Final Report – Volume 1

Water Quality and Biological Assessment of Selected Segments in the Illinois River Basin and Kings River Basin, Arkansas

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EXECUTIVE SUMMARY

E-1 Introduction

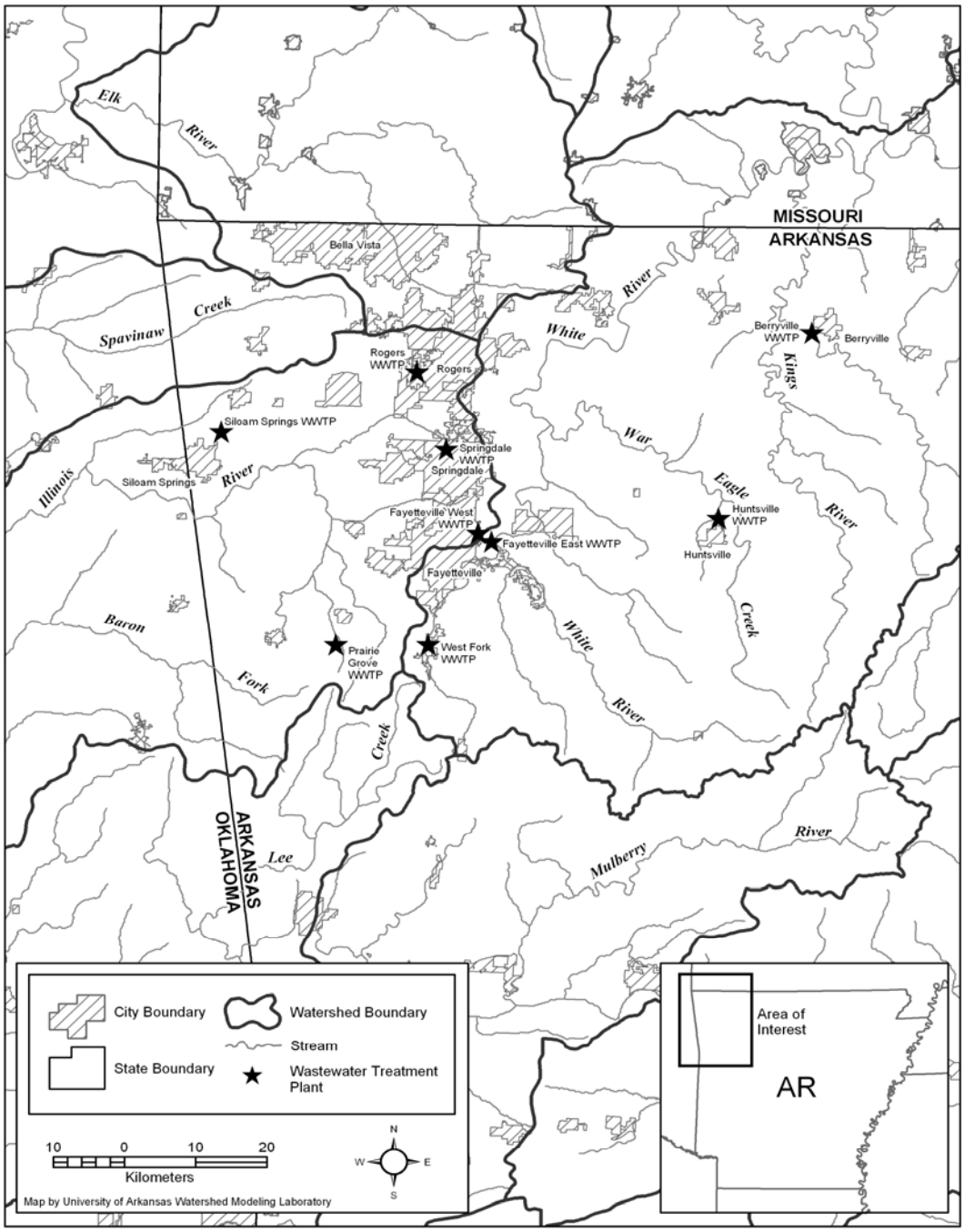
This report presents the characterization of water quality and aquatic biological resources of several streams in the Illinois River basin and Kings River basin in northwest Arkansas to determine the status of aquatic life use. The Illinois River flows predominately westward into Oklahoma and the Kings River flows northward into Missouri. Parsons (Austin, Texas) and the University of Arkansas Biological and Agricultural Engineering Department (Fayetteville, Arkansas) conducted this project, funded by the United States Environmental Protection Agency (USEPA) Region 6. The objective of this project was to provide data to USEPA for use in evaluating the status of attainment of the aquatic life use designated for these streams. This necessitated collecting water quality and biological data for selected water bodies in the Arkansas portion of the Illinois and Kings River basins. A key driver for conducting this project was to obtain more field data in time to support preparation of the Arkansas 2004 Integrated Water Quality Monitoring and Assessment Report. USEPA Region 6 will utilize data collected through this project in combination with other existing chemical, physical, and biological data, to make decisions on whether the segments in these watersheds need to be placed on the Arkansas Department of Environmental Quality's (ADEQ) 2004 Section 303(d) list of impaired waters. Figure E-1 depicts the northwest region of Arkansas where the investigation was performed.

This project utilized sampling and analysis methods and procedures similar to those used in a study conducted by the Arkansas Department of Pollution Control and Ecology Commission (APCEC) initiated in 1995 titled, *Illinois River Water Quality, Macroinvertebrate and Fish Community Survey* (ADEQ 1997). The results of the 1997 ADEQ report were part of a number of different factors that influenced the design of this project. The primary water quality concern targeted in this project was the impact on instream biological communities and aquatic life use made by nutrient concentrations and dissolved oxygen. Of particular interest were those waters upstream and downstream of wastewater treatment plants in the Cities of Rogers, Springdale, Prairie Grove, and Berryville, Arkansas.

The primary "yardstick" or basis for making an aquatic life use impairment determination, or 303(d) listing decision, is ADEQ Regulation 2, the state water quality standards (ADEQ 2002a). The ADEQ 2002 Integrated Water Quality Monitoring and Assessment Report and the state's Continuing Planning Process also provide additional guidance that influences data collection and assessment methods for making an aquatic life use impairment determination. To determine if a water body is impaired data must be assessed consistent with the state's numeric and narrative water quality criteria.

This project was developed, funded, and performed under a highly compressed schedule. It was recognized at the outset of the project that the window for conducting

Figure E-1 Northwest Arkansas Regional Map



sampling was limited and would occur in both the critical season (mid-May to mid-September) and primary season (mid-September to mid-May) as defined by Regulation 2. The sampling approach included one full suite of water quality measurements, water quality chemistry analysis, and one rapid bioassessment protocol during the ADEQ-defined critical season, *i.e.,* prior to September 15, 2003; a second full sampling suite, and a third set of water quality measurements and water chemistry sampling in the primary season (*i.e.,* after September 15). Following USEPA approval of the quality assurance project plan (QAPP) on August 28, 2003, the project was initiated immediately but storm events in early September prohibited completion of a full suite of water quality, water chemistry, and biological sampling in the critical season (prior to September 15, 2003). Additional rains in October caused a significant increase in water flow, necessitating removal of sampling equipment, further delaying data collection progress. Sampling was conducted at 16 different sites; including three regional "minimally impacted" reference streams for comparison.

E-2 Data Assessment Results and Conclusions

When conducting an assessment of aquatic life use impairment both numeric and narrative water quality criteria must be considered. Given the lack of specific Arkansas numeric criteria for nutrients, a suite of indicators including instream concentrations of total phosphorus (TP), daily fluctuations in dissolved oxygen (DO) concentration and DO saturation, elevated pH and total dissolved solids (TDS), habitat characteristics, periphyton presence, filamentous algae presence, benthic community structure, and fish community structure were used to assess the aquatic life use.

The overall ecological condition of the water bodies in the Illinois River basin has been impacted as evidenced by the degraded water quality, habitat quality and biological community. Table E-1 summarizes the three sampling events conducted in the Illinois River and its tributaries and demonstrates impacts in all four major categories of metrics: 1) water quality measurements (DO excursions), 2) water chemistry analysis (elevated concentrations of phosphorus) 3) habitat characteristics, and 4) biological characteristics. This table presents the results of this project in an inter-related manner that supports a weight-of-evidence approach to be used to evaluate the aquatic life use. Multiple stressors at multiple scales are affecting this system at all times. The Illinois River and some of its tributaries are systematically affected by human alterations of the landscape, and by diminishing water quality caused by direct and indirect discharges to the streams.

Streams in the Illinois River basin are nutrient enriched by WWTPs in the region. While nonpoint source pollutants from rainfall runoff also contribute significant nutrient loads, they were not specifically quantified by this study. The ecological impact of nutrient enrichment, regardless of the sources, is generally not manifested in Ozark Plateau streams, primarily due to intact riparian zones resulting in light limitation for algal growth. Algal growth on nutrient enriched passive diffusion periphytometers at stations OSG030 (relatively open canopy) and SPG931UP (relatively closed canopy) demonstrated that algal growth was light limited, consistent with upland streams in the Ozark Plateau ecoregion.

The role of stream habitat, especially riparian zone, in protecting and maintaining aquatic life use in these systems cannot be overstated. Loss of riparian zone cover in streams that are nutrient enriched will result in dramatic increases in algal production, shifts in algal communities to filamentous species, shifts in benthic community functional feeding groups, and shifts in fish communities to grazers. As riparian buffers are removed across the Ozark Plateau, streams are exposed to direct sunlight and increased water temperatures. Both of these variables increase the rate of algal biomass production. Increased algal production due to nutrient enrichment has produced DO impairments at SPG931DN.

Overall, the ecological condition of the water bodies in the Kings River basin display minor water quality, biological, and habitat impacts in isolated locations. As summarized in Table E-2 the Kings River and its tributaries demonstrate minor impacts in three of the four major categories of metrics: 1) water quality measurements (DO excursions), 2) water chemistry analysis (elevated concentrations of phosphorus), and 3) biological characteristics. This table presents the result of this project in an inter-related manner that allows a weight-of-evidence approach to be used to evaluate the aquatic life use. Like the Illinois River basin, the Kings River system is being affected by multiple stressors at multiple scales at all times. The rate and degree of alteration of the landscape is much lower in this basin. However, Table Rock Lake in Missouri, the receiving water for the Kings River, is nutrient enriched, and significant portions of the nutrient loading are coming from the Kings River.

The Kings River, as a relatively unimpacted system, shows the early stages of instream habitat alteration more dramatically than the streams of the Illinois River basin. The primary sources of sediment load in the Kings River are likely NPS loads from agricultural production practices, changes in hydrologic flow regimes due to land use changes within watersheds, and floodplain and in-stream channel alterations. The ecological impact of this dramatic increase in sediment and nutrient loads will be more pronounced in this basin than the Illinois River basin, due to the relatively high level of integrity in the system now.

Table E-1 Summary of Stream Aquatic Life Assessment Scoring for the Illinois River

First Sampling Event (first event for each media)

	Water Quality Measurements			Water Chemistry Analysis		Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
OSG930DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted	Impacted
SPG931UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted
SPG931DN	NA	NA	NA	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted
OSG030	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted
MUD027UP	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted
MUD027DN	Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted
MUD025	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
ILL022	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted	NS	Not Impacted
ILL020	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
SPA048 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Reference	Not Impacted
FLT031 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Reference	Not Impacted

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

Second Sampling Event (second event for each media)

	Water Quality Measurements			Water Chemistry Analysis		Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
OSG930DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
SPG931UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
SPG931DN	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Impacted
OSG030	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
MUD027UP	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
MUD027DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
MUD025	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
ILL022	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS
ILL020	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	NS
SPA048 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Reference	Not Impacted
FLT031 Reference Site	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Reference	Not Impacted

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

Third Sampling Event (third event for each media that was to be sampled)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
OSG930DN	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
SPG931UP	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
SPG931DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
OSG030	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
MUD027UP	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
MUD027DN	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
MUD025	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
ILL022	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
ILL020	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
SPA048 Reference Site	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
FLT031 Reference Site	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS

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NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
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D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
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Table E-2 Summary of Stream Aquatic Life Assessment Scoring for the Kings River

First Sampling Event (first event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted
OSG045DN	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted
KIN037	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
KIN042 Reference Site	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Reference	Impacted

Second Sampling Event (second event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	Not Impacted
OSG045DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Impacted
KIN037	Not Impacted	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
KIN042 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	Not Impacted

Third Sampling Event (third event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
OSG045DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
KIN037	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
KIN042 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS

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Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

E-3 Assessment of Use Attainment Status Using the Weight-of-Evidence Approach

The purpose of this project was to acquire and analyze data to conduct an aquatic life use assessment of the water bodies within the Illinois River basin and Kings River basin using a weight-of-evidence approach. It is recognized that neither a single indicator nor a single event represent adequate information upon which to base an assessment of aquatic life use status. However, when a suite of indicators suggests aquatic life use impact more than one time, there is reasonable cause to characterize aquatic life at that site as impacted to some degree. This report uses a simple algorithm to evaluate each water body based upon the proportion of indicators considered impacted per sample event. While a standard method for applying a weight-of-evidence approach to assess beneficial uses does not exist in Arkansas or USEPA Region 6, this method does provide a rational mechanism for integrating chemical, physical, and biological data and drawing logical conclusions from the aggregated results. Eleven indicators divided into three categories, Water Chemistry, Habitat, and Biological Characteristics, were used to develop this weight-of-evidence summary for the Illinois River and Kings River basins. Each of the eleven indicators were assessed relative to a reference condition, ADEQ Regulation 2 criteria, or USEPA guidance to determine if they were impacted within a reach during an assessment event.

An overall characterization of each site was compiled using the summation of impacted indicators for each site over the three sampling events. The results of this summary assessment are provided in Table E-3. Columns on the right side of Table E-3 tally the total number of impacted indicators per event and then sum the impacted indicators for the three events combined for each site. If less than five of the indicators were determined to be impacted during the three sampling events, the sites were categorized as *unimpacted*. If between five and eight of the indicators were determined to be impacted, the site was categorized *slightly impacted*. If between nine and 12 of the indicators were impacted, the site was determined to be *impacted*. If more than 13 of the indicators were impacted, the sight was determined to be *severely impacted*.

Based upon this weight-of-evidence approach, for the Illinois River sites, four sites scored as unimpacted, five sites scored as slightly impacted, two sites were determined to be impacted, and one was classified as severely impacted (Table E-3). For the Kings River sites, two sites scored as unimpacted, one site scored as slightly impacted, and one site was classified as severely impacted (Table E-3).

Table E-3 Weight-of-Evidence Summary for Illinois and Kings Rivers

Illinois River

Station	Sampling Event	Water Chemistry					Habitat		Biological Characteristics				Indicators Impacted (per event)	Total Number of Indicators Impacted (all events)	Conclusions (based on all events)
		DO min	DO fluct	DO Sat	TP	TDS	Riffle	Pool	Periphyton	Filamentous	Benthics	Fish			
OSG930UP	1	O	O	O	O	O	O	O	X	O	O	O	1	3	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	O	O	0		
	3	X	X	O	O	O	--	--	--	--	--	--	2		
OSG930DN	1	O	O	O	X	O	O	O	X	O	X	X	4	7	**Slightly Impacted**
	2	O	O	O	X	O	O	O	--	--	X	O	2		
	3	--	--	--	X		--	--	--	--	--	--	1		
SPG931UP	1	O	O	O	X	O	X	X	X	O	X	O	5	7	**Slightly Impacted**
	2	O	O	O	O	O	X		--	--	X	O	2		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
SPG931DN	1	--	--	--	X	X	X	O	X	X	X	X	7	16	**Severely Impacted**
	2	X	O	O	X	X	O	O	--	--	X	X	5		
	3	O	X	X	X	X	--	--	--	--	--	--	4		
OSG030	1	O	X	X	X	X	X	O	X	X	O	X	8	12	**Impacted**
	2	O	X	O	X	O	O	O	--	--	O	O	2		
	3	O	X	O	X	O	--	--	--	--	--	--	2		
MUD027UP	1	O	X	O	X	O	X	X	X	O	X	O	6	8	**Slightly Impacted**
	2	X	O	O	O	O	O	O	--	--	X	O	2		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
MUD027DN	1	X	X	X	X	O	X	X	O	O	X	O	7	12	**Impacted**
	2	O	O	O	X	O	X	O	--	--	X	O	3		
	3	--	--	--	X	X	--	--	--	--	--	--	2		
MUD025	1	X	X	O	O	O	X	O	X	O	O	O	4	7	**Slightly Impacted**
	2	X	X	O	X	O	O	O	--	--	O	O	3		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
ILL022	1	O	X	O	X	O	X	O	X	O	--	O	4	6	**Slightly Impacted**
	2	O	O	O	X	O	O	O	--	--	--	--	1		
	3	--	--	--	X	O	--	--	--	--	--	--	1		
ILL020	1	O	O	O	X	O	O	O	X	O	O	O	2	4	**Unimpacted**
	2	O	O	O	X	O	O	O	--	--	O	--	1		
	3	--	--	--	X	O	--	--	--	--	--	--	1		
SPA048	1	O	O	O	O	O	O	O	X	O	O	O	1	1	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	O	O	0		
	3	--	--	--			--	--	--	--	--	--	0		
FLT031	1	O	O	O	O	O	O	O	O	O	O	O	0	2	**Unimpacted**
	2	O	X	O	O	O	O	O	--	--	O	O	1		
	3	O	O	X	O	O	--	--	--	--	--	--	1		

Kings River

Station	Sampling Event	Water Chemistry					Habitat		Biological Characteristics				Number of Indicators	Total Number of Indicators Impacted (all	Conclusions (based on all events)
		DO min	DO fluct	DO Sat	TP	TDS	Riffle	Pool	Periphyton	Filamentous	Benthics	Fish			
OSG045UP	1	O	O	O	O	O	O	O	O	X	O	X	2	3	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	--	O	0		
	3	X	O	O	O	O	--	--	--	--	--	--	1		
OSG045DN	1	X	X	O	X	X	O	O	O	X	X	O	6	16	**Severely Impacted**
	2	O	X	X	X	X	O	O	--	--	X	X	6		
	3	O	X	X	X	X	--	--	--	--	--	--	4		
KIN037	1	O	O	O	X	X	O	O	X	O	O	O	3	8	**Slightly Impacted**
	2	O	X	X	O	X	O	O	--	--	O	O	3		
	3	--	--	--	X	X	--	--	--	--	--	--	2		
KIN042	1	X	O	O	O	O	O	O	O	X	O	X	3	3	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	--	O	0		
	3	O	O	O	O	O	--	--	--	--	--	--	0		

X = Indicates Impacted
O = Indicates Unimpacted -- = not sampled or equipment malfunction
Scoring for Summary:
Summation of three events of impacted indicators: 0 to 4 impacted = "unimpacted"; 5 to 8 impacted = "slightly impacted"; 9 to 12 impacted = "impacted"; 13 or more impacted = "severely impacted."

E-4 Recommendations

This report concludes with a number of recommendations and identifies issues that should be addressed to achieve a more definitive understanding of the ecological condition and aquatic life use support for the water bodies in the Illinois and Kings River basins.

- USEPA Region 6 and the Region 6 states should develop and make available more definitive assessment procedures and translators for assessing narrative criteria and aquatic life use attainment.
- A more thorough characterization of the daily and seasonal dissolved oxygen fluctuations, storm water sampling and phosphorus resuspension in each river basin would provide much needed data to understand the relationship between point source and nonpoint source loading.
- A clear need exists to develop unambiguous methods of assessing biotic and habitat conditions in these and similarly impacted stream systems in Arkansas and across USEPA Region 6.
- The most common and potentially dramatic stressor for these streams, sediment, was not explicitly considered in this assessment. Total suspended solids, sediment oxygen demand, and other sediment related parameters should be investigated throughout both river basins.
- Future monitoring in the watersheds should be considered to better account for the degree or intensity of the processes causing changes in stream substrate.
- The use of "minimally impacted" sites as acceptable reference sites used for investigations of this type should be evaluated and resolved between states and USEPA Region 6.
- USEPA Region 6 should work with the states to develop a consistent, quantitative methodology for a weight-of-evidence approach when using chemical, physical and biological data to determine beneficial use attainment status.

The results of this project combined with other existing water quality data from the Illinois River basin and Kings River basin suggest a trend of declining water and habitat quality which is impacting the biological communities to varying degrees. The results summarized in this report combined with other existing water quality data will allow USEPA to confer with ADEQ in making a decision on whether the aquatic life uses of the water bodies within the Illinois and Kings River basins are impaired and warrant placement on the 2004 Clean Water Act §303(d) list.

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ACRONYMS AND ABBREVIATIONS

μg/L	Micrograms per liter
ADEQ	Arkansas Department of Environmental Quality
APCEC	Arkansas Pollution Control and Ecology Commission
APHA	American Public Health Association
ADPCE	Arkansas Department of Pollution Control and Ecology
AWRC	Arkansas Water Resources Center
°C	Degrees Celsius
cfs	Cubic feet per second
CLI	Community Loss Index
cm	Centimeter
CWA	Clean Water Act
DNR	Department of Natural Resources
DO	Dissolved oxygen
DQO	Data quality objective
DRP	Dissolved reactive phosphorus
EEG	Ecological Engineering Group
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FFG	Functional feeding group
FPOM	Fine particulate organic matter
HBI	Hilsenhoff Biotic Index
lbs/day	Pounds per day
LETSI	Lotic ecosystem trophic status index
m^2	Square mile
MDNR	Missouri Department of Natural Resources
mg/L	Milligrams per liter
mg/m^2	Milligrams per square meter
mm	Millimeter
MPP	Maximum potential productivity
N	Nitrogen
N+P	Nitrate and Phosphate
NAWQA	Ozark Plateaus National Water Quality Assessment
NPDES	National pollutant discharges elimination system
NPS	Nonpoint source
NTU	Nepholometric turbidity units
P	Phosphorus
ppm	Parts per million
QAPP	Quality Assurance Project Plan
QC	Quality control
RBA	Rapid Bioassessment
RBP	Rapid bioassessment protocols
Reg 2	ADEQ Regulation No. 2, state water quality standards
SNK	Student-Newman-Keuls
SRP	Soluble reactive phosphorus

SWDI	Shannon-Weiner Diversity Index
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TMDL	Total maximum daily load
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WWTP	Wastewater treatment plant

SECTION 1
INTRODUCTION

1.1 BACKGROUND

This report presents the characterization of water quality and aquatic biological resources of several streams in the Illinois River basin and Kings River basin in northwest Arkansas. Parsons (Austin, Texas) and the University of Arkansas Biological and Agricultural Engineering Department (Fayetteville, Arkansas) conducted this project, funded by the United States Environmental Protection Agency (USEPA) Region 6. The rationale for conducting this project was to provide data that USEPA can use to evaluate the status of attainment of the aquatic life designated use of the streams. A key driver for conducting this project was to obtain more field data in time to support preparation of the Arkansas 2004 Integrated Water Quality Monitoring and Assessment Report.

This report presents introductory information in Section 1, followed by a description of sampling methodology in Section 2. Sections 3 and 4 present results of the field data collected for the Illinois and Kings Rivers, respectively. Section 5 summarizes the project findings and provides a discussion of the results, and Section 6 presents recommendations.

1.2 PROJECT OBJECTIVES

The objective of this project was to provide data to USEPA for use in evaluating the status of attainment of the aquatic life designated use of the streams. This necessitated collecting water quality and biological data for selected water bodies in the Illinois and Kings River basins in northwest Arkansas. USEPA will utilize data collected through this project in combination with other existing chemical, physical, and biological data, to make decisions on whether the segments in these basins need to be placed on the Arkansas Department of Environmental Quality's (ADEQ) 2004 Section 303(d) list of water quality limited waters.

Water quality in this region prior to recent development has been historically good. Recent changes in agricultural practices and significant population growth in the region led to deterioration in surface water quality (Wagner and Woodruff 1997; Davis and Bell 1998; Haggard *et al*. 2000). Stream nutrient concentrations and loads also increased after increases in the proportion of agricultural and urban land use in the upland zones throughout the region (Haggard *et al*. 2001, Petersen 1992; Petersen *et al*. 1998). Potential sources of excess nutrients include runoff from agricultural lands, erosion from construction sites, on-site septic system failure, and municipal wastewater treatment plants (WWTP).

This project utilized sampling and analysis methods and procedures similar to those used in a study conducted by the Arkansas Department of Pollution Control and Ecology (ADPCE) in 1995 entitled, *Illinois River Water Quality, Macroinvertebrate and Fish Community Survey* (ADEQ 1997). Results of the 1997 ADEQ study were part of a

number of factors that influenced the design of this project. The primary water quality concern targeted in this project was the impact on instream biological communities and aquatic life use caused by excessive nutrient concentrations and low dissolved oxygen. Of particular interest were reaches above and below WWTPs of the Cities of Rogers, Springdale, Prairie Grove, and Berryville, Arkansas.

Water quality data collected for this project included three events of field measurements and water chemistry analysis at each sampling location. The biological and physical characterizations included two rapid bioassessment protocols (RBP) sampling events performed at each location to qualitatively evaluate stream ecology. These RBPs were performed to provide useful data for evaluating the ecological conditions in selected streams.

1.3 GEOGRAPHIC CONTEXT OF STUDY AREA

Figure 1.1 shows the northwest region of Arkansas where the investigation was performed. Sampling was conducted in the Arkansas portion of the Illinois River and Kings River. Portions of the Illinois River study area lie within Washington County and Benton County, AR, and portions of the Kings River study area lie within Carroll County and Madison County, AR. The landscape of the Ozark Highlands (the Ozark Broadleaf Forest – Meadow Province Ecoregion using the United States Forest Service (USFS) Ecoregion classification system) consists of rolling wooded hills, lowland meadows, and karst geology. The primary land uses of northwest Arkansas are forest and agriculture. Annual average rainfall within the study area ranges from 45-50 inches (USFS 1999).

The Illinois River flows predominately westward into Oklahoma. The Arkansas portion of the Illinois River is approximately 40 miles long with a contributing watershed of approximately 1,500 square miles. The annual average flow for the period of record 1995 to 2000 at United States Geological Survey (USGS) gage station number 07195400 was 593 cubic feet per second (cfs). Headwaters of some of the Illinois River tributaries originate in urban or developed areas. Agricultural run-off as well as effluent from the Cities of Fayetteville, Springdale, Rogers, Siloam Springs and Prairie Grove, Arkansas have a significant influence on the water quality of the Illinois River and its tributaries (Nelson *et al*. 2002; Haggard *et al.* 2002; Ekka *et al*. 2003). Figure 1.2 shows sampling stations within the Illinois River basin including the reference sites Flint Creek and Spavinaw Creek, both of which are located just north of the Illinois River.

The Kings River is a subbasin of the Table Rock Reservoir basin and flows northward into Missouri. The Arkansas portion of the Kings River is approximately 42 miles long with a contributing watershed of approximately 838 square miles. The annual average flow for the period of record 1940 to 2000 at USGS gage station 70050500 was 584 cfs. Agricultural run-off as well as effluent from the City of Berryville, Arkansas influences the water quality of the Kings River. Figure 1.3 shows the sampling stations within the Kings River basin where data was collected to support this project.

Figure 1.1 Northwest Arkansas Regional Map

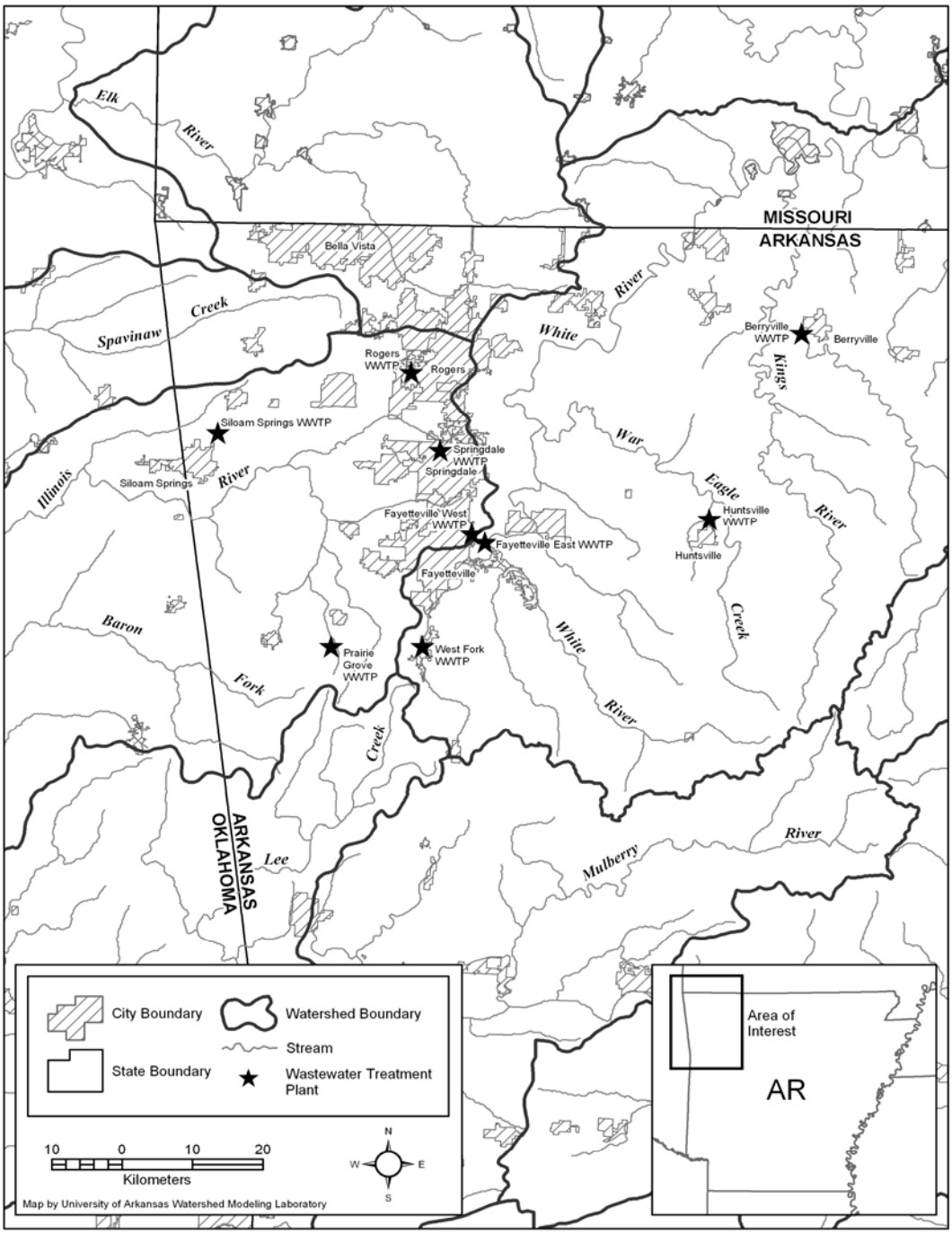


Figure 1.2 Illinois River Sampling Sites

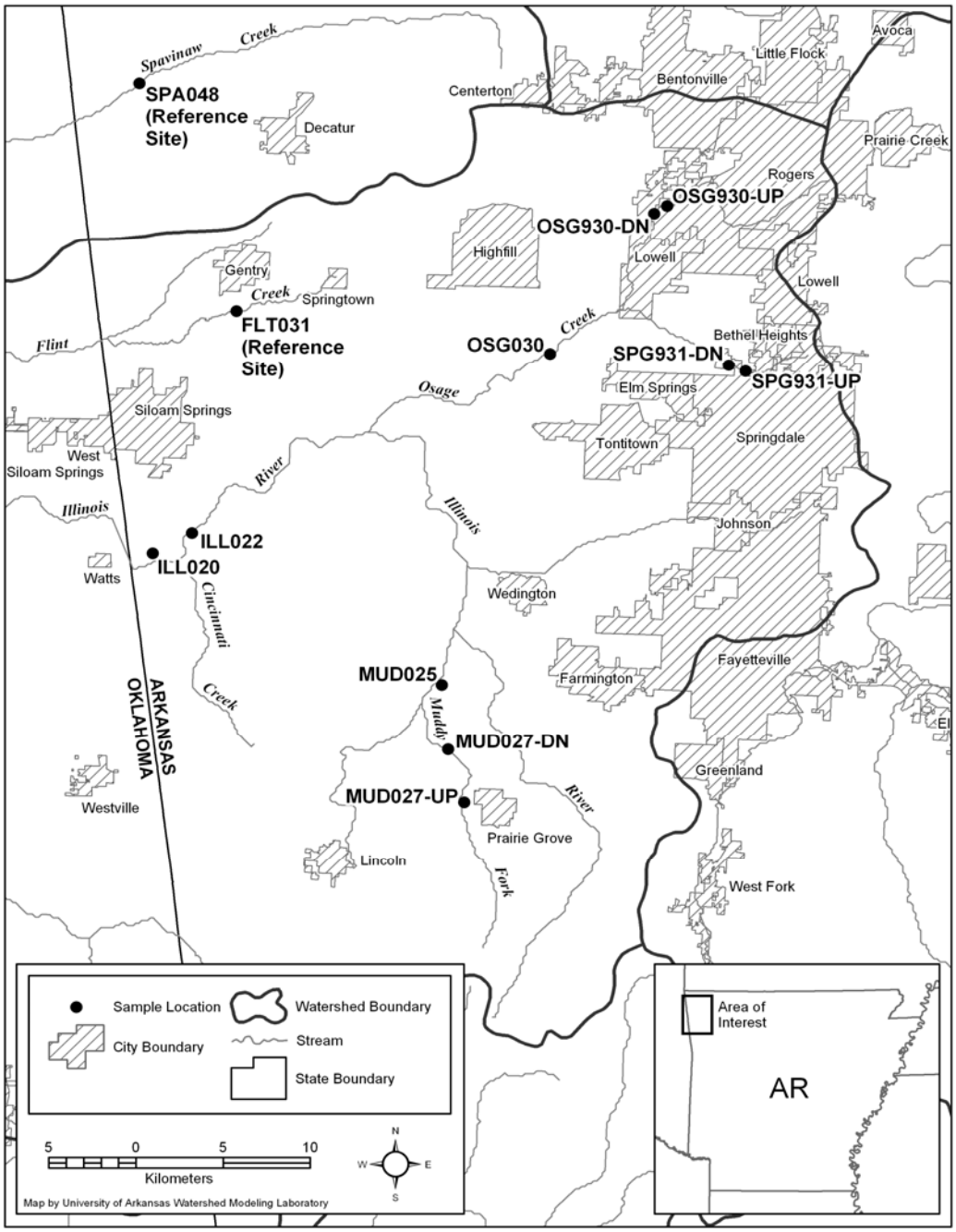
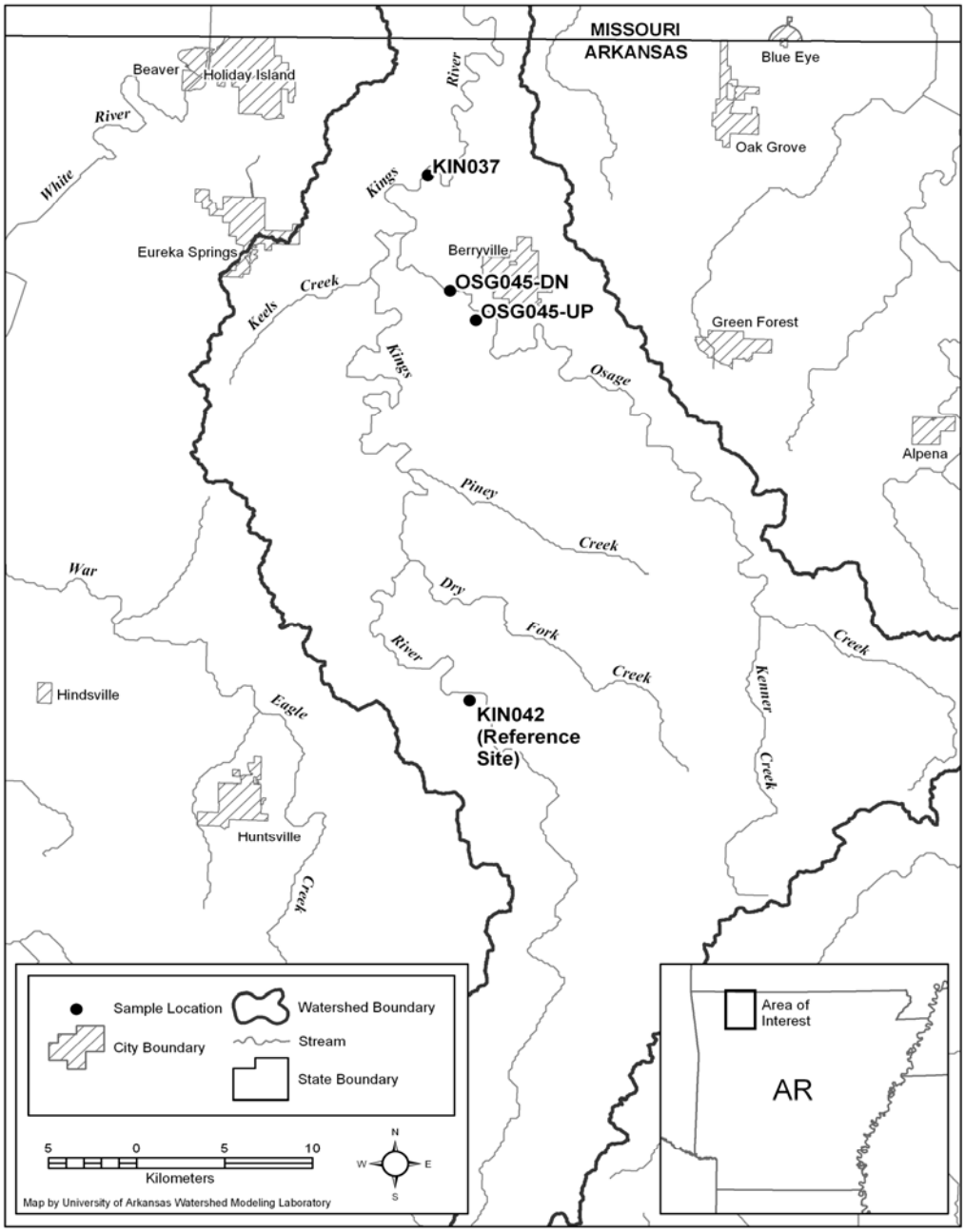


Figure 1.3 Kings River Sampling Sites



1.4 REGULATORY GUIDELINES FOR AQUATIC LIFE USE ATTAINMENT

The USEPA reviewed the ADEQ 2002 Integrated Water Quality Monitoring and Assessment Report in 2003. The 2002 Integrated Water Quality Monitoring and Assessment Report includes ADEQ's 305(b) report and the 303(d) list. In accordance with Clean Water Act (CWA) Section 303(d) and recent USEPA guidance, ADEQ is required to update its Integrated Water Quality Monitoring and Assessment Report every 2 years. April 1, 2004 is the next required submission date for the State Integrated Water Quality Monitoring and Assessment Reports. Section 303(d) of CWA requires states to use all existing and readily available data to assess the status of water quality for all waters of a state. Data collected through this project, in combination with other recent data that are representative of water quality in the Illinois and Kings Rivers, are used to determine the attainment status of aquatic life use. As previously stated in Section 1.2, a major rationale for conducting this project was to acquire sufficient data of known quality, which would allow ADEQ and USEPA Region 6 to make a scientifically valid determination on whether aquatic life use in the Illinois River and/or Kings River and their tributaries is impaired.

The primary "yardstick" or basis for making an aquatic life use impairment determination, or 303(d) listing decision, is ADEQ Regulation No. 2 (Reg 2), the state water quality standards. The ADEQ 305(b) Assessment Methodology and the Continuing Planning Process also provide additional guidance that influences data collection and assessment methods for making an aquatic life use impairment determination. To determine if a water body is impaired, data must be assessed consistent with the state's numeric and narrative water quality criteria. In assessing aquatic life use for the Illinois and Kings River in 2002, USEPA considered other technical factors and water quality indicators summarized below.

The Illinois and Kings Rivers fall within the Ozark Highlands Ecoregion, that is delineated in Appendix A of Reg 2. Regulation 2, Appendix A lists the Kings River as an Extraordinary Resource Water, a Natural and Scenic Waterway, and an Ecologically Sensitive Waterbody. While both rivers have a number of designated uses assigned in Reg 2, this project only focused on presenting data assessment relevant to aquatic life use. The Ecologically Sensitive Waterbody designation for the Illinois River is associated with the presence of the Neosho Muket which is a freshwater bivalve that occurs in the upland streams of the Ozark Plateau in Arkansas, Missouri, and Oklahoma. This bivalve, which is an endangered species, is very sensitive to sediment loading and continues to decline across the region. While this investigation did not include sampling for sediment loading or reconnaissance for the Neosho Muket, this species could serve as an effective indicator of sediment contamination in future studies.

Nitrate-nitrogen data from this investigation are compared to the Safe Drinking Water Act maximum contaminant level for nitrate-nitrogen of 10 milligram per liter (mg/L) for informational purposes only. While there is no aquatic life use criterion for nitrate-nitrogen set out in Reg 2, ADEQ uses this maximum contaminant level to assess waters with a drinking water use as defined in Part III, Chapter 3 of the 2002 305(b)

report. Therefore, Table 1.1 depicts the numeric criteria and guidelines defined by Reg 2 and ADEQ's 2002 305(b) report applicable to the data collected under this project.

Table 1.1 Specific Numeric Criteria and Assessment Guidelines: Ozark Highlands Ecoregion

Parameter	Criteria	Support	Non-Support
Temperature °C (°F)	29 (84.2)	≤10%	>10%
Turbidity (NTU)	10	≤25%	>25%
Total Dissolved Solids (mg/L)	Illinois River, main stem reaches=300 Kings River, main stem reaches=150	≤10%	>10%
pH (standard units)	6.0 – 9.0 (maximum fluctuation of 1 unit in 24-hour period)	≤10%	>10%
Dissolved Oxygen (mg/L) 10-100 mi^2 watershed >100 mi^2 watershed	 6.0 primary; 5.0 critical 6.0 primary; 6.0 critical	≤10%	>10%
Nitrate Nitrogen (mg/L)*	10 (Drinking Water Use)	≤10%	>10%
Total Ammonia – N (mg/L)*	Acute – 12.1	≤1	>1
Total Ammonia – N (mg/L)*	Chronic – 1.3	≤25%	>25%

*Source: ADEQ 2002 305(b) Report Part III, Chapter 3

The Arkansas narrative standard for nutrients, Section 2.509 of Reg 2, states: "Materials stimulating algal growth shall not be present in concentrations sufficient to cause objectionable algal densities or other nuisance aquatic vegetation. As a guideline, total phosphorus shall not exceed 100 µg/L in streams or 50 µg/L in lakes and reservoirs except in waters highly laden with natural silts or color which reduce the penetration of sunlight needed for plant photosynthesis, or in other waters where it can be demonstrated that algal production will not interfere with or adversely affect designated uses and/or fish and wildlife propagation." ADEQ is currently undergoing the state Triennial Standards Review process and is recommending eliminating the use of the 100 micrograms per liter (µg/L) total phosphorus guideline for assessing nutrient impacts to water quality in streams.

USEPA Region 6 acknowledged in its *Decision Document for the Addition of Waterbody/Pollutant Combinations to the Arkansas 2002 §303(d) List* (USEPA Decision Document 2003) that when conducting an assessment of aquatic life use impairment for nutrients in the Illinois and Kings River basins, that both numeric and narrative water quality criteria must be considered. USEPA decided that with numerous sources of data and information and multiple state water quality criteria, a weight-of-evidence approach was necessary to assess aquatic life use impairment. This weight-of-evidence approach places emphasis on instream concentrations of total phosphorus (TP), daily fluctuations in dissolved oxygen (DO) concentration and DO saturation, elevated pH and total dissolved solids (TDS), habitat characteristics, periphyton presence, filamentous algae presence, benthic community structure, and fish community structure.

When reviewing the Arkansas 2002 §303(d) List, USEPA took additional steps to establish a reference value for determining exceedances of total phosphorus. While

Reg 2 lists 0.10 mg/L as a guideline, USEPA looked more closely at the body of nutrient data ADEQ had collected in a 1987 study entitled *Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume 1: Data Compilation*. Using the results of this study, which are summarized in Table 1.2, USEPA calculated a reference value for TP at 0.06 mg/L for the Illinois River and 0.05 mg/L for the Kings River. This allowed USEPA to compare current TP data to average TP concentrations derived by ADEQ from reference sites in the Ozark Highlands. Therefore, to be consistent with the 2002 methodology used to assess total phosphorus data, data in this report are compared to both the 0.10 mg/L guideline recommended by Reg 2 and the reference values of 0.06 mg/L for the Illinois River and 0.05 mg/L for the Kings River calculated by USEPA. The reference values calculated by USEPA are used for screening purposes only and are not considered definitive numeric criteria.

When evaluating data collected under this project related to periphyton presence, filamentous algae presence, benthic community structure, and fish community structure, USEPA chose to follow the assessment methods and metrics used in the 1997 ADEQ report *Illinois River Water Quality, Macroinvertebrate, and Fish Community Survey* (ADEQ 1997). This allowed a larger body of chemical, physical, and biological data to be consistently compared when making an aquatic life use impairment determination. The actual metrics used for determining the degree of biological impairment for each USGS gage station in comparison to the reference sites are described in Sections 3 and 4.

Table 1.2 USEPA Calculation of Ecoregion Reference Values for Total Phosphorus

Date Collected	Reference Stream	Avg. TP mg/l*
9/20/1983	South Fork Spavinaw Creek	0.01
5/15/1984	South Fork Spavinaw Creek	0.01
9/20/1983	Flint Creek	0.08
5/15/1984	Flint Creek @ Hwy 59 Bridge	0.15
8/28/1984	Yocum Creek	0.03
5/1/1985	Yocum Creek	0.07
8/18/1984	Long Creek	0.03
5/6/1985	Long Creek	0.04
9/9/1985	War Eagle Creek	0.05
5/13/1986	War Eagle Creek	0.03
9/9/1985	Kings River	0.09
5/13/1986	Kings River	0.02
	Average	**0.05**

* Average of 3 samples collected during the day

Watershed	Proposed Reference Value (TP mg/L)
Illinois River - Avg. Spavinaw Creek & Flint Ck	0.06
Kings River - Avg. Yocum, Long, War Eagle & Kings River	0.05

Source of Data: Physical, Chemical, and Biological Characteristics of Least-Disturbed Reference Streams in Arkansas' Ecoregions, Volume I: Data Compilation (June 1987) by State of Arkansas Department of Pollution and Ecology

Conducting an aquatic life use assessment for the Illinois and Kings Rivers is complicated because both water bodies are interstate waters and the water quality criteria used for protecting aquatic life use differs among Arkansas, Missouri, and Oklahoma. USEPA acknowledged the need to consider water quality criteria and/or total maximum daily loads (TMDL) from other states since these water bodies flow from Arkansas to Oklahoma and Missouri. While Missouri has not yet adopted numeric standards for phosphorus, the Missouri Department of Natural Resources (DNR) is concerned about the quality of water flowing into the state. The Kings River is one of the major tributaries of the Table Rock Reservoir in Missouri. The State of Oklahoma recently submitted and USEPA approved a numeric standard for phosphorus in the Illinois River of 0.037 mg/L. Because the Illinois River flows into Oklahoma, the Arkansas portion of the river would be required to meet this standard at the state line.

1.5 EXISTING DATA

Water quality in this region has been a topic of concern between Oklahoma and Arkansas for more than 20 years. A number of water quality studies have been conducted at sites throughout the Illinois River basin over the past 20 years while limited data are available from sites within the Kings River basin. Data from a select group of studies are summarized below.

The subsection 1.5.1 provides general overview information for both the Illinois and Kings Rivers, which was primarily derived from three reference documents prepared by USGS. While the USGS reports were organized based on the much larger physiographic provinces, the Springfield Plateau (Illinois River) and the Salem Plateau (Kings River), the reports provided valuable summary data for both the Illinois and Kings River basins. The subsequent subsections present information on each river separately.

1.5.1 Overview of Previous Water Quality Monitoring on the Illinois River and Kings River

Water Quality

Rivers of the Ozark Highlands drain from northwest Arkansas to Missouri (White/Kings River), Kansas (Elk River) Oklahoma (Spavinaw Creek and Illinois River), and east to Arkansas (White River and tributaries to the Black River) (ADEQ 2002). A great number of investigations have been conducted to assess water quality and determine the sources of pollution in the Ozark Plateaus. Arkansas is a leading poultry producer in the United States with an output of over 1 billion chickens each year (Arkansas Agricultural Statistics Service 1996). Poultry litter is often land-applied as a fertilizer to agricultural and pasture lands. Edwards and Daniel (1993a and 1993b) showed that 2 percent to 7 percent of TP in poultry litter could be lost in surface runoff, a high proportion (80% to 95%) of which was in the dissolved form. Dissolved reactive phosphorus (DRP) loss from soil and land-applied poultry litter may transport large amounts of phosphorus (P) into streams and rivers. Phosphorus often acts as a limiting

nutrient for algal growth in streams; therefore, increased P concentrations may increase algal production in northwest Arkansas streams (Haggard *et al*. 2001).

Estimation of the cumulative or individual impact of point and nonpoint sources of P on streams could be more difficult. While concentrations in streams may increase with discharge caused by precipitation, P sorption to sediments often results in a storage-release cycle that ameliorates the peak discharge concentrations and prolongs the elevated in-stream concentrations after the storm discharge abates (USGS 1998). Therefore, the effects of even moderate increases in P loads from point sources could exacerbate the effects of episodic nonpoint source loads through saturation of the in-stream sediment exchange capacity.

In-stream sediment composition determines P sediment storage capacity (Haggard *et al*. 2001). While some investigators have found little relationship between watershed land use and total suspended solids in streams (USGS 1998), recent investigations suggest that urbanization is a major source of increased sediment to streams (USGS 1999; Dogwiler 2003). The five communities of Fayetteville, Rogers, Lowell, Bentonville, and Springdale in the northwest region of Arkansas compose the third-fastest growing municipal region in the U.S. Though not the focus of this study, the effects of land use change and stream sedimentation are evident throughout historic and current studies of water quality in this region. The impact of this rate of urbanization does affect nutrient loads directly.

Several other researchers demonstrated the impacts municipal WWTPs have on P concentrations in streams and sediments (*e.g.,* Dorioz *et al*. 1998; House and Denison 1997). Investigations focused on whole-reach TP retention, as well as specific mechanisms of TP retention such as sediment-P buffering capacity and the amount of TP in sediments (Haggard *et al*. 2001a; Dorioz *et al*. 1998; House and Denison 1997; Reddy *et al*. 1996). The assimilative capacity and TP retention efficiency of Ozark streams are diminished downstream of WWTPs, and the amount of TP from WWTP inputs was significant in determining the degree of water quality impact (Haggard *et al*. 2000).

Algal Community

Stream biotic responses to increased P and nitrogen (N) are typically measured as increased algal biomass production. However, this endpoint is complicated by the number of additional variables besides nutrients governing algal growth. These variables include light, grazing, scouring, and temperature. Blue-green algal cells almost always comprise the largest percentage (relative abundance) of the periphyton (attached algae) community measured in USGS studies, followed by diatoms and green algae. Periphytic communities in streams dominated by agricultural land use in the Ozark Plateau are composed of species adapted to higher nitrate, P, and dissolved organic carbon concentrations (USGS 2002).

Fish Communities

This fish communities subsection is derived from the 1998 USGS Report *Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma – Fish Communities in Streams and their relations to Selected Environmental Factors* (1998), and provides a qualitative summary of the fish communities. Fish community studies have been conducted in this region of Arkansas as far back as 1963, but more recent studies were conducted in the mid-1980s and 1990s. In the 1998 USGS Report on the Ozark Plateaus, 88 different species were collected. Compared to other parts of the U.S., a large number of fish species live in Ozark Plateau streams. Approximately 175 species (including protected species) are present in the Ozark Plateaus province of the Ozark Plateaus National Water-Quality Assessment (NAWQA) Program study unit; at least 19 of which are endemic to the Ozarks area. Consequently, widespread and extreme degradation of water quality (chemical or aquatic habitat factors) could affect several species found nowhere else in the world. Many of these 175 species are intolerant of habitat or water chemistry degradation (USGS 1998).

Land use, watershed size, biotic factors (competition, predator-prey interactions, and periphyton abundance), and riparian habitat characteristics have a significant influence on fish communities within the Illinois and Kings Rivers. Changes in land use from forestland to agriculture land over time have resulted in an increased relative abundance of stonerollers and members of the sucker family and a decreased relative abundance of members of the sunfish and darter families. Most species of darters and some species of sunfish are intolerant of degraded water chemistry and habitat (USGS 1998). As expected, communities from reaches with larger drainage areas demonstrated a greater number of species than communities within smaller drainage areas. A common trait of fish communities of Ozark streams in agricultural basins or downstream from WWTPs is increased relative abundance of stonerollers. Increased periphyton production resulting from more nutrients and sunlight provides a more abundant food source for stonerollers. Often, darters and sunfish compose a smaller percentage of the fish communities of Ozark streams in agricultural basins than in forested basins. USGS (1998) also demonstrates that several other environmental factors (*e.g.* nutrients, organic carbon, suspended sediment, and DO) caused primarily by land-based discharges frequently result in changes in fish communities.

1.5.2 Illinois River Historical Data

Water Quality

The impact of nutrient loading into Arkansas streams on downstream waters in Oklahoma, including Lake Tenkiller, has been a source of historic conflict. The US Supreme Court in 1992 decided in an Oklahoma lawsuit filed against Arkansas that upstream states (Arkansas) could not violate water quality standards of downstream states (Oklahoma) (USSC503 90-1262). In July 2002, Oklahoma adopted a numeric standard

of 0.037 mg/L concentration of TP in the Illinois River and five other streams designated as scenic rivers. USEPA approved that standard in December 2003; however, concentrations of P measured during base flow conditions at 30 sites in the Illinois River and its tributaries in Arkansas between February and April 2002 suggest that soluble reactive phosphorus (SRP) exceeded this water quality standard (Haggard *et al.* 2002). In fact, observations by Nelson *et al*. (2003) suggest that TP loads in the Illinois River at the Highway 59 bridge may be increasing (Nelson and Cash 2003).

The Arkansas portion of the Illinois River basin is comprised of the Flint Creek, Illinois River, Baron Fork, Sager Creek, and Caney Creek drainage areas (Figure 2). An annual average load of 200 tons of P enters Oklahoma from the Arkansas portion of the Illinois River basin. Even though urban land use is relatively small (only 6% of the Arkansas portion), the annual P load from the four municipal WWTPs is approximately 43 percent (90 tons) of the total annual load entering into Oklahoma (Green and Haggard 2001). The remaining P is from agricultural sources, including poultry litter runoff (Nelson *et al.* 2002; USGS Report 98-4164). In 1995, the ADEQ initiated a study of water quality, macroinvertebrates and fish communities in the Illinois River in response to a Consent Administrative Order between the key agencies in Oklahoma and Arkansas. Data assessed for the ADEQ 2002 303(d) List however, indicated that DO concentration, pH, and turbidity did not demonstrate exceedances of Arkansas water quality criteria. In response to this and other data, USEPA expressed concerns that maximum daily DO fluctuations were greater than 3.0 mg/L in some tributaries of the Illinois River (USEPA Decision Document 2003), and that these diel DO fluctuations could cause stress in game fish (USEPA 1986). In addition, DO saturation of over 125 percent was measured at Osage Creek below the City of Rogers, AR, and below the Springdale WWTP in AR (ADEQ 1997)

The ADEQ report identified the Springdale WWTP as the dominant point source of P in the Illinois River watershed during the period sampled. Discharge from the Springdale WWTP often exceeded 10 mg/L TP, with average loads in excess of 369 pounds per day (lbs/day). This load was four times greater than TP loads from the City of Rogers, and 40 times greater than loads from the Fayetteville WWTP (ADEQ 1997).

Ekka *et al*. (2003) showed significant increases in nutrient concentrations, especially P, downstream of WWTPs throughout the Illinois River basin (see Appendix G). As with the 1997 ADEQ Report, the City of Springdale WWTP contributed the highest P load compared with other WWTPs in the basin. Ekka *et al.* also demonstrated that stream sediments downstream of the Springdale WWTP were saturated with phosphorus for approximately 11 miles, representing a large in-stream storage function for P, and illustrating the complexity of assessing the impact of P loads from WWTPs on streams.

In the Illinois River basin, USEPA added Osage Creek reaches 030 and 930 and Spring Creek reach 931 to the Arkansas 2002 303(d) list after determining that TP concentrations and associated biological and chemical impacts were sufficient to support

a listing. The TP concentrations of these reaches ranged from seven to 13 times higher than the Arkansas guideline value (0.1 mg/L TP) (USEPA Decision Document 2003).

Periphyton

Periphyton production, measured using chlorophyll *a*, exhibited considerable variability and some inconsistencies. Chlorophyll *a* values sampled in 1995 ranged from 0.00 milligram per square meter (mg/m^2) to 44.56 mg/m^2. In 1996, the chlorophyll *a* values ranged from 1.13 mg/m^2 to 48.14 mg/m^2. The highest values were found in Spring Creek both above and below the Springdale WWTP, and at the Illinois River site near the Arkansas-Oklahoma state line (ADEQ Water Division 1997). This variability is not uncommon when periphytometers are not protected from grazing (Gelwick and Mathews 1997; Fuller *et al*. 1998). Matlock and others began using aluminum screens to protect artificial substrates from grazing perturbation as a result of similar experiences (Matlock *et al*. 1999).

Macroinvertebrates

Macroinvertebrate communities in the Illinois River were sampled by ADEQ in 1995-96 using RBP III (Plafkin *et al*. 1989). ADEQ collected one sample at each of 19 sites, except at one site at the upper Illinois River (ILL03), where two samples were collected. ADEQ analyzed the samples using a suite of metrics and found that the uppermost site on the Muddy Fork of the Illinois River (MF101A) was "most affected." However, this site was upstream of the Prairie Grove WWTP outfall, and thus the impairment could not be attributed to a national pollutant discharges elimination system (NPDES) source (ADEQ Water Division 1997).

Fish Communities

Fish communities in the Illinois River were sampled by ADEQ in 1995-1996 at 10 sites using a Smith-Root model 15-B backpack electrofishing device. Results indicated "fish community structures were affected" by Rogers, Springdale, and Fayetteville WWTP discharges. They found similarity indices between 64.9 and 70.4 between upstream and immediately downstream of the WWTP outfalls. The findings were consistent with those expected in nutrient-enriched waters, including increased populations of primary feeding fishes (planktonic and periphytonic feeders) below the discharges (particularly stonerollers), and reduced sensitive species, including flow-sensitive darters. Habitat differences did not appear to be the source of this observed affect (ADEQ 1997).

Habitat

Habitat condition at specific sites on the Illinois River was sampled by ADEQ in 1995-96 using RBP (Plafkin *et al*. 1989). In this previous study, ADEQ used the habitat assessment to evaluate suitability of reference sites for comparisons of macroinvertebrate

and fish samples, but did not evaluate the degree of habitat impairment directly at each site. Habitat impairment is an assessment of the degree or intensity of habitat degradation compared with a reference site. ADEQ did measure relative habitat quality; however, it found that habitat quality could have had an impact on macroinvertebrate communities at the mid-Illinois River site and Muddy Fork below the Prairie Grove site and that habitat below the Fayetteville discharge and reference stream might have affected the fish communities (ADEQ 1997).

1.5.3 Kings River Historical Data

The Kings River is in a predominantly rural watershed and has only experienced extensive land use change over the past five to seven years. While some water quality monitoring has been conducted in the past very little ecological data has been collected in recent years in this basin. In 2003 USEPA proposed 303(d) listing of the portion of Osage Creek below the town of Berryville, AR due to high nutrient concentrations, specifically average TP concentrations approximately 16 times greater than the Arkansas guideline value (USEPA 2003). Data from the State of Missouri, provided to Arkansas during the comment period of the Arkansas 2002 303(d) list, was considered by USEPA in making this listing decision. Missouri established a TMDL for TP on the James River because of concerns for increased P concentrations in Table Rock Lake, also the receiving body for the Kings River (see Appendix H for a select group of reports on the Kings River basin). Phosphorus loads to Table Rock Lake have been increasing over the past 10 years, resulting in increased algal growth in the reservoir. The predominant source of TP to the reservoir from Arkansas has been identified as the Kings River.

SECTION 2
SAMPLING METHODOLOGY

This section details the methods and materials used to collect water quality and biological data. Further details on sampling methodology and quality control are located in the USEPA-approved Quality Assurance Project Plan (QAPP) (Parsons QAPP 2003). The water quality data collected includes field measurements and water chemistry analysis. Field measurements consisted of diurnal DO, pH, conductivity, and temperature. Three water chemistry sampling events were conducted, and analysis on several nutrient and physical parameters was provided. The biological and physical characterizations included two RBPs performed at each location to evaluate stream ecological attributes. The RBPs comprised periphyton sampling, habitat assessment (including pebble count), and fish and macroinvertebrate collection. The RBPs helped evaluate whether there was variation in aquatic communities between areas receiving effluent from the indicated municipal WWTPs and areas not receiving effluent, in relation to defined reference sites.

2.1 SAMPLING SCHEDULE AND RAINFALL CONDITIONS

This project was developed, funded, and performed under a compressed schedule in an effort to collect data during the critical season. It was recognized at the outset of the project that the window for conducting sampling was limited and would occur in both the critical season (mid-May to mid-September) and primary season (mid-September to mid-May) as defined by Reg 2. Initially, the project goal was to complete one full suite of water quality measurements, water quality chemistry analysis, and one RBP during the ADEQ-defined critical season, that is prior to September 15, 2003; a second full sampling suite and third set of water quality measurements and water chemistry sampling in the primary season (*i.e.*, after September 15). While sample collection for this project was initiated immediately following USEPA approval of the QAPP on August 28, 2003, the delay in project initiation and storm events in early September prohibited completion of a full suite of water quality, water chemistry, and biological sampling in the critical season (prior to September 15, 2003). Additional rains in October caused significant increases in water flow, necessitating removal of sampling equipment, further delaying data collection progress. Sampling resumed when water flow and characteristics returned to normal. Sample collection required schedule coordination between water quality collection, macro-invertebrate collection, fish collection, and datasonde deployment to avoid interferences from sample activities. Water quality samples were collected first, followed by datasonde round one deployment, macroinvertebrate sampling, then fish sampling. All samples were collected during low flow conditions; thus, any significant precipitation event delayed sampling activities until flow returned to base flow levels. More information on rainfall and flow levels is provided in Sections 3 and 4.

2.2 SAMPLING LOCATIONS

A variety of factors was used to select sampling sites, including reaches with acceptable reference conditions, wastewater discharge locations, history of sampling by

ADEQ, and field reconnaissance, combining experience of the principal investigator and project director. Sites upstream from WWTPs were chosen for reasonable assurance that the site was above the zone of influence of the effluent discharge. Sites downstream of WWTPs were chosen as close as practical to the outfall, but below the zone of mixing of effluent with stream water. Accessibility and safety of the site and the degree to which the location was representative of local stream conditions also influenced monitoring site selection.

The total number of sampling sites for the project is 16 (Figures 2.2 and 2.3). This included three regional "minimally impacted" reference streams for comparison. Table 2.1 presents the reach abbreviations, descriptions, and coordinates for the sampling sites in the Illinois and Kings Rivers for this study.

Table 2.1 Illinois and Kings River Sampling Sites and Descriptions

Illinois River Sampling Sites					
Location ID	**Description**	**Latitude**	**Longitude**	**Altitude (ft)**	**Watershed Area (Square Miles)**
OSG930UP	Osage Creek, Reach 930, Upstream of City of Rogers WWTP	N36°18.148'	W94°12.807'	1,148	31.1
OSG930DN	Osage Creek, Reach 930, Downstream of City of Rogers WWTP	N36°17.891'	W94°13.301'	1,145	32.7
SPG931UP	Spring Creek, Reach 931, Upstream of City of Springdale WWTP	N36°12.825'	W94°09.729'	1,273	12.7
SPG931DN	Spring Creek, Reach 931, Downstream of City of Springdale WWTP	N36°13.021'	W94°10.374'	1,191	13.5
OSG030	Osage Creek, Reach 030, Downstream of City of Rogers WWTP	N36°13.314'	W94°17.213'	1,070	94.7
MUD027UP	Muddy Fork, Reach 027, Upstream of City of Prairie Grove WWTP, Bush Road	N35°58.809'	W94°20.255'	1,132	26.2
MUD027DN	Muddy Fork, Reach 027, Downstream of City of Prairie Grove WWTP	N36°00.508'	W94°20.900'	1,099	32.1
MUD025	Muddy Fork, Reach 025, Lower Muddy Fork	N36°02.600'	W94°21.185'	1,093	63.8
ILL022	Illinois River, Reach 022, Fisher Ford	N36°07.376'	W94°30.816'	919	516.1
ILL020	Illinois River, Reach 020, Lower Illinois River	N36°06.703'	W94°32.302'	915	568.1
SPA048 Reference Site	Spavinaw Creek, Reach 048, Above Decatur, Reference Site	N36°21.858'	W94°33.117'	919	88.3
FLT031 Reference Site	Flint Creek, Reach 031, Reference Site	N36°14.558'	W94°29.258'	1,250	20.6

Kings River Sampling Sites					
Location ID	**Description**	**Latitude**	**Longitude**	**Altitude (ft)**	**Watershed Area (Square Miles)**
OSG045UP	Osage River, Reach 045, Upstream of City of Berryville WWTP	N36°21.826'	W93°36.499'	1,073	149.7
OSG045DN	Osage River, Reach 045, Downstream of City of Berryville WWTP	N36°20.873'	W93°35.506'	1,100	158.9
KIN037	Kings River, Reach 037, Below confluence with Osage Creek	N36°25.558'	W93°37.379'	1,066	465.2
KIN042 Reference Site	Kings River, Reach 042, Reference Site	N36°08.604'	W93°35.658'	1,083	64.3

2.3 WATER QUALITY CHARACTERIZATION

The Ecological Engineering Group (EEG) staff and students in the Biological and Agricultural Engineering Department of the University of Arkansas, Fayetteville, conducted all sampling.

2.3.1 Water Quality Field Measurement

A pair of multi-probe datasondes (YSI® and/or In situ®) were deployed for two 48-hour periods and one 72-hour period (sometimes only one probe was deployed for this event) at each sample site for continuous recording of depth, DO, temperature, pH, and specific conductance. Probes recorded the five field parameters every 5 minutes and stored the data in the probe's internal memory (for the 72-hour deployment, 10 minute intervals were used). EEG personnel downloaded the data from the field probe and transferred it to the project database. The datasondes were calibrated and post calibrated to manufacturer's recommendations.

Along with the parameters measured, the datasondes collected quality control information to verify proper operation of the equipment. Pairs of the datasondes were typically deployed to provide backup datasets in the event of a malfunction or quality control (QC) violation in one or the other datasonde. Data presented are from the datasonde, which exhibited the best internal QC data and the tightest agreement between calibration values and post calibration. Typically, this was based on DO calibration and post calibration unless another parameter exhibited greater variance in calibration and post calibration.

2.3.2 Water Quality Chemical Analysis

Sample Collection and Handling for Laboratory Analysis

The sampling plan included three separate water quality sampling events at each location. Cross-sectional grab samples were collected at each site three times during stable low-flow conditions (with at least 1-week intervals). All grab water samples were collected by EEG personnel and transported to the Arkansas Water Resources Center (AWRC) Water Quality laboratory for sample preparation and analysis. All samples were stored in the dark at or below 4 degrees Centigrade (°C) after collection and prior to analysis. Samples were logged on chain of custody forms and maintained under custody.

All sampling and analyses were conducted in accordance with the techniques prescribed in 40 CFR Part 136 and amendments thereto. The method reference for all field and laboratory parameter analysis is "Standard Methods for the Examination of Water and Wastewater" American Public Health Association (APHA), 20th edition, or later, unless otherwise cited. Specific analysis methods will be discussed later in this section.

Sample Analysis Methods

The AWRC water quality lab analyzed the samples for the designated parameters, including nitrate (N), nitrite, ammonia, ortho-phosphorous, total Kjeldahl nitrogen (TKN), total nitrogen (TN), TP, chlorophyll *a*, total organic carbon (TOC), TDS, temperature, and turbidity. Table 2.2 itemizes the parameters analyzed, calculated, and QC criteria.

Sample Analysis Quality Control

Sample analysis results were reviewed for verification of precision, accuracy, completeness, and reporting limits as indicated in the QAPP. Table 2.2 lists the QC criteria for the analysis.

Table 2.2 Field and Laboratory Analysis Methods and Quality Control

PARAMETER	UNITS	MATRIX	METHOD	STORET	REPORTING LIMIT (RL)	PRECISION of laboratory duplicates RPD	ACCURACY of lab matrix spikes %Rec.	COMPLETE %	RESPONSIBLE AGENCY
Field Parameters									
pH	standard units	water	EPA 150.1	00400	0.1	NA	NA	90	U of A
DO	mg/L	water	EPA 360.1	00300	0.1	NA	NA	90	U of A
Conductivity	uS/cm	water	EPA 120.1	00094	1	NA	NA	90	U of A
Temperature	° C	water	EPA 170.1	00010	NA	NA	NA	90	U of A
Laboratory Parameters									
Ammonia-N	mg/l	water	EPA/350.1	00610	0.02	±20%	±20%	90	U of A
Nitrate-N	mg/l	water	EPA/353.2 or 300.0	00620	0.02	±20%	±20%	90	U of A
Nitrite N	mg/l	water	EPA/354.1	00615	0.04	±20%	±20%	90	U of A
Total Kjeldahl N (TKN)	mg/l	water	EPA/351.1	00625	0.02	±20%	±20%	90	U of A
Total N	mg/l	water	Mathematic	00630	--	--	--	--	U of A
Total P (TP)	mg/l	water	EPA/365.1	00665	0.01	±20%	±20%	90	U of A
Ortho-phosphorus (OP)	mg/l	water	EPA/351.1 or 300.0	00671	0.01	±20%	±20%	90	U of A
Chlorophyll *a*	mg/l	water	EPA 180.1	13855	0.01	±20%	±20%	90	U of A
TOC	mg/l	water	EPA 415.1	00680	0.1	±20%	±20%	90	U of A
TDS	mg/l	water	EPA 160.1	70300	0.1	±20%	±20%	90	U of A
Turbidity	NTUs	water	EPA/180.1	82079	1	±20%	±20%	90	U of A

Reference:

United States Environmental Protection Agency (USEPA) "Methods for Chemical Analysis of Water and Wastes", Manual #EPA-600/4-79-020, 18th Edition Standard Methods for the Examination of Water and Wastewater, 1989.

2.4 STREAM HABITAT CHARACTERIZATION

Two habitat characterizations were performed at each sampling site, one in September through December 9, 2003, the second between December 11 and 28, 2003. The ADEQ method for physical habitat assessment of the Ozark Highlands, Boston and Ouachita mountain streams was used.

A representative stream segment was selected and measured so primary physical habitat characteristics of the stream could be included within the segment (*e.g.,* riffle and pool habitats, when available). The sample segments were located away from the influences of major tributaries and bridge/road crossings (*i.e.,* sufficiently upstream to decrease influences on overall habitat quality). The exact location (latitude and longitude collected via Global Positioning System) of the downstream limit of the segment was recorded on each field data sheet (Table 2.4.1).

A two-tier approach was employed for all streams. This approach employed more quantitative data collection, which allowed for a higher level of precision when comparing sites.

Tier one was an observational (qualitative) approach to assessing various habitat parameters, which assigns a numeric score (0-20) to each parameter. Scores are separated into four broad categories/conditions consisting of poor, 0-5; marginal, 6-10; sub-optimal, 11-15; and optimal, 16-20. Habitat parameters assessed in all streams were epifaunal substrate/available cover, sediment deposition, channel flow status, channel alteration, bank stability, vegetative protection and riparian vegetative zone width. Frequency of riffles (or bends), velocity/depth regime, and embeddedness were assessed in mountain streams.

Tier two combined both a qualitative (visual estimates) and quantitative (in-stream measurements) approach to developing a habitat profile for each sample segment based on eight broad categories. These categories included measurements/estimates of the in-channel cover, substrate, canopy cover, large woody debris within bankfull width, flow, and visual riparian and human influence estimates. Channel canopy cover was determined using a densitometer (Forest Densiometers, Bartlesville, OK 74006). Measurements of cover were made at the head of each riffle and each pool in the study segment, and the measurements were then averaged for the percent cover of the segment. A qualitative estimate was made in each segment of the amount of large woody debris, small woody debris, leaf pack, and fine detritus. A rating of "Rare, Present, Common, or Dense" was used for these estimates. Items not seen, or only seen very infrequently were rated as "Rare." If the item was noted almost everywhere in the segment, then it was rated as "Dense." Present and Common were intermediate ratings between the two extremes. Periphyton and filamentous algae were also noted in the field and qualitatively rated on the Rare to Dense scale.

Each tier employed a comparative metrics approach, using a simple scoring protocol that enables quantitative comparison of sites with each other and reference site

conditions. The close connectivity of various parameters should impact multiple metrics if habitat alteration is occurring.

A stream pebble count was performed in each of two riffles per site during both of the physical habitat characterization events. The diameter of 100 pebbles sampled on diagonal transects across the tops of riffles were recorded and analyzed to determine the particle size distribution of stream substrates.

The degree of substrate embeddedness was computed as the average of the estimates of embeddedness for 10 cobbles selected from the substrate at random at the head of a riffle in the sample segment. Algae growth lines were used to indicate the extent to which the rock was buried in the substrate. An estimate of the percent buried was made and recorded in the field book.

Bankfull width was determined in the field from standard indicators (top of depositional feature, change of vegetation, scour line, *etc*.) at four transects in the study segment and averaged. At each transect, a cross section survey was made of the stream. The average bankfull width and depth was then determined from the cross sections. In addition, the edges of water were recorded on each cross section and the average water surface width and depth was determined for the date of the survey. Hydraulic grade was determined from a water surface profile from the head of the upstream riffle to the head of the farthest downstream riffle. Using this data and the computed hydraulic radius, bank-full velocity and discharge was computed. A standardized Manning's "n" of 0.045 was used in computing the bankfull velocity and discharge.

2.5 AQUATIC LIFE CHARACTERIZATION

All biological data collection was performed by personnel trained in the proper technique for collection under the RBP (Barbour *et al*. 1999). The specific sampling and analysis methods utilized in this project adhered to specific modifications ADEQ made over time to customize RBP protocols to better assess Arkansas aquatic systems (habitat, macroinvertebrates, and fish). Taxonomic identification of fish and macro-invertebrates was performed by Dr. Arthur Brown, Fisheries Biologist, University of Arkansas. Biological collection was performed under a valid state permit for scientific collection, and proper notification of state fish and game personnel for scientific collection was made according to the permit. Fish collected were reported in an annual report to the state in accordance with requirements in the Arkansas Game and Fish Commission Scientific Collection Permit.

2.5.1 Periphyton

Algae samples were collected for biomass values and identified to the lowest practical taxonomic level (Wehr and Sheath 2003). The algal community biomass was also compared with reference and upstream/downstream sites on natural and artificial (Matlock periphytometer) substrates.

Natural Substrates: Periphyton was collected during periods of stable stream flow. Sampling of natural substrates was in conformance with "Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition" Section 6.1, Field Sampling Procedures: Natural Substances, Subsection 6.1.1.2, Single Habitat Sampling. Algal taxonomy and enumeration were performed by the Patrick Center for Environmental Research at the Academy of Natural Sciences in Philadelphia, PA.

Matlock Periphytometer: Periphyton was collected on artificial substrate using the method developed by Matlock *et al*. (1998) for measuring *in situ* periphyton response to nutrient enrichment using a passive diffusion system to enrich the nutrient content on periphyton growth media. Each unit provides control over the rates of nutrient diffusion across the growth media, uses a detachable and disposable growth media, can employ a wide range of reservoir sizes (250 mL to 20 L), and is very inexpensive to produce. This system uses a 0.45-micron nylon membrane filter as a biofilter and a 0.45-micron pore size glass fiber filter as the growth substrate, attached to the top of a 1-Liter low-density polyethylene container.

Measuring Limiting Nutrients

The nutrient trophic status (limiting nutrient) was measured in the 16 target locations in the Illinois and Kings Rivers watersheds two times from August to October 2003. The period of measurement was characterized by low flow conditions with small storm events occurring later in the sample period.

Limiting nutrients (nitrogen, N and/or phosphorous, P) were determined for each stream site using Matlock Periphytometers (Matlock *et al.,* 1998) with modification. Matlock Periphytometers were constructed of a 0.45 micron nylon membrane filter (Cole Parmer CN 2916-44) as a biofilter and Whatman 934-AH glass fiber filter as the growth substrate, attached over the top of a 1-Liter low density polyethylene container with a 2.5-inch diameter hole cut in the lid. The bottles were filled with the treatment nutrient solution, and attached to a floating rack. The four nutrient enrichment treatments were:

1. Control, consisting of deionized water, with a nominal conductivity of 30 µS/cm;
2. Nitrate, consisting of a solution of 0.35 millimole (30 ppm) $NaNO_3$ in deionized water;
3. Phosphate, consisting of a solution of 0.11 millimole (30 ppm) of Na_2HPO_4-$7H_2O$ in deionized water;
4. Nitrate plus Phosphate, consisting of a solution of 30 pm $NaNO_3$ and 30 ppm of Na_2HPO_4-$7H_2O$ in deionized water.

Experimental Design

The Matlock Periphytometer treatments were arranged in a randomized block design consisting of a treatment array of four treatments per block, and 10 replicates of each block per site. Each treatment array of 40 periphytometers was supported on an iron wire frame, attached to PVC pontoons, and anchored in the middle of the river at the sample site. The periphytometers were attached to the wire frame with growth surfaces perpendicular to the water surface and parallel to stream flow (Matlock *et al.,* 1999a). The algal growth surfaces were protected from fish and macro-invertebrate grazing by placing an aluminum screen (8 mesh, or approximately 3 wires per cm, 0.7 mm diameter wire) over the top of each periphytometer, approximately 5 cm from the glass fiber filter growth surfaces.

At the end of the 14-day growth period, the colonized glass fiber filters were placed in 5 mL of 90 percent acetone solution saturated with magnesium carbonate at 5°C, wrapped in aluminum foil, and transported to the laboratory for analysis. Chlorophyll was extracted from the filters for direct measurement in the laboratory using USEPA Standard Method 10200H.3 (APHA 1989). Chlorophyll *a* from each filter sample was expressed as mass (μg) per unit of exposed surface area of the filter (6.6 cm^2) for comparison. Mean chlorophyll *a* concentrations for all treatments across sites were compared using Student-Newman-Keuls' (SNK) Test ($\alpha = 0.05$) in SAS/STAT© (SAS Institute Inc. 1990). Unequal replicates due to sample loss were corrected using the second approximation method as described by Steel and Torrie (1980).

Lotic Ecosystem Trophic Status Index

The lotic ecosystem trophic status index (LETSI) is a tool for making comparisons of stream biotic response to nutrients (Matlock *et al*. 1999b). The underlying assumption of this index is that the Matlock Periphytometer nitrate and phosphate treatment provides a measurement of maximum potential productivity (MPP) of a stream at a given site over the sampling period. The MPP represents the level of periphytic primary productivity (measured as chlorophyll *a* production) that should occur when nutrients are not limiting. The LETSI is then defined as the ratio of the baseline primary productivity (Matlock Periphytometer control treatment) to the MPP.

2.5.2 Benthic Macroinvertebrate Collection

Macroinvertebrates were collected in two separate events at each site using the traveling kick method as required by the ADEQ method for mountain regions. Samples were collected using a combination of kick nets and D-frame dip nets (500 micron mesh) from late August through December. The kick net was placed downstream while the substrate is disturbed upstream. A five-minute kick sample occurred along diagonal transects enabling all microhabitats present to be sampled. Two riffles per site were

sampled. Functional feeding groups were sampled where appropriate (coarse particulate organic matter clusters) using the D-net.

The samples were cleaned of larger debris in the field, preserved in 70 percent ethanol, and labeled with the appropriate identifying information. A subsample of approximately 100 organisms was picked in the laboratory. A 4-inch diameter metal ring was randomly tossed into the tray and organisms within the ring removed for the subsample. Subsampling continued until a minimum of 95 organisms was removed. Some samples may have exceeded 100 organisms, but none was less than 95. Subsamples were identified to the minimum practical levels for taxonomic resolution (Merritt RW & Cummins KW [eds] 1996).

2.5.3 Fish Collection

Fish collection was performed via electrofishing using a pulsed DC Smith-Root backpack electroshocker with an anode and cathode. Collection began at a shallow riffle, or other physical barrier at the downstream limit of the sample reach, and terminated at a similar barrier at the upstream end of the reach. In the absence of physical barriers, block nets were set at the upstream and downstream ends of the reach prior to the initiation of any sampling activities. A minimum 4-person fisheries crew electrofished in an upstream direction using a side-to-side or bank-to-bank sweeping technique to maximize area coverage. All wadeable habitats within the reach were sampled via a single pass. Each team member wore polarized sunglasses, and sampling was conducted only during periods of optimal water clarity and flow. Sampling continued until no new species were collected in two consecutive samplings. Fish were held in livewells (or buckets) for subsequent identification and enumeration.

All fish greater than 20 mm total length collected within the sample segment were identified to species (or subspecies). Specimens that could not be identified with certainty in the field were preserved in a 10 percent formalin solution and stored in labeled jars for subsequent laboratory identification. A representative voucher collection was retained for unidentified specimens, very small specimens, and new locality records. In addition to the unidentified specimen jar, a voucher collection of a subsample of each species identified in the field was preserved and labeled for subsequent laboratory verification, when necessary. Species of special concern (*e.g.,* threatened, endangered) were noted and released immediately on site. Young-of-the-year fish less than 20 mm (total length) were not identified or included in the sample, and were released on site. Specimens that could be identified in the field were counted, examined for external anomalies (*e.g.,* deformities, eroded fins, lesions, and tumors), and recorded on field data sheets. Following the data-recording phase of the procedure, specimens identified and processed in the field were released on site to minimize mortality. Field data sheets were used to record the required data.

All samples received in the laboratory were tracked using a sample log-in procedure that included sample collection location, date, and batch. Assessment of fish population and index conditions were made in accordance with ADEQ Reg 2 requirements.

SECTION 3
ILLINOIS RIVER RESULTS

3.1 SAMPLING SCHEDULE AND RAINFALL CONDITIONS

The purpose of this project is to collect water quality and biological data for selected water bodies in the Illinois and Kings River watersheds to assess attainment of the aquatic life use. Water quality and ecosystem sampling was initiated on August 28, 2003, immediately after USEPA-approval of the QAPP. Sampling activities were scheduled according to the following hierarchy: water quality collection, datasonde deployment, benthic macro-invertebrate sampling, fish sampling, and habitat assessment. Benthic macroinvertebrate, fish, and habitat sampling activities required a rest period of approximately 7 days for the stream to recover before the next activity was initiated. Macroinvertebrate and fish sampling could not be performed when datasondes were deployed because macroinvertebrate sampling creates a significant sediment plume, and fish sampling creates a significant electrical charge, all of which could impair the datasonde readings. In addition, sampling of water quality, benthic macroinvertebrates, and fish required base flow conditions. Therefore, sampling was suspended during and after rainfall events to avoid confounding sampling conditions. There were eight significant rainfall events (> 0.5 inches in 24 hours) in the western half of the Illinois River basin (Spavinaw Creek site) during the sampling period (Figure 3.1) and 10 significant rainfall events in the eastern half of the Illinois River basin (Figure 3.2). These rainfall data are from USGS gauging stations, and are provisional, pending formal certification by the agency (usually within a year of collection). Provisional flow data are provided in Appendix C.

Figure 3.1 Daily Rainfall During Study Period in Western Illinois River Watershed (USGS Gauging Station Data, Provisional)

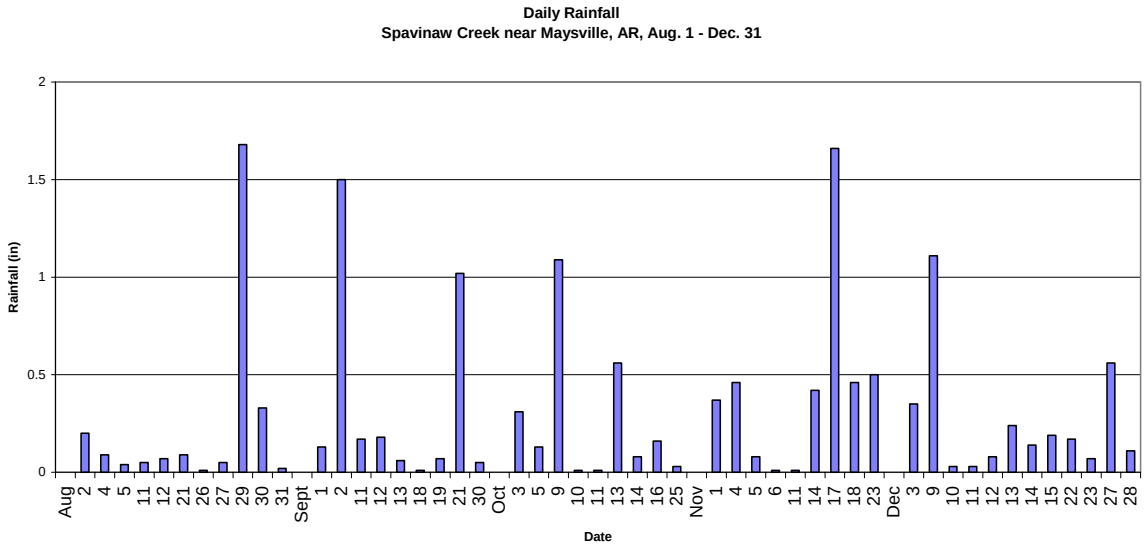
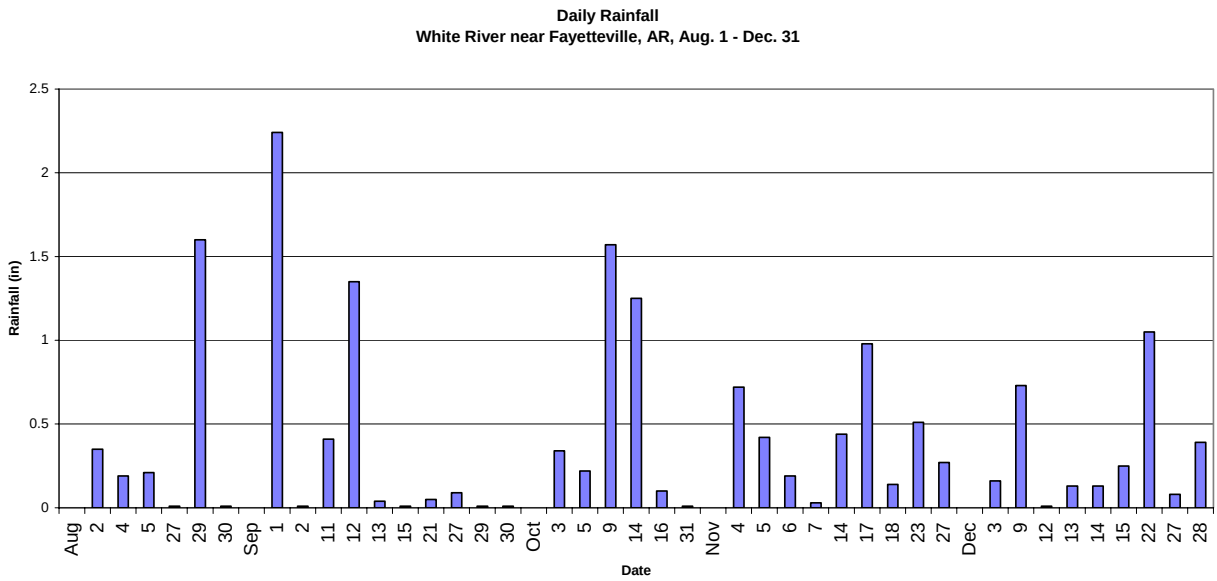


Figure 3.2 Daily Rainfall During Study Period in Eastern Illinois River Watershed (USGS Gauging Station Data, Provisional)



At the outset of the project, concerns were expressed that fall rains could have an impact on execution of the sampling plan. Flows and water depth in the Illinois River at ILL020 and ILL 022 increased over the sample period as a result of the rainfall events. During the late summer, the river was wadeable at these sites, and thus was sampled using the techniques as described. However, during the latter part of the sample period, flows increased to greater than 4.5 feet gage height, restricting sampling for benthic macroinvertebrates and fish. Consideration was given to use of boat shockers to complete the second round sampling for fish, but Dr. Art Brown, stream ecologist with the University of Arkansas, suggested that the two methods of sampling were so different that results would not be comparable. Specific concern was also expressed about the ability to successfully collect *Campostoma spp.* with boat shocking. As a result, the second habitat assessment, macroinvertebrate collection, and fish collection were not completed at the downstream most sites ILL022 and ILL020.

Data reported in this report met the data quality objectives (DQO) identified in the QAPP. While there were data quality deviations from these objectives, as required by the QAPP these deviations are noted in the tables and text. The most common DQO difficulties were associated with collection of diurnal DO data; additional deviations from the DQOs were associated with feasibility of sampling biota in marginally wadeable streams during the rainy season. The problems ranged from inadequate numbers of organisms to inability to sample altogether. Additionally, there were several paired sample events (upstream-downstream) that were separated by as much as four weeks due to rainfall and scheduling conflicts. Table 3.1 presents the sampling dates for each media for each sampling event.

Table 3.1 Sample Schedule

Task	OSG930UP	OSG930DN	SGP931UP	SPG931DN	OSG030	MUD027UP	MUD027DN	MUD025	ILL022	IILL020	SPA048	FLT031
Matlock Periphytometer Deployment 1	14-Aug-03	14-Aug-03	12-Aug-03	12-Aug-03	12-Aug-03	14-Aug-03	14-Aug-03	14-Aug-03	14-Aug-03	14-Aug-03	22-Aug-03	22-Aug-03
Water Quality Sample 1	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03
Matlock Periphytometer Retrieval 1	28-Aug-03	29-Aug-03	15-Oct-04	27-Aug-03	15-Oct-04	28-Aug-03	2-Sep-03	2-Sep-03	3-Sep-03	3-Sep-03	5-Sep-03	5-Sep-03
48 Hour Data Sondee Deployment 1	3-Sep-03	3-Sep-03	18-Sep-03	18-Sep-03	27-Sep-03	23-Sep-03	23-Sep-03	27-Sep-03	25-Sep-03	3-Oct-03	9-Oct-03	9-Oct-03
Benthic Macroinvertebrate Collection 1	3-Sep-03	3-Sep-03	5-Sep-03	5-Sep-03	15-Sep-03	20-Sep-04	13-Sep-04	15-Sep-04	Not Sampled	20-Sep-03	12-Sep-03	12-Sep-03
Fish Collection 1	23-Sep-03	23-Sep-03	26-Sep-03	26-Sep-03	29-Sep-03	5-Oct-03	5-Oct-03	29-Sep-03	21-Oct-03	23-Oct-03	13-Oct-03	8-Oct-03
Periphyton and Habitat Assessments 1	28-Sep-03	17-Oct-03	20-Oct-03	22-Oct-03	24-Oct-03	27-Oct-03	27-Oct-03	29-Oct-03	4-Nov-03	4-Nov-03	21-Nov-03	6-Nov-03
Water Quality Sample 2	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03
Matlock Periphytometer Deployment 2	19-Sep-03	19-Sep-03	18-Sep-03	18-Sep-03	18-Sep-03	24-Sep-03	24-Sep-03	24-Sep-03	25-Sep-03	25-Sep-03	22-Sep-03	22-Sep-03
Matlock Periphytometer Retrieval 2	3-Oct-03	3-Oct-03	2-Oct-03	2-Oct-03	2-Oct-03	9-Oct-03	9-Oct-03	10-Oct-03	13-Oct-03	13-Oct-03	8-Oct-03	10-Oct-03
48 Hour Data Sonde Deployment 2	22-Oct-03	22-Oct-03	14-Oct-03	14-Oct-03	28-Oct-03	16-Oct-03	16-Oct-03	28-Oct-03	10-Dec-03	12-Dec-03	8-Dec-03	8-Dec-03
Fish Collection 2	19-Nov-03	19-Nov-03	24-Oct-03	24-Oct-03	10-Nov-03	30-Oct-03	4-Dec-03	14-Nov-03	Not Sampled	Not Sampled	21-Nov-03	22-Nov-03
Habitat Assessments 2	24-Nov-03	24-Nov-03	24-Nov-03	24-Nov-03	12-Dec-03	12-Dec-03	12-Dec-03	20-Dec-03	20-Dec-03	20-Dec-03	14-Dec-03	14-Dec-03
Benthic Macroinvertebrate Collection 2	1-Dec-03	1-Dec-03	17-Oct-03	3-Oct-03	17-Dec-03	11-Dec-03	3-Dec-03	11-Dec-03	Not Sampled	22-Oct-03	8-Dec-03	8-Dec-03
72 Hour Data Sonde Deployment 3	22-Dec-03	17-Dec-03	24-Dec-03	24-Dec-03	14-Dec-03	9-Dec-03	9-Dec-03	9-Dec-03	2-Jan-04	2-Jan-04	2-Jan-04	2-Jan-04
Water Quality Sample 3	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03
	OSG930UP	OSG930DN	SGP931UP	SPG931DN	OSG030	MUD027UP	MUD027DN	MUD025	ILL022	IILL020	SPA048	FLT031

3.2 WATER QUALITY CHARACTERIZATION

Data results for sites on the Illinois River are presented, for the most part, from upstream to downstream, with parallel creeks covered from north to south, with the reference sites last. Typically, pages with graphs will include results for the upstream then downstream locations for a stream segment. Site location identification numbers and descriptions are provided on Table 2.1 and Figure 1.2 is a map depicting the sampling site locations. Quality controls for investigation results included verifying data using the performance criteria, handling procedures, and QC requirements in the QAPP (Parsons 2003).

3.2.1 Water Quality Field Measurements

Three water quality field measurement deployments were attempted at each of the sampling sites for two separate 48-hour periods and one 72-hour deployment. The datasondes deployed in this project utilized state-of-the-practice instruments (YSI and In Situ brand equipment) and were maintained and calibrated according to manufacturer's recommendation. However, the instruments failed on several occasions, most commonly due to loss of membrane integrity across the probe face. This loss of integrity was most likely caused by scour from increased flow and stream sediments. As a result, data compromised by instrument failure are not included in this report since they would not meet QC requirements.

Water quality field measurements are presented on Table 3.2. In addition to presenting results for DO, pH, specific conductivity, and temperature, the table includes Reg 2 Ecoregion specific standards for comparison. Results above or below the ADEQ water quality criteria or USEPA guidance for this investigation are highlighted on Table 3.2. The DO minimum standard takes into account the season-specific criteria (critical or primary) and the watershed size as required in Reg 2. Appendix B contains graphs of DO concentration, temperature, specific conductivity, and pH versus time for each sampling event. Raw water quality measurement data are also included in Appendix B.

Event 1 Water Quality Measurement Concerns:

Field measurements from the first sampling event that did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation are listed below. Table 3.2 indicates that criteria were not met for:

- 24-hour DO fluctuation and DO % saturation at OSG030;
- 24-hour DO fluctuation at MUD027UP;
- 24-hour DO fluctuation and DO % saturation at MUD027DN;
- DO minimum and 24-hour DO fluctuation at MUD025; and
- 24-hour DO fluctuation at ILL022.

While the DO value recorded at station MUD027UP on the first event was 4.3 mg/L, this is not a water quality standards exceedance since Reg 2 allows a 1 mg/L diurnal depression below the 5.0 mg/L criterion for no more than 8 hours during a 24-hour period when water temperature exceeds 22°C. The lowest DO reading of 4.2 mg/L recorded at MUD025 is an exceedance of the water quality criterion since the water temperature was below 22 C. MUD027DN demonstrated the highest 24-hour DO fluctuation of 6.17 mg/L, and OSG030 had the highest exceedance of the % saturation criteria at 141.7.

Event 2 Water Quality Measurement Concerns:

Results from the second sampling event had six values that did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation. Table 3.2 indicates that criteria were not met for:

- DO minimum at SPG931DN, MUD027UP, and MUD025;
- 24-hour DO fluctuation at OSG030 and FLT031; and
- DO minimum and 24-hour DO fluctuation at MUD025.

The most significant excursions from the water quality criteria were the 4.4 mg/L DO reading at MUD027UP and the 24-hour DO fluctuation of 4.01 mg/L at OSG030.

Event 3 Water Quality Measurement Concerns:

Six results from the field measurements of the third event did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation. Beginning at the upstream sites, Table 3.2 indicates that criteria were not met for:

- DO minimum at OSG930UP;
- 24-hour DO fluctuation at OSG930UP;
- 24-hour DO fluctuation and DO % saturation at SPG931DN;
- 24-hour DO fluctuation at OSG030;
- DO % saturation at the reference site FLT031.

The most significant excursions from the water quality criteria were at OSG930UP (DO minimum of 5.4 mg/L) and at SPG931DN (24-hour DO fluctuation of 4.13 mg/L and the DO % saturation exceedance at 160.1%).

Table 3.2 Water Quality Field Measurement Data for Illinois River

Illinois River - Event 1

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG930UP	7.5	> 5.0	7.0	8.6	1.61	96.1	7.5	7.4	7.6	0.1		393.9	353.0	427.0	20.7	19.3	22.3
OSG930DN	7.5	> 5.0	7.0	8.5	1.39	92.7	7.3	7.2	7.4	0.2		339.0	327.0	350.0	19.3	17.7	20.7
SPG931UP	9.5	> 5.0	8.6	10.8	2.03	116.1	7.4	7.4	7.7	0.3		408.7	403.0	412.0	17.5	15.5	20.4
SPG931DN	DO probe malfunction						7.4	7.3	7.6	0.4		713.5	631.0	752.0	22.3	19.6	24.7
OSG030	10.2	> 5.0	8.4	13.2	3.32	141.7	7.8	7.6	8.3	0.7		361.4	353.0	370.0	17.3	14.0	21.4
MUD027UP	6.2	> 5.0	4.3	8.6	4.06	97.5	7.9	7.4	8.4	0.9	C	409.1	394.3	429.9	20.6	18.9	23.4
MUD027DN	8.0	> 5.0	5.2	11.6	6.17	131.7	8.0	7.6	8.5	0.9		483.3	473.0	491.0	20.7	19.0	23.5
MUD025	5.6	> 5.0	4.2	7.8	3.49	86.5	7.3	7.2	7.7	0.5	C	258.7	242.3	283.6	17.3	14.5	21.3
ILL022	7.9	> 6.0	6.8	10.1	3.30	118.8	7.7	7.5	8.2	0.7		411.0	404.0	415.0	21.6	20.2	23.5
ILL020	8.6	> 6.0	7.4	10.2	2.80	109.7	7.9	7.7	8.2	0.4		408.1	406.0	411.0	17.7	16.8	18.7
SPA048	7.5	> 5.0	6.9	9.0	2.14	96.7	7.4	7.4	7.6	0.2		327.1	322.0	329.0	17.8	17.5	18.7
FLT031	7.0	> 5.0	6.3	7.9	1.36	84.5	7.5	7.3	7.8	0.4	C	222.5	214.8	227.7	17.0	15.8	18.6

Illinois River - Event 2

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG930UP	11.2	> 6.0	9.6	12.3	2.67	124.5	7.1	7.0	7.2	0.2	C	307.1	297.4	320.8	17.3	16.0	18.9
OSG930DN	7.3	> 6.0	6.5	9.0	2.42	98.5	7.4	7.3	7.6	0.3		518.4	474.0	542.0	18.6	17.5	20.1
SPG931UP	8.0	> 6.0	7.6	8.8	1.12	91.9	7.3	7.3	7.4	0.1		332.5	280.0	360.0	16.2	14.9	17.9
SPG931DN	6.4	> 6.0	5.5	7.5	1.78	83.6	7.4	7.3	7.6	0.2	C	588.6	540.8	613.7	19.8	18.4	21.0
OSG030	8.2	> 6.0	6.5	10.6	4.01	103.3	7.7	7.2	8.1	0.8	C	421.6	397.8	438.0	14.1	11.2	15.7
MUD027UP	5.7	> 6.0	4.4	6.9	2.50	71.1	6.9	6.7	7.2	0.4		365.2	345.0	428.0	15.6	13.5	17.0
MUD027DN	7.2	> 6.0	6.1	8.8	2.68	91.0	7.4	7.3	7.7	0.4	C	307.2	295.0	333.4	15.6	12.8	17.9
MUD025	6.7	> 6.0	4.5	8.6	3.40	81.8	7.4	6.9	7.5	0.6		357.0	355.0	361.0	12.6	11.0	13.8
ILL022	11.3	> 6.0	10.6	12.4	1.73	101.8	7.5	7.4	7.7	0.3	C	196.2	184.4	200.2	6.2	5.6	6.9
ILL020	12.1	> 6.0	11.6	13.2	1.61	109.8	7.8	7.0	7.9	0.9		289.0	284.0	297.0	6.6	6.1	7.4
SPA048	9.3	> 6.0	8.7	10.9	2.10	109.0	7.5	6.8	7.6	0.7		289.6	280.0	293.0	14.5	13.5	15.6
FLT031	10.2	> 6.0	8.6	11.7	3.10	103.9	7.6	7.5	7.9	0.5		225.1	207.0	236.0	9.4	6.5	11.9

Illinois River - Event 3

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG930UP	6.8	> 6.0	5.4	9.1	3.59	82.8	7.3	7.0	7.5	0.4	C	240.8	233.3	248.9	10.3	8.9	11.5
OSG930DN	DO probe malfunction						7.4	7.1	7.5	0.4	C	333.1	302.7	353.2	11.3	10.1	12.4
SPG931UP	DO probe malfunction						7.4	7.3	7.8	0.6		354.8	343	364	12	10.8	13.4
SPG931DN	13.1	> 6.0	11.4	16.5	4.13	160.1	7.5	7.4	8.0	0.6		497.9	445.0	547.0	12.9	10.7	14.4
OSG030	10.4	> 6.0	8.7	12.8	3.88	113.5	7.9	7.7	8.3	0.7	C	251.0	232.8	272.1	7.8	5.0	11.1
MUD027UP	Equipment Failure																
MUD027DN	Equipment Failure																
MUD025	DO probe malfunction						7.8	7.7	8.0	0.3	C	124.2	113.5	136.9	6.2	4.1	8.5
ILL022	DO probe malfunction						7.8	7.7	8.1	0.5		271.9	265.0	281.0	12.7	8.8	14.7
ILL020	DO probe malfunction						7.7	7.5	8.2	0.7		261.0	244.0	268.0	12.6	8.9	14.8
SPA048	Equipment Failure																
FLT031	7.6	> 6.0	6.1	9.2	2.07	152.9	7.4	7.2	7.6	0.2	C	160.6	146.8	180.7	10.1	6.8	14.4

* DO min standard depedent upon watershed size and season (ADEQ Reg. No. 2, Oct 2002); when water T exceeds 22 degrees C the critical season DO min standard may be depressed by 1 mg/L for no more than 8 hours during a 24-hr period (ADEQ Reg. No. 2, Oct 2002).
DO 24 hr fluctuation guideline <3.0 mg/L (USEPA Dec 2003).
DO % Sat guideline is <125% (USEPA Dec 2003).
** pH minimum standard is 6.0, pH max standard is 9.0, pH max 24 hour fluctuation <=1.0 (ADEQ Reg. No. 2, October 2002)
*** Temperature standard is <29.0 degrees C (ADEQ Reg. No. 2, October 2002)
Min = Minimum
Max = Maximum
C = conductivity data is provided, this datasonde did not collect specific conductivity data.
Shaded cells represent values that are not within ADEQ standards or USEPA guidance.

3.2.2 Water Quality Chemical Results and Quality Control

Results for water quality chemistry from the three sampling events on the Illinois River are presented in Table 3.3. Figures 3.3 to 3.12 present water chemistry data by parameter. Laboratory QC data are presented in Appendix B.

Table 3.3 Water Quality Analytical Data for Illinois River

Illinois River		Ammonia mg/L	Nitrate mg/L	Nitrite mg/L	TKN mg/L	Total Nitrogen mg/L*	Ortho Phosphate mg/L	Total Phosphorus mg/L	TOC mg/L	TDS mg/L	Turbidity NTU
OSG930UP	8/26/2003	0.044	2.586	0.018	0.323	2.927	0.045	0.072	2.23	196	7
	9/16/2003	0.027	2.361	0.005	0.063	2.429	0.026	0.04	1.19	198	3
	10/7/2003	0.036	2.956	0.003	0.075	3.034	0.045	0.066	1.44	240	1
OSG930DN	8/26/2003	0.077	2.995	0.014	0.578	3.587	0.082	0.138	2.99	256	4
	9/16/2003	0.035	2.794	0.008	0.328	3.130	0.073	0.112	2.91	258	2
	10/7/2003	0.064	4.495	0.01	0.43	4.935	0.08	0.118	3.89	294	1
SPG931UP	8/26/2003	0.059	2.283	0.004	0.205	2.492	0.158	0.224	0.50	259	2
	9/16/2003	0.027	2.141	0.004	0.23	2.375	0.201	0.078	1.07	222	2
	10/7/2003	0.026	2.201	0.002	0.133	2.336	0.059	0.07	1.28	237	2
SPG931DN	8/26/2003	0.09	7.592	0.014	0.892	8.498	2.145	2.47	5.05	448	3
	9/16/2003	0.046	6.219	0.012	0.792	7.023	1.905	2.16	5.29	430	2
	10/7/2003	0.041	3.733	0.012	0.927	4.672	0.16	0.272	5.07	402	1
OSG030	8/26/2003	0.034	3.425	0.011	0.438	3.874	0.915	1.044	2.48	309	5
	9/16/2003	0.021	3.203	0.006	0.297	3.506	0.053	0.534	2.24	277	2
	10/7/2003	0.066	3.312	0.005	0.345	3.662	0.222	0.246	1.08	285	2
MUD027UP	8/26/2003	1.555	0.372	0.031	2.188	2.591	0.03	0.148	5.32	244	6
	9/16/2003	0.063	0.659	0.008	0.32	0.987	0.025	0.062	2.84	213	3
	10/7/2003	0.082	0.531	0.028	0.915	1.474	0.016	0.086	3.84	236	5
MUD027DN	8/26/2003	0.069	2.22	0.053	0.535	2.808	0.475	0.572	3.44	271	9
	9/16/2003	0.044	2.498	0.016	0.551	3.065	0.311	0.416	3.35	246	10
	10/7/2003	0.075	4.559	0.036	0.475	5.070	0.726	0.77	3.57	318	2
MUD025	8/26/2003	0.065	0.51	0.009	0.485	1.004	0.062	0.1	4.16	207	3
	9/16/2003	0.035	1.578	0.013	0.347	1.938	0.096	0.15	3.90	205	5
	10/7/2003	0.028	1.097	0.008	0.4	1.505	0.056	0.086	3.65	204	2
ILL022	8/26/2003	0.005	1.229	0.007	0.295	1.531	0.2	0.228	1.79	243	4
	9/16/2003	0.061	1.839	0.006	0.237	2.082	0.164	0.184	1.53	227	5
	10/7/2003	0.021	2.17	0.004	0.163	2.337	0.022	0.168	8.32	251	3
ILL020	8/26/2003	0.027	1.194	0.008	0.268	1.470	0.19	0.222	1.60	240	5
	9/16/2003	0.042	1.811	0.006	0.195	2.012	0.153	0.164	2.19	228	5
	10/7/2003	0.012	2.044	0.003	0.203	2.250	0.143	0.174	2.07	246	3
SPA048 Reference Site	8/26/2003	0.035	2.579	0.001	0.08	2.660	0.032	0.026	0.37	193	0
	9/16/2003	0.021	2.563	0.002	0.033	2.598	0.023	0.036	0.29	197	1
	10/7/2003	0.045	2.566	0.001	0.113	2.680	0.016	0.026	5.79	212	1
FLT031 Reference Site	8/26/2003	0	2.902	0.011	0.168	3.081	0.06	0.072	0.88	169	1
	9/16/2003	0.017	3.15	0.007	0.177	3.334	0.052	0.072	0.09	164	2
	10/7/2003	0.015	2.64	0.005	0.11	2.755	0.098	0.056	0.41	169	1

* = Total nitrogen calculated adding TKN, nitrite, and nitrate nitrogens.

= value is not within ADEQ standard or guideline value.

Total ammonia chronic guideline value of 1.3 mg/L (ADEQ 2002 305(b) for Ozark Highlands Ecoregion Streams).

Nitrate nitrogen 10 mg/L - Safe Drinking Water Act, maximum contaminant level (2002 ADEQ 305(b))

Total phosphorus guideline value of 0.1 mg/L (ADEQ Regulation No. 2, 2002).

Stream TDS standard 300 mg/L Illinois River, reference sites TDS standard 240 mg/L (ADEQ Reg. No. 2, October 2002).

Turbidity standard 10 NTU (ADEQ Regulation No. 2, October 2002)

Nitrogen

Analysis was conducted for key nitrogen constituents including ammonia, nitrate-nitrogen, nitrite-nitrogen, and TKN. The ammonia result (Figure 3.3) from the August 26 sampling event at MUD027UP exceeded the ADEQ 2002 305(b) guideline for chronic total ammonia (1.3 mg/L). Averaging ammonia results for the three events at

MUD027UP however resulted in a value below the 1.3 mg/L guideline. All ammonia values were well below the acute total ammonia value of 12.1 mg/L.

While this report focuses specifically on assessing the aquatic life use of the Illinois River and its tributaries, analysis of nitrate-nitrogen was conducted for informational purposes only. The ADEQ Reg 2 criteria of 10 mg/L for nitrate-nitrogen on the Illinois River applies to the drinking water designated use. All nitrate-nitrogen values for all three sampling events were lower than the numeric criteria (Figure 3.4). Nitrate concentrations ranged from 0.372 to 7.592 mg/L, with two of the highest values exhibited at SPG931DN (6.219 and 7.592 mg/L).

Nitrite-nitrogen values ranged from 0.001 to 0.053 mg/L (Figure 3.5). The highest values were measured at MUD027DN and MUD027UP, and the lowest values at the reference site SPA048.

TKN values ranged from 0.033 to 2.188 mg/L (Figure 3.6). TN values ranged from 0.987 to 8.498 mg/L (Figure 3.7). The highest TN values detected were at SPG931DN (from 4.672 to 8.498 mg/L). The lowest average TN value over the three sampling events was at MUD025, and the two reference sites had higher values than several of the other sites did.

Phosphorus

In addition to Figures 3.8 and 3.9, which depict ortho-phosphate and TP, a schematic diagram of the Illinois River sites sampled and the TP values for each sampling event are provided in Figure 3.10.

Ortho phosphate values ranged from 0.016 to 2.145 mg/L with the two highest values at SPG931DN. In this section the TP values are compared to the ADEQ Reg 2 guideline of 0.1 mg/L. Exceedances of the 0.1 mg/L guideline are also highlighted on Table 3.3. Beginning with the upstream reaches of the Illinois River, at OSG930UP all TP values are below 0.1 mg/L. At OSG930DN, all are above 0.1 mg/L. For the stations on Spring Creek, a tributary to Osage Creek, at SPG931UP two TP values are below the guideline and one is higher. At SPG931DN, the values are significantly greater than the 0.1 mg/L guideline (highest TP values measured at 2.47 and 2.16 mg/L). Downstream of the confluence of Osage Creek and Spring Creek at OSG030, values exceeded the guideline for all events. The upstream site on Muddy Fork, MUD027UP, begins with one TP above 0.1 mg/L and at MUD027DN all TP events exceed 0.1 mg/L. Heading downstream, TP values decreased significantly, and at MUD025 results for only one event exceeded 0.1 mg/L. After the confluence of Muddy Fork and Osage Creek, TP results at ILL022 exceeded 0.1 mg/L for all three events, as did ILL020 farther downstream. TP for the two reference sites were all below 0.1 mg/L.

In summary, TP exceeded the ADEQ Reg 2 guideline of 0.1 mg/L at each of the sites downstream from WWTPs for all three of the sampling events. In addition, the guideline was exceeded once at SPG931UP, once at MUD027UP, once at MUD025, and on all

three events at OSG030, ILL022, and ILL020. Comparing data to the ADEQ TP guideline of 0.1 mg/L results in 21 exceedances of the 36 TP data points, or 58 percent of the samples exceed the guideline (Table 3.3). Comparing data collected to the USEPA derived ecoregion reference value of 0.06 mg/L for the Illinois River results in 31 TP exceedances of the 36 total samples (including two exceedances in the reference site data) or 86 percent of the samples exceed the guideline.

TOC, TDS, and Turbidity

TOC, TDS, and turbidity data are presented in Figures 3.11, 3.12 and 3.13, respectively, and in Table 3.3. TOC values from all locations over all three events ranged from 0.09 to 8.32 mg/L. The most significant increase in TOC (over all three events) was at SPG931DN compared to SPG931UP. The upstream site ranged from 0.50 to 1.28 mg/L and the downstream site ranged from 5.05 to 5.29 mg/L. TDS ranged from 164 to 448 mg/L, with the highest values at SPG931DN. There is a significant increase in TDS values for all three sampling events downstream of the City of Springdale discharge (SPG931DN). All three samples at SPG931DN exceeded the ADEQ numeric criteria for TDS of 300 mg/L. TDS exceedances also occurred for one event each at OSG030 and MUD027DN. Turbidity values were generally low, ranging from 0 to 10 NTU. The highest turbidity measurements were detected at MUD027DN (with 9 and 10 NTU), respectively, which were below or equal to the ADEQ numeric criterion of 10 NTU.

Figure 3.3 Illinois River Ammonia Results

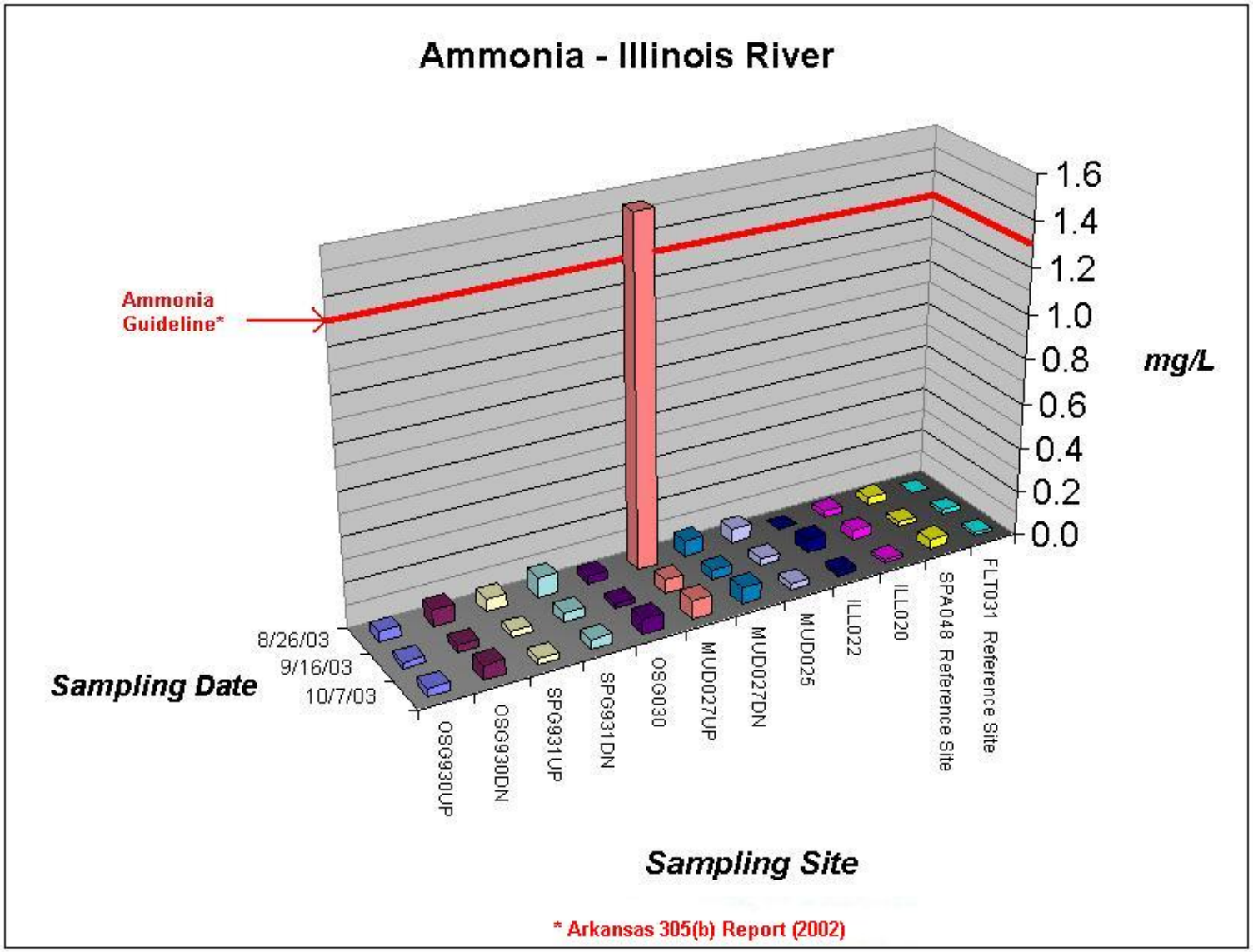


Figure 3.4 Illinois River Nitrate Nitrogen Results

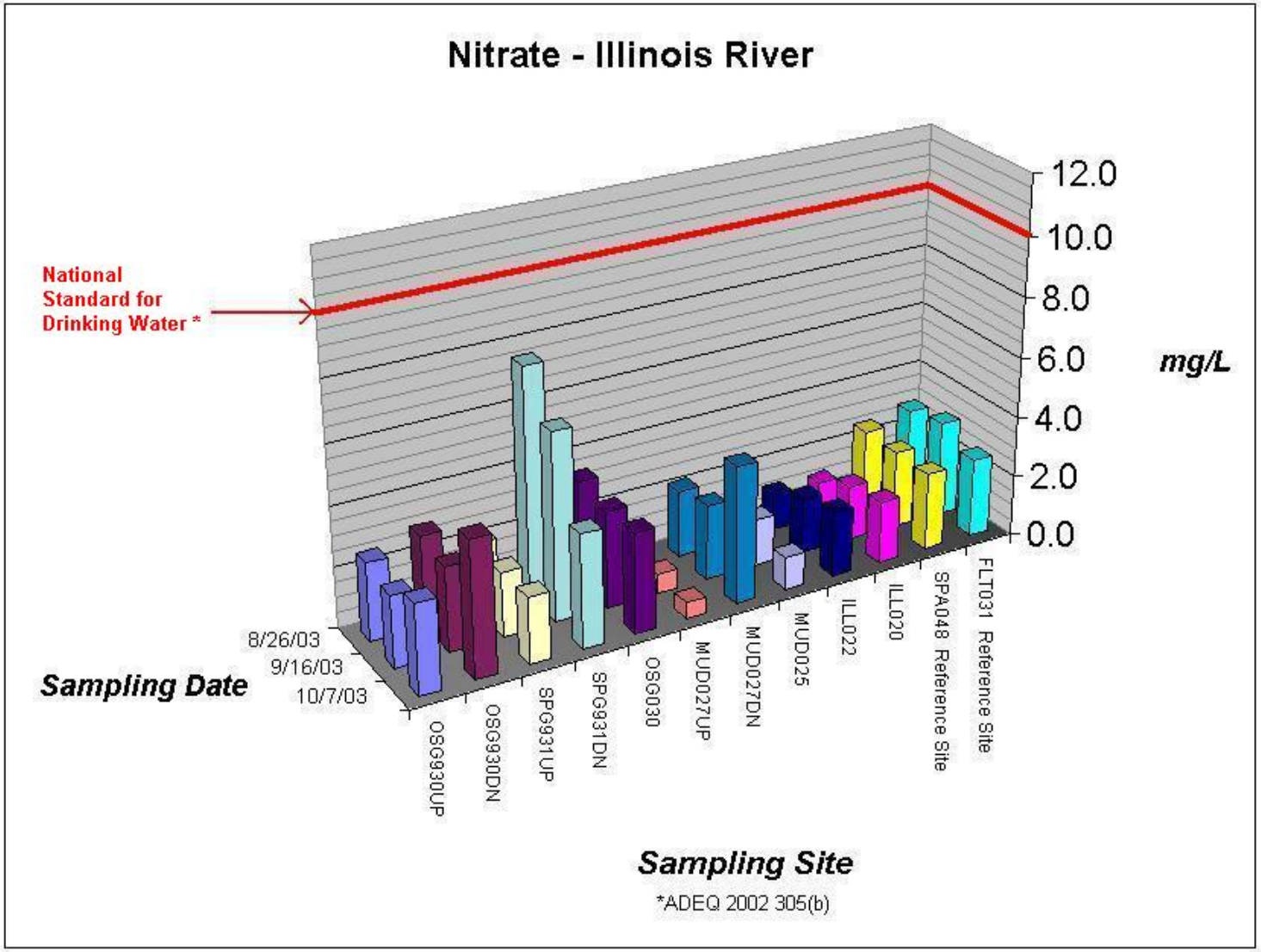


Figure 3.5 Illinois River Nitrite Nitrogen Results

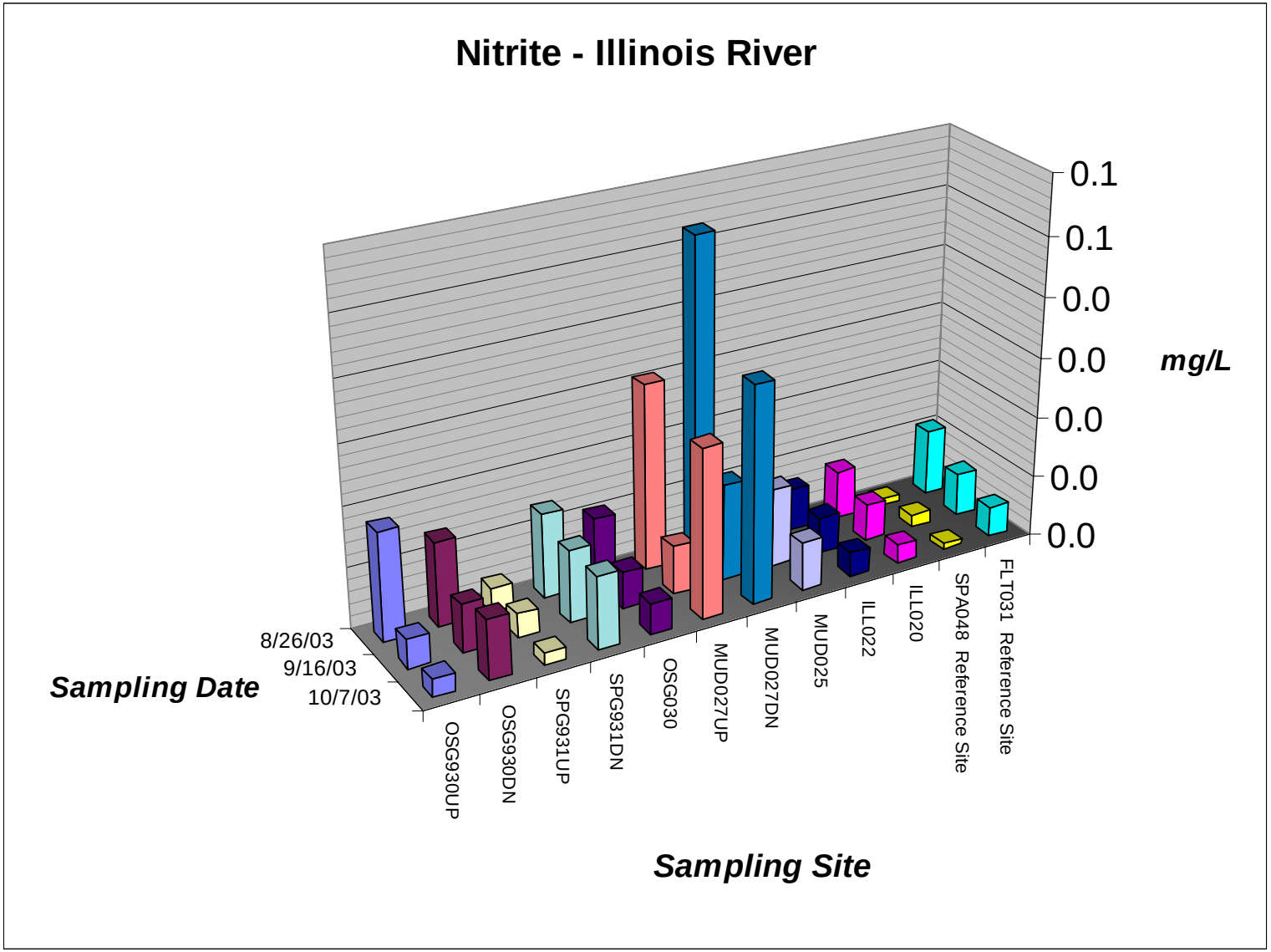


Figure 3.6 Illinois River TKN Results

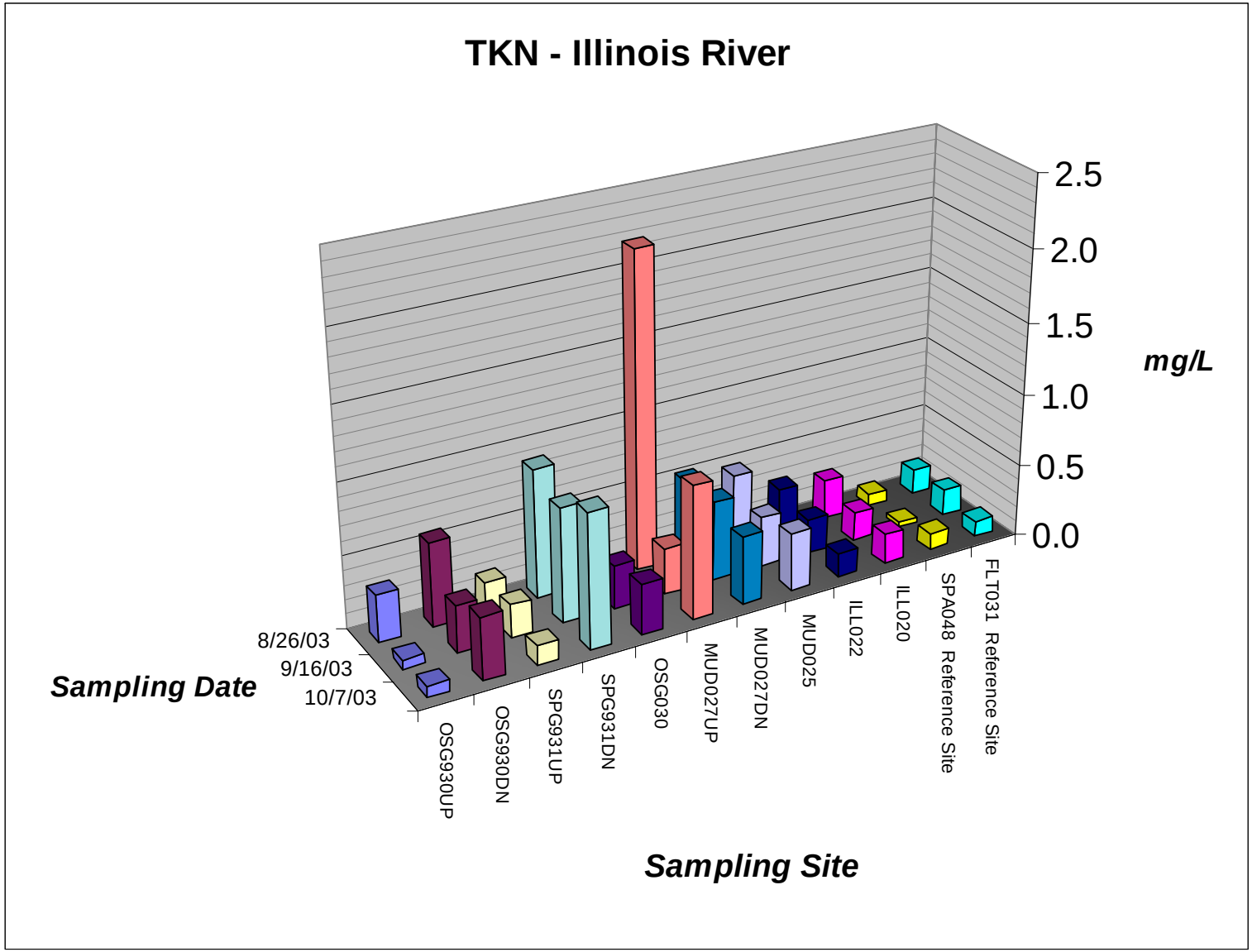


Figure 3.7 Illinois River Total Nitrogen Results

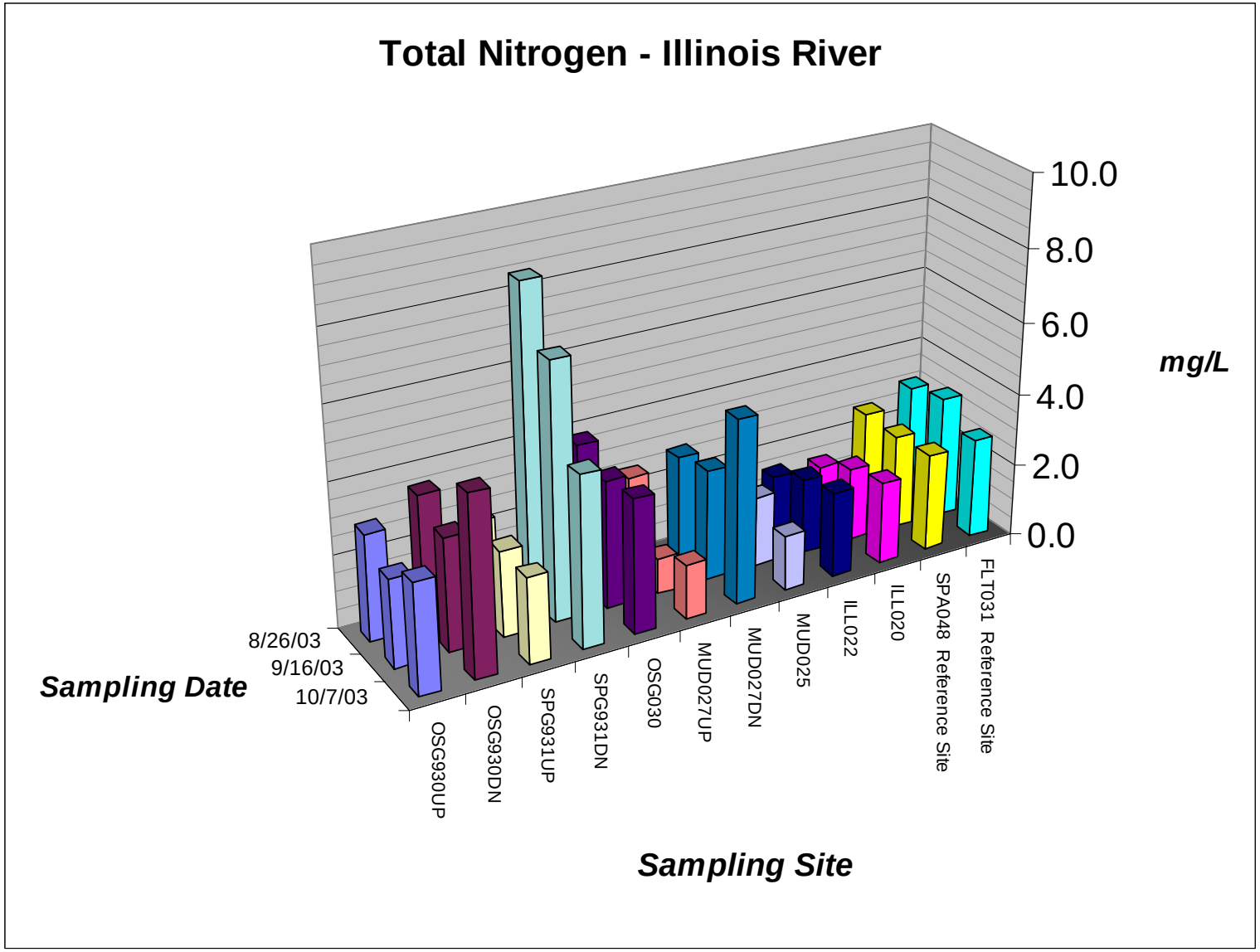


Figure 3.8 Illinois River Ortho Phosphate Results

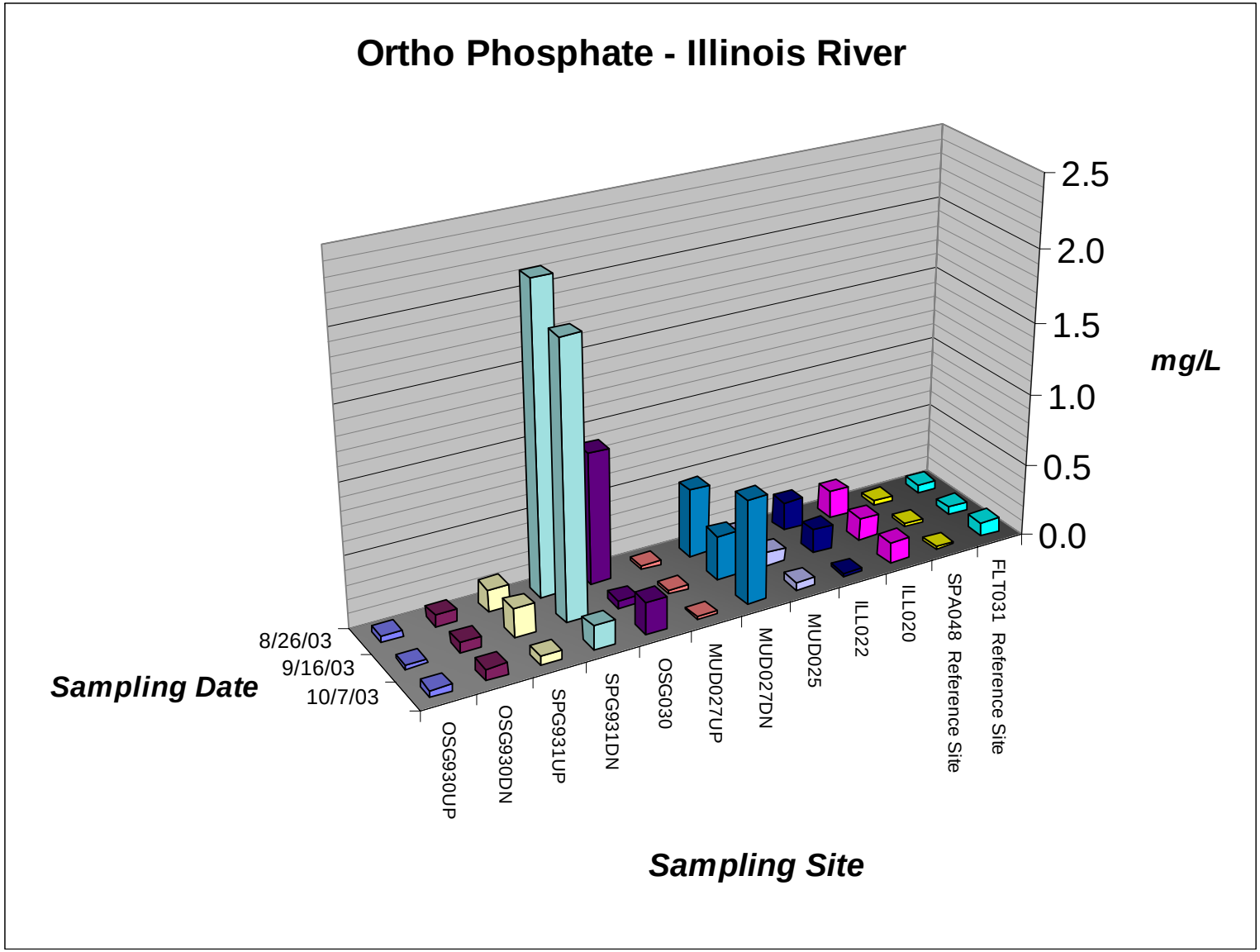


Figure 3.9 Illinois River Total Phosphorus Results

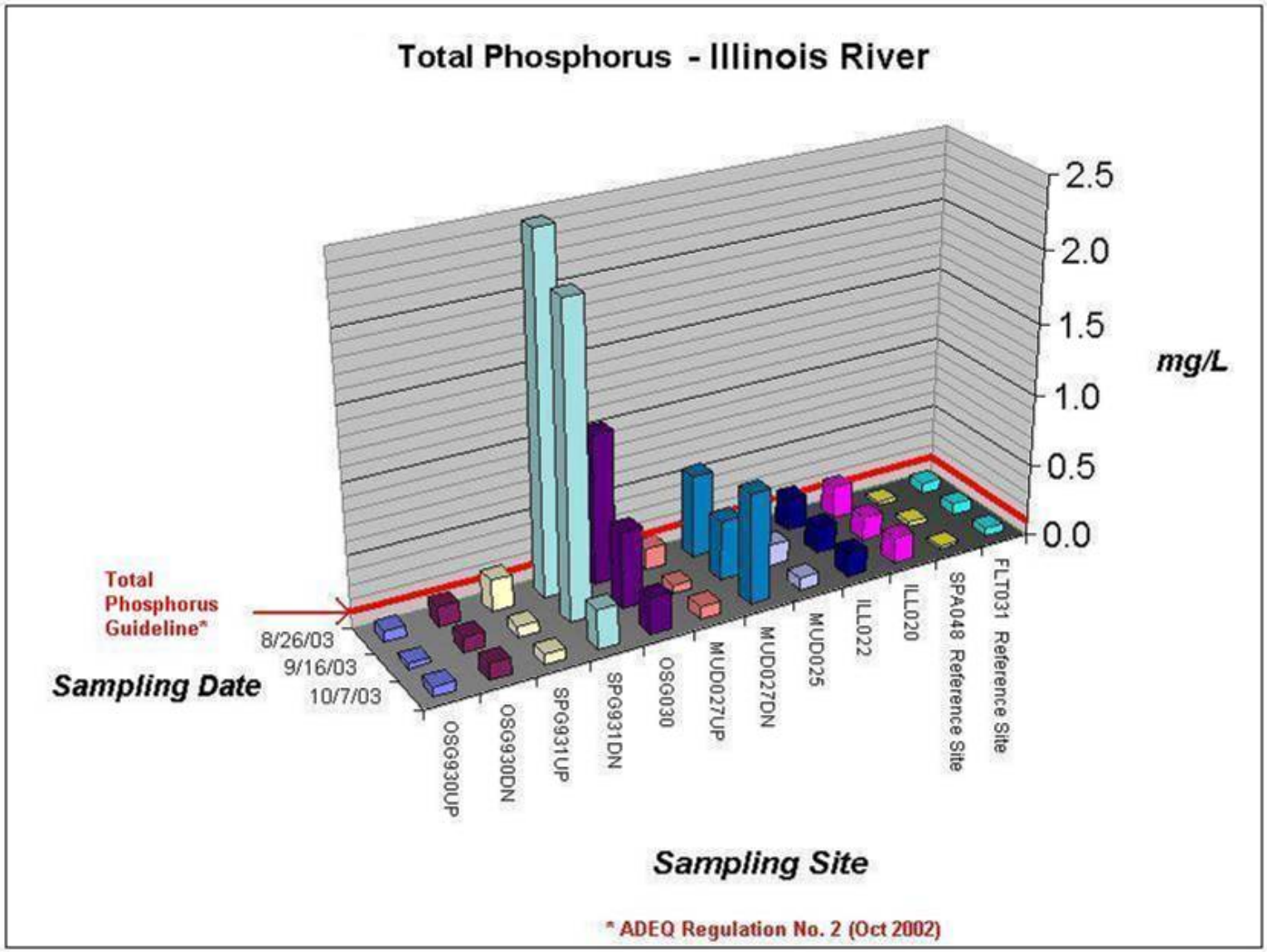
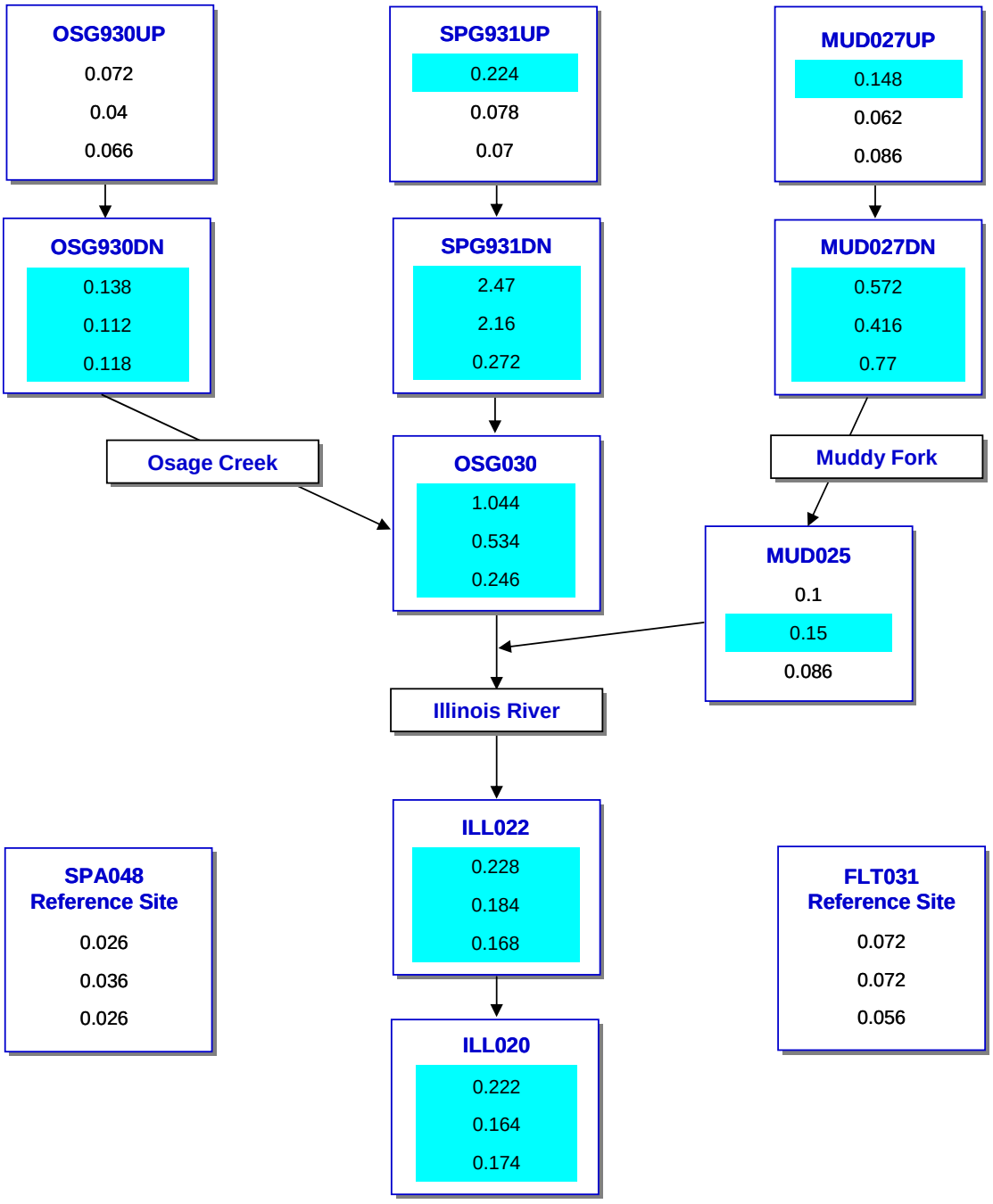


Figure 3.10 TP Values at Sites on the Illinois River (mg/L)



= exceeds total phosphorus (TP) guideline value: 0.1 mg/L (ADEQ Regulation No. 2, 2002)

Values at each site correspond respectively to the following sampling dates:

8/26/2003
9/16/2003
10/7/2003

Figure 3.11 Illinois River TOC Results

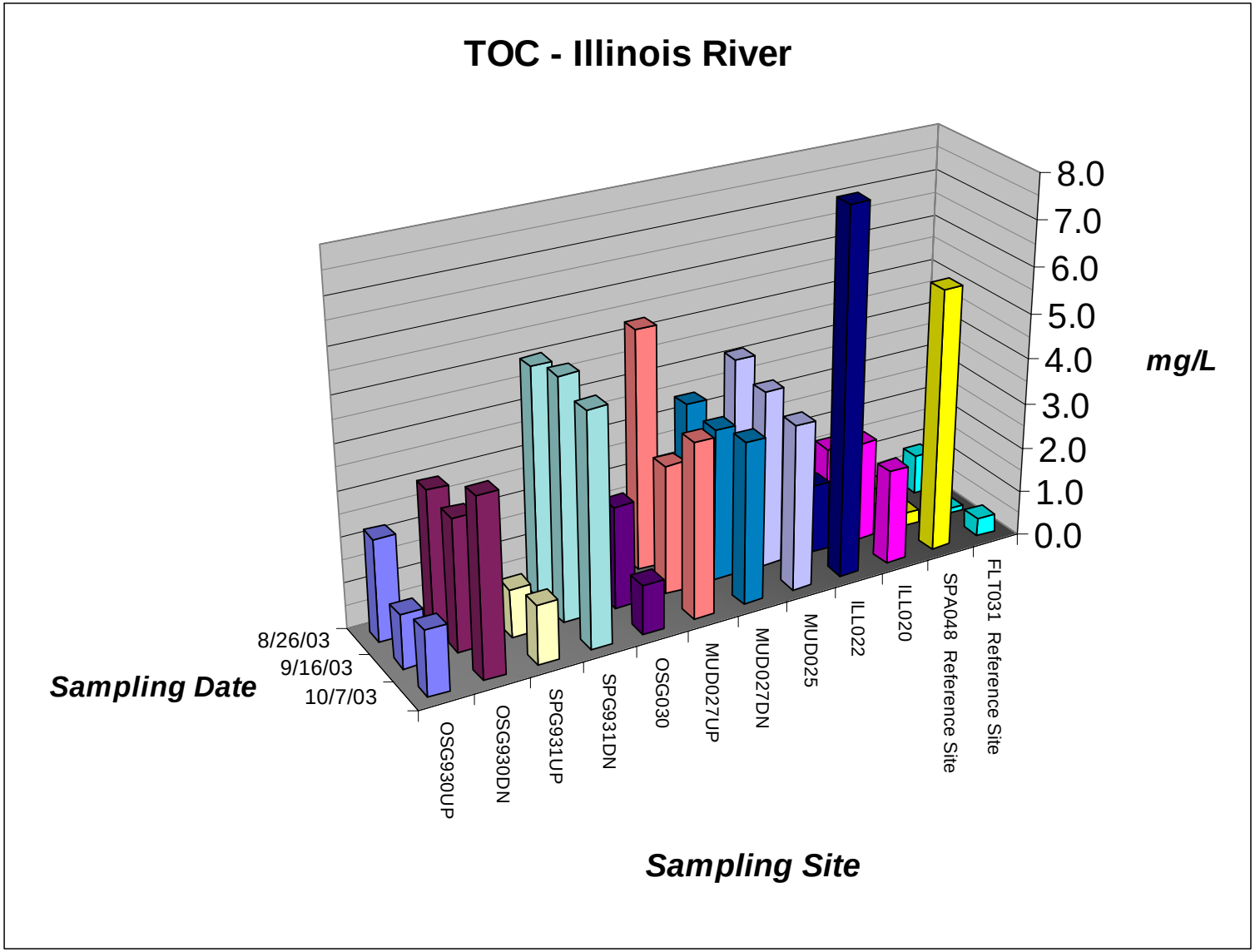


Figure 3.12 Illinois River TDS Results

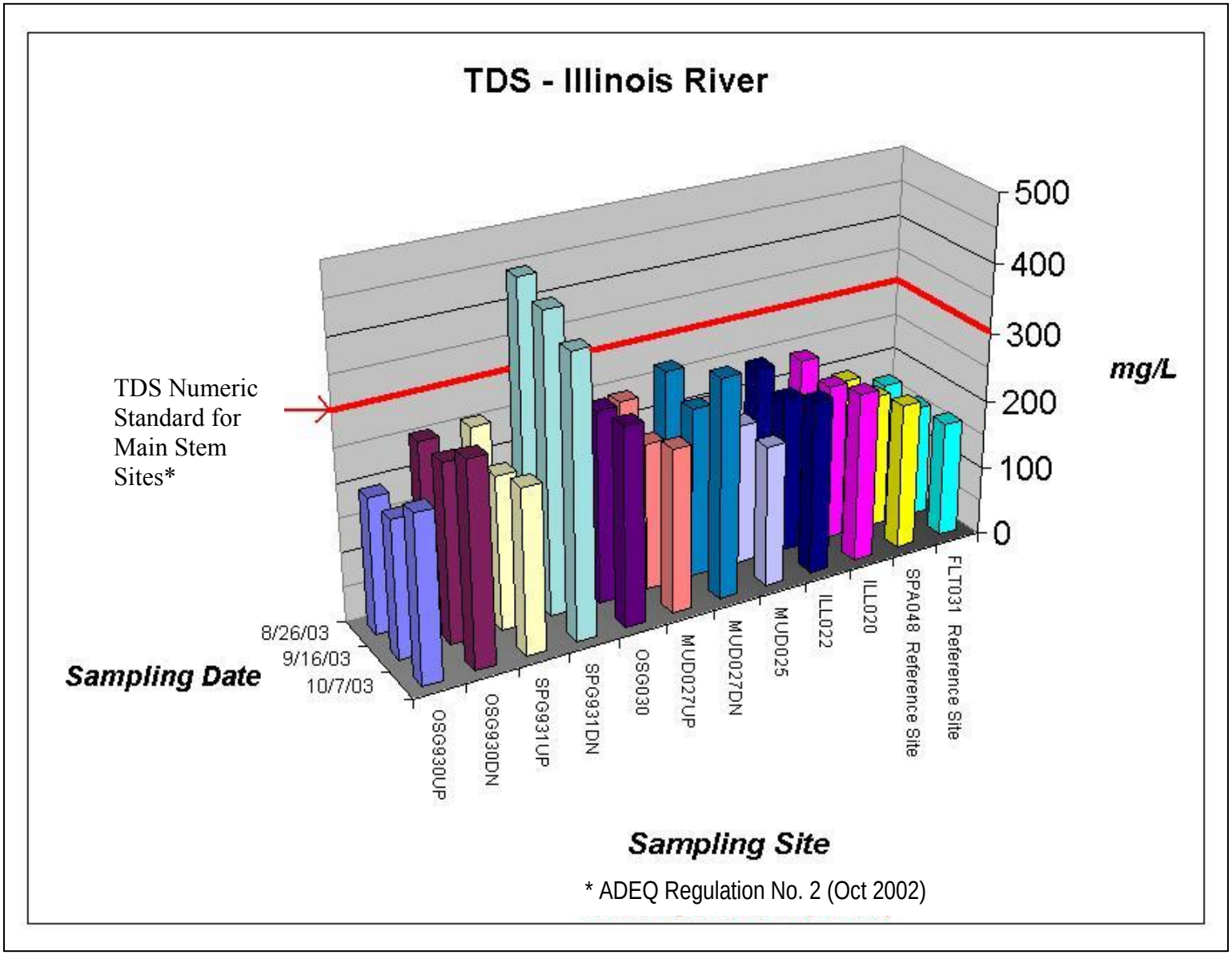
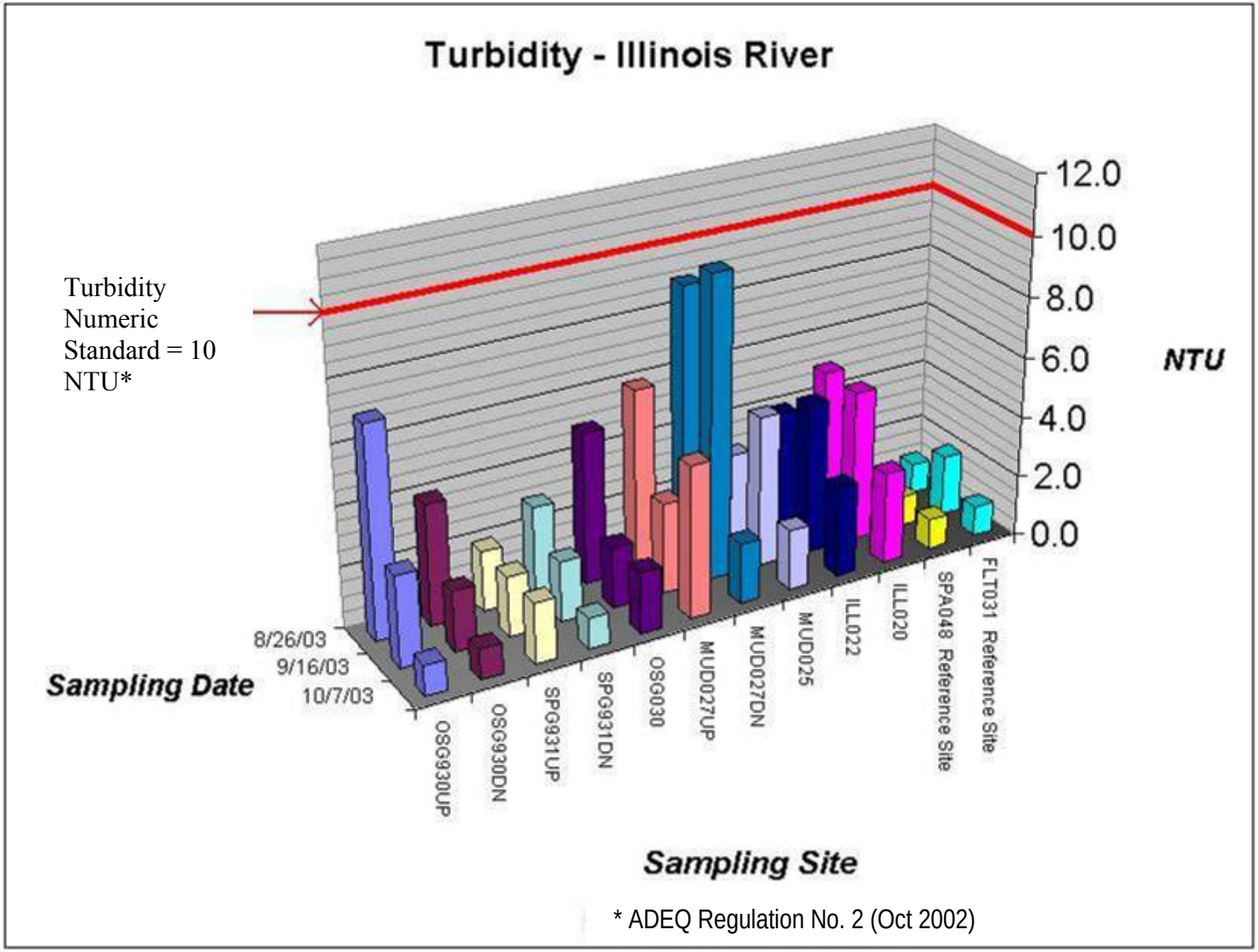


Figure 3.13 Illinois River Turbidity Results



Summary

Water chemistry nutrient results at locations downstream of all of the WWTP discharges were nearly always higher in nutrient concentrations than the respective upstream location. Nutrient concentrations diminish downstream of MUD025; however, all three results at station ILL020 are significantly higher than the Oklahoma TP criterion of 0.037 mg/L for the Illinois River at the state line. TDS exceeded the ADEQ numeric criterion 300 mg/L at three stations. Turbidity results did not exceed the ADEQ numeric criterion of 10 NTU.

3.3 STREAM HABITAT CHARACTERIZATION

Habitat Scoring: The first round of habitat assessments were conducted from September 28, 2003 through November 21, 2003. In the Illinois River basin, during round one, scores for the first round of riffle habitat assessments ranged from 89 at site MUD027UP to 189 at FLT031 (Table 3.4). Pool habitat assessments ranged from 124 at MUD027DN to 184 at FLT031. Round two of the habitat assessments was conducted from November 24, 2003 through December 20, 2003. During this round, riffle scores for the Illinois River basin ranged from 126 at MUD027DN to 174 at SPA048 and pool scores ranged from 140 at MUD027DN to 176 at SPA048 (Table 3.5).

Substrate Characterization: Stream substrate was gravel or a gravel cobble mixture in all sampling sites except for SPG931DN and ILL022 where the substrate was bedrock dominated (Table 3.6). Algae growth was present to some degree on the substrate of all sites. At all sites, sand and fine particles filled some part of the void space between gravel and cobble particles. Average substrate embeddedness ranged from 25% at OSG030 to 54% at ILL020. Algae were common to dense on the substrate at all sites except for FLT031 where it was only noted as present. Large and small woody debris, leaf litter, and percent canopy cover are also noted in the field and recorded in Table 3.6

Geomorphic Characterization: As expected, the bankfull width and depth varied as a power function of the watershed area (Figure 3.14). In general, the sites surveyed were wider and less deep than would be expected from the regional curves for the Ozark region developed by the Arkansas Soil and Water Conservation Commission. Bank erosion was common at all the streams, even at the reference sites. Bankfull velocity and discharge was calculated for each site using Manning's equation (Table 3.6). A single "n" value of 0.045 (clean winding stream, some pools, shoals, weeds and stones) was selected for the calculation (Ward 1995).

Normal channel discharge was calculated as the product of the average segment water surface width, average depth at water surface, and the average velocity (Table 3.6). Discharge increased in the downstream direction in all cases except OSG930 UP and DN. This result was somewhat surprising as the City of Rogers discharges treated effluent between these two sites. The reason for the reduced flow was not determined.

Impacted Sites: Habitat scoring is compared to the scores of the appropriate reference site on the far right of Tables 3.4 and 3.5. These percentages were compared to a value of 75 percent of reference value as was done for habitat communities in the 1997 Illinois River Report (ADEQ 1997). Greater than 75 percent of the reference scoring was determined as supporting in the 1997 report. Periphyton and filamentous algae were considered to render a site *impacted* if they were present in *Common* or *Dense* quantities.

For the first sampling event, the sites categorized as impacted (with scores less than 75 percent of the reference site scores) on the riffle section are SPG931UP, SPG931DN, OSG030, MUD027UP, MUD027DN, MUD025, and ILL022. The pool sections with impacted sites with respect to 75 percent of the reference sites score are SPG931UP, MUD027UP, and MUD027DN.

For the second sampling event on the Illinois River, the impacted riffle sites with respect to 75 percent of the scoring of the reference sites are SPG931UP and MUD027DN. None of the pool sections scored as impacted when compared to the 75 percent of reference score on the second event.

Figure 3.14 Bankfull Width and Depth vs. Watershed Area

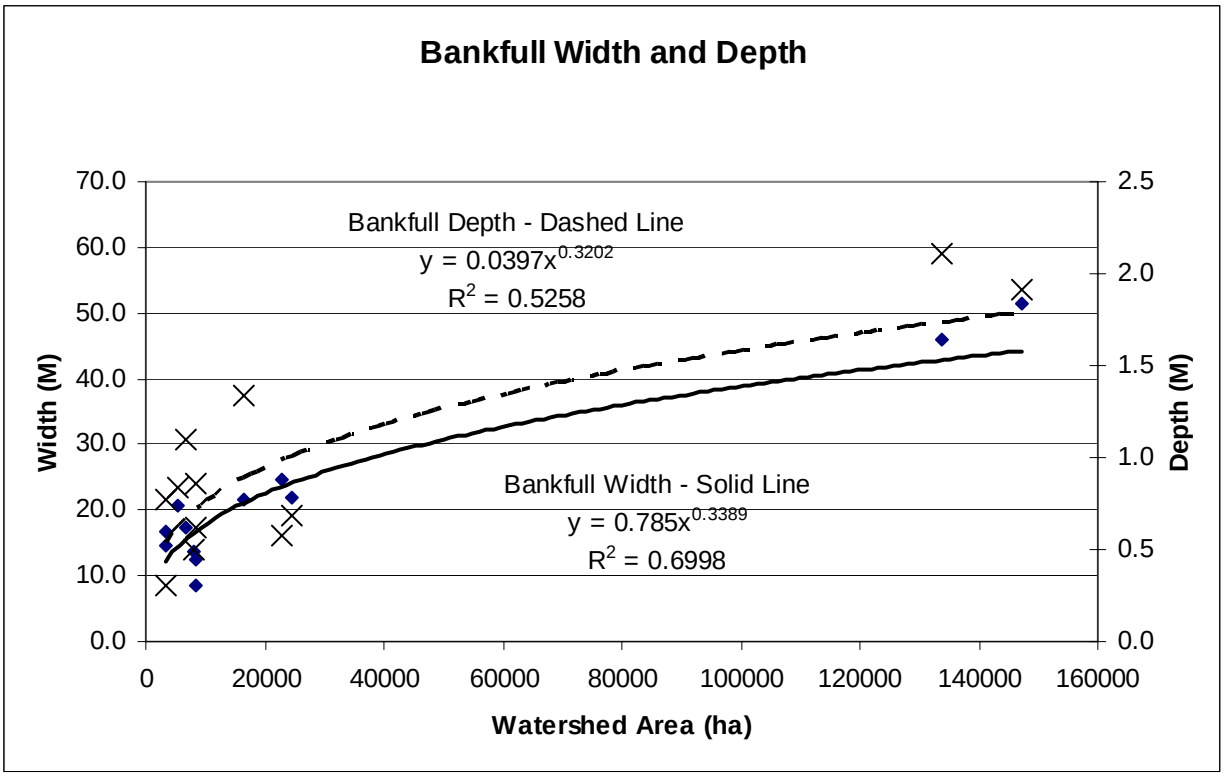


Table 3.4 Habitat Scoring for Illinois River, Event 1

Illinois River Watershed RBA Data - Round 1

Riffle Assessment													Comparison with Reference Site for Impact	
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB			
Description	Epifaunal Substrate/ Available Cover	Embed-dedness	Velocity/ Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of First Reference Site	% of Second Reference Site
OSG 930 UP	18	14	18	10	13	16	16	9	13	8	18	153	81.0	
OSG 930 DN	10	13	15	14	17	18	13	17	15	18	8	158	83.6	
SPG 931 UP	12	10	11	8	16	6	18	11	11	3	7	113	59.8	
SPG 931 DN	14	13	20	8	12	17	18	1	20	2	10	135	71.4	
OSG 30	15	13	15	15	15	13	14	10	10	6	6	132		72.5
MUD 27 UP	13	10	8	8	8	13	4	8	8	4	5	89	47.1	
MUD 27 DN	6	8	8	8	8	12	10	10	10	6	6	92	48.7	
MUD 25	17	11	8	16	13	13	8	15	10	16	8	135		74.2
ILL 20	17	11	16	10	10	12	16	10	15	16	14	147		80.8
ILL 22	8	13	5	10	15	18	6	11	16	10	8	120		65.9
FLT 31	18	15	18	17	15	15	20	15	20	16	20	189	Reference	
SPA 48	18	17	18	16	15	15	19	14	14	20	16	182		Reference

Pool Assessment													Comparison with Reference Site for Impact	
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB			
Description	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Sinuosity	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of First Reference Site	% of Second Reference Site
OSG 930 UP	17	18	15	11	18	20	13	13	17	7	16	165	89.7	
OSG 930 DN	12	16	18	10	17	20	9	8	13	16	7	146	79.3	
SPG 931 UP	6	16	7	8	12	8	10	16	13	4	8	108	58.7	
SPG 931 DN	15	16	18	12	12	15	11	2	20	18	13	152	82.6	
OSG 30	17	14	15	13	15	15	15	10	10	7	7	138		78.0
MUD 27 UP	11	11	13	8	17	15	15	10	7	10	8	125	67.9	
MUD 27 DN	18	12	13	11	15	12	13	8	10	6	6	124	67.4	
MUD 25	20	16	16	14	16	15	15	13	13	16	5	159		89.8
ILL 20	15	17	18	9	14	13	14	13	14	15	15	157		88.7
ILL 22	18	16	18	8	15	18	15	11	15	13	10	157		88.7
FLT 31	16	20	17	13	15	17	15	14	19	18	20	184	Reference	
SPA 48	20	18	17	15	13	15	15	14	14	20	16	177		Reference

Classification				
	Poor	0 - 5	Sub-Opt	11-15
	Marginal	6-10	Optimal	16-20

= Shaded if less than 75 % of reference site score (impacted if shaded).

Table 3.5 Habitat Scoring for Illinois River, Event 2

Illinois River Watershed RBA Data - Round 2

Riffle Assessment													Comparison with Reference Site for Impact	
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB			
Description	Epifaunal Substrate/ Available Cover	Embed-dedness	Velocity/ Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of First Reference Site	% of Second Reference Site
OSG 930 UP	17	15	16	13	15	13	19	12	14	8	8	150	86.7	
OSG 930 DN	16	12	15	14	15	18	18	8	15	18	8	157	90.8	
SPG 931 UP	10	15	10	13	10	6	18	15	15	10	6	128	74.0	
SPG 931 DN	13	13	18	15	13	11	19	5	18	9	15	149	86.1	
OSG 30	17	17	15	14	17	15	16	10	14	5	9	149		85.6
MUD 27 UP	15	13	15	13	15	15	15	10	10	10	8	139	80.3	
MUD 27 DN	13	10	13	10	13	15	13	10	13	8	8	126	72.8	
MUD 25	15	13	15	10	15	15	10	13	10	13	6	135		77.6
ILL 20	16	12	18	11	12	13	17	13	12	10	10	144		82.8
ILL 22	13	15	16	14	18	16	16	16	16	10	10	160		92.0
FLT 31	18	13	16	15	15	15	18	14	18	13	18	173	Reference	
SPA 48	18	13	16	12	13	15	18	15	18	18	18	174		Reference

Pool Assessment													Comparison with Reference Site for Impact	
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB			
Description	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Sinuosity	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of First Reference Site	% of Second Reference Site
OSG 930 UP	16	16	18	12	18	13	18	13	15	8	8	155	90.1	
OSG 930 DN	18	16	18	15	15	18	15	10	13	18	8	164	95.3	
SPG 931 UP	15	16	18	13	13	10	11	18	13	10	10	147	85.5	
SPG 931 DN	15	16	18	13	15	11	15	8	18	10	15	154	89.5	
OSG 30	16	18	16	13	20	15	15	14	17	5	10	159		90.3
MUD 27 UP	16	13	18	13	17	13	13	10	10	10	8	141	82.0	
MUD 27 DN	15	12	15	10	18	13	18	10	13	8	8	140	81.4	
MUD 25	18	15	16	12	17	15	16	13	16	13	6	157		89.2
ILL 20	13	16	18	12	15	13	15	15	13	10	10	150		85.2
ILL 22	13	11	18	15	18	18	15	15	15	10	10	158		89.8
FLT 31	18	16	17	14	14	14	16	14	18	13	18	172	Reference	
SPA 48	18	16	17	13	13	15	15	15	18	20	16	176		Reference

Classification				
	Poor	0 - 5	Sub-Opt	11-15
	Marginal	6-10	Optimal	16-20

= Shaded if less than 75 % of reference site score (impacted if shaded).

Table 3.6 Habitat and Pebble Count Results Illinois River

Station	Inorganic Components					Organic Components			Algae		Substrate Embeddedness %	Canopy Cover %
	% Coverage											
	Small Boulder	Cobble	Gravel	Sand	Silt	Lg Woody Debris	Sm. Woody Debris	Leaf Litter	Periphyton	Filamentatous		
	330 - 610 mm	76 - 329 mm	2 - 75 mm	<0.2mm	fines							
OSG930UP	0%	10%	90%	0%	0%	P	D	C	C/D	P	34%	43%
OSG930DN	0%	14%	86%	0%	0%	D	P	C	C	P	35%	41%
SPG931UP	0%	6%	94%	0%	0%	C	P	P	C	P	38%	38%
SPG931DN*	0%	40%	60%	0%	0%	P	P	P	C/D	C	34%	29%
OSG030	1%	10%	90%	0%	0%	C	P	R	C	C	25%	14%
MUD027UP	0%	11%	83%	0%	6%	C	C	C	P/C	P	31%	75%
MUD027DN	0%	4%	95%	0%	0%	D	P	C	P	P	37%	30%
MUD025	0%	22%	78%	0%	0%	C	C	P	P/C	P	31%	0%
ILL022*	0%	4%	96%	0%	0%	R	R	R	C	R	54%	0%
ILL020	0%	2%	99%	0%	0%	R	R	R	C	R	41%	29%
FLT031	0%	35%	65%	0%	0%	P	C	C	P	R	28%	54%
SPA048	0%	16%	85%	0%	0%	R	R	D	C	R	25 %	20%

* Bedrock Dominate

R = Rare
P = Present

C = Common
D = Dense

3.4 AQUATIC LIFE CHARACTERIZATION

3.4.1 Periphyton

Periphytic growth measurements during the first deployment (August – September 2003) using Matlock periphytometers showed statistically significant differences between many sites on the Illinois River (see Table 3.7). Sites with the same SNK ranking are not significantly different. Periphytic growth, measured as biomass production measured as chlorophyll *a* accumulation over 10-14 days, was the same for FLT031 (Reference Site 1 for the Illinois River), SPG931-UP, and OSG930-UP (SNK Ranking "A"). SPA048 (Reference Site 2 for the Illinois River) biomass production was the same for all remaining sites (SNK Ranking "B") except SPG931-DN. That site, located below the Springdale WWTP outfall, showed the highest productivity of all sites on the Illinois River. LETSIs were greater than 0.8 for all but three sites in the Illinois River (SPA048, SPG931-UP, and OSG930-DN) (Table 3.8). Adding nutrients to the growth media failed to elicit increased algal growth in these systems, suggesting that nutrients were at or above biotic demand levels for algae during the sample period. Primary productivity at all sites in this watershed was limited by something other than nutrients. Most sample sights had relatively closed canopies, indicating the probability that light was limiting algal productivity during the sample period.

Similar results were observed at the Illinois River sites during the second deployment period (early October 2003) (Tables 3.9 and 3.10). Periphytic growth was the same for FLT031, SPG931-UP, OSG930-UP, OSG930-DN, and MUD025. SPG931-DN was again greater than the upstream site (SPG931-UP). However, productivity at SPA048 (Reference Site 2 for the Illinois River) and MUD027-UP were dramatically higher than previously observed. This increase is probably due to several small runoff events in late September that triggered a bloom of filamentous algae during this observation period, resulting in dramatically elevated productivity rates. LETSIs were greater than 0.80 for all sites except SPG931-UP and ILL022, suggesting primary productivity at those sites was limited by something other than nutrients, probably light.

These results illustrate the complex nature of determining point source nutrient impacts on systems with both point and nonpoint pollutant loads. Periphytic growth is a fundamental ecosystem process, and thus is the product of multiple ecosystem inputs, including light, nutrients, and temperature. Measuring this process is difficult; grazing is controlled by covering the periphytometers with aluminum screen. However, in some cases, leaf litter accumulated on the periphytometer racks, potentially limiting light and suppressing algal response to nutrients. Thus, all interpretations should be made in the context that additional observations must be made to include habitat condition, water chemistry, and diurnal DO.

Table 3.7 Chlorophyll *a* Concentrations on Artificial Substrate August/September 2003

Student-Newman-Keuls' (SNK) Test Comparison of Chlorophyll *a* concentrations for Control, Nitrogen (N), Phosphorus (P), and Nitrogen plus Phosphorus (N + P) treatments using the Matlock Periphytometer in the Illinois River basin during the period of August-September, 2003

Site	Treatment	Number of Replicates	Mean Chl. *a* (µg cm^{-2})	Standard Deviation (µg cm^{-2})	SNK Group (µ=0.05)				Limiting Nutrient
OSG930-UP	Control	10	0.32	0.08	A	B			Co-NP
	N	9	0.27	0.08	A	B			Limited
	P	10	0.24	0.05	A				
	N + P	10	0.34	0.09		B			
OSG930-DN	Control	10	0.35	0.22		B			None
	N	10	0.36	0.26		B			
	P	10	0.41	0.23		B			
	N + P	10	0.53	0.28		B			
SPG931-UP*	Control	10	0.16	0.10	A				None
	N	10	0.17	0.08	A				
	P	10	0.25	0.16	A				
	N + P	10	0.22	0.12	A				
SPG931-DN	Control	9	1.88	0.66				E	None
	N	10	2.67	0.85				E	
	P	10	1.85	0.59				E	
	N + P	9	2.14	0.84				E	
OSG030*	Control	10	0.58	0.29		B			None
	N	7	0.49	0.22		B			
	P	10	0.53	0.19		B			
	N + P	10	0.49	0.17		B			
MUD027-UP	Control	10	0.46	0.26		B			None
	N	10	0.39	0.15		B			
	P	10	0.51	0.43		B			
	N + P	10	0.38	0.22		B			
MUD027-DN	Control	10	0.68	0.14		B			None
	N	10	0.71	0.23		B			
	P	10	0.76	0.28		B			
	N + P	10	0.76	0.29		B			
MUD025	Control	10	0.63	0.35		B			None
	N	10	0.68	0.26		B			
	P	9	0.83	0.23		B			
	N + P	10	0.59	0.18		B			
ILL022	Control	9	0.52	0.31		B			None
	N	10	0.52	0.25		B			
	P	9	0.44	0.35		B			
	N + P	8	0.42	0.19		B			
ILL020	Control	8	0.43	0.17		B			None
	N	9	0.50	0.16		B			
	P	9	0.47	0.16		B			
	N + P	9	0.53	0.08		B			
SPA048	Control	10	0.39	0.33		B			None
	N	10	0.50	0.35		B			
	P	9	0.34	0.17		B			
	N + P	10	0.51	0.32		B			

Site	Treatment	Number of Replicates	Mean Chl. *a* (µg cm^{-2})	Standard Deviation (µg cm^{-2})	SNK Group (µ=0.05)	Limiting Nutrient
FLT031	Control	10	0.28	0.04	A	None
	N	9	0.24	0.07	A	
	P	10	0.22	0.07	A	
	N + P	10	0.24	0.08	A	

* First deployment vandalized; redeployed in October 2003.

Table 3.8 Lotic Ecosystem Trophic Status Indices August/September 2003

Lotic Ecosystem Trophic Status Indices using the Matlock Periphytometer in the Illinois River basin during the period of August-September, 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* (µg cm^{-2})	Standard Deviation (µg cm^{-2})	LETSI
OSG930-UP	Control	10	0.32	0.08	0.94
	N + P	10	0.34	0.09	
OSG930-DN	Control	10	0.35	0.22	0.66
	N + P	10	0.53	0.28	
SPG931-UP*	Control	10	0.16	0.10	0.73
	N + P	10	0.22	0.12	
SPG931-DN	Control	9	1.88	0.66	0.88
	N + P	9	2.14	0.84	
OSG030*	Control	10	0.58	0.29	>1.0
	N + P	10	0.49	0.17	
MUD027-UP	Control	10	0.46	0.26	>1.0
	N + P	10	0.38	0.22	
MUD027-DN	Control	10	0.68	0.14	0.89
	N + P	10	0.76	0.29	
MUD025	Control	10	0.63	0.35	>1.0
	N + P	10	0.59	0.18	
ILL022	Control	9	0.52	0.31	>1.0
	N + P	8	0.42	0.19	
ILL020	Control	8	0.43	0.17	0.81
	N + P	9	0.53	0.08	
FLT031	Control	10	0.28	0.04	>1.0
	N + P	10	0.24	0.08	
SPA048	Control	10	0.39	0.33	0.76
	N + P	10	0.51	0.32	

*First deployment vandalized; redeployed in October 2003.

Table 3.9 Chlorophyll *a* Concentrations on Artificial Substrate October 2003

Student-Newman-Keuls' (SNK) Test Comparison of Chlorophyll *a* concentrations for Control, Nitrogen (N), Phosphorus (P), and Nitrogen plus Phosphorus (N + P) treatments using the Matlock Periphytometer in the Illinois River basin during October, 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* (g cm^{-2})	Standard Deviation (g cm^{-2})	SNK Group (=0.05)	Limiting Nutrient
OSG930-UP	Control	10	0.11	0.03	A	None
	N	9	0.11	0.05	A	
	P	10	0.11	0.07	A	
	N + P	10	0.12	0.08	A	
OSG930-DN	Control	10	0.11	0.05	A	None
	N	10	0.09	0.04	A	
	P	10	0.10	0.07	A	
	N + P	10	0.08	0.02	A	
SPG931-UP	Control	9	0.06	0.03	A	None
	N	10	0.05	0.03	A	
	P	10	0.12	0.11	A	
	N + P	10	0.09	0.04	A	
SPG931-DN	Control	10	0.45	0.19	B	None
	N	10	0.43	0.18	B	
	P	9	0.46	0.14	B	
	N + P	10	0.57	0.25	B	
OSG030	Control	10	0.43	0.49	B	None
	N	10	0.38	0.11	B	
	P	10	0.28	0.08	B	
	N + P	9	0.53	0.12	B	
MUD027-UP	Control	10	2.03	0.79	D	None
	N	10	1.03	0.94	D	
	P	10	2.71	1.40	D	
	N + P	10	1.35	1.21	D	
MUD027-DN	Control	10	0.28	0.13	B	None
	N	10	0.24	0.19	B	
	P	10	0.23	0.10	B	
	N + P	9	0.24	0.10	B	
MUD025	Control	10	0.17	0.03	A	None
	N	10	0.18	0.05	A	
	P	10	0.18	0.04	A	
	N + P	10	0.16	0.04	A	
ILL022	Control	10	0.22	0.07	B	None
	N	10	0.22	0.16	B	
	P	10	0.28	0.18	B	
	N + P	9	0.39	0.25	B	
ILL020	Control	10	0.81	0.54	C	None
	N	10	0.70	0.38	C	
	P	10	0.68	0.57	C	
	N + P	10	0.65	0.39	C	
SPA048	Control	9	1.56	1.37	D	None
	N	10	2.28	1.54	D	
	P	10	1.59	1.09	D	
	N + P	10	1.65	1.05	D	
FLT031	Control	10	0.10	0.03	A	None
	N	10	0.11	0.02	A	
	P	10	0.11	0.04	A	
	N + P	10	0.10	0.03	A	

Table 3.10 Lotic Ecosystem Trophic Status Indices October 2003

Lotic Ecosystem Trophic Status Indices using the Matlock Periphytometer in the Illinois River basin during October 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* ($\mu g\ cm^{-2}$)	Standard Deviation ($\mu g\ cm^{-2}$)	LETSI
OSG930-UP	Control	10	0.11	0.03	0.92
	N + P	10	0.12	0.08	
OSG930-DN	Control	10	0.11	0.05	>1.0
	N + P	10	0.08	0.02	
SPG931-UP	Control	9	0.06	0.03	0.67
	N + P	10	0.09	0.04	
SPG931-DN	Control	10	0.45	0.19	0.80
	N + P	10	0.57	0.25	
OSG030	Control	10	0.43	0.49	0.81
	N + P	9	0.53	0.12	
MUD027-UP	Control	10	2.03	0.79	>1.0
	N + P	10	1.35	1.21	
MUD027-DN	Control	10	0.28	0.13	>1.0
	N + P	9	0.24	0.10	
MUD025	Control	10	0.17	0.03	>1.0
	N + P	10	0.16	0.04	
ILL022	Control	10	0.22	0.07	0.56
	N + P	9	0.39	0.25	
ILL020	Control	10	0.81	0.54	>1.0
	N + P	10	0.65	0.39	
FLT031	Control	10	0.10	0.03	1.0
	N + P	10	0.10	0.03	
SPA048	Control	9	1.56	1.37	0.95
	N + P	10	1.65	1.05	

Algae Species

The taxonomic analyses of algal data collected from natural substrates at each site suggest that the periphytic community within the Illinois River basin has been altered below WWTP outfalls. Algal data results and a more in depth analysis of the data are provided in Appendix I. The Shannon-Weiner Diversity Index (SWDI) decreased significantly from 4.25 to 2.86 between the sample sites upstream and downstream of the City of Springdale WWTP (SPG931UP and SPG931DN, respectively) (Table I-1). There was a less severe drop between the other WWTP outfalls, with the exception of the sites above and below the Prairie Grove WWTP on Muddy Fork (MUD027UP and MUD027DN) where the SWDI increased. This increase was likely due to increased flow in the downstream site; the site above the WWTP had higher sediment deposition and much less flow during the critical period. The Siltation Index was higher below the Prairie Grove WWTP outfall than above (0.507 at MUD027UP and 0.754 at

MUD027DN), though the significance of this measurement is unclear. Change in percent dominance was greatest at the site below the Springdale WWTP outfall (Table I-1). The *Lange-Bertalot pollution index* (Barbour *et al.* 2002) was lowest at the sites below the Prairie Grove and Springdale WWTPs (MUD027D and SPG931DN), suggesting the algal communities at these sites were least sensitive to, or most impacted by, pollution.

3.4.2 Benthic Macroinvertebrate Collection

Reference Sites. This report utilizes two types of references sites: site specific and regional. Site-specific reference sites are located immediately above a WWTP outfall, and serve as references for the downstream sites only. Regional reference sites, representing a geographically proximate group of sample sites, have utility but are difficult to analyze because of the degree of general alteration present in most landscapes, and because of the local variability of even the most homogenous ecoregion (Barbour *et al.* 1999). The difficulty of using both types of reference sites for benthic macroinvertebrate analyses in large landscape investigations are exemplified in this study. Watershed sizes for the sample sites varied dramatically, from as small as 12 square miles to as large as 568 square miles. In all cases, upstream reference sites had significantly lower flows than downstream reference sites, so flow rather than pollutants could induce community change. Two regional reference sites were selected to capture some degree of landscape variability. Since P was the pollutant of concern in this study, regional reference sites that had relatively low P concentrations were selected. Flint Creek above the Siloam Springs discharge (FLT031) was selected as a reference site for small watershed stream sample sites (OSG930UP, OSG930DN, SPG931UP, SPG931DN, MUD027UP, and MUD027DN). Spavinaw Creek, above the convergence with Owl Run Creek, (SPA048) was selected as the reference site for larger watershed stream sites (OSG030, MUD025, ILL022, and ILL020). While these reference sites may be marginally impacted by nonpoint source pollutants and land use changes, they are not impacted by point sources and therefore, are still suitable for evaluating point source impacts. However, care should always be exercised in interpreting a single metric or result.

Benthic Macroinvertebrates – First Sampling Event

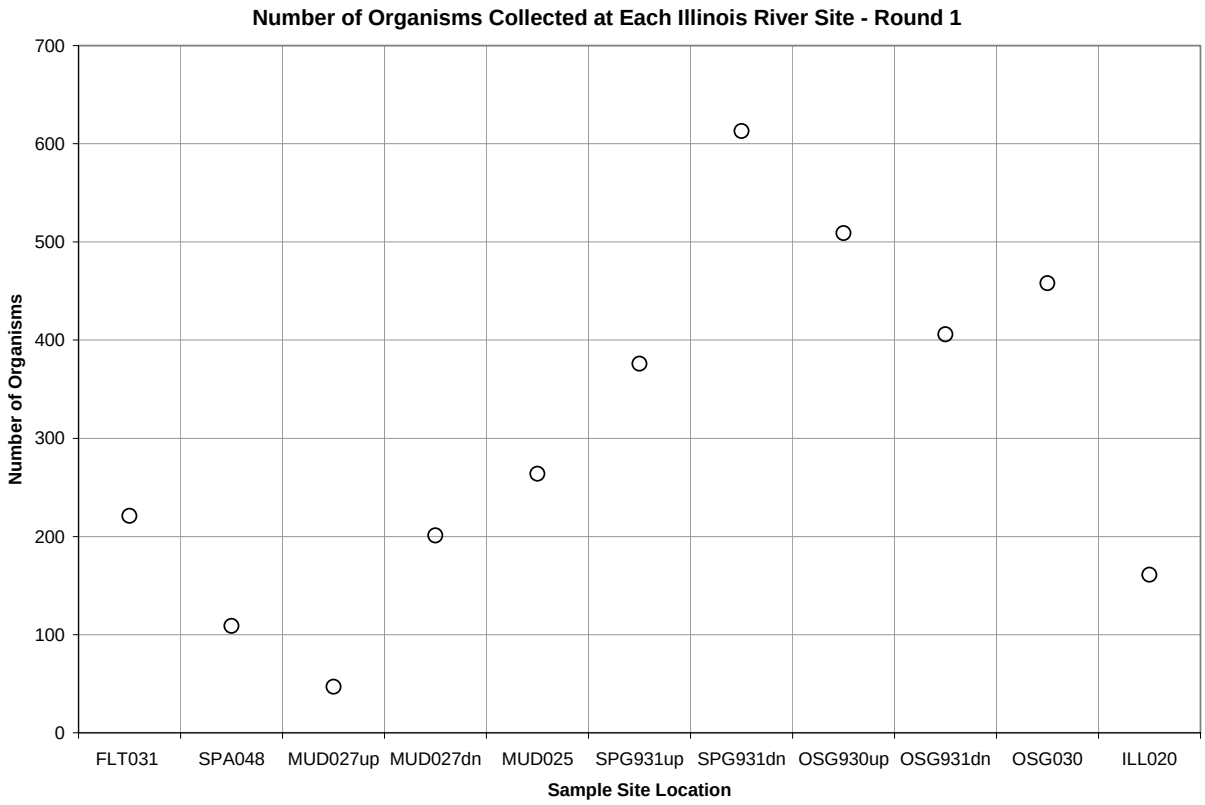
Results of benthic macroinvertebrate sampling during the first round (Critical Period) for the Illinois River are presented in Table 3.11. Raw data on macroinvertebrate collection are provided in Appendix D. Community comparisons were made using the same criteria described in the ADEQ 1997 Illinois River Report (ADEQ 1997) for ease of comparison. Collection procedures produced more organisms overall than in the 1997 collection (Figure 3.15). The 1997 Report was based on sub-sampling 100 organisms from an average collection of less than 130 organisms per site. These analyses were based on sub-sampling 100 organisms from an average initial collection of 285 organisms. This sampling effort resulted in collection of 56 *taxa*, compared with 38 in the 1997 collection, providing a robust estimate of community structure across sites. One site in the Illinois River, ILL022, could not be sampled because no acceptable riffles could be located within 1000 meters of the designated station. The substrate at the site was bedrock, and stream geomorphology had changed at that location to a run-dominated system.

Table 3.11 Benthic Macroinvertebrate Results – Event 1

Metric	STATION										
	OSG930up[c]	OSG930dn[c]	SPG931up[c]	SPG931dn[c]	OSG030[d]	MUD027up[c]	MUD027dn[c]	MUD025[d]	ILL020[d]	FLT031[a]	SPA048[b]
Total Number Identified	123	119	107	114	109	45	109	94	103	102	109
Additional Invertebrates	386	287	269	499	349	2	92	170	58	119	-
Total Number in Sample	509	406	376	613	458	47	201	264	161	221	109
Total Taxa	23	21	13	14	16	11	18	21	17	20	15
EPT Taxa	9	8	6	5	9	4	6	10	9	13	7
EPT Abundance	64	48	33	70	67	10	68	39	69	89	26
Contribution of Dominant Taxa	15%	14%	28%	50%	23%	40%	34%	16%	31%	16%	40%
Scraper Abundance	46	36	3	4	45	3	12	19	43	23	26
Filter Feeder Abundance	31	17	11	58	33	0	48	21	0	40	10
Chironomidae	1	3	7	15	1	18	12	15	1	1	0
Hilsenhoff Biotic Index	4.91	6.03	7.94	7.09	4.60	8.58	6.31	5.66	4.41	4.02	6.06
EPT Index	0.39	0.38	0.46	0.36	0.56	0.36	0.33	0.48	0.53	0.65	0.47
EPT / Chironomids +EPT	0.98	0.94	0.83	0.82	0.99	0.36	0.85	0.72	0.99	0.99	1.00
Scraper / Scraper+Filter Feeder	0.60	0.68	0.21	0.06	0.58	1.00	0.20	0.48	1.00	0.36	0.72
Community Loss Index	0.43	0.48	1.00	1.00	0.50	1.27	0.67	0.38	0.53	Reference A	Reference B
Benthic Macroinvertebrates											
Integrated Scoring[e]	22.34	18.60	14.09	15.35	23.88	13.38	17.23	19.34	25.20	26.88	18.70
Reference Site Comparison[f]	83.1%	69.2%	52.4%	57.1%	127.7%	49.8%	64.1%	103.4%	134.7%	100.0%	100.0%

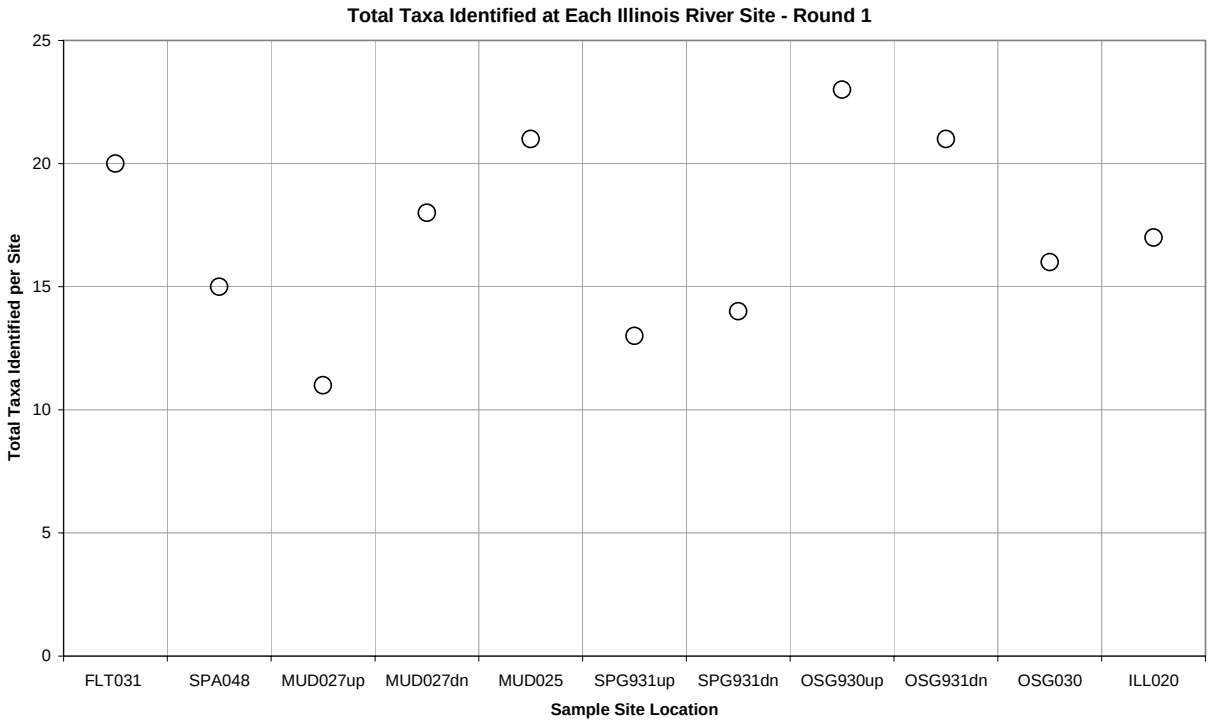
[a] Small Watershed Reference Site
[b] Large Watershed Reference Site
[c] FLT031 is designated reference site
[d] SPA 048 is designated reference site
[e] Integrated Scoring = [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]
[f] Site scoring compared to designated reference site

Figure 3.15 Total Organisms



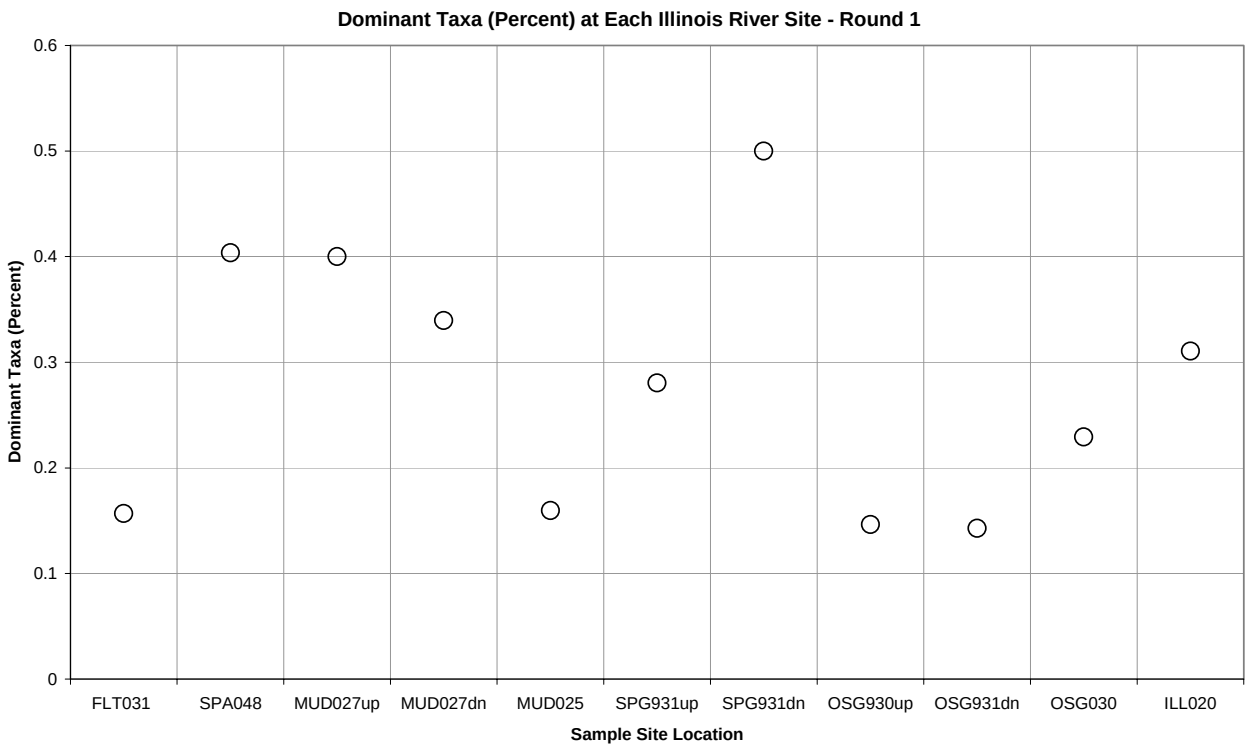
***Taxa* Richness**. *Taxa* richness represents the diversity of *taxa* represented within a sample, and therefore are representative of the *taxa* richness present at a site (Barbour *et al*. 1999). Macroinvertebrate *taxa* richness is based on genus-level identification in the Rapid Bioassessment Protocol. In general, increasing taxa richness means increasing ecosystem integrity, reflecting that niche space, habitat, and food sources are adequate to support a variety of macroinvertebrate assemblages (Barbour *et al.,* 1999). Decreasing *taxa* richness suggests a loss of these ecosystem functions, and thus ecosystem degradation. For small watersheds, both Muddy Fork (MUD027 UP and MUD027DN) and Spring Creek (SPG931UP and SPG931DN) were lower than the FLT031 reference site (Figure 3.16). The Upper Osage Creek sites (OSG930UP and OSG930DN) were higher than the reference site. All larger watershed sites (MUD025, OSG030, and ILL020) had higher *taxa* richness than their regional reference site. *Taxa* richness was lowest in the first round of sampling at MUD027UP (Figure 3.16).

Figure 3.16 Total Taxa



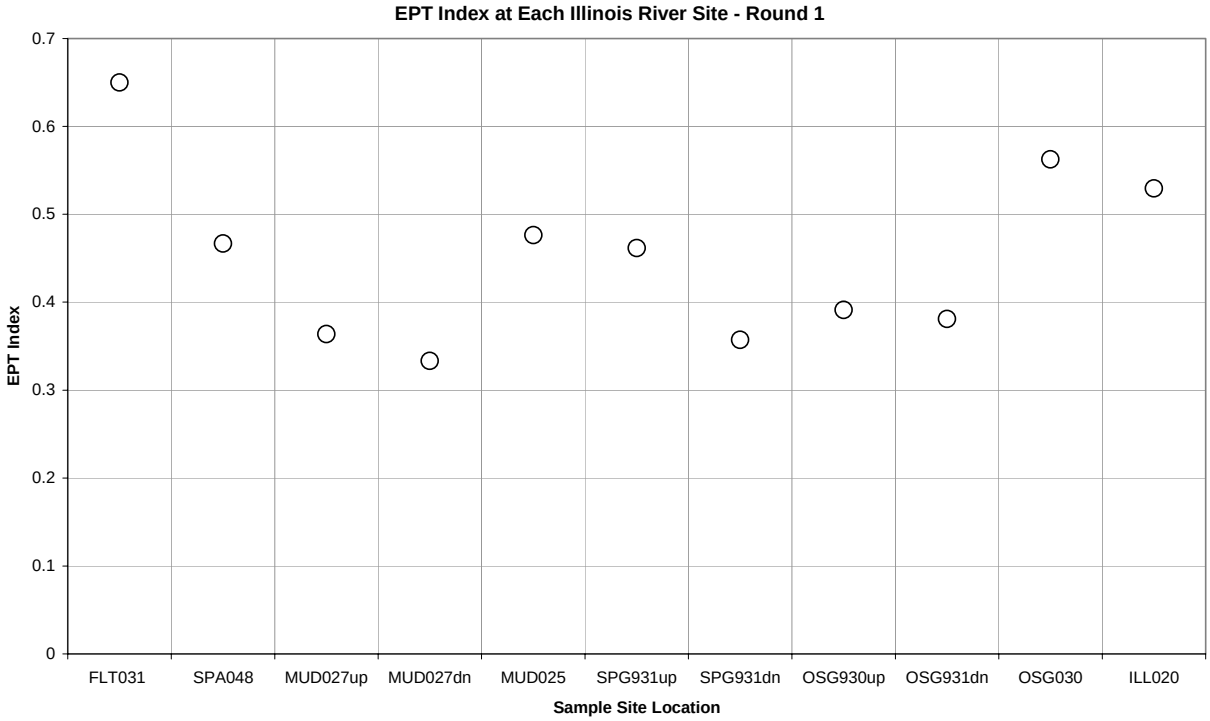
Dominant *Taxa*. The measure of the proportion of the total sample represented by the dominant *taxa* is a measure of community balance and diversity. Stressed ecosystems usually have reduced *taxa*, and as perturbation levels increase, often become dominated by a single taxonomic group. In the Illinois River basin during the first round of sampling, the site with the highest percent dominant *taxa* was SPG931DN, downstream of the Springdale WWTP (Figure 3.17). The upstream site had a dominant *taxa* proportion of 28 percent, while the downstream site dominant *taxa* increased to 50 percent. The lowest dominant *taxa* proportions were at FLT031, MUD025, OSG930UP and OSG930DN.

Figure 3.17 Dominant Taxa



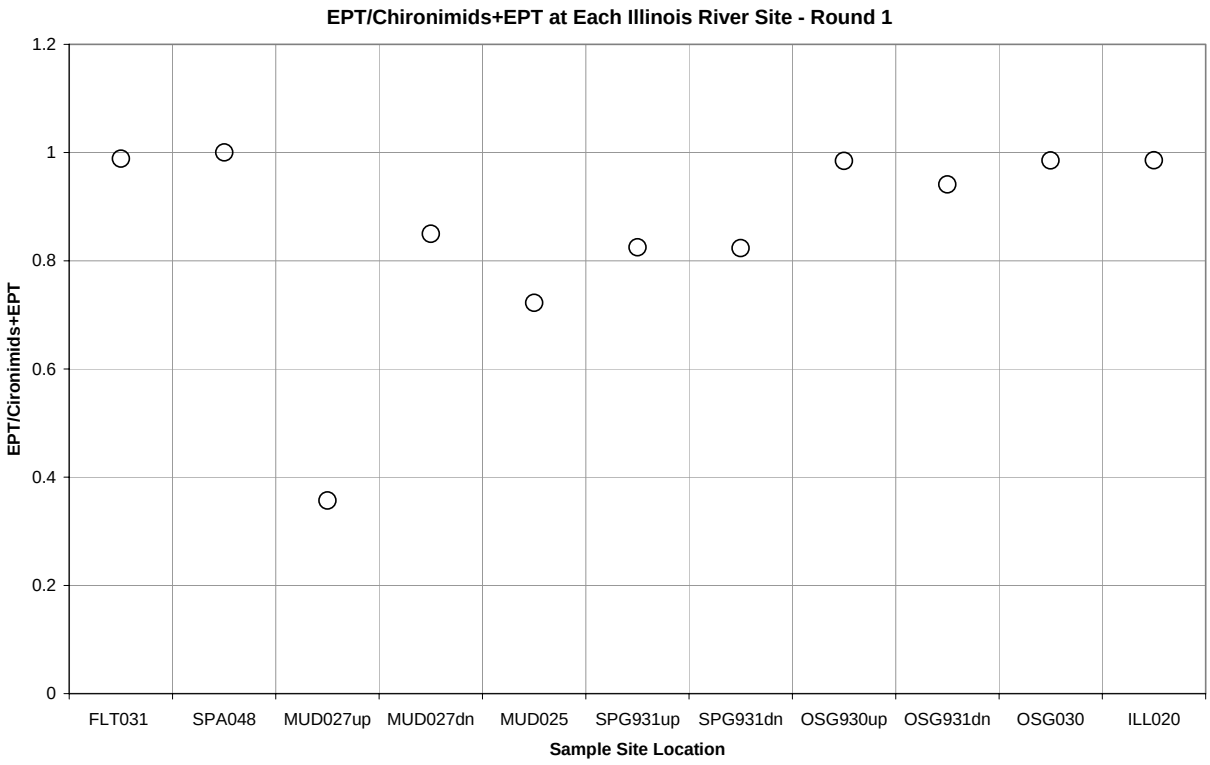
EPT *Taxa* and EPT Index. The presence of sensitive *taxa* (Ephemeroptera, Plecoptera, and Trichoptera, or EPT) at a site represents a composite index of site condition. In general, EPT *taxa* decrease as sites are impacted by toxicants, eutrophication, or other perturbations. However, in headwater streams that are carbon limited, EPT may increase with addition of organic carbon. The EPT Index is the proportion of EPT *taxa* relative to total *taxa*, and represents a more robust characterization than just EPT *taxa* numbers because it takes into account variability in collection effectiveness between sites. In the Illinois River basin during the first round of sampling, the EPT Index was highest at FLT031, the small watershed reference site (Figure 3.18). The lowest EPT Index was at MUD027DN, with less than half the proportional EPT *taxa* of the reference site. It should be noted, however that all Muddy Fork sites are likely substrate limited. The predominant bed material is, as the creek name implies, silt-clay, and thus does not support as robust a benthic macro-invertebrate community as the other sites. The cobble and gravel data presented in Table 3.6 are only representative of the bed material at a single riffle identified in the segment. The EPT Index did not change appreciably between the upstream and downstream Muddy Fork sites or Osage Creek sites. However, the Spring Creek site downstream of the Springdale WWTP (SPG931DN) did have a reduced EPT Index from the upstream site (from 0.46 to 0.36).

Figure 3.18 EPT Index



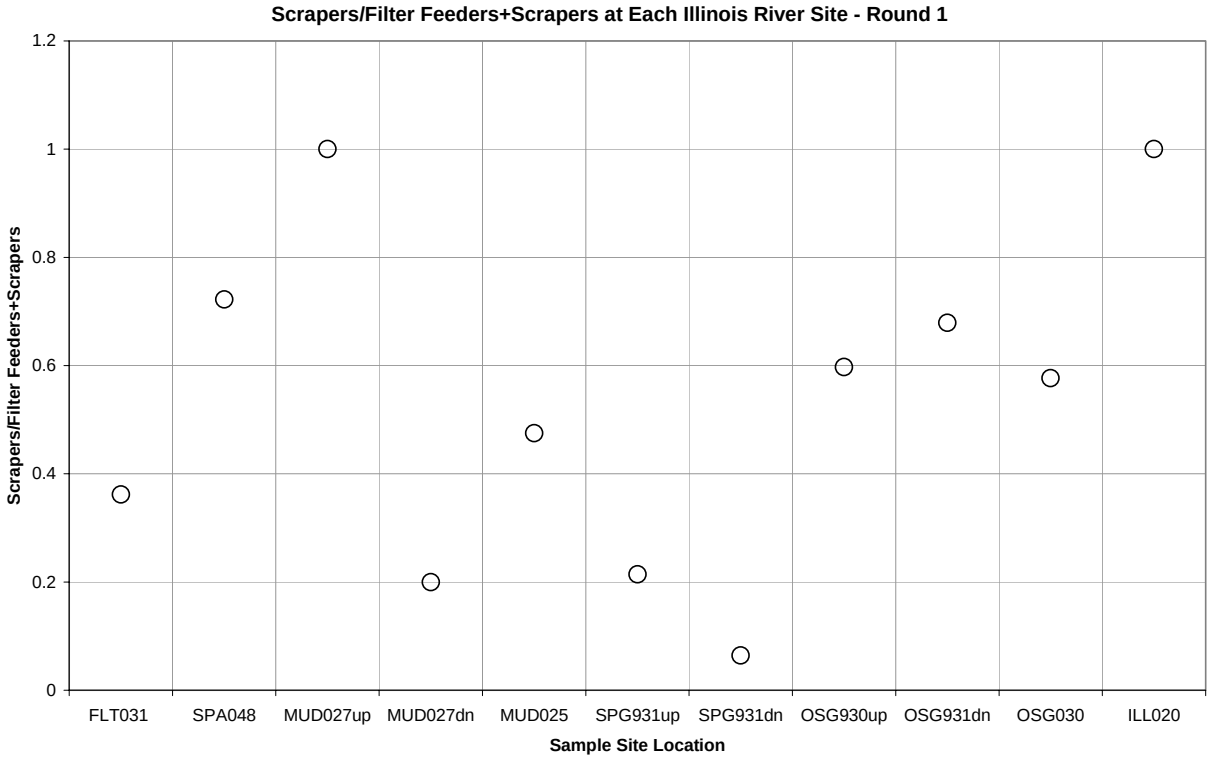
EPT/Chironomids + EPT. The ratio of EPT *taxa* to Chironomidae is a measure of community balance. The EPT *taxa* are generally pollution sensitive, while Chironomids (bloodworms, midge and gnat larvae) are pollution tolerant. Therefore, a high EPT to EPT plus Chironomids ratio suggests a site has high representation of the sensitive species. The lowest ratio in the Illinois River basin first round sampling was at MUD027UP, followed by MUD025 (Figure 3.19). However, it should be noted that very few Chironomids were collected in this and the 1997 sampling. It is likely this is an artifact of the sampling method (traveling D-net); the net has a nominal opening of 0.5 mm, which is larger than most Chironomids. Also, this genus tends to burrow into the substrate in high flowing streams, requiring excavation and sieving to fully sample. Thus, this genus was likely undersampled at all sites during this and the 1997 sampling efforts.

Figure 3.19 EPT/EPT Chironimids



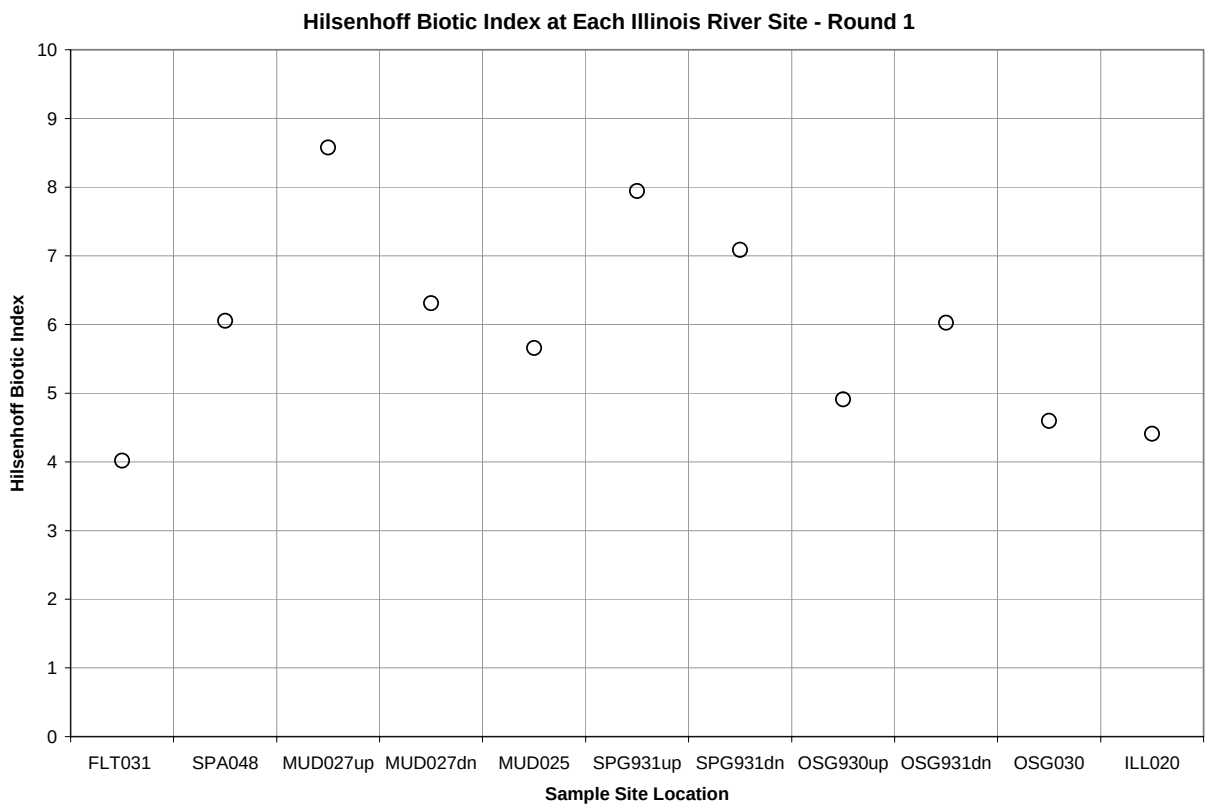
Scrapers/Scrapers + Filter Feeders. Functional feeding group (FFG) ratios provide insight into ecosystem processes from primary production to primary consumption. The ratio of scrapers to other FFGs such as filter feeders provides a relative measure of food sources. Scrapers are diatom feeders, and thus are an indirect measure of diatom abundance. They decrease as filamentous algae and moss increase. Filter feeders attach to filamentous algae and moss, feeding off fine particulate organic matter (FPOM). As such, filter feeders are very sensitive to organically bound toxicants, so care must be exercised in interpreting these ratios. These data illustrate this complexity. The lowest FFG ratio in the Illinois River basin during the first round of sampling (Figure 3.20) was at SPG931DN. This site was characterized by high filamentous algae and moss productivity. While this is indicative of a shift in periphyton community structure from diatoms to filamentous algae, as would be expected in a nutrient enriched stream, it also suggests that the site does not have toxic organic compounds. In contrast, MUD027UP had relatively high nutrients, yet had virtually no filter feeders (FFG ratio of 1.0). This site had notable filamentous algae, and thus should have had some filter feeders. This suggests that other parameters of concern such as organic toxicants may be present at that site. While the ILL020 site had the same ratio, flow, and cobble/gravel substrate, scouring limits filamentous algal growth. However, it is also possible this site has some response from organic toxic compounds.

Figure 3.20 Scrapers/Scrapers+Filterers



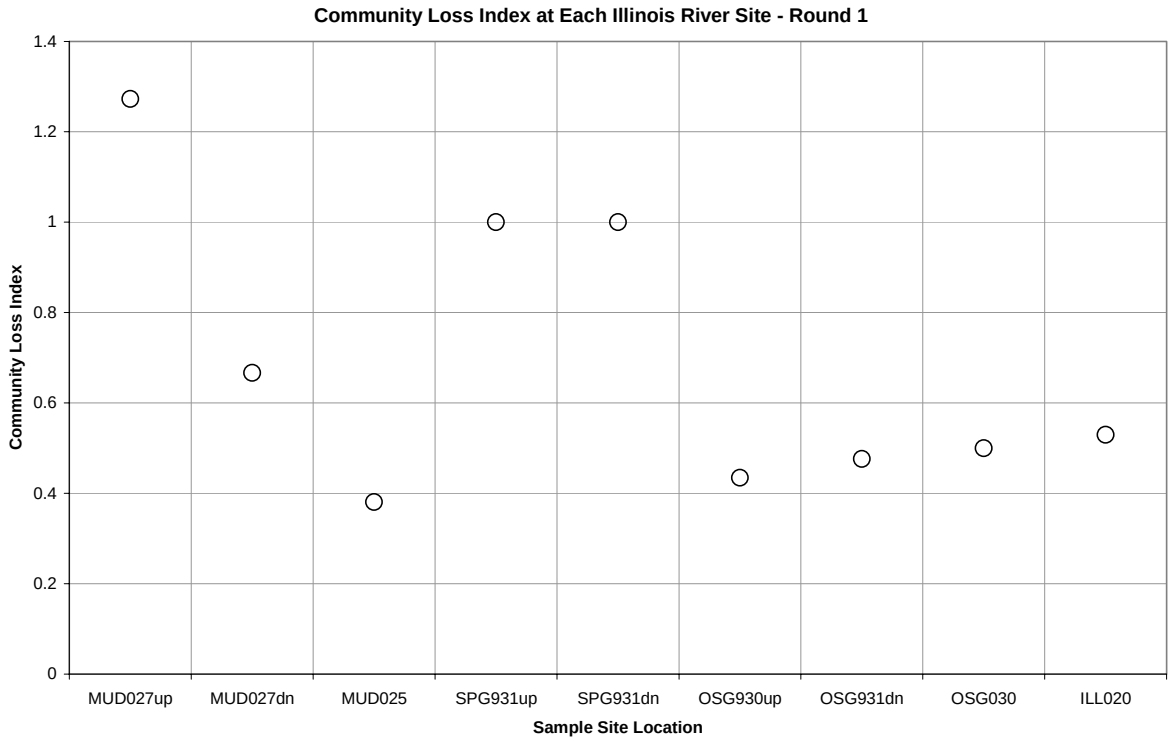
Hilsenhoff Biotic Index. The Hilsenhoff Biotic Index (HBI) is a measure of the relative abundance of benthic macro-invertebrate *taxa* that are tolerant to pollutants (Hilsenhoff 1987). The HBI assigns a tolerance index to each *taxa* ranging from 1 (highest sensitivity) to 10 (lowest sensitivity). The site HBI is the average of the cumulative tolerance indices. In general, HBIs between 1 and 1.75 indicate excellent water quality; between 1.76 and 2.5 indicate good water quality; between 2.15 and 3.75 indicate fair water quality; between 3.76 and 4.0 indicate poor water quality; and greater than 4.0 indicate serious water quality impairment (ADEQ 1997). The lowest HBI in the Illinois River basin during the first round of sampling was 4.0 at FLT031 (Figure 3.21). The highest HBI was at MUD027UP (8.6). The tolerance indices used were from the New Mexico Stream Assessment Guidelines, since those used by ADEQ in 1997 are not cited and not available. The 1997 ADEQ Report found all sites between 2.5 and 3.1. Either there is a major discrepancy between tolerance indices, or the sites have universally degraded. Clearly, the HBI indicated that the most impacted sites in the system are MUD027UP, SPG931UP, SPG931DN, and MUD027DN (Figure 3.21).

Figure 3.21 HBI



Community Loss Index. The Community Loss Index (CLI) measures the loss of benthic *taxa* between a reference site and the comparison site (Courtemanch and Davies 1987). This is an index of dissimilarity, with increasing values representing increasing levels of dissimilarity. The sites most dissimilar from their respective reference site in the Illinois River basin during the first round of sampling were MUD027UP, SPG931UP, SPG931DN, and MUD027DN (Figure 3.22).

Figure 3.22 Community Loss Index



Benthic Macroinvertebrates – Second Sampling Event

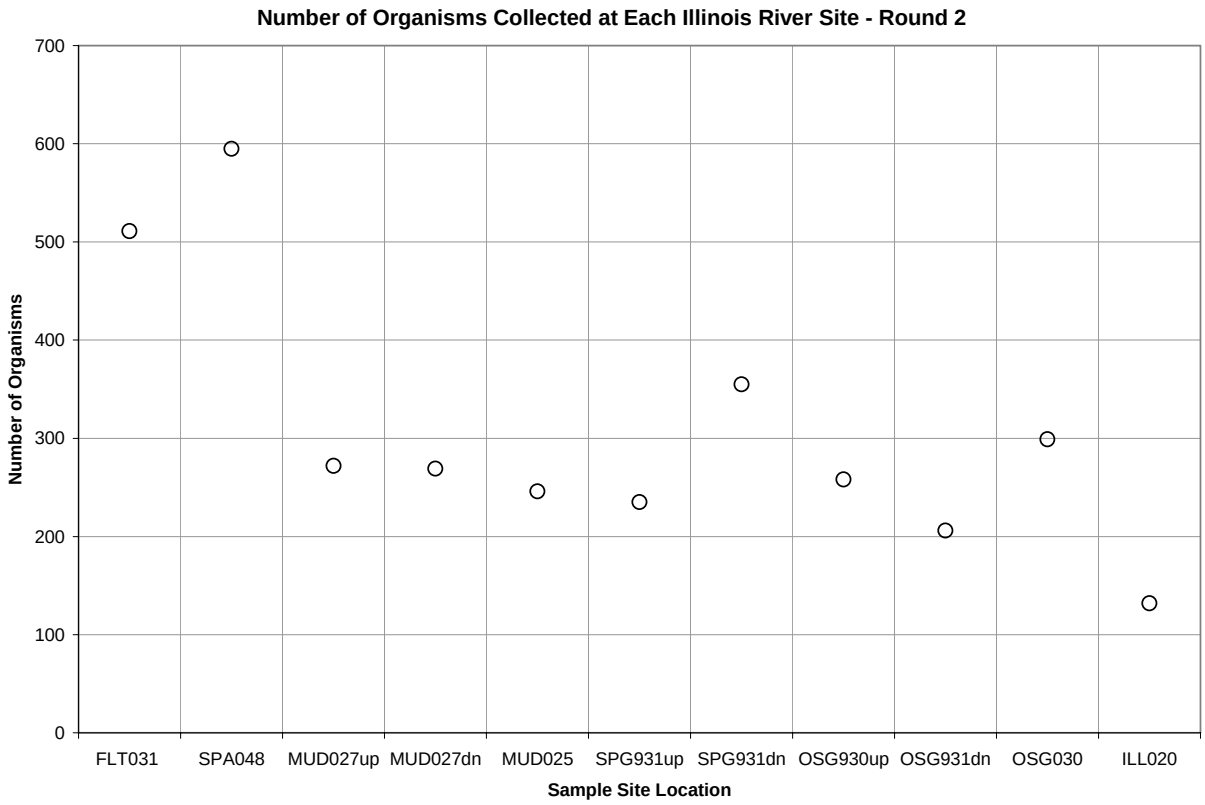
Results of benthic macroinvertebrate sampling during the second round (immediately following the Critical Period) for the Illinois River are presented in Table 3.12. Raw data on macroinvertebrate collection are provided in Appendix D. Community comparisons were made using the same criteria described in the ADEQ 1997 Illinois River Report (ADEQ 1997) for ease of comparison. Collection procedures produced more organisms overall than in the 1997 collection (Figure 3.23). The 1997 Report was based on sub-sampling 100 organisms from an average collection of less than 130 organisms per site. These analyses are based on sub-sampling 100 organisms from an average initial collection of more than 300 organisms. This sampling effort resulted in collection of 57 *taxa*, compared with 38 in the 1997 collection, providing a robust estimate of community structure across sites. One site in the Illinois River, ILL022, could not be sampled because no wadeable riffles could be located within 1000 meters of the designated site. The substrate at the site was bedrock, and stream geomorphology changed at that location to a run-dominated system.

Table 3.12 Benthic Macroinvertebrate Results – Event 2

Metric	STATION										
	OSG930up[c]	OSG930dn[c]	SPG931up[c]	SPG931dn[c]	OSG030[d]	MUD027up[c]	MUD027dn[c]	MUD025[d]	ILL020[d]	FLT031a	SPA048b
Total Number Identified	119	109	119	108	107	125	112	113	111	200	140
Additional Invertebrates	139	97	116	247	192	147	157	133	21	311	455
Total Number in Sample	258	206	235	355	299	272	269	246	132	511	595
Total Taxa	12	15	16	14	16	20	20	21	17	21	19
EPT Taxa	3	5	6	5	9	7	7	8	9	12	8
EPT Abundance	81	74	75	62	83	39	80	75	38	94	46
Contribution of Dominant Taxa	36%	29%	39%	31%	29%	40%	42%	27%	47%	41%	34%
Scraper Abundance	46	43	2	3	41	21	22	36	22	53	30
Filter Feeder Abundance	46	30	28	35	33	13	64	51	10	31	30
Chironomidae	2	6	1	32	4	5	10	2	9	5	0
Hilsenhoff Biotic Index	3.94	5.80	5.67	7.06	3.73	6.52	6.31	4.66	6.41	3.92	5.43
EPT Index	0.25	0.33	0.38	0.36	0.56	0.35	0.35	0.38	0.53	0.57	0.42
EPT / Chironomids +EPT	0.98	0.93	0.99	0.66	0.95	0.89	0.89	0.97	0.81	0.95	1.00
Scraper / Scraper+Filter Feeder	0.50	0.59	0.07	0.08	0.55	0.62	0.26	0.41	0.69	0.63	0.50
Community Loss Index	1.08	0.80	0.81	1.21	0.75	0.70	0.60	0.52	0.71	Reference A	Reference B
Benthic Macroinvertebrates											
Integrated Scoring[e]	27.10	19.09	19.06	15.25	28.89	17.19	17.34	23.21	17.62	27.66	20.34
Reference Site Comparison[f]	98.0%	69.0%	68.9%	55.1%	142.0%	62.1%	62.7%	114.1%	86.6%	100.0%	100.0%

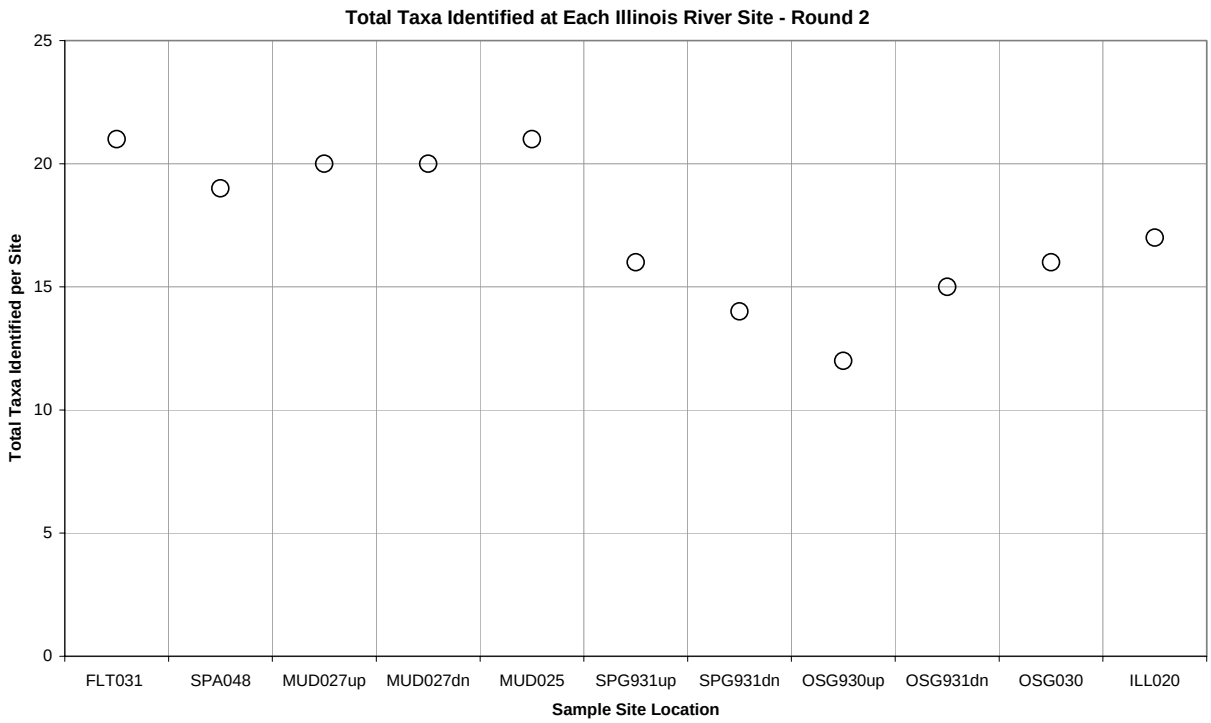
[a] Small Watershed Reference Site
[b] Large Watershed Reference Site
[c] FLT031 is designated reference site
[d] SPA 048 is designated reference site
[e] Integrated Scoring = [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]
[f] Site scoring compared to designated reference site

Figure 3.23 Total Organisms



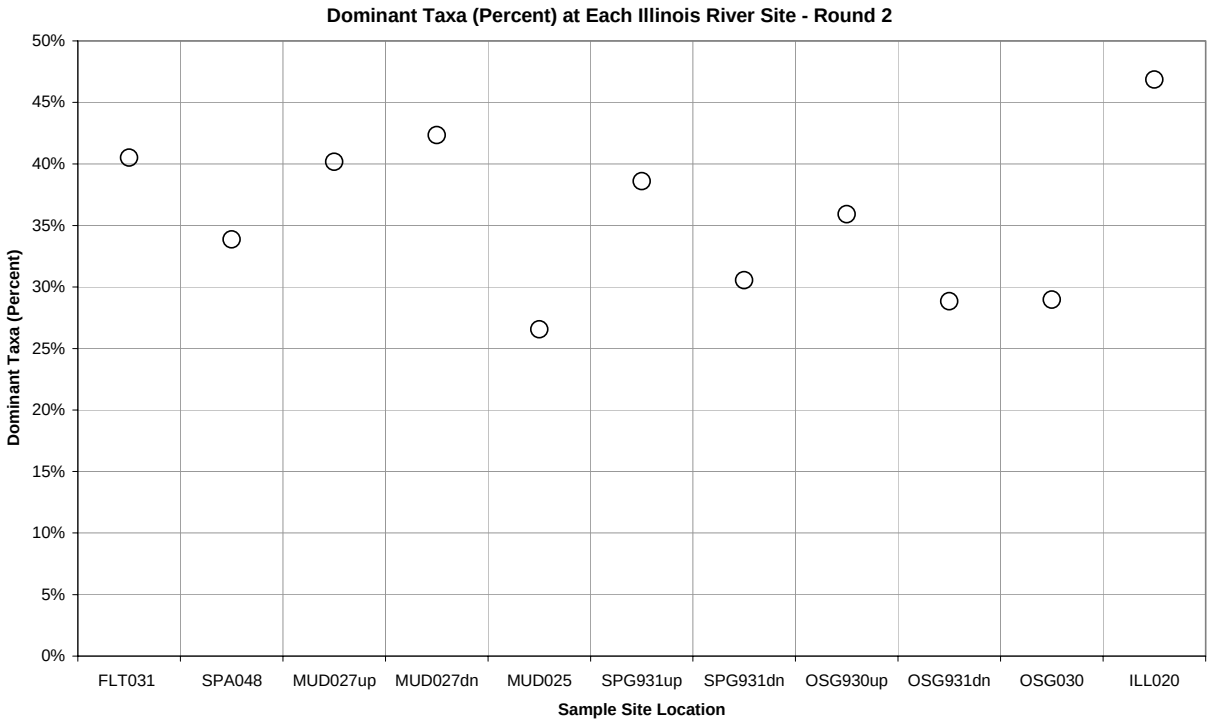
***Taxa* Richness.** During this sampling event, both Spring Creek (SPG931UP and SPG931DN) and Osage Creek (OSG931 UP and OSG931DN) sites were lower than the regional reference site (FLT031) (Figure 3.24). In the larger watershed sites, MUD025 was similar to the reference site (SPA048), while OSG030 and ILL020 had lower *taxa* richness than their regional reference site. *Taxa* richness was lowest in the first round of sampling at OSG930UP (Figure 3.24).

Figure 3.24 Total Taxa



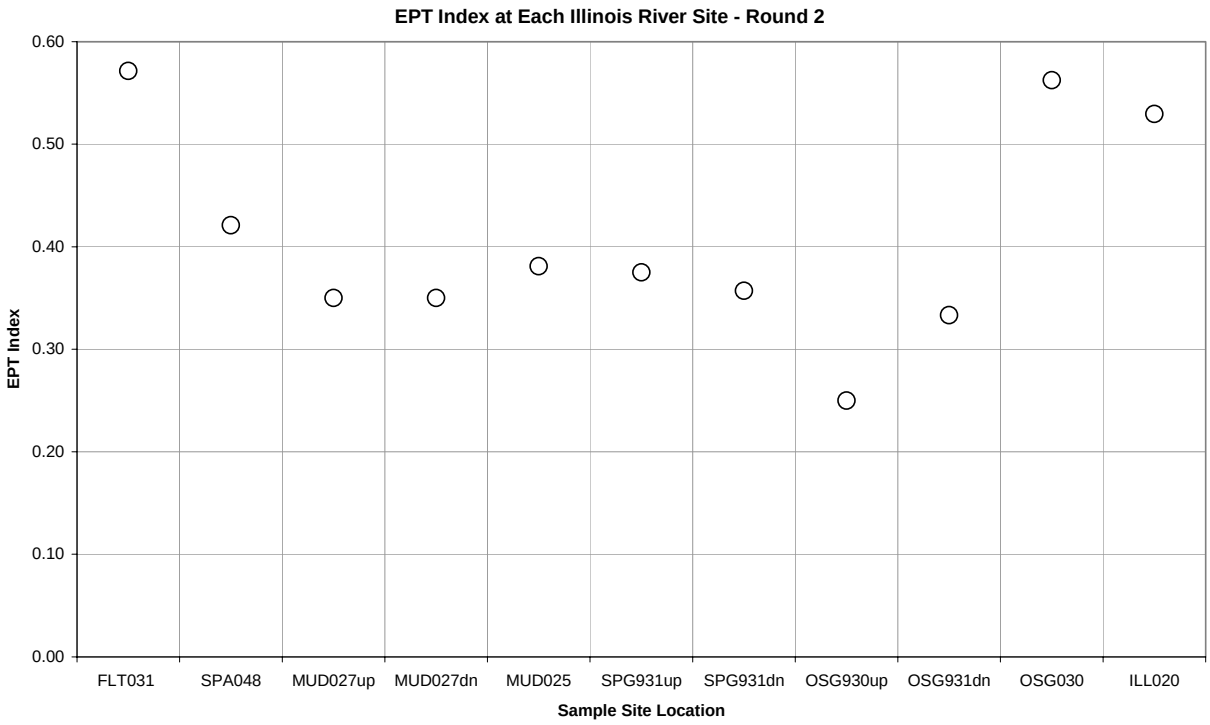
Dominant *Taxa*. In the Illinois River basin during the second round of sampling, the site with the highest percent dominant *taxa* was ILL020 (Figure 3.25). Dominant *taxa* at all sites ranged from 27 to 47 percent.

Figure 3.25 Dominant Taxa



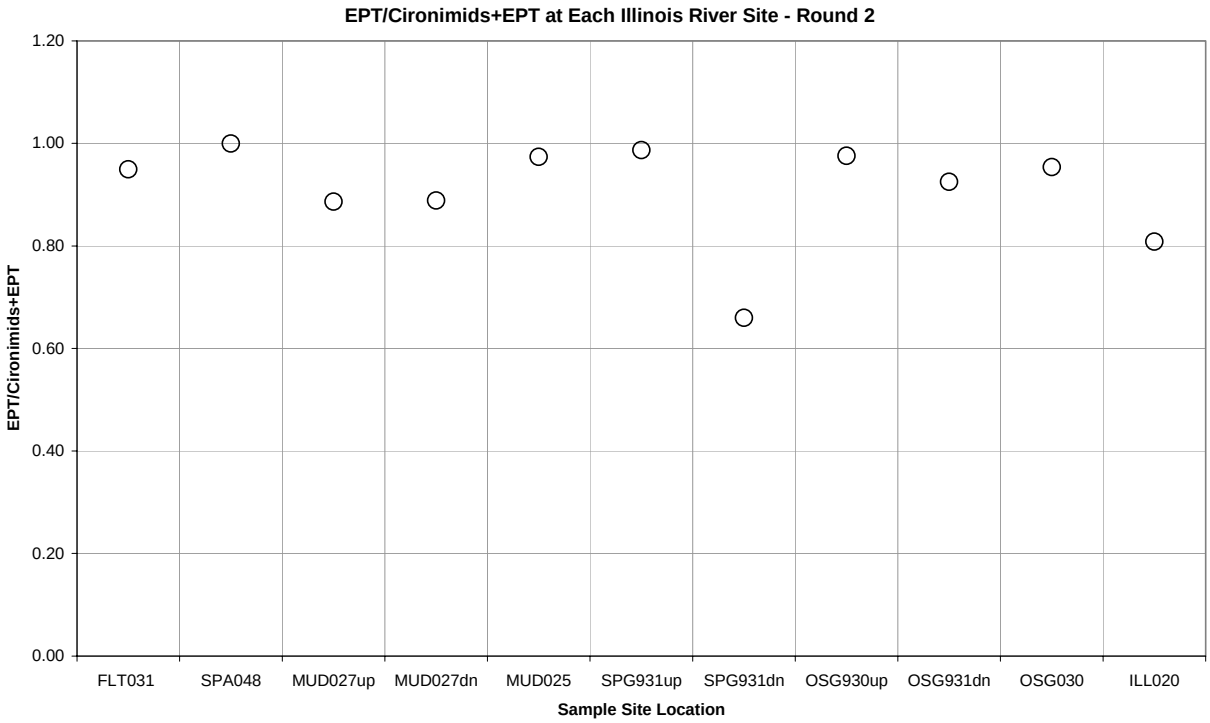
EPT *Taxa* and EPT Index. In the Illinois River basin during sampling in the second round, the EPT Index was highest at FLT031 (57 percent) (Figure 3.26). The lowest EPT Index was at OSG930UP, with less than half the proportional EPT *taxa* of the reference site.

Figure 3.26 EPT Index



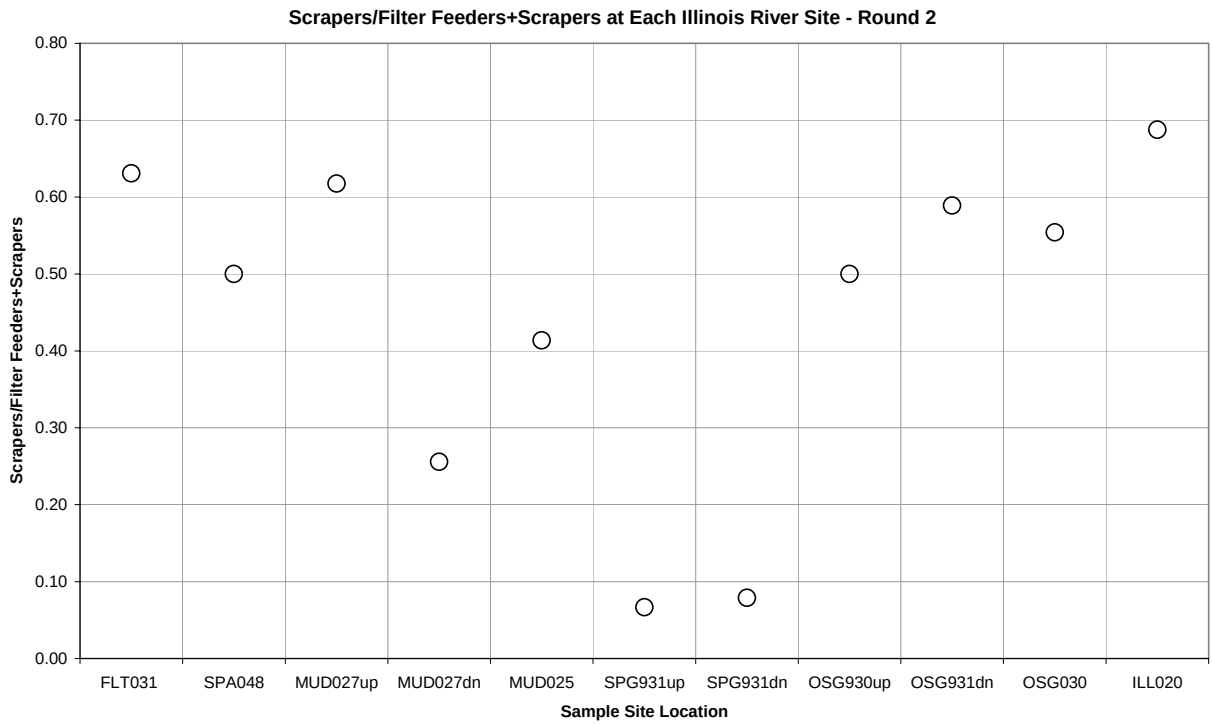
EPT/Chironomids + EPT. The lowest ratio in the Illinois River basin sampling during round two was at SPG931DN (Figure 3.27). This site had the most chironomids of any site sampled, though it should be noted that very few Chironomids were collected in this and the 1997 sampling events. It is likely this is an artifact of the sampling method (traveling D-net); the net has a nominal opening of 0.5 mm, which is larger than most Chironomids. Also, this genus tends to burrow into the substrate in high flowing streams, requiring excavation and sieving to fully sample. Thus, this genus was likely undersampled at all sites during this and the 1997 sampling efforts.

Figure 3.27 EPT/EPT Chironimids



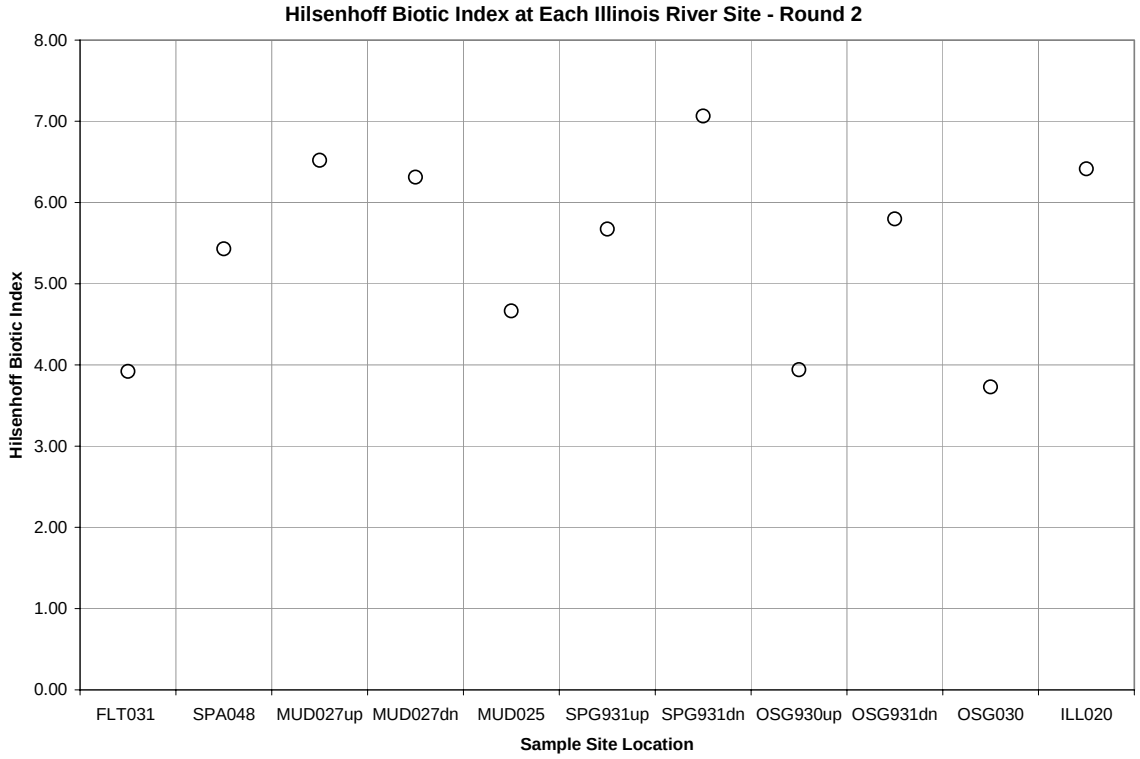
Scrapers/Scrapers + Filter Feeders. The lowest FFG ratio in the Illinois River basin during sampling in round two were SPG931UP, SPG931DN, MUD027DN, and MUD025 (Figure 3.28). These sites were characterized by high filamentous algae and moss productivity. While this is indicative of a shift in periphyton community structure from diatoms to filamentous algae, as would be expected in a nutrient enriched stream, it also suggests that the site does not have toxic organic compounds.

Figure 3.28 Scrapers/Scraper+Filterers



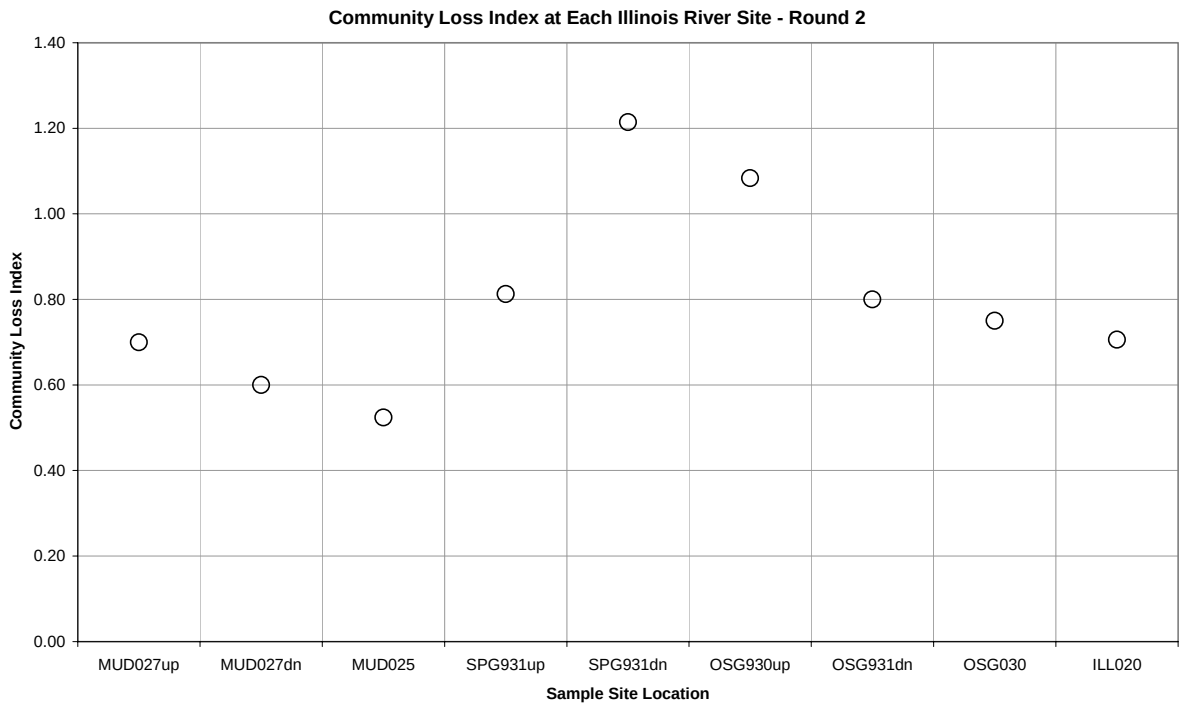
Hilsenhoff Biotic Index. The lowest HBI in the Illinois River basin during round two sampling was 3.9 at FLT031 (Figure 3.29). The highest HBI was at SPG931DN (7.0). The tolerance indices used were from the New Mexico Stream Assessment Guidelines, since those used by ADEQ in 1997 are not cited and not available. The 1997 ADEQ Report found all sites between 2.5 and 3.1. Either there is a major discrepancy between tolerance indices, or the sites have universally degraded. Clearly, the HBI indicated that during the second round sampling, when low flow conditions no longer prevailed, the most impacted sites in the system were MUD027UP , SPG931DN, and MUD027DN (Figure 3.29).

Figure 3.29 HBI



Community Loss Index. CLI measures the loss of benthic *taxa* between a reference site and the comparison site (Courtemanch and Davies 1987). This is an index of dissimilarity, with increasing values representing increasing levels of dissimilarity. The sites most dissimilar from their respective reference site in the Illinois River basin during round two sampling were SPG931DN, and OSG930UP (Figure 3.30).

Figure 3.30 Community Loss Index



3.4.3 Fish Collection

The diversity of fish communities was determined at all sites by use of the Shannon-Weiner Diversity index (SWDI) (Table 3.11). The SWDI threshold for the most impacted fish communities across all sites was 2.30, the fourth quartile distribution of SWDI from this sampling series. Fish communities were also evaluated by comparing metrics above and below the point source discharges at WWTPs for the Cities of Prairie Grove (MUD027UP and MUD027DN), Springdale (SPG931UP and SPG931DN), and Rogers (OSG930UP and OSG930DN), using a modification of Odum's Similarity Index (Odum 1972) (Table 3.12) as described by ADEQ (Illinois River Water Quality, Macroinvertebrate, and Fish Community Survey 1997). These sites were also compared to the reference site at Flint Creek (FLT031). Downstream sites on Osage Creek (OSG030), Muddy Fork (MUD025), and the Illinois River (ILL020 and ILL022) were compared to the reference site on Spavinaw Creek (SPA048). In the ADEQ 1997 study, anything less than 65 was used as the threshold for scoring a fish community as dissimilar to the reference condition. Raw fish data are presented in Appendix E.

Table 3.13 Fish Scoring Summary for Illinois River – Shannon-Wiener Diversity Index

Site	OSG930UP	OSG930DN	SPG931UP	SPG931DN	OSG030	MUD027UP[b]	MUD027DN	MUD025	ILL022[a]	ILL020[a]	SPA048	FLT031
Event 1												
Total Species (Taxa)	14	13	12	13	16	14	21	20	22	16	14	21
Total Numbers	113	199	227	483	251	257	410	527	335	262	260	436
Effort (seconds)	4268	2240	1522	2250	3805	1763	2576	3450	3030	2479	2662	1991
Catch Rate (No./ minute)	1.6	5.3	8.9	12.9	4.0	8.7	9.5	9.2	6.6	6.3	5.9	13.1
No. Sensitive Species	0	2	2	3	4	4	5	3	4	5	4	5
No. Sensitive Individuals	0	64	38	21	20	32	49	163	52	40	51	25
% Cyprinidae	17.7	81.4	46.7	88.8	62.2	63	21.5	27.5	37.6	75.2	38.5	61.7
% Catostomidae	0	0	0.9	1.7	9.2	2.7	39.5	26.6	4.8	7.6	2.3	2.1
% Ictaluridae	0	1	0	1.4	1.2	0.4	0.2	3.6	0.9	0.8	6.9	0.7
% Centrarchidae	61.9	2.5	42.7	5	6.8	22.2	25.6	38.3	43	12.2	0.8	5.7
% Percidae	12.4	2.5	2.2	2.7	6.4	10.5	6.6	3.6	11.9	3.8	28.5	5.5
No. Primary TFL	1	96	58	292	?	147	3	45	25	56	33	101
% Primary TFL	1	48.2	25.6	60.5	?	57.2	0.7	8.5	7.5	21.4	12.7	23.1
No. Key Individuals	11	5	5	5	16	26	9	37	97	86	59	199
% Key Individuals	9.7	2.5	2.2	1	6.4	10.1	2.2	7.6	29	32.8	22.7	45.6
Shannon-Wiener Diversity Index	2.61	1.93	2.83	1.85	2.10	2.32	2.84	2.97	3.24	2.97	3.15	2.59
Event 2												
Total Species (Taxa)	10	15	12	14	15	29	19	23	---	---	13	17
Total Numbers	97	291	501	569	218	384	356	345	---	---	217	508
Effort (seconds)	1632*	1725	1145	1812	1940	1632*	1927	1575	---	---	1819	1465
Catch Rate (No./ minute)	3.6*	10.1	26.3	18.8	6.7	14.1 *	11.1	13.1	---	---	7.2	20.8
No. Sensitive Species	1	3	2	3	3	3	3	4	---	---	4	6
No. Sensitive Individuals	2	10	37	23	15	9	25	56	---	---	24	57
% Cyprinidae	37.1	59.5	60.3	89.5	32.1	47.9	25.3	52.8	---	---	50.7	76.8
% Catostomidae	19.6	6.2	0	0.7	3.2	0.5	0.6	7.8	---	---	5.1	2.2
% Ictaluridae	0	0	1	1.2	3.7	0.3	0.6	2	---	---	5.1	3.3
% Centrarchidae	33	20.3	29.5	1.1	4.6	11.2	25.8	20.3	---	---	0.5	0.8
% Percidae	12.4	4.1	5.8	6.5	9.2	23.7	2.5	5.8	---	---	13.4	3.9
No. Primary TFL	3	104	261	459	15	150	9	117	---	---	20	155
% Primary TFL	3	35.7	52.1	80.7	6.7	39.1	2.5	33.9	---	---	9.2	30.5
No. Key Individuals	43	72	44	86	69	91	15	70	---	---	98	247
% Key Individuals	44.3	24.7	8.8	15.1	31.7	23.7	4.2	20.3	---	---	45.1	48.6
Shannon-Wiener Diversity Index	2.75	2.80	2.45	1.36	2.33	2.95	2.74	3.30	---	---	2.66	2.50

* Time was not confirmed and estimated for calculation purposes.

[a] Illinois River sites not samplable in the time frame of the second round of sampling due to high flow.

[b] Flows were very low during the first round sample period.

[c] Flows at the site sampled during the first round were determined to be impacted by a local bridge and thus uncharacteristic of the reach. The site was relocated upstream of the bridge for second-round sampling.

= Shaded as "Impacted" if Shannon-Weiner Diversity Index is < 2.30 (first quartile)

Table 3.14 Fish Collection Comparison on Illinois River
Odum's Similarity Index

FIRST SAMPLE EVENT

SITE – sampling date	SITE – sampling date	SIMILARITY INDEX
OSG930UP 9-23-03	OSG930DN 9-23-03	40.6
SPG931UP 9-26-03	SPG931DN 9-26-03	59.6
MUD027UP 10-04-03	MUD027DN 10-04-03	36.2
ILL020 10-23-03	SPA048 10-13-03	32.3
ILL022 10-21-03	SPA048 10-13-03	37.8
OSG030 9-29-03	SPA048 10-13-03	31.8
MUD025 10-01-03	SPA048 10-13-03	31.5
OSG930UP 9-23-03	FLT031 10-08-03	45.8
OSG930dn 9-23-03	FLT031 10-08-03	47.2
SPG931UP 9-26-03	FLT031 10-08-03	48.8
SPG931DN 9-26-03	FLT031 10-08-03	43.2
MUD027UP 10-04-03	FLT031 10-08-03	43.4
MUD027DN 10-04-03	FLT031 10-08-03	36.0

SECOND SAMPLING

SITE – sampling date	SITE – sampling date	SIMILARITY INDEX
MUD027UP 10-29-03	MUD027DN 12-05-03	56.6
SPG931UP 10-24-03	SPG931DN 10-24-03	71.4
OSG930UP 11-11-03	OSG930DN 11-19-03	63.1
OSG030 11-12-03	SPA048 11-21-03	70.7
OSG930UP 11-11-03	FLT031 11-21-03	58.6
OSG930DN 11-11-03	FLT031 11-21-03	72.4
SPG931UP 10-24-03	FLT031 11-21-03	58.8
SPG931DN 10-24-03	FLT031 11-21-03	62.5
MUD027UP 10-29-03	FLT031 11-21-03	58.3
MUD027DN 12-05-03	FLT031 11-21-03	37.9
SPA048 11-21-03	MUD025 11-14-03	49.8

Site Comparisons based on Odum Similarity Index modified = $\Sigma C / A + B + D$

ΣC = sum of the proportions of species common to both sample A and sample B

A = total proportions of sample A (=100)

B = total proportions of sample B (=100)

D = sum of the differences of the proportions of species common to sample A and B

At the two Muddy Fork sites above and below Prairie Grove's WWTP (MUD027UP and MUD027DN) the species similarity index was 36.2 during the first sampling event indicating a generally dissimilar community. MUD027UP was dominated by stonerollers while the species in MUD027DN were fairly evenly distributed. The most common species at MUD027DN was Redhorse. The diversity indices of the sites were 2.32 for MUD027UP compared to 2.84 for MUD027DN indicating higher diversity for the lower site than the upper site. The upper site was strongly influenced by a lack of flow during this event. During the second round of sampling, the similarity index for the two sites was 56.6 indicating a more similar fish community than the first round, but still dissimilar. During this second sampling period, the SWDI for the sites were 2.95 at MUD027UP and 2.74 at MUD027DN. The discharge at MUD027UP had improved during the second round of sampling, and the community had responded in kind.

At the two Spring Creek sites above and below Springdale's WWTP (SPG931UP and SPG931DN), the species similarity index was 59.6 during the first sampling event indicating dissimilar or weakly similar communities. The community at SPG931UP was well diversified (SWDI 2.84) while the community at SPG931DN was dominated by stonerollers and had a lower index (1.85). A striking difference in the two sites was the greatly increased discharge and the reduced canopy cover at SPG931DN. During the second round of sampling, the similarity index for these two sites had increased to 71.4 indicating that the sites were now more similar. Stonerollers were still dominant at SPG931DN, and they had increased to 45.1 percent of the community at SPG931UP. During this second sampling period, the SWDIs for the sites were 2.45 at SPG931UP and 1.36 at SPG931DN.

At the two Osage Creek sites above and below Rogers WWTP (OSG930UP and OSG930DN), the species similarity index was 40.6 during the first sampling event, indicating a generally dissimilar community. The downstream site was dominated by stonerollers while there was no dominant species at the upstream site. The diversity indices of the sites were 2.61 for OSG930UP compared to 1.93 for OSG930DN. Low flow may have influenced OSG930UP during the first sampling event. During the second round of sampling, the similarity index for the two sites was 63.1 indicating somewhat more similar communities compared to the first event. The SWDIs were 2.45 and 2.66 for OSG930UP and DN respectively.

During the first sampling event, all the sites above and below WWTPs were dissimilar to the reference site (FLT031). Similarity indices ranged from 36.0 for MUD027DN up to 48.8 for SPG931UP. During the second round of sampling, the index for all the sites had improved, but only OSG930DN at 70.7 had a community similar to the reference. SPG931DN at 62.5 was only slightly dissimilar to FLT031.

The four lower sites (OSG030, MUD025, ILL022, and ILL020) also displayed dissimilarity to the reference site for larger watersheds (SPA048). The most similar site was ILL022 at 37.8. On the second round of sampling, ILL022 and ILL020 were not sampled because of high flow. OSG030 was generally similar to SPA048 during the second round with a similarity index of 70.7. MUD025 was still dissimilar to the

reference site with an index of 49.8. The diversity indices of these four sites indicate that each site, with the exception of OSG030, had diverse communities. The index at ILL022, at 3.24, was the highest of any site sampled. The diversity index at OSG030 was 2.10 during round one and 2.33 during round two of sampling. This put OSG030 in the bottom quartile of site indices for round one, and only one place above the bottom quartile for round two.

3.5 ILLINOIS RIVER SUMMARY

Water Quality Field Measurements

Field measurements from the Illinois River sampling locations indicate occasional occurrences of aquatic life stressors of concern, including low DO measurements, exceedances of the 24-hour DO fluctuation and DO percentage saturation comparison values. While there were no temperature exceedances in any of the three sampling events, the higher temperature readings generally coincided with the low DO measurements that did not meet the criteria, as expected. There were however, unusual occurrences in the local air temperatures over the course of the three sampling events. The low water temperature readings measured at stations ILL022 and ILL020 on the second and third sampling events were verified and corresponded to significant decreases in the ambient air temperature prior to the sampling events.

Water Quality Chemical Results

Nutrient results at locations downstream of all of the WWTP discharges were nearly always higher in nutrient concentrations than the respective upstream location. Likewise, as expected, TDS concentrations downstream of WWTP dischargers in the Illinois River basin were higher than upstream conditions. TDS results downstream of the City of Springdale WWTP discharge exceeded the Reg 2 criterion for all three events.

All nitrate-nitrogen values were lower than the ADEQ Reg 2 criterion for drinking water use of 10 mg/L. TN values ranged from 0.987 to 8.498 mg/L. The highest TN values detected were at SPG931DN (from 4.672 to 8.498 mg/L).

TP values were above the ADEQ narrative guideline of 0.1 mg/L at each of the sites downstream from WWTPs for all three sampling events. In addition, the guideline was exceeded once at SPG931UP, once at MUD027UP, once at MUD025, and at all three events on OSG030, ILL022, and ILL020. Comparing data collected to the ADEQ TP guideline of 0.1 mg/L results in 21 exceedances (58%) of the 36 TP data points. Comparing data collected to the USEPA Ecoregion reference value of 0.06 mg/L for the Illinois River results in 31 TP exceedances (86%) of the 36 total data points (including two exceedances in the reference site data) (USEPA 2003). All three samples at station ILL020 are significantly higher than the Oklahoma TP criterion of 0.037 mg/L for the Illinois River at the state line.

TOC values from all locations over all three events ranged from 0.09 to 8.32 mg/L. The most significant increase in TOC (over all three events) was at SPG931DN compared to SPG931UP where values averaged approximately five times higher. Fourteen percent of the TDS values, which ranged from 164 to 448 mg/L, exceeded the numeric criterion with the highest values at SPG931DN. Turbidity ranged from a low of 0 to 10 NTUs.

Given the water quality sampling approach used for this study, collecting samples under low flow conditions, it is apparent that nutrient loading at the sites investigated over the three water quality sampling events was primarily due to discharge from WWTPs. Significant runoff events did occur during this period, which most likely contributed nonpoint source nutrient loads to the streams during the sample events. The downstream concentrations of TP in the streams of the Illinois River were always elevated from the upstream concentrations.

Stream Habitat Characterization

For the first sampling event, the sites categorized as impacted on the riffle section were SPG931UP, SPG931DN, OSG030, MUD027UP, MUD027DN, MUD025, and ILL022. The pool sections with impacted sites with respect to 75 percent of the score at the reference sites are SPG931UP, MUD027UP, and MUD027DN.

For the second sampling event on the Illinois River, the impacted riffle sites with respect to 75 percent of the scoring of the reference sites are SPG931UP and MUD027DN. None of the pool sections scored as impacted when compared to the 75 percent of the reference score at the second event.

Periphyton

For the first sampling event, periphytic growth at SPG931-DN (downstream of the Springdale, AR WWTP outfall) showed the highest productivity of all sites on the Illinois River. Primary productivity at all sites in this watershed appeared to be limited by something other than nutrients, probably light.

Similar results were observed at the Illinois River reference sites during the second deployment period (early October 2003) with the exception that productivity at SPA048 and MUD027UP were dramatically higher than previously observed. This increase was probably due to several small runoff events in late September that triggered a bloom of filamentous algae during this observation period, resulting in dramatically elevated productivity rates. LETSIs were greater than 0.80 for all sites except SPG931-UP and MUD025, suggesting that primary productivity at those sites is limited by something other than nutrients.

Benthic Macroinvertebrate Collection

The benthic macroinvertebrate community data are an integrated direct measure of physico-chemical condition and habitat condition of the stream. For the purpose of this assessment, an integrated scoring method for benthic macroinvertebrates was utilized. Metrics that represented community-level responses in biota were selected. Metrics that were progressive, that is, where increasing scores reflected improving conditions, were inverted to provide regressive metrics. The integrated scoring for macroinvertebrates uses the following summation of four key indices: [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]. These scores are then compared to the scoring summation of the respective reference site. To judge impacts to the community at each site, the benthic macroinvertebrate community is designated as not impacted if the scoring summation at the site was greater than 83 percent of the score of the respective reference site (ADEQ 1997). Tables 3.11 and 3.12 show the results of this score for each site.

The benthic macroinvertebrates collected in the Illinois River basin suggest that the sites most consistently disturbed or impacted were MUD027UP, SPG931UP, and SPG931DN. The effects of flow (or lack of flow) in the streams is reflected in the differences in response from the first round to the second round of sampling. SPG931DN was consistently impacted across most metrics during both events (HBI, CLI, FFG ratios, EPT index). Many other sites (MUD027UP and MUD027DN, SPG931UP) showed some impact during one event or in one metric, but either recovered or showed no impact in other metrics. This suggests that, over time and variable environmental conditions, SPG931DN is consistently stressed from multiple parameters.

Fish Collection

The 1997 ADEQ Report used the Odum Similarity Index and the Shannon-Weiner Diversity Index for determining fish community impacts. For the purposes of this assessment however, only the SWDI was used to determine impacts because it is considered a more contemporary and quantitative assessment tool. The results of the Odum Similarity Index are provided below and in Table 3.14 above for informational purposes only.

Shannon Wiener Diversity Index Results: For this investigation, fish communities are compared using the SWDI. Fish communities are considered impacted if the SWDI is less than 2.30. Impacted sites for the first sampling event include OSG930DN, SPG931DN, and OSG030. Only SPG931DN scored as impacted using this comparison for the second sampling event. The diversity indices of these sites indicate that each site, with the exception of OSG030 had diverse communities. The index at ILL022 was the highest of any site sampled at 3.24. The diversity index at OSG030 was 2.10 during round one and 2.33 during round two of sampling. This put OSG030 in the bottom quartile of site indices for round one, and only one place above the bottom quartile for round two.

Odum's Similarity Index Results: The second method of evaluation for fish collection results uses the modified Odum's Similarity Index, comparing sites upstream of WWTPs to downstream. The modified Odum Similarity Index data were not considered in scoring the condition of the sites for this investigation, however the Odum Similarity Index was calculated to allow comparison with the 1997 ADEQ Report results.

In the 1997 ADEQ Report, sites scoring less than 65 were categorized as impacted. During the first sampling event, all the sites above and below WWTPs were dissimilar to the reference site (FLT031). During the second round of sampling, the index for all the sites had improved, but only OSG930DN at 70.7 had a community similar to the reference site. SPG931DN at 62.5 was only slightly dissimilar to FLT031.

The four downstream-most sites (OSG030, MUD025, ILL022, and ILL020) were dissimilar to the reference site for larger watersheds (SPA048). The most similar site was ILL022 at 37.8. On the second round of sampling, ILL022 and ILL020 were not sampled because of high flow. OSG030 was generally similar to SPA048 during the second round with a similarity index of 70.7. MUD025 was still dissimilar to the reference site with an index of 49.8.

Summary of Aquatic Life Assessment

Table 3.13 presents a summary of the scoring for each site, media type, and event, which may be utilized in the weight-of-evidence approach in evaluating the status of aquatic life use attainment of the Illinois River and its tributaries.

Table 3.15 Summary of Aquatic Life Assessment Scoring for the Illinois River

First Sampling Event (first event for each media)

	Water Quality Measurements			Water Chemistry Analysis		Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
OSG930DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted	Impacted
SPG931UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted
SPG931DN	NA	NA	NA	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted
OSG030	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted
MUD027UP	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted
MUD027DN	Impacted	Impacted	Impacted	Not Impacted	Impacted	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted
MUD025	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
ILL022	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted	NS	Not Impacted
ILL020	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
SPA048 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Reference	Not Impacted
FLT031 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Reference	Not Impacted

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

Second Sampling Event (second event for each media)

	Water Quality Measurements			Water Chemistry Analysis		Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
OSG930DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
SPG931UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
SPG931DN	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Impacted
OSG030	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
MUD027UP	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
MUD027DN	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted	NS	NS	Impacted	Not Impacted
MUD025	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
ILL022	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS
ILL020	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	NS
SPA048 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Reference	Not Impacted
FLT031 Reference Site	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Reference	Not Impacted

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

Third Sampling Event (third event for each media that was to be sampled)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG930UP	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
OSG930DN	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
SPG931UP	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
SPG931DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
OSG030	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
MUD027UP	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
MUD027DN	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
MUD025	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
ILL022	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
ILL020	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
SPA048 Reference Site	NA	NA	NA	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
FLT031 Reference Site	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

SECTION 4
KINGS RIVER RESULTS

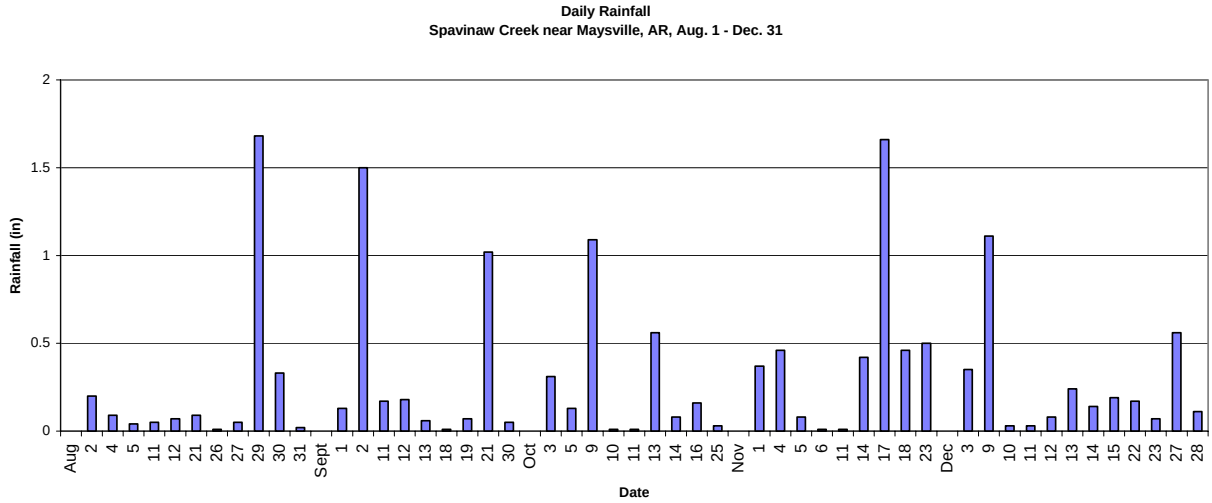
4.1 SAMPLING SCHEDULE AND RAINFALL CONDITIONS

Water quality and ecosystem sampling was initiated on August 28, 2003, immediately after approval of the QAPP by the USEPA. Table 4.1 presents the sampling dates for each media for each sampling event on the Kings River. Sampling activities were scheduled according to the following hierarchy: water quality collection, datasonde deployment, benthic macro-invertebrate sampling, fish sampling, and habitat assessment. Benthic macroinvertebrate, fish, and habitat sampling activities required a rest period of approximately 7 days for the stream to recover before the next activity could be initiated. Macroinvertebrate and fish sampling could not be performed when datasondes were deployed because macroinvertebrate sampling creates a significant sediment plume, and fish sampling creates a significant electrical charge, each of which could impair the datasonde readings. In addition, sampling of water quality, benthic macroinvertebrates, and fish required base flow conditions. Sampling was suspended during and after rainfall events to avoid confounding sampling conditions. There were eight significant rainfall events (> 0.5 inches in 24 hours) in the Kings River basin during the sample period (Figure 4.1). Provisional flow data for the waterbodies are included in Appendix C.

Table 4.1 Sample Schedule

Task	OSG045UP	OSG045DN	KIN037	KIN042
Matlock Periphytometer Deployment 1	19-Aug-03	19-Aug-03	19-Aug-03	18-Aug-03
Water Quality Sample 1	26-Aug-03	26-Aug-03	26-Aug-03	26-Aug-03
Matlock Periphytometer Retrieval 1	29-Aug-03	29-Aug-03	29-Aug-03	29-Aug-03
Benthic Macroinvertebrate Collection 1	19-Sep-03	22-Sep-03	19-Sep-03	14-Sep-03
Fish Collection 1	20-Sep-03	19-Oct-03	15-Oct-03	20-Sep-03
48 Hour Data Sond Deployment 1	4-Nov-03	4-Nov-03	24-Oct-03	24-Oct-03
Substrate and Habitat Assessment 1	16-Nov-03	21-Nov-03	21-Nov-03	26-Oct-03
Water Quality Sample 2	16-Sep-03	16-Sep-03	16-Sep-03	16-Sep-03
Matlock Periphytometer Deployment 2	19-Sep-03	19-Sep-03	19-Sep-03	19-Sep-03
Matlock Periphytometer Retrieval 2	5-Oct-03	5-Oct-03	13-Oct-03	13-Oct-03
48 Hour Data Sond Deployment 2	29-Nov-03	29-Nov-03	16-Nov-03	16-Nov-03
Fish Collection 2	29-Nov-03	29-Nov-03	30-Nov-03	30-Nov-03
Habitat Assessments 2	23-Dec-03	23-Dec-03	23-Dec-03	23-Dec-03
Benthic Macroinvertebrate Collection 2	13-Dec-03	13-Dec-03	13-Dec-03	13-Dec-03
72 Hour Data Sond Deployment 3	28-Dec-03	28-Dec-03	22-Dec-03	27-Dec-03
Water Quality Sample 3	7-Oct-03	7-Oct-03	7-Oct-03	7-Oct-03

Figure 4.1 Daily Rainfall During Study Period in Kings River Watershed (USGS Gauging Station Data, Provisional)



4.2 WATER QUALITY CHARACTERIZATION

Data results for sites on the Kings River are presented from upstream to downstream on Osage Creek and Kings River followed by the reference site KIN042. Site location identification numbers and descriptions are provided on Table 2.1, and Figure 1.3 is a map depicting the sampling site locations. Quality controls for investigation results included verifying data using the performance criteria, handling procedures, and QC requirements in the QAPP (Parsons 2003).

4.2.1 Water Quality Field Measurements

Three water quality field measurement deployments were attempted at each of the sampling sites for two separate 48-hour periods and one 72-hour deployment. The datasondes deployed in this project utilized state-of-the-practice instruments (YSI and In Situ brand equipment) and were maintained and calibrated according to manufacturer's recommendation. However, the instruments failed on several occasions, most commonly due to loss of membrane integrity across the probe face. This loss of integrity was most likely caused by scour from increased flow and stream sediments. As a result, data compromised by instrument failure are not included in this report since they would not meet QC requirements.

Water quality field measurements are presented on Table 4.2. In addition to presenting the results for DO, pH, specific conductivity, and temperature, the table includes Reg 2 ecoregion-specific standards for comparison. Results that did not meet the ADEQ water quality criteria or USEPA guidance for this investigation are highlighted

Table 4.2 Water Quality Field Measurement Data for Kings River

Kings River - Event 1

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG045UP	7.9	> 6.0	6.9	9.3	2.43	103.3	7.8	7.6	8.1	0.4		314.0	298.0	325.0	16.7	13.2	20.5
OSG045DN	7.3	> 6.0	5.5	10.1	4.67	102.4	7.7	7.6	8.1	0.5		631.9	207.0	762.0	16.8	13.3	20.6
KIN037	8.5	> 6.0	7.8	10.7	2.92	113.2	8.0	7.8	8.3	0.3		331.2	307.0	342.0	17.0	14.6	20.2
KIN042 Reference	5.5	> 5.0	4.9	7.1	2.12	68.8	7.3	7.1	7.8	0.5		300.1	296.0	306.0	16.1	13.6	18.5

Kings River - Event 2

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG045UP	12.9	> 6.0	12.0	14.0	1.98	119.8	8.0	7.9	8.1	0.3		301.9	291.0	334.0	6.6	5.5	8.6
OSG045DN	12.7	> 6.0	10.5	16.7	6.25	141.1	8.3	7.9	8.9	1.0		341.2	324.0	354.0	6.9	5.5	8.5
KIN037	10.2	> 6.0	8.7	13.0	3.44	127.3	8.2	7.9	8.5	0.6		276.7	255.0	286.0	13.8	12.9	15.1
KIN042 Reference	8.4	> 6.0	7.7	9.6	1.87	93.7	7.7	7.5	7.8	0.3		176.4	86.0	199.0	13.6	12.1	14.7

Kings River - Event 3

Site	DO (mg/l)					DO % Sat	pH (standard units)					Specific Conductivity (µS/cm)			Temp (°C)		
	Mean	DO Min Std*	Min	Max	DO 24h Fluct*	Max*	Mean	Min**	Max**	24h Fluct **	Note	Mean	Min	Max	Mean	Min	Max***
OSG045UP	2.1	> 6.0	1.5	3.8	1.54	33.5	8.2	8.0	8.5	0.5		302.2	294.0	313.0	7.1	5.4	9.8
OSG045DN	14.6	> 6.0	11.7	19.7	6.38	163.9	8.1	7.9	8.6	0.7		344.6	307.0	356.0	7.5	5.4	9.9
KIN037	DO probe malfunction						8.1	7.7	8.3	0.5	C	176.8	166.0	185.2	7.6	6.0	9.6
KIN042 Reference	9.4	> 6.0	8.1	10.3	1.88	85.9	7.3	7.0	7.6	0.5		70.9	58.8	82.7	7.1	5.1	8.6

* DO min standard depedent upon watershed size and season (ADEQ Reg. No. 2, Oct 2002); when water T exceeds 22 degrees C the critical season DO min standard may be depressed by 1 mg/L for no more than 8 hours during a 24-hr period (ADEQ Reg. No. 2, Oct 2002).
DO 24 hr fluctuation guideline <3.0 mg/L (USEPA Dec 2003).
DO % Sat guideline is <125% (USEPA Dec 2003).

** pH minimum standard is 6.0, pH max standard is 9.0, pH max 24 hour fluctuation <=1.0 (ADEQ Reg. No. 2, October 2002)

*** Temperature standard is <29.0 degrees C (ADEQ Reg. No. 2, October 2002)

Min = Minimum
Max = Maximum
C = conductivity data is provided, this datasonde did not collect specific conductivity data.
Shaded cells represent values that are not within ADEQ standards or USEPA guidance.

on Table 4.2. The DO minimum standard takes into account the season (critical or primary) and the watershed size as required in Reg 2. Appendix B contains graphs of DO concentration, temperature, specific conductivity, and pH versus time for each sampling event. Raw water quality measurement data are also included in Appendix B.

Event 1 Water Quality Measurement Concerns:

Field measurements from the first sampling event (Critical Period) had three results that did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation. Table 4.2 indicates that criteria were not met for:

- DO minimum and 24-hour DO fluctuation at OSG045DN; and
- DO minimum at the reference site KIN042.

Event 2 Water Quality Measurement Concerns:

Results from the second sampling event had four values that did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation. Table 4.2 indicates that criteria were not met for:

- 24-hour DO fluctuation and DO % saturation at both OSG045DN and KIN037

The most significant excursions from the water quality criteria were the 7.03 mg/L 24-hour DO fluctuation and 149.6 % DO % saturation at OSG045DN.

Event 3 Water Quality Measurement Concerns:

Three results in the field measurements of the third event did not meet the ADEQ Reg 2 water quality criteria or USEPA guidance for this investigation. Beginning at the upstream sites, Table 4.2 indicates that criteria were not met for:

- DO minimum at OSG045UP; and
- 24-hour DO fluctuation and DO % saturation at OSG045DN.

The most significant excursions from the water quality criteria were the minimum DO value of 1.5 mg/L at OSG045UP and the 163.9 % DO saturation at OSG045DN.

4.2.2 Water Quality Chemical Results and Quality Control

Results for water quality chemistry for the three sampling events on the Kings River are presented in Table 4.3. Figures 4.2 through 4.11 present all of the nutrient data by parameter. Laboratory QC data are presented in Appendix B.

Table 4.3 Water Quality Analytical Data for Kings River

Kings River		Ammonia	Nitrate	Nitrite	TKN	Total Nitrogen	Ortho Phosphate	Total Phosphorus	TOC	TDS	Turbidity
		mg/L	mg/L	mg/L	mg/L	mg/L*	mg/L	mg/L	mg/L	mg/L	NTU
OSG045UP	8/26/03	0.067	0.028	0.003	0.355	0.386	0.021	0.034	2.21	160	5
	9/16/03	0.039	0.148	0.004	0.235	0.387	0.005	0.040	1.75	181	4
	10/7/03	0.044	0.126	0.003	0.195	0.324	0.005	0.052	1.38	199	5
OSG045DN	8/26/03	0.073	0.085	0.001	0.565	0.651	0.387	0.474	4.06	429	2
	9/16/03	0.048	0.539	0.006	0.335	0.880	0.056	0.232	3.08	383	3
	10/7/03	0.041	0.554	0.004	0.487	1.045	1.865	1.824	4.80	455	2
KIN037	8/26/03	0.054	0.005	0.001	0.407	0.413	0.134	0.174	2.51	254	4
	9/16/03	0.034	0.063	0.004	0.228	0.295	0.004	0.056	1.73	201	3
	10/7/03	0.004	0.016	0.001	0.180	0.197	0.104	0.126	1.51	267	2
KIN042 Reference Site	8/26/03	0.053	0.446	0.003	0.308	0.757	0.004	0.018	1.60	172	2
	9/16/03	0.061	0.324	0.004	0.253	0.581	0.002	0.032	1.81	156	2
	10/7/03	0.031	0.291	0.002	0.113	0.406	0.004	0.014	0.78	169	1

* = Total nitrogen calculated adding TKN, nitrite, and nitrate nitrogens.

= value is not within ADEQ standard or guideline value.

Total ammonia chronic guideline value of 1.3 mg/L (ADEQ 2002 305(b) for Ozark Highlands Ecoregion Streams).

Nitrate nitrogen 10 mg/L - Safe Drinking Water Act, maximum contaminant level (2002 ADEQ 305(b))

Total phosphorus guideline value of 0.1 mg/L (ADEQ Regulation No. 2, 2002).

TDS standard 240 mg/L for Osage Creek sites and reference site, 150 mg/L for Kings River site, (ADEQ Reg. No. 2, October 2002)

Turbidity standard 10 NTU (ADEQ Regulation No. 2, October 2002)

Nitrogen

Analysis was conducted for key N constituents, including ammonia, nitrate-nitrogen, nitrite-nitrogen, and TKN. Ammonia results (Figure 4.2) from all sites were below the ADEQ 2002 305(b) guideline for chronic total ammonia (1.3 mg/L). All nitrate-nitrogen values (Figure 4.3) were lower than ADEQ Reg 2 drinking water criteria of 10 mg/L for the Kings River locations. Nitrate concentrations ranged from 0.05 to 0.554 mg/L, with the highest values at OSG045DN (0.554 and 0.539 mg/L). Nitrite-nitrogen values (Figure 4.4) ranged from 0.001 to 0.006 mg/L. The highest value measured was at OSG045DN. TKN values (Figure 4.5) ranged from 0.113 to 0.565 mg/L with the highest values at OSG045DN. TN values (Figure 4.6) ranged from 0.197 to 1.045 mg/L. The highest TN values detected were at OSG045DN (1.045 and 0.880 mg/L). Nitrate, nitrite, and TN values were higher for all events at the reference site (KIN042) than at both OSG045UP and KIN037.

Figure 4.2 Kings River Ammonia Results

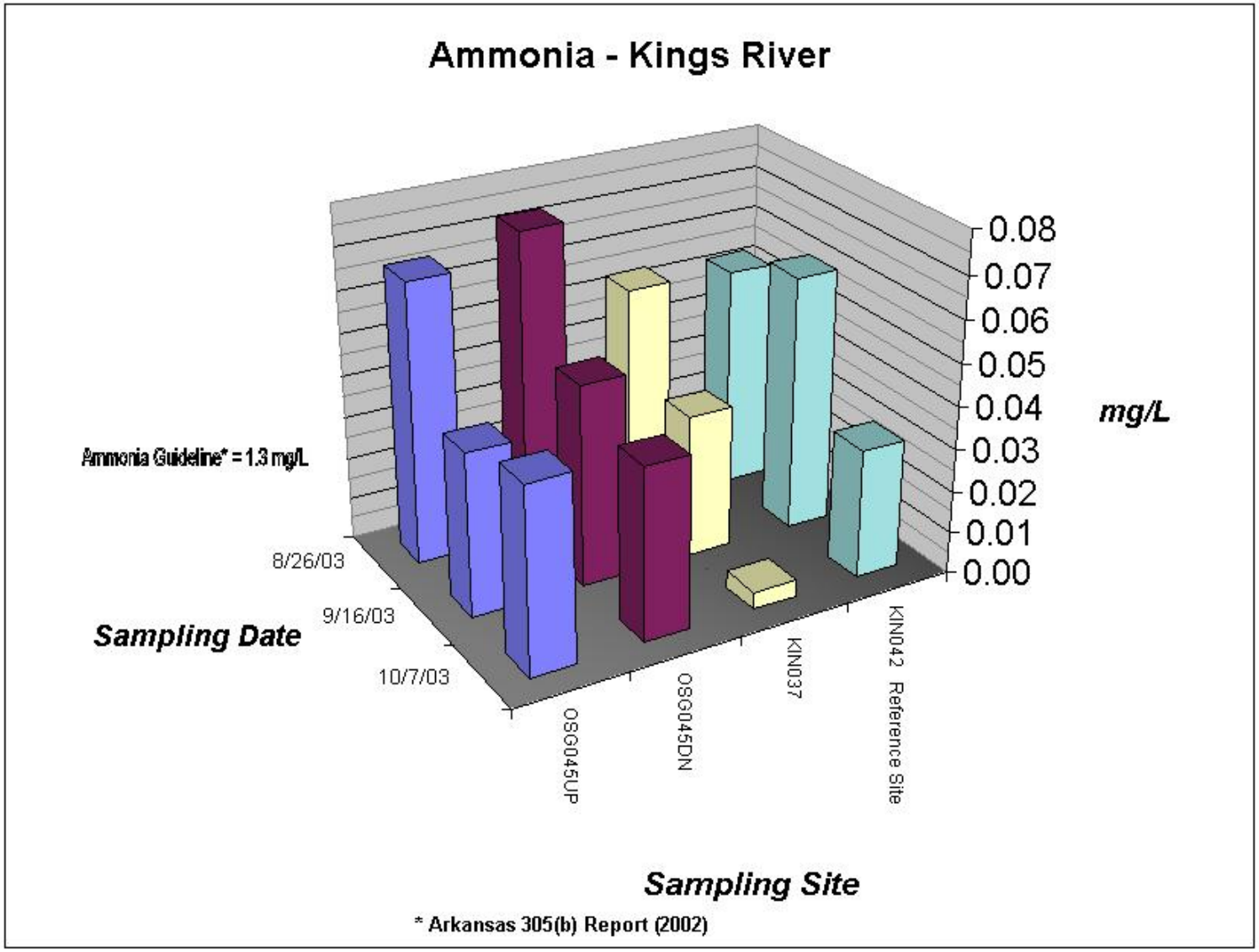


Figure 4.3 Kings River Nitrate Results

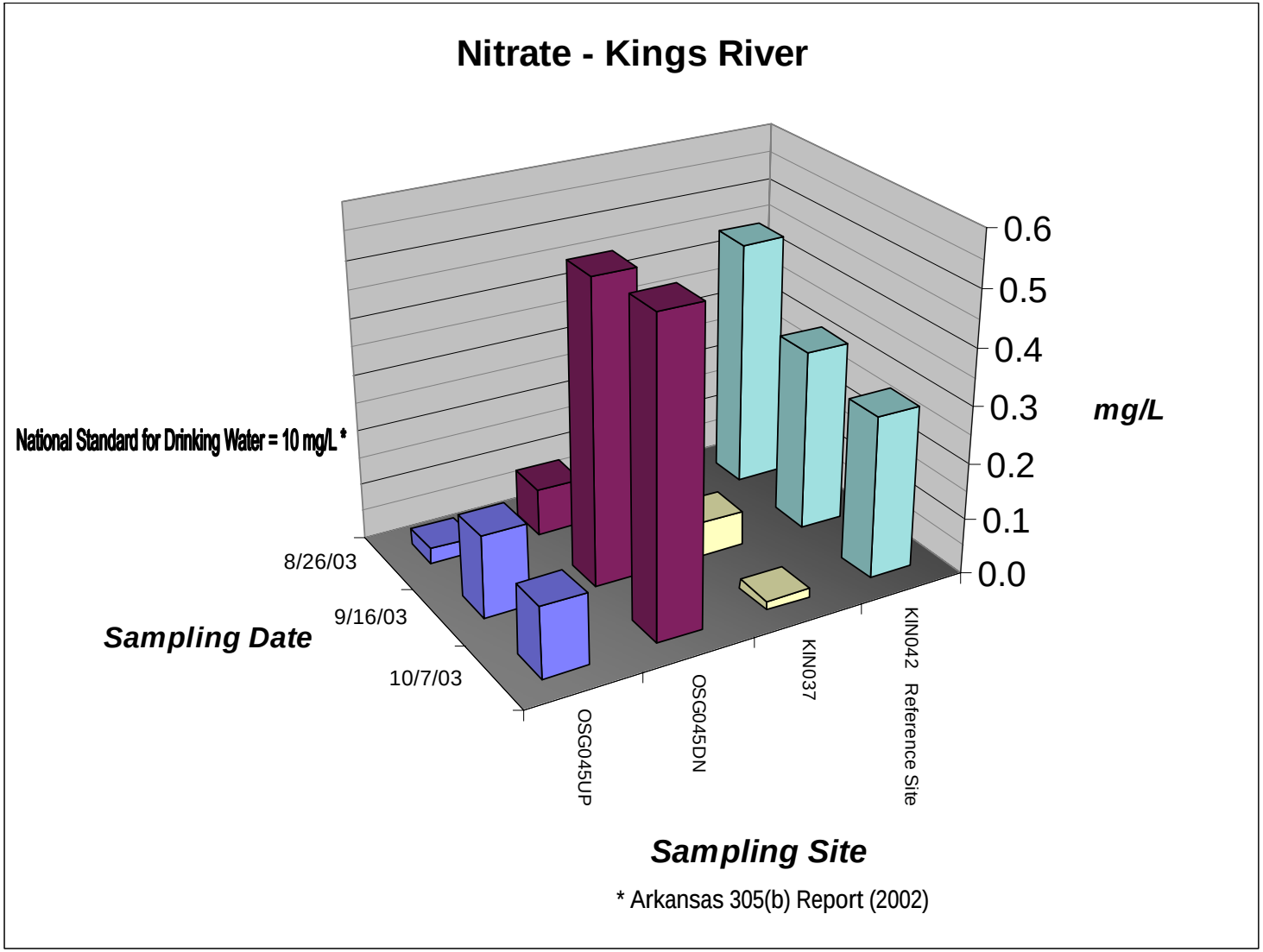


Figure 4.4 Kings River Nitrite Results

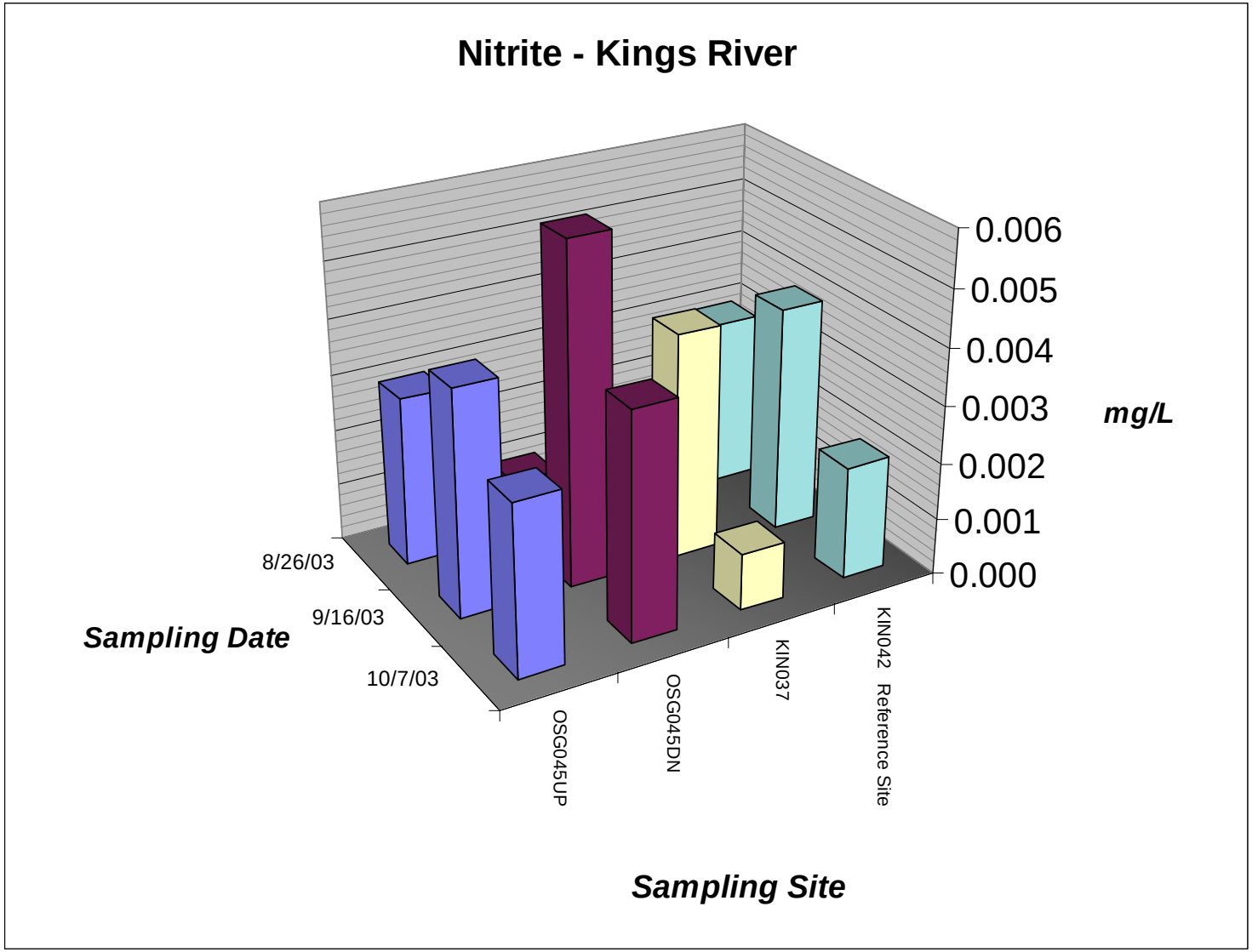


Figure 4.5 Kings River TKN Results

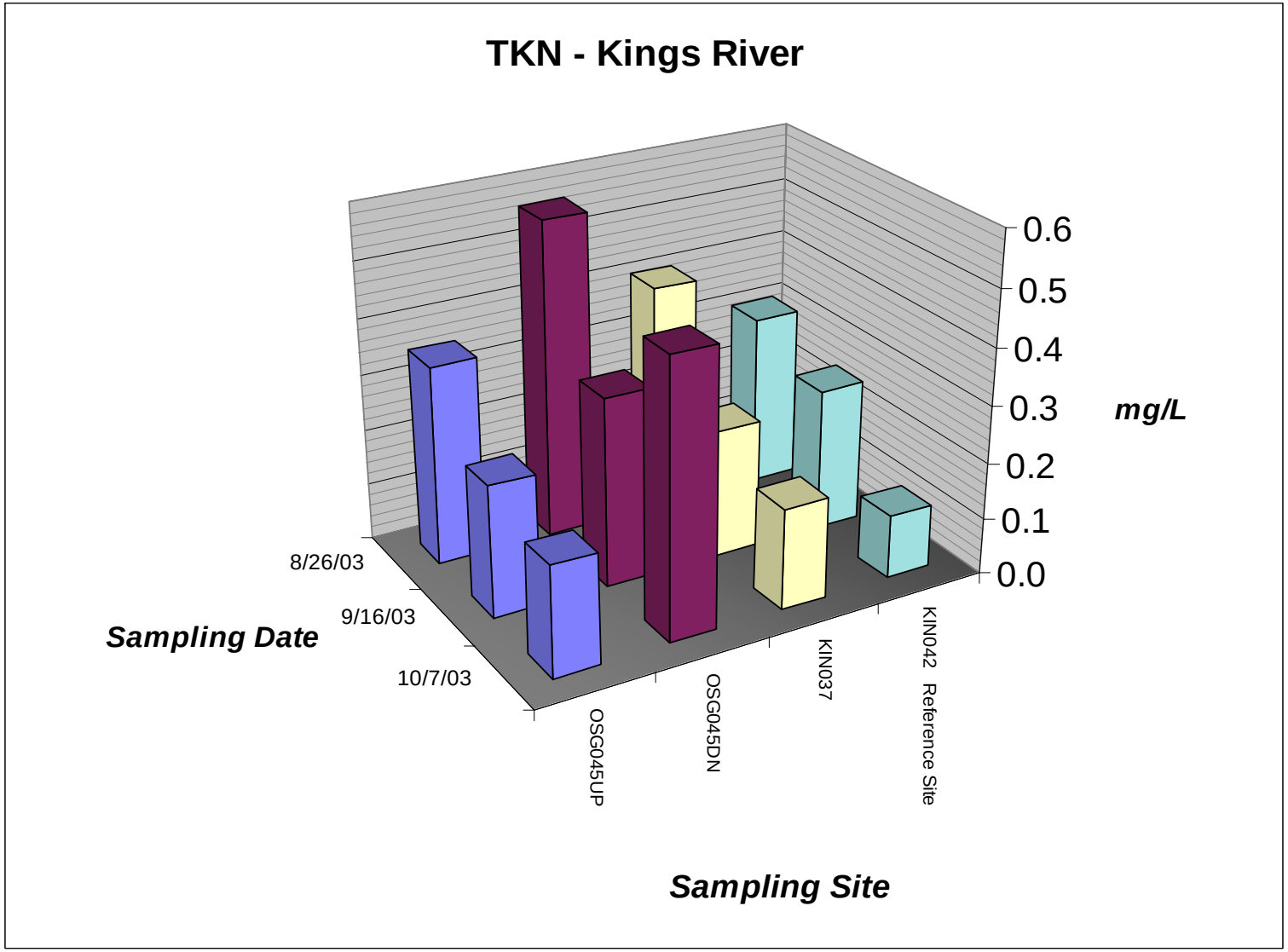
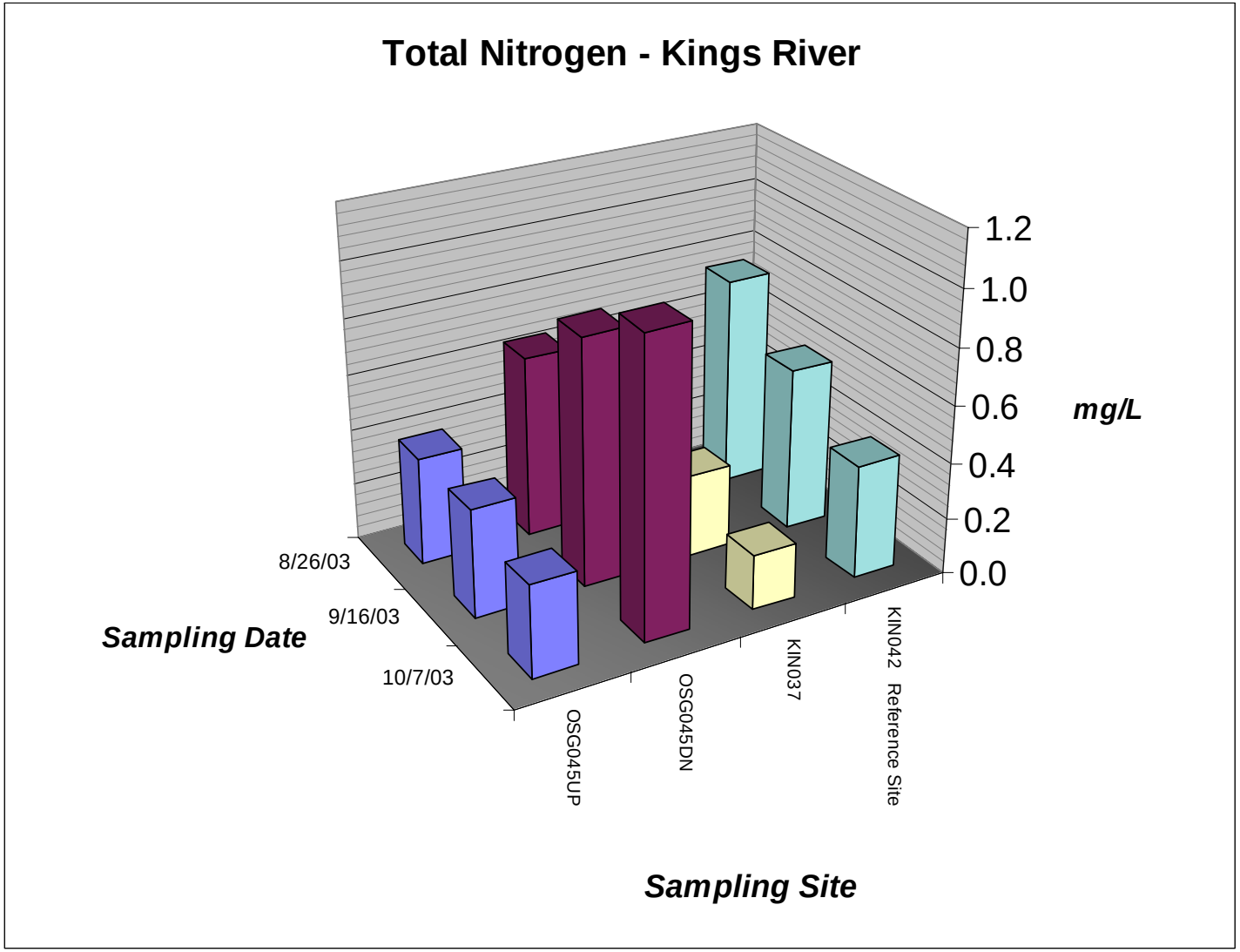


Figure 4.6 Kings River Total Nitrogen Results



Phosphorus

Ortho phosphate values ranged from 0.002 to 1.865 mg/L with the highest value at OSG045DN during the October sampling event (Figure 4.7). TP values on the Kings River ranged from 0.014 to 1.824 mg/L. Figure 4.8 illustrates the TP values by site by event. Exceedances of the 0.1 mg/L guideline are also highlighted on Table 4.3. Beginning at the upstream segment of Osage Creek, OSG045UP all TP values are below 0.1 mg/L. Downstream of the City of Berryville WWTP at OSG045DN, all TP are above 0.1 mg/L. Ortho phosphate and TP concentrations were significantly elevated at OSG045DN on the October 7, 2003 sampling date. Heading downstream, TP values were lower at KIN037, yet results for two of the events exceeded 0.1 mg/L. All TP results at the reference site KIN042 were below 0.1 mg/L and were the lowest average TP results. A schematic diagram of the Kings River sites sampled and the TP values for each sampling event are provided in Figure 4.9. The TP values in the diagram are compared to the ADEQ guideline of 0.1 mg/L.

In summary, TP exceeded the ADEQ guideline of 0.1 mg/L for all events downstream from the Berryville WWTP (OSG045DN) and for two of the three events at KIN037. Comparing data collected to the ADEQ TP guideline of 0.1 mg/L results in five exceedances out of 12 TP data points, or 42 percent of the samples exceeded the guideline (Table 4.3). Comparing TP data collected on the Kings River to the USEPA Ecoregion reference value of 0.05 mg/L for the Kings River results in seven TP exceedances out of 12 total data points or 58 percent of the samples exceeded the guideline.

Figure 4.7 Kings River Ortho Phosphate Results

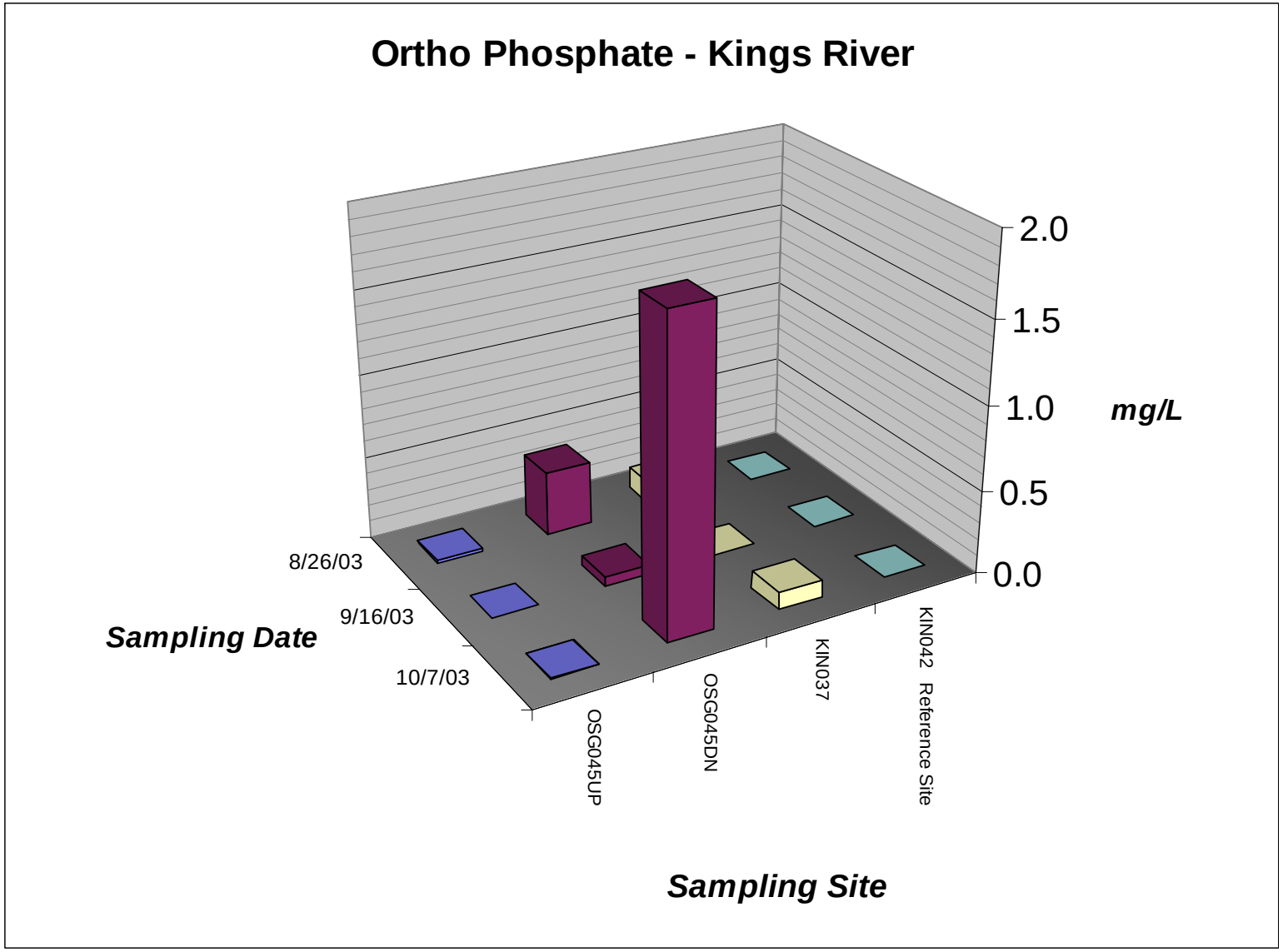


Figure 4.8 Kings River Total Phosphorus Results

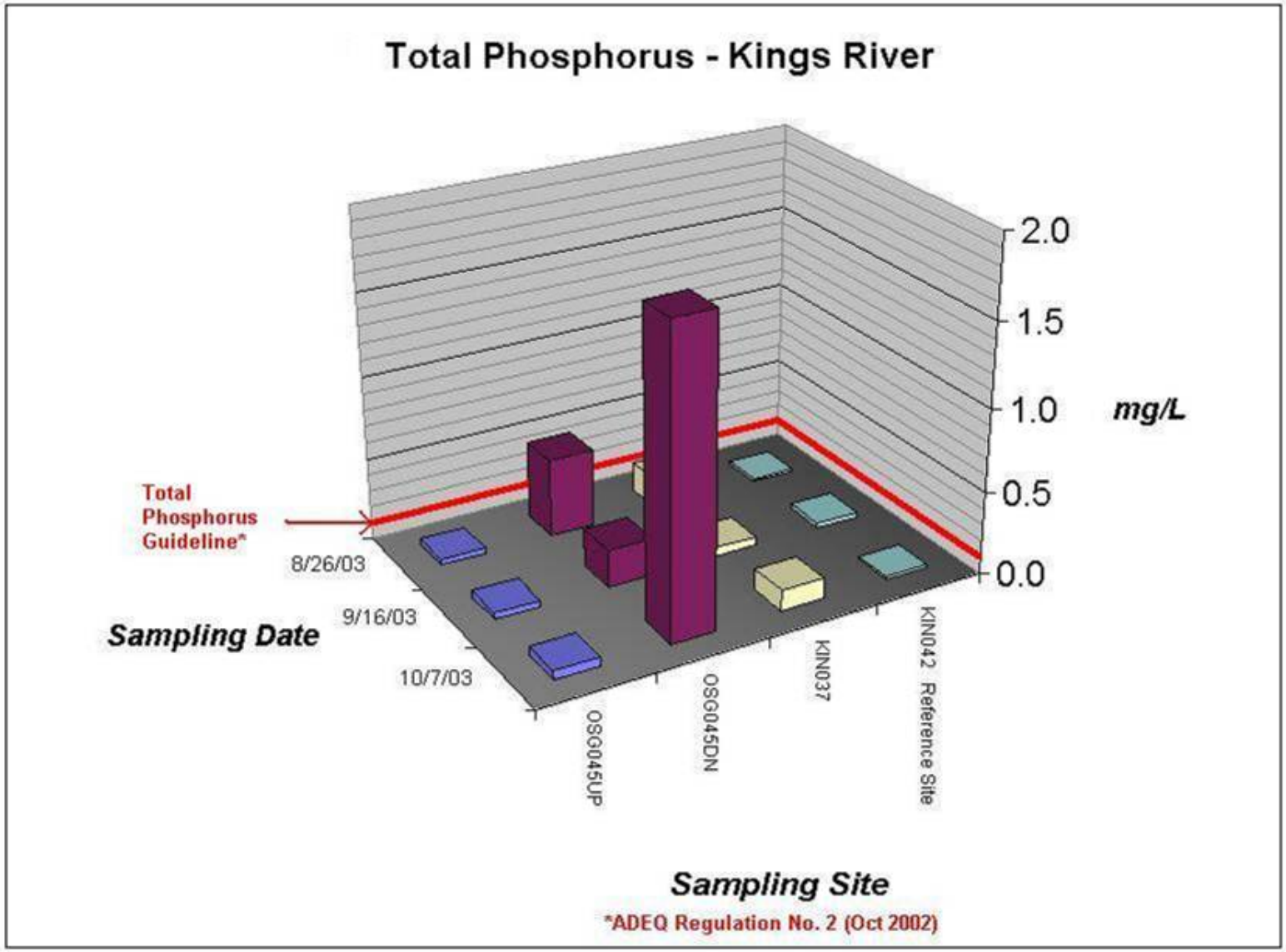
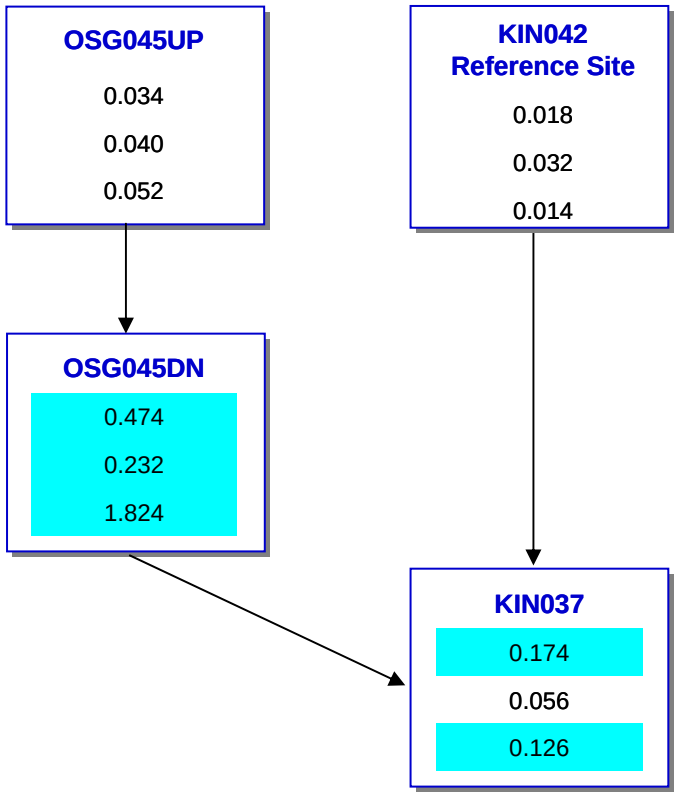


Figure 4.9 TP Values at Sites on the Kings River (mg/L)



= exceeds total phosphorus (TP) guideline value: 0.1 mg/L (ADEQ Regulation No. 2, 2002)

Values at each site correspond respectively to the following sampling dates:

8/26/2003
9/16/2003
10/7/2003

TOC, TDS, and Turbidity

TOC, TDS, and turbidity information is presented on Table 4.3 and Figures 4.10, 4.11, and 4.12, respectively. TOC values from all locations over all three events ranged from 0.78 to 4.80 mg/L. TOC concentrations almost doubled from OSG045UP to OSG045DN, and then decreased downstream at KIN037. TDS ranged from 156 to 455 mg/L, with the highest values at OSG045DN. The ADEQ numeric criterion for TDS at the KIN037 site is 150 mg/L, and all TDS values at this site exceeded the criterion. TDS for the two Osage Creek sites and the reference site is 240 mg/L. This value was exceeded for all three events at OSG045DN. Turbidity ranged from 1 to 5 NTUs, with the two highest turbidity measurements at OSG045UP (5 NTUs each). All turbidity values on the Kings River were lower than the ADEQ numeric criterion of 10 NTUs.

Figure 4.10 Kings River TOC Results

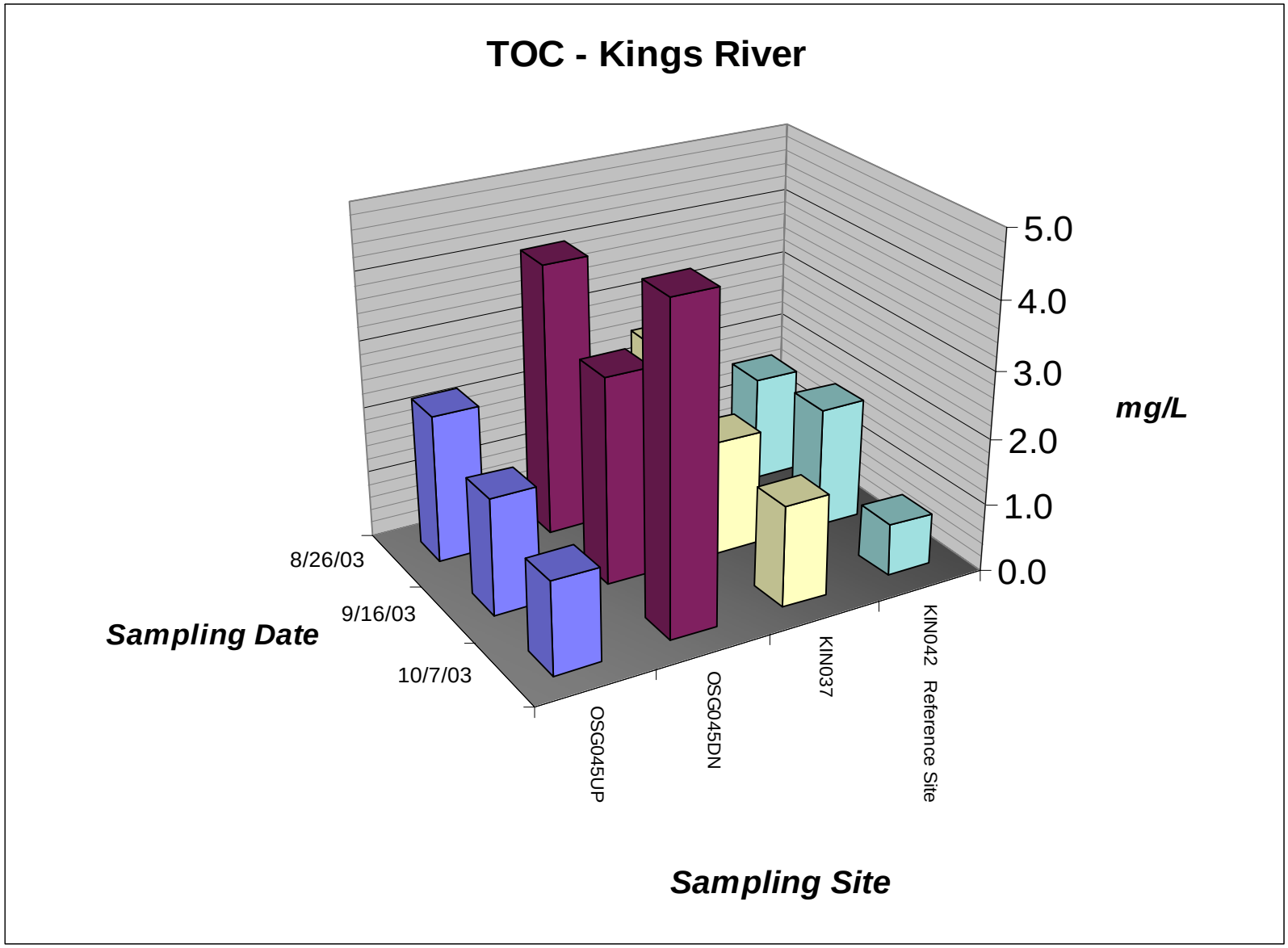


Figure 4.11 Kings River TDS Results

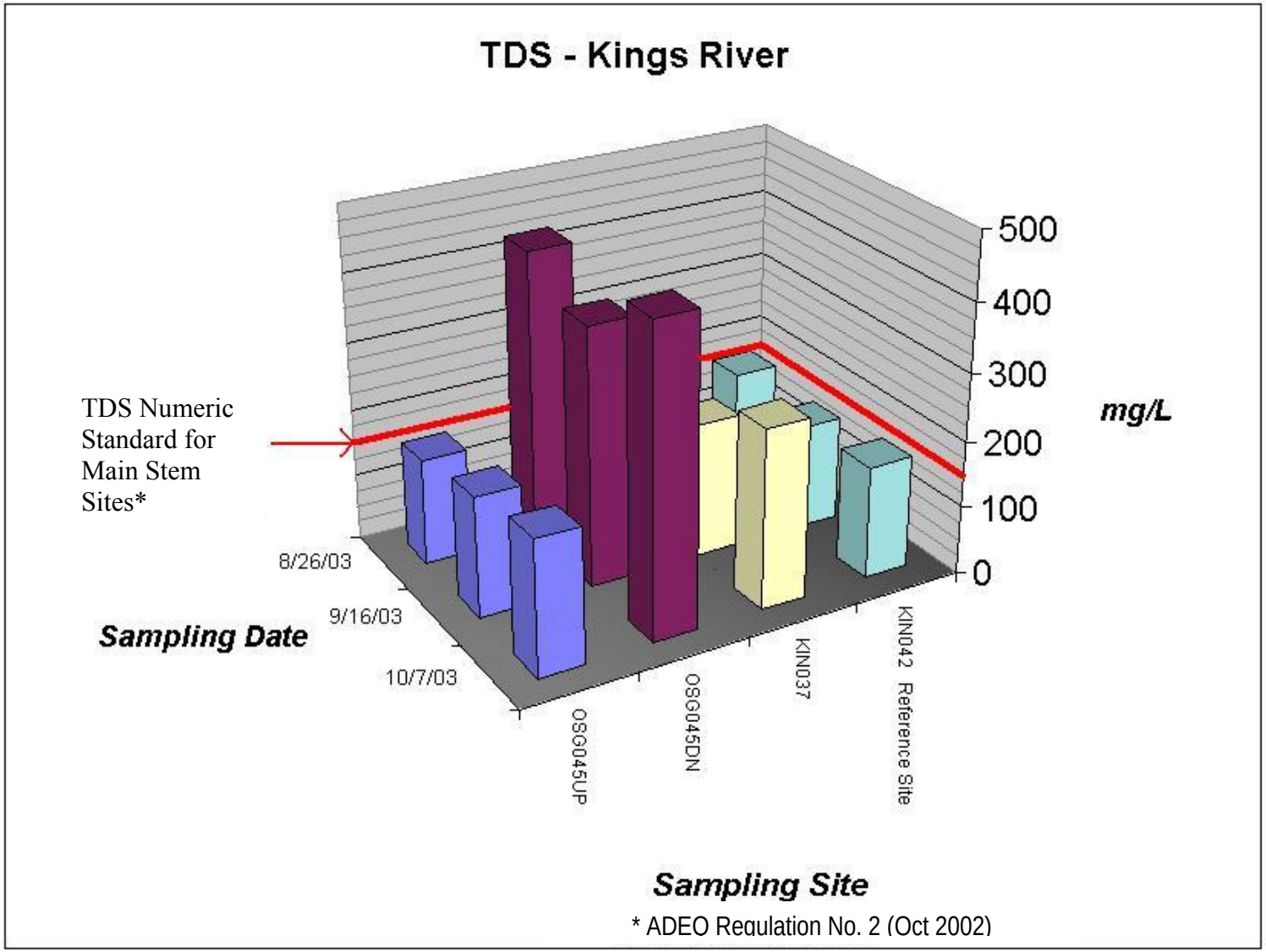
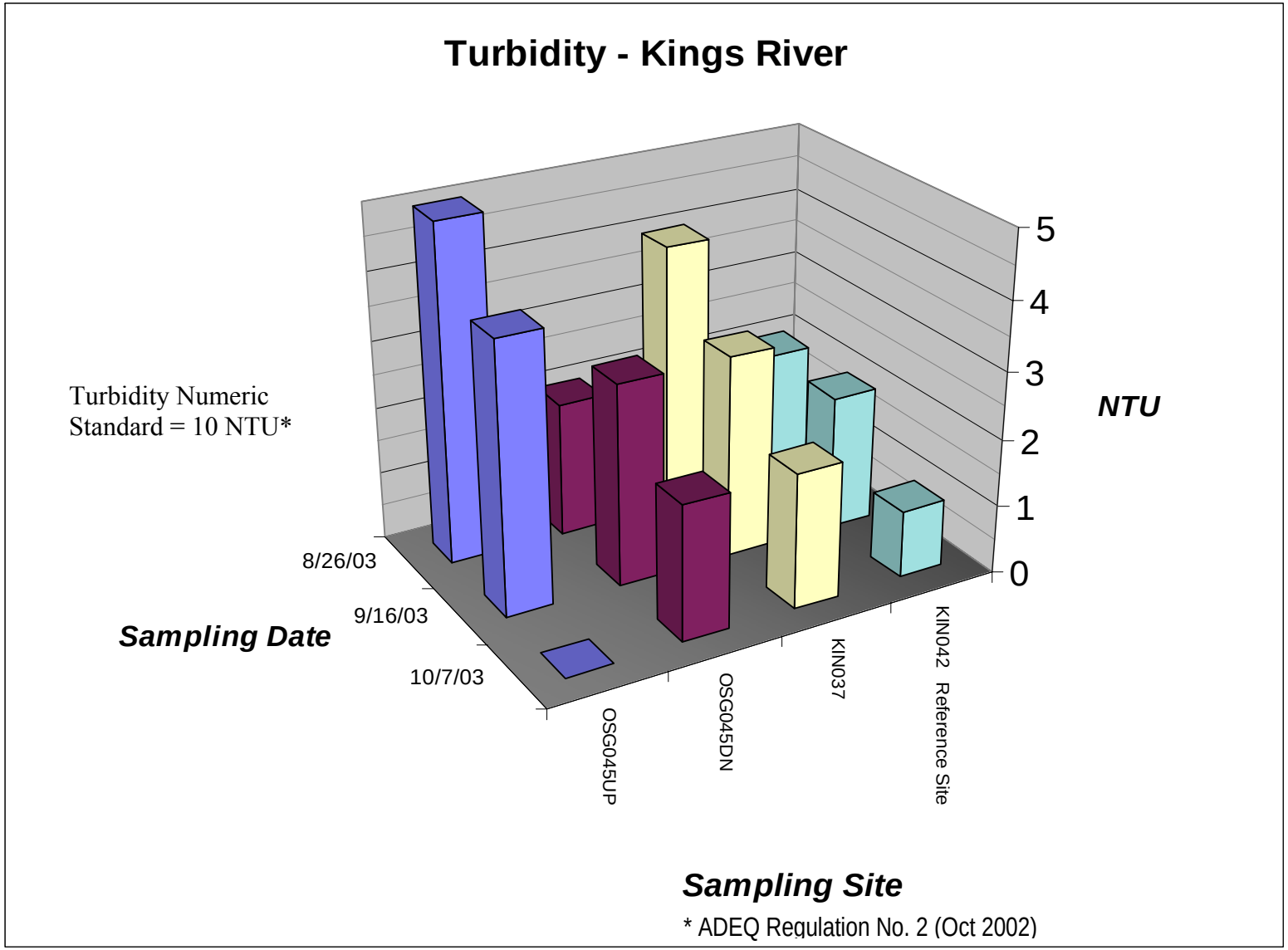


Figure 4.12 Kings River Turbidity Results



Summary

Nutrient results at the site downstream of the Berryville WWTP discharge (OSG045DN) were all higher in concentration than the upstream location (OSG045UP), with the exception of the nitrite nitrogen value for the August 26, 2003 event. Comparing nutrient data for all three events (Table 4.3), OSG045DN typically had the highest value for each nutrient parameter; however, this same location also typically had at least one value lower than similar event data at other sites, including the reference site. The reason for the significant increase in TN, ortho phosphate, and TP concentrations on the October 7, 2003 sampling date is unknown. TDS criterion was exceeded for each sampling event at KIN037 and OSG045DN.

4.3 STREAM HABITAT CHARACTERIZATION

Habitat Scoring:

The first round of habitat assessments on the Kings River were conducted from October 26, 2003 through November 21, 2003. For the first sampling event in the Kings River basin, the range for riffles was 131 at OSG045UP to 171 at OSG045DN (Table 4.4). Pool assessments in the Kings River basin ranged from 144 at OSG045 up to 159 at KIN037. The second round of habitat assessments were conducted on December 23, 2003. Habitat scoring for Round 2 sampling on the Kings River ranged from 146 at OSG045UP to 159 at KIN042 for riffles and 152 at OSG045UP to 172 at KIN037 for pools (Table 4.5).

Substrate Characterization: Stream substrate was gravel or a gravel cobble mixture in all sampling sites in the Kings River (Table 4.6). Algae growth was present to some degree on the substrate of all sites. At all sites, sand and fine particles filled some part of the void space between gravel and cobble particles. Average substrate embeddedness ranged from 37 percent at KIN037 and KIN042 to 54 percent at OSG045DN. Algae were common to dense on the substrate at all sites except for KIN037 where it was noted as rare. Large and small woody debris, leaf litter, and percent canopy cover were also noted in the field and recorded in Table 4.6.

Geomorphic Characterization: As expected, the bankfull width and depth varied as a power function of the watershed area (Figure 4.13). In general, the sites surveyed were wider and less deep than would be expected from the regional curves for the Ozark region developed by the Arkansas Soil and Water Conservation Commission. Bank erosion was common at all the sites, even at the reference sites. Bankfull velocity and discharge was calculated for each site using Manning's equation. A single "n" value of 0.045 (clean winding stream, some pools, shoals, weeds and stones) was selected for the calculation (Ward 1995). Normal channel discharge was calculated as the product of the average segment water surface width, average depth at water surface, and the average velocity.

Impacted Sites: Habitat scoring is compared to the score at the reference site on the far right on Tables 4.4 and 4.5. These percentages were compared to a value of 75 percent of reference value as was done for habitat communities in the 1997 Illinois River Report (ADEQ 1997). A subject segment scoring greater than 75 percent of the reference scoring was determined as supporting in the 1997 Report. Periphyton and filamentous algae were considered to render a site *impacted* if they were present in *Common* or *Dense* quantities. For both events and both riffle and pool sections on the streams sampled in the Kings River basin, including the Kings River and Osage Creek, none of the sites had values lower than 75 percent of the reference site score for either of the two events, hence none of the sites are categorized as impacted for habitat.

Figure 4.13 Bankfull Width and Depth vs. Watershed Area

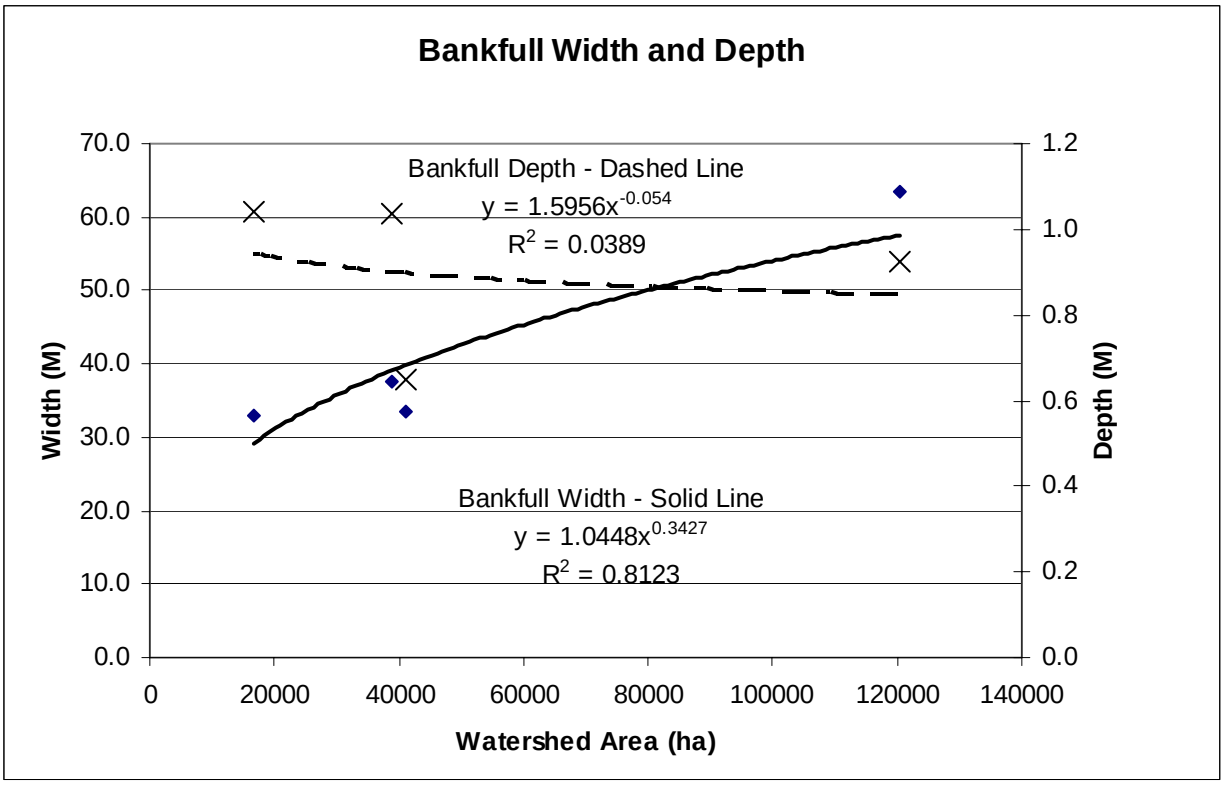


Table 4.4 Habitat Scoring for Kings River, Event 1

Riffle Assessment													Comparison with Reference Site for Impact
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB		
Description	Epifaunal Substrate/ Available Cover	Embed-dedness	Velocity/Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of Reference Site
OSG 45 UP	10	12	15	10	12	10	12	8	18	6	18	131	78.9
OSG 45 DN	13	15	18	11	11	18	17	17	17	18	16	171	103.0
KIN 37	15	14	18	10	10	14	20	10	18	12	19	160	96.4
KIN 42 Reference	16	15	18	13	10	15	20	15	15	9	20	166	Reference

Pool Assessment													Comparison with Reference Site for Impact
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB		
Description	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Sinuosity	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of Reference Site
OSG 45 UP	10	16	15	12	14	12	15	8	18	6	18	144	93.5
OSG 45 DN	12	16	16	11	9	16	12	15	15	18	15	155	100.6
KIN 37	13	16	16	10	16	13	15	10	18	13	19	159	103.2
KIN 42 Reference	14	16	9	14	8	15	16	15	19	8	20	154	Reference

Classification				
	Poor	0 - 5	Sub-Opt	11-15
	Marginal	6-10	Optimal	16-20

= Shaded if less than 75 % of reference site score (impacted if shaded).

Table 4.5 Habitat Scoring for Kings River, Event 2

Riffle Assessment													Comparison with Reference Site for Impact
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB		
Description	Epifaunal Substrate/ Available Cover	Embed-dedness	Velocity/Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of Reference Site
OSG 45 UP	12	12	15	10	10	16	18	15	10	18	10	146	91.8
OSG 45 DN	15	10	18	10	10	18	18	13	13	18	11	154	96.9
KIN 37	17	12	18	10	13	15	18	15	18	13	20	169	106.3
KIN 42 Reference	18	14	18	10	10	13	20	12	15	11	18	159	Reference

Pool Assessment													Comparison with Reference Site for Impact
Parameter	1	2	3	4	5	6	7	8LB	8RB	9LB	9RB		
Description	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Sinuosity	Bank Stability, Left Bank	Bank Stability, Right Bank	Riparian Vegetative Zone Width, Left Bank	Riparian Vegetative Zone Width, Right Bank	Total	% of Reference Site
OSG 45 UP	17	15	11	11	15	15	15	15	10	10	18	152	92.1
OSG 45 DN	15	11	18	11	13	18	15	13	13	18	15	160	97.0
KIN 37	17	15	18	12	12	15	15	18	16	14	20	172	104.2
KIN 42 Reference	18	18	16	11	18	13	15	12	15	11	18	165	Reference

Classification				
	Poor	0 - 5	Sub-Opt	11-15
	Marginal	6-10	Optimal	16-20

= Shaded if less than 75 % of reference site score (impacted if shaded).

Table 4.6 Habitat and Pebble Count Results Kings River

Station	Inorganic Components					Organic Components			Algae		Substrate Embed-dedness %	Canopy Cover %
	% Coverage					% Coverage			Periphyton	Filamentatous		
	Small Boulder	Cobble	Gravel	Sand	Silt	Lg. Woody Debris	Sm. Woody Debris	Leaf Litter				
	330 - 610 mm	76 - 329 mm	2 - 75 mm	<0.2mm	fines							
OSG045UP	0%	18%	82%	0%	0%	R	P	R	P	C/D	39	1
OSG045DN	0%	19%	81%	0%	0%	R	R	R	P	D	54	8
KIN037	0%	10%	90%	0%	0%	P	P	R/P	C	R	37	43
KIN042	0%	5%	95%	0%	0%	R/P	R	R	P	C	37	3

R = Rare C = Common
P = Present D = Dense

4.4 AQUATIC LIFE CHARACTERIZATION

4.4.1 Periphyton

Periphytic growth measurements during the first deployment (August – September 2003) using Matlock Periphytometers on the Kings River are provided in Table 4.7. Periphytic growth, measured as biomass production measured as chlorophyll *a* accumulation over 10-14 days on the Kings River basin sites was the same at KIN042 (reference site for the Kings River), KIN037 and OSG045-DN (Table 4.8). However, site OSG045-UP, located above the Berryville WWTP, showed elevated primary productivity. This site was the only one that showed nutrient limitations during the first deployment period; the site was phosphorus limited (Table 4.7). The LETSI was greater than 0.8 for three sites in the Kings River (KIN042, KIN037, and OSG042-DN) (Table 4.10). Primary productivity at these sites in this watershed is limited by something other than nutrients, probably light.

Productivity at the Kings River sites on the second periphyton event was similar to the initial deployment, with the exception of OSG045-UP, which showed elevated productivity, approaching the MPP observed in the first deployment (Table 4.7). Primary productivity during the second round of Matlock Periphytometers at all Kings River sites was limited by something other than nutrients as well (Table 4.9).

These results illustrate the complex nature of determining point source nutrient impacts on systems with both point and nonpoint pollutant loads. Periphytic growth is a fundamental ecosystem process, and thus is the product of multiple ecosystem inputs, including light, nutrients, and temperature. Measuring this process is difficult. Grazing is controlled by covering the periphytometers with aluminum screen; however, in some cases, leaf litter accumulated on the periphytometer racks, potentially inducing light limitation and suppressing the algal response to nutrients. Thus, all interpretations must be made in the context of additional observations.

Table 4.7 Chlorophyll *a* Concentrations on Artificial Substrate August/September 2003

Student-Newman-Keuls' (SNK) Test Comparison of Chlorophyll *a* concentrations for Control, Nitrogen (N), Phosphorus (P), and Nitrogen plus Phosphorus (N + P) treatments using the Matlock Periphytometer in the Kings River basin during the period of August-September, 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* ($\mu g\ cm^{-2}$)	Standard Deviation ($\mu g\ cm^{-2}$)	SNK Group (μ=0.05)	Limiting Nutrient
OSG045-UP	Control	8	0.63	0.09	C	P-Limited
	N	10	0.63	0.24	C	
	P	10	1.06	0.28	D	
	N + P	10	1.95	0.58	E	
OSG045-DN	Control	10	0.23	0.09	A	None
	N	9	0.26	0.06	A	
	P	9	0.31	0.19	A	
	N + P	10	0.26	0.06	A	
KIN037	Control	10	0.26	0.09	A	None
	N	8	0.29	0.11	A	
	P	10	0.29	0.12	A	
	N + P	10	0.27	0.10	A	
KIN042	Control	10	0.20	0.08	A	None
	N	10	0.19	0.10	A	
	P	10	0.23	0.10	A	
	N + P	10	0.18	0.11	A	

Table 4.8 Lotic Ecosystem Trophic Status Indices August/September 2003

Lotic Ecosystem Trophic Status Indices using the Matlock Periphytometer in the Kings River basin during the period of August-September, 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* ($\mu g\ cm^{-2}$)	Standard Deviation ($\mu g\ cm^{-2}$)	LETSI
OSG045-UP	Control	8	0.63	0.09	0.32
	N+P	10	1.95	0.58	
OSG045-DN	Control	10	0.23	0.09	0.88
	N+P	10	0.26	0.06	
KIN037	Control	10	0.26	0.09	0.96
	N+P	10	0.27	0.10	
KIN042	Control	10	0.20	0.08	>1.0
	N+P	10	0.18	0.11	

Table 4.9 Chlorophyll *a* Concentrations on Artificial Substrate October 2003

Student-Newman-Keuls' (SNK) Test Comparison of Chlorophyll *a* concentrations for Control, Nitrogen (N), Phosphorus (P), and Nitrogen plus Phosphorus (N + P) treatments using the Matlock Periphytometer in the Kings River basin during the period of October 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* (µg cm^{-2})	Standard Deviation (µg cm^{-2})	SNK Group (µ=0.05)	Limiting Nutrient
OSG045-UP	Control	10	1.47	0.70	D	None
	N	10	1.42	0.38	D	
	P	10	1.64	0.50	D	
	N + P	10	1.76	0.67	D	
OSG045-DN	Control	10	0.31	0.12	A	None
	N	10	0.39	0.21	A	
	P	10	0.35	0.18	A	
	N + P	10	0.29	0.13	A	
KIN037	Control	10	0.34	0.17	B	None
	N	10	0.36	0.35	B	
	P	10	0.32	0.15	B	
	N + P	10	0.36	0.21	B	
KIN042	Control	7	0.26	0.20	B	None
	N	10	0.28	25	B	
	P	10	0.23	0.20	B	
	N + P	10	0.17	0.13	B	

Table 4.10 Lotic Ecosystem Trophic Status Indices October 2003

Lotic Ecosystem Trophic Status Indices using the Matlock Periphytometer in Kings River basin during October 2003.

Site	Treatment	Number of Replicates	Mean Chl. *a* (µg cm^{-2})	Standard Deviation (µg cm^{-2})	LETSI
OSG045-UP	Control	10	1.47	0.70	0.84
	N+P	10	1.76	0.67	
OSG045-DN	Control	10	0.31	0.12	>1.0
	N+P	10	0.29	0.13	
KIN037	Control	10	0.34	0.17	0.94
	N+P	10	0.36	0.21	
KIN042	Control	7	0.26	0.20	>1.0
	N+P	10	0.17	0.13	

Algae Species

The taxonomic analyses of algal data collected from natural substrates at each site suggest that the periphytic community within the Kings River basin has been altered below WWTP outfalls. Algal data results and a more in depth analysis of the data are provided in Appendix I. The Shannon-Weiner Diversity Index (SWDI) decreased from 4.25 to 3.69 between the sample sites upstream and downstream of the City of Berryville WWTP (OSG045UP and OSG045DN, respectively) (Table I-2). The siltation index below the Berryville WWTP was very high (0.77) compared with the upstream site (0.32), suggesting that OSG045DN has higher sediment and silt deposition than OSG045UP. The *Lange-Bertalot pollution index* (Barbour *et al.* 2002) is a measure of organic pollution based on the rating of species within a community from tolerant of pollution (1) to less tolerant (2) to sensitive to pollution (3). The higher the composite rating (from 1 to 3) the more sensitive the community is to pollution (Barbour et al, 2002). The site most polluted, according to this metric, was the lowest site in the basin (KIN037), followed by the site downstream of the Berryville WWTP (OSG045DN).

4.4.2 Benthic Macroinvertebrate Collection

Benthic Macroinvertebrates – First Sampling Event

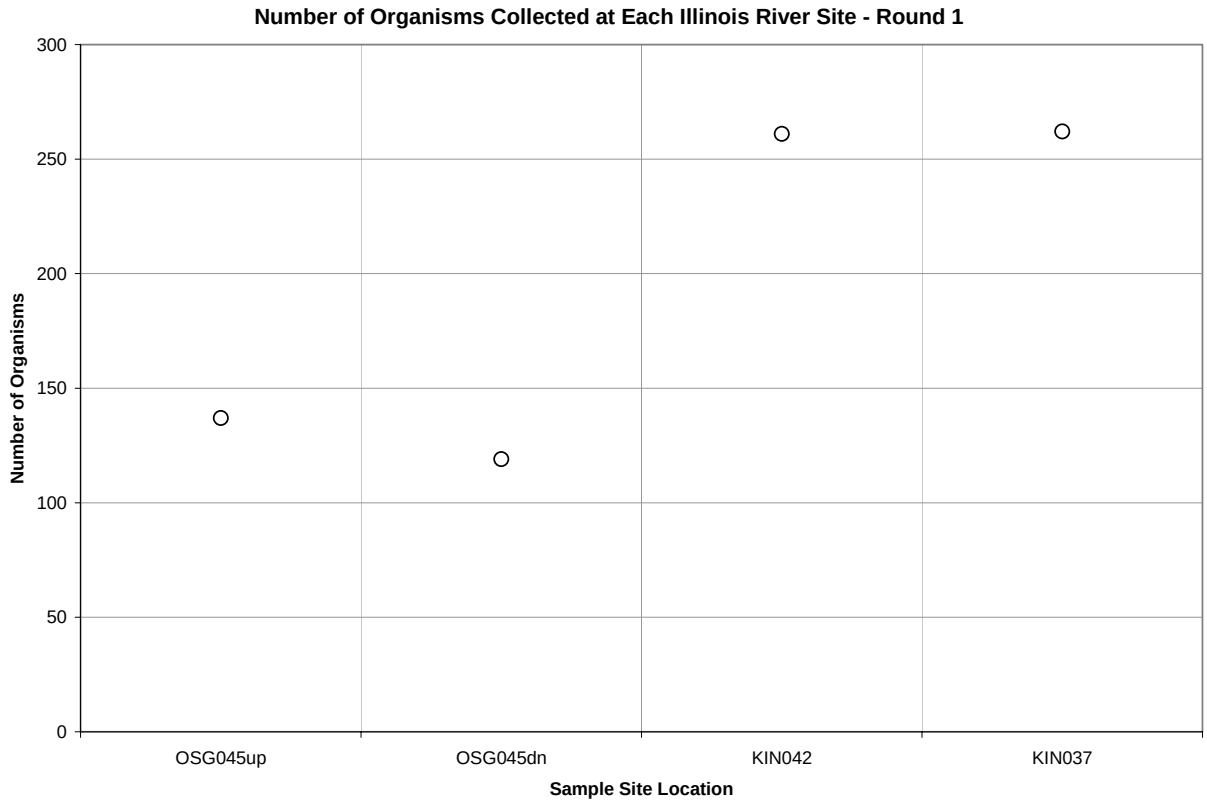
Results of benthic macroinvertebrate sampling during the first round for the Kings River are presented in Table 4.11. Raw data on macroinvertebrate collection are provided in Appendix D. Community comparisons were made using the same criteria described in the ADEQ 1997 Illinois River Report (ADEQ 1997) for ease of comparison. Collection procedures produced more organisms overall than in the 1997 collection (Figure 4.14). These analyses are based on sub-sampling 100 organisms from an average initial collection of 195 organisms from 28 *taxa*, providing a robust estimate of community structure across sites. The downstream most site in the Kings River, KIN037, was difficult to sample due to high flows.

Table 4.11 Benthic Macroinvertebrate Results – Event 1

	STATION			
Metric	OSG045up	OSG045dn	KIN037	KIN042
Total Number Identified	137	119	107	103
Additional Invertebrates	0	0	155	158
Total Number in Sample	137	119	262	261
Total Taxa	17	18	19	16
EPT Taxa	7	5	10	8
EPT Abundance	54	70	79	83
Contribution of Dominant Taxa	30%	31%	17%	50%
Scraper Abundance	54	18	32	17
Filter Feeder Abundance	49	23	33	65
Chironomidae	0	1	1	1
Hilsenhoff Biotic Index	4.35	5.18	4.75	4.06
EPT Index	0.41	0.28	0.53	0.50
EPT / Chironomids +EPT	1.00	0.99	0.99	0.99
Scraper / Scraper+Filter Feeder	0.52	0.44	0.49	0.21
Community Loss Index	0.41	0.28	0.16	Reference
Benthic Macroinvertebrates				
Integrated Scoring[a]	24.92	20.99	23.07	26.34
Reference Site Comparison[b]	94.6%	79.7%	87.6%	100.0%

[a] Integrated Scoring = [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]
[b] Site scoring compared to designated reference site

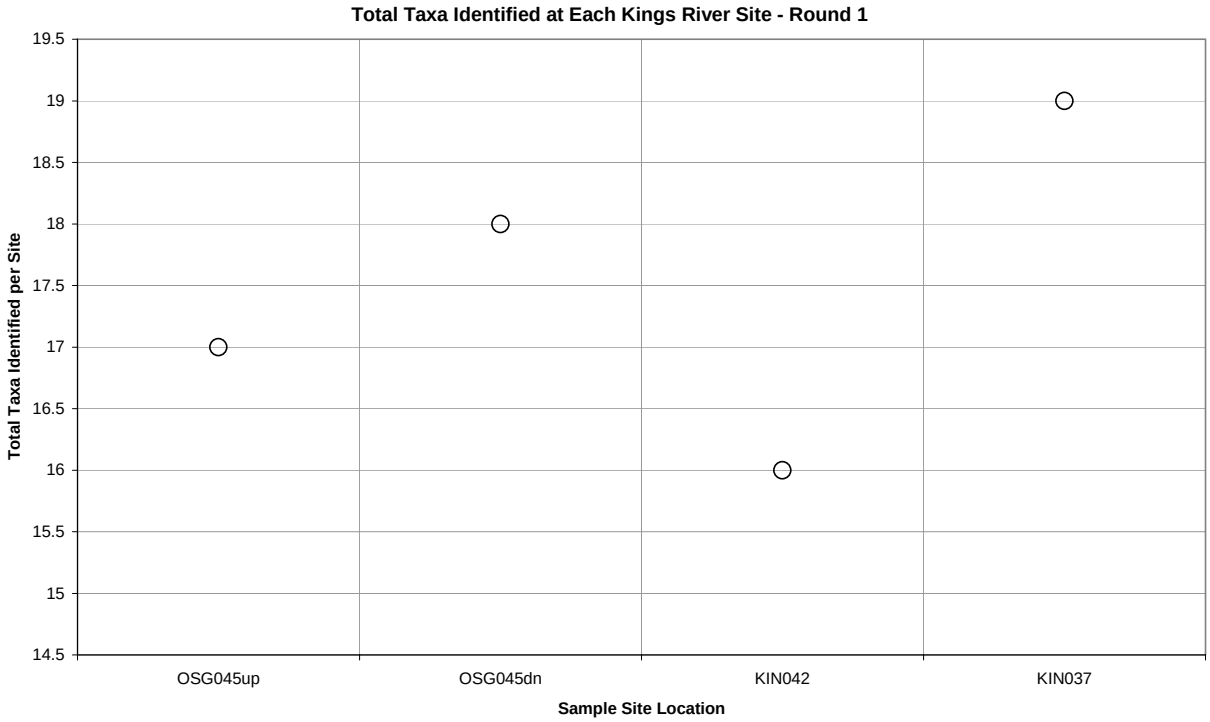
Figure 4.14 Total Organisms



Reference Sites. This report utilizes two types of references sites: site specific and regional. The site-specific reference site is immediately above the Berryville WWTP outfall (OSG045UP), and serves as reference for the downstream site only (OSG045DN). Regional reference sites, representing a geographically proximate group of sample sites, have utility but are difficult to analyze because of the degree of general impact present in most landscapes, and because of the local variability of even the most homogonous ecoregion (Barbour *et al*. 1999). The regional reference site on the Kings River (KIN042) was selected to represent the least impacted site from human alteration of the watershed; as a result, it is located on the upstream extreme of the Kings River, just below where the river emerges from the Boston Mountain Ecoregion onto the Ozark Plateau Ecoregion. The downstream most site on the Kings River (KIN037) provides information as to the degree of impact of human activities on the watershed from the most upper segment to the lower segment.

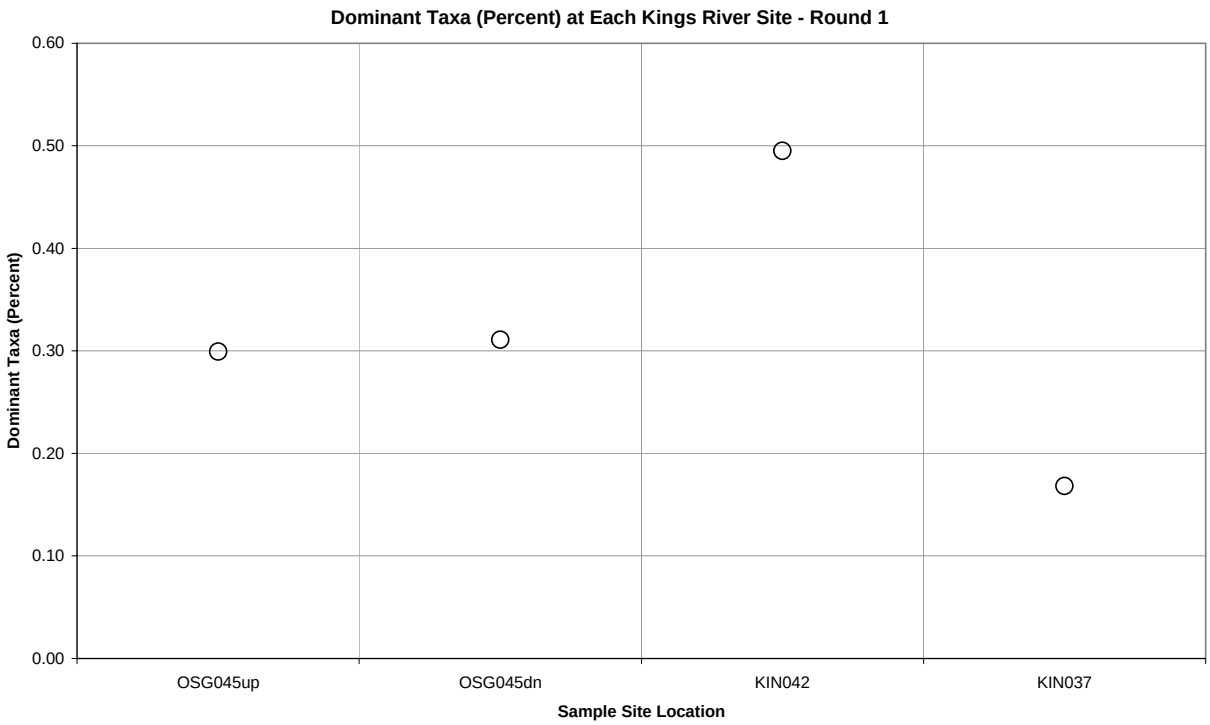
***Taxa* Richness**. *Taxa* richness represents the diversity of *taxa* represented within a sample, and therefore is representative of the *taxa* richness present at a site (Barbour *et al*. 1999). Macroinvertebrate *taxa* richness is based on genus-level identification in the RBP. In general, increasing *taxa* richness means increasing ecosystem integrity, reflecting that niche space, habitat, and food sources are adequate to support a variety of macroinvertebrate assemblages (Barbour *et al*. 1999). Thus, decreasing *taxa* richness suggests a loss of these ecosystem functions, and thus ecosystem degradation. *Taxa* richness across all Kings Rivers sites was relatively similar, ranging from 16 to 19 *taxa* per site (Figure 4.15).

Figure 4.15 Total Taxa



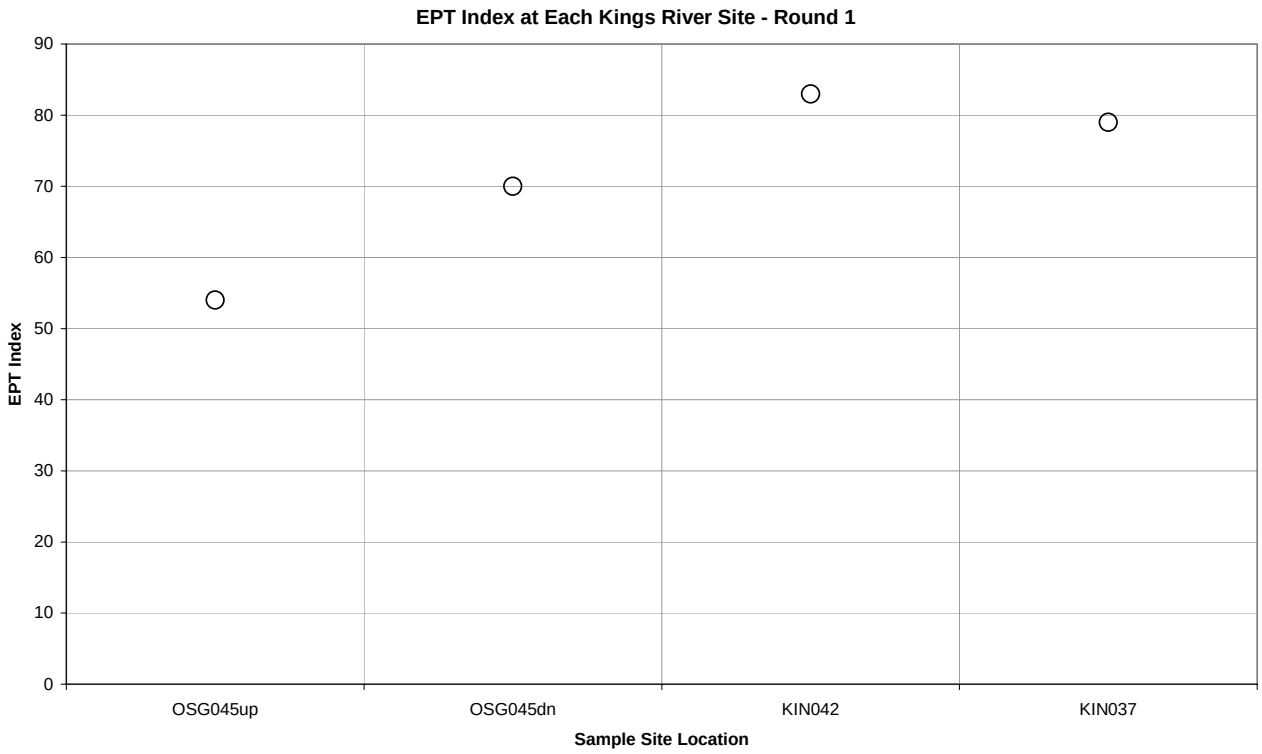
Dominant *Taxa*. The measure of the proportion of the total sample represented by the dominant *taxa* is a measure of community balance and diversity. Stressed ecosystems usually have reduced *taxa*, and as perturbation levels increase, often become dominated by a single taxonomic group. In the Kings River basin during the first sampling event, the site with the highest percent dominant *taxa* was KIN042, with 50 percent of all organisms coming from one *Ephemeroptera* taxa, *Isonychia* (Figure 4.16).

Figure 4.16 Dominant Taxa



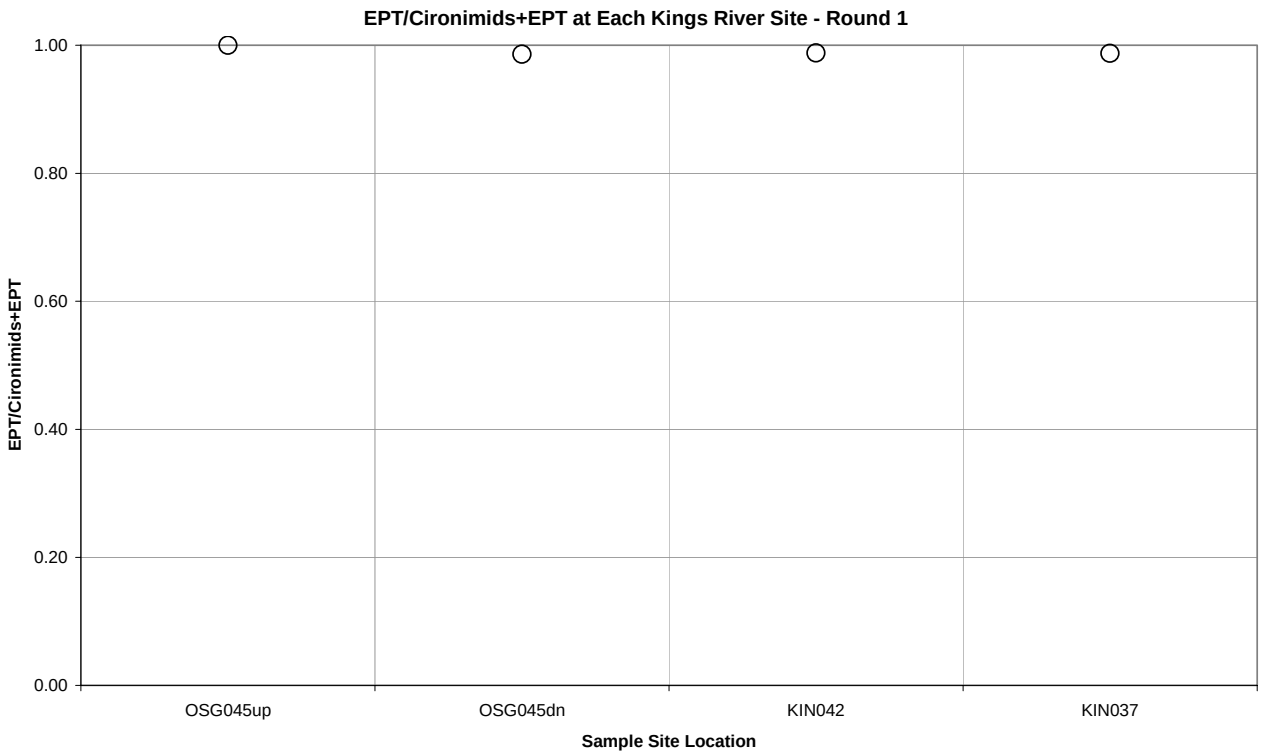
EPT *Taxa* and EPT Index. The presence of sensitive *taxa* (Ephemeroptera, Plecoptera, and Trichoptera, or EPT) at a site represents a composite index of site condition. In general, EPT *taxa* decrease as sites are impacted by toxicants, eutrophication, or other perturbations. However, in headwater streams that are carbon limited, EPT may increase with addition of organic carbon. The EPT Index is the proportion of EPT *taxa* relative to total *taxa*, and represents a more robust characterization than just EPT *taxa* numbers because it takes into account variability in collection effectiveness between sites. In the Kings River basin during the first round of sampling, the EPT Index was highest at KIN042 (83 percent), followed by KIN037 (79 percent) (Figure 4.17). The EPT Index values at OSG045UP above and OSG045DN and below the Berryville WWTP outfall were 54 and 70 percent, respectively.

Figure 4.17 EPT Index



EPT/Chironomids + EPT. The ratio of EPT *taxa* to Chironomidae is a measure of community balance. The EPT *taxa* are generally pollution sensitive, while Chironomids (bloodworms, midge and gnat larvae) are pollution tolerant. Therefore, a high EPT to EPT plus Chironomids ratio suggests a site has high representation of the sensitive species. Virtually no Chironomids were collected on the Kings River, so this metric provides no comparative insight (Figure 4.18). It is likely this is an artifact of the sampling method (traveling D-net); the net has a nominal opening of 0.5 mm, which is larger than most Chironomids. Also, this genus tends to burrow into the substrate in high flowing streams, requiring excavation and sieving to fully sample. This genus was likely under-sampled at all sites during this sampling effort.

Figure 4.18 EPT/EPT Chironomids

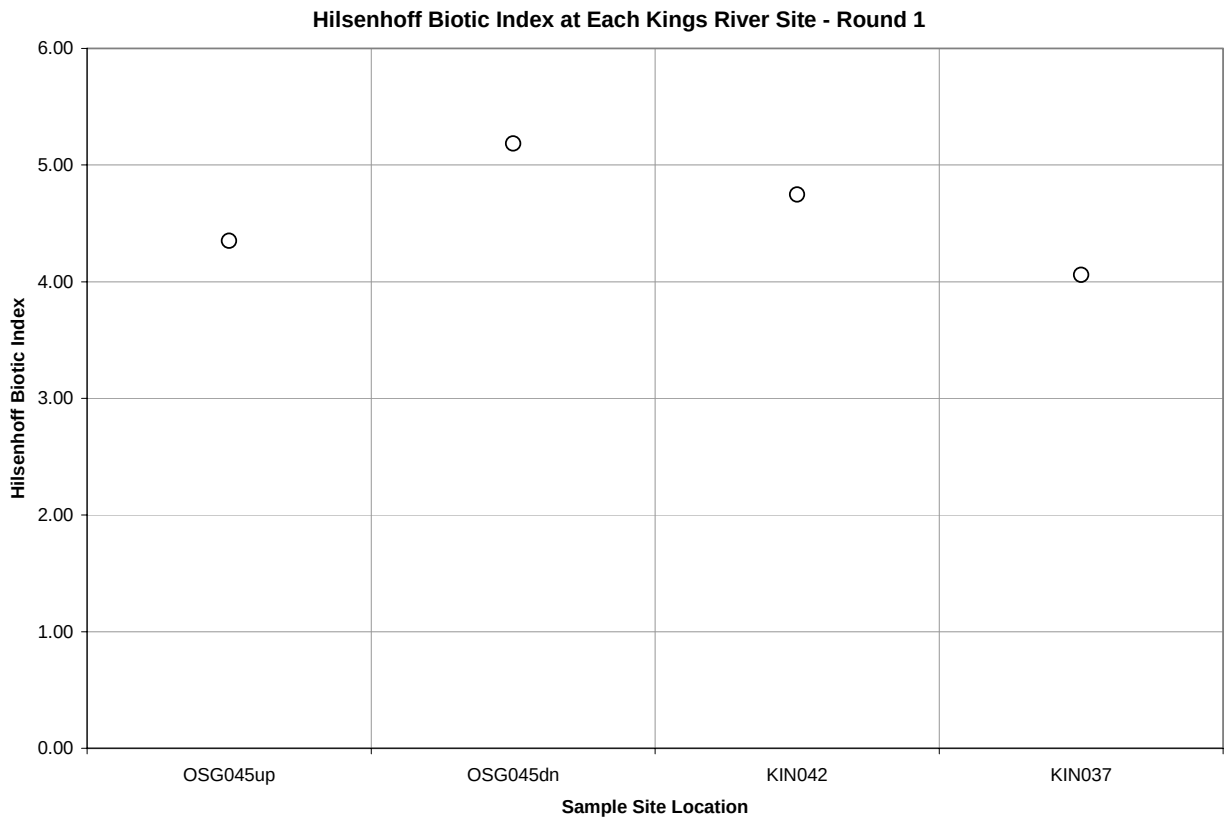


Scrapers/Scrapers + Filter Feeders. FFG ratios provide insight into ecosystem processes from primary production to primary consumption. The ratio of scrapers to other FFGs such as filter feeders provides a relative measure of food sources. Scrapers are diatom feeders, and thus are an indirect measure of diatom abundance. They decrease as filamentous algae and moss increase. Filter feeders attach to filamentous algae and moss, feeding off FPOM. As such, filter feeders are very sensitive to organically bound toxicants, so care must be exercised in interpreting these ratios. These data illustrate this complexity. The lowest FFG ratio in the Kings River basin during first round sampling was at the regional reference site (KIN042) (Figure 4.19).

Figure 4.19 Scrapers/Scrapers+Filterers

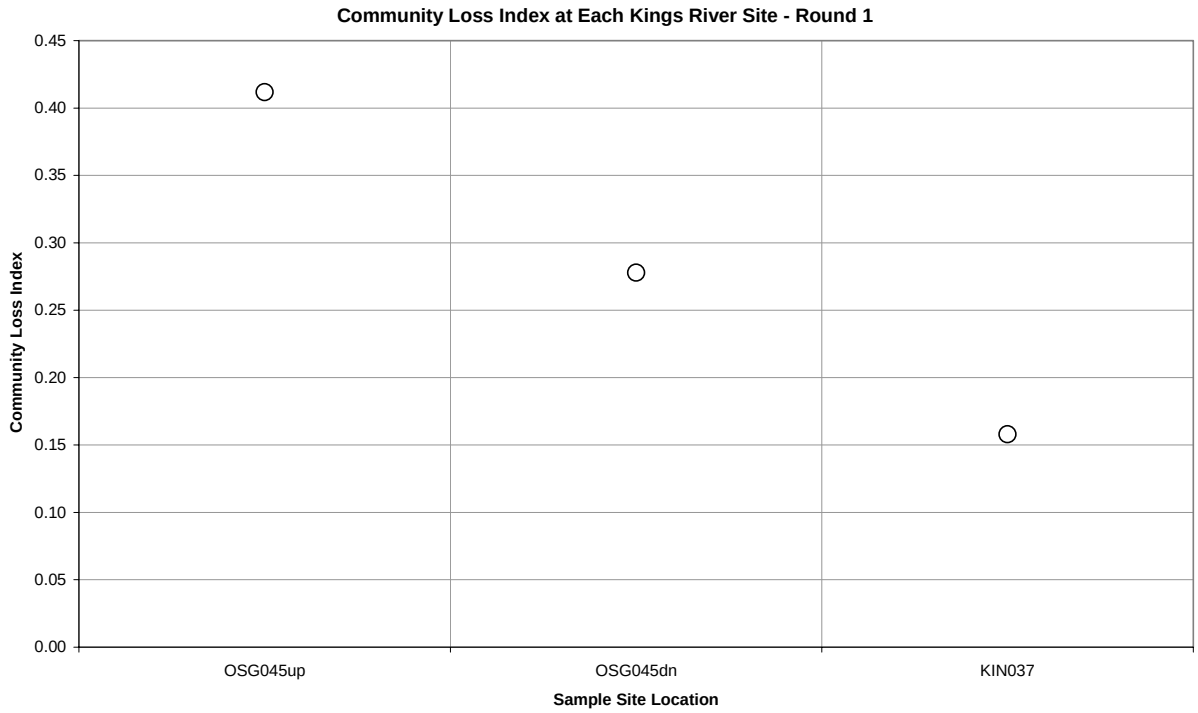
Hilsenhoff Biotic Index. HBI is a measure of the relative abundance of benthic macro-invertebrate *taxa* that are tolerant to pollutants (Hilsenhoff 1987). The HBI assigns a tolerance index to each *taxa* ranging from 1 (highest sensitivity) to 10 (lowest sensitivity). The site HBI is the average of the cumulative tolerance indices. In general, HBIs between 1 and 1.75 indicate excellent water quality, between 1.76 and 2.5 indicate good water quality, between 2.15 and 3.75 indicate fair water quality, between 3.76 and 4.0 indicate poor water quality, and greater than 4.0 indicate serious water quality impairment (ADEQ 1997). The lowest HBI in the Kings River basin during round one sampling was 4.0 at KIN037 (Figure 4.20). The highest HBI was at OSG045DN (5.2). The tolerance indices used were from the New Mexico Stream Assessment Guidelines, since those used by ADEQ in 1997 are not cited and not available. The HBI indicated that all sites sampled during the first round of sampling in the Kings River were impacted.

Figure 4.20 HBI



Community Loss Index. CLI measures the loss of benthic *taxa* between a reference site and the comparison site (Courtemanch and Davies 1987). This is an index of dissimilarity, with increasing values representing increasing levels of dissimilarity. All sites were compared with KIN042 as the reference site. The site most dissimilar from KIN042 was OSG045UP. This site is characterized by a diminished riparian canopy cover and increased sedimentation, with much longer runs and fewer riffles/pools (Figure 4.21).

Figure 4.21 Community Loss Index



Benthic Macroinvertebrates – Second Sampling Event

Results of benthic macroinvertebrate sampling during the second round (immediately following the Critical Period) for the Kings River are presented in Table 4.12. Community comparisons were made using the same criteria described in the ADEQ 1997 Illinois River Report (ADEQ 1997) for ease of comparison. Collection procedures produced more organisms overall than in the 1997 collection (Figure 4.22). Neither the regional reference site on the Kings River (KIN042) nor the upstream site (OSG045UP) were successfully sampled in the second round due to persistent high flows. Macroinvertebrate sampling was also compromised at OSG045DN due to the high flows – only 18 organisms were collected. More than 350 organisms were collected at KIN037. This was the most downstream site, thus less prone to stream depth fluctuations, and had long, persistent riffles that made collection possible even during elevated flows.

Table 4.12 Benthic Macroinvertebrate Results – Event 2

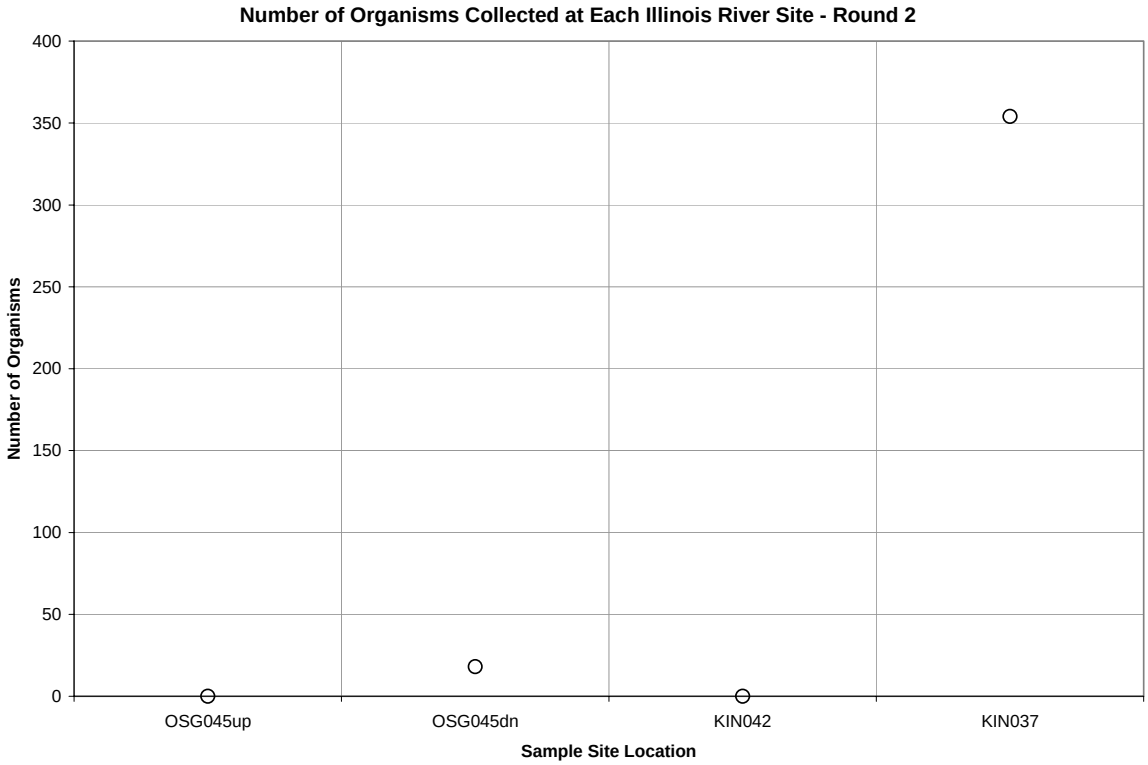
	STATION			
Metric	OSG045up	OSG045dn	KIN037	KIN042
Total Number Identified	NS	18	113	NS
Additional Invertebrates	NS	0	241	NS
Total Number in Sample	NS	18	354	NS
Total Taxa	NS	8	15	NS
EPT Taxa	NS	2	9	NS
EPT Abundance	NS	2	83	NS
Contribution of Dominant Taxa	NS	28%	28%	NS
Scraper Abundance	NS	5	13	NS
Filter Feeder Abundance	NS	3	26	NS
Chironomidae	NS	5	15	NS
Hilsenhoff Biotic Index	NS	7.11	1.20	NS
EPT Index	NS	0.25	0.60	NS
EPT / Chironomids +EPT	NS	0.29	0.85	NS
Scraper / Scraper+Filter Feeder	NS	0.63	0.33	NS
Community Loss Index	NS	0	0	Reference
Benthic Macroinvertebrates				
Integrated Scoring[a]	NS	15.22	85.07	NS
Reference Site Comparison[b]	NS	57.8%	323.0%	NS

[a] Integrated Scoring = [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]

[b] Site scoring compared to designated reference site from Event I

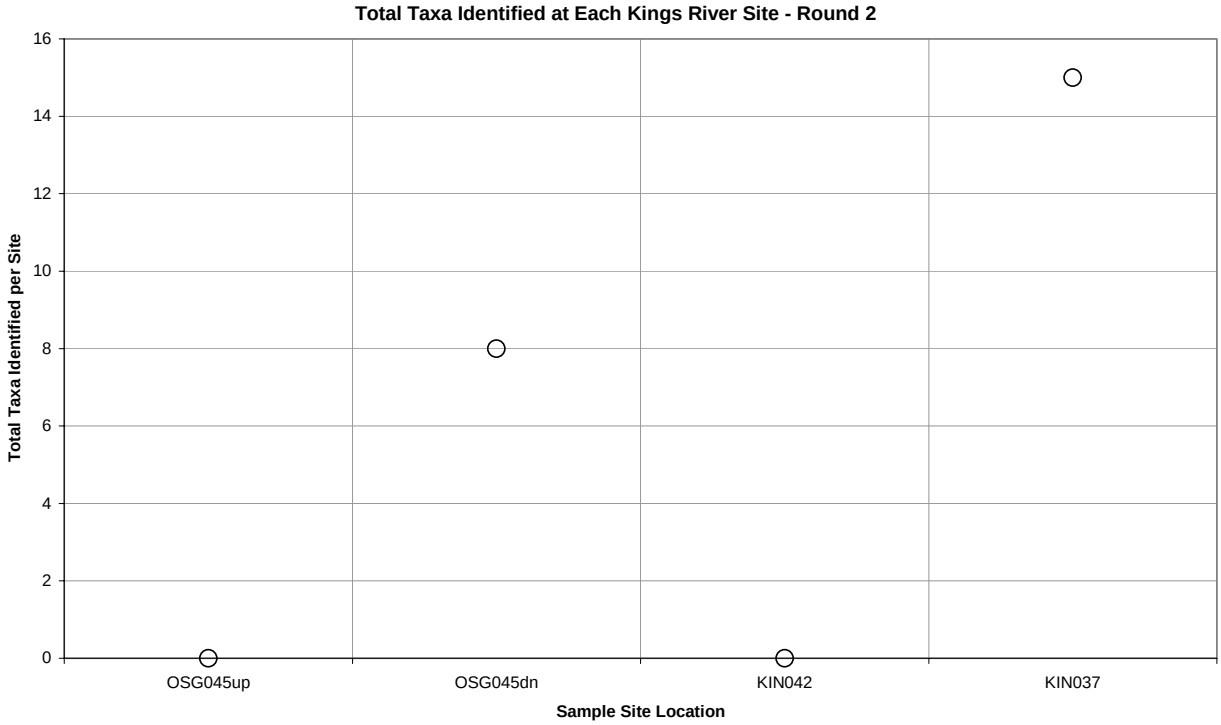
NS = Not Sampled

Figure 4.22 Total Organisms



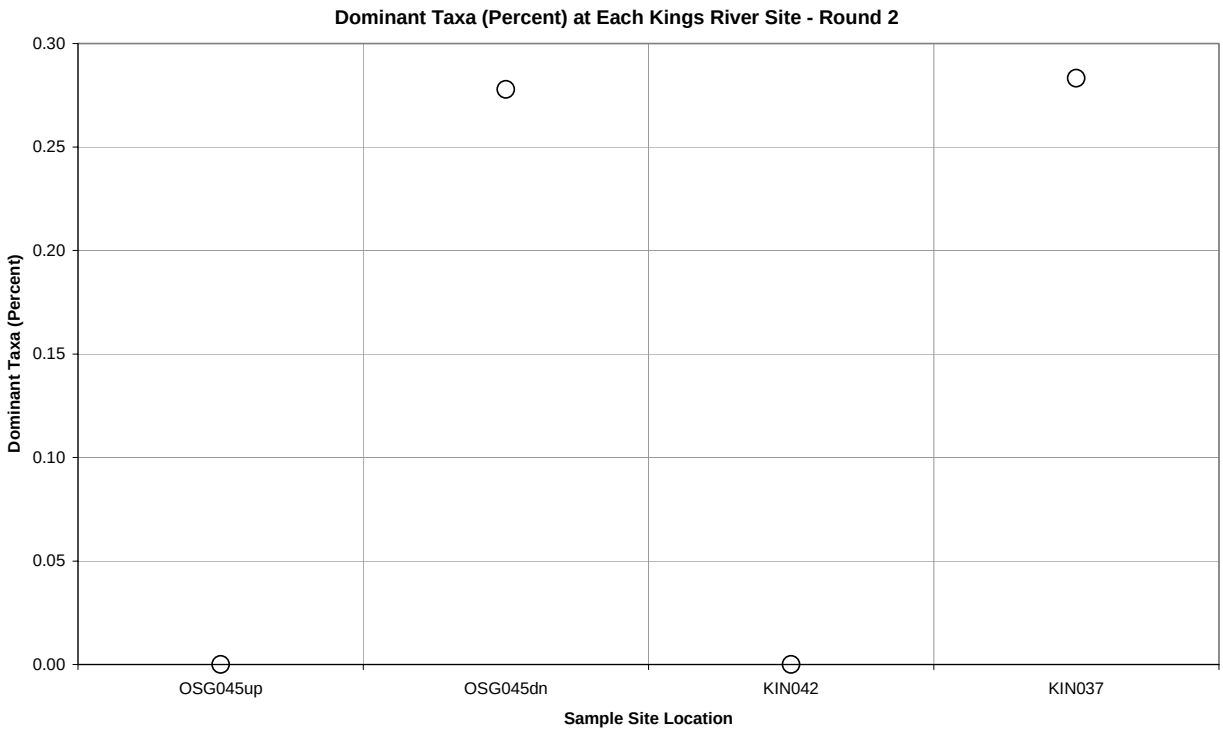
Taxa Richness. *Taxa* richness in the two sites sampled during the second sampling event on the Kings River was lowest at OSG045DN (8 *taxa*) while KIN037 was similar to round one sampling, at 15 *taxa* per site (Figure 4.23).

Figure 4.23 Total Taxa



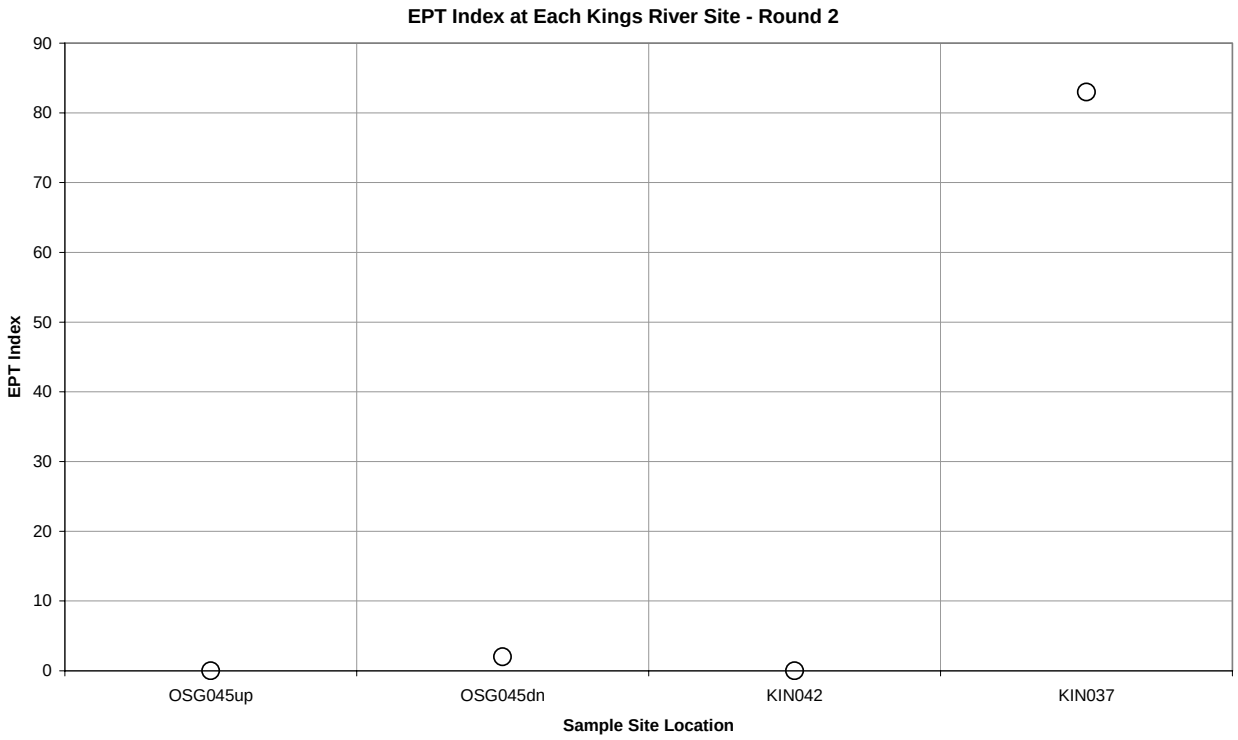
Dominant Taxa. In the Kings River basin during round two sampling, both OSG045DN and KIN037 had similar dominant *taxa*, at less than 30 percent (Figure 4.24).

Figure 4.24 Dominant Taxa



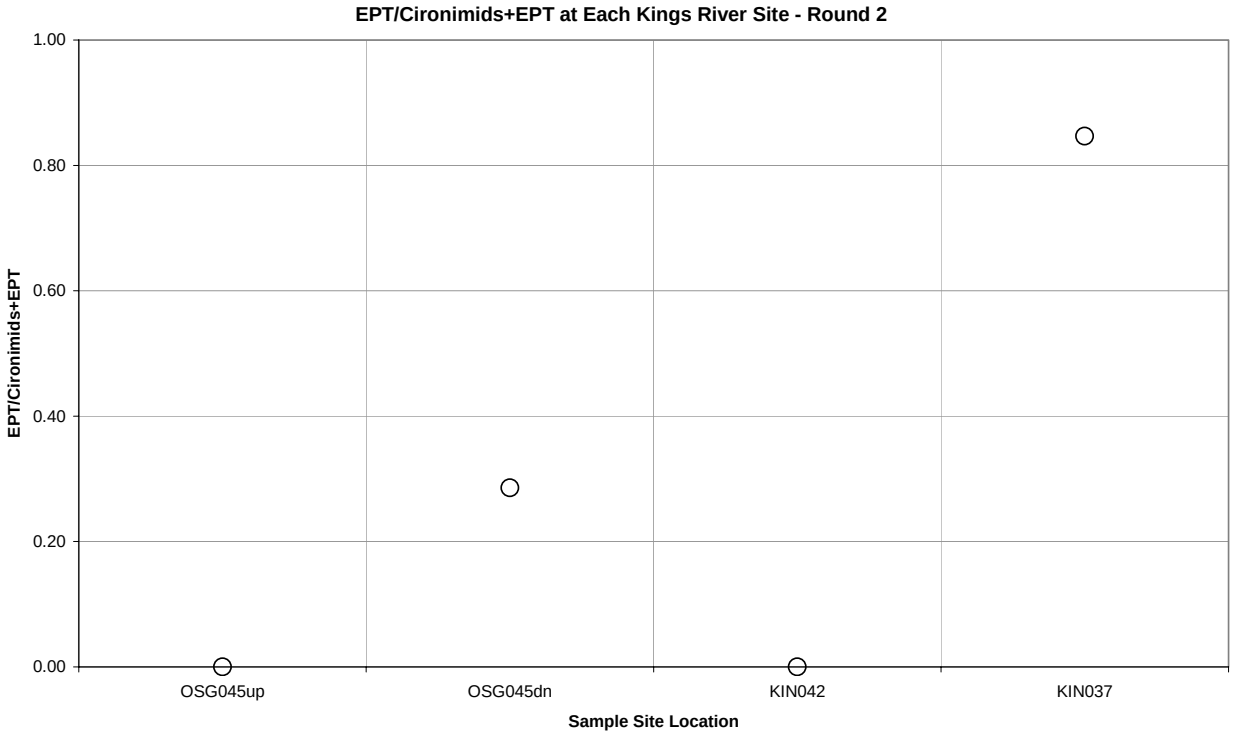
EPT *Taxa* and EPT Index. In the Kings River basin during round two sampling, the EPT Index at KIN037 was 83 percent, similar to round one (79 percent) (Figure 4.25). The EPT Index value at OSG045DN below the Berryville WWTP outfall was 2 percent, though this is based on too small a sample to be significant.

Figure 4.25 EPT Index



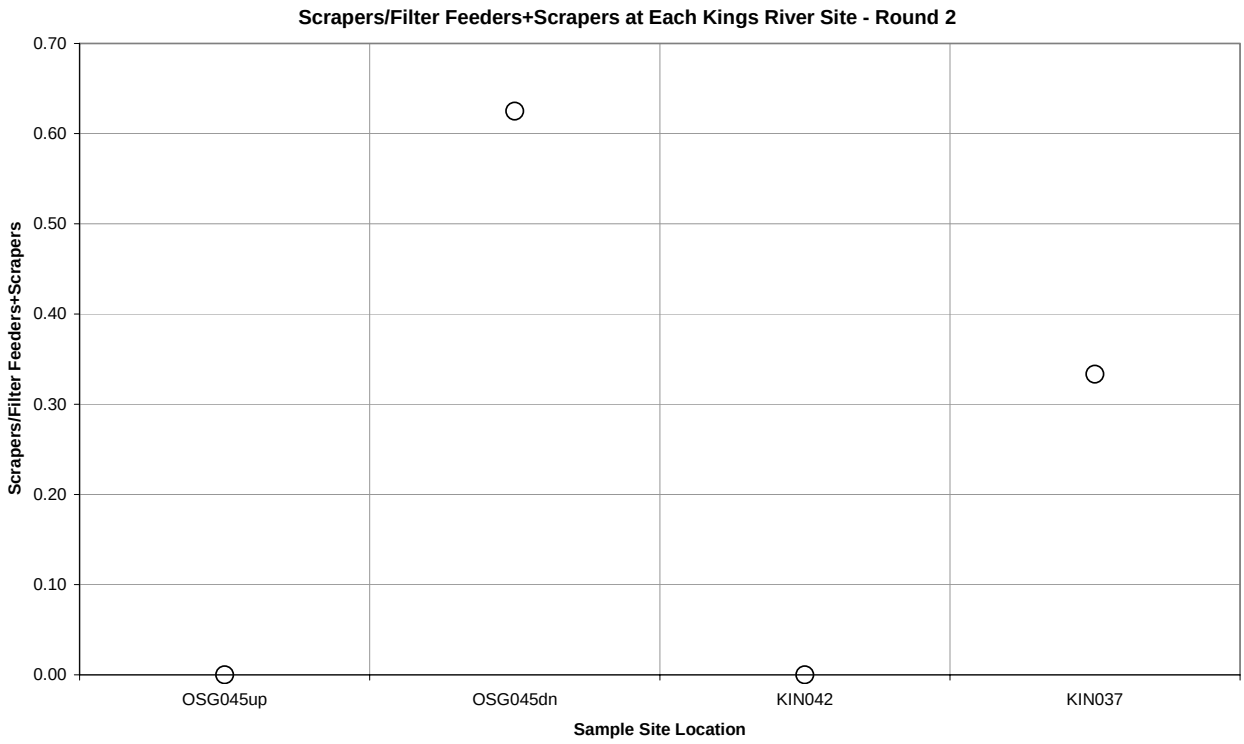
EPT/Chironomids + EPT. Many more Chironomids were collected on the Kings River during round two than in round one (Figure 4.26). In fact, more than 10 percent of KIN037 samples were Chironomids.

Figure 4.26 EPT/EPT Chironimids



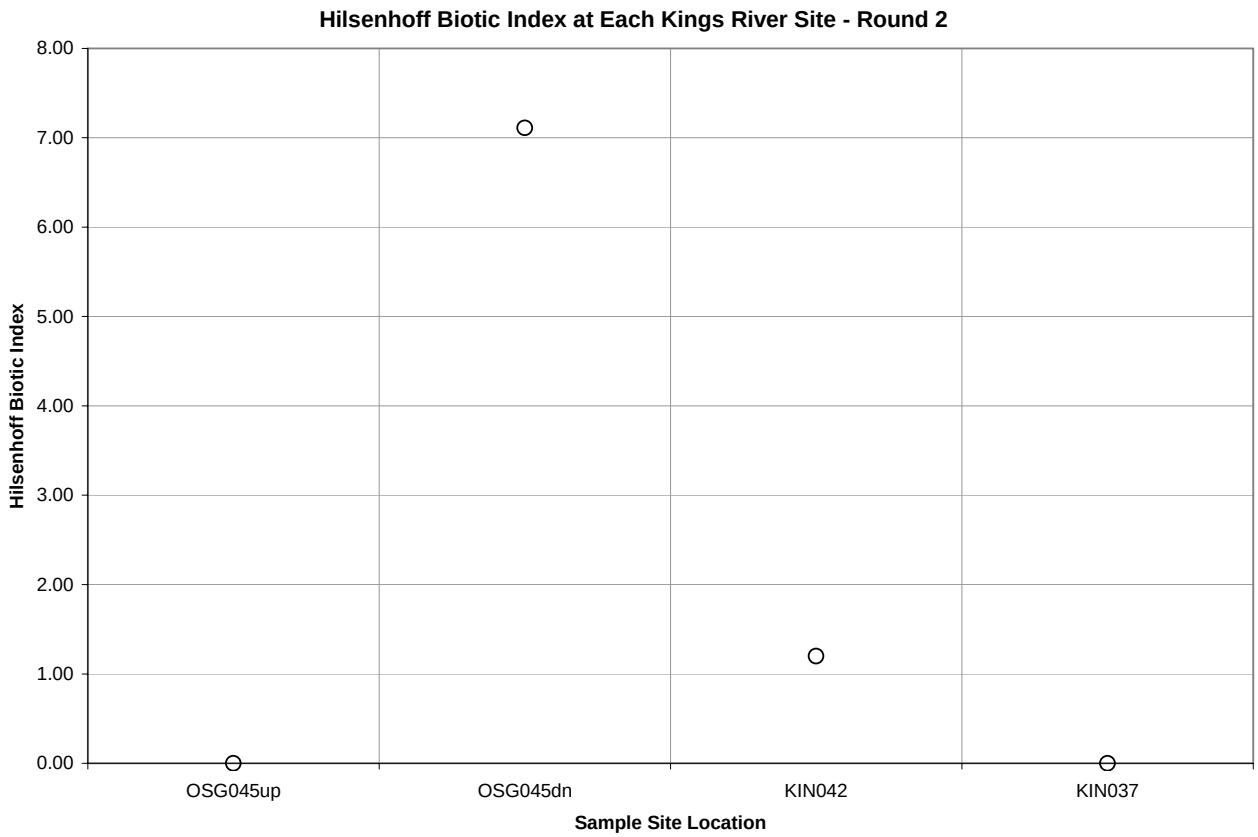
Scrapers/Scrapers + Filter Feeders. The FFG ratio at OSG045DN was higher during round two than round one (Figure 4.27). The FFG ratio of KIN037 was lower during round two compared with round one. These ratios may be reflective of flow regime and seasonal impacts more than water quality impacts during this sample period.

Figure 4.27 Scrapers/Scraper+Filterers



Hilsenhoff Biotic Index. HBI was the lowest measured during this assessment in the Kings River basin during round two sampling at KIN037 (1.20) (Figure 4.28). The highest HBI during round one was 5.2 at OSG045DN; during round two it was 7.1. The tolerance indices used were from the New Mexico Stream Assessment Guidelines, since those used by ADEQ in 1997 are not cited and not available. The HBI indicated that during round two, only OSG045DN in the Kings River was impacted.

Figure 4.28 HBI



Community Loss Index. CLI could not be measured due to lack of data from reference sites during round two; therefore, data are not reported.

4.4.3 Fish Collection

The diversity of fish communities was determined at all sites by use of the SWDI (Table 4.13). The SWDI threshold for the most impacted fish communities across all sites was 2.30, the fourth quartile distribution of SWDI from this sampling series. Fish communities were also evaluated by comparing metrics above and below the point source discharges at the City of Berryville WWTP (OSG0457UP and OSG45DN) using a modification of Odum's Similarity Index (Odum 1972) (Table 4.14) as described by

ADEQ (Illinois River Water Quality, Macroinvertebrate, and Fish Community Survey 1997). Fish community diversity was also evaluated by comparing fish sampling from sites at OSG45UP, OSG45DN, and KIN037 with the reference site at Kings River (KIN042). In the ADEQ 1997 study, anything less than 65 was used as the threshold for scoring a fish community as dissimilar to the reference condition. Raw fish data are presented in Appendix E.

Fish communities considered impacted using the SWDI of less than 2.30 for the first sampling event include OSG045UP and KIN042. The low diversity index of 1.86 at site OSG045UP appeared to be related to flow, which was impacted by a local bridge and thus uncharacteristic of the segment. For the second sampling event, only OSG045DN scored as impacted using this comparison, while the diversity index improved above 2.30 for OSG045UP and KIN042. Raw fish data are presented in Appendix E.

The second method used to compare collection results was the modified Odum's Similarity Index comparing sites upstream of WWTPs to downstream, and comparing each site with the reference site, with sites scoring less than 65 being categorized as impacted (scoring from ADEQ 1997 Report). During the first sampling event, OSG045UP was dissimilar to the downstream WWTP site (44.3 similarity index) and all sites were dissimilar to the reference site (37.9 to 63.6 similarity indices). During the second round of sampling, the indices for all the sites had improved to the reference site with the exception of KIN037. Results of OSG045UP compared to OSG045DN were dissimilar, but improved from the first round of sampling to 61.9 similarity index. Comparing each site to the reference site, OSG045UP and OSG045DN each had a community similar to the reference (76.9 and 66.6 similarity indices) and KIN037 was dissimilar with regard to the reference site (60.5 similarity index).

4.5 KINGS RIVER SUMMARY

Water Quality Field Measurements

Field measurements from the Kings River sampling locations indicate occasional occurrences of aquatic life stressors including low DO measurements, some results above the standard for 24-hour DO fluctuation, and a few DO % saturation values above 125 percent. While there were no temperature exceedances in any of the three sampling events, the higher temperature readings generally coincided with the low DO measurements that did not meet the criteria, as expected. There were however, unusual occurrences in the local air temperatures over the course of the three sampling events. The low water temperature readings measured at stations OSG045UP and OSG045DN on the second and third sampling events were verified and corresponded to significant decreases in the ambient air temperature prior to the sampling events.

Table 4.13 Fish Scoring Summary for Kings River- Shannon-Wiener Diversity Index

Site	OSG045UPa	OSG045DN	KIN037	KIN042
Event 1				
Total Species (Taxa)	14	23	25	17
Total Numbers	276	553	604	434
Effort (seconds)	2297	2497	4897	2532
Catch Rate (No./ minute)	7.2	13.3	7.4	10.3
No. Sensitive Species	5	4	4	6
No. Sensitive Individuals	209	102	91	248
% Cyprinidae	2.5	60.4	73	74.7
% Catostomidae	15.6	7.6	2	3.2
% Ictaluridae	0.7	0.5	2.5	0.5
% Centrarchidae	79.7	16.6	14.6	16.8
% Percidae	1.1	12.3	4.5	3.2
No. Primary TFL	0	211	347	322
% Primary TFL	0	38.2	57.5	74.2
No. Key Individuals	54	120	115	29
% Key Individuals	19.6	21.7	19	6.7
Shannon-Wiener Diversity Index	1.86	3.26	2.40	2.28
Event 2				
Total Species (Taxa)	26	20	19	20
Total Numbers	372	539	521	430
Effort (seconds)	2365	2420	1848	2829
Catch Rate (No./ minute)	9.4	13.4	16.9	9.1
No. Sensitive Species	6	4	5	5
No. Sensitive Individuals	128	41	199	137
% Cyprinidae	62.4	88.1	80.4	66.3
% Catostomidae	4.3	3	0.6	1.9
% Ictaluridae	1.1	0.4	0.6	0.5
% Centrarchidae	23.4	5	8.6	17.7
% Percidae	4.6	2.4	9.2	6.3
No. Primary TFL	128	42	166	137
% Primary TFL	34.4	7.8	31.9	31.9
No. Key Individuals	114	443	122	38
% Key Individuals	30.6	82.2	23.4	8.8
Shannon-Wiener Diversity Index	3.24	1.46	2.74	2.93

* Time was not confirmed and estimated for calculation purposes.

[a] Flows at the site sampled during the first round were determined to be impacted by a local bridge and thus uncharacteristic of the reach. The site was relocated upstream of the bridge for second-round sampling.

= Shaded as "Impacted" if Shannon-Weiner Diversity Index is < 2.30 (first quartile)

Table 4.14 Fish Collection Comparison on Kings River - Odum's Similarity Index

FIRST SAMPLING

SITE – sampling date	SITE – sampling date	SIMILARITY INDEX
OSG045up 9-20-03	OSG045dn 10-19-03	44.3
OSG045up 9-20-03	KIN042 9-20-03	37.9
OSG045dn 10-19-03	KIN042 9-20-03	63.6
KIN037 10-15-03	KIN042 9-20-03	62.8

SECOND SAMPLING

SITE – sampling date	SITE – sampling date	SIMILARITY INDEX
OSG045up 11-22-03	OSG045dn 11-22-03	61.9
OSG045up 11-22-03	KIN042 11-22-03	76.9
OSG045dn 11-22-03	KIN042 11-22-03	66.6
KIN037 11-29-03	KIN042 11-22-03	60.5

Site Comparisons based on Odum Similarity Index modified = Σ C / A + B + D
Σ C = sum of the proportions of species common to both sample A and sample B
A = total proportions of sample A (=100)
B = total proportions of sample B (=100)
D = sum of the differences of the proportions of species common to sample A and B

Water Quality Chemical Results

Nutrient parameter results at the site downstream of the Berryville WWTP discharge (OSG045DN) were almost all higher in concentration than the respective upstream location (OSG045UP). All nitrate-nitrogen values were lower than ADEQ Reg 2 criteria of 10 mg/L for the Kings River locations. Nitrate concentrations ranged from 0.05 to 0.554 mg/L, with the highest values at OSG045DN (0.554 and 0.539 mg/L).

TP values on the Kings River ranged from 0.014 to 1.824 mg/L. TP exceeded the ADEQ guideline of 0.1 mg/L for all events downstream from the Berryville WWTP (OSG045DN) and for two of the three events farther downstream at KIN037. Comparing data collected to the ADEQ TP narrative guideline of 0.1 mg/L resulted in five exceedances (42%) of the 12 TP data points. Comparing TP data collected on the Kings River to the USEPA Ecoregion reference value of 0.05 mg/L for the Kings River results

in seven TP exceedances (58%) of the 12 total data points (USEPA 2003). The reason for the excessively high concentrations of TN, ortho phosphate, and TP at OSG045DN is most likely related to loadings contributed by the Berryville WWTP, however nonpoint source runoff may also be contributing these constituents of concern.

TOC values from all locations over all three events ranged from 0.78 to 4.80 mg/L. TOC concentrations almost doubled from OSG045UP to OSG045DN, and then decreased downstream at KIN037. All TDS values at KIN037 and OSG045DN exceeded the criterion. Turbidity ranged from 1 to 5 NTUs with the two highest turbidity measurements at OSG045UP (5 NTUs each).

Stream Habitat Characterization

For both events and both riffle and pool sections on the Kings River, none of the sites had values lower than 75 percent of the reference site score for either of the two events, hence, none of the Kings River sites are categorized as impacted for stream habitat.

Periphyton

Periphytic growth for the first event on the Kings River was the same at KIN042 (reference site for the Kings River), KIN037 and OSG045-DN. However, site OSG045-UP, located above the Berryville WWTP, showed elevated primary productivity. Primary productivity at the sites in this basin is limited by something other than nutrients, probably light.

Productivity at the Kings River sites on the second deployment were also similar during the first deployment, with the exception of OSG045-UP, which had suggested P-limitation in September, and showed elevated productivity but no nutrient limitation in October. Primary productivity during the second round of Matlock Periphytometers at all Kings River sites was limited by something other than nutrients as well.

Benthic Macroinvertebrate Collection

The benthic macroinvertebrate community data are an integrated direct measure of physico-chemical condition and habitat condition of the stream. For the purpose of this assessment, an integrated scoring for benthic macroinvertebrates was utilized. Metrics that represented community-level responses in biota were selected. Metrics that were progressive, that is, where increasing scores reflected improving conditions, were inverted to provide regressive metrics. The integrated scoring for macroinvertebrates uses the following summation of four indices: [(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder]. Tables 4.11 and 4.12 show the result of this score for each site. These scores are then compared to the scoring summation of the respective reference site. To judge impacts to the community at each site, the benthic macroinvertebrate community is designated as not impacted if the

scoring summation at the site was greater than 83 percent of the score of the reference site (ADEQ 1997).

During round one sampling, *taxa* richness across all Kings Rivers sites was relatively similar, ranging from 16 to 19 *taxa* per site. The HBI at all four Kings River sites indicated serious water quality impact to the macroinvertebrate community. The macroinvertebrate community at OSG045UP is slightly impacted as demonstrated by the reference site comparison score of 79.7 (Table 4.11); however, the scores represent acceptable habitat quality.

Taxa richness in the two sites sampled during round two on the Kings River was lowest at OSG045DN (8 *taxa*) while KIN037 was similar to round one sampling, at 15 *taxa* per site. The HBI values during round two improved were significantly different compared to results from round one. The 7.1 HBI value at OSG045DN indicated a further decline in water quality at this site and the 1.2 HBI value at KIN037 indicated marked improvement from round one. As previously stated, neither the regional reference site on the Kings River (KIN042) nor the upstream site (OSG045UP) were successfully sampled in the second round due to persistent high flows. This factor limits the utility of the reference site comparison score from the second event for both OSG045DN and KIN037 shown on Table 4.12. Since there was no way to calculate an integrated score for the reference site KIN042 in the second sample event, the scores shown at the bottom of Table 4.12 for OSG045DN and KIN037 were calculated by using the integrated score for KIN042 from the first sampling event. This approach is based on the premise that the score from the first event for KIN042 represents an acceptable reference condition for the other Kings River sampling sites.

Fish Collection

The 1997 ADEQ Report used the Odum Similarity Index and the Shannon-Weiner Diversity Index for determining fish community impacts. For the purposes of this assessment however, only the SWDI was used to determine impacts because it is considered a more contemporary and quantitative assessment tool. The results of the Odum Similarity Index are provided below and in Table 4.14 above for informational purposes only.

Shannon Wiener Diversity Index Results:. For this investigation, fish communities are compared using the SWDI. Fish communities are considered impacted if the SWDI is less than 2.30. Fish communities considered impacted using the SWDI of less than 2.30 for the first sampling event include OSG045UP and KIN042. Only OSG045DN scored as impacted using this comparison for the second sampling event.

Odum's Similarity Index Results: The second method of evaluation for fish collection results uses the modified Odum's Similarity Index, comparing sites upstream of WWTPs to downstream, and comparing each site with the reference site, with scores of less than 65 being categorized as impacted. The modified Odum Similarity Index data were not considered in scoring the condition of the sites for this investigation, however

the Odum Similarity Index was calculated to allow comparison with the 1997 ADEQ Report results.

During the first sampling event, OSG045UP was dissimilar to the upstream WWTP site, and all sites were dissimilar to the reference site. During the second round of sampling, the indices for all the sites had improved with the exception of KIN037. Results of OSG045UP compared to OSG045DN were dissimilar. Comparing each site to the reference site, OSG045UP and OSG045DN each had a community similar to the reference and KIN037 was dissimilar with regard to the reference site.

Summary of Stream Aquatic Life Assessment

Table 4.15 presents a summary of the scoring for each site, media type, and event, which may be utilized in the weight-of-evidence approach in evaluating the status of aquatic life use attainment of the of the Kings River and its tributaries.

Table 4.15 Summary of Stream Aquatic Life Assessment Scoring for the Kings River

First Sampling Event (first event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Impacted
OSG045DN	Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Not Impacted
KIN037	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted
KIN042 Reference Site	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Reference	Impacted

Second Sampling Event (second event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	Not Impacted
OSG045DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	Not Impacted	Not Impacted	NS	NS	Impacted	Impacted
KIN037	Not Impacted	Impacted	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	Not Impacted	Not Impacted
KIN042 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	Not Impacted

Third Sampling Event (third event for each media)

	Water Quality Measurements					Habitat Characterization		Biological Characterization			
Reach ID	**Dissolved Oxygen Minimum**	**Dissolved Oxygen Fluctuation**	**Dissolved Oxygen Saturation**	**Nitrate Nitrogen Concentration**	**Phosphorous Concentration**	**Riffle[1]**	**Pool**	**Periphyton Presence**	**Filamentous Algae Presence**	**Macroinvertebrate Community**	**Fish Community**
OSG045UP	Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS
OSG045DN	Not Impacted	Impacted	Impacted	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
KIN037	NA	NA	NA	Not Impacted	Impacted	NS	NS	NS	NS	NS	NS
KIN042 Reference Site	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Not Impacted	NS	NS	NS	NS	NS	NS

NA = Not Applicable, equipment mulfunction.
NS = Not Sampled: water level too high for wading, no riffle for sampling macroinvertebrates, not in scope of work for sampling.
D.O. Fluctuation Scoring (in a 24 hour period): <=3.0 mg/L fluctuation = Not Impacted, >3.0 mg/L fluctuation = Impacted
D.O. Saturation Scoring: <125% = Not Impacted, >125% = Impacted
Periphyton Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Filamentous Algae Presence Scoring: Rare or Present Occurrence = Not Impacted; Present/Common, Common, or Dense Occurrence = Impacted
Nitrogen Concentration Scoring: < 10 mg/L nitrate nitrogen = Not Impacted, >= 10 mg/L = Impacted
Phosphorous Concentration Scoring: Total Phosphorous <=100.0 ug/L = Not Impacted, >100.0 ug/L = Impacted (Arkansas, Regulation 2, Oct 2002, guideline only)
Habitat Condition Scoring: < 75% Reference Site(s) Score = Impacted; >= 75% Reference Site(s) Score = Not Impacted
Macroinvertebrate Integrated Scoring: Sum of 4 Indices: ([(1/HBI)*100]+[EPT Index]+[EPT/Chironomids+EPT]+[Scraper/Scraper+Filter Feeder];
Compared to pertinent Reference Site: >83% Reference Site = Not Impacted, <=83% Reference Site = Impacted
Fish Community Scoring: Shannon-Weiner Diversity Index < 2.30 (first quartile) = Impacted, >=2.30 = Not Impacted.
See Sections 2, 3, and 4 in report text for further description of scoring methodology and sampling dates.
Reference = Reference site, not scored against itself.
1 = Using Reference Based Rapid Bioassessment Analysis figure.

SECTION 5
DISCUSSION AND CONCLUSIONS

5.1 INTEGRATED ANALYSIS

Determining ecological quality from the many and varied measurements made during this assessment requires integration of key metrics. Therefore, results of the biotic and habitat assessments were integrated using a combination of key metrics compared with controls (Table 5.1). Wherever possible, metrics used in this report were based on State or USEPA guidelines and procedures. Absent those guidelines, metrics that represented community-level responses in biota were selected. Metrics that were progressive, that is, where increasing scores reflected improving habitats, were inverted to provide regressive metrics. The X- and Y- axis were represented as percent of reference for each integrated metric. The Y-axis, Biological Condition, was presented as the sum of each of the parameters for fish, benthic macro-invertebrates, and algae, presented as a percent of Reference Sites (0-100% range). Similarly, the X-axis, Habitat Condition, was presented as the sum of Riffle and Pool RBA scores, as a percent of the Reference Sites (0-100% range). Thus, RBA protocol habitat scores from riffles and pools were aggregated to provide habitat quality. These data were analyzed by plotting the biological condition as a percent of each designated reference site with the habitat quality as a percentage of each designated reference site. The plot included designated stream condition zones for each variable (Barbour *et al.* 1990). The data used for these plots are presented in Sections 3 and 4 of this report.

Table 5.1 Integrated Analysis Metrics for Calculating Habitat Quality and Biological Condition

Fish	Benthic Macroinvertebrates	Algae	Habitat
1/S-W Index*100	1/HBI*100	1/Chlorophyll *a*	Riffle RBA
% Primary TFL	EPT Index		Pool RBA
% Key Individuals	EPT / Chironomids +EPT		
	Scraper / Scraper + Filter Feeder		

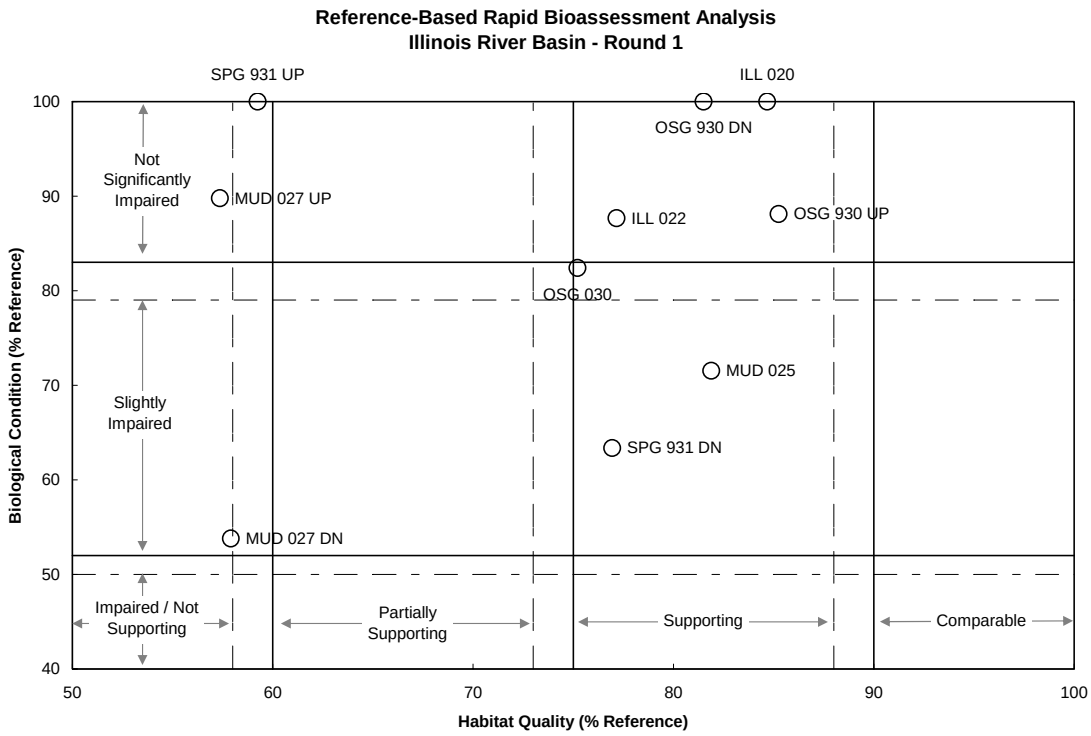
5.1.1 Illinois River

First Round

The integrated analysis of water quality and ecological quality of the first round of sampling in the Illinois River suggested that the water body most impacted was MUD027DN, immediately downstream of the Prairie Grove WWTP. As summarized in Table 3.13, this site demonstrated impacts in all four major categories of metrics: 1) water quality measurements (DO excursions); 2) water chemistry analysis (elevated concentrations of P); 3) habitat characteristics and 4) biological characteristics. Figure 5.1 provides further demonstration of the poor habitat quality and impacted biological community at this site during the first sampling event. Integration of these different metrics supports a weight-of-evidence that the aquatic life use of Muddy Fork is

impacted by a variety of stressors. The site was characterized by long runs with silt loam substrate, high-suspended solids, deeply entrenched stream bank, heavy impact from roads and housing, and high nutrient loads (see photographs in Appendix F). The site upstream of the Prairie Grove WWTP outfall (MUD027UP) had similar habitat quality, but had significantly better biological condition, relative to the reference site (FLT031) (Figure 5.1). The site upstream of the Prairie Grove WWTP outfall (MUD027UP) also had slightly improved water quality field measurement results. The Spring Creek site above Springdale's WWTP outfall (SPG931UP) showed no difference in biological condition relative to the control, but was impacted by periphyton presence, excessive P concentrations, and significant habitat alteration from urbanization in the area (see photographs in Appendix F). In Figure 5.1, the site downstream of the Springdale WWTP (SPG931DN) showed similar habitat as all but three sites, yet the biological condition was only better than MUD027DN when compared with the reference site (FLT031), suggesting that something other than habitat may be affecting biotic condition. The middle watershed sites (OSG030 and MUD025) also displayed slight biological impacts, and habitat quality showed no impacts when compared with their reference site (SPA048). The remaining four sites (OSG930UP, OSG930DN, ILL020, and ILL022) were not significantly impacted biologically, and had acceptable habitat quality.

Figure 5.1 Integrated Analysis - Illinois River, Event 1



The primary *loci* of habitat impacts throughout the system were riffle habitats. This sampling event occurred during the critical low flow period (August-September 2003), so lack of base flow was a major contributing factor to loss of habitat in many of these streams. The general improvement of habitat quality from upstream to downstream across all but the Rogers WWTP sites (OSG930UP and DN) reflects flow-driven improvements in habitat quality.

Two sites showed degraded habitat quality, but the biological community did not manifest any discernable impacts (SPG931UP and MUD027UP). When sampled, these sites demonstrated sufficient water quality capable of supporting a more robust biota. However, both stations are located in urban areas, have altered hydrologic flow regimes, and could change to impaired very quickly in response to diminishing water quality. From an ecosystem perspective, these sites are in a transition state, and likely at risk (see Leuben and Poudevigne 2002, in region L on Figure 5.2).

Figure 5.2 Ecosystem Stability

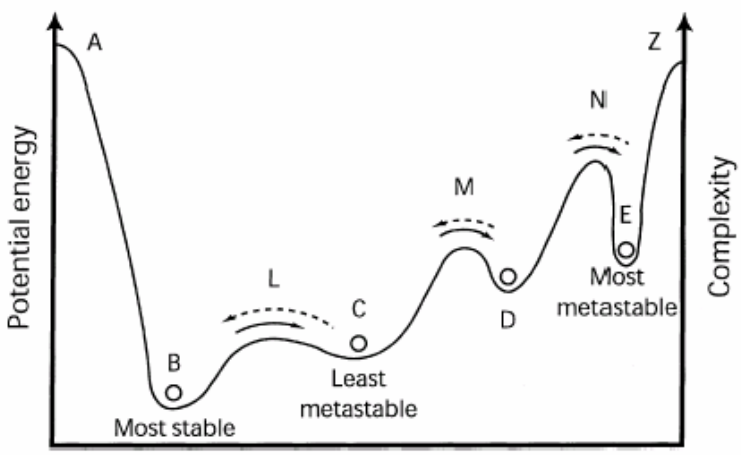


Fig. 1 Stability states of ecosystems in terms of potential energy or complexity (adapted from Godron & Forman, 1983). Point B is the most stable. Points C, D, and E are metastable. Points A, L, M, N and Z are unstable. The transitions from B to C and to E are difficult, but increase the degree of metastability; such a progression corresponds to a series of successional stages that begins with the most stable state, moves rapidly to the least stable state, and thereafter gradually increase its metastability. Transitions from E to D, to C and to B are less difficult; they correspond to a degradation of the ecological system.

This figure, from Rob Leuven and I. Poudevigne's article "Riverine landscape dynamics and ecological risk assessment" (Freshwater Biology 2002) captures the

complexity of predicting ecosystem shift – the process is non-linear, unstable, and complex. Systems are resilient to change until a threshold is reached, at which time they become transitional, and unstable. When water bodies are near their individual threshold, change to a more degraded state can happen very quickly with very little additional perturbation.

Ecological quality at the three sites (SPG931DN, OSG030 and MUD025) is significantly influenced by water quality. These sites had moderate to high nutrient enrichment with opening canopy and increased flow. While these three sites currently have acceptable habitat quality and a slightly degraded biologically community, if habitat or water chemistry at these sites are further impacted, the ecological quality of these sites will degrade rapidly.

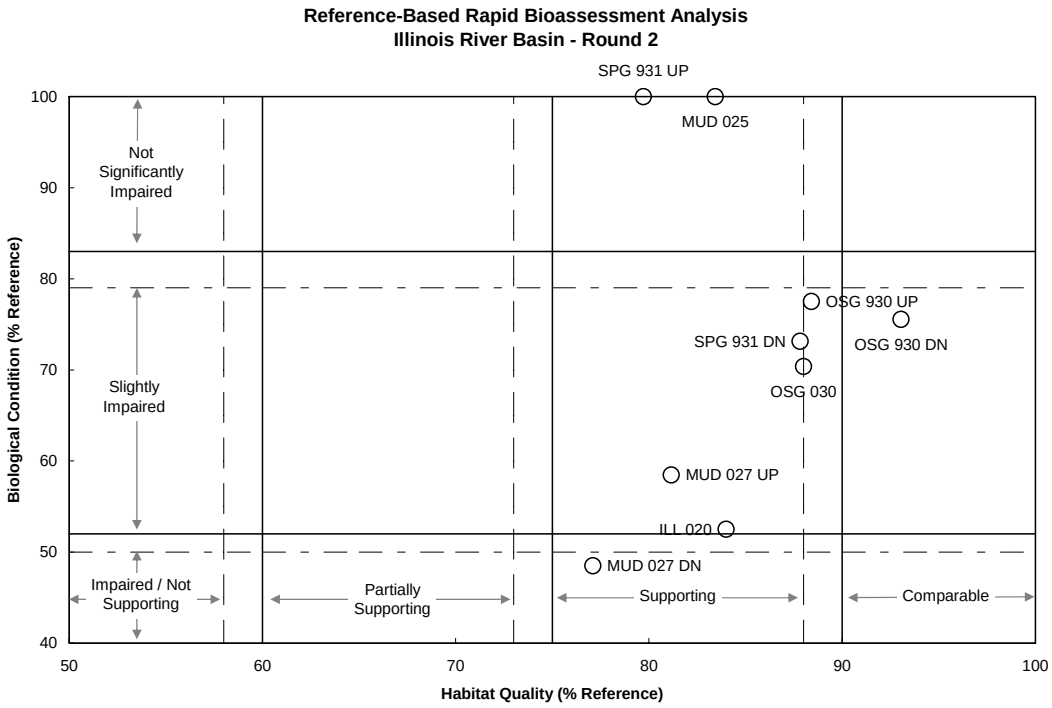
Ecological quality at the upper reach of Osage Creek above and below the Rogers WWTP (OSG930UP and DN) was stable and of sufficient quality. It should be noted that these sites have increased sediment loads from a soil quarry immediately upstream of the sites. This quarry is currently unregulated, with a notable plume of silt and clay loading to the stream channel emanating from the site. This and other sources of sediment can shift the biological condition to impacted, and significantly degrade habitat conditions.

The ecological quality of the downstream most sites in the Arkansas side of the Illinois River basin (ILL020 and ILL022) was stable, not significantly impacted biologically, and with supporting habitats. These sites had elevated nutrients, but had stable high flows, and robust fish and macroinvertebrate communities. However, the high periphyton productivity and P concentrations at these two downstream sites suggest the potential for high algal growth if riparian habitat is altered so that light exposure increases.

Second Round

The integrated analysis of ecological quality of the second round of sampling in the Illinois River illustrated the effects of low flow on habitat and biotic condition in the Illinois River basin (Figure 5.3). Increased flow resulting from rains that began in late August resulted in an overall increase in habitat scores relative to the reference sites. The three sites with the most impacted habitat during round one (SPG931UP, MUD027UP and MUD027DN) moved from “Not Supporting” in habitat to “Supporting” and the water quality conditions at these three sites improved only slightly. Biological condition at MUD025 also improved with increased flow; however, phosphorus concentrations increased possibly as a result of nonpoint source loading from rainfall runoff throughout the watershed. The biological condition of MUD027DN did not improve with increased flow; however, it decreased to “impaired.” MUD027UP and ILL020 also showed degraded biological condition during round two sampling.

Figure 5.3 Integrated Analysis - Illinois River, Event 2



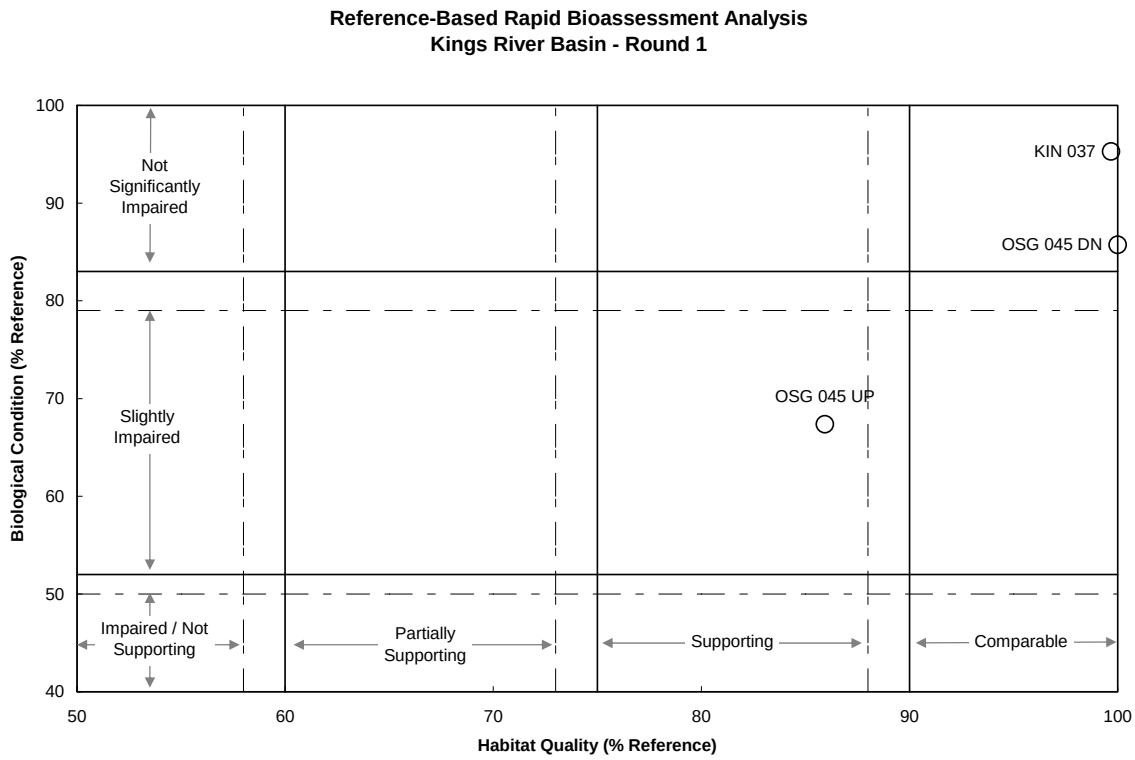
Water quality conditions expressed little change from the second monitoring event to the third event. Change in concentrations of P improved in only one site, MUD025.

5.1.2 Kings River

First Round

The integrated analysis of ecological quality of the first round of sampling in the Kings River suggested that the site most impacted was OSG045UP, immediately upstream of the Berryville WWTP (Figure 5.4). The presence of filamentous algae is a manifestation of the nutrient enrichment and habitat impact. This site had acceptable habitat quality and slightly impacted biological conditions relative to the reference site (KIN042). Water quality conditions were slightly degraded downstream of the Berryville WWTP (OSG045DN) as manifested by the excursions from the DO criteria and elevated P concentrations. This stream segment was characterized by long runs with bedrock substrate, deeply entrenched stream bank, heavy impact from roads and grazing, and loss of riparian vegetative cover (see photographs in Appendix F). The remaining sites were not significantly impacted biologically and had comparable habitat to the reference site.

Figure 5.4 Integrated Analysis – Kings River, Event 1



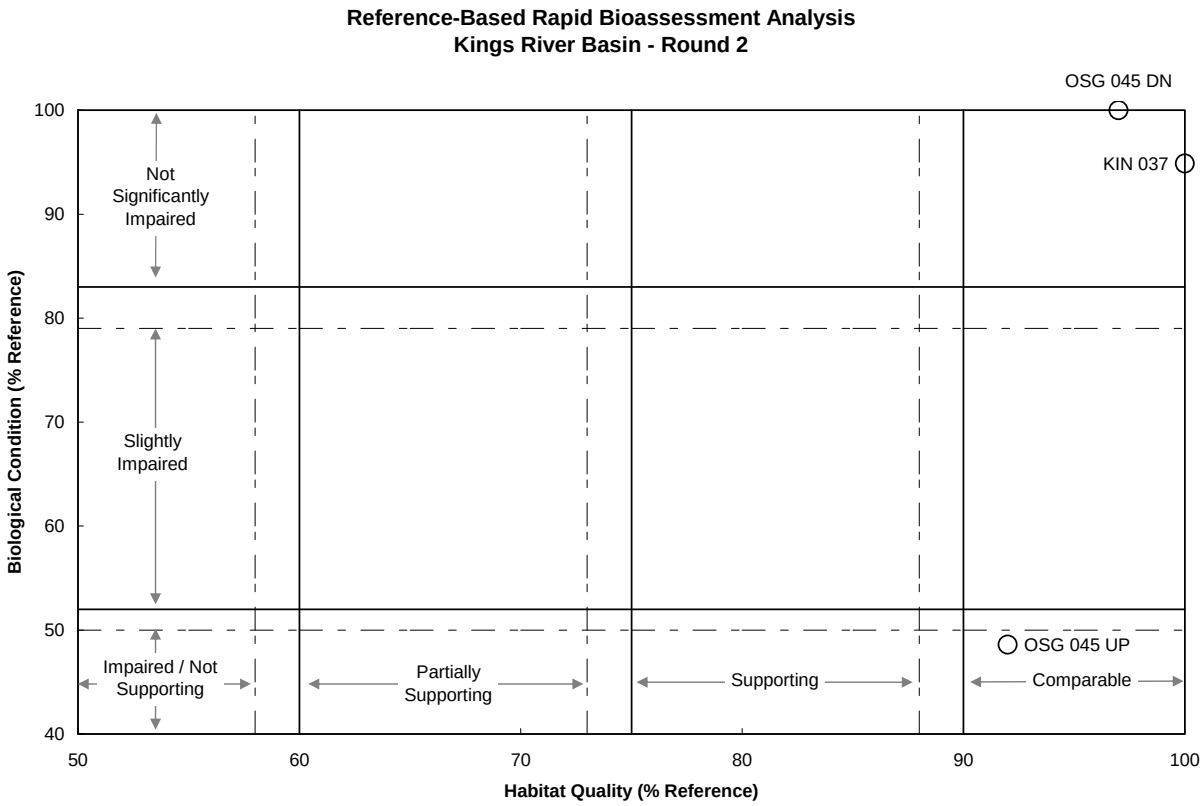
As with the Illinois River basin, the primary habitats of concern in the Kings River sites were riffle habitats. The riffle-pool geomorphology in these systems is shifting to long, extended runs, which will result in dramatic shifts in biota and habitat. This sampling event occurred during the critical low flow period (August-September 2003), so base flow was at its annual low in these streams. The general improvement of habitat quality from upstream to downstream of the WWTP (OSG045DN) reflects flow-driven improvements in habitat quality. Despite these low flow conditions, water quality was generally acceptable in the Kings River basin.

Second Round

The integrated analysis of ecological quality of the second round of sampling in the Kings River indicated that this system was less sensitive to flow during the extreme low flow condition of late August (Figure 5.5). Using the reference-based RBA diagram, both OSG045DN and KIN037 demonstrate biological and habitat conditions of acceptable quality. These two sites, KIN037 and OSG045DN, did not change significantly from round one to round two. Both sites remained comparable to the control site (KIN045) with regard to both biological condition and habitat quality. However, OSG045UP, the site manifesting the most significant habitat degradation, demonstrated some improvement in both biological and habitat condition during round

two. Water quality conditions during the second round remained unchanged except for DO concerns that were measured at KIN037.

Figure 5.5 Integrated Analysis – Kings River, Event 2



5.2 RESULTS OF THIS INVESTIGATION AND OTHER INVESTIGATIONS

5.2.1 Illinois River

Results of this investigation are consistent with those found by others studies conducted within the basin (see Appendices G, Ekka *et al.* 2003 and Nelson and Cash 2003 for example). The impact of WWTPs on instream SRP is clear (Figure 5.6). SRP concentration in streams below the Fayetteville (Mud Creek) and Rogers (Osage Creek) WWTPs increased from below 0.05 mg/L to about 0.10 mg/L over the sampling period between January 2001 and August 2003. Instream SRP in Flint Creek below the Siloam Springs WWTP increased from about 0.1 mg/L to greater than 1 mg/L. These sites are all downstream of the reference site FLT031. The greatest instream SRP impact came from the Springdale WWTP, where concentrations went from less than 0.1 mg/L to greater than 2 mg/L, with some measurements greater than 7.5 mg/L. It should be noted that those high P concentrations were measured prior to the agreement between Springdale and ADEQ to reduce TP discharge concentrations to below 1.0 mg/L.

Subsequent measurements made for this assessment showed TP concentrations dropped from 2.47 mg/L in August 2003 to 0.27 mg/L in October 2003.

Changes in mean water column SRP concentrations downstream from WWTP input are presented in Figure 5.6 as a function of distance at (a) Mud Creek (b) Spring Creek (c) Osage Creek, and (d) Sager/Flint Creeks. Error bars represent the standard deviations (from Ekka *et al*. 2003 Appendix G). These data clearly suggest a high level of impact on in-stream P concentrations from point sources in the Illinois River basin.

Ekka *et al.* 2003 (Appendix G) also showed that sediment in the streams is a sink for P in streams below WWTPs, and that sediments in Osage, Spring, Mud, and Sager Creeks are saturated with P. There was no measurable biological uptake of P in those streams for distances up to approximately 5 miles downstream. In addition, sediments from those streams downstream of the WWTPs released P in high amounts (Figure 5.7), suggesting that the sediments will act as a P source when instream P concentrations are decreased. The resulting impact of WWTP P discharge will be long-term availability of increased SRP in streams, even if the WWTP effluent concentration is relatively low.

Nelson and Cash 2003 evaluated 56 water samples in 2002 at ILL020, composed of base flow grab and flow-weighted composite storm samples (Appendix G). They found the total load of TP from the Illinois River basin at that site during that year was slightly over 240 tons, with a resulting mean concentration of 0.41 mg/L TP. They compared that data with data from previous studies and found the peak mean annual TP concentration in the Illinois River was 0.53 mg/L in 1999. Since that time, storm flow TP concentrations (NPS loads) have been decreasing, while base flow concentrations (PS loads) have remained the same. This indicates that nonpoint source loads of P have been responding to changes in best management practices implemented throughout the basin.

This report and previous water quality assessments of the Illinois River basin have resulted in the collection of a wide array of chemical, physical and biological data. The data available can be expressed in wide array of parameters (e.g., DO, TDS, P) and assessment metrics (e.g., pools, macroinvertabrate community). While a standard method for applying a weight-of-evidence approach to assess beneficial uses does not exist in Arkansas or USEPA Region 6, this report employs a rational mechanism for integrating the chemical, physical, and biological data collected under this project and drawing logical conclusions from the aggregated results. This report uses a simple algorithm to evaluate each water body based upon the proportion of indicators considered impacted per sample event. When a suite of indicators (e.g., DO, TDS, fish community) suggests aquatic life use impact more than one time, there is reasonable cause to characterize aquatic life at that site as impacted to some degree.

Eleven indicators divided into three categories, Water Chemistry, Habitat, and Biological Characteristics, were used to develop a weight-of-evidence summary for the Illinois River basin. Each of the eleven indicators were assessed relative to a reference condition, ADEQ Regulation 2 criteria, or USEPA guidance to determine if they were impacted within a reach during an assessment event.

An overall characterization of each site was compiled using the summation of impacted indicators for each site over the three sampling events. The results of this summary assessment for the Illinois River are provided in Table 5.2. Columns on the right side of Table 5.2 tally the total number of impacted indicators per event and then sum the impacted indicators for the three events combined for each site. If less than five of the indicators were determined to be impacted during the three sampling events, the sites were categorized as unimpacted. If between five and eight of the indicators were determined to be impacted, the site was categorized slightly impacted. If between nine and 12 of the indicators were impacted, the site was determined to be impacted. If more than 13 of the indicators were impacted, the sight was determined to be severely impacted. Based upon this weight-of-evidence approach, for the Illinois River sites, four sites scored as unimpacted, five sites scored as slightly impacted, two sites were determined to be impacted, and one was classified as severely impacted.

Table 5.2 Weight-of-Evidence Summary for the Illinois River Sites

Illinois River

Station	Sampling Event	Water Chemistry					Habitat		Biological Characteristics				Indicators Impacted (per event)	Total Number of Indicators Impacted (all events)	Conclusions (based on all events)
		DO min	DO fluct	DO Sat	TP	TDS	Riffle	Pool	Periphyton	Filamentous	Benthics	Fish			
OSG930UP	1	O	O	O	O	O	O	O	X	O	O	O	1	3	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	O	O	0		
	3	X	X	O	O	O	--	--	--	--	--	--	2		
OSG930DN	1	O	O	O	X	O	O	O	X	O	X	X	4	7	**Slightly Impacted**
	2	O	O	O	X	O	O	O	--	--	X	O	2		
	3	--	--	--	X		--	--	--	--	--	--	1		
SPG931UP	1	O	O	O	X	O	X	X	X	O	X	O	5	7	**Slightly Impacted**
	2	O	O	O	O	O	X		--	--	X	O	2		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
SPG931DN	1	--	--	--	X	X	X	O	X	X	X	X	7	16	**Severely Impacted**
	2	X	O	O	X	X	O	O	--	--	X	X	5		
	3	O	X	X	X	X	--	--	--	--	--	--	4		
OSG030	1	O	X	X	X	X	X	O	X	X	O	X	8	12	**Impacted**
	2	O	X	O	X	O	O	O	--	--	O	O	2		
	3	O	X	O	X	O	--	--	--	--	--	--	2		
MUD027UP	1	O	X	O	X	O	X	X	X	O	X	O	6	8	**Slightly Impacted**
	2	X	O	O	O	O	O	O	--	--	X	O	2		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
MUD027DN	1	X	X	X	X	O	X	X	O	O	X	O	7	12	**Impacted**
	2	O	O	O	X	O	X	O	--	--	X	O	3		
	3	--	--	--	X	X	--	--	--	--	--	--	2		
MUD025	1	X	X	O	O	O	X	O	X	O	O	O	4	7	**Slightly Impacted**
	2	X	X	O	X	O	O	O	--	--	O	O	3		
	3	--	--	--	O	O	--	--	--	--	--	--	0		
ILL022	1	O	X	O	X	O	X	O	X	O	--	O	4	6	**Slightly Impacted**
	2	O	O	O	X	O	O	O	--	--	--	--	1		
	3	--	--	--	X	O	--	--	--	--	--	--	1		
ILL020	1	O	O	O	X	O	O	O	X	O	O	O	2	4	**Unimpacted**
	2	O	O	O	X	O	O	O	--	--	O	--	1		
	3	--	--	--	X	O	--	--	--	--	--	--	1		
SPA048	1	O	O	O	O	O	O	O	X	O	O	O	1	1	**Unimpacted**
	2	O	O	O	O	O	O	O	--	--	O	O	0		
	3	--	--	--			--	--	--	--	--	--	0		
FLT031	1	O	O	O	O	O	O	O	O	O	O	O	0	2	**Unimpacted**
	2	O	X	O	O	O	O	O	--	--	O	O	1		
	3	O	O	X	O	O	--	--	--	--	--	--	1		

X = Indicates Impacted
O = Indicates Unimpacted -- = not sampled or equipment malfunction
Scoring for Summary:
Summation of three events of impacted indicators: 0 to 4 impacted = "unimpacted"; 5 to 8 impacted = "slightly impacted"; 9 to 12 impacted = "impacted"; 13 or more impacted = "severely impacted."

Figure 5.6 Soluble Reactive Phosphorus in Illinois River Basin Streams from Ekka et al.

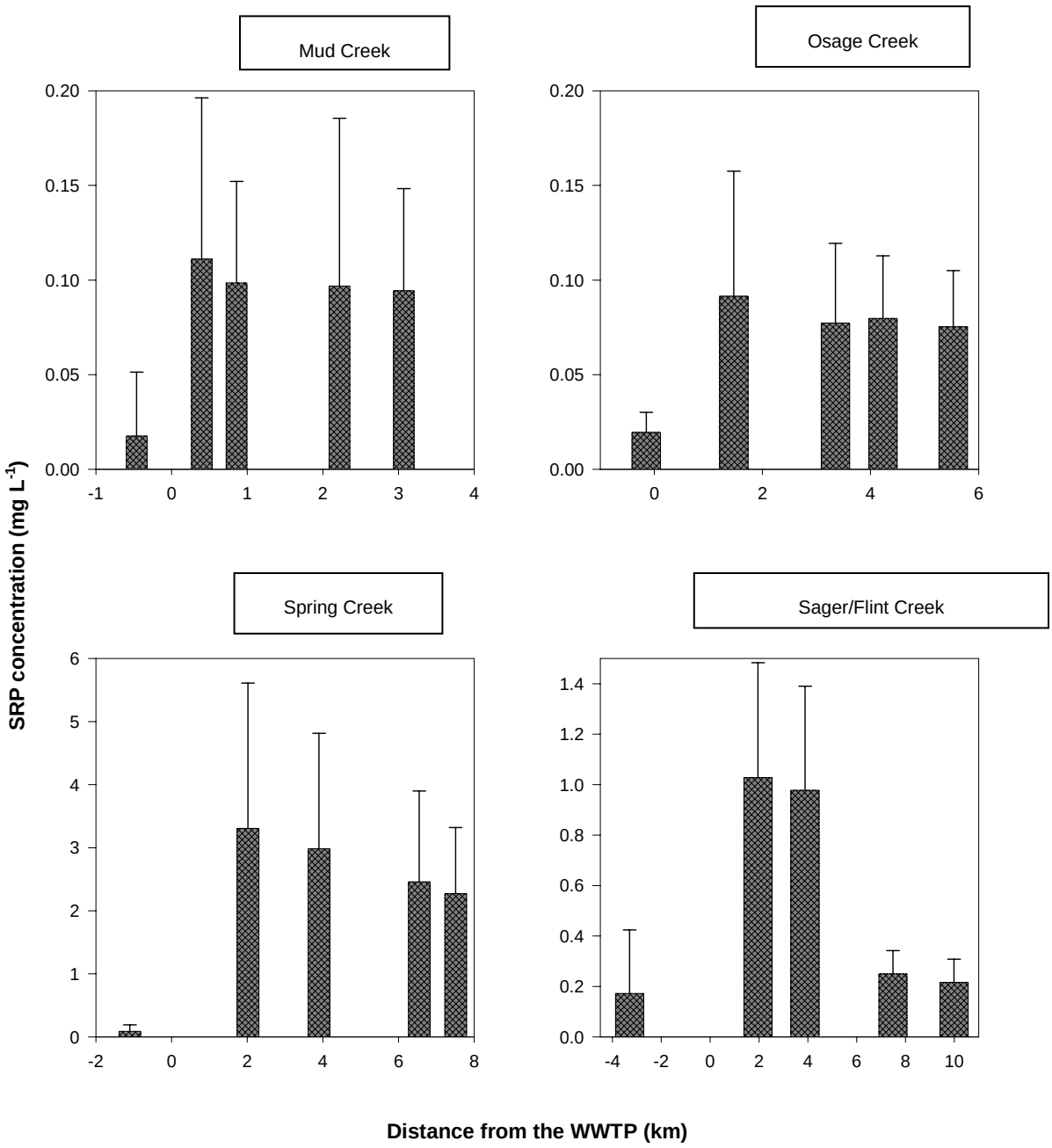
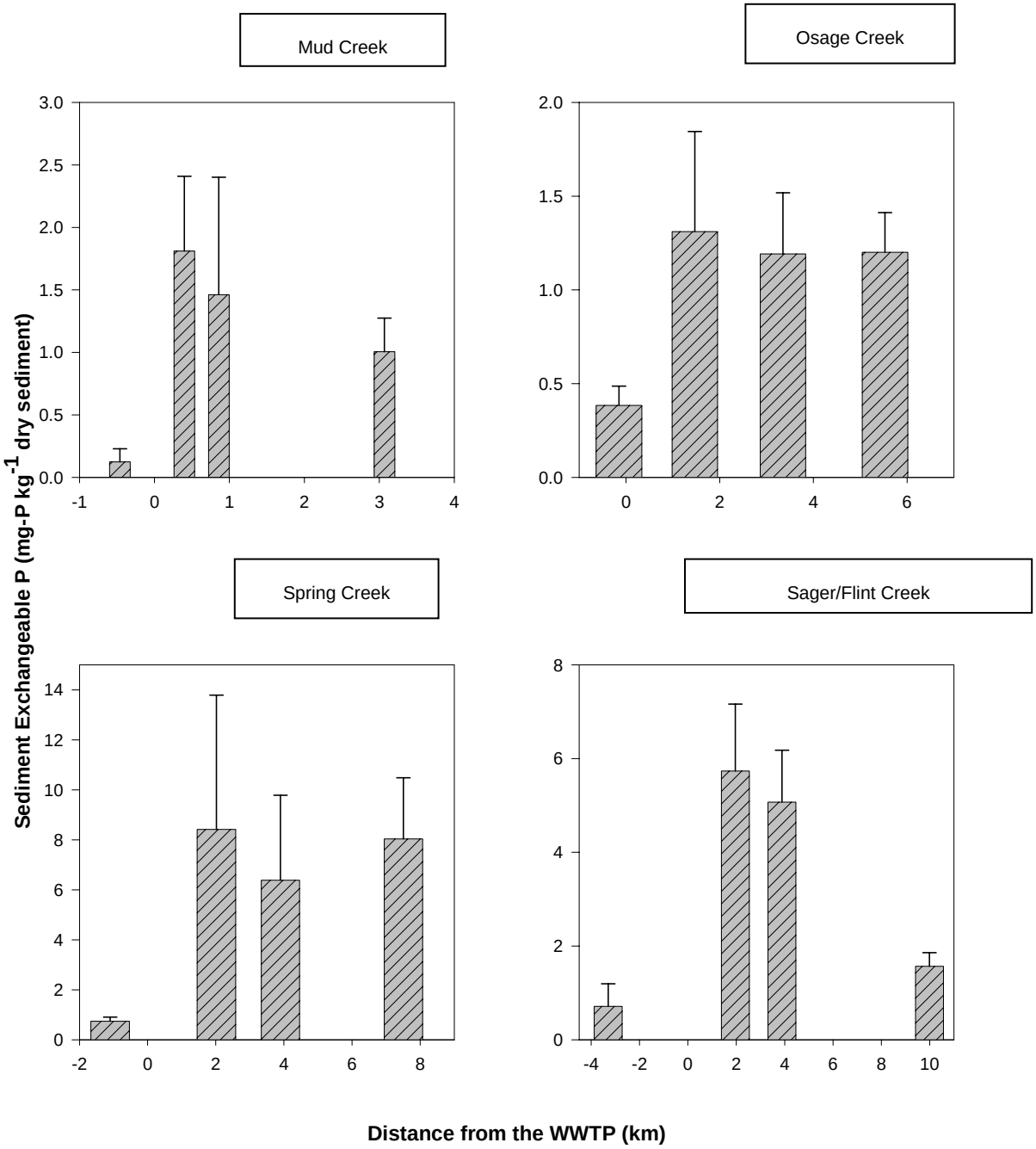


Figure 5.7 Easily Exchangeable Phosphorus Illinois River



Easily exchangeable P (EXP) at: (a) Mud Creek (b) Spring Creek (c) Osage Creek, and (d) Sager/Flint Creeks upstream and downstream of the municipal WWTP.

5.2.2 Kings River

The Kings River flows from Arkansas into Table Rock Lake in Missouri (see Appendix H for select reports on the Kings River basin). The Missouri Department of Natural Resources (MDNR) proposed adding the lake to its 303(d) list in 2002 for nutrients (P). Sampling at the Kings River arm of Table Rock Lake from 1992-2002 showed that segment to be consistently eutrophic (Appendix H). Nutrient monitoring by MDNR during 2002 showed P concentrations on average at 0.1 mg/L, and on occasion in excess of 0.2 mg/L in the Kings River arm. These levels are of concern to the MDNR, as they are adequately high to cause increased eutrophication of the reservoir.

This report and previous water quality assessments of the Kings River basin have resulted in the collection of a wide array of chemical, physical and biological data. The data available can be expressed in wide array of parameters (e.g., DO, TDS, P) and assessment metrics (e.g., pools, macroinvertabrate community). While a standard method for applying a weight-of-evidence approach to assess beneficial uses does not exist in Arkansas or USEPA Region 6, this report employs a rational mechanism for integrating the chemical, physical, and biological data collected under this project and drawing logical conclusions from the aggregated results. This report uses a simple algorithm to evaluate each water body based upon the proportion of indicators considered impacted per sample event. When a suite of indicators (e.g., DO, TDS, fish community) suggests aquatic life use impact more than one time, there is reasonable cause to characterize aquatic life at that site as impacted to some degree.

Eleven indicators divided into three categories, Water Chemistry, Habitat, and Biological Characteristics, were used to develop a weight-of-evidence summary for the Kings River basin. Each of the eleven indicators were assessed relative to a reference condition, ADEQ Regulation 2 criteria, or USEPA guidance to determine if they were impacted within a reach during an assessment event.

An overall characterization of each site was compiled using the summation of impacted indicators for each site over the three sampling events. The results of this summary assessment for the Kings River are provided in Table 5.3. Columns on the right side of Table 5.3 tally the total number of impacted indicators per event and then sum the impacted indicators for the three events combined for each site. If less than five of the indicators were determined to be impacted during three sampling events, the sites were categorized as unimpacted. If between five and eight of the indicators were determined to be impacted, the site was categorized slightly impacted. If between nine and 12 of the indicators were impacted, the site was determined to be impacted. If more than 13 of the indicators were impacted, the sight was determined to be severely impacted. Based upon this weight-of-evidence approach, for the Kings River sites, two sites scored as unimpacted, one site scored as slightly impacted, and one site was classified as severely impacted (Table 5.3).

Table 5.3 Weight-of-Evidence Summary for Kings River Sites

Kings River

Station	Sampling Event	Water Chemistry					Habitat		Biological Characteristics				Number of Indicators	Total Number of Indicators Impacted (all	Conclusions (based on all events)
		DO min	DO fluct	DO Sat	TP	TDS	Riffle	Pool	Periphyton	Filamentous	Benthics	Fish			
OSG045UP	1	O	O	O	O	O	O	O	O	X	O	X	2		
	2	O	O	O	O	O	O	O	--	--	--	O	0	3	**Unimpacted**
	3	X	O	O	O	O	--	--	--	--	--	--	1		
OSG045DN	1	X	X	O	X	X	O	O	O	X	X	O	6		
	2	O	X	X	X	X	O	O	--	--	X	X	6	16	**Severely Impacted**
	3	O	X	X	X	X	--	--	--	--	--	--	4		
KIN037	1	O	O	O	X	X	O	O	X	O	O	O	3		
	2	O	X	X	O	X	O	O	--	--	O	O	3	8	**Slightly Impacted**
	3	--	--	--	X	X	--	--	--	--	--	--	2		
KIN042	1	X	O	O	O	O	O	O	O	X	O	X	3		
	2	O	O	O	O	O	O	O	--	--	--	O	0	3	**Unimpacted**
	3	O	O	O	O	O	--	--	--	--	--	--	0		

X = Indicates Impacted
O = Indicates Unimpacted -- = not sampled or equipment malfunction
Scoring for Summary:
Summation of three events of impacted indicators: 0 to 4 impacted = "unimpacted"; 5 to 8 impacted = "slightly impacted"; 9 to 12 impacted = "impacted"; 13 or more impacted = "severely impacted."

5.3 OVERALL ECOLOGICAL CONDITIONS

5.3.1 Illinois River

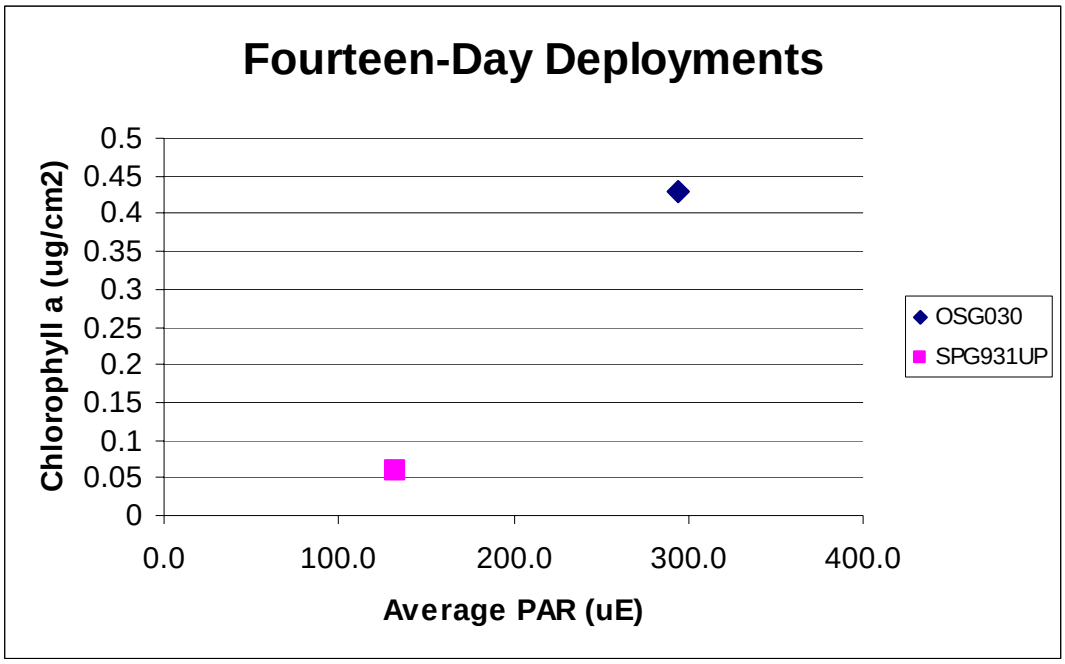
The data assessment provided by this report and represented in other studies of the Illinois River basin demonstrate diminishing water and habitat quality caused by direct and indirect discharges to the streams and ongoing human alterations of the landscape. Multiple stressors at multiple scales are affecting the river system at all times. The overall ecological condition of the water bodies in the Illinois River basin clearly displays water quality, habitat quality, and biological community impacts.

Streams in the Illinois River basin are nutrient enriched by WWTPs in the region. While nonpoint source loads also contribute significant nutrient loading to the streams, the sampling approach of this project was not designed to identify and quantify nonpoint sources of nutrient and sediment loading. The ecological impact of nutrient enrichment, regardless of the sources, is generally not manifested in Ozark Plateau streams, primarily due to intact riparian zones resulting in light limitation for algal growth. Algal growth on nutrient enriched passive diffusion periphytometers at OSG030 (relatively open canopy) and SPG931UP (relatively closed canopy) demonstrated that algal growth was light limited, consistent with upland streams in the Ozark Plateau ecoregion (Figure 5.8).

The role of stream habitat, especially riparian zones, in protecting and maintaining aquatic life use in these systems cannot be overstated. Loss of riparian zone cover in streams that are nutrient enriched will result in dramatic increases in algal production, shifts in algal communities to filamentous species, shifts in benthic community functional feeding groups, and shifts in fish communities to grazers. As riparian buffers are removed across the Ozark Plateau, streams are exposed to direct sunlight and increased

water temperatures. Both of these variables increase the rate of algal biomass production. Increased algal production caused by nutrient enrichment has produced exceedances of the DO criterion at SPG931DN.

Figure 5.8 Chlorophyll *a* Concentration in Response to Photosynthetically Active Radiation in Two Streams in the Illinois River Basin, October 2003.



The other major impact to stream habitat observed in this study was the high level of substrate embeddedness. The sources of this sediment load are likely non-point sources from urban and agricultural production practices, changes in hydrologic flow regimes due to land use changes within watersheds, and floodplain and in-stream channel alterations. The ecological impact of this dramatic increase in sediment loads cannot be overstated. Sediments alter the geochemical processes in streams by sorbing and desorbing P. The increased sediment loads directly affect nutrient loading to and transport through the water column. Sediments alter the benthic macroinvertebrate communities by filling critical interstitial spaces. Increased sediment loads alter the fish community by altering nesting substrates and changing stream riffle-pool systems to runs, thus destroying critical habitat for indicator species such as madtoms and skulpins.

5.3.2 Kings River

The overall ecological condition of the Kings River is still good, both biologically and in habitat quality. Like the Illinois River basin, this system is being affected by multiple stressors at multiple scales at all times. The rate and degree of alteration of the landscape is much lower in this basin. However, the receiving body for the Kings River

(Table Rock Lake in Missouri) is nutrient enriched, and significant portions of the nutrient loading are coming from the Kings River.

The Kings River, as a relatively unimpacted system, shows the early stages of instream habitat alteration more dramatically than the streams of the Illinois River basin. The primary sources of sediment load in the Kings River are likely non-point source loads of sediment from agricultural production practices, changes in hydrologic flow regimes due to land use changes within watersheds, and floodplain and in-stream channel alterations. The ecological impact of this dramatic increase in sediment and nutrient loads has the potential to be more dramatic in this basin than the Illinois River basin due to the relatively high level of integrity in the system now.

SECTION 6
RECOMMENDATIONS

6.1 RECOMMENDED ACTIONS

The primary goal of this project was to provide data for USEPA to evaluate the status of attainment of the aquatic life use of the streams in the Illinois and Kings River basins. A key driver for conducting this project was to obtain more chemical, habitat, and biological field data in time to support the preparation of the Arkansas 2004 Integrated Water Quality Monitoring and Assessment Report. While the data collected during the execution of this project provided significant insights into the condition of these aquatic ecosystems, the utility of these data is limited by several factors, a few of which are outlined below.

- The lack of standardized assessment criteria for aquatic life use attainment is a critical limitation for this project. It was clear that the streams in this system were stressed to varying degrees. Some stream segments were clearly degraded relative to regional and local reference site conditions. Chemical and biological data indicated high nutrient loads, and habitat data suggested significant shifts in substrate and flow regimes at many sites. However, no criteria explicit enough to use for these parameters have been developed in Arkansas. There is also no numeric criterion for TP for Illinois or Kings River. USEPA Region 6 and the states within Region 6 should develop and make available more definitive assessment procedures and translators for assessing narrative criteria and aquatic life use attainment.
- There are no published methods for assessing benthic macroinvertebrate community structure metrics. There are no standard references for Arkansas stressor coefficients for the HBI. There is no list of indicator genera for benthic macro-invertebrates by ecoregion. A clear need exists to develop unambiguous methods of assessing biotic and habitat conditions in these and similarly impacted stream systems in Arkansas and across USEPA Region 6.
- Given the short sampling period duration of this project, limited water quality data were obtained during the critical season. A more thorough characterization of the daily and seasonal DO fluctuations, storm water sampling, and P resuspension would provide much needed data to understand the relationship between point source and nonpoint source loading.
- A clear need exists to develop unambiguous methods of assessing biotic and habitat conditions in these and similarly impacted stream systems in Arkansas and across USEPA Region 6. These methods must be peer-reviewed, published in recoverable venues, and available to investigators.
- In addition, perhaps the most common and potentially dramatic stressor for these streams, sediment, was not explicitly considered in this assessment. Total suspended solids, sediment oxygen demand, and other sediment-related parameters must be more thoroughly investigated throughout both river basins.

- The data collected during this project suggest that stream substrate was changing from gravel-cobble to sand-gravel, and that stream geomorphology was changing from riffle-pool to run structures. These changes will significantly alter the chemistry and biology of these streams. However, no explicit investigations of the degree or intensity of these processes has been investigated or reported. Future monitoring in the watersheds should be considered to better account for the degree or intensity of the processes causing changes in stream substrate.
- The selection of reference sites for comparative purposes is always problematic. The criteria for a reference site is not that the site be pristine, but rather that it not be impacted by the sources of concern. The reference sites used for this investigation appropriately reflected the systemic impact of land use change in the Ozark Plateau on water quality and ecosystem integrity. However, they did not adequately benchmark the degree to which water quality within the entire Ozark Plateau has been affected by human activities over recent years. The use of "minimally impacted" sites as acceptable reference sites used for investigations of this type should be evaluated and resolved between states and USEPA Region 6.
- USEPA Region 6 should work with the states to develop a consistent, quantitative methodology for a weight-of-evidence approach when using chemical, physical and biological data to determine beneficial use attainment status.

The combination of these factors warrant the need to rely on a weight-of-evidence approach that considers the integrated evaluation of chemical, physical, and biological data to make an aquatic life use impairment determination. The data collected under this project combined with other existing water quality data from the Illinois River basin and Kings River basin suggest a trend of declining water and habitat quality which is impacting the biological communities to varying degrees. The results summarized in this report combined with other existing water quality data will allow USEPA to confer with ADEQ in making a decision on whether the aquatic life use of the water bodies within the Illinois and Kings River basins is impaired and warrant placement on the 2004 §303(d) list.

6.1.1 Illinois River

Water quality in the Illinois River was being affected by point source discharges during the sample period for this project. The impacts of municipal WWTP discharges on downstream sites (SPG931DN, MUD027DN, and OSG930DN) are indicated by the DO extremes and the increased P concentration. Downstream of the Springdale and Prairie Grove WWTPs, water quality appears to be the most impacted. The cumulative effect of those impacts has been to alter the ecological characteristics of the streams downstream of the discharge point.

The ecological integrity of the streams in the Illinois River basin is being systematically degraded by alteration of the landscape, alteration of hydrologic flow regimes, loss of riparian zone structure, and enhanced primary productivity through nutrient enrichment. The specific causes, the percent contribution of annual nutrient or

sediment loading from point and nonpoint sources, and degrees of these changes are beyond the scope of this project. However, determining a single cause or source of biotic impairment will be difficult without additional data and modeling characterizing the sources and impacts of each of these processes on water and habitat quality. The loss of sensitive species of macroinvertebrates in this system is cause for concern. The presumed causal factor is loss of in-stream habitat due to sedimentation and geomorphologic alteration. Proving causality will require assessing the impact of watershed-level changes and stressors on this system, including measuring sediment loads to the streams, analyzing alterations of hydrologic regimes and associated geomorphologic alteration, and assessing land use change impacts on stream ecosystem functions such as primary productivity. This comprehensive approach will be necessary to develop causal relationships between the numerous processes affecting water quality in the Illinois River basin and the sources of those impacts.

6.1.2 Kings River

Water quality in the Kings River was affected by point source loadings from the City of Berryville, AR during the sample period for this project. The impacts of the City of Berryville's WWTP discharge on OSG045DN are indicative of the DO extremes, the increased P concentration, and the increased percent imbeddedness of sediment.

The ecological integrity of the streams in the Kings River basin are at risk of being further degraded from altered hydrologic flow regimes, increased sedimentation, and loss of riparian vegetation. These processes are currently not being monitored or assessed. The loss of sensitive species of fish and macroinvertebrates in this system is cause for concern. The presumed causal factor is loss of in-stream habitat due to sedimentation and geomorphologic alteration. Proving causality will require assessing the impact of land use practices, particularly riparian zone management, on stream ecosystem processes such as sedimentation, primary productivity, and refugia.

6.2 LIMITATIONS OF THIS REPORT

The data collected and analyzed in this report represent a limited view of the condition of the Illinois River and Kings River basins. This view does not capture the full dynamic characteristics of this system. As suggested previously, a systematic analysis of each basin at the watershed level will be necessary to develop causal relationships between ecosystem impact phenomena and specific pollutant sources. This report does not fully address the impacts caused by the cumulative effects of nonpoint source contributions and point sources other than those generally discussed in this report.