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Arkansas Water Resources Center

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2004 POLLUTANT LOADS
AT ARKANSAS HIGHWAY 59 BRIDGE

Submitted to the
Arkansas Soil and Water Conservation Commission
and the
Arkansas-Oklahoma Arkansas River Compact Commission

By
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SUMMARY

Results for Illinois River at AR59 for calendar year **2004**.

Pollutant	Total Discharge (m^3/yr)	Total Load (kg/yr)	Average Discharge (m^3/s)	Mean Concentrations (mg/l)
	565,760,474		17.8	
N03-N		1,207,335		2.13
TKN		512,358		0.91
TP		281,425		0.5
TSS		92,080,737		163

- Comparison between the loads and discharge calculated for 2003 to previous years indicate a decline in all parameters.

Comparison between 1997, 1998, 1999, 2000,2001,2002, 2003 and 2004 **loads**

Para meter	**1997** Loads	**1998** Loads	**1999** Loads	**2000** Loads	**2001** Loads	**2002** Loads	**2003** Loads	**2004** Loads
Discharge (m^3)	458,460,000	588,000,000	635,000,000	536,000,000	532,000,000	531,000,000	289,188,000	565,760,000
N03-N (kg/yr)	1,020,000	1,390,000	1,560,000	1,100,000	1,520,000	1,340,000	591,000	1,207,000
TKN (kg/yr)	301,000	481,000	514,000	462,000	447,000	294,000	144,000	512,000
TP (kg/yr)	127,000	232,000	267,000	283,000	256,000	218,000	64,000	281,000
TSS (kg/yr)	18,400,000	72,600,000	77,100,000	63,600,000	70,800,000	39,000,000	11,845,000	92,080,000

- The total phosphorus load significantly increased in 2004 compared to 2003. This increase can be attributed to two primary factors. Storm loads were increased by a factor of 10, which is primarily the result of increased storm flows from 46 million cubic meters to 290 million cubic meters. Base-flow P concentrations continued to fall to 0.11 mg/l as a result of declining WWTP discharges

INTRODUCTION

Automatic water sampler and a U. S. Geological Survey gauging station were established in 1995 on the main stem of the Illinois River at the Arkansas Highway 59 Bridge. Since that time, continuous stage and discharge measurements and water quality sampling have been used to determine pollutant concentrations and loads in the Arkansas portion of the Illinois River. This report represents the results from the measurement and sampling by the Arkansas Water Resources Center -Water Quality Lab for January 1, 2004 to December 31, 2004.

PREVIOUS RESULTS

In the fall of 1995, a gauge was installed at the Highway 59 Bridge by the USGS and automatic sampling equipment was installed by the Arkansas Water Resource Center. In September 1995, sampling was begun on the Illinois River. Grab samples were taken every week and storms were sampled using an automatic sampler set to take samples every 4 hours. During the period from September 13, 1995 to September 15, 1996 one hundred thirty seven grab samples and discrete storm samples were collected and analyzed. Table 1 summarizes the results from that study (Parker et al, 1997).

Table 1. Results from **1996** study period (Parker et al, 1997)

Nutrients	Total Discharge (m^3/yr) 300,775,680	Total Load (kg/yr)	Average Discharge (m^3/s) 9.5	Average Flow Weighted Concentrations (mg/l)
N03-N		550,000		2.0
NH3-N		8,530		0.031
TKN		201,000		0.74
TP		89,900		0.29
TSS		27,000,000		89
TOC		1,130,000		4.2

Sampling was discontinued on September 15, 1996 and no water quality samples were taken between September 15, 1996 and November 1, 1996. Stage and discharge was still recorded for this period, however, no loads were calculated. Water quality sampling was resumed on November 1, 1996. The sampling protocol was changed to collection of grab samples every two weeks and flow-weighted storm composite samples. Between November 1, 1996 and December 31, 1996 a total of four grab samples and one storm composite sample were collected and analyzed. Stage and discharge were recorded.

During the period from January 1, 1997 to October 15, 1997, there were twenty-six grab samples and twenty-five storm composite samples collected and analyzed using the same protocol. During the period from October 15, 1997 to December 31, 1997, the sampling protocol was changed to taking grab samples every two or three days and taking discrete storm samples every thirty or sixty minutes. In this period, there were twenty-four grab samples and one hundred and forty storm discrete samples collected and analyzed. The loads and mean concentrations for 1997 calculated using these samples are summarized in Table 2.

Table 2. Results from **1997**-study period (Nelson and Soerens, 1998).

Pollutant	Total Discharge (m^3/yr) 458,460,000	Total Load (kg/yr)	Average Discharge (m^3/s) 14.5	Mean Concentrations (mg/l)
N03-N		1,020,000		2.24
TKN		301,000		0.66
TP		127,000		0.28
TSS		18,400,000		40.2

In the periods from January 1, 1998 to May 15, 1998 and November 1, 1998 to December 31, 1998, the Illinois River sampling was supplemented by sampling from another research project. That project, sponsored by the USGS Water Resource Institute Program, was titled "Investigation of Optimum Sample Interval for Determining Storm Water Pollutant Loads" by Marc Nelson, Thomas Soerens and Jean Spooner. The sampling protocol for that project consisted of taking grab samples every two days and discrete storm water samples at thirty-minute intervals on the rising limb and sixty-minute intervals on the falling limb of storm hydrographs. Storm water sampling was begun at a variable trigger level set to the current stage plus ten percent and adjusted every two days. After the first thirty-six hours of each storm, sample times were increased to from four to twenty-four hours until the stage fell below the initial trigger. All samples were collected within twenty-four hours. All samples were analyzed for nitrate nitrogen (NO3-N), ammonia nitrogen (NH4-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), ortho phosphate (O-P) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

In the period from May 16, 1998 to October 31, 1998, the sampling protocol was changed back to the collection of grab samples every two weeks and flow-weighted composite samples during storms. Storms were defined as all flows above a five-foot trigger level. Once stage had risen above the trigger, a USGS programmable data logger began summing the volume of water discharged. Once a determined amount of water had been discharged, the data logger sent a signal to an automatic water sampler that filled one of twenty-four one-liter bottles. The total was then reset to zero and discharge was again summed for the next sample. In this fashion up to twenty-four samples, each representing an equal volume of storm water was collected. The volume of water represented by each individual sample was eight million cubic feet. These samples were retrieved before all twenty-four bottles were filled, or within 48 hours after being taken. The individual samples were composited into a flow-weighted composite storm sample by combining equal volumes of each. Samples were taken as long as the stage remained above the trigger level. All samples were analyzed for nitrate nitrogen (NO3-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

In the period from January 1, 1998 to December 31, 1998, there were four hundred and forty nine samples collected and analyzed. These results are summarized in Table 3.

Table 3. Results from **1998**-study period (Nelson and Soerens, 1999).

Pollutant	Total Discharge (m^3/yr) 588,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 18.6	Mean Concentrations (mg/l)
N03-N		1,390,000		2.37
TKN		481,000		0.82
TP		232,000		0.39
TSS		72,600,000		123.5

In the period from January 1, 1999 to December 31, 1999, there were three hundred and sixty nine samples collected and analyzed. These results are summarized in Table 4.

Table 4. Results from the **1999** study period (Nelson and Soerens, 2000)

Pollutant	Total Discharge (m^3/yr) 635,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 20.0	Mean Concentrations (mg/l)
N03-N		1,560,000		2.45
TKN		514,000		0.81
TP		267,000		0.42
TSS		77,100,000		121

In the period from January 1, 2000 to December 31, 2000, there were fifty-one samples collected and analyzed. These results are summarized in Table 5.

Table 5. Results for Illinois River at AR59 for Calendar Year **2000**. (Nelson and Soerens, 2001).

Pollutant	Total Discharge (m^3/yr) 536,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 17	Mean Concentrations (mg/l)
N03-N		1,100,000		2.06
TKN		462,000		0.86
TP		283,000		0.53
TSS		63,600,000		118

In the period from January 1, 2001 to December 31, 2001, there were forty-nine samples collected and analyzed. These results are summarized in Table 6.

Table 6. Results for Illinois River at AR59 for Calendar Year **2001**. (Nelson and Soerens, 2002).

Pollutant	Total Discharge (m^3/yr) 532,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 16.9	Mean Concentrations (mg/l)
N03-N		1,520,000		2.86
TKN		447,000		0.84
TP		256,000		0.48
TSS		70,800,000		133

In the period from January 1, 2002 to December 31, 2002, there were Fifty-six samples collected and analyzed. These results are summarized in Table 7.

Table 7.Results for Illinois River at AR59 for calendar year **2002**. (Nelson and Cash, 2003).

Pollutant	Total Discharge (m^3/yr) 531,000,000	Total Load (kg/yr)	Average Discharge (m^3/s) 16.8	Mean Concentrations (mg/l)
N03-N		1,340,000		2.52
TKN		294,000		0.55
TP		218,000		0.41
TSS		38,900,000		73

Table 8 Results for Illinois River at AR59 for calendar year **2003**(Nelson and Cash, 2004).

Pollutant	Total Discharge (m^3/yr) 289,188,131	Total Load (kg/yr)	Average Discharge (m^3/s) 9.1	Mean Concentrations (mg/l)
N03-N		590,943		2.04
TKN		144,041		0.50
TP		64,854		0.22
TSS		11,845,136		41

METHODS

There were no samples collected at this site from January 1, 2004 to March 31, 2004. Base flow concentrations for this period were estimated as the average value for the rest of the year. The concentrations during the one storm event that occurred during this period (March 3, 2004) were estimated using the Stage / Concentration regression developed from the discretely sampled storm event (November 3, 2004). Table 9 lists the regression coefficients determined from that storm.

Table 9. Regression equations determined from discrete storm samples 2004

parameter	Regression equation	Regression coefficient
Nitrate-N	y = -0.0002x + 2.435	R^2 = 0.443
Total Phosphorus	y = 0.0001x + 0..556	R^2 = 0.0789
Ammonia-N	y = 0.00005x + 0.1009	R^2 = 0.4651
TN	y = 0.00006x + 0.4398	R^2 = 0.3942
Phosphate-P	y = 0.00002x + 0.2267	R^2= 0.077
TSS	y = 0.0456x + 215.36	R^2 = 0.0452

In the period from April 1, 2004 to December 31, 2004, the Illinois River sampling followed the following protocol. Base flow grab samples were taken every two weeks using the automatic sampler. Storm flow-weighted composite samples were taken during all storm events except one. The storm on November 1 was sampled using 54 discrete samples. Sampling was initiated when the river stage exceeded the trigger level of 5 feet. Flow-weighted composite samples were taken by causing the sampler to collect a single discrete sample for every four million cubic feet of water that passed the bridge. These discrete samples were collected once per day and composited by taking equal volumes from each discrete and combining them to form a single sample for analysis. Flow-weighted composite samples were taken from trigger level to trigger level of all storm events where the river stage was above the trigger for at least twelve hours. Samples were collected every 30 minutes for the first 24 samples and every 60 minutes for the next 30 samples during the discretely sampled storm event on November 1. All samples were collected within twenty-four hours of being taken. All samples were analyzed for nitrate nitrogen (NO3-N), ammonia nitrogen (NH4-N), total nitrogen (TN), total phosphorus (TP), ortho-phosphate (O-P) and total suspended solids (TSS). AWRC Field Services personnel collected all samples and all samples were analyzed by the AWRC Water Quality Lab using standard field and laboratory QA/QC procedures.

Calendar year pollutants loads and mean concentrations were calculated from the collected data. USGS stage and discharge data in thirty-minute intervals was used to calculate thirty-minute total volumes. Each volume was assigned a pollutant concentration. The pollutant concentrations were assigned by applying the results of grab samples between storm trigger levels and the results of storm water samples above trigger levels. All concentration data were assigned to the time periods from half way to the previous sample to half way to the subsequent sample except the first and last of a storm or base flow period which were assigned to the start or end of the period. Thirty-minute loads were calculated by multiplying thirty-minute volumes by their assigned concentrations. The yearly loads were calculated by summing the thirty-minute loads during the calendar year. Yearly mean concentrations were calculated by dividing the yearly load by the yearly volume.

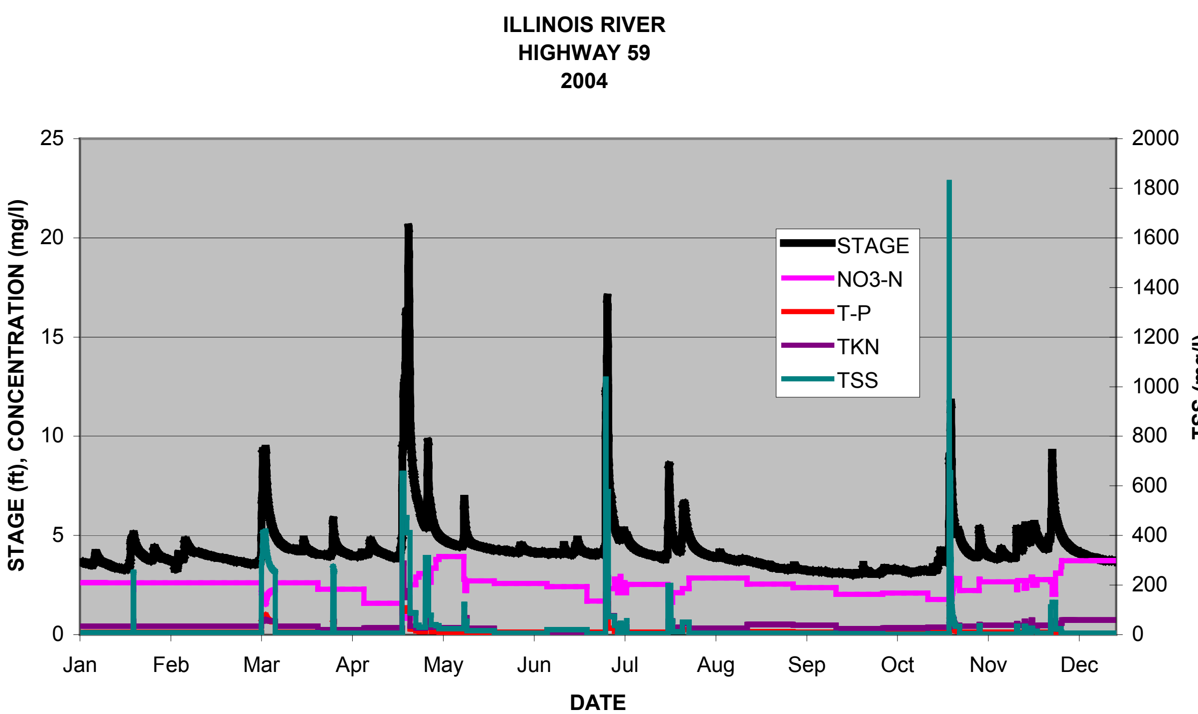
RESULTS

In the period from April 1, 2004 to December 31, 2004, there were 60 discrete storm samples, 31composite storm samples and 19 base-flow grab samples collected, analyzed and used to calculate loads. These results are summarized in Table 10 and Figure 1.

Table 10. Results for Illinois River at AR59 for Calendar Year **2004**.

Pollutant	Total Discharge (m^3/yr) 565,760,474	Total Load (kg/yr)	Average Discharge (m^3/s) 17.8	Mean Concentrations (mg/l)
N03-N		1,207,335		2.13
TKN		512,358		0.91
TP		281,425		0.5
TSS		92,080,737		163

Figure 1. Recorded stage and measured concentration for 2004.



DISCUSSION

The loads that were calculated for the year 2004 should be considered a reliable estimate of the actual loads in the Illinois River in Arkansas. The base flow concentrations for the period when no sampling occurred were estimated using the average value for the rest of the year. The wastewater treatment plants that discharge into this river were in the process of improving their systems for the removal of phosphorus, so that, the estimate of Phosphorus concentrations may slightly underestimate the actual values. However, the concentrations at the end of 2003 were very close to the average values applied to the first part of 2004. The stage / concentration regression values used to estimate the storm concentrations for the one storm event in March were very poor fits with the highest R^2 value less than 0.5. These estimates probably slightly underestimated the actual storm concentrations. The potential underestimation of the concentrations during this time should have minimal effect on the total annual loads and mean concentrations for the year. The volume for which concentration estimates were made was 17% of the total volume for the year.

Results from eight years water quality monitoring for total phosphorus are summarized in Figures 2 to 4. The mean concentrations were determined by dividing the annual load by the annual discharge. Shown in figure 2 are the base and storm flows and concentrations. Base flow concentrations represent the phosphorus load determined when the river stage was below five feet divided by the total discharge that occurred when the river stage was below five feet. Storm flow concentrations are loads divided by discharge above five feet. These results show a decreasing trend in base-flow concentrations in the last four years. Figure 4 shows that the reduction in T-P base-flow loads measured at the 59 Bridge correlates well with the reduction of T-P discharged by the municipal WWTPs into the river.

Figure 2 trends in discharge and T-P concentrations.

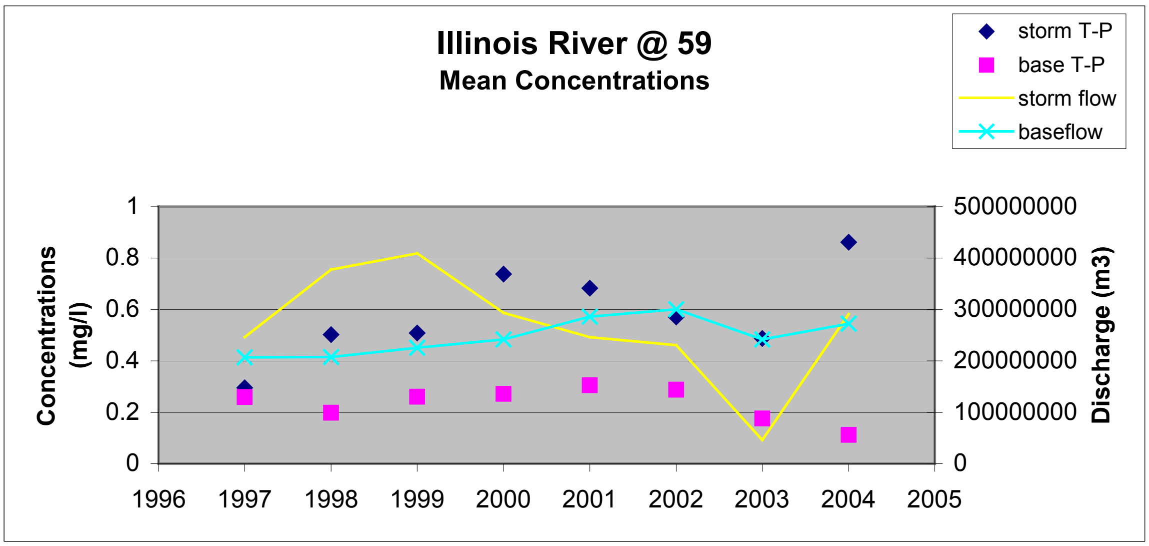


Figure 3 Trends in phosphorus loads

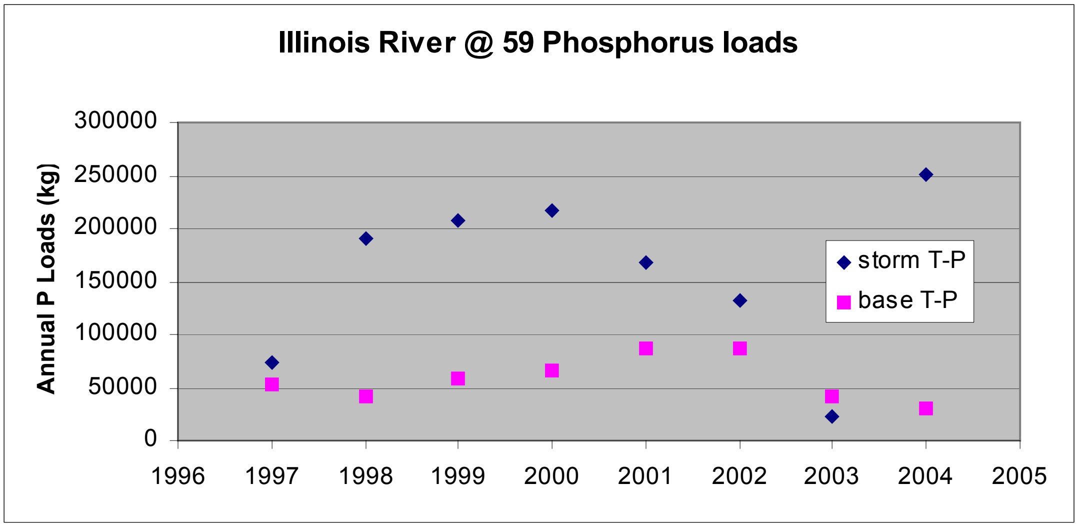
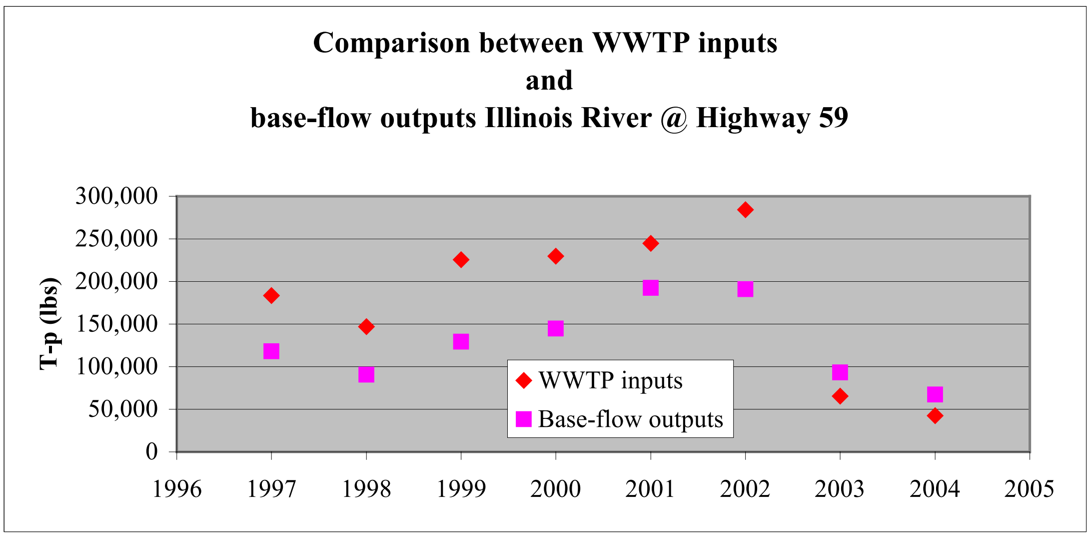


Figure 4 Comparison of measured base-flow T-P load to WWTP T-P discharge.



Storm-flow loads tend to be related to discharge, with higher loads associated with higher discharges. This relationship was observed throughout the study period. The decreasing trend in storm-flow loads in three of the last four years can probably be attributed to the decreasing storm-flow discharges in those years, The last year shows increasing discharge and a corresponding increase in concentrations of phosphorus.

The loads and concentrations developed for the Illinois River can be compared to loads and concentrations developed in other watersheds in Northwest Arkansas. six other watersheds have been monitored using the same monitoring and load calculation protocols. The only differences between the protocols are that trigger levels and storm composite sample volumes are different for each site. This means that the distinction between storm and base flows (defined here as the trigger level) may be relatively different at each site.

The averaged results for the seven watersheds are summarized in Table 11 and Figure 5. The table and figure show TSS and phosphorus as total annual loads per watershed acre, as storm loads per watershed acre and as base-flow concentrations. Normalizing total and storm loads to a per acre basis allows easy comparison between watersheds of differing sizes. The total loads indicate the mass of TSS or P that are being transported to a receiving water body. Storm loads per unit area may be used to represent relative impacts from non-point sources.

The Illinois River watershed has relatively low total TSS compared to the others (except Ballard Creek) and most of the TSS is transported during storm events. The P load for the Illinois is fairly consistent with the other watersheds with the White at Wyman, Ballard creek and Osage and showing higher levels of P per acre especially during storm events (Ballard is lower during storms and higher during base-flows). The Kings River showed lower total values and the West Fork showed much lower base-flow values).

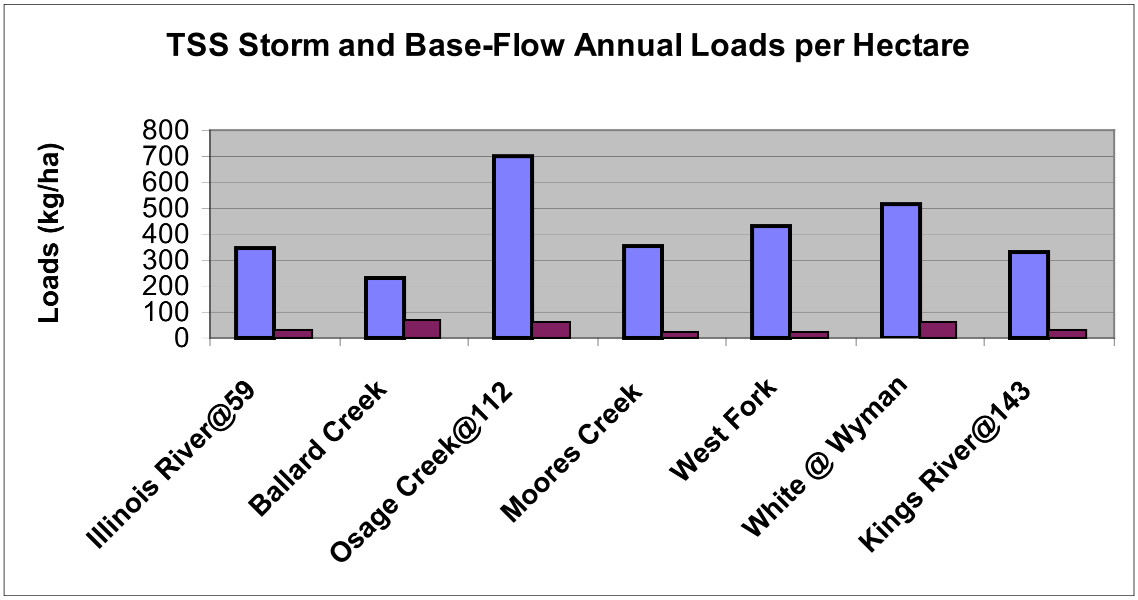
The base-flow concentrations show relative levels of TSS and P that are impacting in-stream biological activity during most of the year. These are the values that are of greatest interest for determining impacts to in-stream macro invertebrate habitat and nuisance algae production. The Illinois River has average concentrations of TSS compared to the others. It is low compared to the White at Wyman and Osage Creek. The base-flow P concentrations for all of the watersheds except the West Fork are similar.

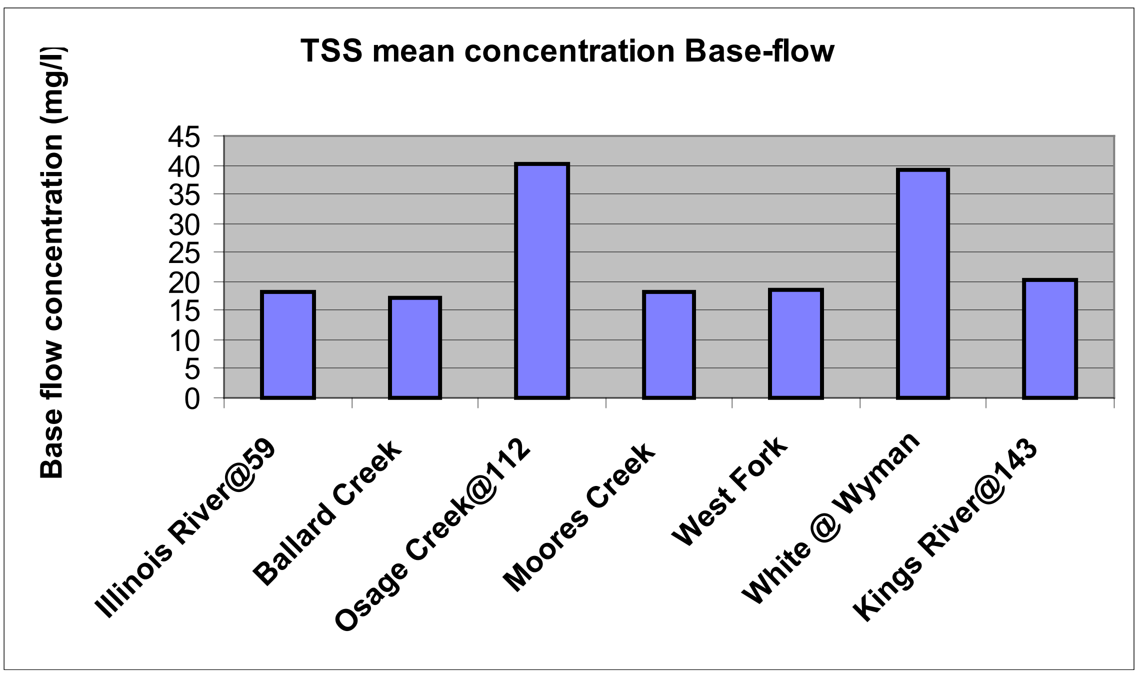
All of the following data are averages for the years of data collection noted. The Illinois River has the longest period of data collection and has made the greatest improvements. The average values therefore do not represent the current conditions.

Table 11 Comparison of seven watersheds

	Illinois River@59	Ballard Creek	Osage Creek@112	Moores Creek	West Fork	White @ Wyman	Kings River@143
Hectares	148,930	7,106	8,988	1,000	30,563	103,603	136,497
YEARS of data	8	2	3	4	3	2	6
tss load (kg/ha)	374	303	764	838	454	576	360
tss load storm (kg/ha)	345	232	702	781	433	514	333
tss load base (kg/ha)	29	72	62	57	22	62	27
tss conc. base (mg/l)	18	17	40	18	19	39	20
p load (kg/ha)	1.45	1.69	1.54	2.80	1.06	1.69	0.88
p storm load (kg/ha)	1.06	1.04	1.23	2.22	1.04	1.26	0.63
p load base (kg/ha)	0.39	0.66	0.30	0.58	0.02	0.44	0.24
p base conc. (mg/l)	0.23	0.16	0.19	0.17	0.02	0.24	0.20
Total Nitrogen load (kg/ha)	10.80	17.54	19.54	7.72	3.89	4.62	4.54
NO3-N base conc. (mg/l)	2.43	2.62	3.59	2.20	0.34	0.55	0.85
DISCHARGE (m^3/ha)	3,465	5,583	5,130	3,011	4,303	4,009	2,964

Figure 5 Comparison of seven watersheds





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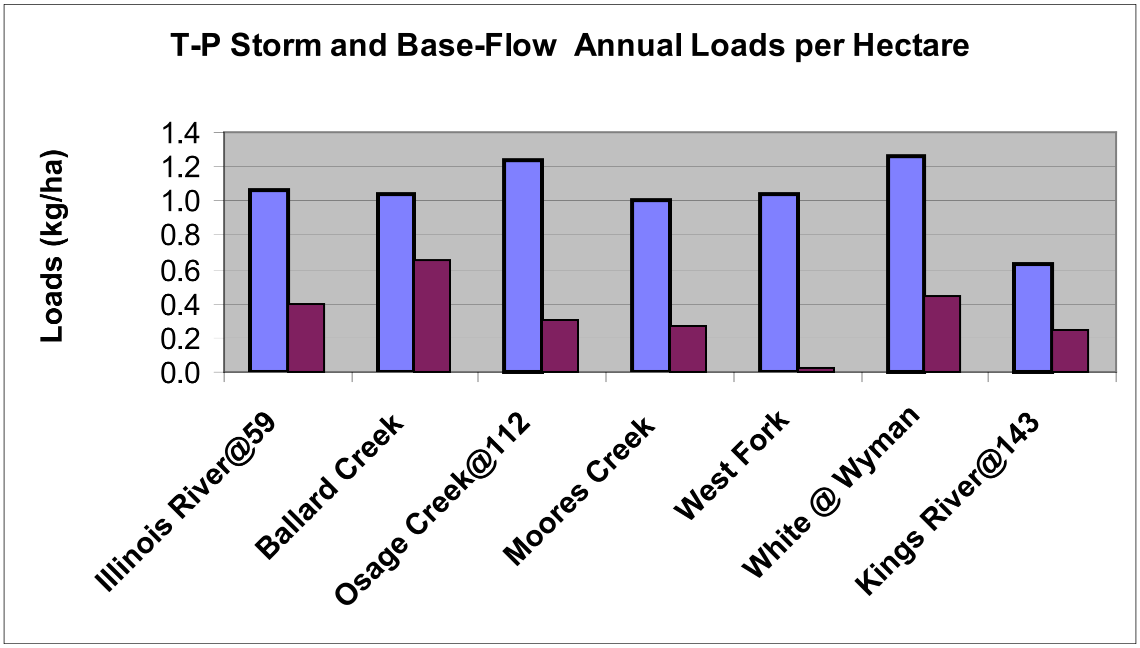

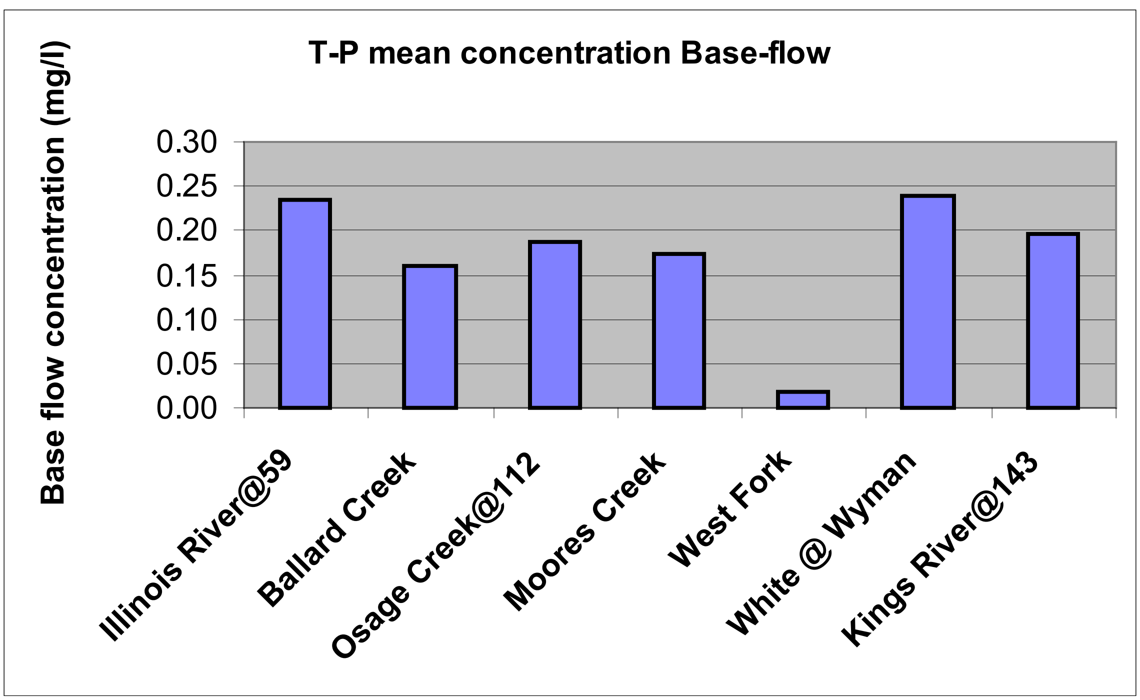

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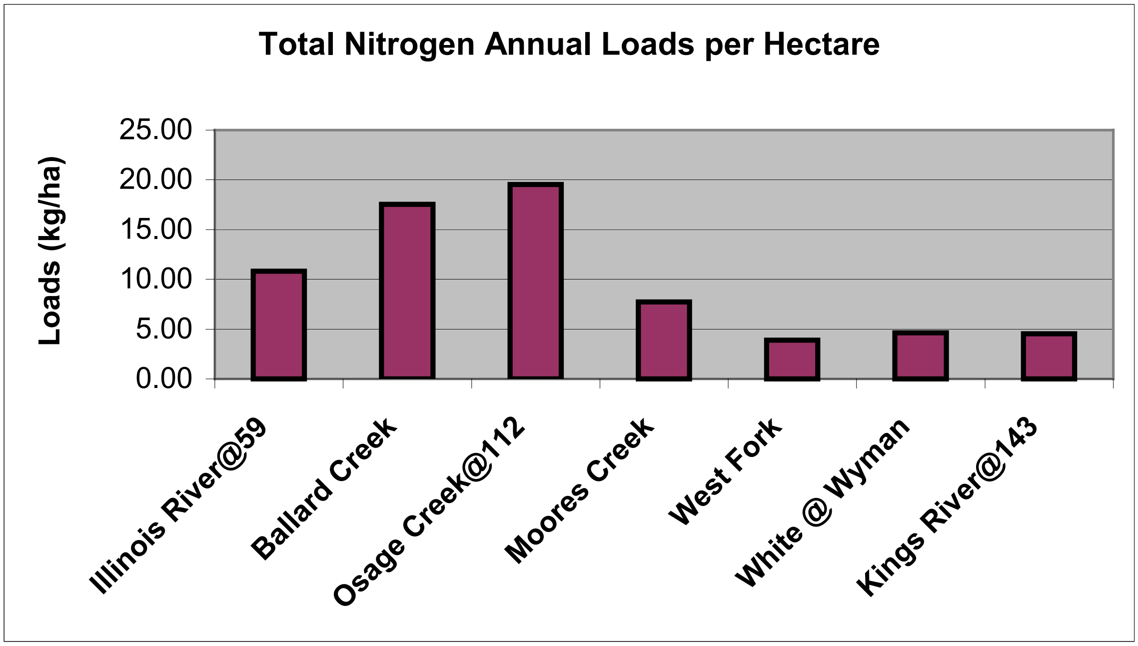

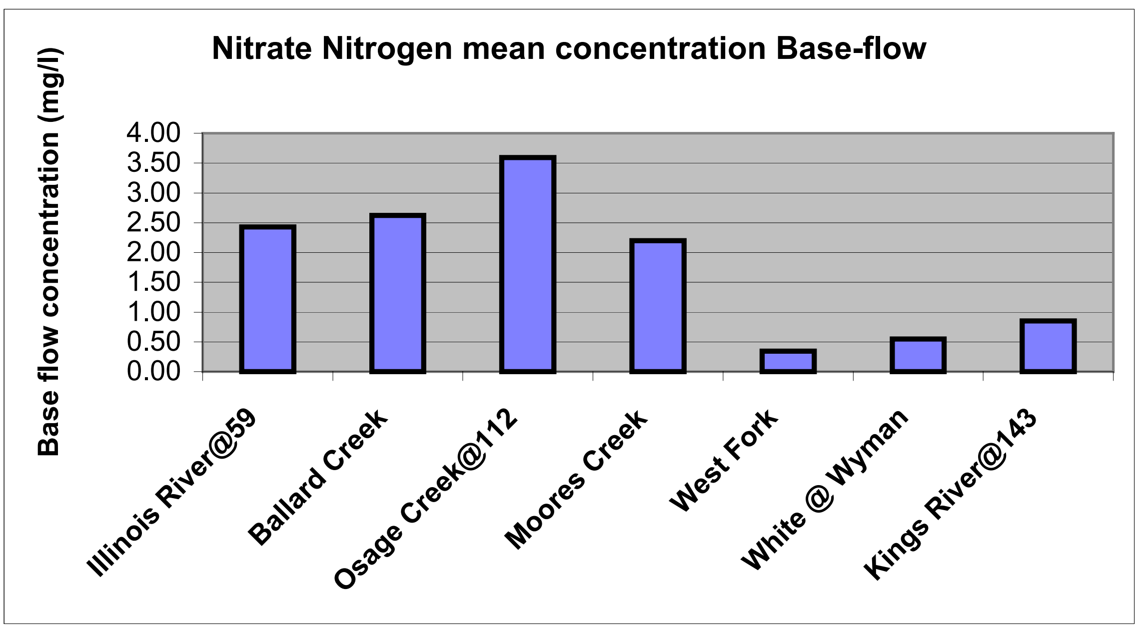

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