OKLAHOMA SCENIC RIVERS COMMISSION

A REPORT ON THE WATER QUALITY OF THE ILLINOIS RIVER

Geoffrey A. Canty
Water Quality Specialist
Oklahoma Conservation Commission
Water Quality Division

Final Report
August, 1996

Revised (09/23/97)

EXECUTIVE SUMMARY

Introduction

The Illinois River is classified as a scenic river from the point where it enters Oklahoma until it reaches the confluence of Baron Fork Creek, roughly four miles north of Lake Tenkiller. Over the past several years, the quality of Lake Tenkiller has been degrading primarily due to problems associated with nutrient and sediment loadings (OWRB, *et al.,* 1996). As part of a complete assessment program, the Oklahoma Scenic River Commission (OSRC) continuously monitors the water quality in order to track the status of the river. In 1992 the Water Quality Division of the Oklahoma Conservation Commission (OCC) developed a working agreement with the OSRC to monitor the river's water quality; however, the responsibilities are now being assumed by the US Geological Survey (USGS).

In fulfillment of the agreement with the OSRC, this document will summarize the water quality conditions for the 1992 - 1996 period of investigation. This document will also examine the water quality trend of the Illinois River since 1980.

Background

A. Site Description

The Illinois River Basin encompasses 1,069,530 acres of land in Oklahoma and Arkansas. The river begins in northwest Arkansas and flows in a westerly direction across the Ozark portion of the state until it enters into Oklahoma near the town of Watts. In Oklahoma, the river flows in a westerly direction until it reaches the confluence of Flint Creek. There, the river meanders to the southwest, towards the city of Tahlequah. After Tahlequah, the river flows into Lake Tenkiller where the river's flow is temporally detained until it ultimately drains into the Arkansas River near the town of Gore.

According to Oklahoma's Water Quality Management Plan, the Illinois River basin, in Oklahoma, is contained in Segment 121700 (OK Dept. of Pollution Control, 1979). In 1970 the state legislature passed a law declaring the Upper Illinois River, above lake Tenkiller, as a scenic river. Basically, the Upper Illinois River basin is contained by the portion of Segment 121700 north of Lake Tenkiller extending to the Arkansas border, just east of the town of Watts. Township 16 divides the watershed into upper and lower river portions.

Based on the mandate of the Oklahoma Scenic River Act, the Illinois River must receive preferential treatment and protection (Roberts /Schornick and Associates, 1984). However, over the past decade, the water quality of the river has become suspect. With the degradation of ground water and surface water resources, the quality of the river has declined and consequently, the quality of Lake Tenkiller has degraded. There has been considerable disagreement between the State of Oklahoma and the State of Arkansas on defining the problem and determining the cause of pollution. Several studies and numerous reports have been generated describing the plight of the river, but so far no viable solutions have been developed.

In order to monitor the status of the river's water quality, the OSRC implemented a water quality sampling program. In 1992 the responsibilities of the sampling program were assumed by the Water Quality Division of the OCC. Under the direction and protocol of the OCC, monthly samples were collected at various points along the river and major tributaries. Sampling points were strategically selected to identify points or areas that may be contributing pollution to the river and also to be used for comparison purposes.

B. Sampling Locations

Water quality sampling on the Illinois River has been supervised by the OSRC since December of 1980 (Lynch, 1992). Sampling locations have remained somewhat consistent but have changed slightly depending on the agency performing the collection. The sampling locations selected by the OCC are presented in Table 1. Most of the sites were located directly on the river; however, there were three tributary streams monitored for cause and effect purposes. These feeder streams included Flint Creek, Sager Creek, and Baron Fork Creek.

Table 1 Legal and narrative descriptions for 1992 -1996 OCC sampling locations along the Illinois River.

SAMPLING LOCATIONS			
Name	**Abbreviation**	**Legal**	**Narrative**
IL River us Osage Creek	IRUO	ne/se4 19n 32w	county road bridge
IL River at Highway 16	HWY	sw/sw15 17n 33w	Arkansas Highway 16 Bridge
IR at Camp Paddle Trails	CMP	se/ne/ne14 19n 25e	50 ft downstream of Camp Paddle Trials boat launch
IL River us Flint Creek	IRUF	sw/ne/nw35 20n 24e	mile upstream of confluence of Flint Creek
Flint at Fagan Creek	FAG	nw/nw/ne13 20n 26e	old bridge mile downstream of confluence with Fagan Creek
Sager Creek	SAG	nw/ne/se15 20n 25e	county bridge 3 stream miles downstream of wastewater effluent discharge
Flint Creek us IL River	FLT	nw/ne35 20n 24e	mile upstream of confluence with Illinois River
IL River ds Flint Creek	IRDF	ne/nw/nw35 20n 24e	mile downstream of confluence with Illinois River
IL River at Round Hollow	RND	se/nw/sw26 19n 23e	Round Hollow Public Access Area
IL River at No Head Hollow	NH	se/nw12 17n 22e	No Head Hollow Public Access Area
IL River at Echota Bend	ECH	ne/ne/nw24 17n 22e	Echota Public Access Area
IL River at Tahlequah	TAL	ne/ne/sw35 17n 22e	mile upstream of confluence with Illinois River
IL River us Baron Fork	IRUB	ne/se/ne24 16n 22e	mile upstream of confluence with Baron Fork River
Baron Fork Creek	BFK	nw/sw/nw19 17n 23e	mile upstream of confluence with Illinois River

us = upstream
ds = downstream

METHODS

Introduction

Water quality samples were collected on a monthly basis starting in April 1992 and continued until June 1996. During this time period the river was monitored for physical and chemical parameters. Periphyton and fecal coliform bacteria samples were not collected over this entire time period, but representative collections were made for analysis purposes.

Physical / Chemical Parameters

The water quality parameters are summarized in Table 2. Collection procedures followed strict operating guidance as presented in the OCC Standard Operating Procedures (OCC, 1995). For quality assurance reasons, a blank, a duplicate and a spiked sample were collected during each sampling episode.

Table 2 Parameters tested for during sample collection along the Illinois River. (Parenthesizes indicate term abbreviation.)

SAMPLED PARAMETERS	
Temperature (TEMP)	Total Phosphorous (TP)
Conductivity (COND)	Ortho-phosphorous (O-P)
Total Suspended Solids (TSS)	Total Nitrogen (TN)
Turbidity (TURB)	Total Kjeldahl Nitrogen (TKN)
Alkalinity (ALK)	Nitrate (NO_3-N)
Hardness (HARD)	Chem. Oxygen Demand (COD)
Dissolved Oxygen (DO)	Chloride (Cl^-)
pH	Sulfate (SO_4)

Periphyton

Periphyton samples were collected for approximately one year (1992 - 1993) and were to be used for comparison with a previously collected data set (1985 - 1986). Periphyton collections and preparation followed standard operating protocols as outlined in Methods 6 and 19 of the Standard Operating Procedures as developed by the OCC Water Quality Division (1995).

Fecal Coliform Bacteria

Fecal coliform bacteria were collected on a monthly basis beginning in August of 1995 and continued until June of 1996. Samples were collected at the same locations as the chemical water quality parameters. After collection, samples were stored on ice and transported to a certified laboratory within 24 hours. Sampling procedures followed those outlined in the OCC Water Quality Division's standard operating procedures and the method of analysis followed either multiple-tube fermentation (#9221) or membrane filter (#9222D) standard procedures (APHA *et al.*, 1989).

RESULTS and DISCUSSION

Parameters

A. Nutrients

- Overall, nutrient concentrations were found to be excessive at all locations along the Illinois River and tributary streams. Also, both total phosphorous and total nitrogen did not appear to be limiting; therefore, eutrophication in Lake Tenkiller is likely to continue.

- Nitrate and orthophosphate were the predominating contaminants in the Illinois River. These pollutants are of concern because they are in a chemical form that is readily available for algal uptake and are direct indicators of human pollution.

- Phosphate phosphorous levels at all sampling locations exceeded the suggested EPA concentration (0.05 mg/L). Levels were up to ten times greater than the levels recommended to prevent lentic water eutrophication. The lowest levels were observed at the tributary creeks and towards the headwaters of the river. Fagan Creek and Baron Fork Creek had total phosphorous levels of 0.07 and 0.06 mg/L, respectively, and the Illinois River near Osage Creek had an average concentration of 0.10 mg/L. These levels are low when compared with the rest of the river, but these concentrations are still of concern. Most values ranged between 0.10 and 0.20 mg/L, but Sager Creek had higher levels. The Sager Creek sampling site was located three miles downstream of the city of Siloam Springs Arkansas. High concentrations (0.53 mg/L, average) were expected due to the proximity of the city's wastewater treatment facility.

- Total nitrogen concentrations were much greater than desired levels. Although there is not any recommended levels currently available, all sites exceeded the "pristine" or "unpolluted" concentration (0.12 mg/L) by almost ten times. Excluding Sager Creek, nitrogen values ranged from 1.35 - 2.69 mg/L for total nitrogen, 1.12 - 2.19 mg/L for nitrate, and 0.30 - 0.52 mg/L for TKN. Sager Creek values were typically much higher than any other location for total nitrogen, nitrate, and TKN (5.9 mg/L, 5.56 mg/L, and 0.55 mg/l, respectively).

- Analysis of the loading data indicated that approximately 169,500 kg/year total phosphorous and 2,065,000 kg/year of total nitrogen were entering the state of Oklahoma from Arkansas. Another 29,700 kg/year of total phosphorous and 244,000 kg/year of total nitrogen were added due to in-state contributions.

B. Physical / Chemical

- Turbidity levels of the tributary streams tended to be lower than the river sites. Sager, Flint and Baron Fork Creeks had the lowest turbidity, while Camp Paddle Trails was the highest. Comparison of the turbidity values with the water quality standards indicated that Camp Paddle Trails and the Illinois River downstream of Flint Creek were the only sites that exceeded the allowable limits for turbidity, (34 and 12 NTU, respectively).

- Chemical oxygen demand was slightly elevated throughout the length of the river. This indicated that an undesirable amount of organic matter was entering the river.

- Alkalinity, pH, conductivity, hardness, and total suspended solid levels were within the generally accepted ranges. Therefore, these parameters were not of concern.

Trend Analysis

A. Time Period 1992 - 1996

- Although the statistical interpretation of the data indicated that there were some significant trends, the four year time period was not long enough to make quantifiable conclusions. As a result, any identifiable trend was likely to be speculative.

B. Time Period 1980 - 1996

- Turbidity increased at four sites, Camp Paddle Trails, No Head Hollow, Flint Creek near Fagan Creek, and Echota Bend; however, only one site was of significant concern. Camp Paddle Trails had a increasing trend of 0.59 NTU/year which was thought to be due to eroding lake bed sediments from Lake Frances. Conversely, turbidity at Sager Creek decreased.

- Four sites experienced a decrease in the amount of total phosphorous (Camp Paddle Trails, the Illinois River upstream of Flint Creek, Round Hollow, and Sager Creek). The decrease in phosphorous was small but significant at these sites with the exception of Sager Creek. Trend analysis at Sager Creek indicated a 0.044 mg/L per year decrease in phosphorous over the fifteen year time period. This sizable decrease was assumed to be due to the sewage treatment plant upgrade implemented by the city of Siloam Springs.

- Total nitrogen was particularly of concern because a positive trend was observed at all seven sampling sites evaluated. The increase in concentration varied from 0.036 to 0.232 mg/L per year, but all values were of significant magnitude. The reason for the increase in nitrogen was probably due to the added pressure of agriculture, recreation, and population development in the watershed; however, no responsible source of pollution could be identified by this study.

Periphyton

- Based on periphyton analysis, the 1992 - 1993 data indicated that the various river locations were determined to be “moderately impaired” to “impaired”; however, the Tahlequah site was found to be “severely impaired”. Comparing the 1985 - 1986 findings with the 1992 - 1993 results indicated that Highway 16 decreased from “severely impaired” to “moderately impaired” and Round Hollow decreased from “impaired” to “moderately impaired”. In contrast, Tahlequah increased from “slightly impaired” to “severely impaired”. No conclusive explanation for the increase or decrease in periphyton growth rates could be made based on this study. Overall, the impaired nature of the river water quality was due to elevated nutrient levels.

Fecal Coliforms

- In general, there did not appear to be a problem with fecal coliform contamination during the 1995 - 1996 time period. However, during high flow events there were concentrations that greatly exceeded water quality protection levels.

Specific Location Effects

- Osage Creek was contributing a significant amount of nutrients to the Illinois River. Nutrient concentrations for nitrate, total phosphorous, and orthophosphate increased sharply at the Illinois River at Highway 16 site. Although no accusatory conclusions can be drawn from this study, discharge from urban areas located in the Osage Creek Watershed was the likely culprit.

- Despite the elevated nutrient concentrations, Sager Creek may not be drastically affecting the Illinois River. Although the concentration levels for nitrate, total nitrogen, orthophosphate, and total phosphorous were higher than any other sampling location, there was no acute effect observed on the Illinois River. Further study is needed to determine the impact on Lake Tenkiller.

TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 METHODS

3.0 RESULTS

4.0 DISCUSSION

5.0 SUMMARY AND CONCLUSIONS

7.0 APPENDIX

1.0 INTRODUCTION

1.1 Introduction

The Illinois River is classified as a scenic river from the point where it enters Oklahoma until it reaches the confluence of Baron Fork Creek, roughly four miles north of Lake Tenkiller. Over the past several years, the quality of Lake Tenkiller has been degrading primarily due to problems associated with nutrient and sediment loadings (OWRB, *et al.,* 1996). As part of a complete assessment program, the Oklahoma Scenic River Commission (OSRC) continuously monitors the water quality in order to track the status of the river. In 1992 the Water Quality Division of the Oklahoma Conservation Commission (OCC) developed a working agreement with the OSRC to monitor the river's water quality; however, the responsibilities are now being assumed by the US Geological Survey (USGS).

In fulfillment of the agreement with the OSRC, this document will summarize the water quality conditions for the 1992 - 1996 period of investigation. This document will also examine the water quality trend of the Illinois River since 1980.

1.2 Background

A. Site Description

The Illinois River Basin encompasses 1,069,530 acres of land in Oklahoma and Arkansas. The river begins in northwest Arkansas and flows in a westerly direction across the Ozark portion of the state until it enters into Oklahoma near the town of Watts. In Oklahoma, the river flows in a westerly direction until it reaches the confluence of Flint Creek. There, the river meanders to the southwest, towards the city of Tahlequah. After Tahlequah, the river flows into Lake Tenkiller where the river's flow is temporally detained until it ultimately drains into the Arkansas River near the town of Gore. The Illinois River watershed is outlined in Figure 1.1.

According to Oklahoma's Water Quality Management Plan, the Illinois River basin, in Oklahoma, is contained in Segment 121700 (OK Dept. of Pollution Control, 1979). In 1970 the state legislature passed a law declaring the Upper Illinois River, above lake Tenkiller, as a scenic river. Basically, the Upper Illinois River basin is contained by the portion of Segment 121700 north of Lake Tenkiller extending to the Arkansas border, just east of the town of Watts. Township 16 (in Oklahoma) divides the watershed into upper and lower river portions.

Based on the mandate of the Oklahoma Scenic River Act, the Illinois River must receive preferential treatment and protection (Roberts /Schornick and Associates, 1984). However, over the past decade, the water quality of the river has become suspect. With the degradation of ground water and surface water resources, the quality of the river has declined and consequently, the quality of Lake Tenkiller has degraded. There has been considerable disagreement between the State of Oklahoma and the State of Arkansas on defining the problem and determining the cause of pollution. Several studies and numerous reports have been generated describing the plight of the river, but so far no viable solutions have been developed.

Figure 1.1 Illinois River Drainage Basin. Sampling locations are listed along the river.

In order to monitor the status of the river's water quality, the OSRC implemented a water quality sampling program. In 1992, the responsibilities of the sampling program were assumed by the Water Quality Division of the OCC. Under the direction and protocol of the OCC, monthly samples were collected at various points along the river and major tributaries. Sampling points were strategically selected to identify points or areas that may be contributing pollution to the river and also to be used for comparison purposes.

B. Sampling Locations

Water quality sampling on the Illinois River has been supervised by the OSRC since December of 1980 (Lynch, 1992). Sampling locations have remained somewhat consistent but have changed slightly depending on the agency performing the collection. The sampling locations selected by the OCC are presented in Table 1.1. Most of the sites were located directly on the river; however, there were three tributary streams monitored as a means to estimate inputs from various portions of the watershed. These feeder streams included Flint Creek, Sager Creek, and Baron Fork Creek.

Table 1.1 Legal and narrative descriptions for 1992 -1996 OCC sampling locations along the Illinois River.

SAMPLING LOCATIONS

Name	Abbreviation	Legal	Narrative
IL River us Osage Creek	IRUO	ne/se4 19n 32w	county road bridge
IL River at Highway 16	HWY	sw/sw15 17n 33w	Arkansas Highway 16 Bridge
IR at Camp Paddle Trails	CMP	se/ne/ne14 19n 25e	50 ft downstream of Camp Paddle Trials boat launch
IL River us Flint Creek	IRUF	sw/ne/nw35 20n 24e	mile upstream of confluence of Flint Creek
Flint at Fagan Creek	FAG	nw/nw/ne13 20n 26e	old bridge mile downstream of confluence with Fagan Creek
Sager Creek	SAG	nw/ne/se15 20n 25e	county bridge 3 stream miles downstream of wastewater effluent discharge
Flint Creek us IL River	FLT	nw/ne35 20n 24e	mile upstream of confluence with Illinois River
IL River ds Flint Creek	IRDF	ne/nw/nw35 20n 24e	mile downstream of confluence with Illinois River
IL River at Round Hollow	RND	se/nw/sw26 19n 23e	Round Hollow Public Access Area
IL River at No Head Hollow	NH	se/nw12 17n 22e	No Head Hollow Public Access Area
IL River at Echota Bend	ECH	ne/ne/nw24 17n 22e	Echota Public Access Area
IL River at Tahlequah	TAL	ne/ne/sw35 17n 22e	mile upstream of confluence with Illinois River
IL River us Baron Fork	IRUB	ne/se/ne24 16n 22e	mile upstream of confluence with Baron Fork River
Baron Fork Creek	BFK	nw/sw/nw19 17n 23e	mile upstream of confluence with Illinois River

us = upstream
ds = downstream

2.0 METHODS

2.1 Introduction

Water quality samples were collected on a monthly basis starting in April 1992 and continued until June 1996. During this time period the river was monitored for physical and chemical parameters. Periphyton and fecal coliform bacteria samples were not collected over this entire time period, but representative collections were made for analysis purposes.

2.2 Physical / Chemical Parameters

The water quality parameters are summarized in Table 2 .1. Collection procedures followed strict operating guidance as presented in the OCC Standard Operating Procedures (OCC, 1995). For quality assurance reasons, a blank, a duplicate and a spiked sample were collected during each sampling episode. (Quality assurance results are presented in Appendix 7.1.)

Table 2.1 Parameters tested for during sample collection along the Illinois River. (Parenthesizes indicate term abbreviation.)

SAMPLED PARAMETERS	
Temperature (TEMP)	Total Phosphorous (TP)
Conductivity (COND)	Ortho-phosphorous (O-P)
Total Suspended Solids (TSS)	Total Nitrogen (TN)
Turbidity (TURB)	Total Kjeldahl Nitrogen (TKN)
Alkalinity (ALK)	Nitrate (NO_3-N)
Hardness (HARD)	Chem. Oxygen Demand (COD)
Dissolved Oxygen (DO)	Chloride (Cl^-)
pH	Sulfate (SO_4)

2.3 Periphyton

Periphyton samples were collected for approximately one year (1992 - 1993) and were to be used for comparison with a previously collected data set (1985 - 1986). Periphyton collections and preparation followed standard operating protocols as outlined in Methods 6 and 19 of the Standard Operating Procedures as developed by the OCC Water Quality Division (1995).

2.4 Fecal Coliform Bacteria

Fecal coliform bacteria were collected on a monthly basis beginning in August of 1995 and continued until June of 1996. Samples were collected at the same locations as the chemical water quality parameters. After collection, samples were stored on ice and transported to a certified laboratory within 24 hours. Sampling procedures followed those outlined in the OCC Water Quality Division's standard operating procedures and the method of analysis followed either multiple-tube fermentation (#9221) or membrane filter (#9222D) standard procedures (APHA *et al.*, 1989).

3.0 RESULTS

3.1 Introduction

In this section, the analytical results for the time period April 1992 - March 1996 are presented along with trend analyses for the time periods 1992 - 1996 and 1980 - 1996. Data has been analyzed with respect to annual averages, overall averages, trends, and seasonality. Methods of data analysis include:

1. Parameter vs. Location-- Annual Average ,
2. Parameter vs. Location-- Four Year Average,
3. Parameter vs. Date, and
4. Trend analysis.

Also, results of the periphyton and fecal coliform bacteria tests are presented. Information presented in this section is purely the results of data manipulation, no interpretations or explanations are provided here. In Section 4.0 a comprehensive discussion and interpretation of the data will be presented.

3.2 Parameter vs. Location—Annual Average

Annual averages were calculated for each site for all parameters of interest (see Table 7.2.1). Graphical representations are presented in Appendix 7.2, Figures 7.2.1 - 7.2.60. The data for the 1996 collection period may not be consistent with previous years because there was only three months of data available. As a result, high flow events or unusually low values may have skewed the data in a manner that is not representative of twelve-month sampling period.

As a note of caution, information or relationships presented in these graphs and tables should be used for qualitative purposes only; further statistical analysis would be needed before statistical significance determinations can be made.

3.3 Parameter vs. Location—Four Year Average

A comparison of each parameter for the entire four-year period was made with respect to each site. Average data for all sampling locations is presented in Table 3.1. Four-year averages were used extensively in the discussion section as a means to present the data. When needed statistical methods were applied to add validity to the findings. Graphical representation are presented in Appendix 7.3, Figures 7.3.1 - 7.3.12. These figures should be used for qualitative purposes only; specific conclusions should be made with caution.

Table 3.1 Four-year averages for each sampling location and for all parameters sampled along the Illinois River data (1992-1996).

FOUR YEAR AVERAGES

SITE	TN	TKN	NO3	TP	O-P	TSS	TURB	HARD	Cl	SO4	COD	pH	COND	ALK
IRUO	2.28	0.47	1.81	0.14	0.08	20.32	9.47	106.2	5.00	10.89	6.69	7.32	221.8	73
HWY	2.66	0.47	2.19	0.25	0.20	60.05	6.57	107.9	7.59	12.01	8.58	7.37	226.4	100
CMP	2.69	0.51	2.19	0.22	0.16	45.97	34.08	103.8	6.09	12.11	5.58	7.51	215.7	109
IRUF	2.38	0.39	1.98	0.17	0.11	8.64	5.27	101.5	7.75	11.39	3.51	7.58	236.6	112
FAG	2.51	0.52	2.02	0.12	0.07	6.62	3.40	99.59	5.00	18.11	3.84	7.46	230.9	85
SAG	5.90	0.55	5.56	0.62	0.53	5.09	3.64	114.2	34.74	16.56	5.83	7.32	291.6	85
FLT	2.36	0.36	1.99	0.12	0.10	8.20	3.11	92.46	6.67	12.91	3.22	7.53	202.5	93
IRDF	2.43	0.43	2.00	0.20	0.14	26.84	12.55	99.25	7.51	10.95	4.91	7.59	215.6	106
RND	2.35	0.46	1.88	0.18	0.14	24.84	4.60	98.35	6.21	12.37	5.96	7.79	216.1	105
NH	2.17	0.42	1.75	0.18	0.12	33.17	7.38	95.69	6.30	12.21	5.91	7.60	211.8	99
ECH	2.06	0.44	1.63	0.16	0.12	24.51	4.50	92.47	6.03	12.68	4.94	7.73	198.3	99
TAL	1.95	0.37	1.63	0.17	0.10	27.33	9.98	94.77	8.91	14.38	5.81	7.62	204.7	94
IRUB	1.85	0.36	1.52	0.17	0.13	25.52	5.82	91.22	5.78	15.67	5.16	7.64	207.4	89
BFK	1.37	0.30	1.12	0.12	0.06	9.87	2.96	80.86	5.00	16.49	3.62	7.53	162.2	85

3.4 Parameter vs. Date

In order to show the change in the water quality for a particular parameter, a series of graphs were constructed to compare average parameter concentration verses each year. This was conducted on an individual site basis for all four years. See Figures 7.4.1 - 7.4.168 in Appendix 7.4. Although trend analyses may be interpreted from these graphs, firm or final conclusions should not be made from them. More statistically valid interpretations can be drawn from the WQSTAT trend analysis presented in the following sections.

3.5 Trend Analysis

A. Time Period 1992-1996

Trend analysis was conducted using only data parameters of concern. Since Lake Tenkiller is being adversely affected by nutrient and sediment loadings, trend analyses were performed on total phosphorous, total nitrogen, and turbidity. Data were analyzed to determine if there were any discernible patterns over the time period April 1992 through March 1996. Also, seasonality determinations were made to distinguish between trend and regular cyclic patterns. Both trend and seasonality determinations were made using WQSTAT water quality statistics program. This software package uses Kruskal-Wallis Test for seasonality and Kendall Tau for trend determination. For both determinations an alpha value of 0.05 was assumed or a 95% confidence interval. (Values with 90% confidence intervals were presented for informative purposes only.) Since only a four-year time period was analyzed, quantitative trend values could not be determined. Instead, a confidence level and the direction of the trend were reported. Results of these tests are presented in Table 3.2. (A more detailed explanation of the terms and statistical methods introduced in this section will be presented in the discussion portion of this document. See Section 4.0.)

Table 3.2 Results of WQSTAT statistical analysis for trend and seasonality determination for the Illinois River data 1992-1996.

SEASONALITY AND TREND DETERMINATION

Site	Parameter	Kruskal-Wallis (seasonality)	Kendall Tau (trend)
IRUO	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	not significant	95% (decrease)
HWY	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	not significant	not significant
CMP	Turbidity	not significant	not significant
	Total Phosphorous	95%	90% (decrease)
	Total Nitrogen	not significant	not significant
IRUF	Turbidity	not significant	not significant
	Total Phosphorous	not significant	95% (decrease)
	Total Nitrogen	95%	not significant
IRDF	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	not significant
RND	Turbidity	not significant	90% (decrease)*
	Total Phosphorous	95%	not significant
	Total Nitrogen	not significant	not significant
NH	Turbidity	not significant	90% (decrease)*
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	not significant
ECH	Turbidity	not significant	90% (decrease)*
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	not significant
TAL	Turbidity	not significant	95% (decrease)*
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	not significant
IRUB	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	90% (decrease)
BFK	Turbidity	not significant	not significant
	Total Phosphorous	90%	95% (increase)*
	Total Nitrogen	95%	not significant
FAG	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	90% (decrease)
FLT	Turbidity	not significant	90% (decrease)
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	not significant
SAG	Turbidity	not significant	not significant
	Total Phosphorous	not significant	not significant
	Total Nitrogen	not significant	95% (increase)

*The trend observation may be due to an anomaly in the sample data. Extreme peaks were observed which may have skewed the data.

B. Time period 1980 - 1996

Trend analysis was conducted on data collected by the OCC and data generated by the OSRC to establish a pattern in water quality over the past fifteen years (December 1980 - March 1996). Again, trend analysis was conducted on parameters of concern, which included total phosphorous, total nitrogen, and turbidity. Also, seasonality determinations were made to distinguish between trends and regular cyclic patterns. Both trend and seasonality determinations were made using WQSTAT, water quality statistics program. For this application, the Kruskal-Wallis test for seasonality and a Seasonal Kendall Tau test for trend determination were employed. (Seasonal Kendall Tau test is a seasonal equivalent of the nonparametric Sen slope estimate (Gilbert, 1987).) For both seasonality and trend analysis, an alpha value of 0.05 was assumed or a 95% confidence interval. (Values with 90% confidence intervals were presented for informative purposes only.)

Only seven sites were available for comparison because certain sampling locations changed when the OCC assumed sampling responsibilities. The time period was approximately 15 years for all locations except for the No Head Hollow site. This location was sampled for 8 years. With the larger time period, a more reliable trend analysis was developed and an actual quantitative value was determined for the magnitude of the trend. Results of these tests are presented in Table 3.3.

Table 3.3 Results of WQSTAT statistical analysis for trend and seasonality determination for selected sites on the Illinois River for the time period 1980 - 1996. Values in parenthesis indicate the direction and magnitude of the trend.

SEASONALITY AND TREND DETERMINATION

Site	Parameter	Kruskal-Wallis (seasonality)	Seasonal Kendall Tau (trend)
CMP	Turbidity	95%	95% (+0.5941 mg/L/yr)*
	Total Phosphorous	not significant	95% (-0.0081 mg/L/yr)
	Total Nitrogen	95%	95% (+0.0360 mg/L/yr)
IRUF	Turbidity	not significant	not significant
	Total Phosphorous	not significant	95% (-0.0067 mg/L/yr)
	Total Nitrogen	95%	95% (+0.0614 mg/L/yr)
RND	Turbidity	not significant	not significant
	Total Phosphorous	90%	95% (-0.0047 mg/L/yr)
	Total Nitrogen	95%	95% (+0.0439 mg/L/yr)
NH	Turbidity	90%	95% (+0.4000 mg/L/yr)
	Total Phosphorous	90%	not significant
	Total Nitrogen	95%	95% (+0.1548 mg/L/yr)
ECH	Turbidity	not significant	95% (+0.1250 mg/L/yr)*
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	95% (+0.0478 mg/L/yr)
FAG	Turbidity	not significant	95% (+0.0429 mg/L/yr)
	Total Phosphorous	not significant	not significant
	Total Nitrogen	95%	95% (+0.0514 mg/L/yr)
SAG	Turbidity	not significant	95% (-0.0250 mg/L/yr)
	Total Phosphorous	95%	95%(-0.0442 mg/L/yr)
	Total Nitrogen	not significant	95% (+0.2325 mg/L/yr)

* The trend observation may be due to an anomaly in the sample data. Extreme peaks were observed which may have skewed the data.

3.6 Periphyton

Periphyton data collection involved two data sampling time periods. Periods of collection were 1985 - 1986 and 1992 - 1993. Unfortunately, the sampling sites were not consistent, and there were not regular, monthly collections during these time periods. Due to weather and elevated stream discharge (floods), there were times when samples could not be collected. However, when a collection event was possible, at least two replicates were gathered.

Since there was not year round data, time period averages were taken. That is, all of the monthly samples were averaged and a single value was given to each sampling site for each time period. Data results are displayed in Tables 3.4 and 3.5.

Table 3.4 High, low and average concentrations of chlorophyll for select sites along the Illinois River for the time period 1985-86.

PERIPHYTON AVERAGES FOR 1985-86
(μg/cm^2)

SITE	HIGH	AVG	LOW
BFK	6.56	3.89	1.22
IRUB	8.45	6.29	4.13
ECH	16.12	11.05	5.97
RND	9.37	6.20	3.02
HWY	14.04	10.11	6.18
IRUO	4.46	3.42	2.38
NH	8.31	5.23	2.15
TAL	3.96	2.55	1.14

Table 3.5 High, low and average concentrations of chlorophyll for select sites along the Illinois River for the time period 1992-93.

PERIPHYTON AVERAGES FOR 1992-93
(μg/cm^2)

SITE	HIGH	AVG	LOW
BFK	4.22	3.52	2.83
IRUF	7.15	5.43	3.70
ECH	8.82	7.14	5.45
RND	6.35	4.87	3.39
HWY	4.91	3.62	2.33
IRUO	4.88	4.07	3.25
NH	10.71	7.77	4.84
TAL	10.65	8.49	6.34
FAG	8.32	6.21	4.09
FLT	3.98	3.35	2.73
CMP	4.14	3.23	2.32
IRDF	5.73	4.82	3.90

As a method of comparison, statistical analysis was performed on the two sampling time periods. A population mean was calculated by averaging all of the replicates for each sampling period over the entire year. Unfortunately, seasonal comparisons could not be made because of gaps in the data. The data collected was analyzed using hypothesis testing of two populations. A listing of statistical results is presented in Table 3.6.

Table 3.6 Statistical comparison of the periphyton data collections for the 1985-86 verses the 1992-1993 time periods. Underlined cells indicate significant values (α=0.05).

STATISTICAL INTERPRETATION				
SITE	**t**	**sp**	**df**	**t α**
BFK	0.69	3.04	46	2.02
IRUB	1.28	4.29	41	2.02
ECH	5.24	6.58	54	2.01
RND	2.04	4.96	50	2.01
HWY	9.38	4.93	41	2.02
IRUO	-1.29	2.02	39	2.02
NH	-2.58	7.51	42	2.02
TAL	-7.33	4.98	39	2.02

3.7 Fecal Coliform Bacteria

Monthly bacteria samples were collected along the river to qualitatively determine if the water quality was suitable for recreational activities. Samples were collected from August 1995 through June 1996. Results of fecal coliform bacterial analysis are presented in Table 3.7. A geometric mean was calculated instead of an arithmetic mean for analysis purposes. A geometric mean is calculated by taking the square root of the sum of the data set. Under conditions where there is extreme fluctuation in the data, a square root value provides a more representative estimation of the mean. An arithmetic mean would provide an unrepresentative value that is not a true representation of the actual central tendency of the data set. (Please note, annual averages are typically not used for interpreting fecal coliform bacteria results. For this report, annual averages were calculated for descriptive purposes.) Annual geometric means are presented in Table 3.8.

Table 3.7 Monthly results of fecal coliform bacteria for selected sites along the

Illinois River (August 1995 - June 1996). Underlined cells indicate data values that exceed water quality protection levels.

FECAL COLIFORM BACTERIA MONTHLY RESULTS

DATE	IRUO	HWY	CMP	FAG	FLT	IRUF	IRDF	RND	NH	ECT	TAL	BFK	IRUB	SAG
Aug 1995	210	72	130	100	36	10	18	10	45	36	27	170	72	140
Sep	310	530	430	160	120	45	63	120	320	120	260	45	230	45
Oct	130	54	54	91	5	18	36	10	54	36	10	5	27	27
Nov	63	63	5	140	27	27	10	27	18	10	27	5	10	100
Dec	49	76	18	66	17	16	22	8	16	12	24	4	25	160
Jan 1996	560	350	520	200	410	10	350	380	410	370	450	230	510	63
Feb	36	48	8	120	100	84	140	4	12	12	12	8	20	24
Mar	90	27	63	170	5	18	10	18	27	36	36	5	10	45
Apr	120000	21000	4100	1600	72	270	140	190	4800	4800	2800	16000	30000	5600
May	230	280	200	81	81	45	110	81	100	5	45	110	120	130
Jun	110	36	10	210	18	18	5	18	5	54	36	10	27	18

Table 3.8 Annual, geometric means of fecal coliform bacteria for select locations along the Illinois River (August 1995 - June 1996).

ANNUAL BACTERIA AVERAGES

Site	Geometric Mean	Site	Geometric Mean
IRUO	239	RND	30
HWY	151	NH	64
PT	77	ECT	49
FAG	158	TAL	61
FLT	29	BFK	36
IRUF	38	IRUB	82
IRDF	39	SAG	88

4.0 DISCUSSION

4.1 Introduction

Monitoring various water quality parameters provides a general understanding of the river's health and integrity. Because a river is a dynamic system, it is difficult to determine the status of the water quality based on isolated discontinuous sampling events. Each sampling episode is an instantaneous image that represents the water quality for that specific moment-- one sampling event is not a fair representation of the entire system. With this understanding, it is necessary to collect as many isolated events over as long of a time period as possible so that a more representative description of the river can be formed. The four year time period that the OCC collected data provides an assessment of the current river conditions; however, the time frame was too short to provide long term water quality trends.

Please note, for the purposes of consistent discussion, all sites were compared using Oklahoma water quality standards. Locations in Arkansas (Highway 16 and the Illinois River upstream of Osage Creek) do not fall under Oklahoma jurisdiction and are not subject to Oklahoma's regulations.

In this section, the 1992 - 1996 data will be used to discuss the river's water quality. The discussion will focus on: specific parameters; long and short term trend analyses; periphyton; fecal coliform bacterial; and specific sampling locations of concern.

4.2 Parameters

In this subsection, the parameters of interest will be discussed with respect to sampling location. Average values encompassing the 1992 - 1996 time period were used for discussion purposes. These values are summarized in Table 3.1 and graphical representations are depicted in Figures 7.3.1 - 7.3.112. Although average values can be misleading, due to the large variability associated with individual collection events, means do provide a central tendency value that is useful for descriptive purposes.

Prior to discussing the water quality findings, each parameter will be briefly defined and, when available, a standard or desirable value will be provided for comparison purposes.

A. Nutrient Parameters

Nutrient nonpoint source pollution has been a particularly controversial issue. The controversy arises when human demands result in undesirable environmental effects. Aquatic plants and photosynthetic organisms require a variety of nutrients in varying amounts for growth and development. Macronutrients, (such as nitrogen, carbon, and phosphorous) and micronutrients (such as iron, calcium, and magnesium) are available to aquatic organisms in a variety of forms and concentrations. Growth and development depends on a balance of these chemicals. In natural ecosystems, phosphorus and nitrogen are the elements that usually limit the growth of photosynthetic organisms. Aquatic systems are typically limited by phosphorous and terrestrial systems are more often limited by nitrogen. When an aquatic environment is overburdened with nutrients the growth limiting effects of phosphorous and nitrogen is removed and the photosynthetic organisms are capable of proliferating at accelerated rates. Typically, this is manifested as an algal bloom. Chronic nutrient over loading can lead to eutrophication or premature aging of lentic environments. As a consequence, determining the acceptable amount of nutrients that can be released to the environment becomes the principal concern of water quality officials.

Over fertilization is a common problem in agricultural areas where manure is applied to crop and pasture lands. As mentioned earlier, nitrogen is typically the limiting nutrient to terrestrial plants; thus, larger amounts of nitrogen are needed in comparison to phosphorous and other elements. When calculated amounts of manure and animal litters are added to meet nitrogen requirements a subsequent excessive application of phosphorous may occur. As a result, runoff and ground water from agricultural areas can have elevated levels of nutrients, which adversely affects receiving streams. Consequently, watershed management of nutrient applications plays a critical role in protecting water quality.

Rivers could be termed "unique" from a watershed prospective when the climate, geology, landuse, and land area are taken into consideration. Therefore, it is difficult to determine acceptable nutrient loadings or standard levels on a generalized scale. Rivers, similar in size to the Illinois River, tend to have nutrient concentrations modified by human activities such as sewage treatment, livestock management, row crop production, and industrial discharges. Nutrient inputs from these sources prevent the development of a "summery value" to estimate the overall impact caused by the nutrient loading. The dilemma is caused by several factors including seasonal changes, differences between polluted and unpolluted segments, and also by biological and chemical interactions (Allan, 1995).

Attempts have been made to estimate "natural" nutrient concentration using rivers and streams located in areas where anthropogenic sources are thought to be minimal. According to Allan (1995), these concentrations tend to be similar to average concentrations found in rain. For instance, a summed value for inorganic nitrogen (nitrate, nitrite, and ammonia) was found to be 0.12 mg/L with nitrate as the major constituent (Allan, 1995). Levels of phosphorous were found to be low with concentrations of dissolved phosphorous around 0.01 mg/L and total dissolve phosphorous (including dissolved organic forms) approximately 0.025 mg/L (Allan, 1995). Natural values suggest theoretical ideal conditions, but these concentrations should not be considered as standards or even goals. Human activities have altered the nutrient balance of most ecosystems; therefore, it is now important to find nutrient concentrations that do not cause excessive harm or disrupt the aquatic system. The EPA has developed suggested phosphorous levels similar to the natural or pristine levels. Phosphorous is discussed in more detail in the following section along with the EPA guidelines for phosphorous concentrations.

1. Phosphorous

Phosphorous in the phosphate form is a macronutrient essential to plant growth. In natural waters, phosphorous occurs almost solely as phosphate, which can be classified into orthophosphates and organically bound phosphates. Of these two forms, over 90% of the phosphorous in fresh water is normally found in the organic phosphate state. In terms of lake loading, phosphorous is often used as the primary measure of determining whether algal blooms will occur. According to the EPA (1986), total phosphate phosphorous should not exceed 0.050 mg/L in flowing streams that enter water bodies (measured at the point of entry) or 0.025 mg/L in lakes or reservoirs. Flowing waters that do not discharge to water bodies can have a concentration of 0.100 mg/L without causing eutrophication (Mackenthun, 1973). At this time there is not a definitive standard set by the State of Oklahoma.

Orthophosphate refers to the inorganic, soluble form of phosphate. Generally, orthophosphate is the chemical form that is readily available to algae and is also an indicator of human pollution.

Review of Table 3.1 indicated that the four-year average for most locations exceeded the EPA suggested concentrations. The lowest levels were observed at the tributary creeks and towards the headwaters of the river. Fagan Creek and Baron Fork Creek had total phosphorous levels of 0.0.7 and 0.06 mg/L, respectively, and the Illinois River near Osage Creek had an average concentration of 0.08 mg/L. These levels were low when compared with the rest of the river, but these concentrations are still of concern. Most other locations ranged between 0.10 and 0.20 mg/L, but Sager Creek had more elevated levels. The Sager Creek sampling site was located three miles downstream of the city of Siloam Springs, Arkansas. Elevated concentrations (0.53 mg/L, average) were expected due to the proximity of the city's wastewater treatment facility.

According to the literature, approximately 90% of the phosphorous found in typical aquatic environments was bound in the organic form. However, this was not the case in the Illinois River. The average percent of total phosphorous that was in the form of orthophosphate was 70%, which indicated that only 30% was in the organically bound form. The lowest percentage of orthophosphate was 50% at Baron Fork Creek and the highest was 85% downstream of Siloam Springs. With a large percentage of un-associated phosphorous available, eutrophication is likely to continue at points downstream-- particularly at Lake Tenkiller. Orthophosphate concentrations of this magnitude are unusual which suggests that something other than phosphorous is the limiting nutrient and that eutrophication could proceed at elevated rates.

2. Nitrogen

Total Nitrogen represents the summation of all nitrogen containing compounds. For water quality purposes, the forms of interest include (listed in order of decreasing oxidation state) nitrate, nitrite, ammonia and organic nitrogen. Depending on the form of nitrogen, the impact on water quality is varied.

Nitrate is of concern primarily because of eutrophication and drinking water concerns. The toxicity effect of nitrate on warmwater fish species does not become a concern until levels approach 90 mg/L (Knepp and Arkin, 1973), but for human health concerns, nitrate should be at or below 10 mg/L in raw drinking water sources (OWRB, 1994).

Nitrite is of concern because it is toxic to warmwater fish species and because it has some effects on human health with respect to drinking water. Nitrite levels at or below 5 mg/L should adequately protect most species of warmwater fish (McCoy, 1972).

According to Standard Methods (APHA *et al.*, 1989), organic nitrogen is defined as organically bound nitrogen in the trinegative oxidation state. This definition does not include all organic nitrogen compounds, but most forms, such as proteins, peptides, and amino acids, comprise organic nitrogen. When organic nitrogen and ammonia are determined together the term total Kjeldahl nitrogen (TKN) is used to indicate the combination. For this study, ammonia and organic nitrogen are reported together as TKN.

Review of Table 3.1 indicated that, with the exception of Sager Creek, nitrate and total nitrogen fluctuated moderately between sampling locations. Organic nitrogen (TKN) also varied somewhat between sites. Excluding Sager Creek, nitrogen values ranged from 1.37 - 2.69 mg/L for total nitrogen, 1.12 - 2.19 mg/L for nitrate and 0.3 - 0.52 mg/L for TKN. Sager Creek values were typically higher than any other location for total nitrogen, nitrate, and TKN (5.9 mg/L, 5.56

mg/L, and 0.55 mg/l, respectively). These observations are graphically depicted in Figures 7.3.7 - 7.3.9. (See Appendix 7.3.)

Concentrations of inorganic nitrogen (nitrate) exceeded the “unpolluted” or “pristine” environment concentration (0.12 mg/L) by over a factor of 10 at all locations. Differences of this magnitude exemplify the impact that watershed activities have on downstream water quality. The underlying stratum of the Illinois River watershed is a porous limestone media that offers little resistance to ground water movement and provides limited chemical or biological interaction with nutrient sources. As a result, agricultural practices and septic systems are very likely contributing significant amounts of nonpoint source pollution in the form of nitrate. Calculation of the percent nitrate fraction of total nitrogen supported this assumption. The average percentage of total nitrogen that was nitrate was determined to be 82.5%. Sager Creek had the largest percentage of nitrate (94.3%), while the lower percentage sites had values varying between 79 to 80%. If nitrogen were not readily available, then organic forms of nitrogen would predominate. In other words, unpolluted or less impaired waters have organic nitrogen as the dominant form of nitrogen.

3. Nutrient Loadings

In order to assess the nutrient load due to in-state contributions, the point where the river enters Oklahoma (Camp Paddle Trails) and the Tahlequah sampling points were compared. Since the river increases in volume by roughly 1.5 times between these two locations (USGS, 1994), it can be misleading to make a direct comparison of nutrient concentration without correcting for flow. For example, the total nitrogen concentration was lower at Tahlequah (1.97 mg/L) than at Camp Paddle Trails (2.68 mg/L); however, making the assumption that there is less nitrogen at Tahlequah would not be correct. If the flow volume difference of 1.5 is considered, than the concentration of total nitrogen at Tahlequah would be 2.93 mg/L which is somewhat greater than the Camp Paddle Trails concentration. This indicates that there is more nitrogen in the river at Tahlequah although the concentration is less.

As a means for direct comparison, the nutrient loadings in kilograms per year were calculated for the total phosphorous and total nitrogen parameters. By comparing the nutrient loadings at the two sites, the differences in flow are accounted for. Discharge volumes from the USGS gauging stations at Watts and Tahlequah were used for flow estimates. (Volumes differences between the Camp Paddle Trails and Watts locations were assumed to be minimal.) Flow values from 1990 to 1994 were averaged and the mean value was used as the discharge volume (USGS 1990, 1991, 1992 1993, & 1994). Average nutrient concentrations from the 1992 -1996 time period were used to represent average river concentrations. Loadings were calculated by multiplying average concentration (mg/L) by average discharge (cfs) to produce an annual load (kg/yr). The results for the Camp Paddle Trails and the Tahlequah sites are displayed in Table 4.1.

Table 4.1 Nutrient load calculations for the Camp Paddle Trails and the Tahlequah sampling locations along the Illinois River. Load and nutrient calculations as made by the OCC and the USGS.

Nutrient Load Calculations					
	Ave Discharge (cfs)	Total Phos. (mg/L)	Total Nitrogen (mg/L)	Total Phos. Loading (kg/yr)	Total Nitrogen Loading (kg/yr)
OCC CMP PAD TRL	863.6	0.22	2.68	169,500	2,065,000
OCC TAHLEQUAH	1313.6	0.17	1.97	199,200	2,309,000
USGS WATTS	863.6	0.208	2.55	161,800	1,964,000
USGS TAHLEQUAH	1313.6	0.085	1.77	99,600	2,065,000
DEQ WATTS *	-	0.296	2.37	-	-
DEQ TAHLEQUAH*	-	0.150	1.74	-	-

*Nutrient concentrations were based on Oklahoma Department of Environmental Quality data for monthly samples collected from 12/75 to 9/86 and semi-annual samples collected from 2/87 to 2/93 (Wright, 1994).

Analysis of the loading data indicated that approximately 169,500 kg/year of total phosphorous and 2,065,000 kg/year of total nitrogen were entering the state of Oklahoma from Arkansas. Comparing these figures with the Tahlequah values suggested that there was a significant increase in total phosphorous and total nitrogen within the state of Oklahoma also (29,700 and 244,000 kg/year, respectively).

An increase of this magnitude is of concern because nutrients are removed (or are detained in alternative chemical forms) from the water as the river flows downstream. There is no truly reliable way to quantitatively predict the rate at which this occurs; however, significant quantities of nutrients are detained or temporarily stored by uptake of streamside vegetation, algae, invertebrates, and fish. With this natural attenuation, one would expect the nutrients levels to decrease if there was no additional input; however, this was not the case. As a result, watershed influences (within Oklahoma) are contributing significantly to the nutrient load.

In order to check the accuracy of the data collection and nutrient load estimations, water quality data from the USGS were compared with the OCC data. Average total phosphorous and total nitrogen values were calculated from bimonthly USGS data for the time period 1990 - 1994. These values are reported in Table 4.1. Moderate difference were expected due to temporal and spatial sampling differences, but statistically there was no difference between the USGS and OCC data with the exception of the Tahlequah total phosphorous data. The USGS Tahlequah site had a significantly lower total phosphorous value than the OCC data. The reason for this discrepancy was probably due to temporal differences and also the number of data collection episodes. For the Tahlequah site, the OCC collected 63 samples from 1992 - 1996 while the USGS data consisted of 38 samples collected from 1990 - 1994. However, the 0.085 mg/L USGS value was suspected to be low.

As a further comparison, an average nutrient concentration based on a fifteen year data set from the Oklahoma Department of Environmental Quality (DEQ) was reviewed. According to a study authored by Jay Wright (1994), DEQ concentration calculations were similar to concentration determined by the OCC. (See Table 4.1.) This finding supports the assumption that the USGS total phosphorous value for Tahlequah was too low. The fifteen year average USGS concentration was 0.15 mg/L and the OCC result was 0.17 mg/L. Subsequently, the Illinois River is likely experiencing an increase in total phosphorous and total nitrogen within the state of Oklahoma.

B. Physical / Chemical Parameters

1. Alkalinity

Alkalinity is the measure of all titratable bases or the acid-neutralizing capacity of water (APHA *et al.*, 1989). In simpler terms, it is a measure of the buffering capacity of water or it is a measure of the quantity and types of compounds that shift the pH of an aquatic system in the alkaline range (Allan, 1995). Carbonates, bicarbonates, phosphates, and hydroxides all contribute to alkalinity. Alkalinity is an important aspect of water quality because it has an indirect effect on the toxicity of certain pollutants. Carbonate and bicarbonate will complex particular heavy metals and reduce overall toxicity. Furthermore, freshwater environments depend on alkalinity to buffer the pH changes that occur because of photosynthetic activities. Due to these beneficial properties, the National Technical Advisory Committee (NTAC, 1968) established a recommended minimum alkalinity level of 20 mg/L as $CaCO_3$.

Review of the Illinois River data indicated that none of the sampling locations had alkalinity levels below 20 mg/L. On average, all sites had approximately 100 mg/L with a low of 73 mg/L near Osage Creek and a high of 109 mg/L at Camp Paddle Trails. Alkalinity levels in the Illinois River should never be a problem due to the limestone bedrock that is prevalent throughout the watershed.

2. Chemical Oxygen Demand

Chemical oxygen demand is a measure of the amount of oxidizable substances found in the water. Materials, which contribute to COD, are generally organic in nature and would include algae, detached periphyton, leaf debris, and/or other material that was living at one time. This is an important parameter as it represents the amount of oxygen that would be used up as these materials decay. There is no standard for COD in streams; however, values below 5.0 would be desirable (Lynch, 1992 and Butler, 1996).

Analysis of the data indicated that most of the sampling locations along the river exceeded this ideal level. Chemical oxygen demand levels ranged from 3.59 up stream of Flint Creek to a high of 6.91 near Osage Creek. These values indicated that there is slightly higher than desired levels of organic matter in the river. In contrast, the tributary streams were generally below this level with the exception of Sager Creek. Tributary stream values ranged from 3.26 near Fagan Creek to 5.88 at Sager Creek.

3. Conductivity

The ability of an aqueous solution to carry an electric current is numerically expressed as conductivity (APHA *et al.*, 1989). Conductivity is an approximate predictor of dissolved compounds such salts, inorganic acids, and bases. However, organic compounds are not efficient conductors of electricity and consequently, are not accounted for by conductivity measurement. Quantities of dissolved solids do not become of concern until concentration reach extremely high or low levels. In general, extreme levels of dissolved solids can affect biotic communities by inhibiting certain species. Waters with lower concentrations of ionic compounds tend to have reduced fauna, particularly mollusks and crustaceans (Allan, 1995), and waters with high concentrations may interfere with osmotic regulation. As a general rule, conductivity measurements of less than 10 µS and greater than 800 - 2000 µS may adversely affect certain species (Butler, 1996).

Conductivity values for the Illinois River did not vary greatly between sites and were well within the accepted range. The highest conductivity value was observed at Sager Creek (291.6 µS) and the lowest was at Baron Fork Creek (162.2 µS).

4. Hardness

Polyvalent metallic cations are the cause of water hardness. In fresh water environments, the majority of hardness is due to calcium and magnesium ions although iron, strontium, and manganese can contribute to hardness in some circumstances. In order to standardize reporting, hardness is recorded as mg/L as calcium carbonate ($CaCO_3$). Using this standard format, water can be classified as being "soft", "moderately hard", "hard", or "very hard". See Table 4.2.

Table 4.2 Classification of water by hardness content (EPA, 1986).

HARDNESS CLASSIFICATION	
mg/L $CaCO_3$	**Classification**
0 - 75	soft
75 - 150	moderately hard
150 - 300	hard
300 - above	very hard

Although there is uncertainty associated with the effect that hardness has on the aquatic environment, there is an overall benefit associated with increased hardness. The debate is focused around the chemical mechanisms involved with the positive water quality effects. For instance, is the toxicity of various metals reduced due to the formation of metal complexes or is the effect associated with one of the principal cations contributing to hardness (EPA, 1986). However, it has been shown that the toxicity of metals in water containing carbonate hardness was greatly reduced (EPA, 1986).

Based on Table 4.2, the Illinois River water was determined to be moderately hard at all sites. The hardness values were lowest at Baron Fork Creek (80.86) and highest at Sager Creek (114.2); however, the difference between sites was not substantial. With respect to toxicity effects, the hardness levels at all sites were considered to be acceptable.

5. pH

Hydrogen activity in water is measured as pH. This represents the acid-base equilibrium achieved by various dissolved compounds, salts, and gases (EPA, 1986). Chemical and biological systems in natural waters are affected by changes in pH through dissociation of weak acids and bases. For instance, pH influences the dissociation of weak acid and bases which in turn affects the toxicity of certain compounds. For productive streams, from a warmwater community perspective, water should have a pH of between 6.5 and 9.0 (OWRB, 1994). Data presented in Table 3.1 indicated that pH was not of concern at any location. Fluctuation in pH varied only slightly from 7.3 to 7.8-- well within the desired range.

6. Total Suspended Solids

When organic and inorganic particulate matter is physically entrained in the water it is considered to be suspended solids. Suspended solids included sediments as well as detritus and planktonic organisms. Suspended solids are important because of aesthetics reasons and also due to the adverse impacts on fish. A study conducted by the European Inland Fisheries Advisory Commission (EIFAC, 1965) identified the following affects:

1. Increased mortality and/or reduced growth rates;
2. Prevention of successful development of fish eggs and larvae;
3. Modification of natural movement and migration habits; and
4. Reduction in the abundance of food available to fish species.

Macroinvertebrates are also adversely affected by suspended solids that settle out of suspension. Several studies have identified instances where invertebrate populations are significantly reduced (Gammon, 1970, EIFAC, 1965, and Tebo, 1955).

Adverse impacts on benthic macroinvertebrate populations have been observed at total suspended concentrations of as low as 80 mg/L (Gammon, 1970); however, no sampling sites along the Illinois River approached this level. Highway 16 had the highest concentration with 60.05 mg/L and Sager Creek had the lowest with 5.09 mg/L. In general, the tributary streams had lower concentrations of suspended solids than the river sites. This suggests that the main body of the river may be experiencing excessive bank erosion or algal blooms. Another possibility is that something is agitating the mainstem of the river that is not present in the tributary streams such as bottom feeding fish or canoers. All of these factors could contribute to elevated levels of suspended solids.

7. Turbidity

Water clarity is measured in terms of turbidity. Turbidity is caused by suspended inorganic and organic mater, soluble colored compounds, and also by plankton and microscopic organisms. Turbid waters are aesthetically displeasing and detract from the recreational use aspect of water bodies. In addition, turbid water tends to directly harm fish by damaging and interfering with gill function and also by inhibiting site-feeding fish. Oklahoma has developed water quality standards for turbidity based on detrimental effects to fish. For more resistant species, a standard of 25 NTU was established while 10 NTU was instituted for more sensitive species such as smallmouth bass (OWRB, 1994). (Arkansas's turbidity standard for the Illinois River is 10 NTU (Arkansas Department of Pollution Control and Ecology, 1995).)

Aesthetic concerns are of great importance when the recreational use aspect of the Illinois River is considered. Since the river attracts a significant number of visitors each year, it is important that the river aesthetics remain high because recreational users perceive murky water as polluted water. In addition, murky water is not pleasant to swim in nor is it safe because of underwater hazards.

Review of the Illinois River data (see Table 3.1) indicated that the turbidity levels of the tributary streams tended to be lower than the river sites. Sager, Flint and Baron Fork Creeks had the lowest turbidity (3.64, 3.11, and 2.96, respectively), while Camp Paddle Trails was the highest. Comparison of the turbidity values with the water quality standards indicated that Camp Paddle Trails and the Illinois River downstream of Flint Creek were the only sites that exceeded the allowable limits for turbidity, (34 and 12 NTU, respectively). Please note, only base flow turbidites were compared. If high flow events were considered in the calculations, then the turbidites levels would be considerably higher.

4.3 Trend Analysis

Trend analysis was used to determine long term changes in water quality. There are several methods available for accomplishing this; however, in this report the Kendall Tau and the Seasonal Kendall Tau tests were performed utilizing the WQSTAT software package developed by the Colorado State University.

Several precautions should be mentioned with regard to the use of trend data. Although trend analysis using these techniques does provide an interpretation of the statistical significance of the trend, this does not mean that any trend is of a great magnitude. As an example, values which increase or decrease greatly over time but which fluctuate widely across individual years may not be found to show a statistically significant trend. On the other hand are the values which increase or decrease only slightly over time but which vary little across a year. These values may be found to have a significant trend, despite the small change in values over time.

It should be mentioned that there was a high degree of variation in the data, that is, values fluctuated widely from month to month. This degree of variation probably biased the trend analysis in certain circumstances. Some of this fluctuation is due to changes in river volume; therefore, if values could be examined in terms of loading, the data would probably be more uniform. Unfortunately, loadings could not be calculated for each site because flow data was not available.

Trend analysis was performed on the data for two time periods 1992 - 1996 and 1980 - 1996. Analysis was conducted on the pollution parameters of most concern in Lake Tenkiller (total phosphorous, total nitrogen, and turbidity). Results of trend analysis are presented with respect to time period in the following sections.

A. Time Period: 1992 - 1996

Conclusions based on the data presented in this section should not be made without a note of caution. With respect to the arguments presented above, a four-year time period is more susceptible to the effects of a highly varied data set. Although the WQSTAT model was utilized to calculate all trends and seasonal effects, each sampling event represented an isolated grab sample for an entire month period. Fluctuations or anomalies due to high flow events or un-representative conditions can have a significant effect on such collection frequencies. Extrapolating a four-year trend from these data does not necessarily produce a completely representative result; however, a qualitative estimate of trend can be concluded. Quantitative increases or decreases in trend cannot be calculated due to the small data set, a larger time period would be needed. Thus, the magnitude of the increase or decrease could not be determined. (Results are presented in Table 3.3.)

1. Turbidity

In general, turbidity did not change significantly over the four-year period. According to the model, Round Hollow, No Head Hollow, Echota Bend, Tahlequah, and Flint Creek all had a negative trend, or experienced a decrease in turbidity. However, in each instance only a 90% confidence level was associated with all of the sites. A 95% confidence interval would lend more credibility to this conclusion.

Seasonal cycling of turbidity effects was not observed at any of the sites along the river or tributary creeks.

2. Total Phosphorous

Only three locations experience any sort of trend, Camp Paddle Trails, Illinois River upstream of Flint Creek, and Baron Fork Creek. Camp Paddle Trails and the upstream location near Flint Creek experienced a decrease in total phosphorous, while levels at Baron Fork Creek increased. The decrease at Camp Paddle Trails was suspect because there was only a 90% significance level and the increase at Baron Fork Creek was suspect because there were peaks or high levels of phosphorous during the later years which may have skewed the data.

Data from the Camp Paddle Trails and Round Hollow sites indicated that there was some significant seasonal variation in phosphorous concentration.

3. Total Nitrogen

Three sites experienced a decrease in nitrogen while one site increased; however, only one was significant. Flint Creek near Fagan Creek, the Illinois River near Osage Creek, and the Illinois River upstream of Baron Fork Creek sites all have a negative trend associated with them, but this decrease in nitrogen was only 90% significant with the exception of the Osage Creek location. In addition, the Sager Creek site experienced a significant increasing trend.

Total nitrogen seemed to be the only parameter that varied seasonally. Ten of the fourteen sites had significant seasonal effects.

B. Time Period: 1980 - 1996

Sample collection for this time period began in December 1980 and continued until March 1996. Sites selected by the OCC differed slightly from those used by the OSRC. Sampling locations that were the same throughout the entire period were Camp Paddle Trails, Illinois River upstream of Flint Creek, Round Hollow, No Head Hollow, Echota Bend, Flint Creek near Fagan Creek, and Sager Creek. These sites were consistent throughout the time period, but not all sites had a complete fifteen-year data set. For instance, only eight years of data were available for the No Head Hollow location.

Trend analysis for the fifteen-year period was considered to be more reliable than the four year period presented earlier. Having a larger data set provides a more representative picture of actual river condition. For this time period, the Seasonal Kendall Tau test was utilized which allowed for a quantitative estimate of trend to be determined. Also, this method was more robust, that is, it was more resistant to random errors and fluctuations in the data set. Despite these added benefits, conclusions made in this section should not be made without caution. (Results are presented in Table 3.4.)

1. Turbidity

In general, turbidity seemed to increase at four sites (CMP, NH, FAG and ECH) but the No Head Hollow and Camp Paddle Trails sites were the only locations of concern. Camp Paddle Trails had an increase of 0.59 NTU/year and the No head Hollow site had an increase of 0.4 NTU/ year. It is important to note that the data sets throughout this time period had a significant amount of variation. This could have biased the results and indicated a trend when in actuality the increase may not have occurred or that it may not have been as great as indicated.

As a method of confirmation, the data sets for the seven sampling locations were adjusted for river flow. Since elevated flows tend to have notably higher and less consistent turbidities than base flows, the high flow turbidities were removed from the data set so a base flow comparison could be made. Results of this comparison yielded a significant increase at Camp Paddle Trails (0.59 NTU/year) and a significant decrease at Sager Creek (0.056 NTU/year). See Figure 4.1 for a pictorial view of the trend locations.

Comparing the two methods of analysis yielded the same results for Camp Paddle Trails but not completely for the No Head Hollow site. After further data manipulation, the trend for No Head Hollow was only 90% significant; therefore, some question exists if there is a true trend. However, for the Camp Paddle Trails site, it is fair to state that the increasing trend may be indicative of watershed changes. The Camp Paddle Trail location was situated downstream of the Lake Frances. On May 6, 1990 the dam was breached which affected the river hydrology and allowed lake sediments to enter the river. Analysis of the trend data indicated that there was a sizable increase in the peak amount of sediment after the dam was removed. This increase in turbidity was assumed to be due to the erosion of the lake bed.

With the exception of Sager Creek, turbidity effects at all other sites did not increase or decrease significantly. The decrease in turbidity at the Sager Creek site may be due to improvements at the wastewater treatment plant. Turbidity levels appeared to decrease during the mid 1980s, which corresponds to the Siloam Springs wastewater facility upgrade.

Seasonal variation in turbidity was apparent at both Camp Paddle Trails and No Head Hollow. This suggested that the large peaks observed might be due to high flow patterns and erosion. Analysis of the data indicated that the large peaks predominated during the spring and fall months, which corresponds to the “rainy season”.

2. Total Phosphorous

Four sites experienced a decrease in the amount of total phosphorous (CMP, IRUF, RND, and SAG). The decrease in phosphorous was small but sizable at these sites with the exception of Sager Creek. Trend analysis at Sager Creek indicated a 0.044 mg/L per year decrease in phosphorous over the fifteen year time period. This sizable decrease was due primarily to the sewage treatment plant upgrade by the city of Siloam Springs. See Figure 4.2 for a pictorial view of the trend locations.

Significant, seasonal fluctuation of phosphorous was not observed at any of the sites along the river or tributary creeks.

3. Total Nitrogen

Total nitrogen was particularly of concern because a positive trend was observed at all seven locations. The magnitude of the trend varied from 0.036 to 0.232 mg/L per year. All of these increases were consequential, but the No Head Hollow and Sager Creek sites were particularly high (0.125 and 0.232 mg/l per year, respectively). The reason for the increase in nitrogen was probably due to the added pressure of agriculture, recreation, and urban development in the watershed. However, no responsible source of pollution could be identified from this study. See Figure 4.3 for a pictorial view of the trend locations.

Total nitrogen seemed to fluctuate seasonally at all sites except Sager Creek. The seasonally changes occurred during the spring and fall months which suggested that storm-water discharge and overland flow may be contributing high levels of nitrogen to the river. Sager Creek did not have a seasonal effect associated with it probably because the sewage treatment plant was the primary source of nitrogen entering the creek. Since this is a consistent and dominating source of nitrogen, the seasonal increase would probably be masked. According to the Arkansas Department of Pollution Control and Ecology (1995), concentrations of nitrate-nitrogen (the largest component of total nitrogen in the Illinois River watershed) were greatest downstream of the wastewater treatment plant for both low and high flow events. This finding supports the argument that the treatment plant is the dominating source of nitrogen for Sager Creek.

4.4 Periphyton

Similar to other biological assessments, periphyton collection is a bioassessment method used to appraise the health and integrity of an aquatic ecosystem. By measuring the *in situ* growth rate of the microfloral community the lentic community can be classified with respect to water quality. Theoretically, the faster the growth rate, the poorer the water quality.

Periphyton, as defined by Wetzel (1983), usually refers to the microfloral growth (autotrophic) that appears on the substrata. This classification segregates out phytoplanktonic from the aesthetically displeasing, slimy, benthic growth that typically covers the aquatic substrate. Periphyton consists of numerous groups of algae ranging from filamentous green and blue-green algae to diatoms and others (Lynch, 1993). In contrast, phytoplankton consists of small autotrophic organisms having little to no power of locomotion (Wetzel, 1983).

Periphyton water quality classification is based on chlorophyll a concentrations/unit area. Table 4.3 presents the stream classification standards loosely adopted by the OCC.

Table 4.3 Stream classification based on periphyton collection using chlorophyll a as the measure of water quality. (Chlorophyll a levels are loosely adopted by the Oklahoma Conservation Commission (Butler, 1996).)

STREAM CLASSIFICATION BASED ON CHLOROPHYLL a CONCENTRATION ($\mu g/cm^2$)	
Stream Classification	**Chlorophyll a Concentration**
un-impaired	≤ 1.00
slightly impaired	1.00 - 2.00
moderately impaired	2.00 - 4.00
impaired	4.00 - 8.00
severely impaired	> 8.00

Figure 4.1 A map of the Illinois River Drainage Basin outlining the locations of increasing and decreasing turbidity trends.

Figure 4.2 A map of the Illinois River Drainage Basin outlining the locations of decreasing total phosphorous trends.

Figure 4.3 A map of the Illinois River Drainage Basin outlining the locations of increasing total nitrogen trends.

The Illinois River data was evaluated with the values presented in Table 4.3 and a comparison between the 1992 - 1993 and 1985 - 1986 data was made (see Table 4.4). The goal of this comparison was to determine if there was an improvement or regression in the health of the stream over the eight-year time period.

Table 4.4 Average periphyton data and statistical comparison of time periods 1985-86 and 1992-93 are presented along with a biological classification of stream health for Illinois River data.

PERIPHYTON COMPARISON				
SITE	**1985-86 AVG (μg/cm^2)**	**1992-93 AVG (μg/cm^2)**	**STAT. SIGNIF.**	**CLASS**
BFK	3.9	3.52	not significant	mod. impaired
IRUB	6.29	NA	NA	impaired
IRUF	NA	5.43	NA	impaired
ECH	11.05	7.14	95%	impaired
RND	6.20	4.87	95%	mod impaired
HWY	10.11	3.62	95%	mod. impaired
IRUO	3.42	4.07	not significant	mod. impaired
NH	5.23	7.77	95%	impaired
TAL	2.55	8.49	95%	sev. impaired
FAG	NA	6.21	NA	impaired
FLT	NA	3.35	NA	mod. impaired
CMP	NA	3.23	NA	mod. impaired
IRDF	NA	4.82	NA	impaired

NA = Comparisons were not made due to the availability of data.

Classification of the 1992 - 1993 river locations indicated that all site were impaired to one degree or another. Most sites were either “moderately impaired” or “impaired”, but the Tahlequah site was classified as “severely impaired”.

Comparison of the two time periods suggested that most of the sites remained the same, although some locations improved while others degraded. Statistical interpretation of the data indicated that Highway 16 decreased from “severely impaired” to “moderately impaired” and Round Hollow decreased from “impaired” to “moderately impaired”. In contrast, Tahlequah increased from “slightly impaired” to “severely impaired”. No conclusive explanation for the increase or decrease in periphyton growth rates could be drawn based on this study.

4.5 Fecal Coliform Bacteria

Total coliform bacteria refers to a group of microorganisms (bacteria) that are aerobic and facultative, gram negative, non-spore-forming, rod shaped, and ferment lactose with gas production within 48 hours at 35° C (APHA *et al.*, 1989). Total coliform bacteria are excreted in high number in human and animal fecal material, but not all are of fecal origin. Fecal coliform bacteria are a subset of the total group and include all coliform bacteria that can ferment lactose at 44.5° C (Bitton, 1994). Fecal coliform bacteria are only associated with fecal material from warm blooded animals. It is important to note that it is not possible to distinguish between animal and human contamination. Therefore, runoff events may cause large influxes of fecal coliform bacteria from animal husbandry activities.

Fecal coliform bacteria are useful indicators of water quality for recreational activities. Since many of the human diseases of concern are perpetuated through fecal material, measuring the quantity of fecal bacteria found in the stream environment can provide a threshold level of concern that disease causing organisms may be present. The greater the concentration of fecal coliform bacteria the greater the possibility for pathogens. Oklahoma has developed a water quality standard for recreational use water bodies which is paraphrased as follows: bacteria of the fecal coliform group should not exceed a monthly geometric mean of 200 (assumed to be colony forming units (CFU))/100 mL of sample and no more than 10% of a thirty day sampling period should exceed 400/100 mL (OWRB, 1994).

Fecal coliform bacteria sampling on the Illinois River was conducted monthly from August 1995 to June 1996. Monthly results are present in Table 3.7 and annual averages are listed in Table 3.8. Analysis of annual averages suggested that all of the sites were within the 200/100 mL range with the exception of the Illinois River upstream of Osage Creek. Here, the geometric mean was elevated above 200 CFU. (Annual averages are typically not used for interpreting fecal coliform bacteria results. For this report, annual averages were calculated for descriptive purposes.) It should be noted that the sampling frequency was less than representative. In this case, only one sample was collected during a thirty-day period, which does not provide a representative result for a particular month. However, if the standards are strictly followed, then any single sampling event in a monthly sampling protocol would be a violation of water quality standards (OWRB, 1994). In other words, one sample greater than 400/100 mL is greater than 10% for the month and would be considered a violation.

Graphical representations of the annual fecal coliform bacteria results are presented in Figures 7.5.1 - 7.5.14. Review of these figures indicated that there was not a seasonal pattern of fecal coliform bacteria contamination. However, analysis of Table 3.7 implied that there were episodes when fecal coliform bacteria levels were elevated above allowable limits, particularly during the month of April. Since the majority of the locations along the river experienced elevated levels of fecal coliform bacteria, this concentration was probably an extreme value that was not necessarily representative of typical conditions. During and prior to sample collection there had been a period of heavy rain. Run off from the surrounding cattle pastures or over flow from sewage treatment facilities may have been responsible for the elevated levels of fecal coliform bacteria. Since there were elevated levels at all site along the river and tributary streams, it is likely that the cause of contamination was due to animal husbandry activities. However, the specific source of fecal contamination could not be distinguished (i.e. human verses animal waste). Due to the serious, potential consequences that are associated with contacting human waste, extreme caution should be exercised when discounting extreme data values. The probability of direct negative effect on human health and welfare far outweighs any other water quality parameter.

Overall, there did not appear to be a significant problem with fecal coliform bacteria contamination during this time period. Nevertheless, during high flow events there were concentrations that vastly exceeded water quality protection levels. Further testing should be conducted to determine if the elevated levels are common after all rains. If elevated levels are prevalent after storm events, then recreational users should be warned about the potential danger of fecal coliform bacteria contamination during high flows. In addition, it is recommended that a fecal coliform bacteria sample collection protocol be implemented that will provide statistically valid results. Based on the current, limited data, there may be cause for concern but more reliable data is needed to confirm or refute this presumption.

4.6 Specific Location Effects

In this section, differences in water quality will be discussed with respect to sampling location. Locations and activities within the Illinois River watershed may have particular consequences on the overall health of the river. Two specific examples will be presented.

Review of the four year average nutrient data (Figures 7.3.8 - 7.3.12) indicated that there was an increase in nutrient pollution (nitrate, total nitrogen, orthophosphate, total phosphorous, and COD) between the Illinois River upstream of Osage Creek and the Highway 16 sampling locations. Although no accusatory conclusions can be made from this data, the increase in pollution may be due to nutrient loading coming from Osage Creek. Flow from Osage Creek contains wastewater effluent from the cities of Springdale and Rogers along with nonpoint source pollution from the surrounding watershed. Since the flow volume of Osage Creek is considerably greater than the Illinois River prior to the confluence, it is fair to assume that the elevated nutrient concentrations observed at the Highway 16 site are due primarily to watershed activities in the Osage Creek area. Nutrient concentrations increased as follows: nitrate increased 1.2 times, orthophosphate more than doubled (0.08 mg/L to 0.20 mg/L), and total phosphorous increased from 0.14 mg/L to 0.25 mg/L. Increases such as these are of concern since the Osage Creek watershed has experienced a tremendous amount of urban development in the recent past and is currently experiencing tremendous growth. Nutrient pollution is likely to continue if steps are not taken to mitigate the amount of nutrients being released to the Osage Creek watershed.

A second location of interest is the Sager Creek site. Sager Creek has historically received a considerable amount of attention due to exceptionally high levels of nutrients. Examination of the Figures 7.3.8 - 7.3.11 indicated that Sager Creek continues to have elevated concentration of nutrients. As mentioned previously, Sager Creek receives sewage treatment effluent from the city of Siloam Springs. Reported concentrations were notably higher than any other site for nitrate, total nitrogen, orthophosphate, and total phosphate. Despite these findings, Sager Creek may not be significantly affecting the Illinois River. According to a report Arkansas Department of Pollution Control and Ecology (ADPCE) (1995) the effects of the wastewater treatment plant are minimal. Fish and macroinvertebrate assessments as well as periphyton monitoring indicated that Sager Creek habitat was not adversely affected by the time flow reached the mouth of the creek (ADPCE, 1995).

Comparing the nutrient loading of Sager Creek with the receiving creek (Flint Creek) indicated that 6,100 kg/year of a total 18,300 kg/year of total phosphorous and 58,000 kg/year of a total 360,000 kg/year total nitrogen were contributed by Sager Creek. Values of this amount are noteworthy because the area of the Sager Creek watershed that comprises the Flint Creek watershed is small, but the nutrient loading was disproportionately large. Nonetheless, the overall impact on the Illinois River was not evident based on the concentration levels at the Illinois River downstream of Flint Creek site. Obviously there is a dilution factor to consider and there is undoubtedly an additional nutrient discharge to the river, but there did not appear to be a noteworthy effect. Further study is needed to specifically determine if the effluent from Siloam Springs is significantly contributing to the degradation of Lake Tenkiller.

5.0 SUMMARY and CONCLUSIONS

5.1 Introduction

The Illinois River is classified as a scenic river from the point where it enters Oklahoma until it reaches the confluence of Baron Fork Creek, roughly four miles north of Lake Tenkiller. Over the past several years, the quality of Lake Tenkiller has been degrading primarily due to problems associated with nutrient and sediment loadings (OWRB, *et al.,* 1996). As part of a complete assessment program, the Oklahoma Scenic River Commission (OSRC) continuously monitors the water quality in order to track the status of the river. In 1992 the Water Quality Division of the Oklahoma Conservation Commission (OCC) developed a working agreement with the OSRC to monitor the river's water quality; however, the responsibilities are now being assumed by the US Geological Survey (USGS). In fulfillment of the agreement with the OSRC, this document summarized the water quality conditions for the 1992 - 1996 period of investigation. From this four-year sampling period, the following conclusions were made.

5.2 Parameters

A. Nutrients

- Overall, nutrient concentrations were found to be excessive at all locations along the Illinois River and tributary streams. Also, both total phosphorous and total nitrogen did not appear to be limiting; therefore, eutrophication in Lake Tenkiller is likely to continue.

- Nitrate and orthophosphate were the predominating contaminants in the Illinois River. These pollutants are of concern because they are in a chemical form that is readily available for algal uptake and are direct indicators of human pollution.

- Phosphate phosphorous levels at all sampling locations exceeded the suggested EPA concentration of 0.05 mg/L. Levels were up to ten times greater than the concentration recommended to prevent lentic water eutrophication. The lowest levels were observed at the tributary creeks and towards the headwaters of the river. Fagan Creek and Baron Fork Creek had total phosphorous levels of 0.07 and 0.06 mg/L, respectively, and the Illinois River near Osage Creek had an average concentration of 0.10 mg/L. These levels are low when compared with the rest of the river, but these concentrations are still of concern. Most values ranged between 0.10 and 0.20 mg/L, but Sager Creek had higher levels. The Sager Creek sampling site was located three miles downstream of the city of Siloam Springs, Arkansas. High concentrations (0.53 mg/L, average) were expected due to the proximity of the city's wastewater treatment facility.

- Total nitrogen concentrations were much greater than desired levels. Although there is not any recommended levels currently available, all sites exceeded the "pristine" or "unpolluted" concentration (0.12 mg/L) by almost ten times. Excluding Sager Creek, nitrogen values ranged from 1.35 - 2.69 mg/L for total nitrogen, 1.12 - 2.19 mg/L for nitrate, and 0.30 - 0.52 mg/L for TKN. Sager Creek values were typically much higher than any other location for total nitrogen, nitrate, and TKN (5.9 mg/L, 5.56 mg/L, and 0.55 mg/l, respectively).

- Analysis of the loading data indicated that approximately 169,500 kg/year total phosphorous and 2,065,000 kg/year of total nitrogen were entering the state of Oklahoma from Arkansas. Another 29,700 kg/year of total phosphorous and 244,000 kg/year of total nitrogen were added due to in-state contributions.

B. Physical / Chemical

- Turbidity levels of the tributary streams tended to be lower than the river sites. Sager, Flint and Baron Fork Creeks had the lowest turbidity, while Camp Paddle Trails was the highest. Comparison of the turbidity values with the water quality standards indicated that Camp Paddle Trails and the Illinois River downstream of Flint Creek were the only sites that exceeded the allowable limits for turbidity, (34 and 12 NTU, respectively).

- Chemical oxygen demand was slightly elevated throughout the length of the river. This indicated that an undesirable amount of organic matter was entering the river.

- Alkalinity, pH, conductivity, hardness, and total suspended solid levels were within the generally accepted ranges. Therefore, these parameters were not of concern.

5.3 Trend Analysis

A. Time Period 1992 - 1996

- Although the statistical interpretation of the data indicated that there were some significant trends, the four-year time period was not long enough to make quantifiable conclusions. As a result, any identifiable trend was likely to be speculative.

B. Time Period 1980 - 1996

- Turbidity increased at four sites, Camp Paddle Trails, No Head Hollow, Flint Creek near Fagan Creek, and Echota Bend; however, only one site was of significant concern. Camp Paddle Trails had a increasing trend of 0.59 NTU/year which was thought to be due to eroding lake bed sediments from Lake Frances. Conversely, turbidity at Sager Creek decreased.

- Four sites experienced a decrease in the amount of total phosphorous (Camp Paddle Trails, the Illinois River upstream of Flint Creek, Round Hollow, and Sager Creek). The decrease in phosphorous was small but significant at these sites with the exception of Sager Creek. Trend analysis at Sager Creek indicated a 0.044 mg/L per year decrease in phosphorous over the fifteen year time period. This sizable decrease was assumed to be due to the sewage treatment plant upgrade implemented by the city of Siloam Springs.

- Total nitrogen was particularly of concern because a positive trend was observed at all seven sampling sites evaluated. The increase in concentration varied from 0.036 to 0.232 mg/L per year, but all values were of significant magnitude. The reason for the increase in nitrogen was probably due to the added pressure of agriculture, recreation, and urban development in the watershed; however, no responsible source of pollution could be identified by this study.

5.4 Periphyton

- Based on periphyton analysis, the 1992 - 1993 data indicated that the various river locations were determined to be “moderately impaired” to “impaired”; however, the Tahlequah site was found to be “severely impaired”. Comparing the 1985 - 1986 findings with the 1992 - 1993 results indicated that Highway 16 decreased from “severely impaired” to “moderately impaired” and Round Hollow decreased from “impaired” to “moderately impaired”. In contrast, Tahlequah increased from “slightly impaired” to “severely impaired”. No conclusive explanation for the increase or decrease in periphyton growth rates could be made based on this study. Overall, the impaired nature of the river was due to elevated nutrient levels.

5.5 Fecal Coliform Bacteria

- In general, there did not appear to be a problem with fecal coliform bacteria contamination during the 1995 - 1996 time period. However, during high flow events there were concentrations that greatly exceeded water quality protection levels.

5.6 Specific Location Effects

- Osage Creek was contributing a significant amount of nutrients to the Illinois River. Nutrient concentrations for nitrate, total phosphorous, and orthophosphate increased sharply at the Illinois River at Highway 16 site. Although no accusatory conclusions can be drawn from this study, discharge from urban areas located in the Osage Creek Watershed was the likely culprit.

- Despite the elevated nutrient concentrations, Sager Creek may not be drastically affecting the Illinois River. Although the concentration levels for nitrate, total nitrogen, orthophosphate, and total phosphorous were higher than any other sampling location, there was no acute effect observed on the Illinois River. Further study is needed to determine the impact on Lake Tenkiller.

6.0 BIBLIOGRAPHY

Allan, J.D., (1995), Stream Ecology: Structure and Function of Running Waters, Chapman and Hall, London, England.

APHA, AWWA, and WPCF, (1989), Standard Methods For the Examination of Water and Wastewater, 17th edition, eds. L.S. Clesceri, A.E. Greenberg, and R.R. Trussell, American Public Health Association, Washington D.C.

Arkansas Department of Pollution Control and Ecology, (1995), "Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas", Arkansas Department of Pollution Control and Ecology, Water Quality Division, Little Rock, Arkansas.

Arkansas Department of Pollution Control and Ecology, (1995), "Water Quality Survey and Biological Assessment of the Effects of Wastewater Discharges From the City of Siloam Springs on Sager Creek", Draft Report, Arkansas Department of Pollution Control and Ecology, Water Quality Division, Little Rock, Arkansas.

Bitton, G., (1994), Wastewater Microbiology, Wiley-Liss, New York, New York.

Butler, D., (1996), personal communication, Oklahoma Conservation Commission Water Quality Division, June 1996.

Colorado State University, (1988), WQSTAT: A Water Quality Statistics Program, Colorado State University, Fort Collins, Colorado.

EPA, (1986), Quality Criteria for Water 1986, US Environmental Protection Agency, EPA 440/5-86-001, US Government Printing Office, Washington D.C.

European Inland Fisheries Advisory Commission, (1969), "Water Quality Criteria for European Freshwater Fish-- Extreme pH Values and Inland Fisheries", prepared by EIFAC Working Party on Water Quality Criteria for European Freshwater Fish, Water Research 3:593.

Gammon, J.R., (1970), The Effect of Inorganic Sediment on Stream Biota, EPA Water Pollution Control Research Series 18050 DWC 12/70, US Government Printing Office, Washington D.C.

Gilbert, R.O., (1987), Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold Co., New York, New York.

Knepp, G.L. and G.F. Arkin, (1973), "Ammonia Toxicity Levels and Nitrate Tolerance of Channel Catfish", The Progressive Fish-Culturist, 35:221.

Lynch, R., (1993), "Development of Rapid Bioassessment Protocols for Oklahoma Utilizing Characteristics of the Diatom Community", Oklahoma Conservation Commission, Oklahoma City , Oklahoma.

Lynch, R., (1992), "Oklahoma Scenic Rivers Commission Report on Water Quality, Illinois River", Oklahoma Conservation Commission, Oklahoma City, Oklahoma.

McCoy, E.F., (1972), Role of Bacteria in the Nitrogen Cycle in Lakes, EPA, Water Pollution Control Research Series, EP 2.10:16010 HER 03/72, US Government Printing Office, Washington D.C.

Mackenthun, K.M., (1973), Toward a Cleaner Aquatic Environment, US Government Printing Office, Washington D.C.

NTAC, (1968), National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, US Government Printing Office, Washington D.C.

OCC, (1995), "Standard Operating Procedures Document for the Collection and Analysis of Water Quality Samples", Methods 6 and 19, Oklahoma Conservation Commission, Oklahoma City, Oklahoma.

Oklahoma Department of Pollution Control, (1979), Area-wide Waste Treatment Management 208 Plan for Oklahoma- Water Quality Management Plan for Illinois River, Segment 121700.

OWRB, (1994), "Water Quality Standards" Oklahoma Administrative Code Title 785, Oklahoma Water Resources Board, Oklahoma City, Oklahoma.

OWRB, US Army Corps of Engineers, and Oklahoma State University, (1996), "Cooperative "Clean Lakes" Project Phase I Diagnostic and Feasibility Study on Tenkiller Lake, Oklahoma" Oklahoma Water Resources Board, Oklahoma City, Oklahoma.

Roberts/Schornick and Associates, (1984), Illinois River Assessment Report, Norman, Oklahoma.

Tebo, L.B., Jr., (1955), "Effects of Siltation, Resulting from Improper Logging, on the Bottom Fauna of a Small Trout Stream in the Southern Appalachians", The Progressive Fish-Culturist, 17:64.

USGS, (1994), "Water Resources Data Oklahoma Water Year 1994, Volume 1: Arkansas River Basin", U.S. Geological Survey Water-Data Report OK-94-1, Oklahoma City, Oklahoma.

USGS, (1993), "Water Resources Data Oklahoma Water Year 1993, Volume 1: Arkansas River Basin", U.S. Geological Survey Water-Data Report OK-93-1, Oklahoma City, Oklahoma.

USGS, (1992), "Water Resources Data Oklahoma Water Year 1992, Volume 1: Arkansas River Basin", U.S. Geological Survey Water-Data Report OK-92-1, Oklahoma City, Oklahoma.

USGS, (1991), "Water Resources Data Oklahoma Water Year 1991, Volume 1: Arkansas River

Basin", U.S. Geological Survey Water-Data Report OK-91-1, Oklahoma City, Oklahoma.

USGS, (1990), "Water Resources Data Oklahoma Water Year 1990, Volume 1: Arkansas River Basin", U.S. Geological Survey Water-Data Report OK-90-1, Oklahoma City, Oklahoma.

Wetzel, R.G., (1983), Limnology, second edition, Saunders College Publishing, Fort Worth Texas.

Wright, J.C., (1994), "The Detection of Trends and Changes in the Stream and Rivers of Oklahoma", Masters Thesis, University of Oklahoma, Norman, Oklahoma.

7.0 APPENDIX

7.1 Quality Assurance Data Results

7.2 Tabular and Graphical Results of Parameter vs. Location-- Annual Average

Table 7.2.1 Annual averages for each site and for all parameters for the 1992 -1996 Illinois River data.

ANNUAL AVERAGES

SITE	DATE	TURB	COD	TSS	TN	TKN	NO3	TP	HARD	CL	SO4	O-P	DO	pH	COND	TEMP	ALK
IRUO	1992	24.81	8.20	34.78	2.31	0.48	1.82	0.13	103.78	NA	NA	0.09	8.61	7.23	256.83	17.22	88.33
IRUO	1993	24.79	10.40	25.32	2.74	0.69	2.06	0.11	90.76	NA	NA	0.06	8.43	7.65	173.20	15.76	90.18
IRUO	1994	17.21	4.52	15.00	2.00	0.45	1.55	0.14	119.53	5.00	10.00	0.04	8.88	7.60	215.92	15.75	97.00
IRUO	1995	10.48	4.26	7.10	1.99	0.24	1.76	0.18	113.67	5.00	11.16	0.13	10.30	7.87	237.20	16.88	108.60
IRUO	1996	4.27	2.50	6.33	2.37	0.44	1.94	0.13	125.67	7.20	10.00	0.10	8.92	7.36	250.67	15.36	90.27
HWY	1992	53.74	9.87	83.63	2.88	0.59	2.29	0.28	98.50	NA	NA	0.24	8.41	7.32	264.40	15.06	80.83
HWY	1993	53.58	14.36	86.57	3.09	0.69	2.40	0.19	89.57	NA	NA	0.14	8.60	7.50	181.09	14.60	82.67
HWY	1994	17.28	5.47	18.67	2.52	0.36	2.16	0.23	114.43	5.00	18.05	0.22	9.08	7.78	227.25	16.03	97.00
HWY	1995	53.04	3.79	75.18	2.89	0.51	2.39	0.28	108.05	6.70	13.10	0.23	9.40	8.04	234.09	16.52	98.82
HWY	1996	4.64	2.50	3.00	2.81	0.32	2.49	0.07	127.67	12.77	10.00	0.04	8.79	7.81	264.67	14.34	86.94
CMP	1992	20.86	9.13	28.88	2.67	0.50	2.19	0.26	99.25	NA	NA	0.21	9.50	7.56	269.50	17.73	88.17
CMP	1993	43.38	8.53	57.00	3.05	0.62	2.43	0.21	87.87	NA	NA	0.13	9.73	7.04	178.27	14.88	83.25
CMP	1994	25.79	5.18	36.82	2.57	0.54	2.03	0.17	108.72	5.00	10.00	0.10	9.68	7.98	225.00	16.88	93.08
CMP	1995	41.17	3.41	48.61	2.43	0.37	2.07	0.26	104.19	5.28	11.63	0.22	9.08	7.48	220.80	15.89	92.91
CMP	1996	9.43	2.50	9.67	2.42	0.20	2.24	0.07	118.37	10.50	10.00	0.04	8.69	7.79	249.33	15.28	85.52
IRUF	1992	5.31	2.77	11.64	2.09	0.37	1.71	0.17	109.71	NA	NA	0.14	7.95	7.51	282.83	14.68	104.75
IRUF	1993	8.08	5.30	8.38	2.89	0.65	2.24	0.14	91.35	NA	NA	0.09	9.08	7.74	195.50	16.44	86.56
IRUF	1994	8.42	4.05	11.83	2.18	0.41	1.76	0.14	96.03	5.00	10.00	0.10	7.43	6.51	192.67	17.85	96.20
IRUF	1995	8.62	2.50	4.15	2.35	0.19	2.14	0.23	106.96	7.84	11.81	0.14	9.01	7.65	234.30	16.84	98.20
IRUF	1996	4.24	2.50	4.33	2.73	0.34	2.40	0.06	124.33	11.93	10.00	0.04	7.90	7.54	226.50	7.63	93.00
IRDF	1992	13.52	4.77	19.50	2.29	0.35	1.93	0.18	101.60	NA	NA	0.14	9.31	7.52	274.20	16.00	88.17
IRDF	1993	41.75	8.64	14.28	2.84	0.65	2.19	0.19	82.24	NA	NA	0.14	9.44	7.05	155.45	15.03	75.91
IRDF	1994	15.72	4.93	21.29	2.26	0.40	1.86	0.15	103.29	5.00	16.65	0.08	9.63	7.87	213.08	16.64	87.67
IRDF	1995	35.10	2.85	51.55	2.41	0.36	2.05	0.29	104.07	5.78	10.00	0.23	9.05	7.77	223.09	16.66	95.45
IRDF	1996	4.34	2.50	6.00	2.59	0.21	2.38	0.14	127.67	15.73	10.00	0.09	8.26	7.71	240.00	8.07	94.67
RND	1992	15.84	4.36	21.94	2.12	0.36	1.76	0.16	112.11	NA	NA	0.13	9.09	7.43	257.83	13.61	91.83
RND	1993	31.79	11.13	47.67	2.85	0.73	2.12	0.16	81.20	NA	NA	0.16	9.81	7.24	153.67	15.78	77.17
RND	1994	16.53	5.80	24.33	2.18	0.49	1.68	0.15	100.54	5.00	10.00	0.08	10.79	8.17	210.92	18.09	87.83

RND	1995	7.14	2.75	4.23	2.17	0.25	1.92	0.28	101.69	5.89	13.02	0.22	9.12	8.08	224.55	16.79	91.55
RND	1996	2.20	2.50	4.33	1.67	0.86	2.28	0.06	118.33	10.30	10.00	0.04	8.65	7.73	235.67	8.00	94.00

Table 7.2.1 (continued)

Annual averages for each site and for all parameters for the 1992 -1996 Illinois River data.

ANNUAL AVERAGES

SITE	DATE	TURB	COD	TSS	TN	TKN	NO3	TP	HARD	CL	SO4	O-P	DO	pH	COND	TEMP	ALK
NH	1992	39.44	7.53	52.83	1.96	0.40	1.57	0.18	94.67	NA	NA	0.12	8.78	7.44	250.67	14.50	88.67
NH	1993	26.66	7.83	42.09	2.60	0.59	2.01	0.15	80.25	NA	NA	0.10	9.23	7.07	153.42	15.75	74.75
NH	1994	26.30	6.63	35.58	2.04	0.50	1.54	0.15	102.03	5.00	10.00	0.07	8.42	7.74	201.17	18.22	85.75
NH	1995	8.30	2.81	7.73	2.01	0.20	1.81	0.26	102.55	6.02	12.82	0.22	8.48	7.81	217.27	16.80	91.00
NH	1996	3.68	2.50	5.67	2.63	0.35	2.28	0.09	124.33	11.23	10.00	0.05	8.51	7.64	233.33	8.20	93.67
ECH	1992	38.14	6.00	14.17	1.85	0.36	1.50	0.14	82.89	NA	NA	0.11	8.81	7.43	247.20	15.81	86.33
ECH	1993	22.49	6.56	45.50	2.49	0.59	1.89	0.13	79.10	NA	NA	0.10	9.31	7.20	157.27	15.96	77.58
ECH	1994	27.68	5.42	34.08	1.93	0.55	1.41	0.14	101.15	5.00	10.00	0.07	9.77	8.03	205.75	18.14	86.33
ECH	1995	6.12	2.75	5.55	1.97	0.29	1.69	0.24	97.82	5.70	13.41	0.20	8.35	7.81	214.09	17.25	91.91
ECH	1996	2.23	2.50	2.67	2.67	0.58	2.09	0.07	132.97	10.60	10.00	0.03	8.33	7.65	231.67	8.43	91.33
TAL	1992	39.99	7.37	62.61	1.90	0.41	1.49	0.18	93.89	NA	NA	0.10	8.63	7.33	241.50	17.03	90.33
TAL	1993	20.85	7.66	41.50	2.47	0.56	1.91	0.21	78.34	NA	NA	0.09	8.99	7.13	164.73	16.26	74.50
TAL	1994	17.97	5.48	31.14	1.76	0.51	1.34	0.13	92.60	10.00	10.00	0.07	9.60	8.06	199.92	18.00	88.00
TAL	1995	6.45	4.30	7.70	1.80	0.20	1.61	0.19	100.87	7.23	15.02	0.13	8.82	7.94	211.45	17.31	89.45
TAL	1996	2.97	6.65	3.20	2.26	0.29	2.16	0.05	119.68	16.62	12.32	0.05	8.79	7.55	236.67	9.43	90.33
IRUB	1992	38.84	7.93	57.56	1.68	0.43	1.25	0.15	95.88	NA	NA	0.11	8.43	7.36	244.20	16.83	87.20
IRUB	1993	13.38	6.02	18.41	2.24	0.43	1.82	0.18	81.73	NA	NA	0.15	9.46	7.81	168.56	15.79	76.70
IRUB	1994	17.46	5.41	26.50	1.71	0.41	1.36	0.12	94.80	5.00	17.45	0.05	9.32	7.73	192.67	17.71	83.17
IRUB	1995	7.41	2.50	8.60	1.72	0.17	1.56	0.25	90.44	6.01	15.88	0.23	8.27	7.44	202.00	16.44	85.60
IRUB	1996	2.17	2.50	5.67	2.18	0.28	1.91	0.13	119.67	7.20	10.00	0.05	8.34	7.42	220.00	8.30	91.00
BFK	1992	9.05	3.28	9.63	1.23	0.24	1.00	0.06	80.75	NA	NA	0.03	9.20	7.36	187.80	16.70	82.40
BFK	1993	21.67	6.59	15.44	1.80	0.50	1.41	0.06	70.40	NA	NA	0.04	8.85	6.94	136.30	17.32	74.45
BFK	1994	9.62	3.02	10.83	1.23	0.36	0.96	0.08	86.39	5.00	21.50	0.02	10.30	8.10	151.42	17.32	73.17
BFK	1995	4.43	2.50	5.23	1.25	0.15	1.11	0.16	80.65	5.00	16.17	0.13	8.31	7.41	148.36	16.34	74.55
BFK	1996	1.27	2.50	2.00	2.17	0.65	1.53	0.36	111.10	7.53	10.00	0.03	8.38	7.42	171.67	8.37	73.33
FAG	1992	2.29	3.72	4.38	2.31	0.61	1.73	0.09	103.27	NA	NA	0.05	8.57	7.48	263.33	17.36	91.00
FAG	1993	10.43	5.89	11.05	3.17	0.85	2.37	0.10	86.97	NA	NA	0.04	8.62	7.42	188.45	14.88	75.25
FAG	1994	5.62	2.73	6.09	2.56	0.39	2.22	0.07	103.03	5.00	10.00	0.03	8.60	7.06	212.50	15.91	86.67
FAG	1995	4.71	3.51	5.86	2.07	0.26	1.82	0.23	103.27	5.00	20.33	0.16	9.45	7.82	221.82	17.80	87.55

FAG	1996	2.35	2.50	1.33	2.10	0.34	1.78	0.15	121.67	7.30	10.00	0.11	11.87	8.42	187.67	12.33	82.33

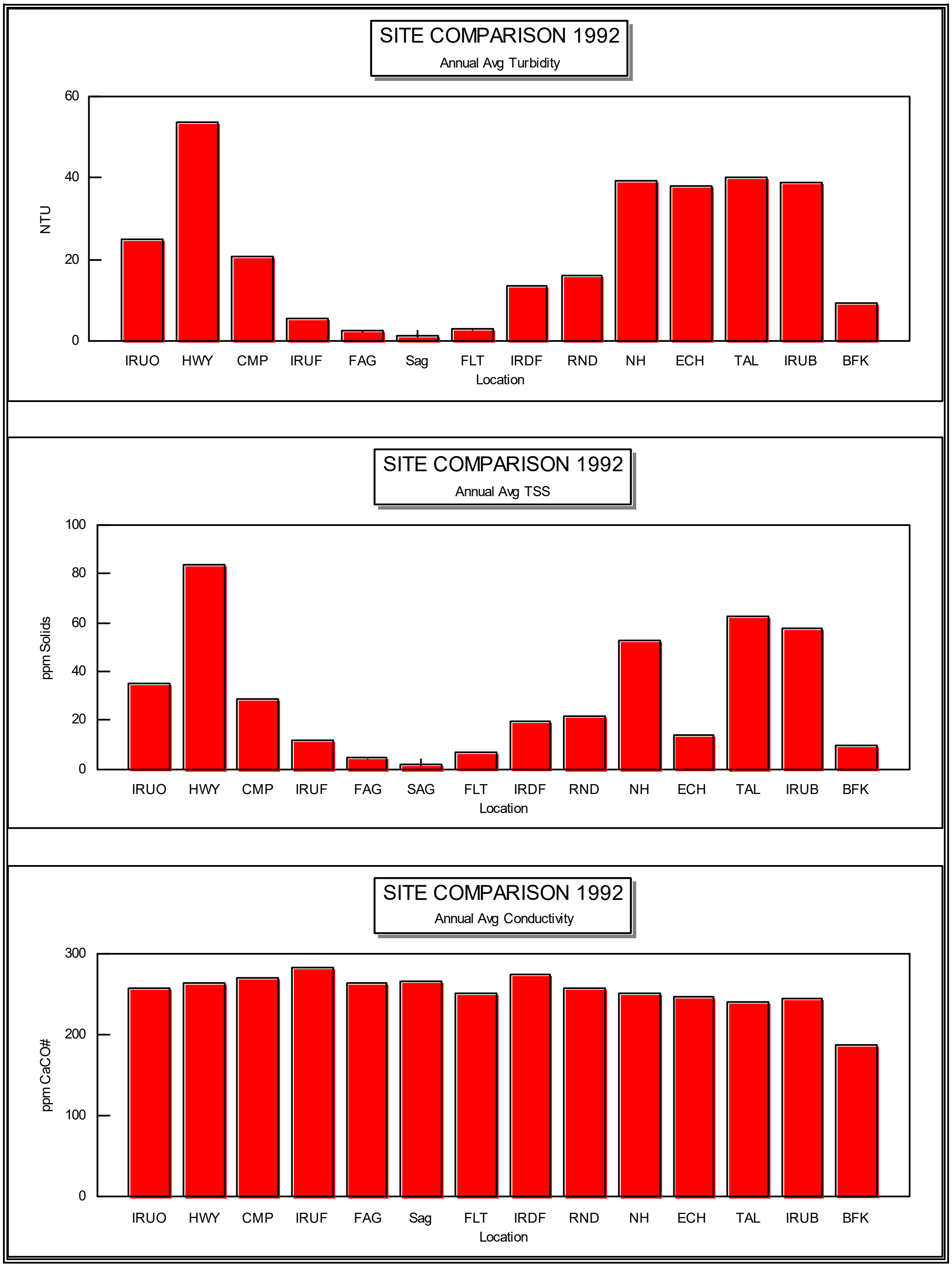
Table 7.2.1 (continued)

Annual averages for each site and for all parameters for the 1992 -1996 Illinois River data.

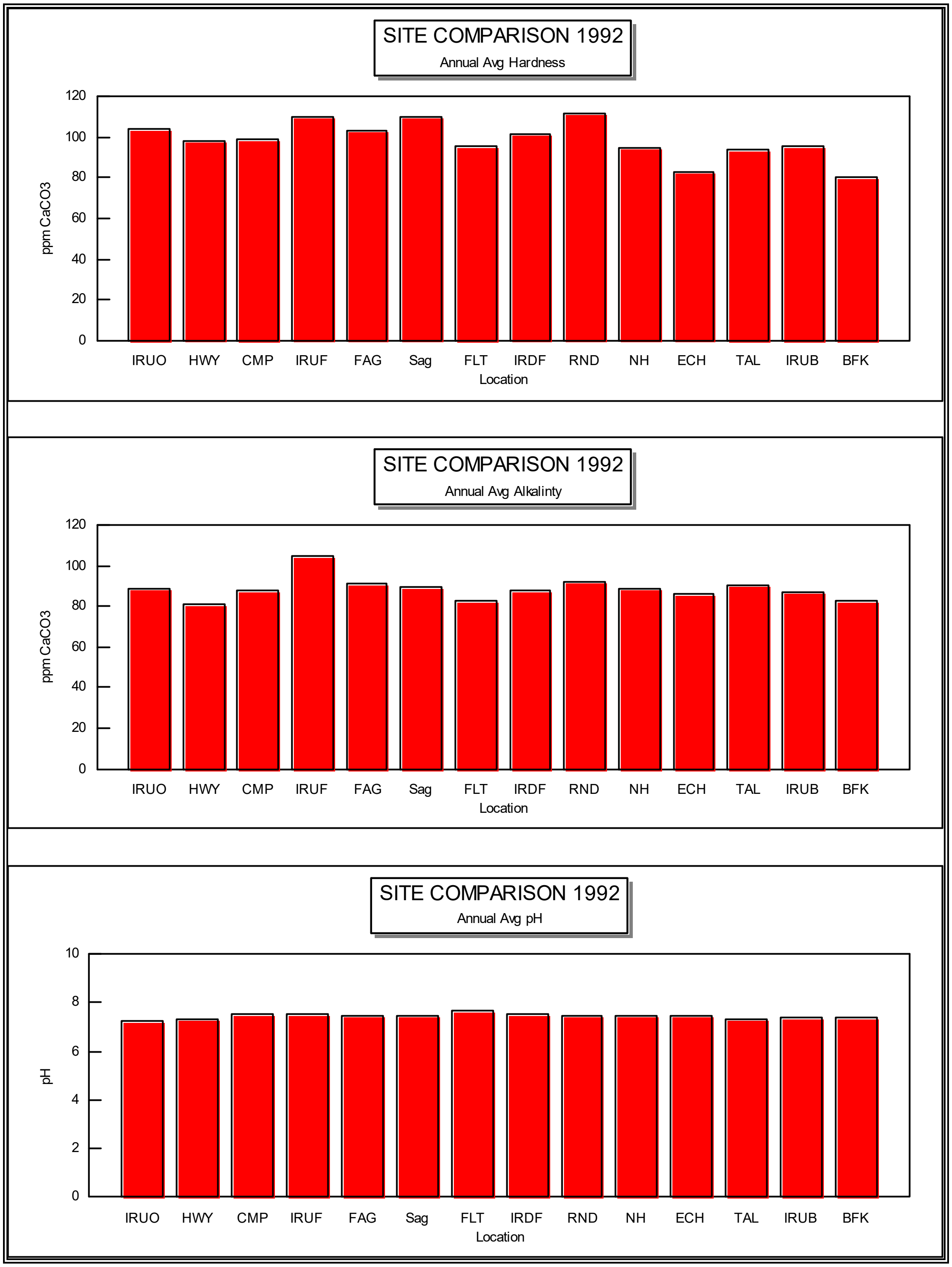
ANNUAL AVERAGES

SITE	DATE	TURB	COD	TSS	TN	TKN	NO3	TP	HARD	CL	SO4	O-P	DO	pH	COND	TEMP	ALK
FLT	1992	2.80	2.79	7.05	2.14	0.29	1.85	0.13	95.70	NA	NA	0.11	9.63	7.69	251.00	15.39	83.00
FLT	1993	11.56	5.21	12.30	2.73	0.67	2.05	0.12	79.05	NA	NA	0.09	9.67	7.72	169.09	15.28	76.58
FLT	1994	2.89	2.73	3.23	2.22	0.27	1.96	0.11	99.52	5.00	10.00	0.06	10.45	8.00	200.33	16.59	81.42
FLT	1995	6.65	2.50	11.18	2.32	0.26	2.06	0.13	93.10	6.02	13.71	0.15	10.24	7.99	209.27	16.51	80.09
FLT	1996	0.87	2.50	1.50	3.04	0.19	2.87	0.11	111.63	12.73	10.00	0.09	10.06	7.74	236.00	7.83	82.67
SAG	1992	1.10	5.46	1.64	5.62	0.42	5.21	0.71	110.22	NA	NA	0.65	8.29	7.46	265.33	18.70	89.83
SAG	1993	8.58	8.34	15.58	4.72	0.64	4.09	0.42	98.43	NA	NA	0.40	8.58	6.86	221.82	14.21	85.25
SAG	1994	3.93	3.49	1.97	6.41	0.54	5.87	0.53	125.33	21.73	10.00	0.46	8.53	7.09	319.50	15.80	93.33
SAG	1995	4.66	5.48	3.80	6.24	0.58	5.72	0.70	114.96	34.74	17.29	0.54	10.28	8.16	315.00	16.37	90.00
SAG	1996	1.26	13.17	1.87	7.92	0.47	10.00	1.00	124.13	47.77	17.80	0.85	10.60	8.29	435.50	10.35	91.67

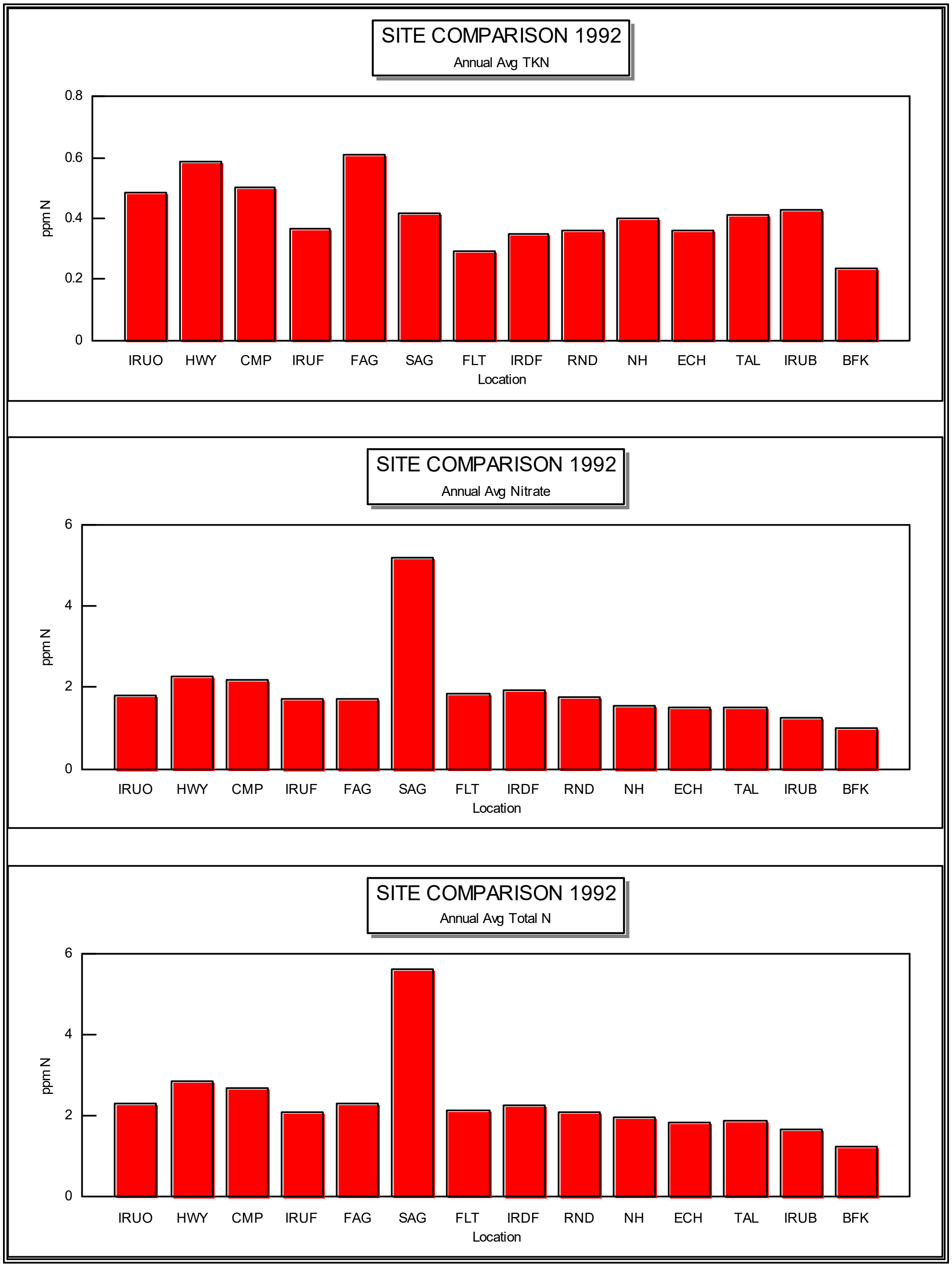
1992 Physical and Chemical Parameters



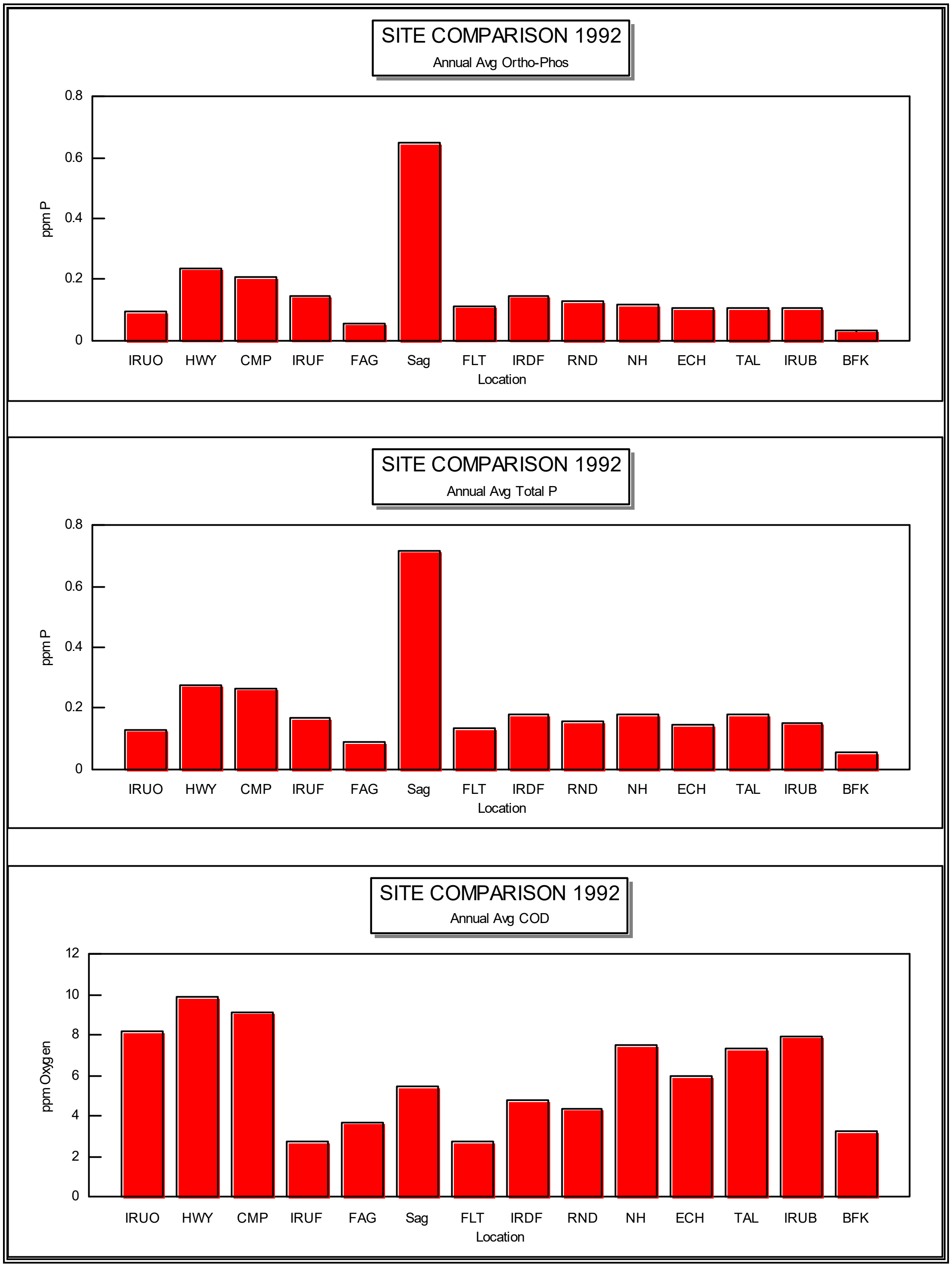
Figures 7.2.1 - 7.2.3 Annual (1992) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS and conductivity.



Figures 7.2.4 - 7.2.6 Annual (1992) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity and pH.

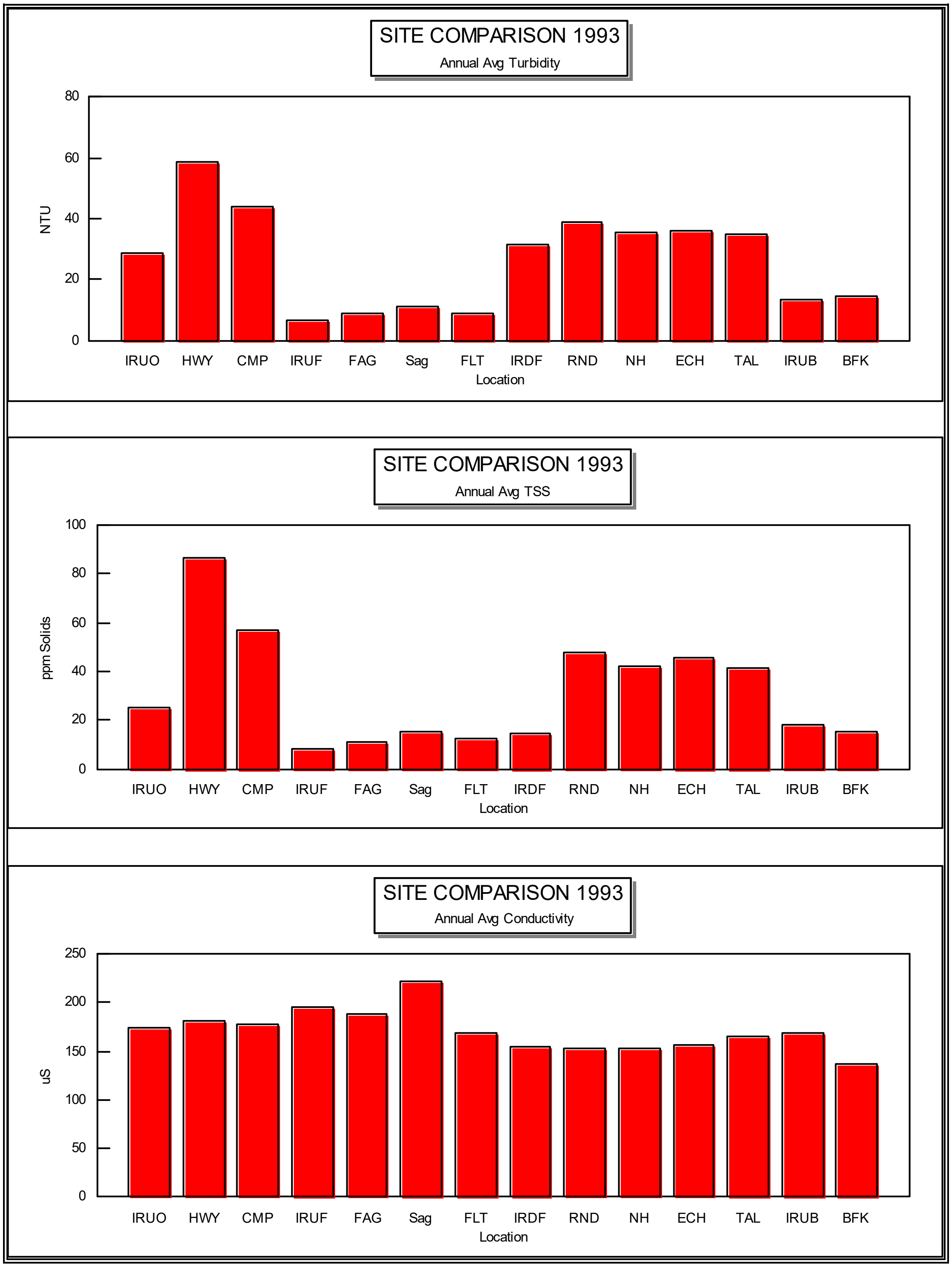


Figures 7.2.7 - 7.2.9 Annual (1992) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate and total nitrogen.

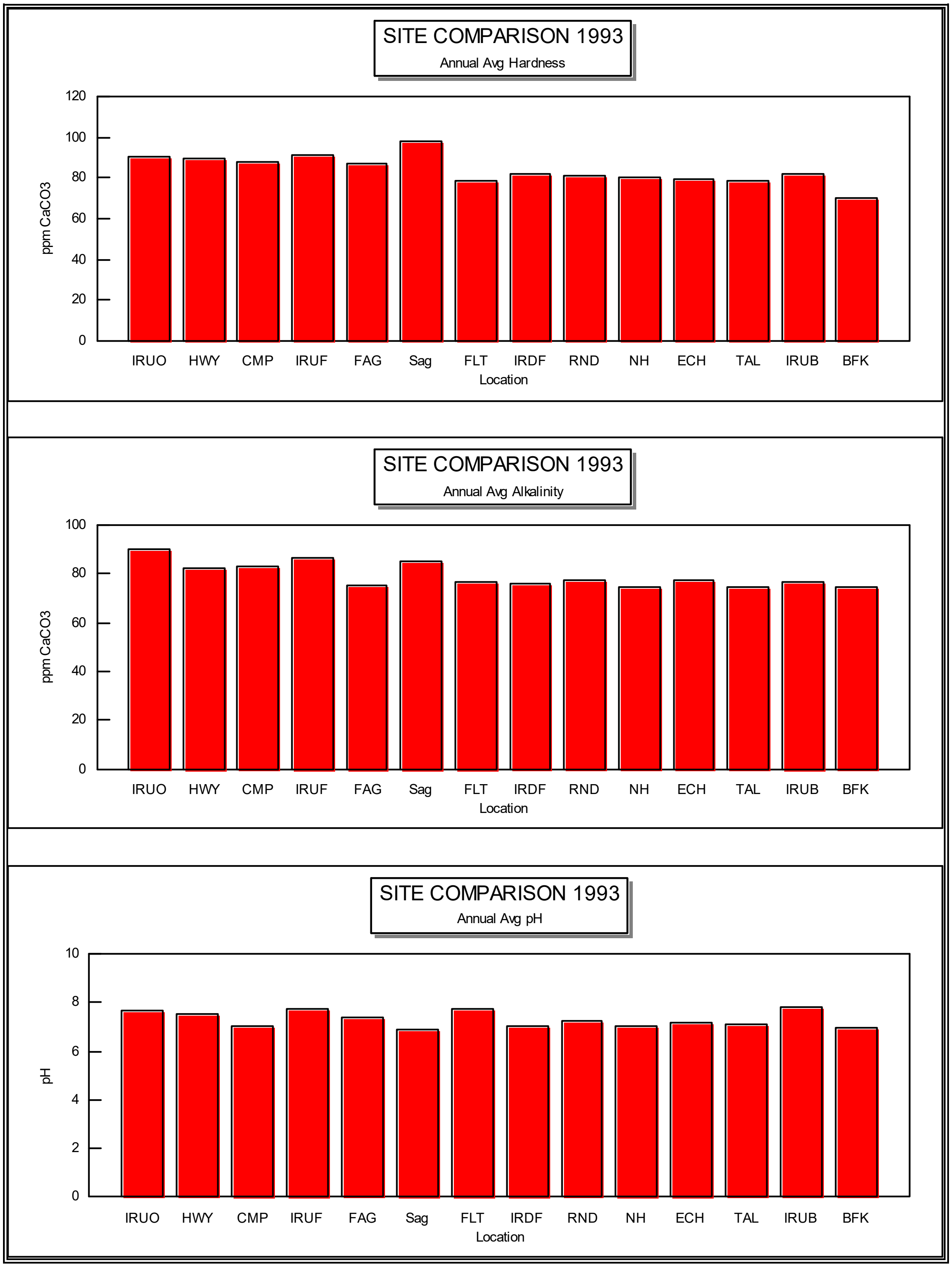


Figures 7.2.10 - 7.2.12 Annual (1992) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: orthophosphate, total phosphorous and COD.

1993 Chemical and Physical Parameters

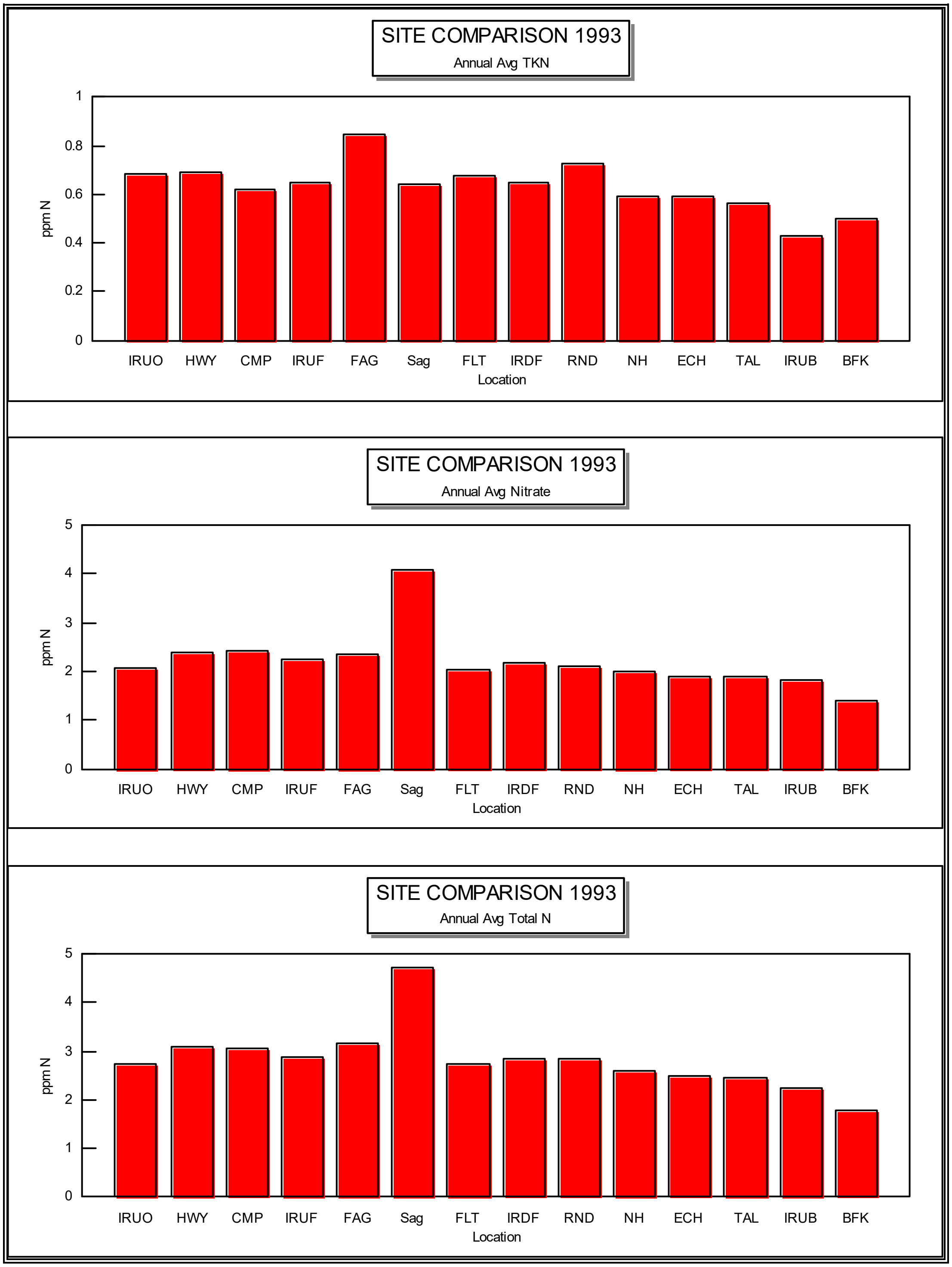


Figures 7.2.13 - 7.2.15 Annual (1993) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS and conductivity.

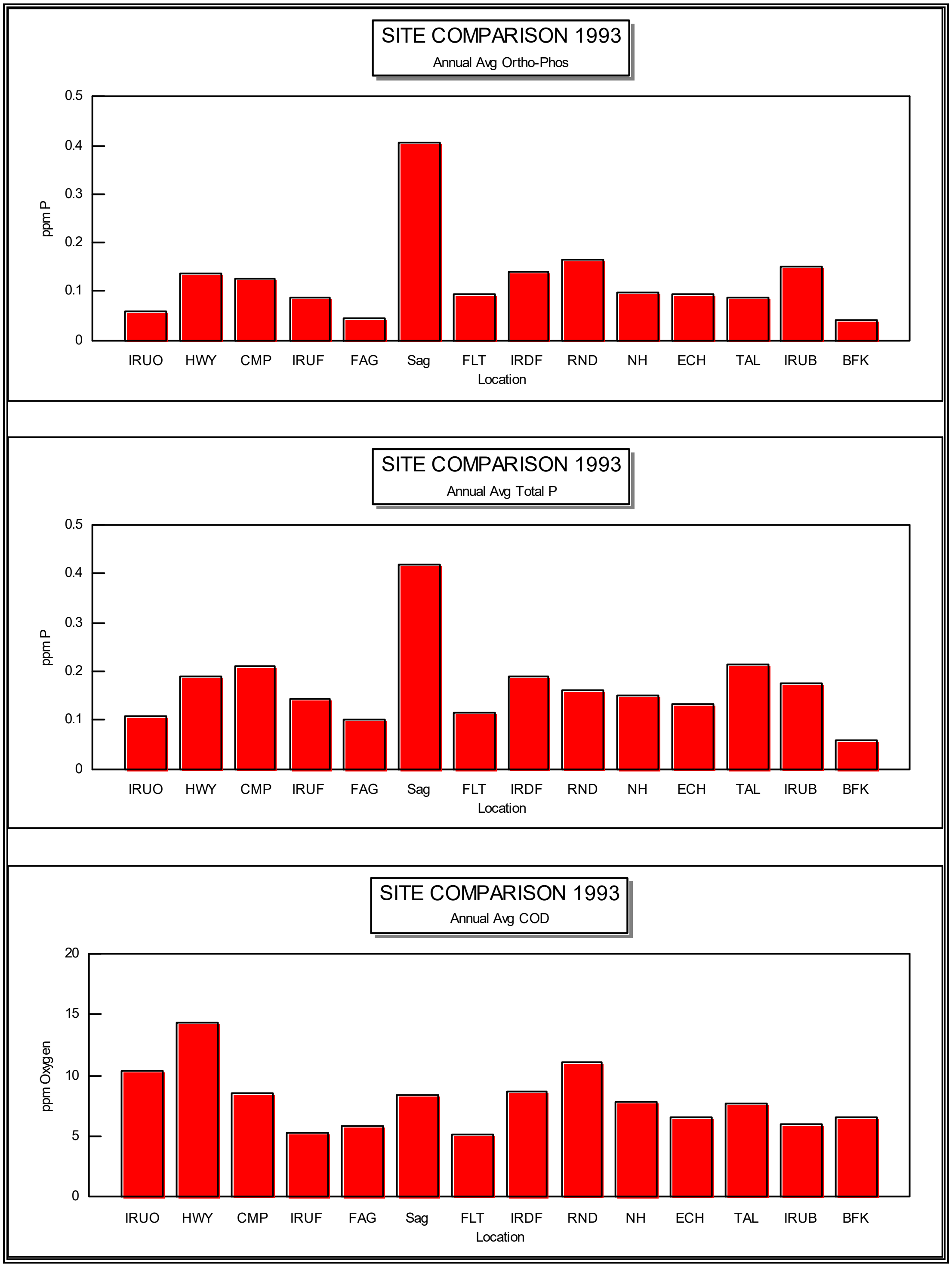


Figures 7.2.16 - 7.2.18 Annual (1993) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity, and pH.

1993 Nutrients

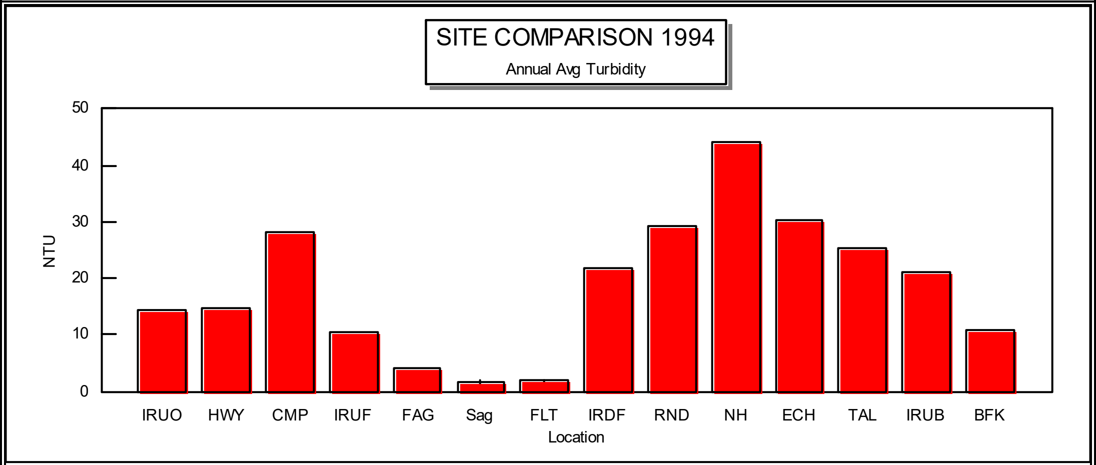


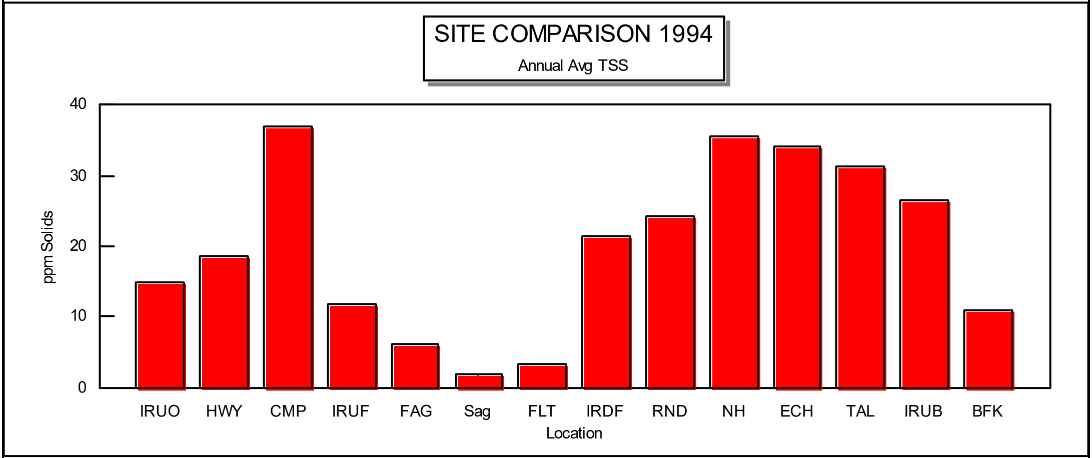
Figures 7.2.19 - 7.2.21 Annual (1993) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate and total nitrogen.

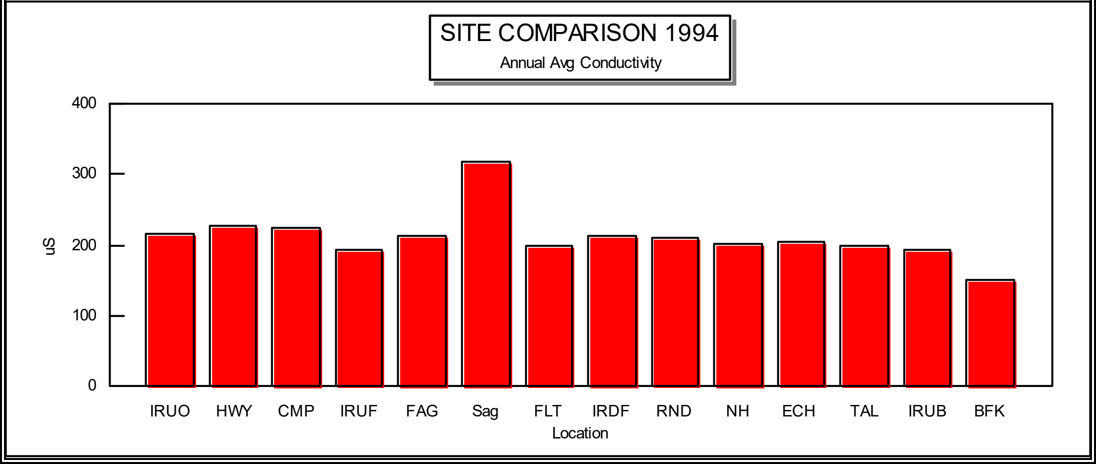


Figures 7.2.22 - 7.2.24 Annual (1993) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: ortho phosphorous, total phosphorous, and COD.

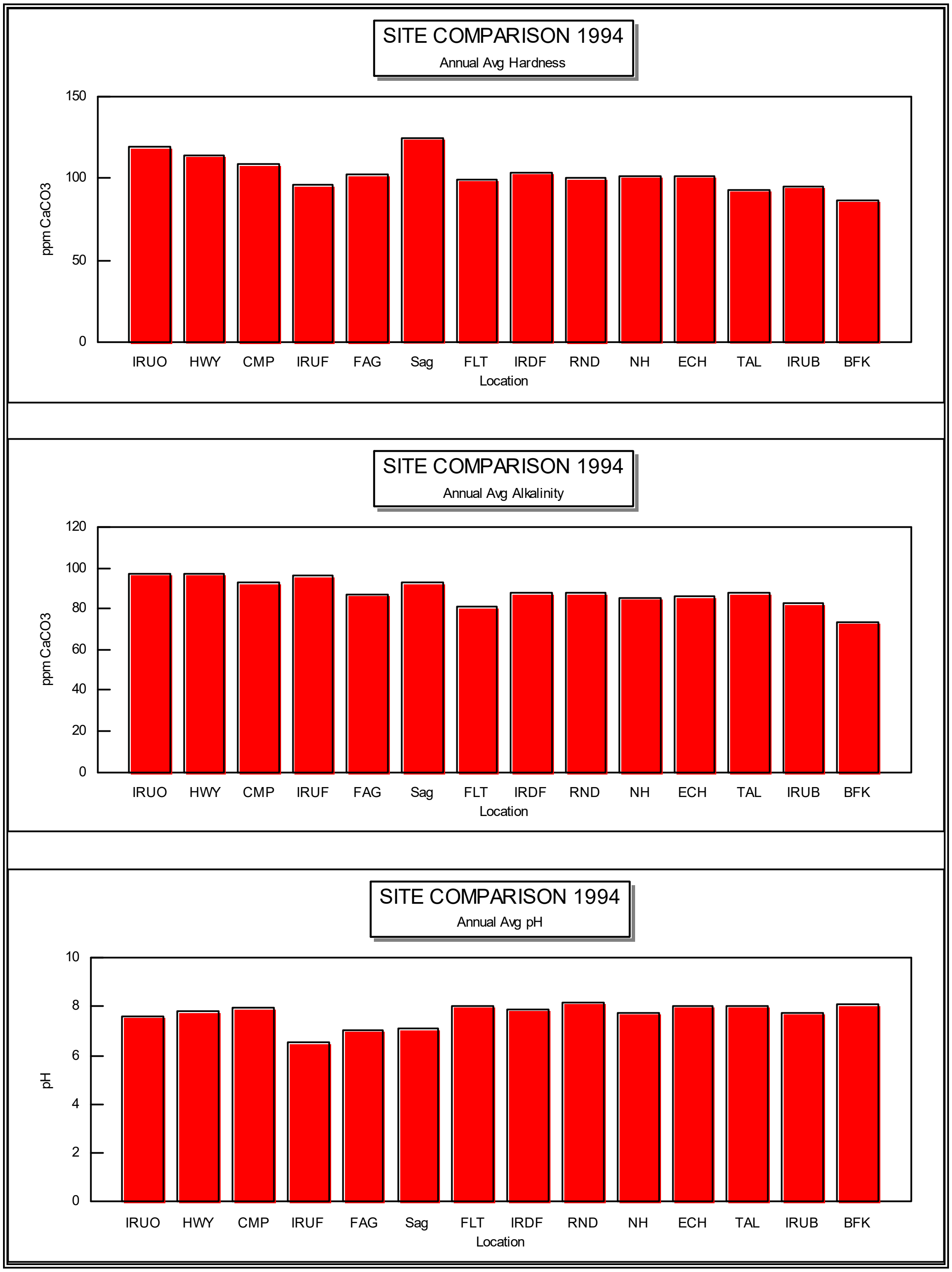
1994 Physical and Chemical Parameters





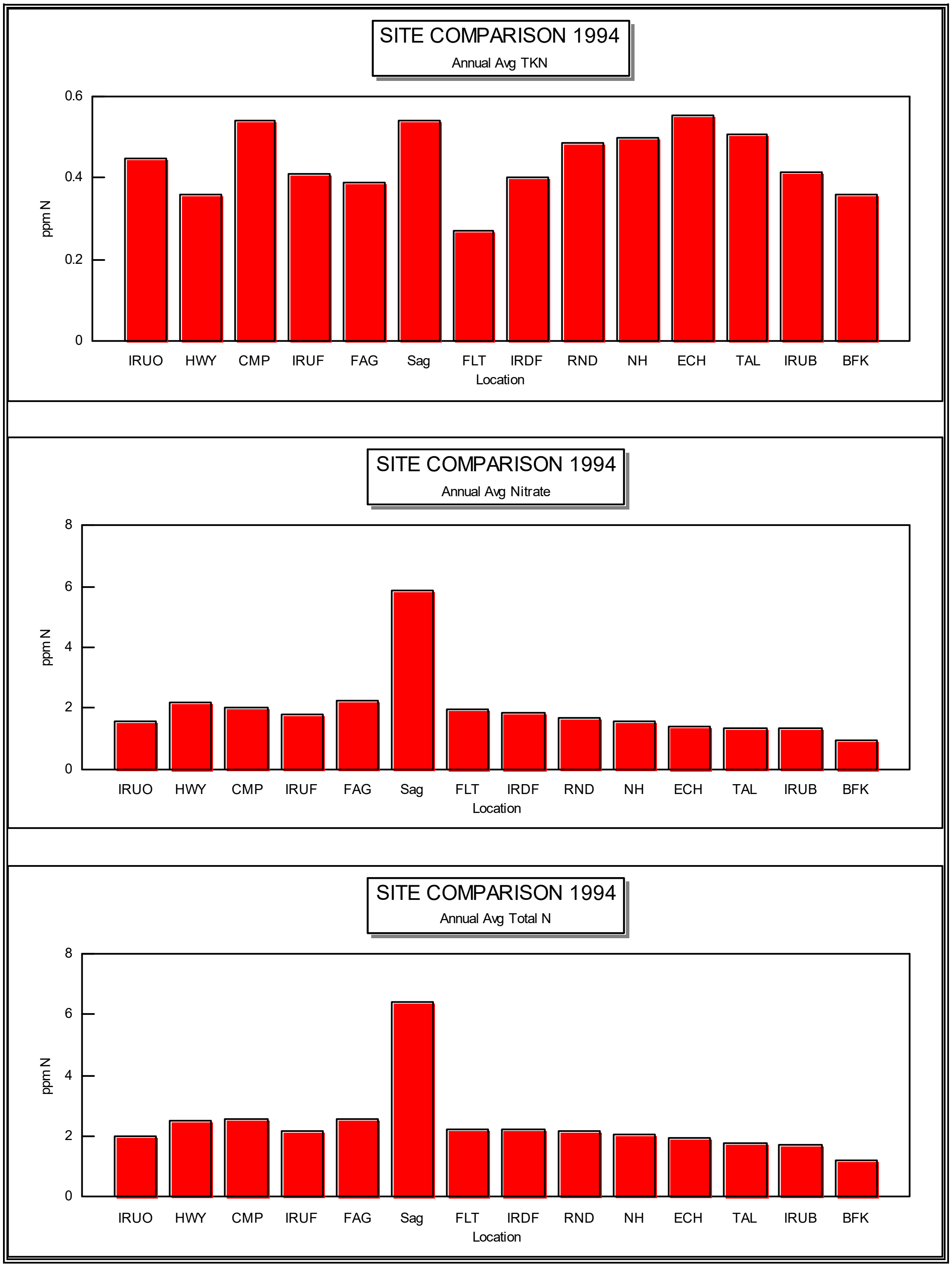


Figures 7.2.25- 7.2.27 Annual (1994) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS, and conductivity.

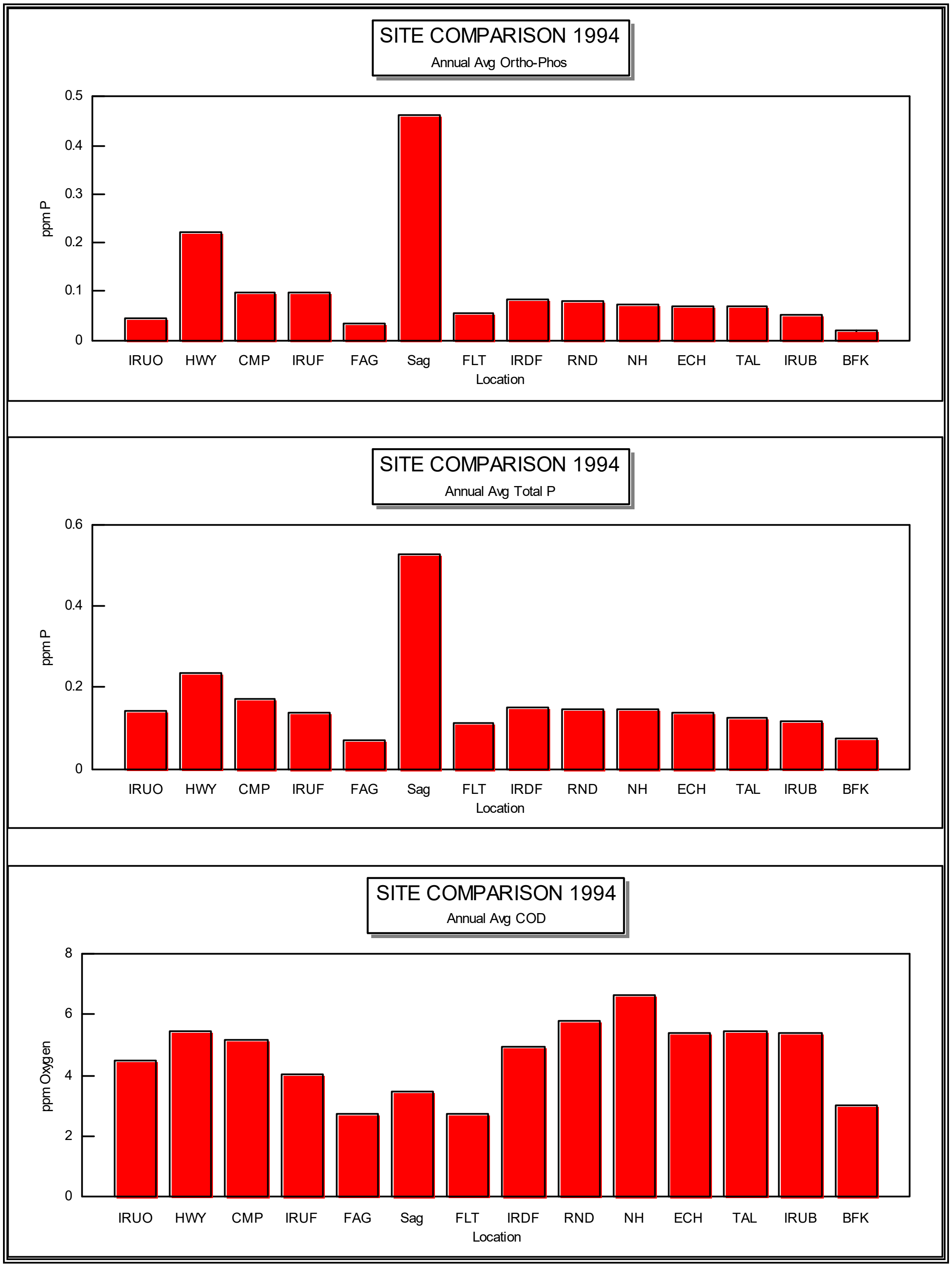


Figures 7.2.28 - 7.2.30 Annual (1994) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity, and pH.

1994 Nutrient Parameters

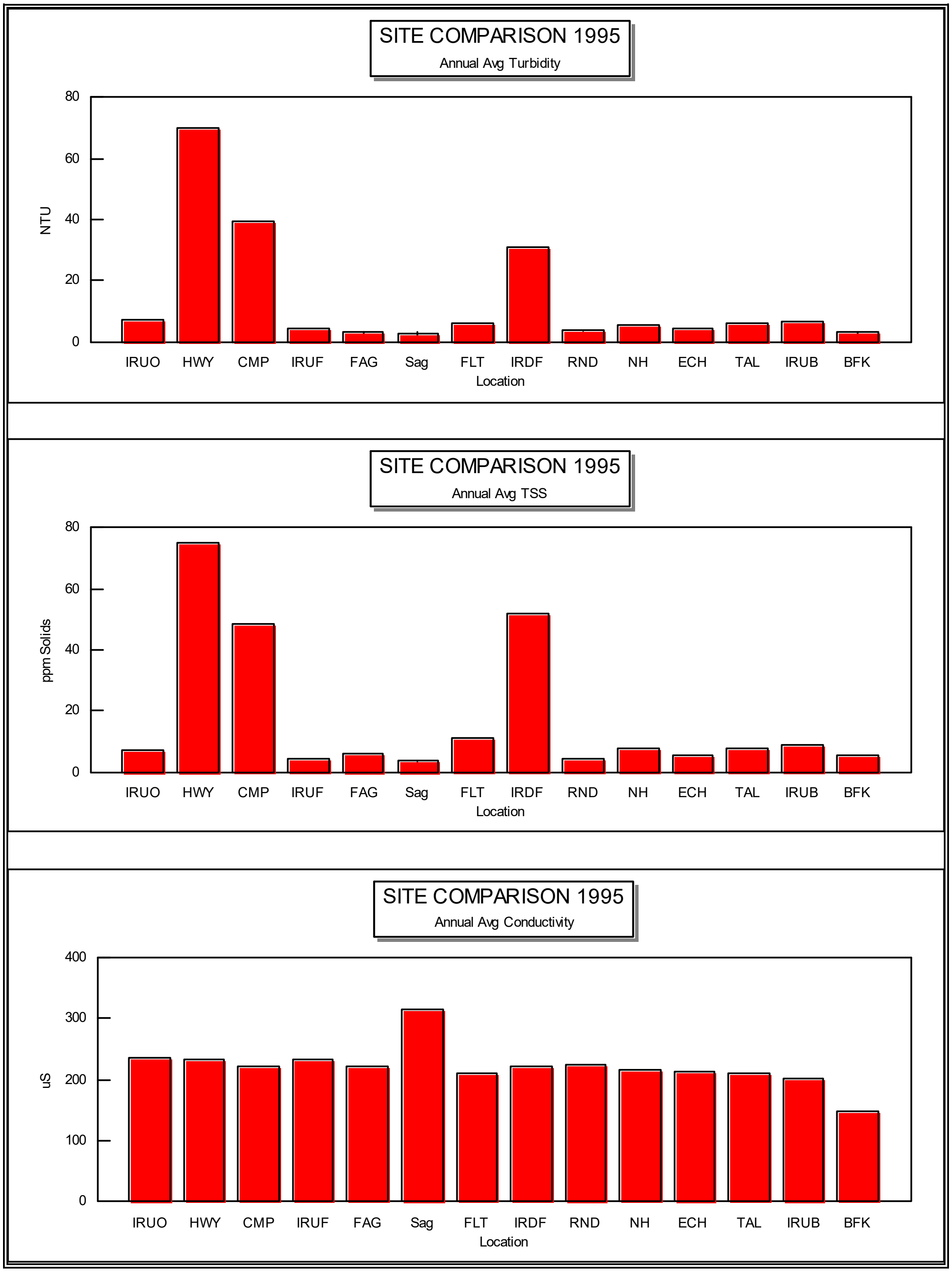


Figures 7.2.31 - 7.2.33 Annual (1994) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate, and total nitrogen.

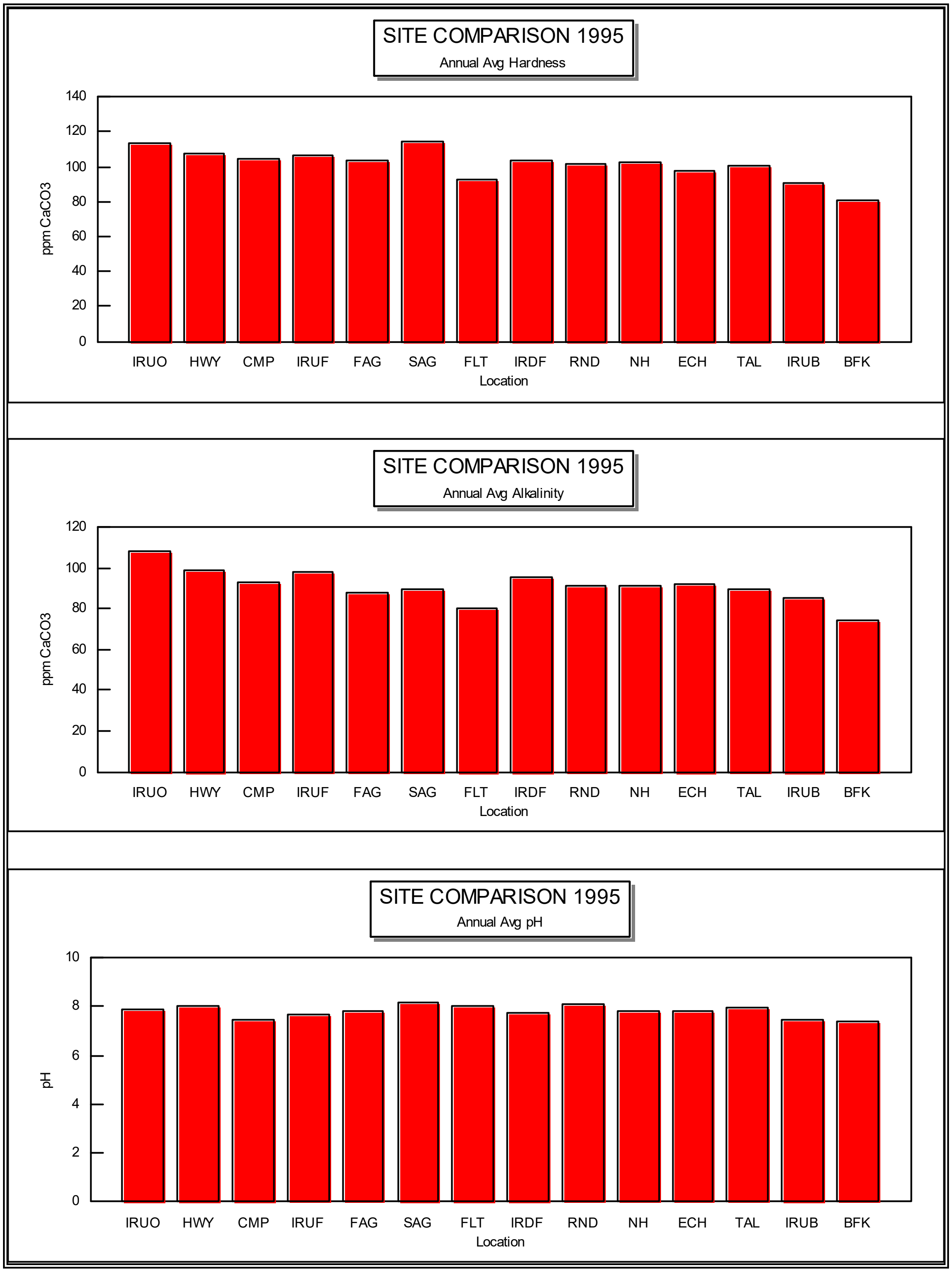


Figures 7.2.34 - 7.2.36 Annual (1994) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: orthophosphate, total phosphate, and COD.

1995 Chemical and Physical Parameters

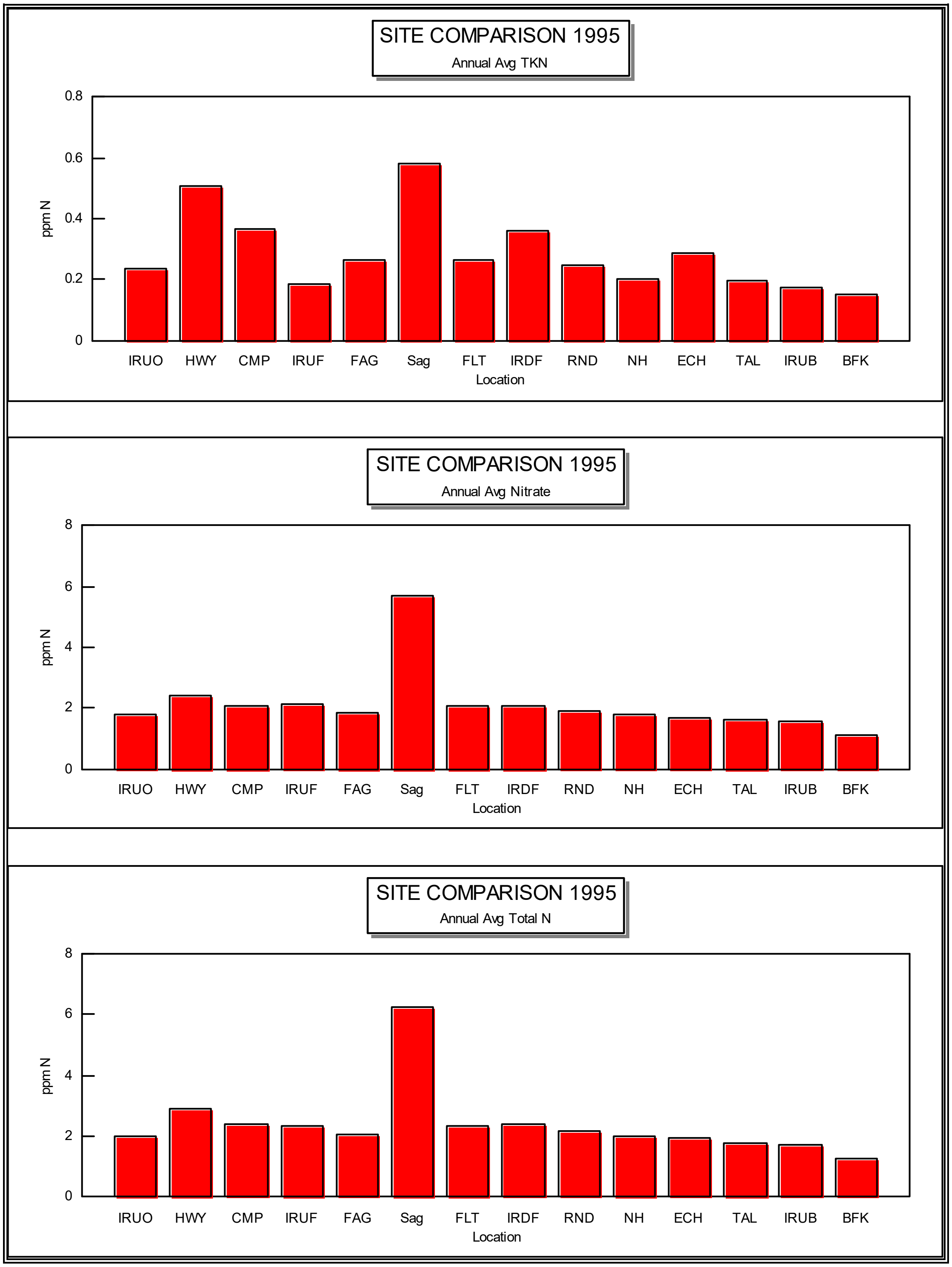


Figures 7.2.37 - 7.2.39 Annual (1995) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS, and conductivity.

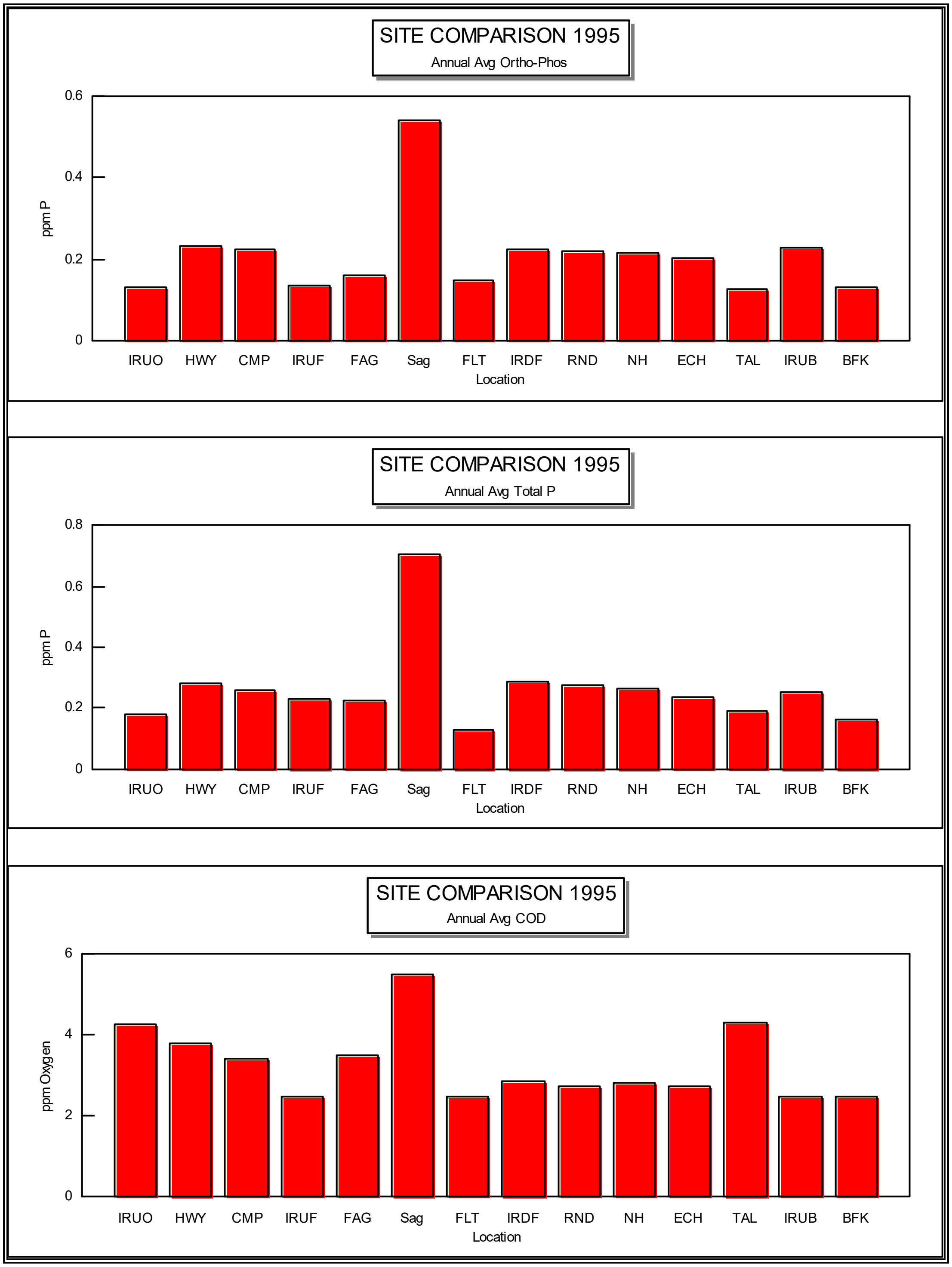


Figures 7.2.40 - 7.2.42 Annual (1994) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity, and pH.

1995 Nutrient Parameter

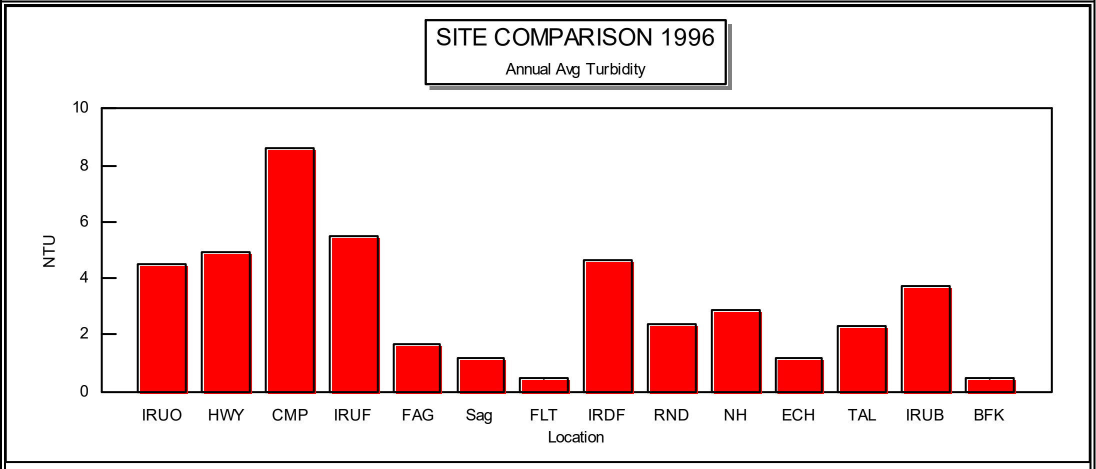


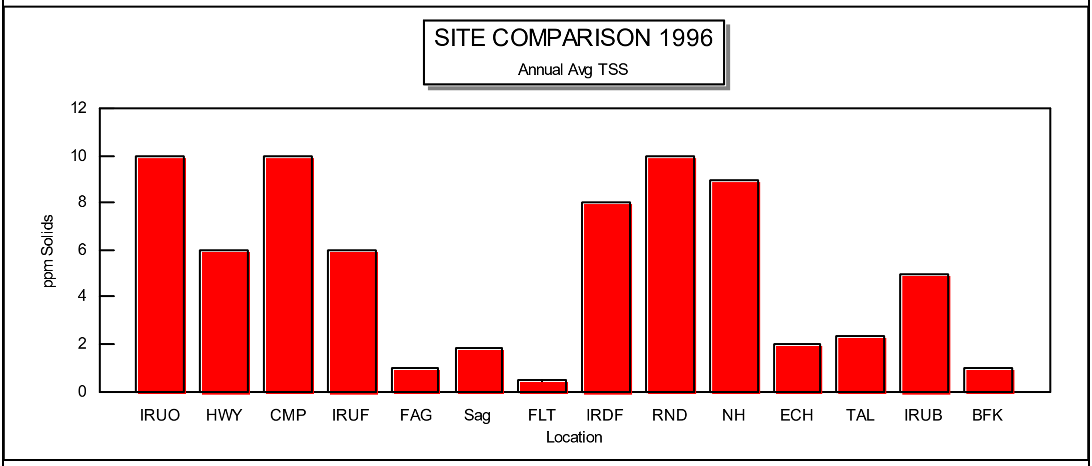
Figures 7.2.43 - 7.2.45 Annual (1995) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate, and total nitrogen.

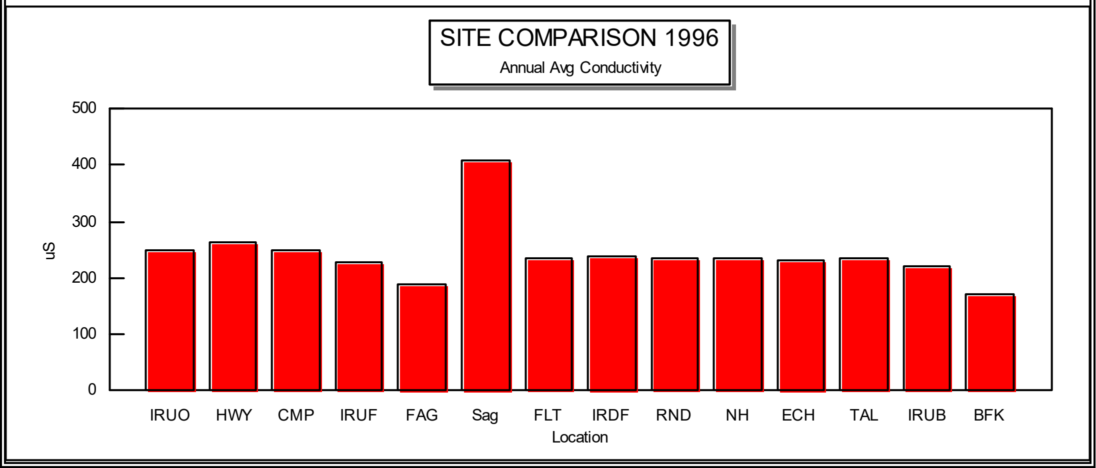


Figures 7.2.46 - 7.2.48 Annual (1995) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: orthophosphate, total phosphate, and COD.

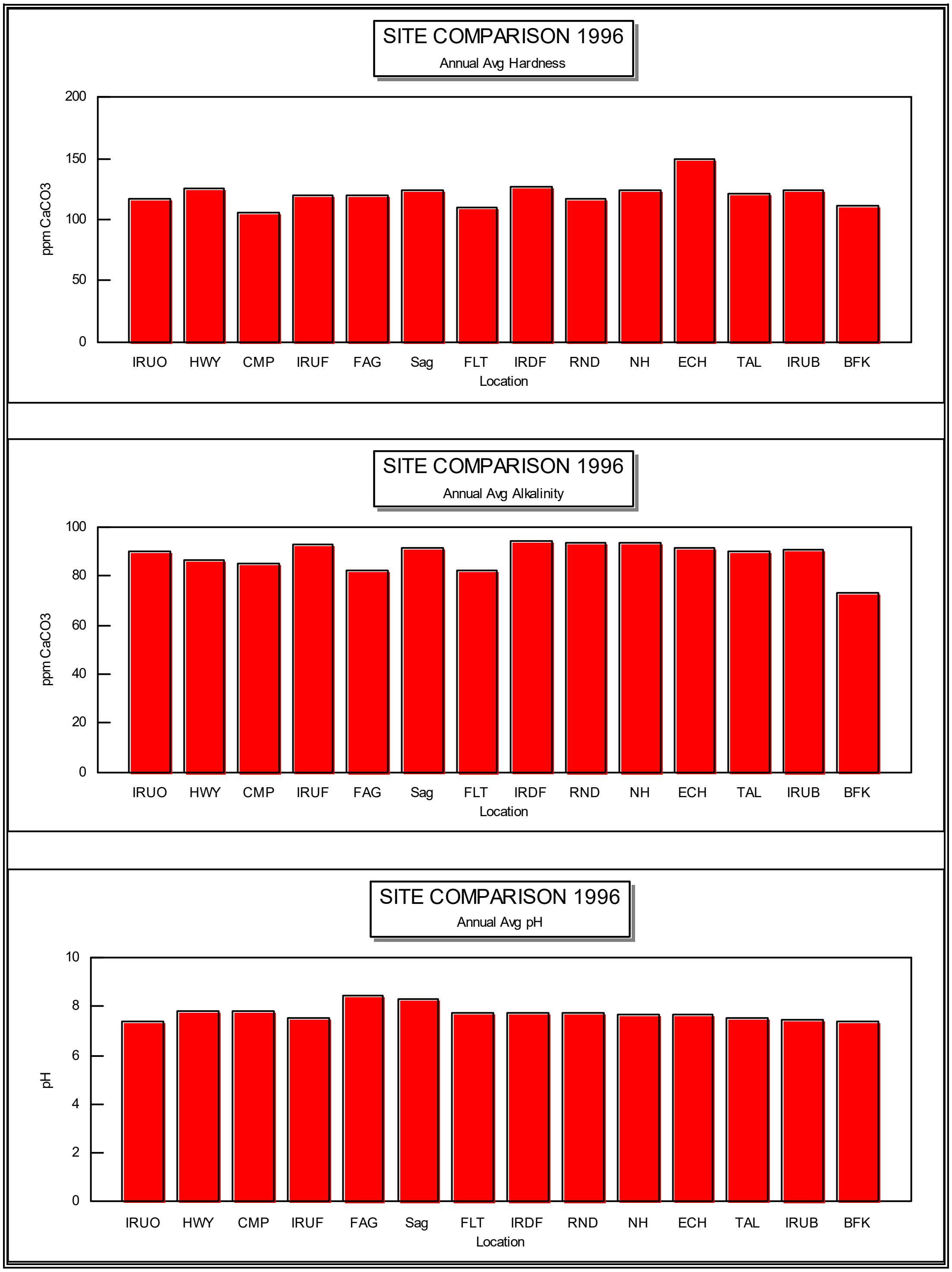
1996 Physical and Chemical Parameters





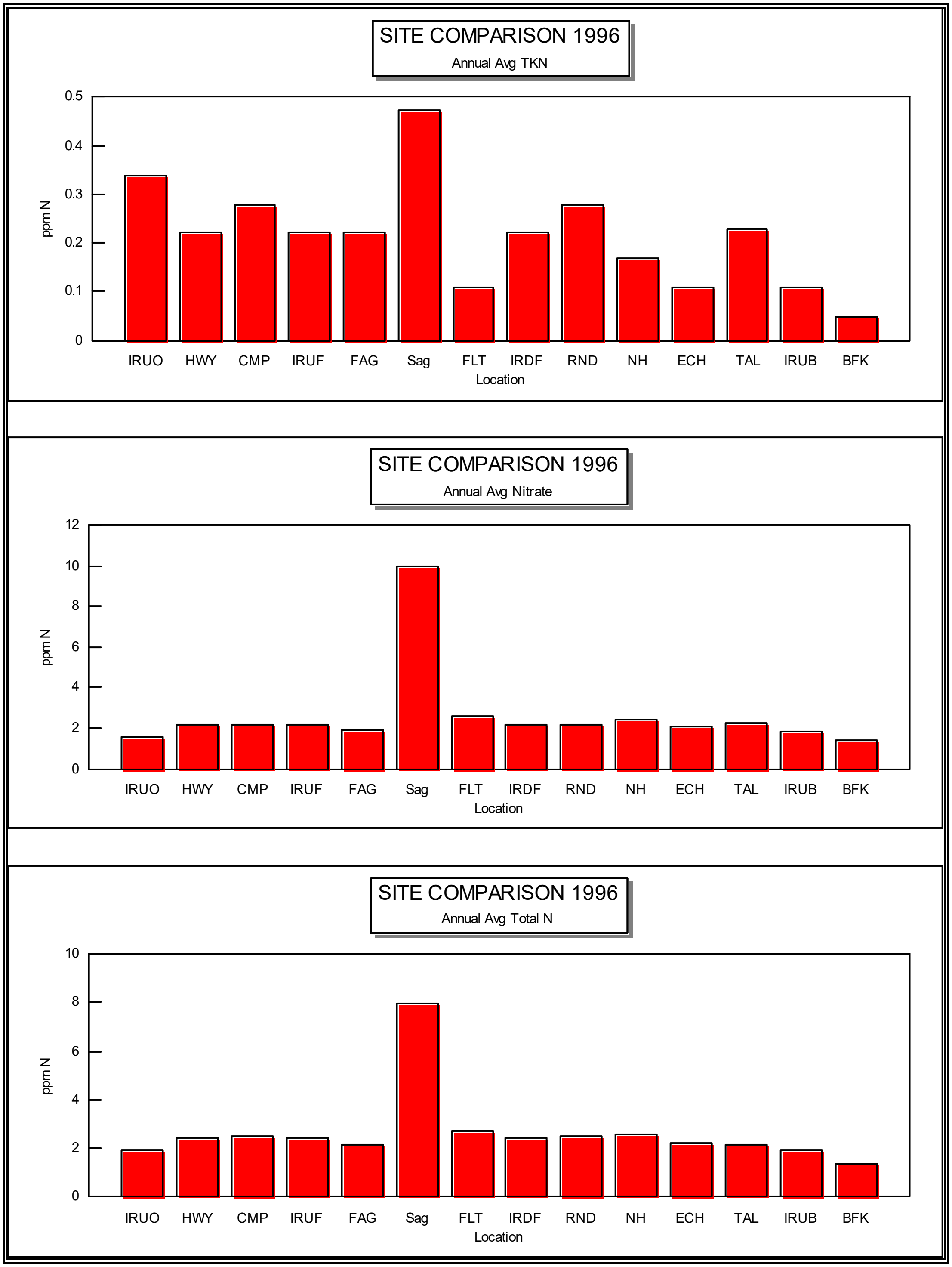


Figures 7.2.49 - 7.2.51 Annual (1996) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS, and conductivity.

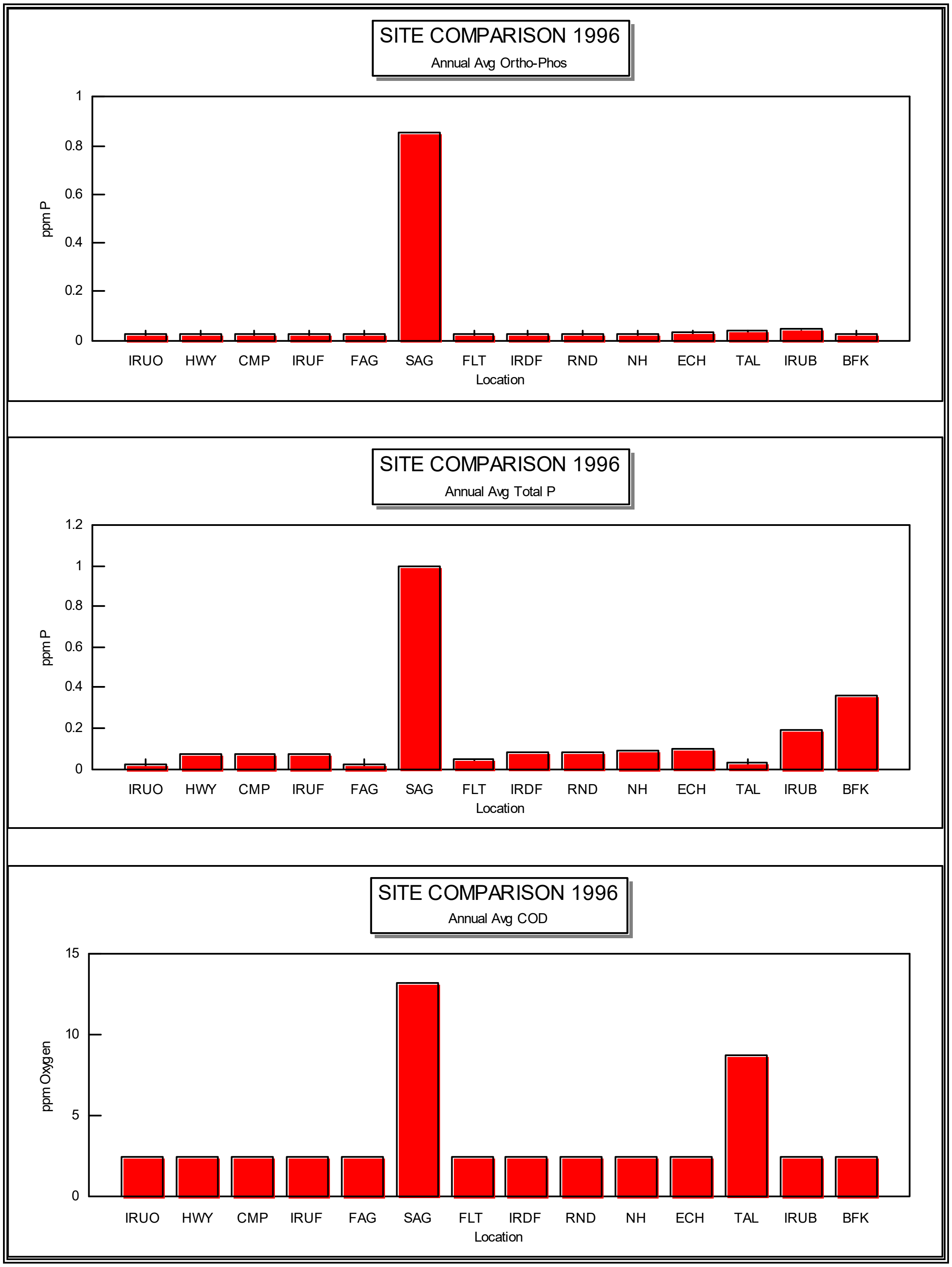


Figures 7.2.52 - 7.2.54 Annual (1996) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity, and pH.

1996 Nutrient Parameters

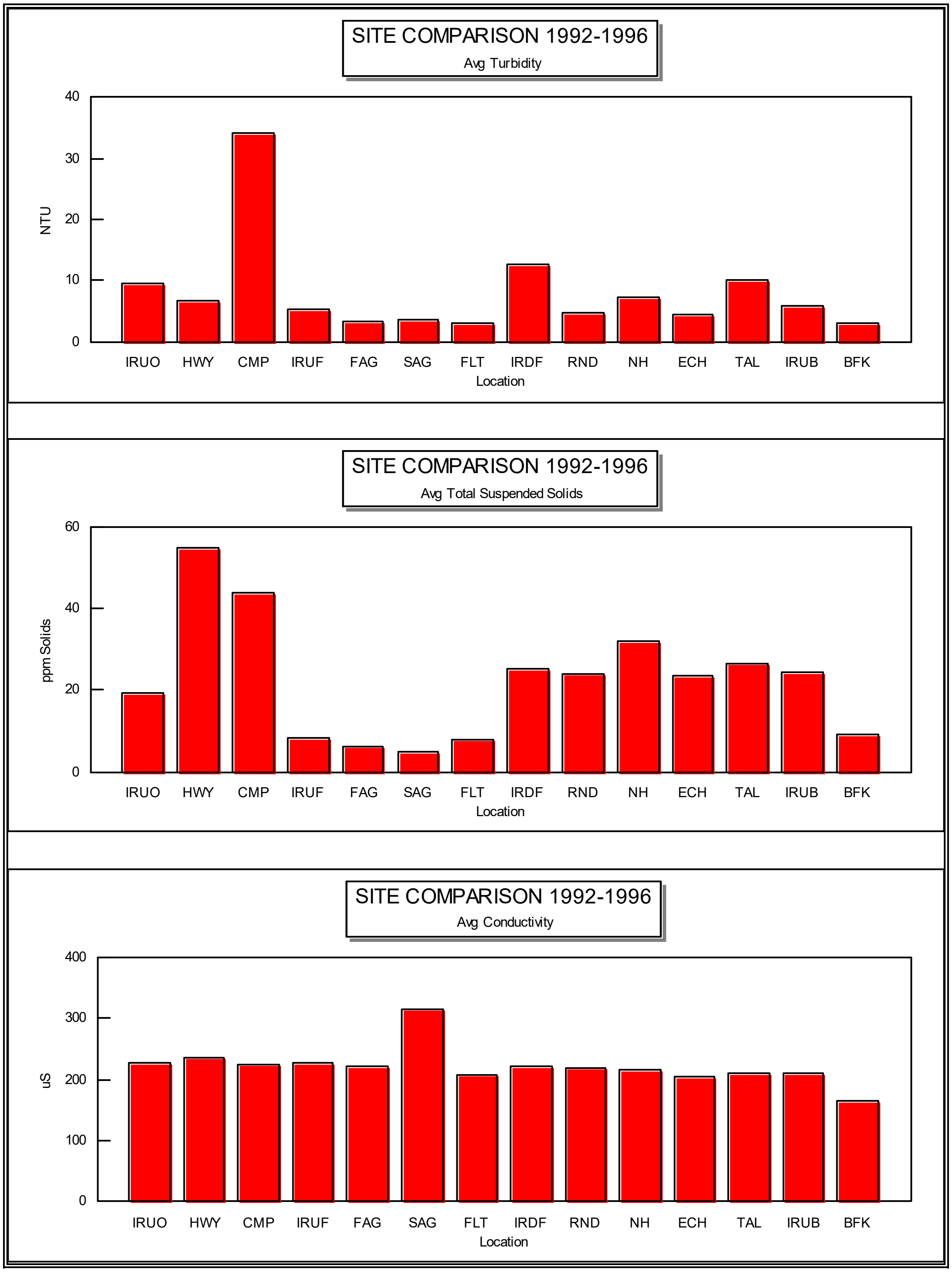


Figures 7.2.55 - 7.2.57 Annual (1996) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate, and total nitrogen.

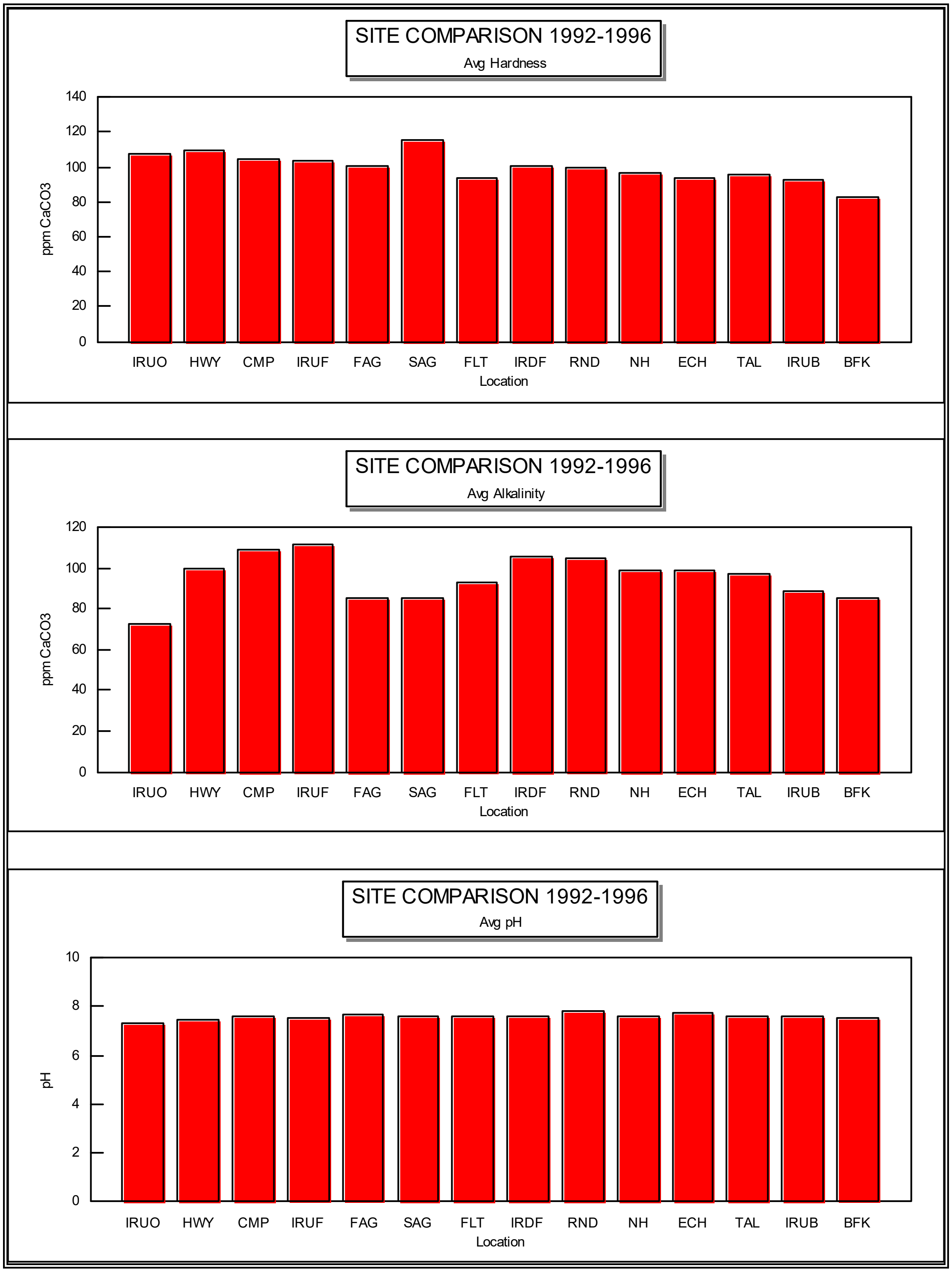


Figures 7.2.58 - 7.2.60 Annual (1996) mean concentration comparison for various sites along the Illinois River. Parameters covered by these graphs include: orthophosphate, total phosphate, and COD.

7.3 Graphical Results of Parameter vs. Location—Four Year Average
Average Site Comparison 1992 - 1996



Figures 7.3.1 - 7.3.3 Four year average concentrations for various sites along the Illinois River. Parameters covered by these graphs include: turbidity, TSS, and conductivity.


SITE COMPARISON 1992-1996

Avg Hardness

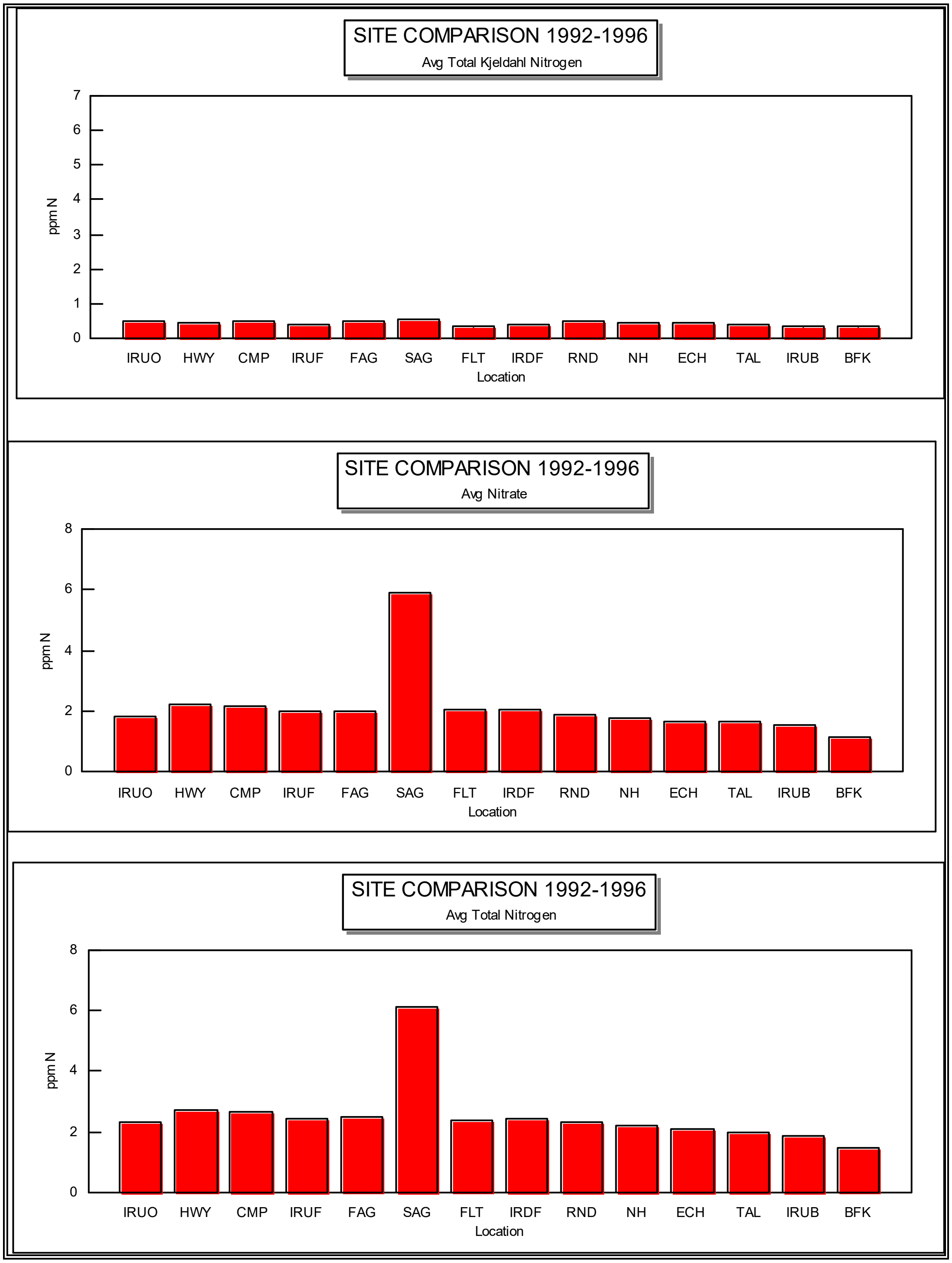
SITE COMPARISON 1992-1996

Avg Alkalinity

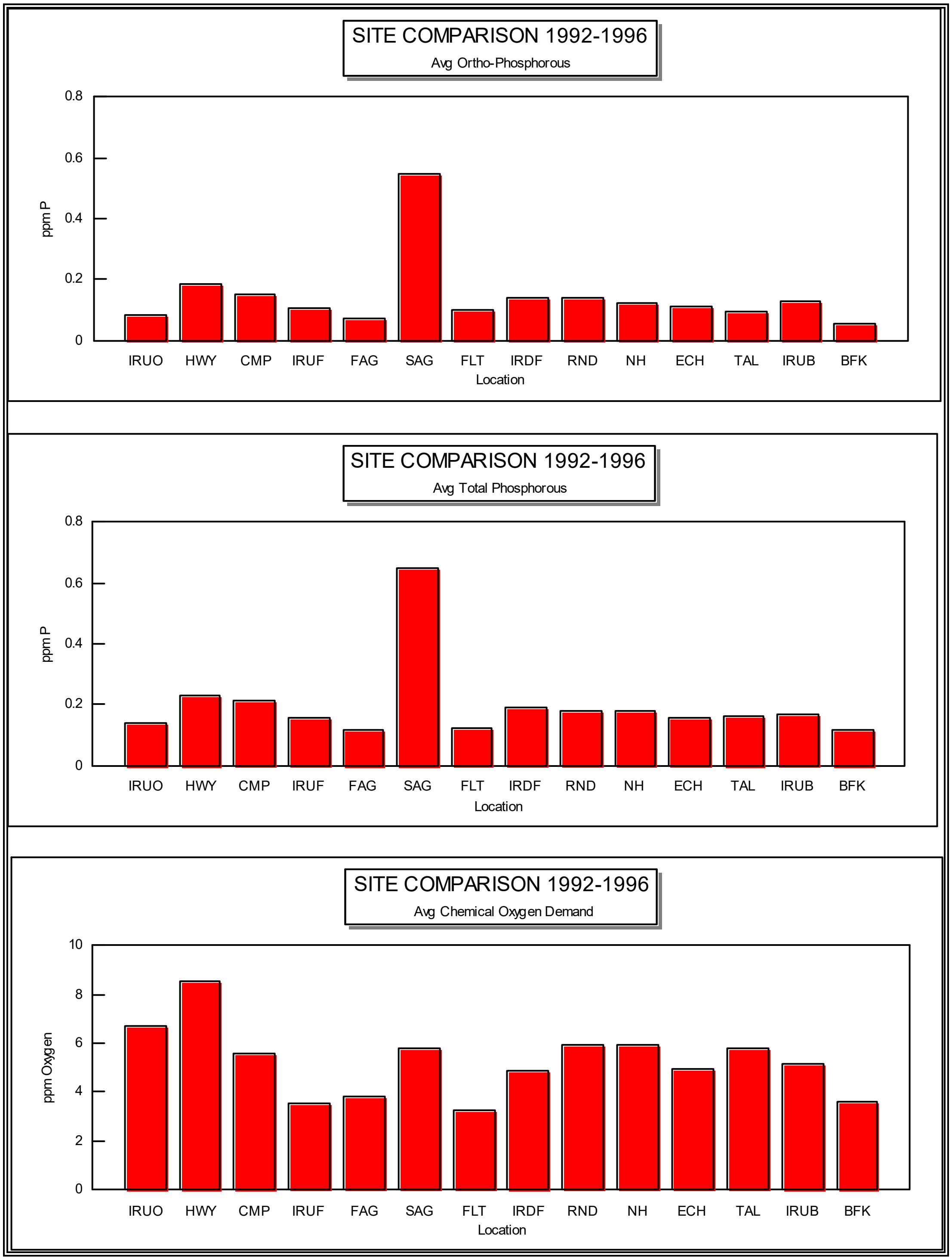
SITE COMPARISON 1992-1996

Avg pH

Figures 7.3.4 - 7.3.6 Four year average concentrations for various sites along the Illinois River. Parameters covered by these graphs include: hardness, alkalinity, and pH.



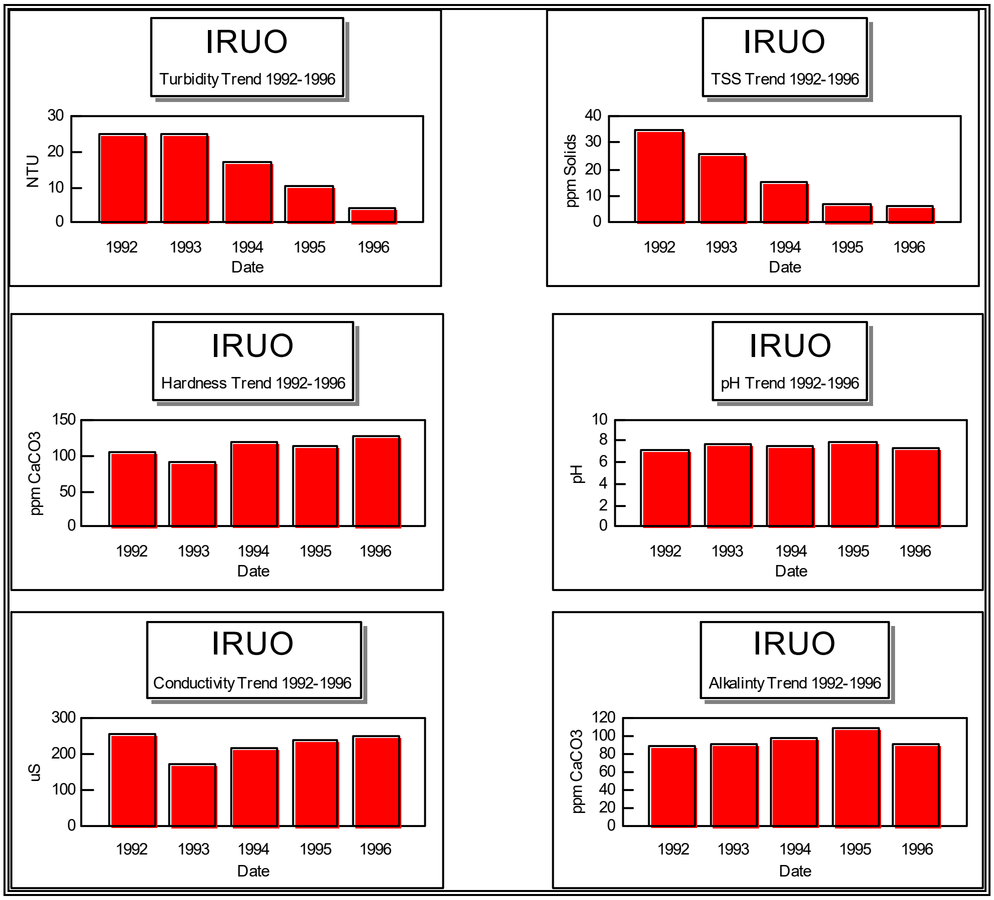
Figures 7.3.7 - 7.3.9 Four year average concentrations for various sites along the Illinois River. Parameters covered by these graphs include: TKN, nitrate, and total nitrogen.



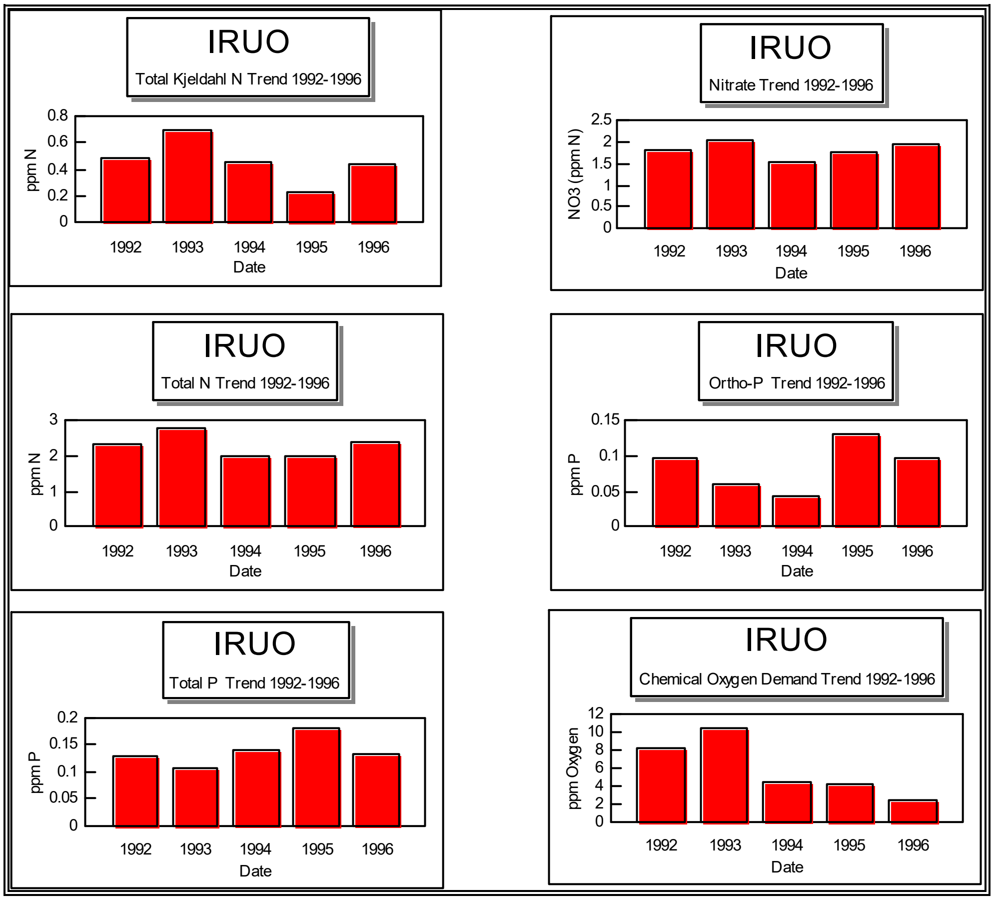
Figures 7.3.10 - 7.3.12 Four year average concentrations for various sites along the Illinois River. Parameters covered by these graphs include: ortho-phosphate, total phosphorous, and cod.

7.4 Parameter vs. Date

Illinois river Upstream of Osage Creek

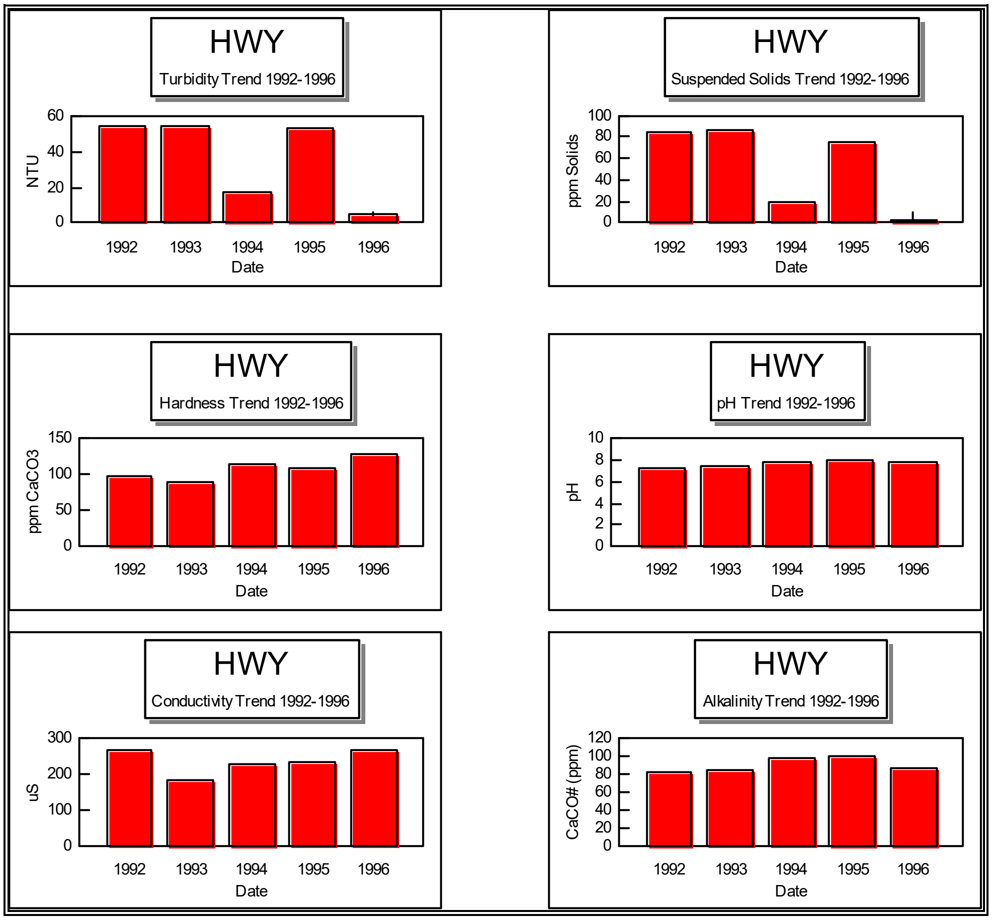


7.4 .1- 7.4.6 Yearly comparison of physical parameters for the Illinois River upstream of Osage Creek location.

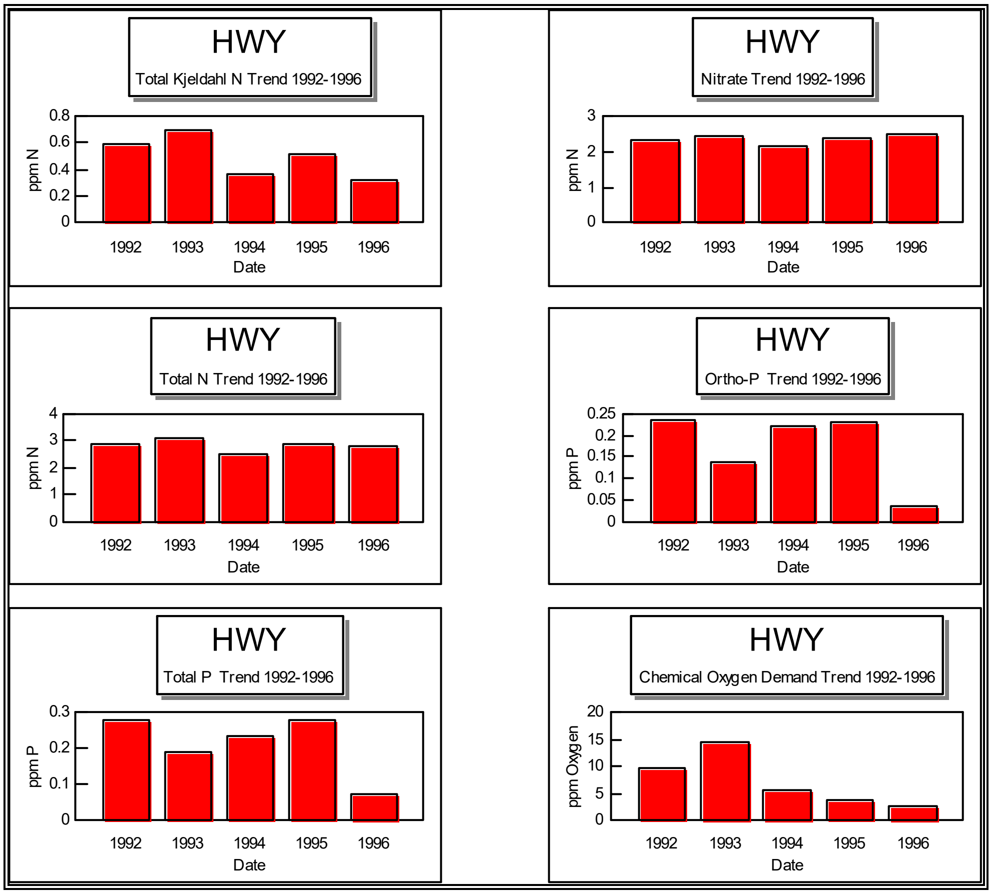


7.4.7 - 7.4.12 Yearly comparison of nutrient parameters for the Illinois River upstream of Osage Creek location.

Highway 16

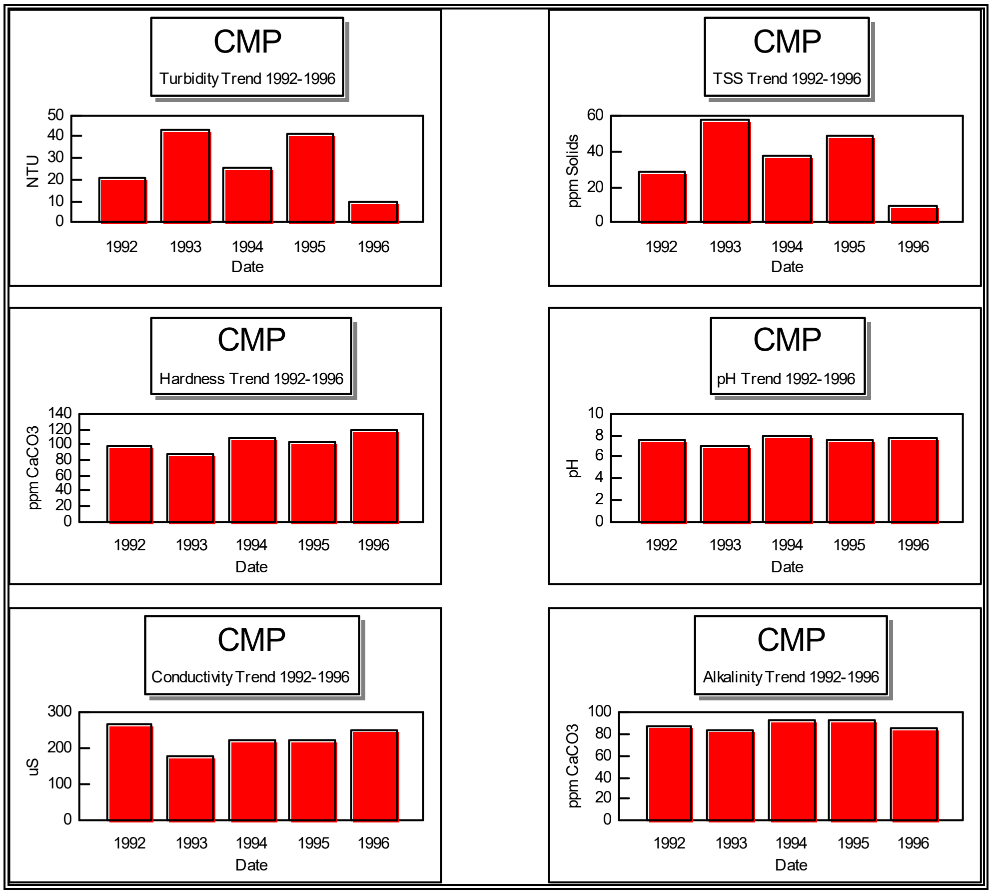


7.4.13 - 7.4.18 Yearly comparison of physical parameters for the Illinois River at Highway 16 location.

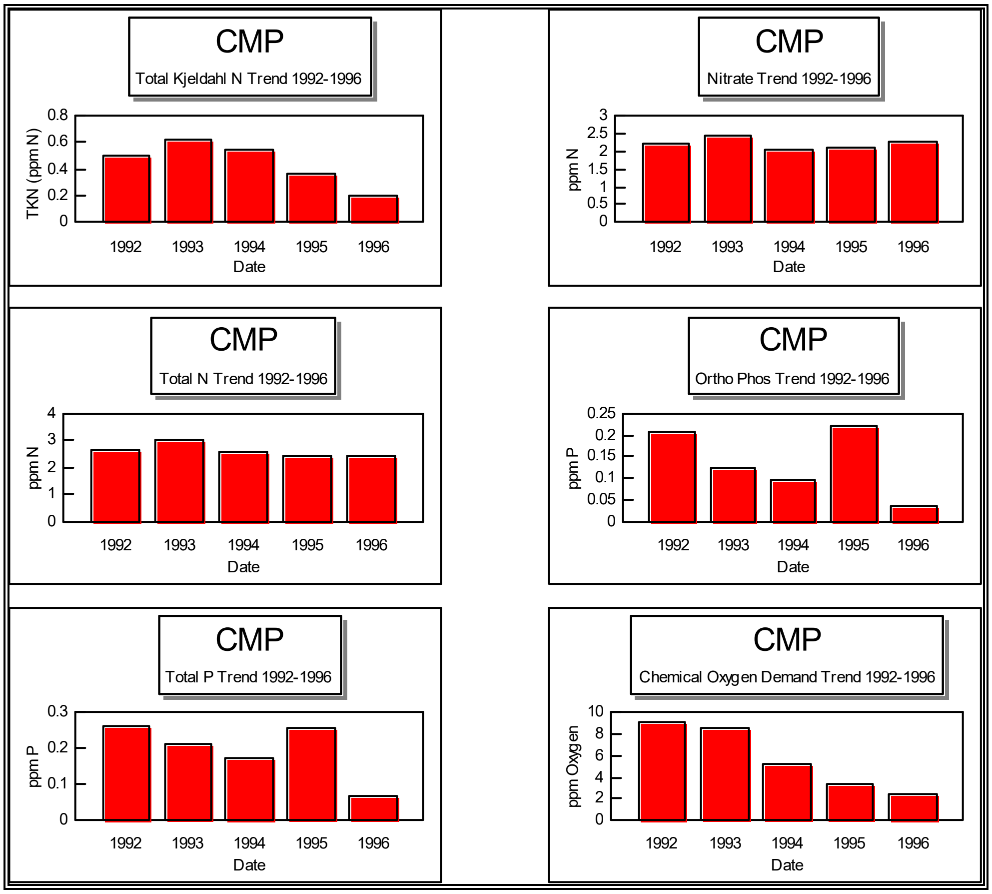


7.4.19 - 7.4.24 Yearly comparison of nutrient parameters for the Illinois River at Highway 16 location.

Camp Paddle Trials

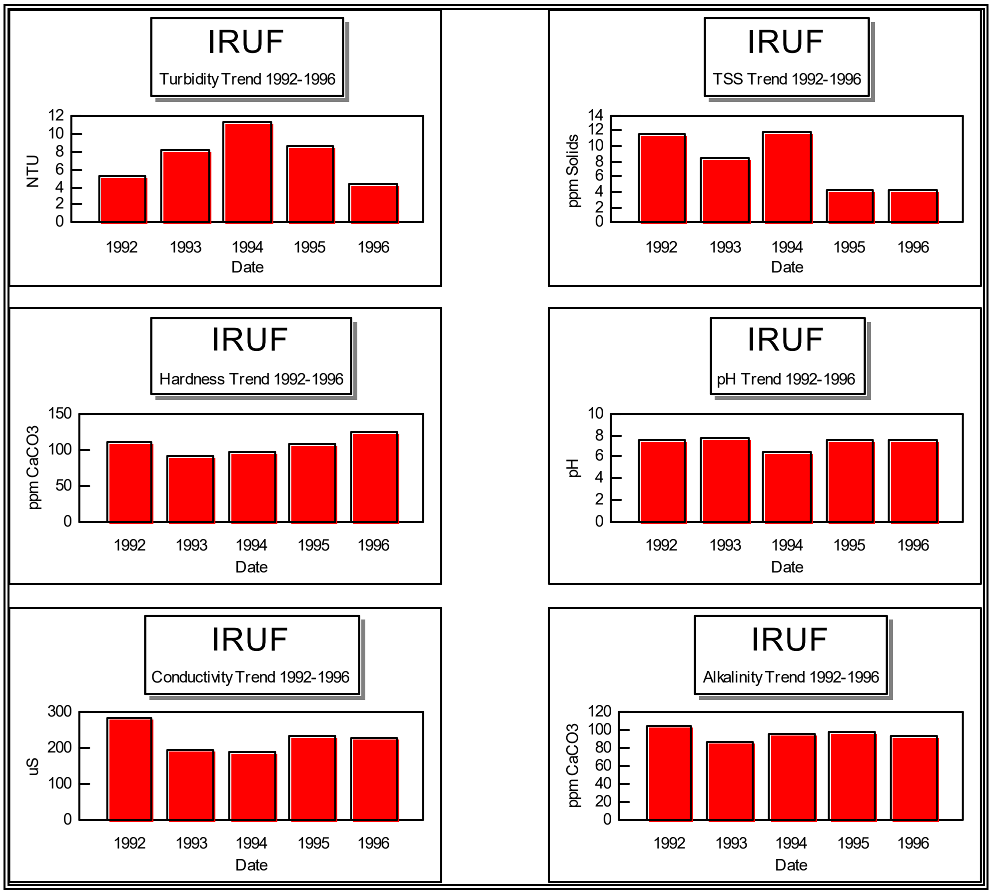


7.4.25 - 7.4.30 Yearly comparison of physical parameters for the Illinois River at Camp Paddle Trails location.

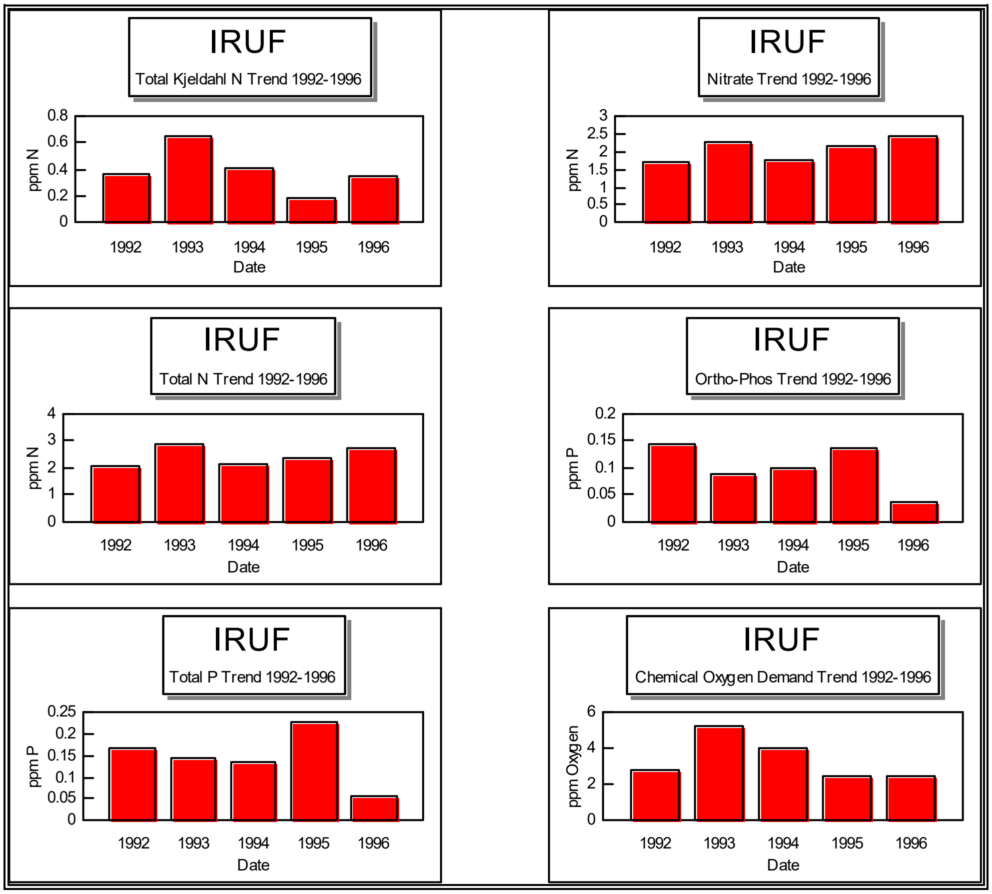


7.4.31 - 7.4.36 Yearly comparison of nutrient parameters for the Illinois River at Camp Paddle Trials location.

Illinois River Upstream of Flint Creek

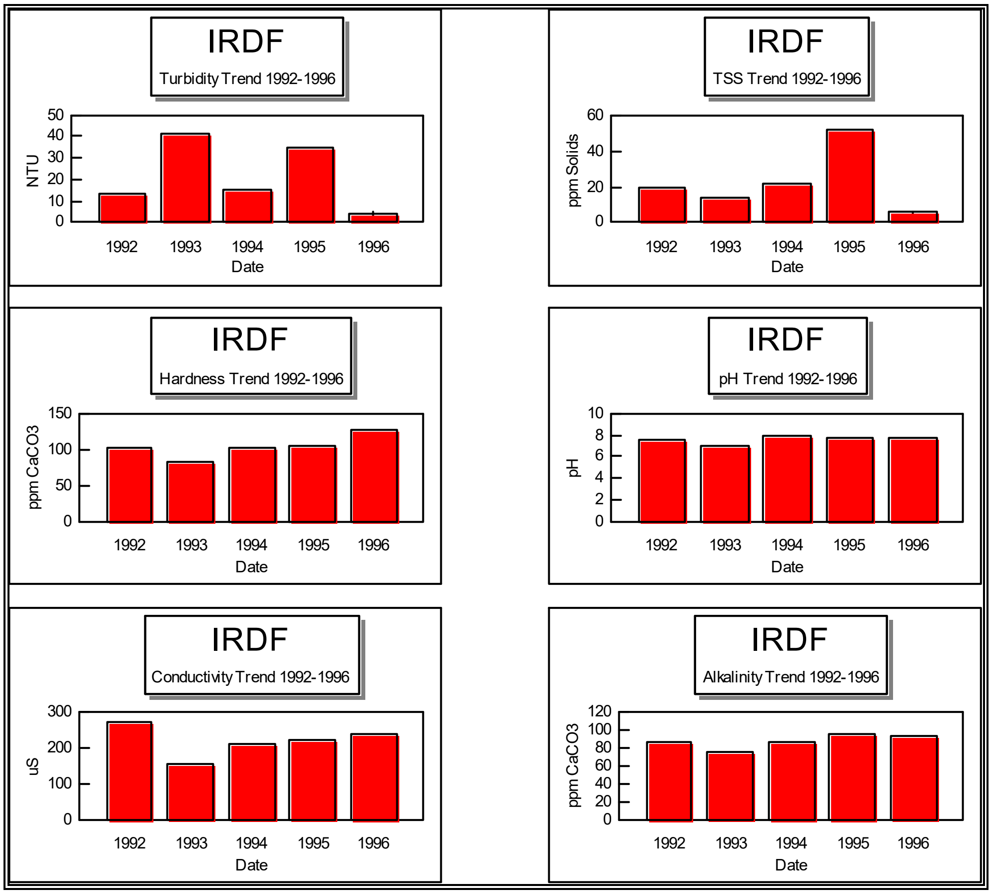


7.4.37 - 7.4.42 Yearly comparison of physical parameters for the Illinois River upstream of Flint Creek location.

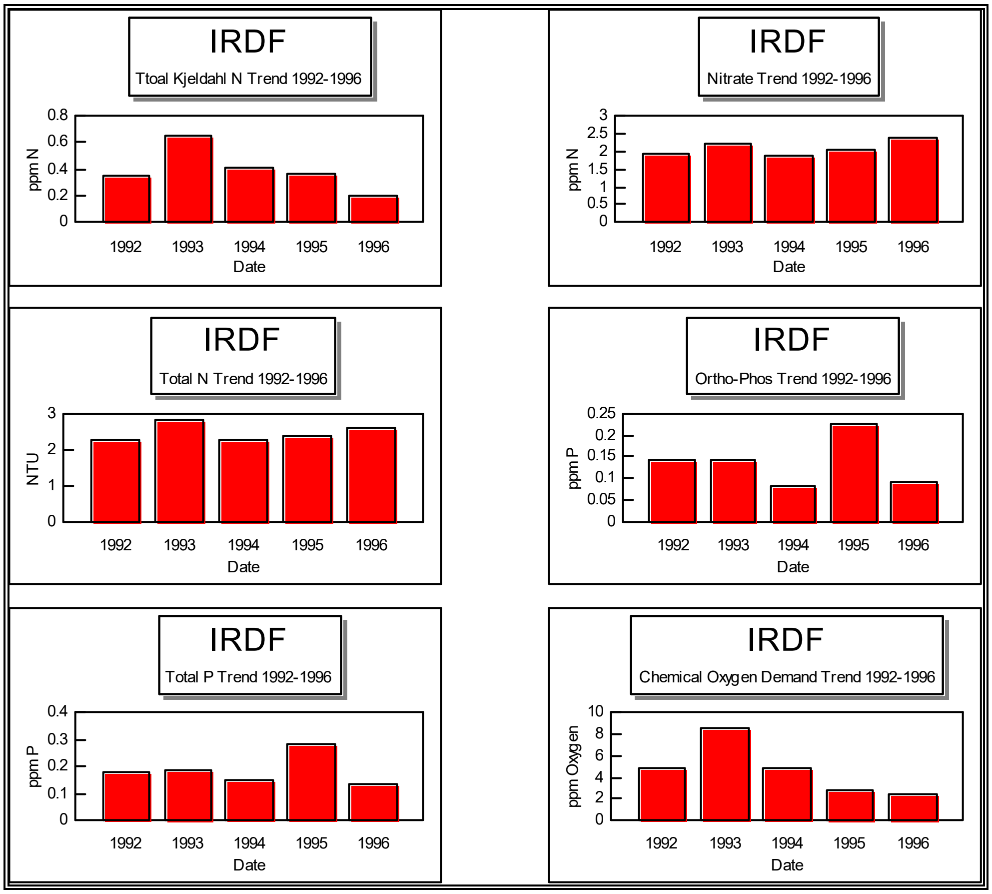


7.4.43 - 7.4.48 Yearly comparison of nutrient parameters for the Illinois River upstream of Flint Creek location.

Illinois River Downstream of Flint Creek

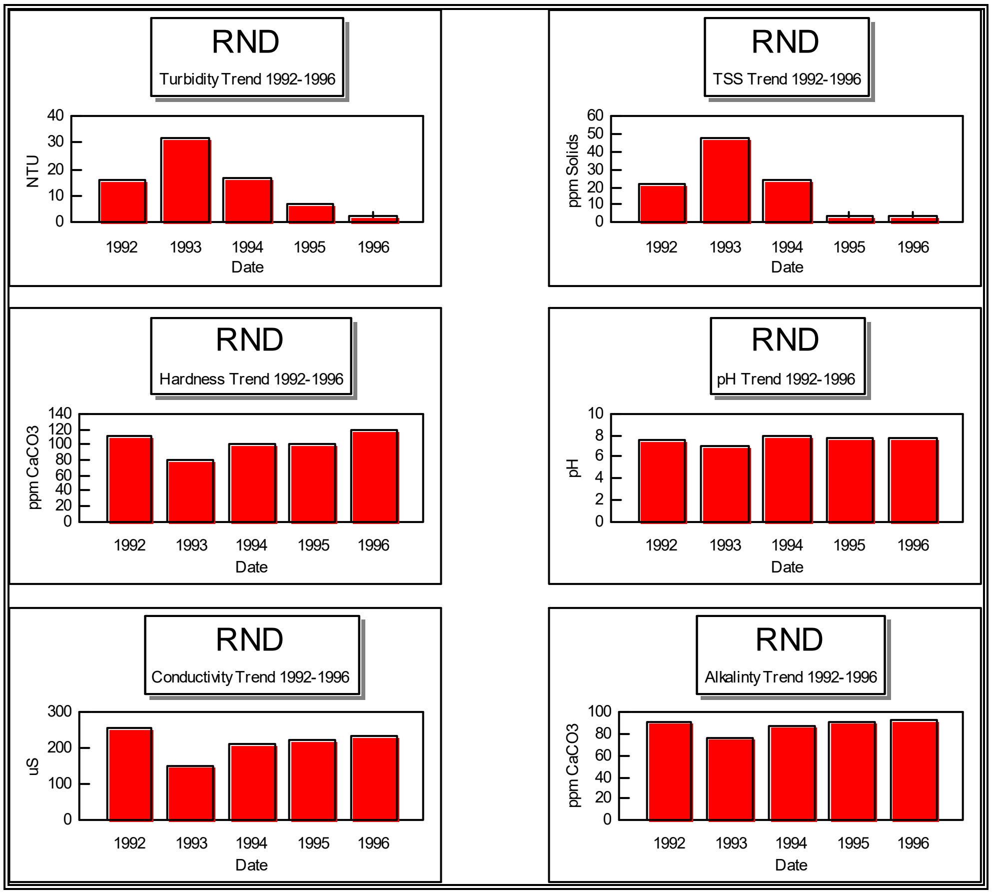


7.4.49 - 7.4.54 Yearly comparison of physical parameters for the Illinois River downstream of Flint Creek location.

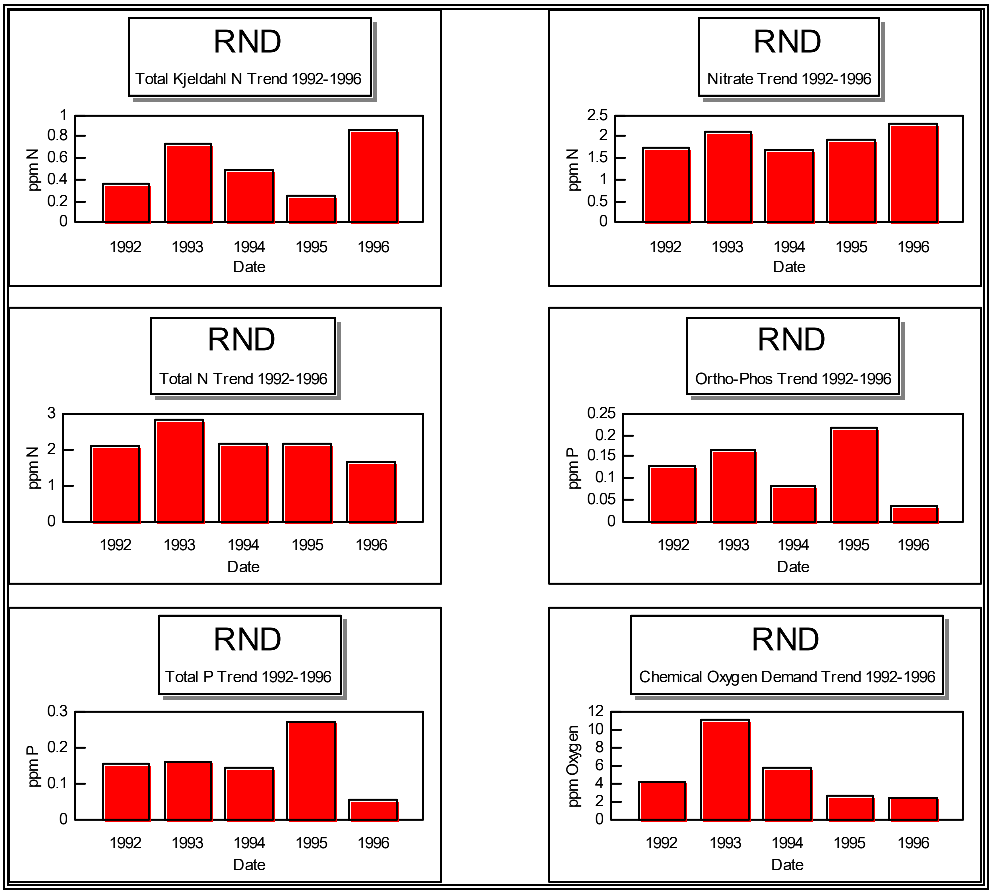


7.4.55 - 7.4.60 Yearly comparison of nutrient parameters for the Illinois River downstream of Flint Creek location.

Round Hollow

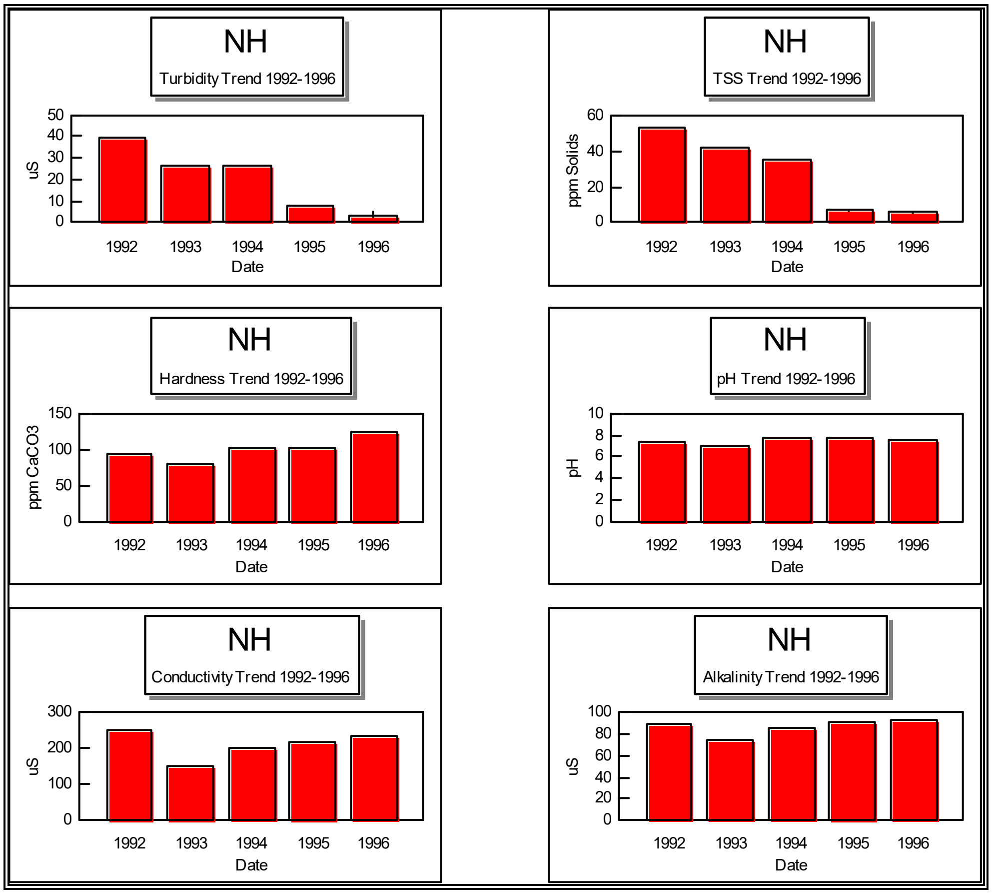


7.4.61 - 7.4.66 Yearly comparison of physical parameters for the Illinois River at Round Hollow location.

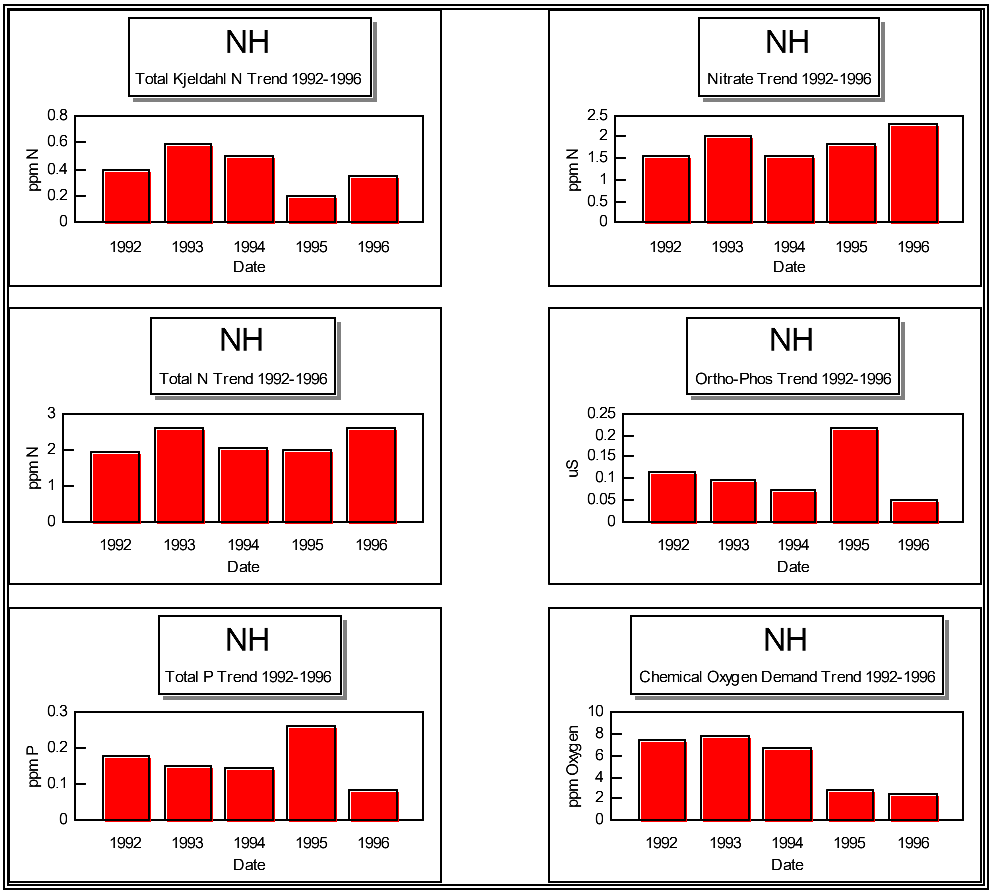


7.4.67 - 7.4.72 Yearly comparison of nutrient parameters for the Illinois River at Round Hollow location.

No Head hollow

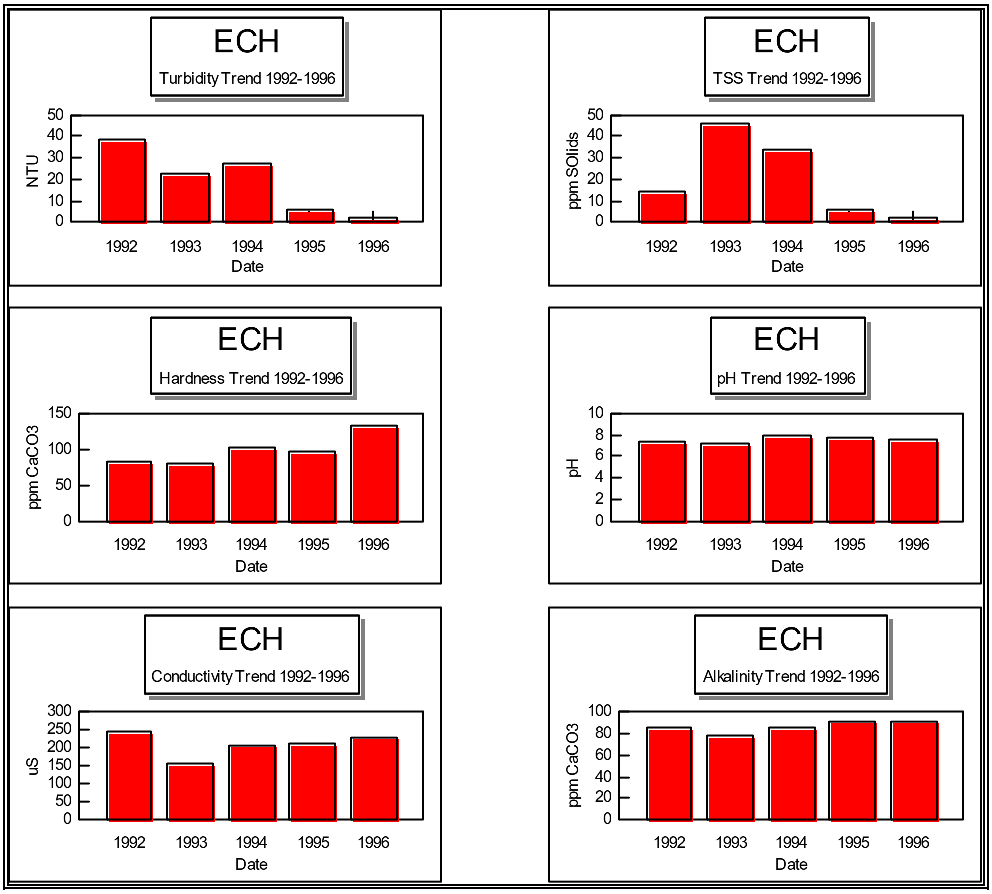


7.4.73 - 7.4.78 Yearly comparison of physical parameters for the Illinois River at No Head Hollow location.

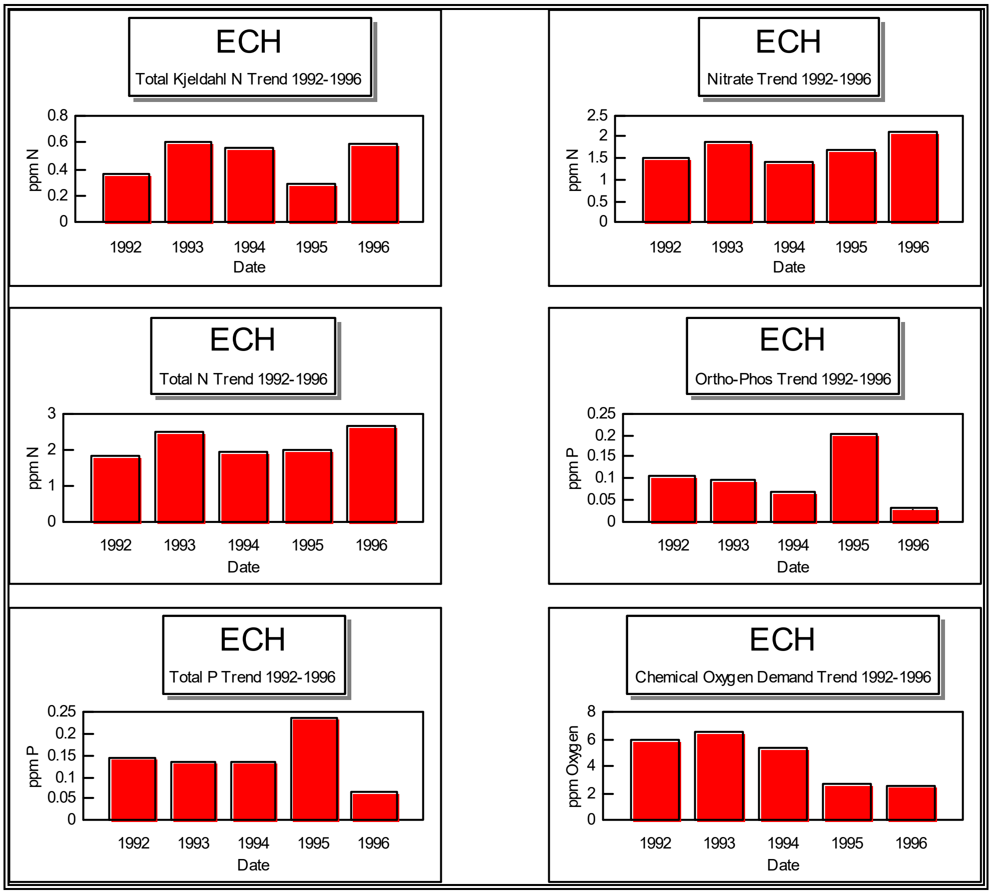


7.4.79 - 7.4.84 Yearly comparison of nutrient parameters for the Illinois River at No Head Hollow location.

Echota Bend

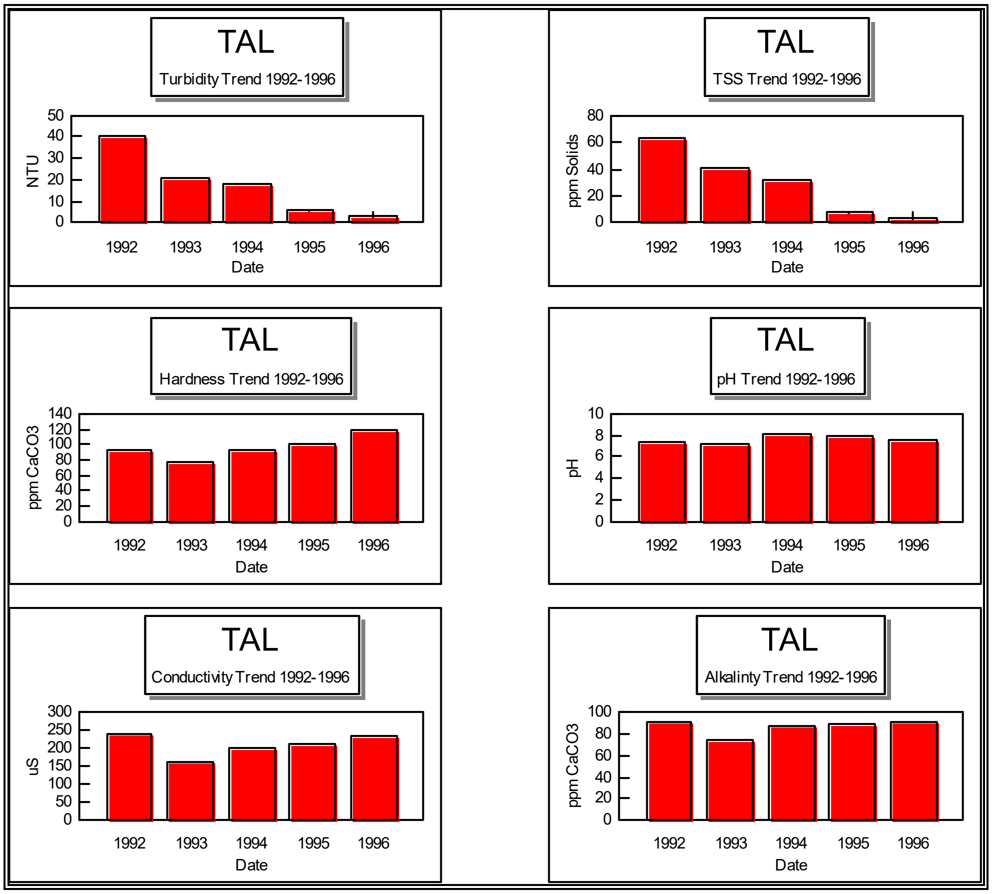


7.4.85 - 7.4.90 Yearly comparison of physical parameters for the Illinois River at Echota Bend location.

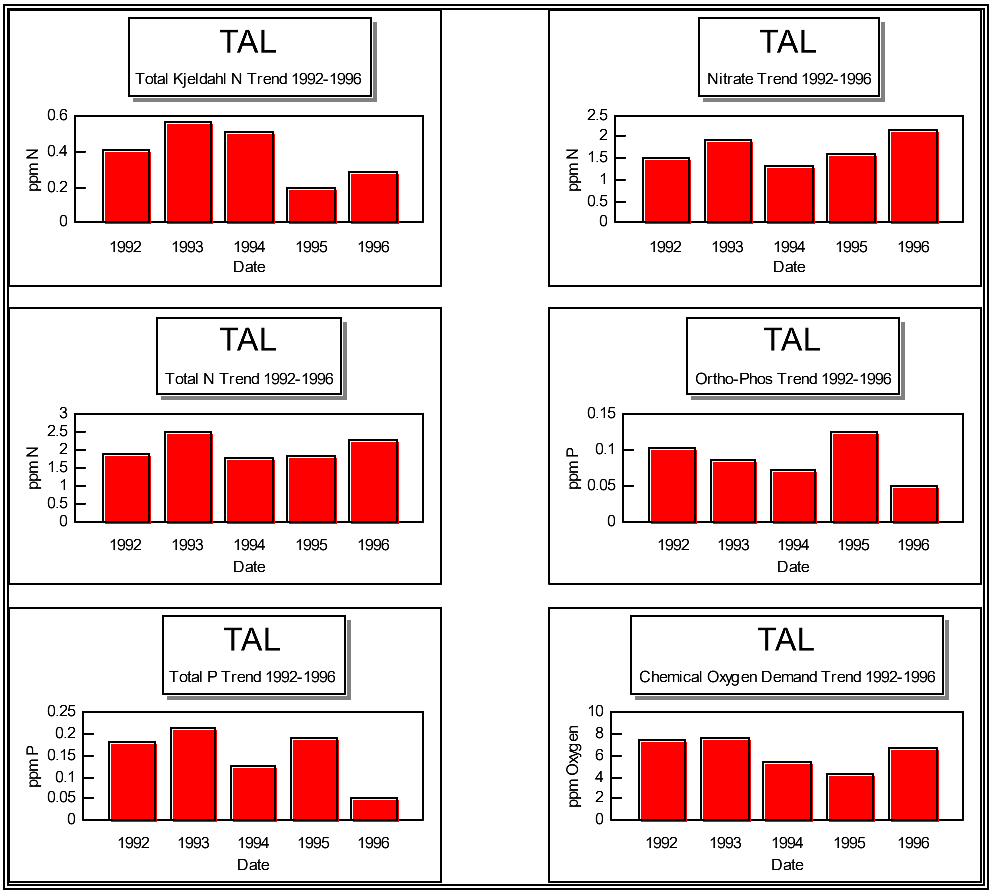


7.4.91 - 7.4.96 Yearly comparison of nutrient parameters for the Illinois River at Echota Bend location.

Tahlequah

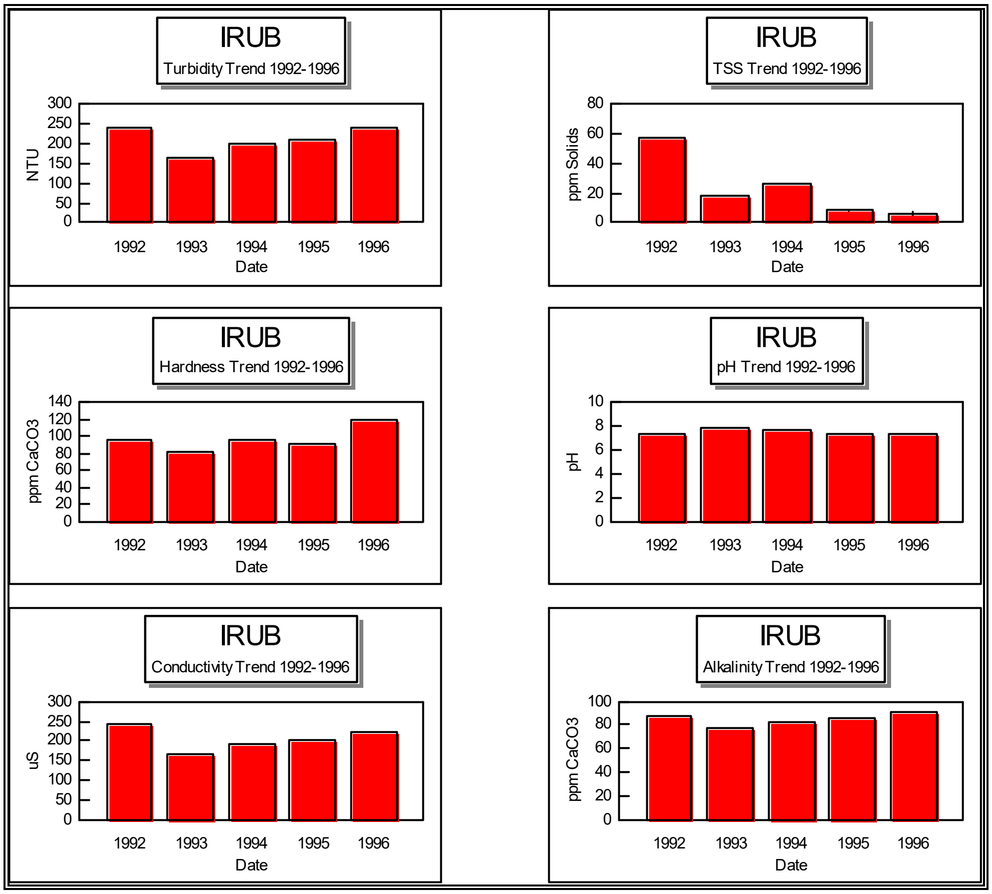


7.4.97 - 7.4.102 Yearly comparison of physical parameters for the Illinois River at Tahlequah location.

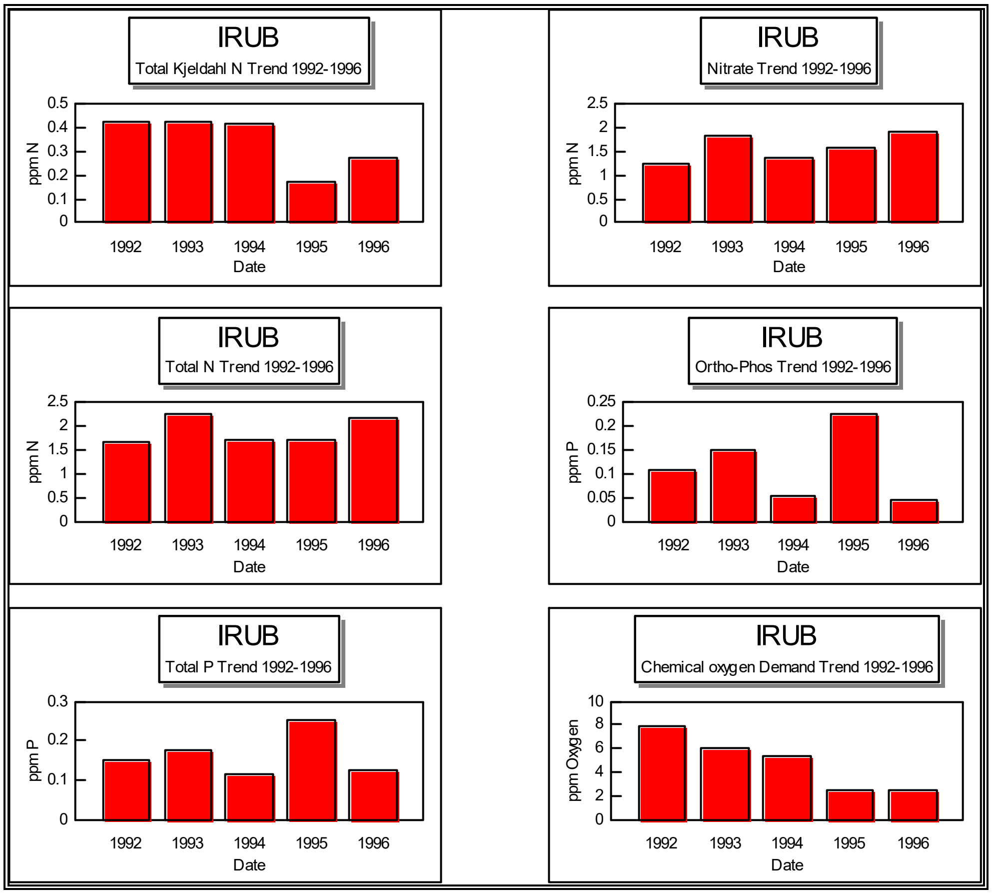


7.4.103 - 7.4.108 Yearly comparison of nutrient parameters for the Illinois River at Tahlequah location.

Illinois River Upstream of Baron Fork Creek

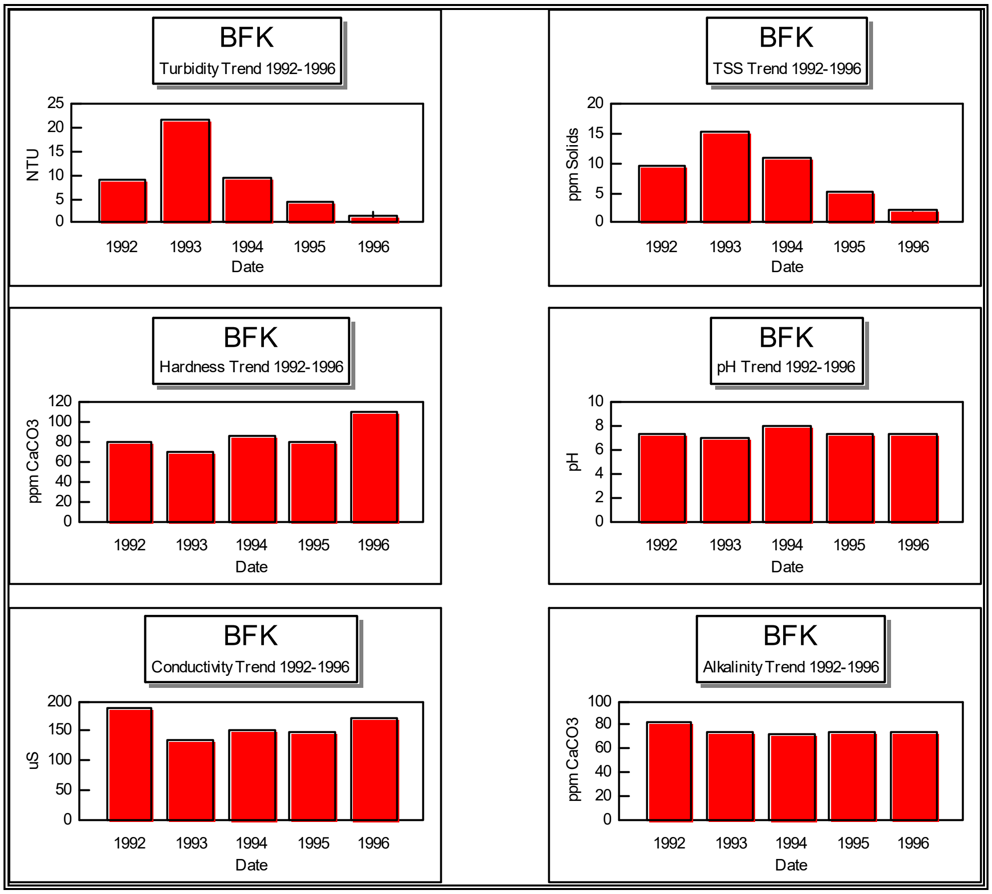


7.4.109 - 7.4.114 Yearly comparison of physical parameters for the Illinois River upstream of Baron Fork Creek location.

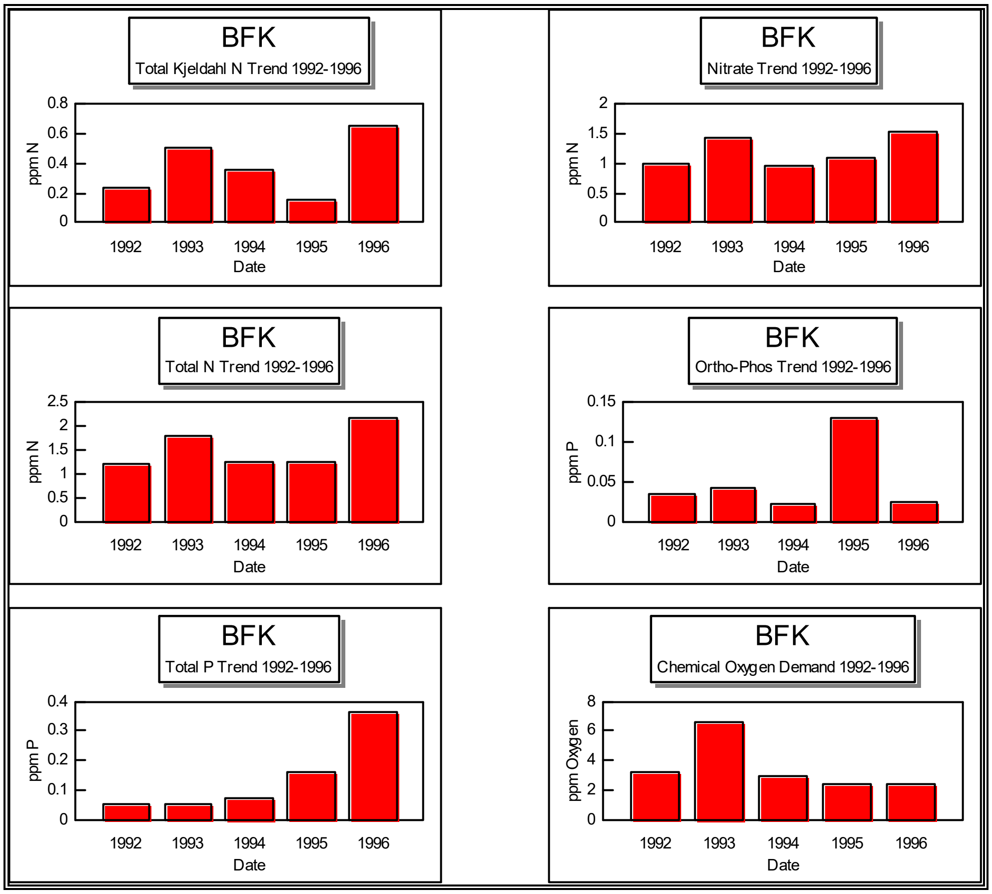


7.4.115 - 7.4.120 Yearly comparison of nutrient parameters for the Illinois River upstream of Baron Fork Creek location.

Baron Fork Creek

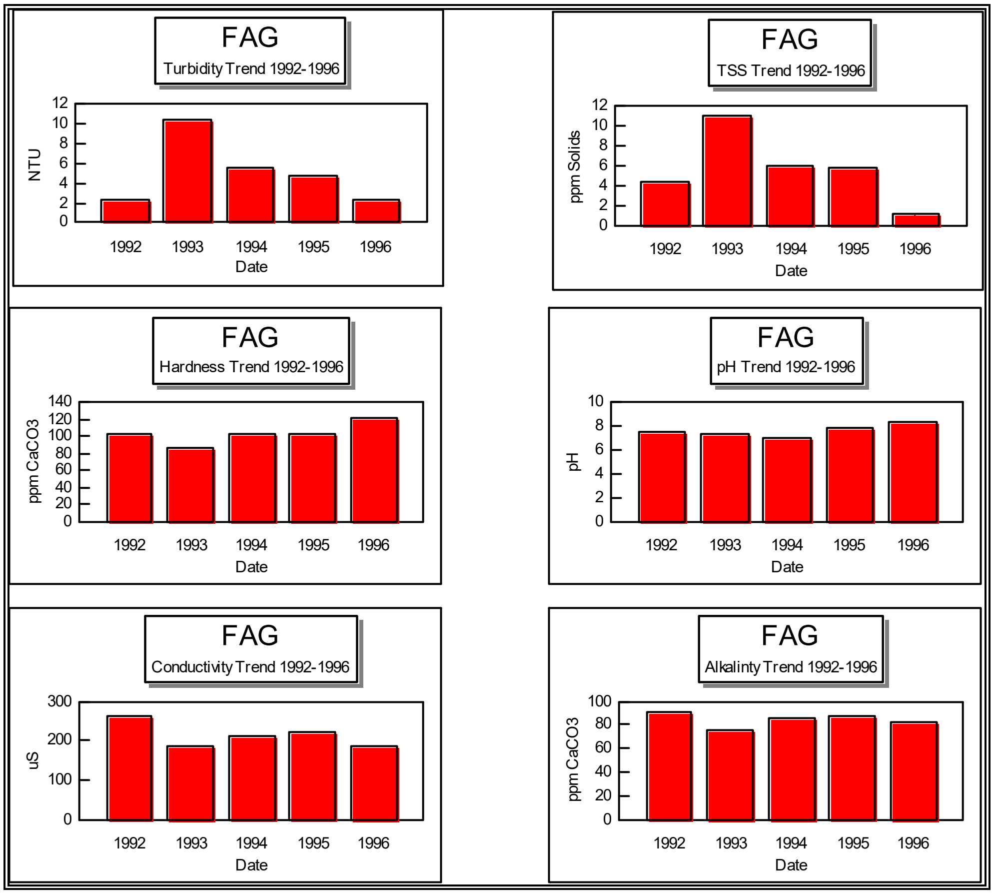


7.4.121 - 7.4.126 Yearly comparison of physical parameters for the Baron Fork Creek location.

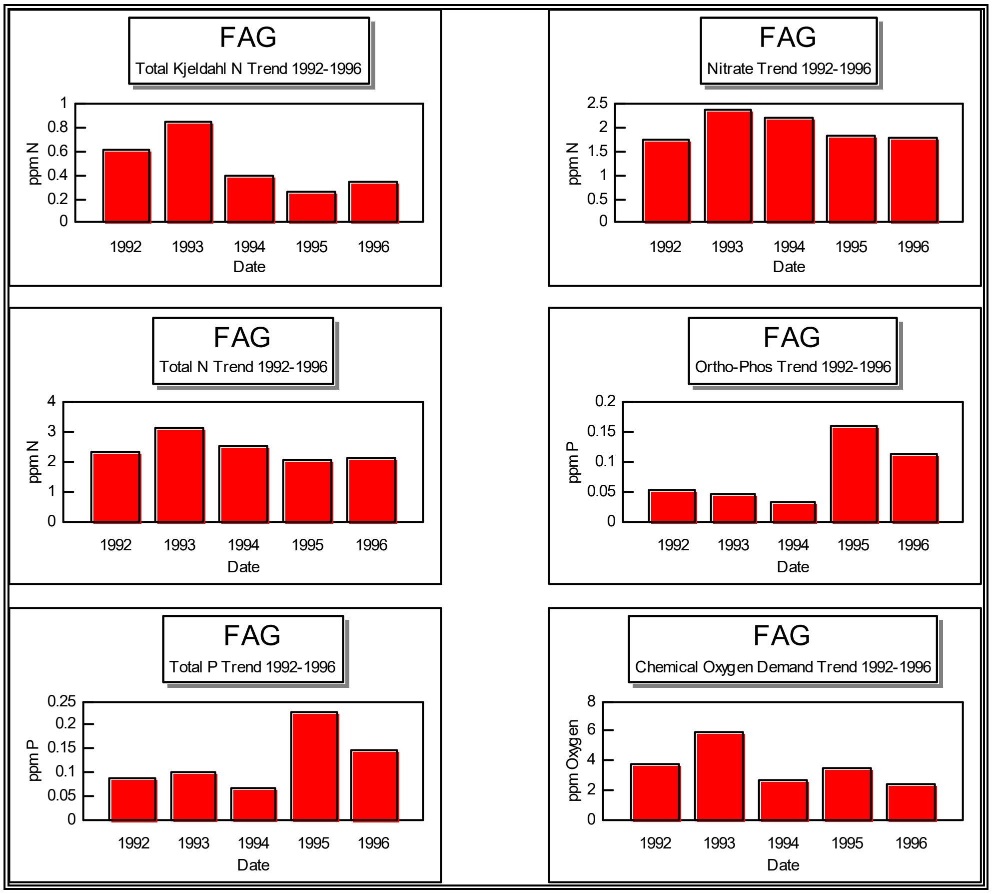


7.4.127 - 7.4.132 Yearly comparison of nutrient parameters for the Baron Fork Creek location.

Flint Creek Upstream of Fagan Creek

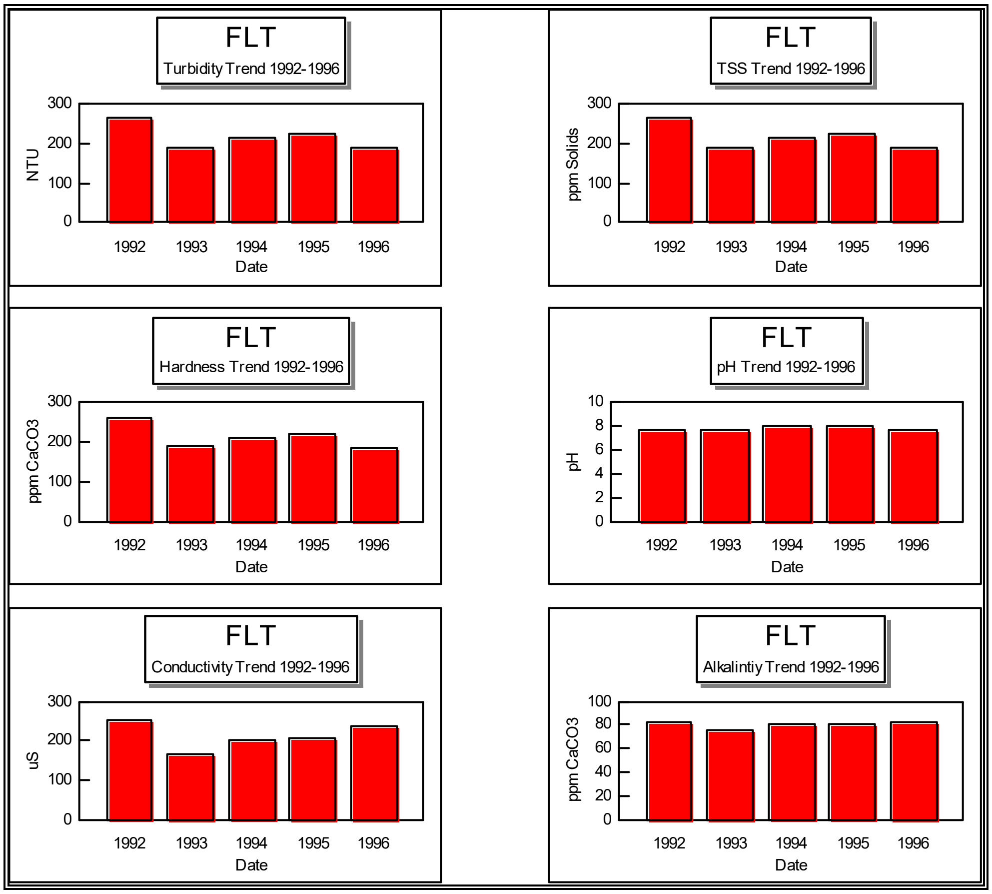


7.4.133 - 7.4.138 Yearly comparison of physical parameters for the Flint Creek near Fagan Creek location.

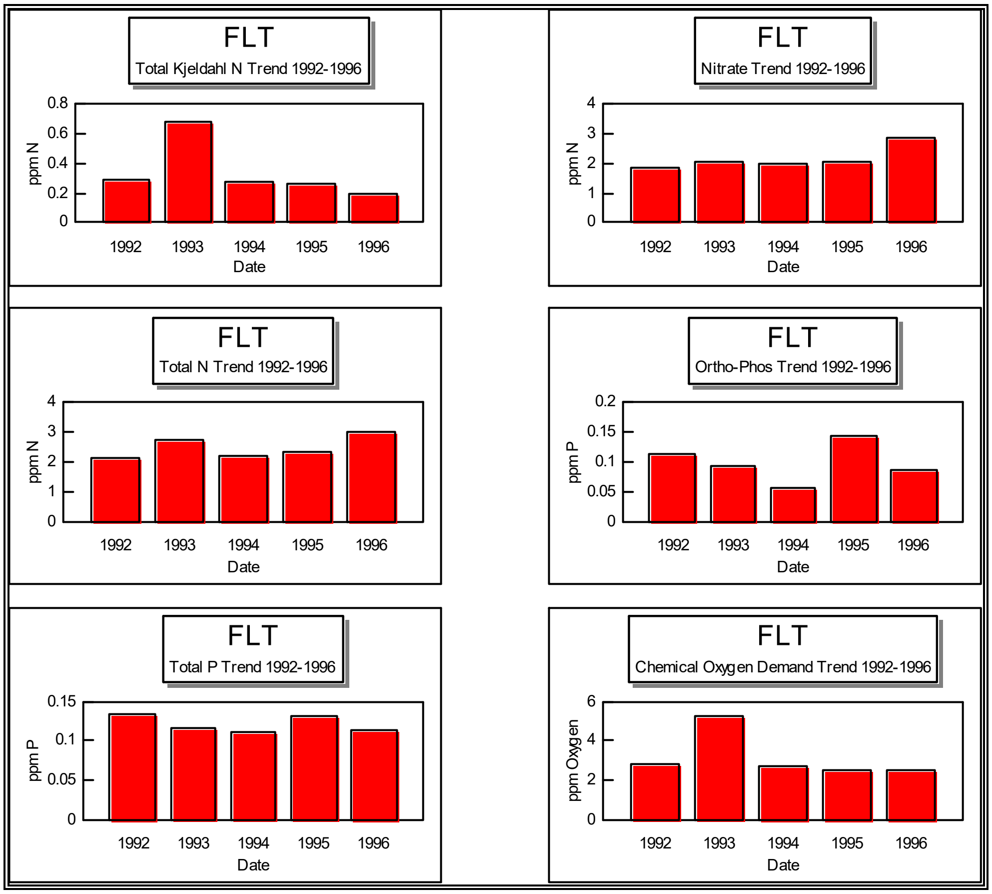


7.4.139 - 7.4.144 Yearly comparison of nutrient parameters for the Flint Creek near Fagan Creek location.

Flint Creek

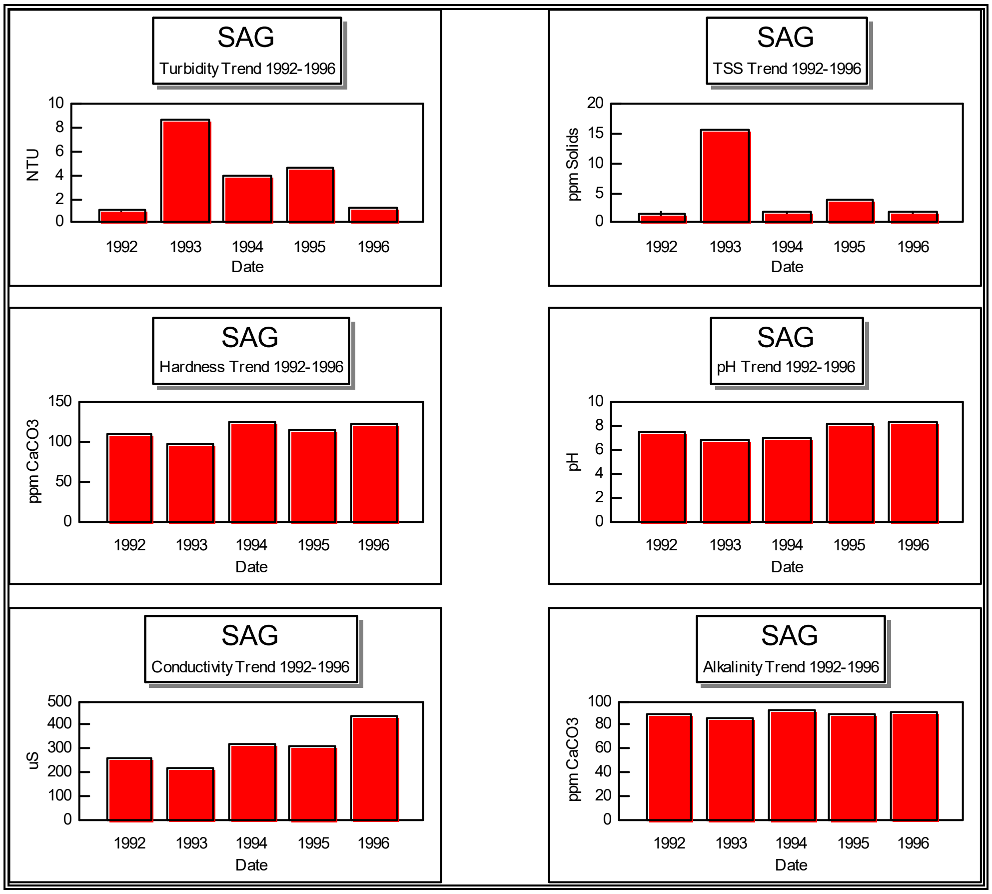


7.4.145 - 7.4.150 Yearly comparison of physical parameters for the Flint Creek location.

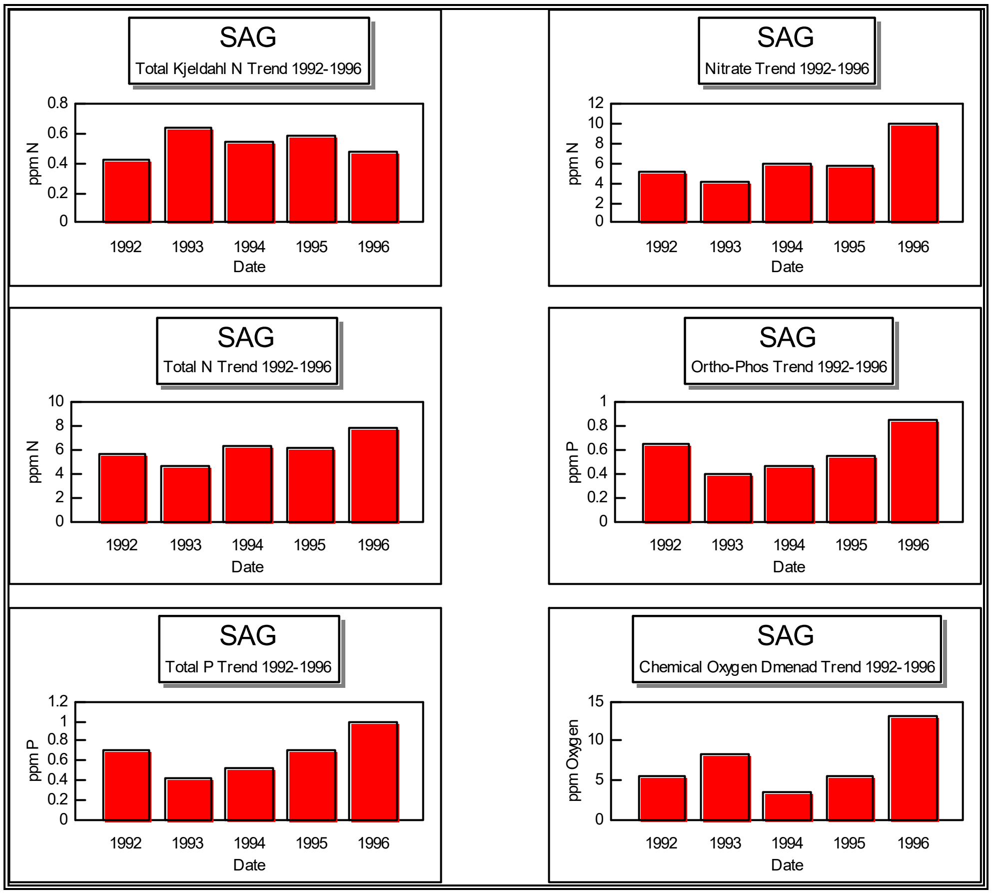


7.4.151 - 7.4.156 Yearly comparison of nutirent parameters for the Flint Creek location.

Sager Creek



7.4.157 - 7.4.162 Yearly comparison of physical parameters for the Sager Creek location.



7.4.163 - 7.4.168 Yearly comparison of nutrient parameters for the Sager Creek location.

7.5 Fecal Coliform Data With Respect to Location

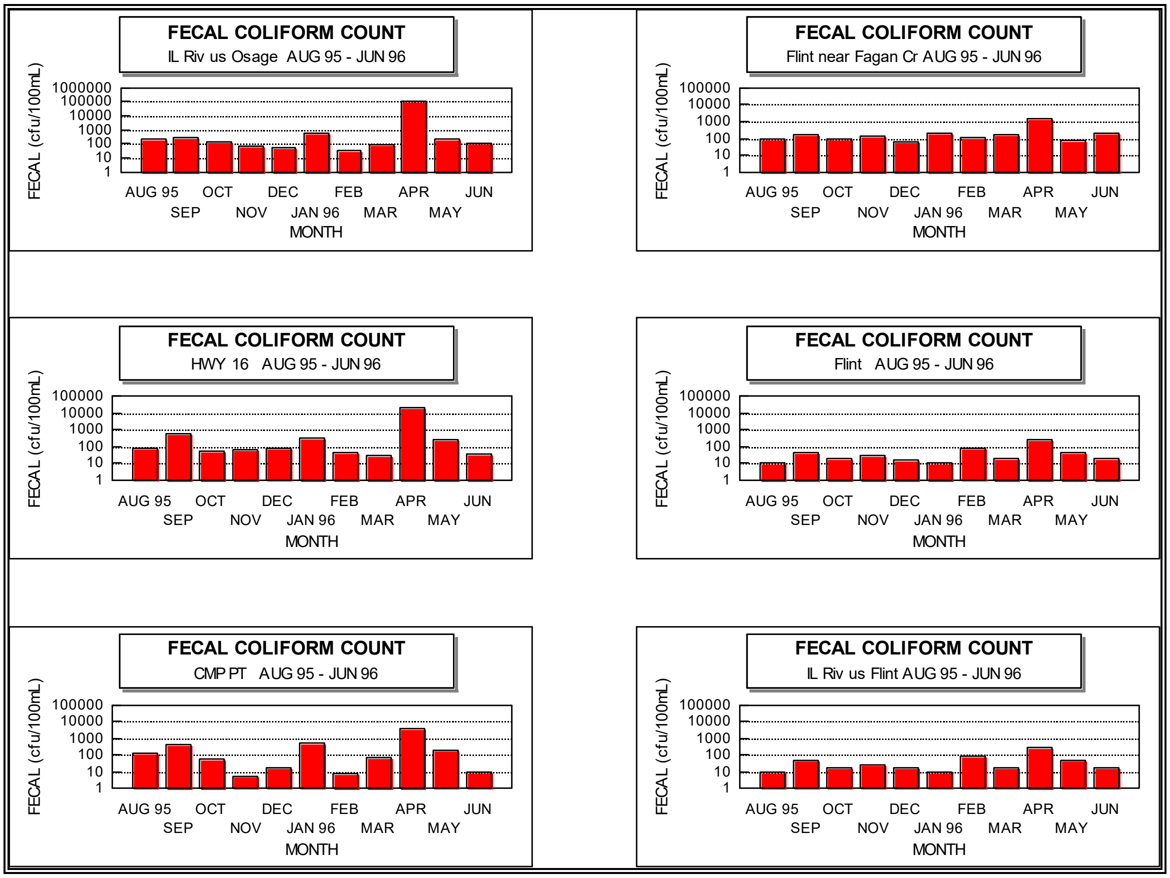


Figure 7.5.1 -7.5.6 Annual fecal coliform bacteria counts for individual locations on the Illinois River.

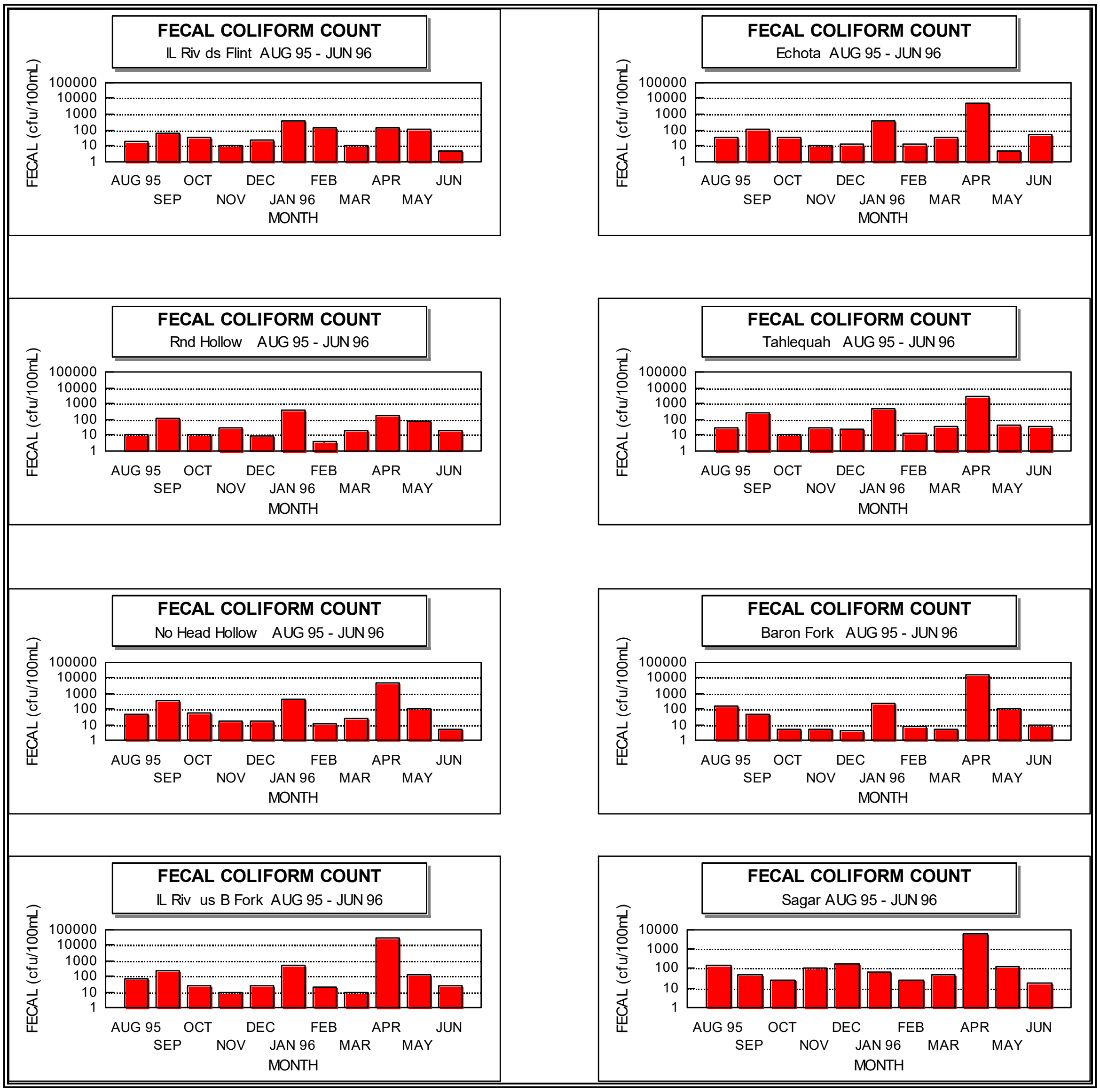


Figure 7.5.7 -7.5.14 Annual fecal coliform bacteria counts for individual locations on the Illinois River.