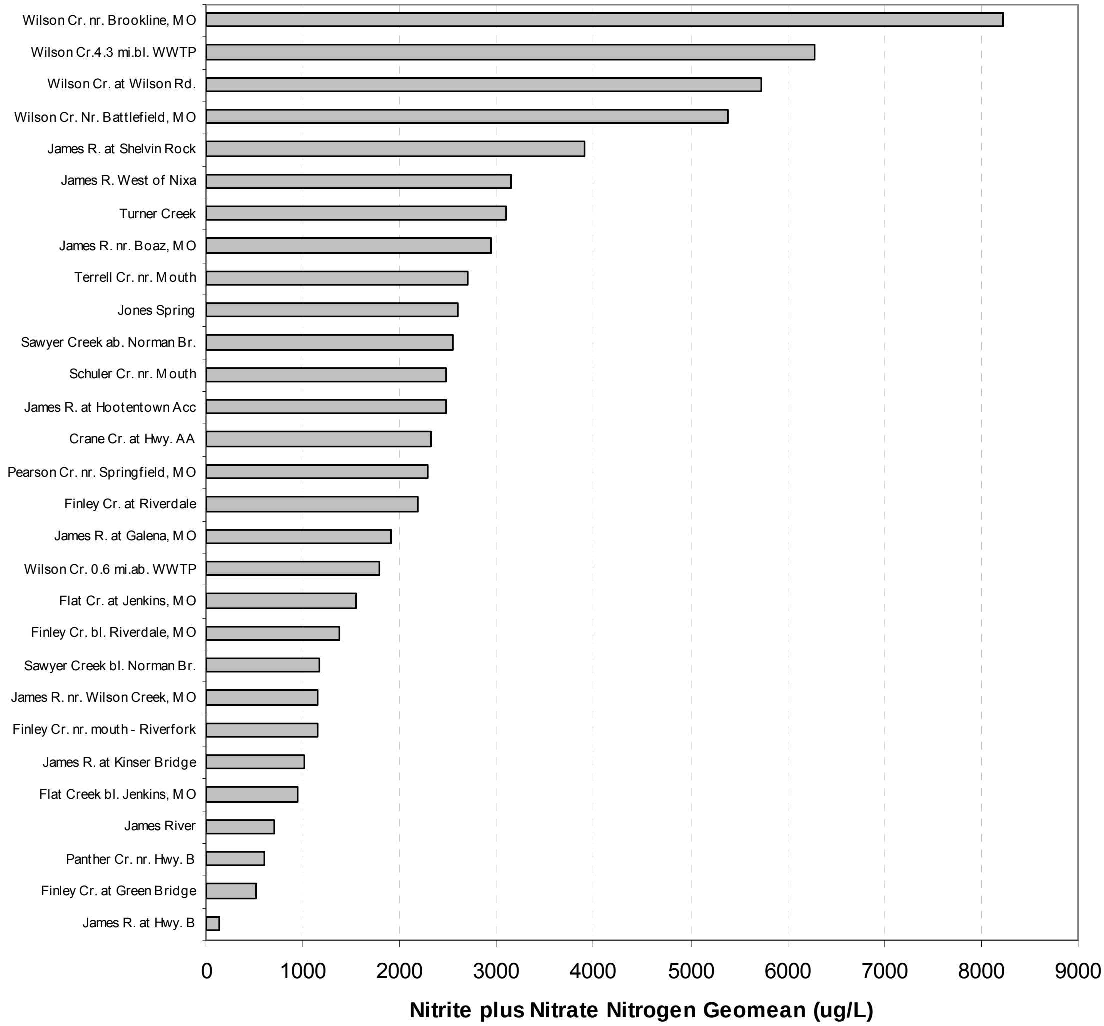

FIGURE 28. Nitrate plus Nitrtte Nitrogen Geomeans in the James River Basin (10/1/1992 – 9/16/2005)

4.1.3 Nutrient Limitations

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).

Average TN:TP ratios suggest streams in the James River Basin may currently be phosphorus limited, if nutrients are limiting. In March 2001, the City of Springfield completed phosphorus removal upgrades to its Southwest WWTP. These upgrades have altered those portions Wilson Creek and the James River located downstream from the Springfield Southwest WWTP from a nitrogen- to a phosphorus-limited system (Table 11). Prior to the phosphorus removal upgrades, all water quality stations downstream of the Springfield Southwest WWTP had TN:TP average ratios of less than 10. Subsequent to the upgrades, average ratios of TN:TP downstream of the Springfield Southwest WWTP ranged from 26 to 44. Average TN:TP ratios at monitoring sites outside the influence of the Springfield Southwest WWTP ranged from 14 to 528 (Table 12).

A comparison of k_s constants to nitrogen and phosphorus geomean concentrations suggests nutrients may not limit algal growth in streams in the James River Basin. Total nitrogen geomean values ranged from 346 µg/L to 10,867 µg/L, which are greater than 5 times the suggested k_s value for nitrogen of 25 µg/L. Approximately less than half of the total geomean concentrations were greater than 5 times the suggested upper k_s value for phosphorus of 30 µg/L. High concentrations of phosphorus (i.e., >150 µg/L) found at some monitoring sites suggest phosphorus may not currently limit the growth of algae in portions of the James River Basin. However, nutrients, particularly phosphorus, limit algal growth in downstream nutrient sinks (i.e., Table Rock and Taneycomo Lakes).

TABLE 11. TN:TP Ratios for Monitoring Sites Downstream of the Springfield Southwest WWTP – Pre and Post Upgrades

Site Number	Station Name	TN:TP (Average)		Count		Period of Record	
		Pre-Upgrade	Post-Upgrade	Pre-Upgrade	Post-Upgrade	Pre-Upgrade	Post-Upgrade
7052152	Wilson Cr. nr. Brookline, MO	4.8	37.0	105	84	9/2/1992-1/23/2001	3/7/2001-7/22/2004
7052160	Wilson Cr. nr. Battlefield, MO	6.6	30.7	54	49	9/21/1993-1/23/2001	3/29/2001-6/17/2004
2375/2.4	Wilson Cr.4.3 mi.bl. WWTP	7.9	26.3	48	17	9/21/1993-1/23/2001	3/29/2001-1/2/2004
2375/1.0	Wilson Cr. at Wilson Rd.	9.3	44.1	61	53	9/2/1992-1/23/2001	3/29/2001-1/2/2004
2362/8.1	James R. West of Nixa	8.0	34.6	70	42	9/2/1992-2/20/2001	3/9/2001-1/2/2004
7052250	James R. nr. Boaz, MO	6.4	43.1	95	23	7/10/1973-11/8/2000	3/7/2001-7/21/2004
2362/2.6	James R. at Shelvin Rock	5.0	35.7	5	36	6/4/1993-11/2/1993	8/22/2001-8/27/2003
2347/27.4	James R. at Hootentown Acc	9.0	31.4	47	18	9/2/1992-1/23/2001	3/29/2001-1/2/2004
7052500	James R. at Galena, MO	9.6	32.6	62	116	6/4/1993-2/6/2001	3/6/2001-9/16/2005

Notes: The Pre and Post-Upgrade refers to the phosphorus removal upgrade completed at the Springfield SW WWTP in March 2001.

TABLE 12. TN:TP Ratios for Monitoring Sites in the James River Basin Not Downstream of the Springfield Southwest WWTP

Site Number	Station Name	TN:TP (Average)	Count	Period of Record
2368/0.7	Panther Cr. nr. Hwy. B	54.0	28	8/22/2001-10/9/2002
7050690	Pearson Cr. nr. Springfield, MO	81.7	79	8/18/1999-3/24/2005
2375/7.3	Wilson Cr. 0.6 mi.ab. WWTP	14.9	12	1/21/1993-3/13/2003
3368/0.1	Schuler Cr. nr. Mouth	48.0	23	5/31/1995-1/2/2004
2376/0.7	Terrell Cr. nr. Mouth	33.0	41	12/1/1994-1/2/2004
2352/13.6	Finley Cr. at Green Bridge	527.6	27	8/22/2001-10/9/2002
2352/4.0	Finley Cr. at Riverdale	14.4	28	8/22/2001-10/9/2002
7052340	Finley Cr. at Hwy 160	67.0	25	7/10/1973-7/8/1975
7052345	Finley Cr. bl. Riverdale, MO	21.1	46	6/27/2001-7/25/2004
2352/0.3	Finley Cr. nr. mouth - Riverfork	17.7	53	6/4/1993-1/2/2004
2381/0.9	Crane Cr. at Hwy. AA	97.2	36	8/22/2001-8/27/2003
2397/2.8	Flat Cr. 0.5 mi.ab. Cassville	109.7	14	4/25/2004-7/17/2005
2387/37.1	Flat Cr. 5 mi.bl. Cassville	38.0	15	4/25/2004-7/17/2005
2387/23.7	Flat Cr. at Stubblefield Access	64.6	12	4/25/2004-6/26/2005
7052800	Flat Cr. at Jenkins, MO	57.7	48	10/12/1999-9/15/2003
7052820	Flat Creek bl. Jenkins, MO	64.4	12	10/27/2003-9/7/2004
2365/19.7	James R. at Hwy. B	116.9	27	8/22/2001-10/9/2002
2365/2.3	James R. at Kinser Bridge	62.9	37	8/22/2001-8/27/2003
7051600	James R. nr. Wilson Creek, MO	33.8	109	7/10/1973-1/2/2004

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 2000; 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).

Geomeans of sestonic chlorophyll *a* data collected in the James River Basin are lower than the EPA Region 7 RTAG draft stream level of 8.0 μg/L (Table 13). The greatest geomean sestonic chlorophyll *a* concentration reported in the dataset was 6.3 μg/L at the Finley Creek at Riverdale station below the City of Ozark. Sestonic chlorophyll *a* concentrations along the James River trend slightly upward from upstream to downstream, peaking at the Shelvin Rock station with a geomean concentration of 4.7 μg/L (Figures 29 and 30). The Pearson Creek near Springfield station had the lowest observed sestonic chlorophyll a concentration, with a value of 1.9 μg/L (Figure 31).

TABLE 13. Selected Statistics for the James 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)
2368/0.7	Panther Cr. nr. Hwy. B	7/12/2001	10/9/2002	30	2.0	2.5	2.2	0.7	7.6	1.6	1.4	1.6	2.8	5.1
7050690	Pearson Cr. nr. Springfield, MO	7/12/2001	10/9/2002	30	1.8	2.3	1.9	0.4	5.7	1.3	1.1	1.4	3.1	4.3
7052152	Wilson Cr. nr. Brookline, MO	7/12/2001	8/27/2003	39	3.4	4.9	3.9	1.3	15.9	4.1	2.2	2.5	4.6	12.2
2375/1.0	Wilson Cr. at Wilson Rd.	7/12/2001	8/27/2003	39	2.4	3.0	2.6	0.5	8.9	1.7	1.8	2.0	3.2	4.6
2352/13.6	Finley Cr. at Green Bridge	7/12/2001	10/9/2002	30	2.6	3.1	2.7	1.1	10.2	1.8	1.5	1.8	3.7	4.9
2352/4.0	Finley Cr. at Riverdale	7/12/2001	10/9/2002	30	6.2	7.3	6.3	2.0	18.2	4.4	3.1	4.3	8.7	15.9
2381/0.9	Crane Cr. at Hwy. AA	7/12/2001	8/27/2003	39	2.5	3.1	2.7	0.9	9.2	1.9	1.7	1.8	3.1	6.0
2365/19.7	James R. at Hwy. B	7/12/2001	10/9/2002	30	3.4	4.4	3.7	0.5	13.8	2.9	2.5	2.7	4.3	7.7
2365/2.3	James R. at Kinser Bridge	7/12/2001	8/27/2003	39	3.6	6.1	4.2	1.5	65.9	10.2	2.1	3.0	5.3	8.5
2362/8.1	James R. West of Nixa	10/1/2000	12/17/2003	27	4.7	5.3	3.5	0.6	17.1	4.8	0.9	1.5	6.1	13.4
2362/2.6	James R. at Shelvin Rock	7/12/2001	8/27/2003	39	4.7	6.9	4.7	1.5	41.8	8.4	1.9	2.5	6.8	11.2
7052500	James R. at Galena, MO	7/12/2001	8/27/2003	39	3.0	5.3	3.7	1.0	30.0	6.1	1.5	2.3	5.1	10.3

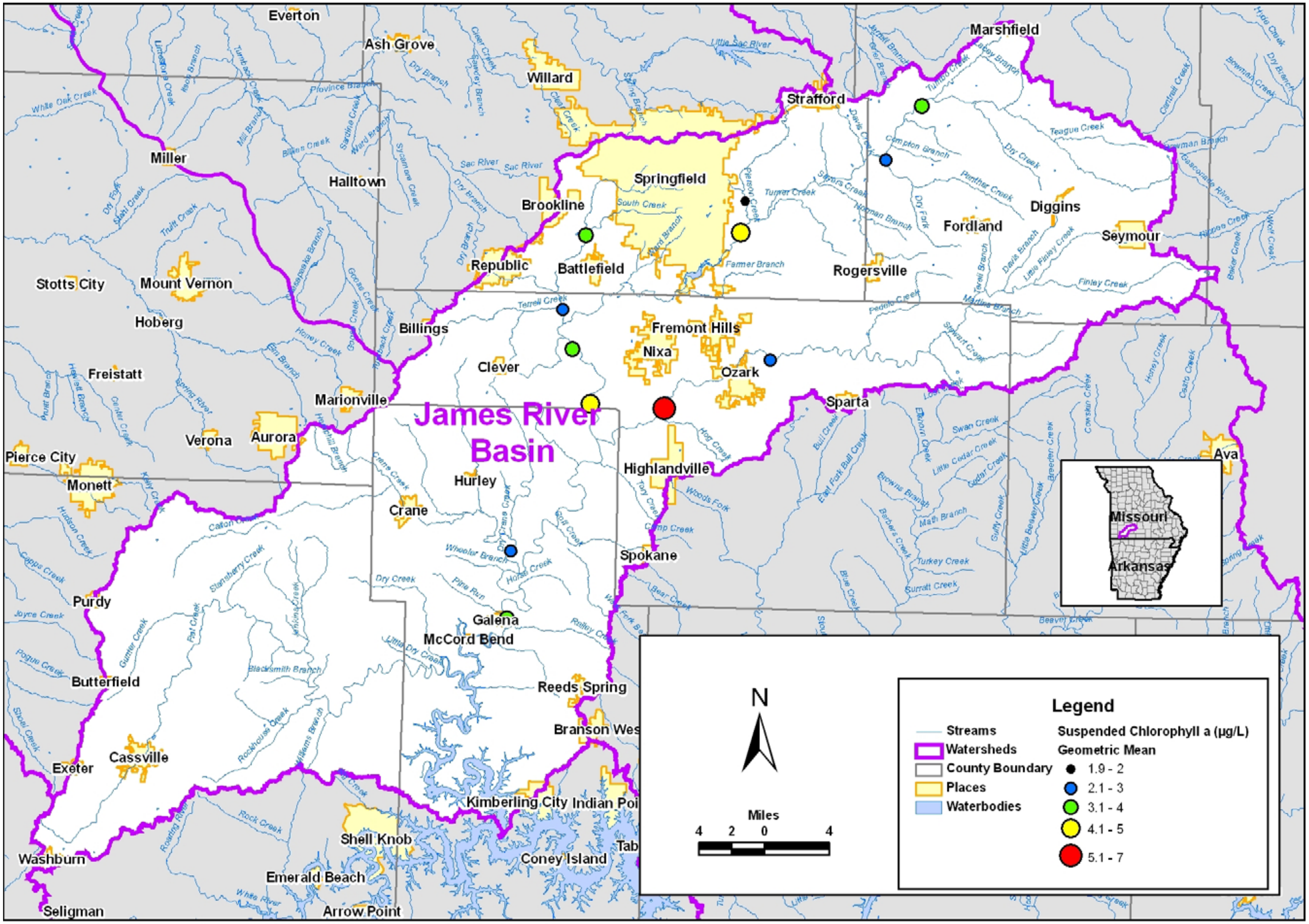

FIGURE 29. Sestonic Chlorophyll *a* Geomeans at Select Stations in the James River Basin

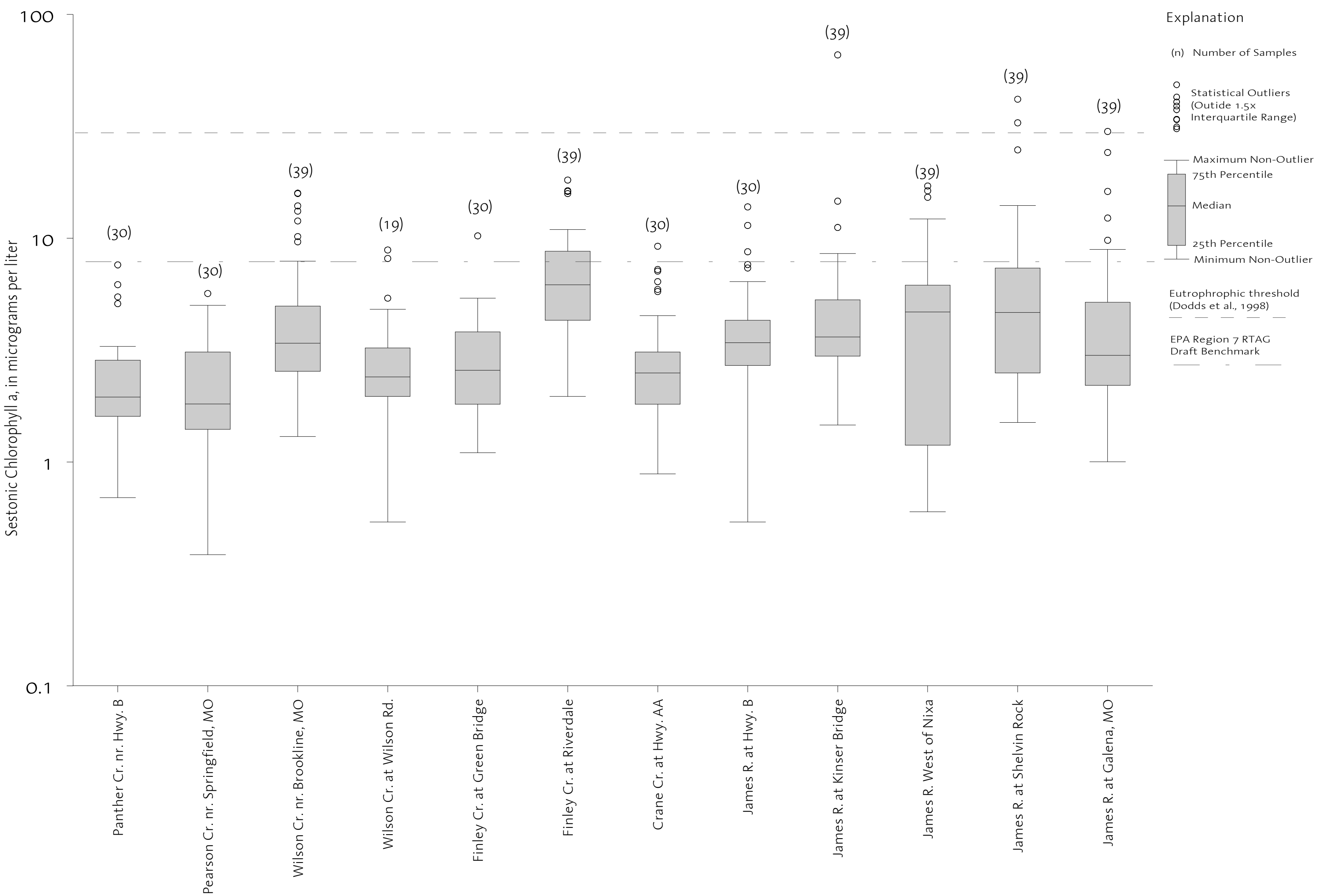

FIGURE 30. Box Plot of Sestonic Chlorophyll *a* in the James River Basin (October 1, 2000 to December 17, 2003) Compared to Eutrophication Threshold and EPA Region 7 RTAG Draft Benchmark

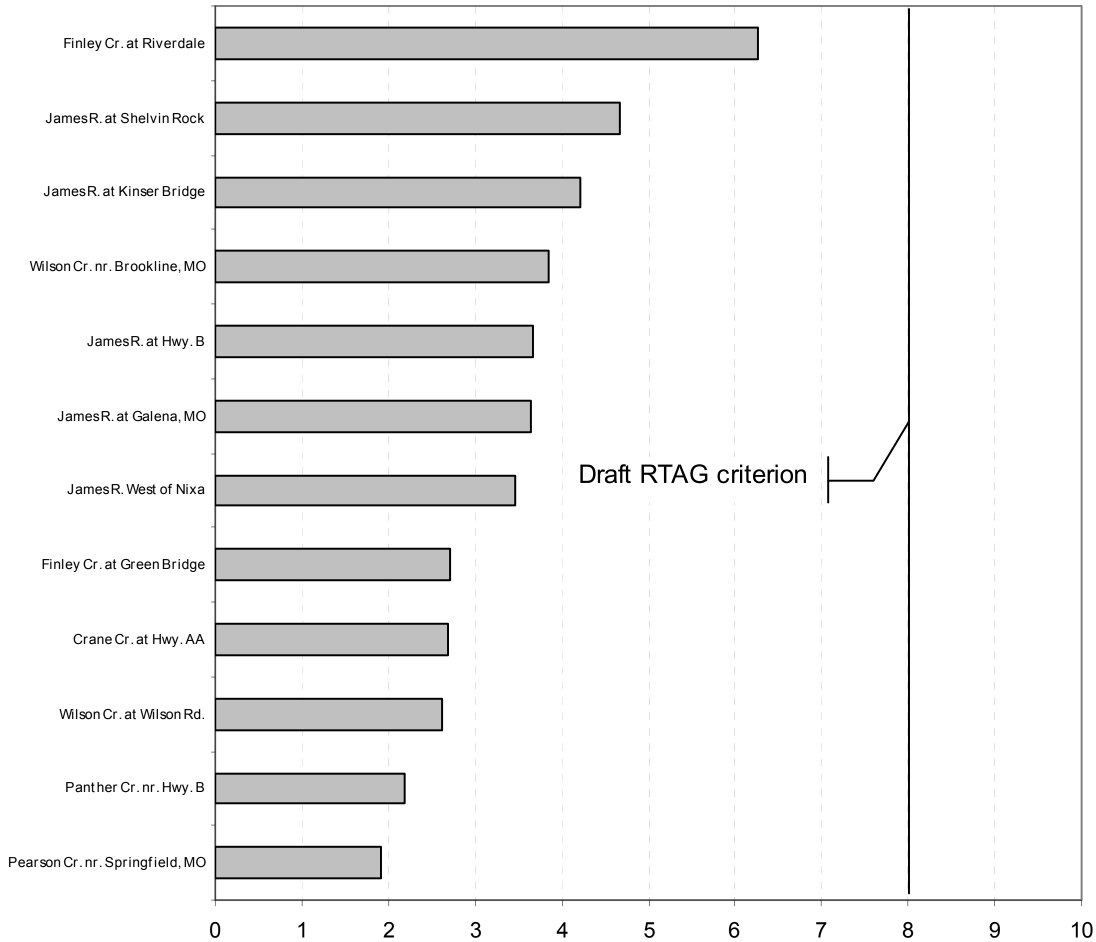

FIGURE 31. Sestonic Chlorophyll *a* Geomeans in the James River Basin (10/1/2000 – 12/17/2003)

Geomeans of benthic chlorophyll *a* data collected in the James River Basin are lower than the EPA Region 7 RTAG draft level of 40 mg/m²; however, upper percentiles and maximum values exceeded this level at some sites (Table 14). The greatest geomean benthic chlorophyll *a* concentration reported in the dataset was 29.1 mg/m² at the Finley Creek at Riverdale station below the City of Ozark. The maximum observed geomean benthic chlorophyll *a* concentration reported in the dataset was 405.5 mg/m² at the Wilson Creek at Wilson Road station located downstream of the Springfield Southwest WWTP. No obvious trend or pattern exists for benthic chlorophyll *a* concentrations in the James River Basin (Figures 32 and 33). The James River at Galena station had the lowest observed benthic chlorophyll a concentration, with a value of 4.4 mg/m² (Figure 34).

TABLE 14. Selected Statistics for the James River Basin - Benthic Chlorophyll *a*

Site Number	Station Name	Begin Date	End Date	Count (#)	Median (mg/m^2)	Mean (mg/m^2)	Geomean (mg/m^2)	Minimum (mg/m^2)	Maximum (mg/m^2)	Std.Dev. (mg/m^2)	Percentiles 10th (mg/m^2)	25th (mg/m^2)	75th (mg/m^2)	90th (mg/m^2)
2368/0.7	Panther Cr. nr. Hwy. B	8/15/2001	10/9/2002	24	17.7	21.6	18.8	7.7	49.7	138.7	9.5	11.9	29.9	37.7
7050690	Pearson Cr. nr. Springfield, MO	7/12/2001	10/9/2002	29	5.7	11.7	5.6	0.6	66.8	274.9	1.3	2.5	12.1	26.0
7052152	Wilson Cr. nr. Brookline, MO	7/12/2001	8/27/2003	35	8.4	21.1	7.7	0.4	246.4	1920.5	1.2	3.2	18.1	38.9
2375/1.0	Wilson Cr. at Wilson Rd.	7/12/2001	8/27/2003	35	15.1	39.4	17.8	2.9	405.5	5783.5	5.4	8.6	24.9	102.1
2352/13.6	Finley Cr. at Green Bridge	7/12/2001	10/9/2002	28	6.1	8.3	6.6	1.8	27.3	43.1	3.2	4.6	8.7	16.5
2352/4.0	Finley Cr. at Riverdale	7/12/2001	10/9/2002	28	32.1	40.5	29.1	7.2	170.5	1449.2	8.5	17.2	45.0	71.8
2381/0.9	Crane Cr. at Hwy. AA	7/12/2001	8/27/2003	35	7.2	8.1	6.6	1.6	31.4	34.6	3.1	3.9	9.1	15.7
2365/19.7	James R. at Hwy. B	7/12/2001	10/9/2002	29	9.9	11.8	10.2	4.0	34.3	56.3	5.4	7.5	13.1	19.4
2365/2.3	James R. at Kinser Bridge	7/12/2001	8/27/2003	36	8.9	11.4	9.2	1.9	44.7	72.0	3.9	6.8	13.5	20.4
2362/2.6	James R. at Shelvin Rock	7/12/2001	8/27/2003	36	13.2	21.1	13.1	2.1	120.6	697.1	4.1	7.3	22.4	37.3
7052500	James R. at Galena, MO	7/12/2001	8/27/2003	35	3.5	11.5	4.4	0.0	122.7	651.2	1.7	2.6	7.1	18.2

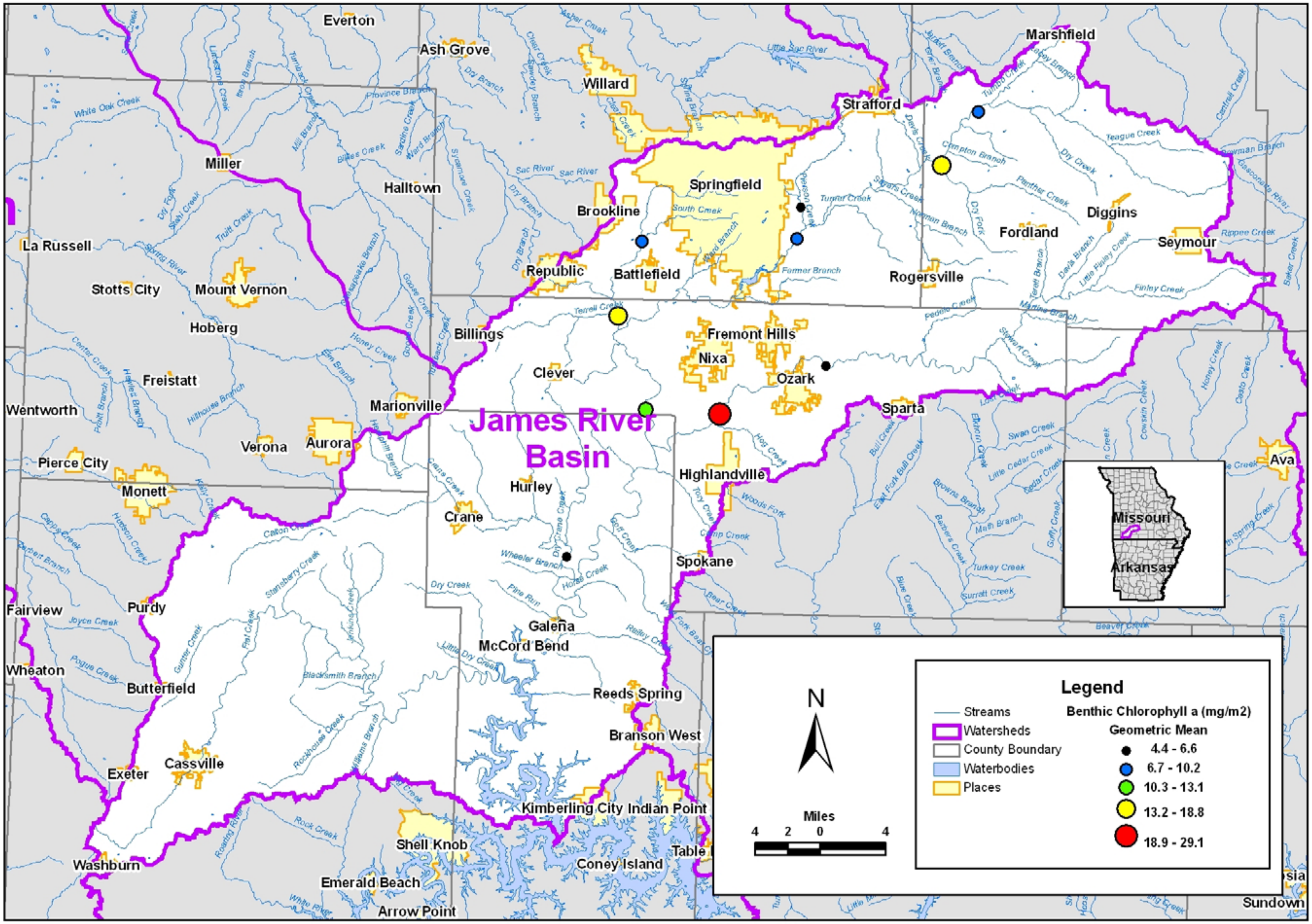

FIGURE 32. Benthic Chlorophyll *a* Geomeans at Select Stations in the James River Basin

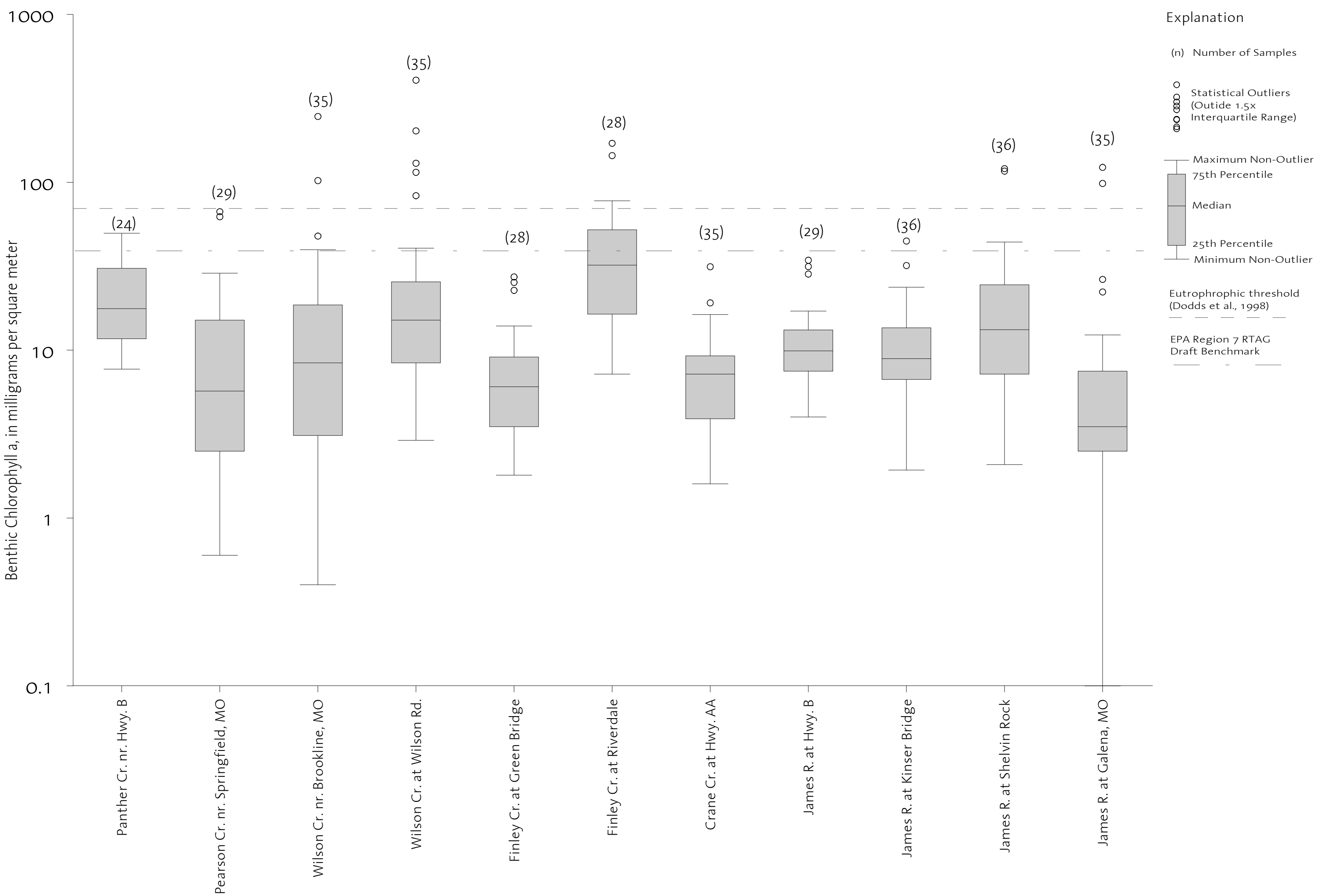

FIGURE 33. Box Plot of Benthic Chlorophyll *a* in the James River Basin (October 1, 2000 to December 17, 2003) Compared to Eutrophication Threshold and EPA Region 7 RTAG Draft Benchmark

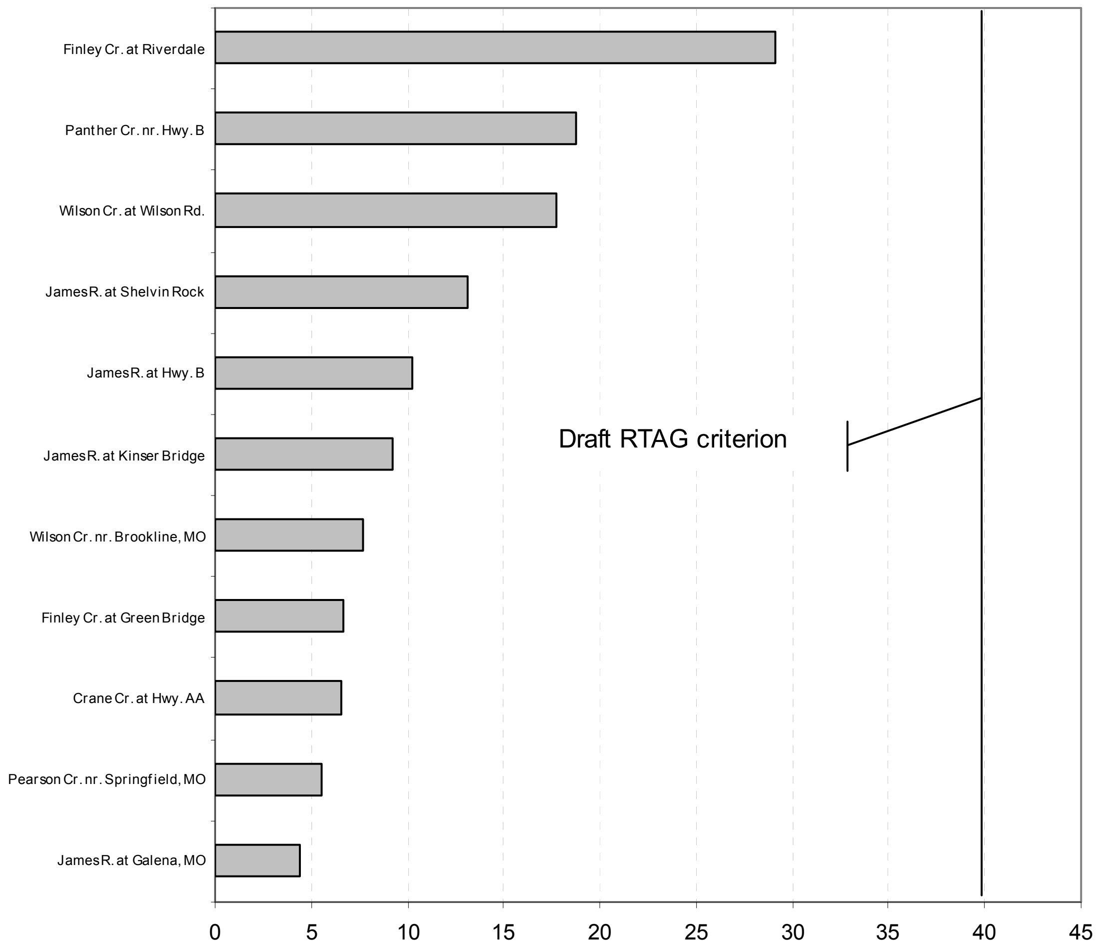

FIGURE 34. Benthic Chlorophyll *a* Geomeans in the James River Basin (10/1/2000 – 12/17/2003)

4.2 Escherichia coli

E. coli is an indicator organism used to test for the presence of pathogenic bacteria. Although *E. coli* are generally not harmful, their presence in high levels indicates that fecal contamination and the potential presence for pathogens exists. Sources of *E. coli* can include wild and domestic animal waste, domestic wastewater, and sewer overflows. 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[13], respectively. The water quality criteria are expressed as a recreational season

[13] 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.

(April 1 – October 31) geomean. The James River, Finley Creek, Flat Creek, and Pearson Creek all have Category A whole body contact use designations. Wilson Creek is designated for Category B whole body contact recreation (Carnahan, 2005).

The annual *E. coli* geomean concentrations at the James River near Boaz water quality station do not suggest any temporal trend in *E. coli* concentrations (Figure 35). The available *E. coli* period of record for the Boaz station spanned from 1997 to 2006; however, no *E. coli* data were available for 2002.

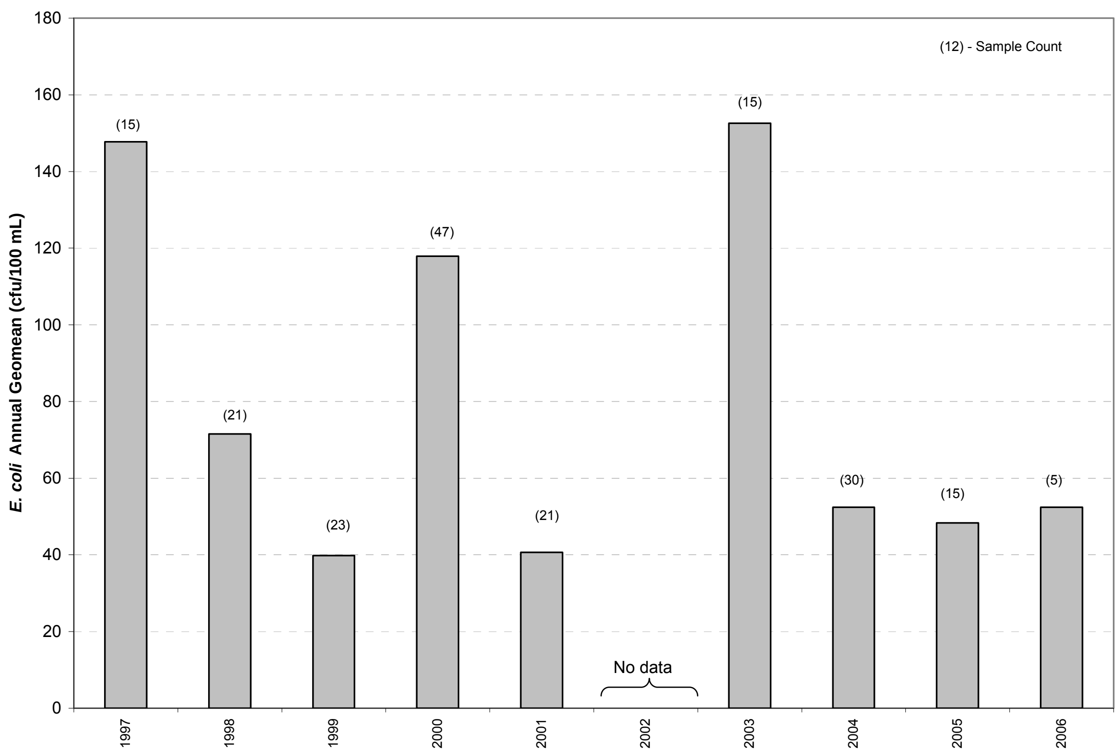

FIGURE 35. *E. coli* Annual Geomeans Measured in the James River at the Boaz Station

E. coli geomean concentrations are the greatest at monitoring sites located downstream of the City of Springfield in Wilson Creek, ranging from 138 cfu/100 mL to 462 cfu/100 mL (Table 15 and Figure 36). The Pearson Creek site was the only monitoring station with a *E. coli* geomean concentration to exceed the applicable criterion. The *E. coli* geomean concentration at the Pearson Creek (WBCR-A) station was 290 cfu/100 mL. Figure 37 illustrates a clear downward trend in *E. coli* concentrations as one travels downstream the James River. Although Wilson Creek had the greatest observed concentrations of *E. coli*, no station geomean value in Wilson Creek exceeded the WBCR-B criterion of 548 cfu/100 mL (Figure 38).

TABLE 15. Selected Statistics for the James River Basin - *E. coli*

Site Number	Station Name	BeginDate	EndDate	Count (#)	Median (cfu/100mL)	Geomean (cfu/100mL)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Std.Dev. (cfu/100mL)	Percentiles 10th (cfu/100mL)	Percentiles 25th (cfu/100mL)	Percentiles 75th (cfu/100mL)	Percentiles 90th (cfu/100mL)
7050690	Pearson Cr. nr. Springfield, MO	11/23/1999	7/21/2004	47	240	290	1	71000	12687	8	140	590	5520
2375/7.2	Springfield SW WWTP 001	8/11/2000	9/27/2000	20	112	118	0	2419	848	25	52	257	2419
7052152	Wilson Cr. nr. Brookline, MO	11/5/1997	7/22/2004	66	220	138	1	4800	757	12	45	535	675
2375/5.6	Wilson Cr. 1.6 mi.bl. SW WWTP	8/1/2000	9/27/2000	19	435	460	122	1414	467	206	238	770	1414
2375/5.5	Rader Spring	8/2/2000	9/27/2000	18	268	413	172	2419	618	199	216	795	1304
2375/4.9	Wilson Cr. 2.3 mi.bl. SW WWTP	8/1/2000	8/15/2000	13	378	462	142	1413	413	216	326	921	1159
7052160	Wilson Cr. Nr. Battlefield, MO	11/23/1999	11/4/2003	50	290	312	1	76000	14466	22	78	770	8580
2375/1.0	Wilson Cr. at Wilson Rd.	6/25/1997	5/3/2006	211	196	238	6	12032	1486	53	101	435	1986
2352/14.9	Finley Cr. at Hwy 125	1/26/1999	5/3/2006	126	14	14	1	4838	437	3	5	29	95
2352/9.5	Finley Cr. at Ozark C.P.	2/3/1999	5/3/2006	143	59	56	1	4838	477	6	22	143	401
7052340	Finley Cr. at Hwy 160	1/28/1999	5/3/2006	119	29	31	1	4838	447	6	12	67	183
7052345	Finley Cr. bl. Riverdale, MO	6/27/2001	7/22/2004	43	40	50	2	21000	3194	5	15	140	576
2352/0.3	Finley Cr. nr. mouth - Riverfork	6/21/1999	9/1/2004	77	21	21	2	365	45	7	12	37	63
7052800	Flat Cr. at Jenkins, MO	10/12/1999	9/15/2003	48	16	14	1	910	160	1	5	41	73
7052820	Flat Creek bl. Jenkins, MO	10/27/2003	9/7/2004	12	6	6	1	210	59	1	1	17	47
7051600	James R. nr. Wilson Creek, MO	8/1/2000	9/27/2000	17	65	70	4	261	69	33	55	135	184
2362/8.1	James R. West of Nixa	6/19/1997	5/3/2006	202	66	69	0	4838	762	12	27	156	401
7052250	James R. nr. Boaz, MO	11/5/1994	7/21/2004	42	55	43	1	1300	220	8	18	100	198
2362/2.6	James R. at Shelvin Rock	1/26/1999	5/3/2006	128	27	35	2	4838	593	7	14	94	218
2347/27.4	James R. at Hootentown Acc	6/14/1999	9/1/2004	154	37	36	0	4838	425	10	18	72	142
2347/16.0	James R. at McCall Bridge Rd	6/14/1999	9/1/2004	94	21	23	0	4838	717	5	12	36	86
2347/10.9	James R. at Kerr Access	6/14/1999	9/1/2004	95	12	14	1	1553	208	3	6	27	65
7052500	James R. at Galena, MO	6/14/1999	9/8/2004	170	7	8	0	9300	750	1	2	25	74
2347/5.2	James R. at Shoals Cmpgd	5/24/2000	9/1/2004	85	11	11	0	1046	130	2	5	22	42

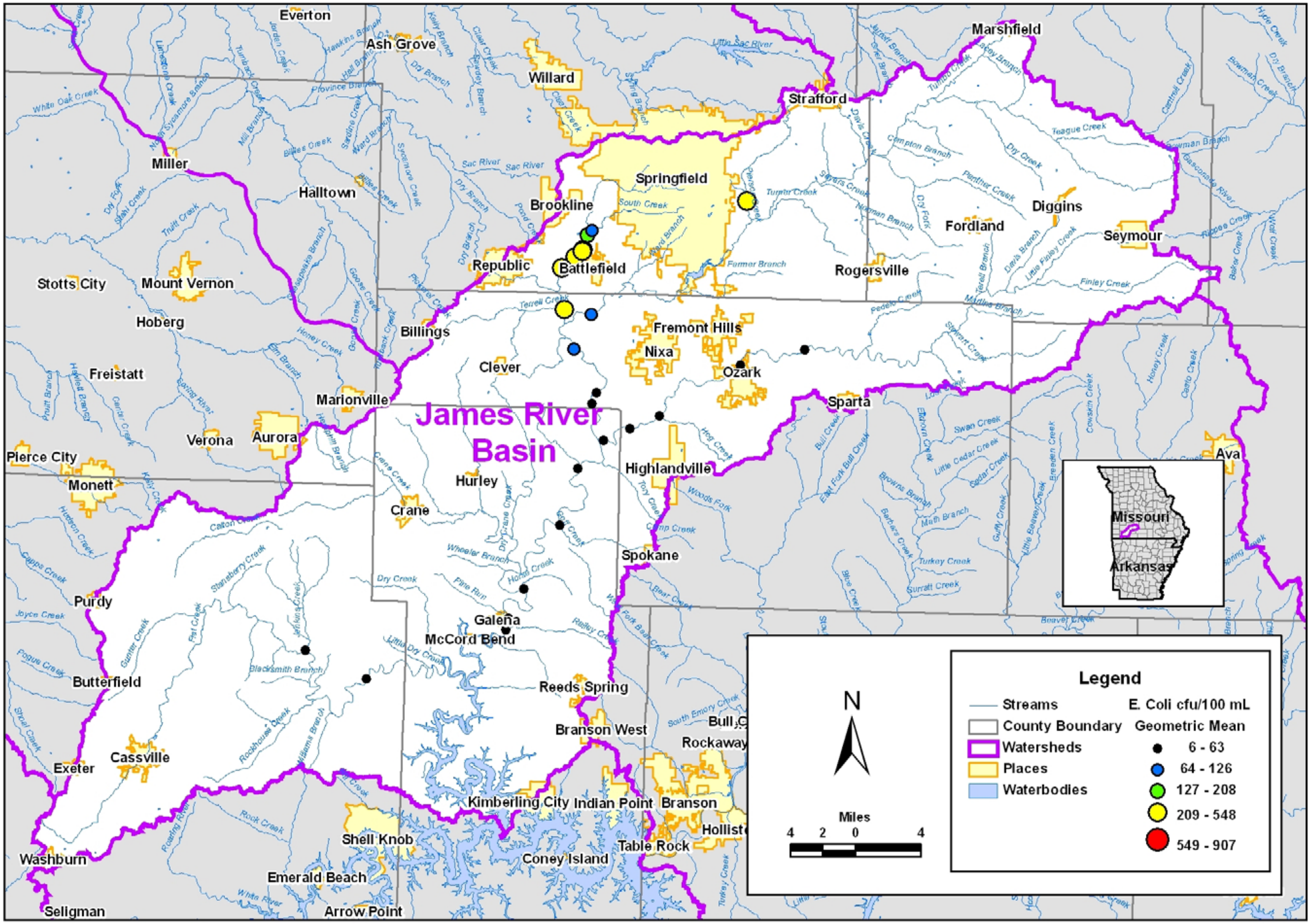

FIGURE 36. *E. coli* Geomeans at Select Stations in the James River Basin

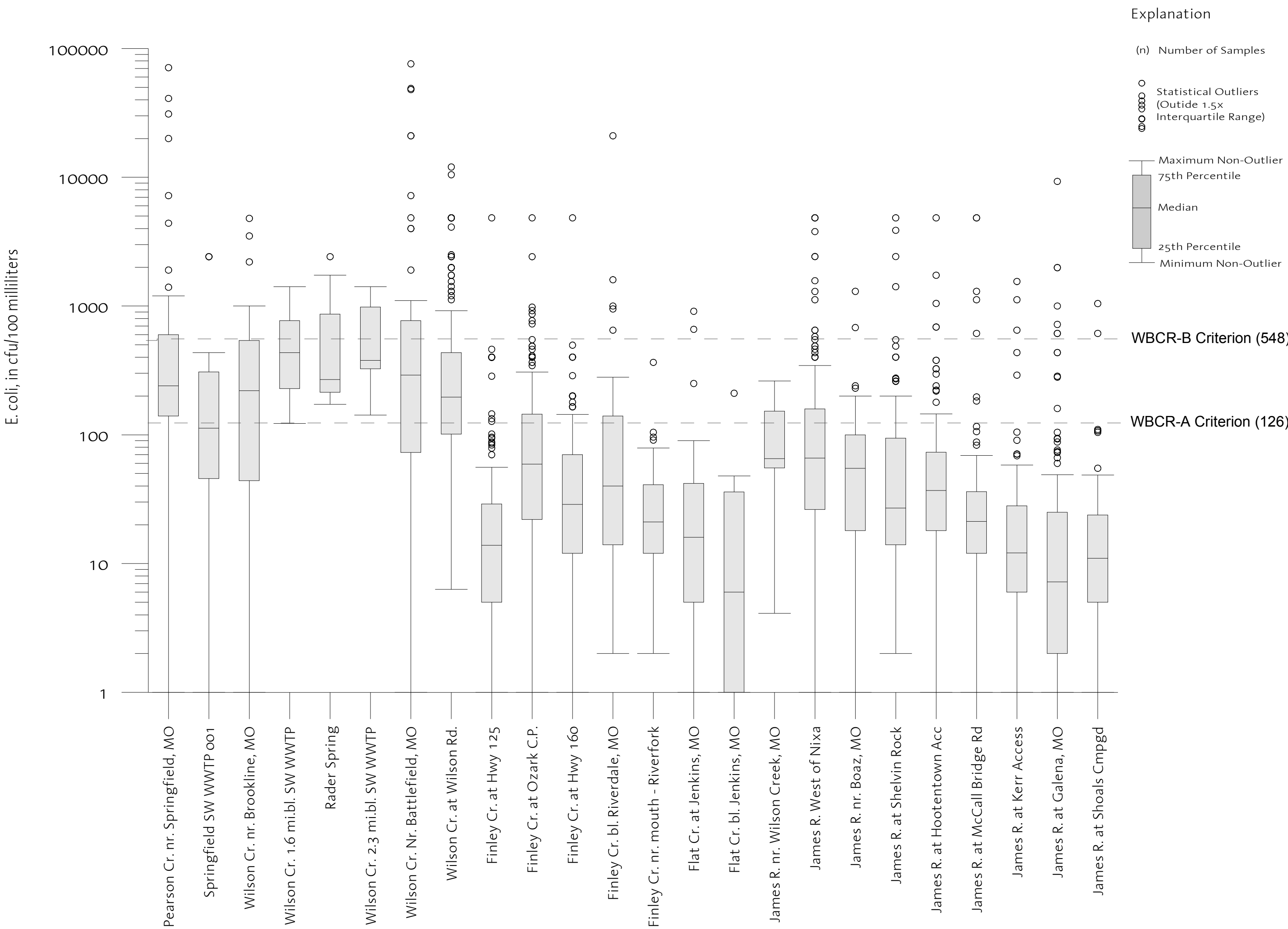

FIGURE 37. Box Plot of *E. coli* in the James River Basin (June 19, 1997 to May 3, 2006) Compared to Whole Body Contact Recreational Use Criteria

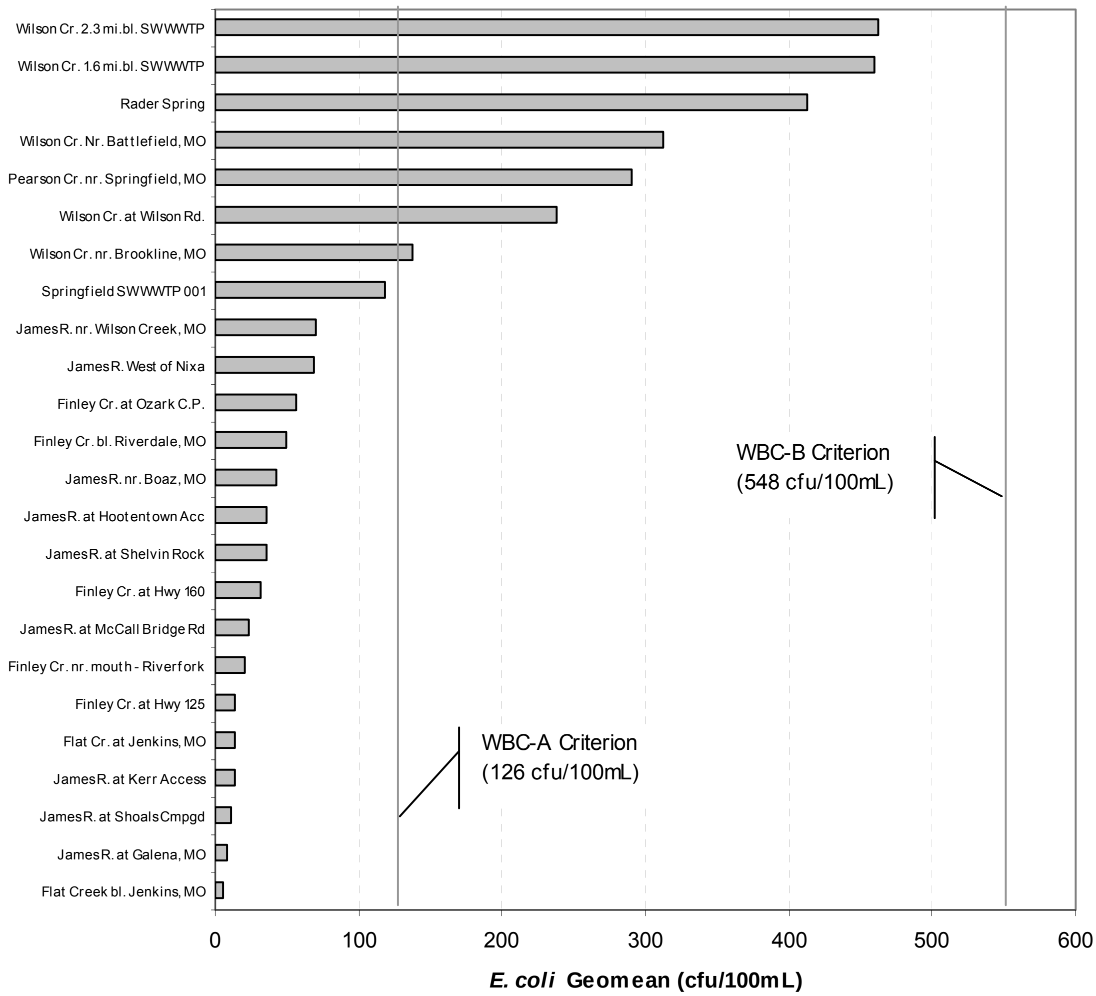

FIGURE 38. *E. coli* Geomeans in the James River Basin (June 19, 1997 to May 3, 2006)

5. BIOLOGICAL MONITORING

In general, biological (macroinvertebrate and fish) monitoring data are not readily available for the James River Basin. Digital data available for sample sites are typically limited to site locations and dates sampled. Paper or hardcopy data are available and typically provide information, but specific sample locations are not given and are usually referred to as part of a section in the Public Land Survey system. Paper copy records require extensive tabulation and analysis in their current form to evaluate links to water quality. Paper copy data gathered for this project will be available through the WQIP literature database.

Two types of data were compiled for this report and provided by three sources (Table 16). Sampling locations for sites from the Missouri Department of Conservation (MDC) (fish), MDNR (macroinvertebrates), and the USGS (macroinvertebrates and fish) were gathered for this report. Specifics on digital databases gathered for this study are presented here:

1.) The MDNR database includes five macroinvertebrate sampling locations in the James River Basin on three bodies of water (Figure 39). The majority of the samples were collected between March and October of 1997, with one site visited in September of 2004. Information included with these data are limited to the waterbody, latitude/longitude, collection date, and sample number.

2.) MDC's database includes 14 fish monitoring locations throughout the James River Basin. These sites were visited between 1994 and 2005, with the majority being visited since 2001. There is some information included with these data, but no explanation accompanied the dataset.

3.) The National Water-Quality Assessment Program (NAWQA) data from the USGS is a comprehensive and very well organized dataset. At any particular site, both macroinvertebrate and fish data were collected between 1993 and 2004. These data while informative are limited within the study area, with only one site located within the James River Basin.

TABLE 16. Summary of Digital Biological Databases for the James River Basin

Data Types	Collection Agency	# of Sites	Collection Date
Macro-invertebrates	MDNR	5	1997 and 2004
Fish	MDC	14	1994 and 2005
Fish and Macro-invertebrates	USGS (NAWQA)	1	1993 and 2004

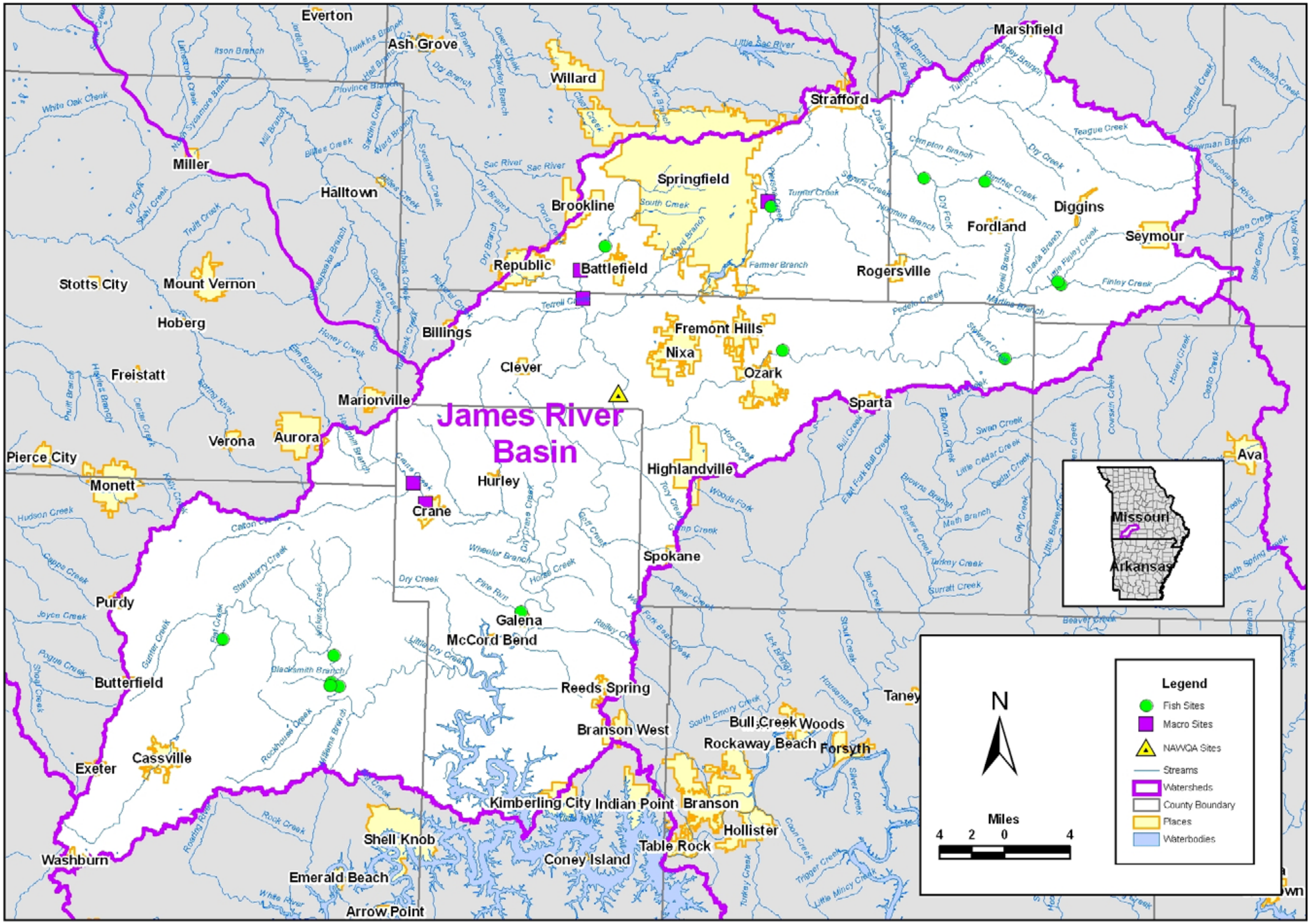

FIGURE 39. James River Basin – Biology Sampling Sites

6. DATA GAPS

Extensive water quality data exist for the James River Basin. However, because the data were collected for a specific purpose, the existing ambient data often do not provide the specific information needed by water quality researchers, managers and policy makers. 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; and
    - 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 James 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.

6.1 Spatial Gaps

Based on the information needs of the WQIP described above, the water quality monitoring network in the James 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. Potential sources of pollution identified in this report include the Springfield metropolitan area, the Cities of Nixa and Ozark, and the relatively high concentration of CAFOs near Cassville. Therefore, impact and baseline stations should be situated relative to these sources of pollution.

Water quality data in the James River Basin was compiled from 42 sampling stations (see Figure 10 in Section 3.1). The 42 samplings stations are well distributed and positioned to address the goals of the WQIP. However, spatial considerations may only be fully analyzed within the context of other issues such as temporal and parameter gaps. For example, a temporal gap may be limited to certain area. Therefore, spatial issues will continue to be discussed in subsequent sections.

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 short-term intensive studies, long-term monitoring, and potential storm event sampling. Temporal characteristics of sampling stations in the James River Basin are discussed below.

Existing ambient water quality data in the James River Basin are generally sufficient in terms of sample duration to address the information goals of the WQIP. Most of the MDNR, MSU, and LMVP monitoring sites appear to have only been monitored for short durations (i.e., no longer than 2 or 3 years). The large majority of monitoring sites, however, have been monitored over a period of several years (Figure 40). Therefore, significant data exist to address trends, baseline conditions, and extreme conditions on the James River and its major tributaries.

The observed sampling frequency in the James River Basin can vary by site and collection entity, but generally appears suitable for the information goals of the WQIP. 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.

Sites sampled at a consistent frequency over a sufficiently long period of time should yield a representative set of storm water runoff samples. However, analysis of non-point issues may require special storm event studies. Without further analysis, 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. Only 15% of all USGS sample events in the James River Basin were taken in runoff conditions since October 1, 1992. In addition, only three of the USGS sites constitute approximately 66% of runoff sample events.

Some of the WQIP goals will require continued monitoring throughout the James River Basin; however, is unclear which sites are currently active and which sites have been discontinued. An analysis of site visit frequency suggests most of the CU sites were no longer sampled after 1999. Additionally, most other sites appear to have discontinued operation (i.e., stopped sampling) around 2004. However, it is likely at least some of the cessations in site visits observed in Figure 1 may simply be a reflection of the MDNR database (i.e., the source of much of the WQIP data) not being fully up-to-date. Four sites (Wilson Creek near Brookline, James River at Boaz, James River at Galena, and Flat Creek at Jenkins) are MDNR-supported USGS sites and are known to be long-term and currently active (MDNR, 2005c). The CCHD and the SCHD are also known to currently maintain several active long-term sites (personal correspondence).

Further investigation may be necessary to determine if monitoring efforts on Flat Creek and Crane Creek need to be supplemented or revived. Only one site on Crane Creek (at Highway AA) is known to exist and its current monitoring status is unknown. Crane Creek is an important tributary of the James River that warrants continued monitoring. Three other sites that may warrant further investigation are located along Flat Creek (above Cassville, below Cassville, and at Stubblefield Access). The current status of these sites is unclear and only one[14] other monitoring station is currently located along Flat Creek (Flat Creek below Jenkins).

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. Potential opportunities for cooperative intra-agency collection efforts will also be discussed below.

Nutrient and bacteria sample coverage is relatively thorough throughout the James River Basin. Some form of nutrients (i.e., TP, TN, or $NO_3 + NO_2$) or a nutrient response variable (i.e., chlorophyll *a*) has been sampled for at 38 of the 42 monitoring sites (Table 17). *E. coli* was sampled for at approximately half of the monitoring sites (24 of the 42 monitoring sites). However, *E. coli*, which is a human health criterion, was sampled for in those waterbodies with the highest likelihood of recreational activities (i.e., James River, Wilson Creek, Flat Creek, and Finley Creek).

Most collection entities have focused their collection efforts on TP and nitrogen to the exclusion of sestonic or benthic chlorophyll *a* (Table 18). Sestonic and benthic chlorophyll *a* are often considered the primary response variables to excessive nutrient loading. TP was sampled for at all 42 monitoring sites identified for purposes of this review; however, sestonic and benthic chlorophyll *a* were only sampled for at 12 monitoring sites. MSU and UMC are the only organizations to collect chlorophyll *a* concurrent with TP.

Out of the nine entities collecting water quality samples in the James River Basin, only the USGS, MSU, and SPW made significant efforts to take flow measurements (Table 19). Ideally flow measurements should be taken concurrently with water quality samples. Flow values allow for a more robust analysis of water quality data. Periods of high flow are typically associated with stormwater runoff, which can cause increases in nutrient and bacteria levels. Flow data are also critical for understanding loadings (mass per time). Although few agencies apparently collect flow data, it should be noted, as discussed in Section 2.6, there are nine USGS gaging stations in the James River Basin. Potentially discharge data from these USGS gaging stations could be used in analyzing existing ambient water quality data in the James River Basin.

[14] Actually two other sites are identified on Flat Creek; however, one site appears to have been activated at the same time the other site was discontinued (i.e., there is effectively only one other monitoring station).

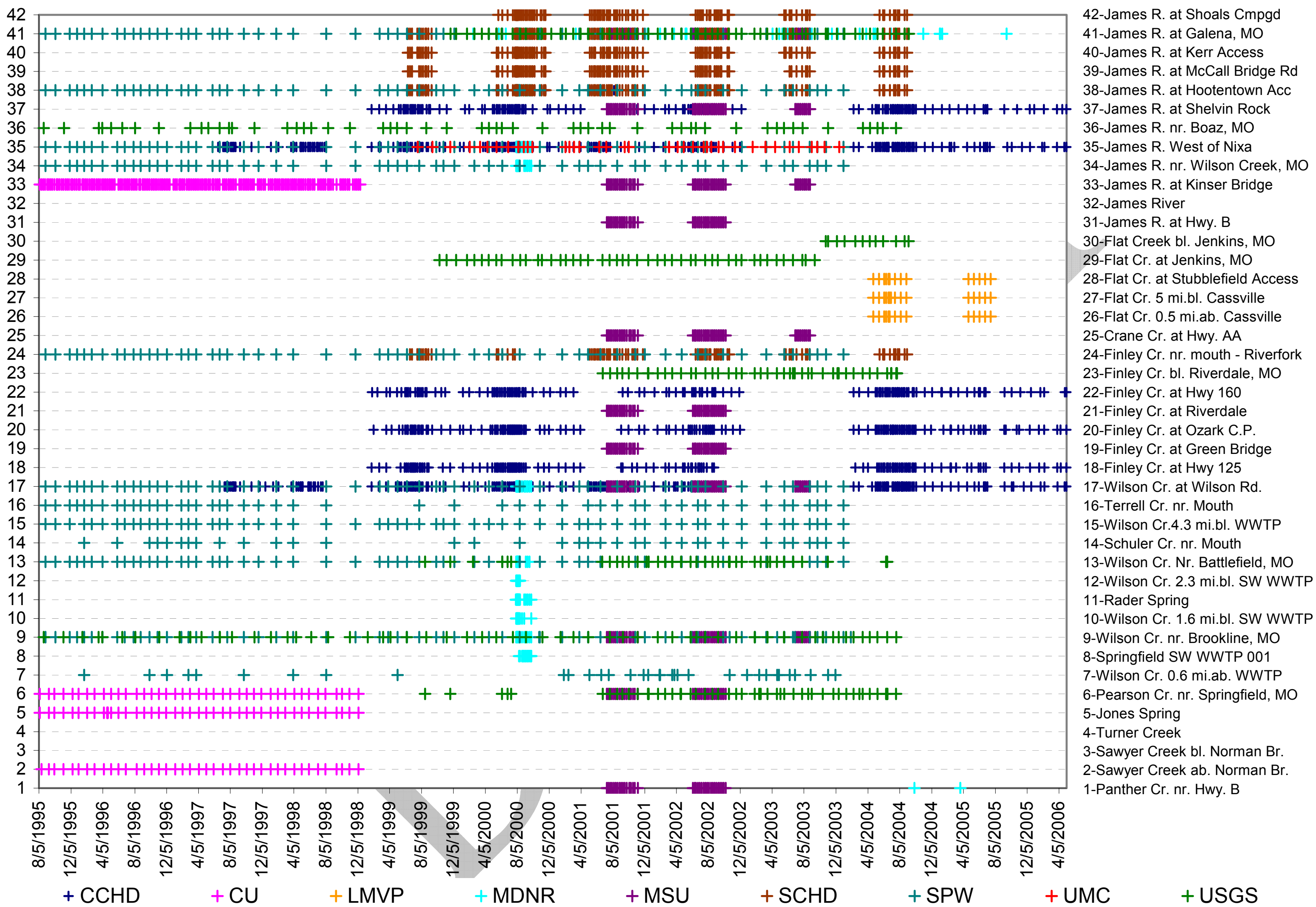

FIGURE 40. Monitoring Visits by Collection Entity from August 1995 to April 2006

Opportunities exist for different collection entities to work collaboratively. Multiple sampling agencies are sampling the same streams for different purposes. With little additional effort, agencies could increase the number of samples collected per site visit. A count of sample events suggests no entity is collecting all of the parameters of interest (i.e., TP, TN, $NO_3 + NO_2$, *E. coli*, sestonic chlorophyll *a*, and benthic chlorophyll *a*) (Table 19). Collectively among all agencies, less than three parameters of interest were sampled for during 65% of all sample events (Figure 41). Potentially by aggregating some sample sites and increasing the number of samples collected, agencies could work together to develop a more robust dataset on the James River Basin.

TABLE 17. Count of Total and Parameter Sampling Events by Site in the James River Basin

Site	Total Sample Events	Sample Events by Parameter						
		TP	TN	NO_2+NO_3	*E. coli*	Sestonic Chl.*a*	Benthic Chl.*a*	Flow
Panther Cr. nr. Hwy. B	89	42	28	75	0	30	24	24
Sawyer Creek ab. Norman Br.	258	187	0	244	0	0	0	0
Sawyer Creek bl. Norman Br.	156	114	0	139	0	0	0	0
Turner Creek	53	11	0	49	0	0	0	0
Jones Spring	58	12	0	56	0	0	0	0
Pearson Cr. nr. Springfield, MO	229	119	80	213	47	30	29	72
Wilson Cr. 0.6 mi.ab. WWTP	49	35	19	23	0	0	0	3
Springfield SW WWTP 001	18	0	0	0	17	0	0	0
Wilson Cr. nr. Brookline, MO	237	196	192	204	66	39	35	184
Wilson Cr. 1.6 mi.bl. SW WWTP	17	0	0	6	16	0	0	0
Rader Spring	20	0	0	7	17	0	0	0
Wilson Cr. 2.3 mi.bl. SW WWTP	17	1	0	8	13	0	0	0
Wilson Cr. nr. Battlefield, MO	131	114	106	116	49	0	0	58
Schuler Cr. nr. Mouth	41	26	26	32	0	0	0	11
Wilson Cr.4.3 mi.bl. WWTP	74	73	65	70	0	0	0	27
Terrell Cr. nr. Mouth	62	47	46	59	0	0	0	14
Wilson Cr. at Wilson Rd.	349	123	117	131	210	39	35	67
Finley Cr. at Hwy 125	126	0	0	0	126	0	0	0
Finley Cr. at Green Bridge	36	27	28	27	0	30	28	29
Finley Cr. at Ozark C.P.	143	0	0	0	143	0	0	0
Finley Cr. at Riverdale	36	28	28	28	0	30	28	29
Finley Cr. at Riverdale, MO.	208	72	25	25	119	0	0	88
Finley Cr. bl. Riverdale, MO	46	46	46	46	42	0	0	45
Finley Cr. nr. mouth - Riverfork	150	66	56	72	74	0	0	58
Crane Cr. at Hwy. AA	45	36	36	36	0	39	35	37
Flat Cr. 0.5 mi.ab. Cassville	14	14	14	0	0	0	0	0
Flat Cr. 5 mi.bl. Cassville	15	15	15	0	0	0	0	0
Flat Cr. at Stubblefield Access	14	13	13	0	0	0	0	0
Flat Cr. at Jenkins, MO	48	48	48	48	48	0	0	48
Flat Creek bl. Jenkins, MO	12	12	12	12	12	0	0	12
James R. at Hwy. B	36	28	27	27	0	30	29	29
James River	93	46	0	80	0	0	0	0
James R. at Kinser Bridge	559	155	37	347	0	39	36	37
James R. nr. Wilson Creek, MO	369	270	122	250	17	0	0	313
James R. West of Nixa	330	124	114	91	202	35	0	62
James R. nr. Boaz, MO	336	269	118	226	45	0	0	328
James R. at Shelvin Rock	184	42	41	46	128	39	36	41
James R. at Hootentown Acc	232	78	65	83	150	0	0	30
James R. at McCall Bridge Rd	94	0	0	3	91	0	0	0
James R. at Kerr Access	93	1	1	1	92	0	0	1
James R. at Galena, MO	333	203	186	210	167	39	35	166
James R. at Shoals Cmpgd	82	0	0	0	82	0	0	0

Note: Total sample events is a count of days a site was visited by an agency summed over all agencies.

TABLE 18. Count of Sampling Events Concurrent with Total Phosphorus Sampling Events by Collection Entity and Site in the James River Basin

Collection Agency	Site	Total TP Sample Events	Co-Occuring Sample Events				
			TN	NO_2+NO_3	Sestonic Chl.*a*	Benthic Chl.*a*	Flow
CU	James R. at Kinser Bridge	118	0	114	0	0	0
CU	Panther Cr. nr. Hwy. B	14	0	13	0	0	0
CU	Pearson Cr. nr. Springfield, MO	38	0	36	0	0	0
CU	James River	46	0	44	0	0	0
CU	Jones Spring	12	0	12	0	0	0
CU	Sawyer Creek ab. Norman Br.	187	0	182	0	0	0
CU	Sawyer Creek bl. Norman Br.	114	0	105	0	0	0
CU	Turner Creek	11	0	10	0	0	0
LMVP	Flat Cr. at Stubblefield Access	13	12	0	0	0	0
LMVP	Flat Cr. 5 mi.bl. Cassville	15	15	0	0	0	0
LMVP	Flat Cr. 0.5 mi.ab. Cassville	14	14	0	0	0	0
MDNR	Pearson Cr. nr. Springfield, MO	2	2	2	0	0	2
MDNR	James R. at Galena, MO	36	36	36	0	0	0
MSU	Finley Cr. at Green Bridge	27	27	27	22	22	27
MSU	Finley Cr. at Riverdale	28	28	28	23	23	28
MSU	James R. at Shelvin Rock	36	36	36	31	31	36
MSU	James R. at Hwy. B	28	27	27	23	23	28
MSU	James R. at Kinser Bridge	37	37	37	32	32	36
MSU	Panther Cr. nr. Hwy. B	28	28	28	23	23	24
MSU	Wilson Cr. at Wilson Rd.	37	37	37	32	32	36
MSU	Crane Cr. at Hwy. AA	36	36	36	31	31	35
MSU	Pearson Cr. nr. Springfield, MO	28	27	28	23	23	28
MSU	Wilson Cr. nr. Brookline, MO	37	37	37	32	32	36
MSU	James R. at Galena, MO	31	29	31	25	25	30
SPW	James R. at Kerr Access	1	1	1	0	0	1
SPW	James R. at Hootentown Acc	78	65	75	0	0	28
SPW	Finley Cr. nr. mouth - Riverfork	66	53	64	0	0	51
SPW	James R. at Shelvin Rock	6	5	5	0	0	3
SPW	James R. West of Nixa	86	75	83	0	0	60
SPW	Wilson Cr. at Wilson Rd.	86	79	83	0	0	28
SPW	Wilson Cr.4.3 mi.bl. WWTP	73	65	70	0	0	26
SPW	Wilson Cr. 0.6 mi.ab. WWTP	35	12	12	0	0	2
SPW	Terrell Cr. nr. Mouth	47	41	46	0	0	9
SPW	Schuler Cr. nr. Mouth	26	23	26	0	0	1
SPW	James R. nr. Wilson Creek, MO	68	59	66	0	0	48
SPW	Wilson Cr. nr. Brookline, MO	95	91	91	0	0	69
SPW	Wilson Cr. nr. Battlefield, MO	74	66	71	0	0	25
SPW	James R. at Galena, MO	77	62	74	0	0	63
UMC	James R. West of Nixa	38	38	0	34	0	0
USGS	Wilson Cr. 2.3 mi.bl. SW WWTP	1	0	1	0	0	0
USGS	Pearson Cr. nr. Springfield, MO	51	51	51	0	0	41
USGS	James R. nr. Wilson Creek, MO	202	50	153	0	0	199
USGS	Wilson Cr. nr. Brookline, MO	64	64	64	0	0	64
USGS	Wilson Cr. nr. Battlefield, MO	40	40	40	0	0	32
USGS	James R. nr. Boaz, MO	269	118	217	0	0	267
USGS	Finley Cr. at Riverdale, MO.	72	25	25	0	0	72
USGS	Finley Cr. bl. Riverdale, MO	46	46	46	0	0	45
USGS	James R. at Galena, MO	59	59	59	0	0	59
USGS	Flat Cr. at Jenkins, MO	48	48	48	0	0	48
USGS	Flat Creek bl. Jenkins, MO	12	12	12	0	0	12

Note: Total TP sample events is a count of days a site was visited by an agency to collect TP. Co-occuring sample events is the count of days a site was visited by an agency for a particular parameter during a TP sample event.

TABLE 19. Count of Parameters Monitored by Collection Entity

Collection Agency	Total Sample Events	Parameter Sample Events						
		TP	TN	NO_2+NO_3	*E. coli*	Sestonic Chl.*a*	Benthic Chl.*a*	Flow
CCHD	932	0	0	0	932	0	0	0
CU	1325	540	0	1057	0	0	0	0
LMVP	43	42	42	0	0	0	0	0
MDNR	230	38	38	95	181	0	0	2
MSU	450	353	350	352	0	384	350	370
SCHD	525	0	0	0	525	0	0	0
SPW	933	818	729	851	0	0	0	464
UMC	39	38	39	0	0	35	0	0
USGS	1015	864	513	735	335	0	0	977

Note: Total sample events is a count of days a site was visited by an agency summed over all sites. Parameter sample events is a count of days a parameter was sampled for by an agency summed over all sites.

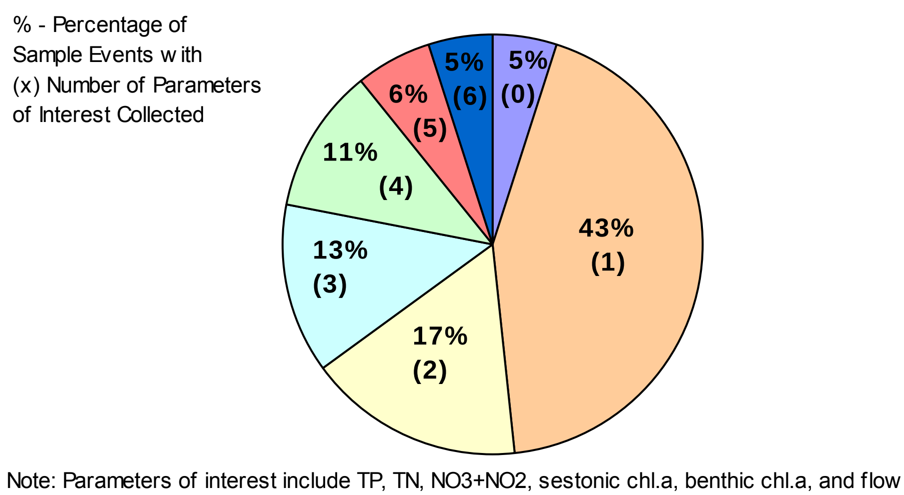

FIGURE 41. Number of Parameters of Interest Collected during Sampling Events

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 0.0 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 does limit the interpretation of the ambient water quality data in streams with low background levels of phosphorus. The most notable TP detection limit issues were with USGS samples at Flat Creek at and below Jenkins (Table 20). The percentage of samples below detection limit at Flat Creek at and below Jenkins was 44% and 92%, respectively. TP detection limits at these sites ranged from 40 to 60 µg/L; however, calculated TP geomeans for these sites ranged from 21 to 32 µg/L (see Section 4.1.1). A more accurate assessment of TP geomeans would require an adjustment in laboratory methods. TP detection limits, where provided, were satisfactory for most other sampling sites.

Nitrogen detection limits, where reported, did not appear to be a significant issue for TN, $NO_3 + NO_2$, or TKN[15] samples. MEC identified no TN samples as being below laboratory detection limits. 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). A small fraction of $NO_3 + NO_2$ samples (fewer than 2% for all but 2 sites) reported levels below laboratory detection limits; however, this likely had little effect on reported ambient concentrations (Table 21). Four sites had greater than 20% of their TKN samples below detection limits; however, this likely had little effect since the detection limits were considerable lower than ambient TN levels at these sites (Table 22). Generally, detection limits for existing nitrogen data in the James River Basin appear to be sufficient for interpretation of the ambient water quality data.

[15] Although TKN is not specifically a parameter of interest, it is a component of calculated TN values.

TABLE 20. Total Phosphorus Sample Results Reported Below Detection Limit

Agency	Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit(s)*
CU	James R. at Kinser Bridge	119	3	2.5%	0(3)
CU	Panther Cr. nr. Hwy. B	14	1	7.1%	0(1)
CU	Pearson Cr. nr. Springfield, MO	38	2	5.3%	0(2)
CU	James River	47	1	2.1%	0(1)
CU	Jones Spring	22	3	13.6%	0(3)
CU	Sawyer Creek ab. Norman Br.	187	2	1.1%	0(2)
CU	Sawyer Creek bl. Norman Br.	115	1	0.9%	0(1)
CU	Turner Creek	11	0	0.0%	NA
LMVP	Flat Cr. at Stubblefield Access	13	0	0.0%	NA
LMVP	Flat Cr. 5 mi.bl. Cassville	15	0	0.0%	NA
LMVP	Flat Cr. 0.5 mi.ab. Cassville	14	0	0.0%	NA
MDNR	Pearson Cr. nr. Springfield, MO	2	0	0.0%	NA
MDNR	James R. at Galena, MO	36	0	0.0%	NA
MSU	Finley Cr. at Green Bridge	27	0	0.0%	NA
MSU	Finley Cr. at Riverdale	28	0	0.0%	NA
MSU	James R. at Shelvin Rock	36	0	0.0%	NA
MSU	James R. at Hwy. B	28	0	0.0%	NA
MSU	James R. at Kinser Bridge	37	0	0.0%	NA
MSU	Panther Cr. nr. Hwy. B	28	0	0.0%	NA
MSU	Wilson Cr. at Wilson Rd.	37	0	0.0%	NA
MSU	Crane Cr. at Hwy. AA	36	0	0.0%	NA
MSU	Pearson Cr. nr. Springfield, MO	28	0	0.0%	NA
MSU	Wilson Cr. nr. Brookline, MO	37	0	0.0%	NA
MSU	James R. at Galena, MO	31	0	0.0%	NA
SPW	James R. at Kerr Access	1	0	0.0%	NA
SPW	James R. at Hootentown Acc	83	2	2.4%	50(2)
SPW	Finley Cr. nr. mouth - Riverfork	71	4	5.6%	50(4)
SPW	James R. at Shelvin Rock	6	0	0.0%	NA
SPW	James R. West of Nixa	92	2	2.2%	50(2)
SPW	Wilson Cr. at Wilson Rd.	91	1	1.1%	50(1)
SPW	Wilson Cr.4.3 mi.bl. WWTP	78	0	0.0%	NA
SPW	Wilson Cr. 0.6 mi.ab. WWTP	35	0	0.0%	NA
SPW	Terrell Cr. nr. Mouth	51	0	0.0%	NA
SPW	Schuler Cr. nr. Mouth	30	3	10.0%	50(3)
SPW	James R. nr. Wilson Creek, MO	73	5	6.8%	50(5)
SPW	Wilson Cr. nr. Brookline, MO	102	1	1.0%	50(1)
SPW	Wilson Cr. nr. Battlefield, MO	79	0	0.0%	NA
SPW	James R. at Galena, MO	82	2	2.4%	50(2)
UMC-Jones	James R. West of Nixa	38	0	0.0%	NA
USGS	Wilson Cr. 2.3 mi.bl. SW WWTP	1	0	0.0%	NA
USGS	James River WLA Study Site 5	4	0	0.0%	NA
USGS	James River WLA Study Site 1	4	2	50.0%	50(2)
USGS	Pearson Cr. nr. Springfield, MO	60	12	20.0%	40(7), 60(5)
USGS	James R. nr. Wilson Creek, MO	202	13	6.4%	10(4), 20(2), 50(7)
USGS	Wilson Cr. nr. Brookline, MO	64	0	0.0%	NA
USGS	Wilson Cr. nr. Battlefield, MO	50	0	0.0%	NA
USGS	James R. nr. Boaz, MO	271	1	0.4%	60(1)
USGS	Finley Cr. at Riverdale, MO.	72	1	1.4%	10(1)
USGS	Finley Cr. bl. Riverdale, MO	55	2	3.6%	40(2)
USGS	James R. at Galena, MO	59	3	5.1%	40(1), 60(2)
USGS	Flat Cr. at Jenkins, MO	48	21	43.8%	40(2), 50(6), 60(13)
USGS	Flat Creek bl. Jenkins, MO	12	11	91.7%	40(11)

* - Detection limit reported in µg/L followed by the count in ( ) at that detection limit (e.g., 10(4) means 4 samples with a laboratory detection limit of 10 µg/L). NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

TABLE 21. Nitrate plus Nitrite Sample Results Reported Below Detection Limit

Agency	Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit(s)*
CU	James R. at Kinser Bridge	311	0	0.0%	NA
CU	Panther Cr. nr. Hwy. B	47	2	4.3%	0(2)
CU	Pearson Cr. nr. Springfield, MO	132	0	0.0%	NA
CU	James River	81	0	0.0%	NA
CU	Jones Spring	76	0	0.0%	NA
CU	Sawyer Creek ab. Norman Br.	244	0	0.0%	NA
CU	Sawyer Creek bl. Norman Br.	140	1	0.7%	0(1)
CU	Turner Creek	49	0	0.0%	NA
MDNR	James R. at Hootentown Acc	6	0	0.0%	NA
MDNR	James R. West of Nixa	6	0	0.0%	NA
MDNR	Wilson Cr. at Wilson Rd.	6	0	0.0%	NA
MDNR	Wilson Cr. 2.3 mi.bl. SW WWTP	6	0	0.0%	NA
MDNR	Rader Spring	6	0	0.0%	NA
MDNR	Wilson Cr. 1.6 mi.bl. SW WWTP	8	0	0.0%	NA
MDNR	Pearson Cr. nr. Springfield, MO	2	0	0.0%	NA
MDNR	James R. nr. Wilson Creek, MO	5	0	0.0%	NA
MDNR	Wilson Cr. nr. Brookline, MO	6	0	0.0%	NA
MDNR	Wilson Cr. Nr. Battlefield, MO	4	0	0.0%	NA
MDNR	James R. at Galena, MO	42	0	0.0%	NA
MSU	Finley Cr. at Green Bridge	27	0	0.0%	NA
MSU	Finley Cr. at Riverdale	28	0	0.0%	NA
MSU	James R. at Shelvin Rock	36	0	0.0%	NA
MSU	James R. at Hwy. B	27	0	0.0%	NA
MSU	James R. at Kinser Bridge	37	0	0.0%	NA
MSU	Panther Cr. nr. Hwy. B	28	0	0.0%	NA
MSU	Wilson Cr. at Wilson Rd.	37	0	0.0%	NA
MSU	Crane Cr. at Hwy. AA	36	0	0.0%	NA
MSU	Pearson Cr. nr. Springfield, MO	28	0	0.0%	NA
MSU	Wilson Cr. nr. Brookline, MO	37	0	0.0%	NA
MSU	James R. at Galena, MO	31	0	0.0%	NA
SPW	James R. at Kerr Access	1	0	0.0%	NA
SPW	James R. at McCall Bridge Rd	3	0	0.0%	NA
SPW	James R. at Hootentown Acc	82	0	0.0%	NA
SPW	Finley Cr. nr. mouth - Riverfork	77	1	1.3%	2000(1)
SPW	James R. at Shelvin Rock	10	0	0.0%	NA
SPW	James R. West of Nixa	91	0	0.0%	NA
SPW	Wilson Cr. at Wilson Rd.	93	0	0.0%	NA
SPW	Wilson Cr.4.3 mi.bl. WWTP	75	0	0.0%	NA
SPW	Rader Spring	1	0	0.0%	NA
SPW	Wilson Cr. 0.6 mi.ab. WWTP	23	0	0.0%	NA
SPW	Terrell Cr. nr. Mouth	63	0	0.0%	NA
SPW	Schuler Cr. nr. Mouth	36	0	0.0%	NA
SPW	James R. nr. Wilson Creek, MO	93	1	1.1%	2000(1)
SPW	Wilson Cr. nr. Brookline, MO	100	0	0.0%	NA
SPW	Wilson Cr. nr. Battlefield, MO	77	0	0.0%	NA
SPW	James R. at Galena, MO	84	0	0.0%	NA
USGS	Wilson Cr. 2.3 mi.bl. SW WWTP	4	0	0.0%	NA
USGS	James River WLA Study Site 5	12	0	0.0%	NA
USGS	James River WLA Study Site 1	12	0	0.0%	NA
USGS	Pearson Cr. nr. Springfield, MO	60	0	0.0%	NA
USGS	James R. nr. Wilson Creek, MO	163	1	0.6%	100(1)
USGS	Wilson Cr. nr. Brookline, MO	70	0	0.0%	NA
USGS	Wilson Cr. nr. Battlefield, MO	50	0	0.0%	NA
USGS	James R. nr. Boaz, MO	231	2	0.9%	100(2)
USGS	Finley Cr. at Riverdale, MO.	25	0	0.0%	NA
USGS	Finley Cr. bl. Riverdale, MO	55	0	0.0%	NA
USGS	James R. at Galena, MO	59	0	0.0%	NA
USGS	Flat Cr. at Jenkins, MO	48	0	0.0%	NA
USGS	Flat Creek bl. Jenkins, MO	12	1	8.3%	60(1)

* - Detection limit reported in µg/L followed by the count in ( ) at that detection limit (e.g., 10(4) means 4 samples with a laboratory detection limit of 10 µg/L). NA = not applicable (i.e., 0% of the samples below the laboratory detection limit).

TABLE 22. Total Kjeldahl Nitrogen Sample Results Reported Below Detection Limit

Agency	Name	Sample Count	Samples Below Detection Limit	Percent Below Detection Limit	Detection Limit(s)*
MDNR	Pearson Cr. nr. Springfield, MO	2	1	50.0%	50(1)
MDNR	James R. at Galena, MO	36	9	25.0%	50(1), 200(7), 1000(1)
SPW	James R. at Kerr Access	1	0	0.0%	NA
SPW	James R. at Hootentown Acc	72	12	16.7%	0(2), 10(1), 50(8), 100(1)
SPW	Finley Cr. nr. mouth - Riverfork	64	13	20.3%	0(3), 10(1), 50(8), 100(1)
SPW	James R. at Shelvin Rock	6	0	0.0%	NA
SPW	James R. West of Nixa	83	6	7.2%	10(1), 50(4), 100(1)
SPW	Wilson Cr. at Wilson Rd.	88	6	6.8%	10(1), 50(4), 100(1)
SPW	Wilson Cr.4.3 mi.bl. WWTP	72	6	8.3%	10(2), 50(4)
SPW	Wilson Cr. 0.6 mi.ab. WWTP	19	0	0.0%	NA
SPW	Terrell Cr. nr. Mouth	52	8	15.4%	0(2), 10(1), 50(4), 100(1)
SPW	Schuler Cr. nr. Mouth	30	11	36.7%	0(2), 10(1), 50(6), 83(1), 100(1)
SPW	James R. nr. Wilson Creek, MO	81	10	12.3%	0(3), 10(1), 50(4), 83(1), 100(1)
SPW	Wilson Cr. nr. Brookline, MO	101	5	5.0%	0(1), 10(2), 50(2)
SPW	Wilson Cr. nr. Battlefield, MO	74	8	10.8%	10(1), 50(6), 100(1)
SPW	James R. at Galena, MO	70	8	11.4%	0(1), 10(1), 50(5), 100(1)
USGS	Pearson Cr. nr. Springfield, MO	60	1	1.7%	100(1)
USGS	James R. nr. Wilson Creek, MO	50	0	0.0%	NA
USGS	Wilson Cr. nr. Brookline, MO	64	0	0.0%	NA
USGS	Wilson Cr. nr. Battlefield, MO	50	0	0.0%	NA
USGS	James R. nr. Boaz, MO	122	1	0.8%	200(1)
USGS	Finley Cr. at Riverdale, MO.	25	0	0.0%	NA
USGS	Finley Cr. bl. Riverdale, MO	55	0	0.0%	NA
USGS	James R. at Galena, MO	59	0	0.0%	NA
USGS	Flat Cr. at Jenkins, MO	48	1	2.1%	100(1)
USGS	Flat Creek bl. Jenkins, MO	12	2	16.7%	100(2)

* - Detection limit reported in µg/L followed by the count in ( ) at that detection limit (e.g., 10(4) means 4 samples with a laboratory detection limit of 10 µg/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). Metadata about the geographic coordinates (e.g., accuracy and datum) can be critical for determining the exact location of a site. Generally not much information was available regarding sample sites beyond the geographic coordinates. In some instances, however, even the geographic coordinates were not readily available. Unless a sample collection site can be identified, the water quality data are of little use. MEC identified 13 sampling sites potentially in the James River Basin with no geographic coordinates. Eleven of these sites were sampled by CU, and 2 sites were sampled by SPW. However, 10 of these sites

have fewer than 10 samples. 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 James 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. Chief among these data sources are the Watershed Committee of the Ozarks (WCO), MSU, CCHD, SPW, SCHD, and Greene County. Although much data from the MSU, CCHD, SCHD and SPW were already incorporated in the MDNR database, some water quality data were only available directly from these sources. 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;
- Non-point source loading issues;
- Special studies in support of nutrient criteria development;
- Further investigate toxicity issues; 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 James 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.

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 2007. 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).

Although significant nutrient data are available in the WQIP database, they are likely insufficient for all the data analysis methods recommended by MDNR. Where current data are sufficient, further analysis based on MDNR's suggestions is recommended. However, additional causal (nutrient) and response (algae) data are necessary. In particular, there are relatively little paired causal and response variable data currently available. WQIP should therefore design and implement special nutrient water quality studies with the goal of supporting the development of technically sound nutrient criteria.

Further Investigate Toxicity Issues

Previous studies by the USGS, the National Park Service, the Missouri Department of Conservation, and biologists at City Utilities of Springfield suggest Wilson and Pearson Creeks aquatic life communities are impaired due to toxicity. MDNR met with the City of Springfield officials in October 2004, and the City agreed to modify their monitoring to include toxicity testing modeled after the work done on Hinkson Creek in Boone County. Hinkson Creek is also apparently impacted by unknown toxicity. Available toxicity data should be further analyzed and if necessary, more focused monitoring efforts may be necessary in Wilson and Pearson Creeks.

Continue to Populate Database with Historical Data

Much water quality data in the James River Basin have not been incorporated into the WQIP database due to a lack of common metadata and suitable data storage format. As indicated in this report, much data are known to exist but will require a considerable amount of effort to add to the database. 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.

8. REFERENCES

Adamski, J.C., J.C. Petersen, D.A. Freiwald, and J.V. Davis, (1995). Environmental and Hydrologic Setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma. U.S. Geological Survey Water-Resources Investigations Report 94-4022.

Aldrich, M.W., D. Meinert, (1994). Soil Survey of Barry County Missouri. United States Department of Agriculture Soil Conservation Service.

Carnahan. (2005). Code of State Regulations; Missouri Water Quality Standards, Title 10, Division 20, Chapter 7.

Chapra, S.C, (1997). *Surface Water-Quality Modeling*. The McGraw-Hill Companies, Inc., New York.

Correll, D.L. (1999). "Phosphorus: a rate limiting nutrient in surface waters." *Poultry Sci*. 78:674-682.

Dodds, W. (2006). "Eutrophication and Trophic State in Rivers and Streams." *Limnology Oceanography*. 51(1, part 2), 671-680.

Dodds, W., J.R. Jones, and E.B. Welch. (1998). "Suggested Classification of stream trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus." *Water Research*. 32(5): 1455-1462.

Driscoll, C.T., et al. (2003). Nitrogen Pollution: From the Sources to the Sea. Hubbard Brook Research Foundation. Science Links™ Publication. Vol. 1, no. 2.

Hessen, D.O., P.Færøvig, and T.Andersen. (2002). "Light, Nutrients, and P:C Ratios in Algae: Grazer Performance Related to Food Quality and Quantity." *Ecology*. 83(7), 1886-1898.

Kiner, L.K. and C. Vitello, (1997). James River Basin Inventory and Management Plan. Missouri Department of Conservation.

Knowlton, M.F. and J.R. Jones, (1989). Summer Distribution of Nutrients, Phytoplankton and Dissolved Oxygen in Relation to Hydrology in Table Rock Lake, a Large Midwestern Reservoir. Arch. Hydrobiol./Suppl. 83(2):197-225.

Missouri Department of Natural Resources (MDNR). (2006a). Missouri's Proposed 2004/2006 303(d) List. Water Protection Program. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2006b). Water Quality Data for Waters on the 2002 303(d) List Proposed for Delisting in 2006 – Wilson Creek. <http://www.dnr.mo.gov/env/wpp/waterquality/303d/2006pn/proposed-2002-listing-data.htm> (March 20, 2007).

Missouri Department of Natural Resources (MDNR). (2006c). Methodology for the Development of the 2006 Section 303(d) List in Missouri. Water Pollution Control Program. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2006d). Water Quality Data for Waters on the 2002 303(d) List Proposed for Delisting in 2006 – Pearson Creek. <http://www.dnr.mo.gov/env/wpp/waterquality/303d/2006pn/proposed-2002-listing-data.htm> (March 20, 2007).

Missouri Department of Natural Resources (MDNR). (2006e). Water Quality Data for Waters on the 2002 303(d) List Proposed for Delisting in 2006 – James River. <http://www.dnr.mo.gov/env/wpp/waterquality/303d/2006pn/proposed-2002-listing-data.htm> (March 20, 2007).

Missouri Department of Natural Resources (MDNR). (2005a). Missouri Water Quality Report - 2004. Water Protection Program. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2005b). Nutrient Criteria Plan. WaterProtection Program. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2005c). A Proposal for a Water Quality Monitoring Strategy for Missouri. Water Pollution Control Program. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2005d). Nutrient Criteria Plan. Water Protection Program. Jefferson City, MO. (September 13, 2005).

Missouri Department of Natural Resources (MDNR). (2004a). Total Maximum Daily Load Information Sheet – James River. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2004b). Total Maximum Daily Load Information Sheet – Wilsons Creek. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2004c). Total Maximum Daily Load Information Sheet – Pearson Creek. Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). (2001). Total Maximum Daily Load (TMDL) for James River, Webster, Greene, Christian and Stone Counties, Missouri. Jefferson City, MO.

Newman, A. (1996). "Water pollution point sources still significant in urban areas." *Environmental Science and Technology*, 29, 114.

National Water Quality Monitoring Council (NWQMC). (2006). "Data Elements for Reporting Water Quality Monitoring Results for Chemical, Biological, Toxicological, and Microbiological Analytes." Prepared by: Methods and Data Comparability Board of the National Water Quality Monitoring Council. NWQMC Technical Report No. 3. April, 2006.

Richards, J.M. and B.T. Johnson. (2002). Water quality, selected chemical characteristics, and toxicity of base flow and urban stormwater in the Pearson Creek and Wilson's Creek Basins, Greene County, Missouri, August 1999 to August 2000. USGS Water-Resources Investigations Report 02-4124.

Seelig, B. and J. Nowatzki. (2001). "Water Quality and Nitrogen." North Dakota State University Agriculture and University Extension. <http://www.ag.ndsu.edu/pubs/h2oqual/watnut/ae1216w.htm> (December 19, 2006).

Smith, V.H., G.Tilman, and J.Nekola. (1999). "Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems." *Environmental Pollution*. 100 (1999) 179-196.

U.S. Environmental Protection Agency (EPA). (2006). "Introduction to TMDLs." <http://www.epa.gov/owow/tmdl/intro.html> (March 20, 2007).

U.S. Environmental Protection Agency (EPA). (2003a). A Summary of General Assessment Factors for Evaluating Quality of Scientific and Technical Information. United States Environmental Protection Agency, Washington, D.C. EPA-100/B-03/001.

U.S. Environmental Protection Agency (EPA). (2003b). Implementation Guidance for Ambient Water Quality Criteria for Bacteria – November 2003 Draft. United States Environmental Protection Agency, Washington, D.C. EPA. EPA-823-B-03-XXX.

U.S. Environmental Protection Agency (EPA). (2000). Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion XI United States Environmental Protection Agency, Washington, D.C. EPA. EPA-822-B-00-020.

U.S. Environmental Protection Agency (EPA). (1985). Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). United States Environmental Protection Agency, Washington, D.C. EPA. EPA/600/3-85/040.