Water Quality Monitoring in the Yellow River Watershed 2005

Iowa Geological Survey
Technical Information Series No. 50

Iowa Department of Natural Resources
Jeffrey R. Vonk, Director
June 2006

COVER

The Yellow River watershed
monitoring site at Dousman Creek.

Photo courtesy of Michelle Kilgore.

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Iowa Geological Survey
Technical Information Series 50

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The work on which this report is based
was performed in accordance with a cooperative agreement
between the Iowa Department of Natural Resources
and the U.S. National Park Service.

June 2006

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INTRODUCTION

Under Section 303(d) of the Clean Water Act, the State of Iowa is required to submit a list of all waters that do not meet state water quality standards. Waterbodies on this list are considered "impaired" and need to be fixed to bring them into compliance with water quality standards. In 2002, two segments of the Yellow River were added to the State of Iowa's 303(d) impaired waters list (Figure 1). One segment, which runs through Effigy Mounds National Monument (EFMO), is listed for high levels of indicator bacteria and another segment is listed for habitat alterations.

This project provides baseline water quality data for long-term monitoring of the Yellow River watershed. This data could aid in the development of a Total Maximum Daily Load (TMDL) plan to resolve identified water quality impairments. The project involved cooperation among the U.S. National Park Service, USDA-Natural Resources Conservation Service (NRCS), Iowa Department of Natural Resources, University of Iowa Hygienic Lab (UHL), U.S. Geological Survey-Water Resources Division (USGS), and the Allamakee County Soil & Water Conservation District (SWCD). Project objectives included:

- Maintain a USGS streamflow gage.
- Measure temperature, specific conductance, dissolved oxygen, and pH to establish baseline water quality conditions.
- Determine the pollution loads for bacteria, turbidity, nutrients, and chloride.
- Determine if the sources for bacteria, turbidity, nutrients, and chloride are point or non-point.

Twelve sample locations in the Yellow River watershed were selected for water-quality monitoring (Figure 1). Weekly sampling occurred at the Yellow River-Ion, a site equipped with a USGS gage, from April 5, 2005, through October 27, 2005. Weekly sampling at the remaining sites occurred from May 12, 2005, through October 27, 2005. This report summarizes all data collected from April 5, 2005, through October 27, 2005.

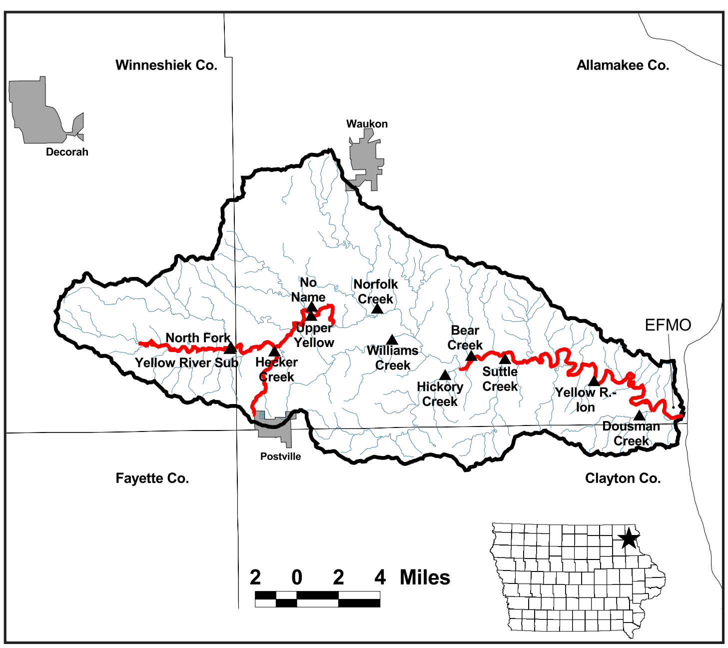


Figure 1. Location of the Yellow River basin in northeast Iowa. Triangles show the location of water quality monitoring sites. Segments of the Yellow River that are currently classified as impaired are shown with red lines.

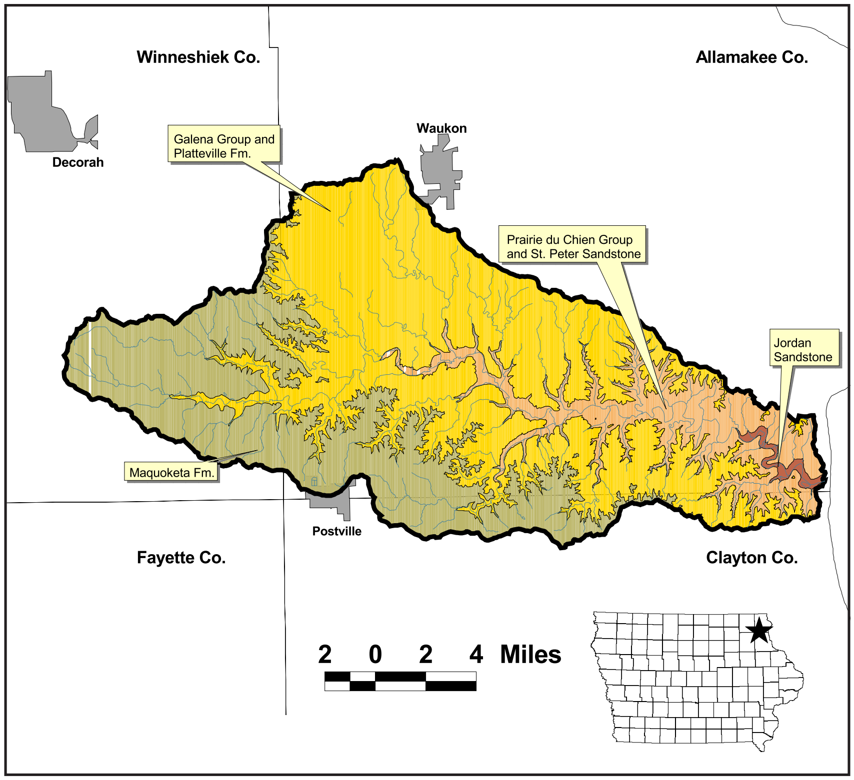


Figure 2. Bedrock geology of the Yellow River watershed.

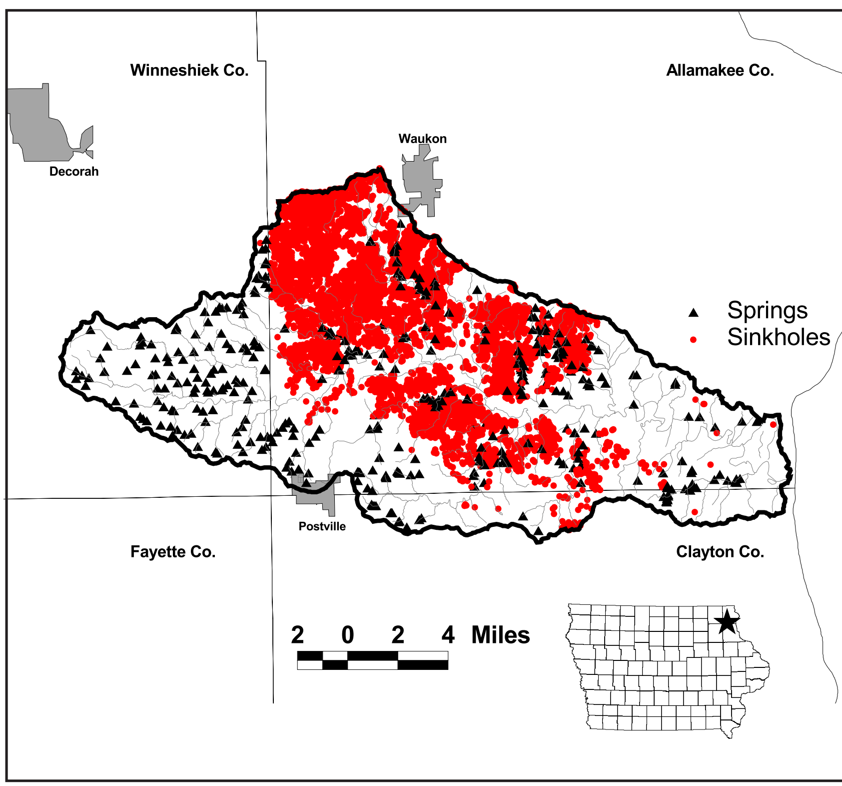


Figure 3. Location of sinkholes and springs in the Yellow River watershed.

PROJECT SETTING

The Yellow River watershed encompasses 154,500 acres in Winneshiek, Clayton, and Allamakee counties in northeast Iowa. The Yellow River watershed is located within the Paleozoic Plateau landform region. Figure 2 shows the bedrock geology in the Yellow River watershed. Four geological mapping units are present in the watershed: the "Jordan Sandstone," the "Prairie du Chien Group and St. Peter Sandstone," the "Galena Group and Platteville Fm.," and the "Maquoketa Formation" (Witzke et al., 1998).

The Paleozoic Plateau landform region is characterized by shallow, near-surface bedrock with karst development (Prior, 1991). Springs and disappearing stream segments are common in the Yellow River watershed. Over 2,000 sinkholes, primarily in the Galena Group and Platteville Fm., have been identified in the watershed. Figure 3 shows the locations of known sinkholes and springs in the watershed.

Segments of the Yellow River and some of its tributaries have been classified by the State of Iowa for designated uses. Figure 4 shows the location of these segments, and Appendix A provides information on the designation of each segment.

Landuse percentages for the watershed area that drains to each sampling point are included in Appendix B. The data represented in the appendix are from a calculation based on the 2002 Land Cover Grid of Iowa, which is available at http://www.igsb.uiowa.edu/nrgislibx/.

In general, the western half of the Yellow River watershed is dominated by row crop production, while the majority of the eastern half of the watershed consists of grasslands and forests. Forested land is primarily concentrated in areas with steep topography. The Williams Creek watershed has the highest percentage of row crop production (58%), while the Dousman Creek watershed has the lowest percentage of row crop production (18%).

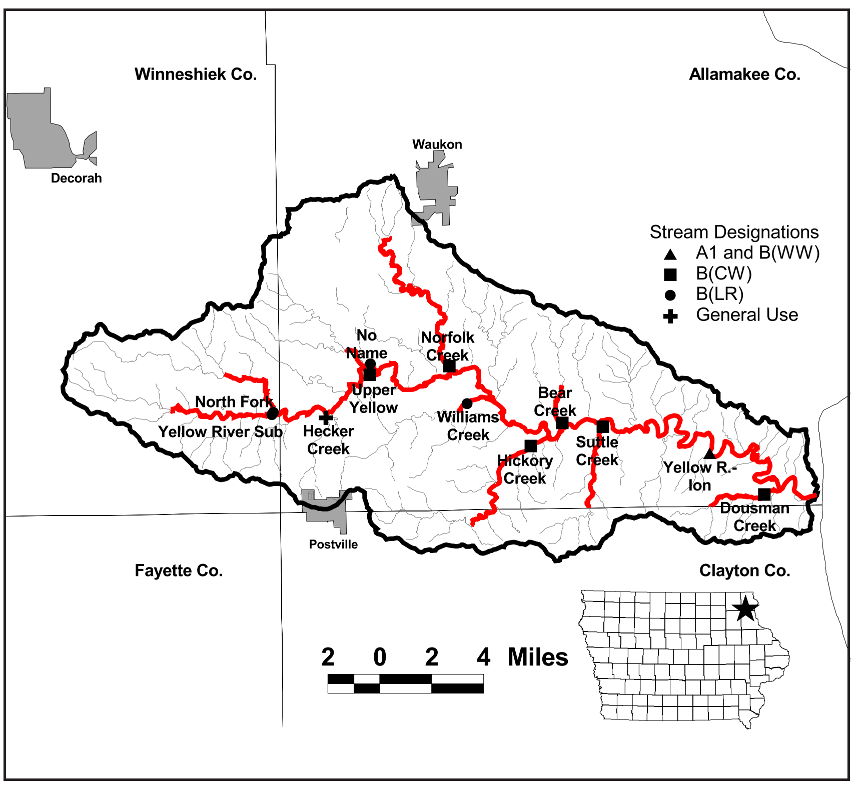


Figure 4. State of Iowa designated stream segments in the Yellow River watershed. Designated segments are shown in bold red lines.

CLIMATIC CONDITIONS

Climate data were obtained from the Iowa Department of Agriculture and Land Stewardship Climatology Bureau (http://www.agriculture.state.ia.us/climatology.htm). Conditions in 2005 were characterized by warmer temperatures and slightly less precipitation than normal in northeast Iowa. In northeast Iowa, temperatures were above long-term averages from July through November. Total precipitation in 2005 was 1.4 inches below normal in Allamakee County, 3.9 inches below normal in Clayton County, and 0.1 inches below normal in Winneshiek County. These conditions contrast those experienced in 2004, which had cooler than average temperatures and significantly higher than normal precipitation.

Daily rainfall data were collected at a USGS site near Marquette, Iowa, which is approximately 6 miles southeast from the Yellow River-Ion site. This data was used to approximate the rainfall received in the Yellow River watershed. Figure 5 illustrates the rainfall record at Marquette. Four thunderstorms, which occurred on 6/26, 8/11, 8/18, and 9/19, 2005, produced rainfall in excess of 1 inch. These storms all increased stream flow in the Yellow River.

STREAM DISCHARGE

A USGS stream gage was installed at the Yellow River-Ion site to provide continuous stream discharge measurements on the Yellow River. This stream gage has been operational since September 21, 2004 and real-time stream discharge data are available online at http://waterdata.usgs.gov/nwis/uv?05389000.

Mean daily discharge measurements for the Yellow River-Ion site are illustrated in Figure 5. In general, stream flow in the Yellow River

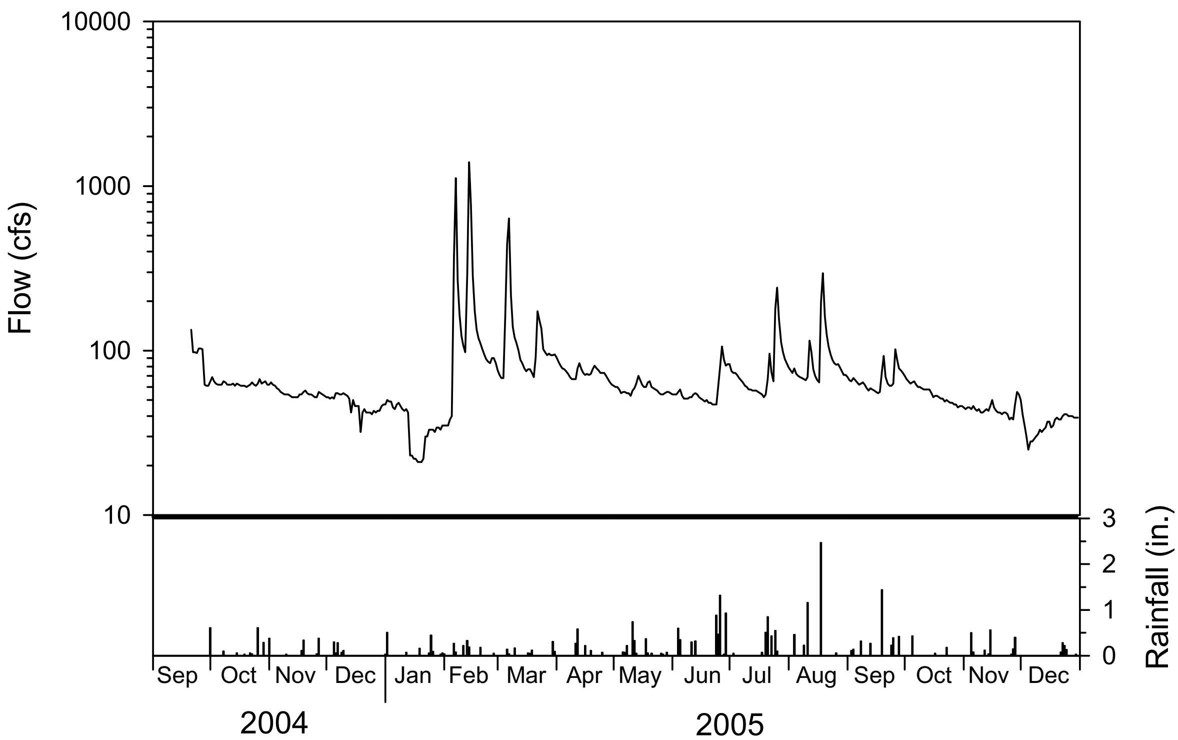


Figure 5. Daily stream discharge of the Yellow River, measured at Ion, and daily rainfall amounts, measured near Marquette, IA (includes provisional data from October 1 though December 31, 2005).

is flashy, with typical baseflow conditions occasionally interrupted by short-lived, high-flow events. The maximum daily discharge in 2005 (1,400 cfs) occurred on February 14, 2005 after a rainfall occurred on frozen ground. Heavy rainfall events in June, July, August, and September, 2005, increased flow for short periods during the summer.

The USGS program HYSEP (Sloto and Crouse, 1996) was used to estimate the percentage of Yellow River discharge (Figure 6). Baseflow accounted for more than 90% of the Yellow River discharge in October through December, 2004, and April through June, 2005. Snowmelt and storms during the spring and storms during the summer decreased the amount of baseflow in the remaining months.

Stream discharge was measured at the remaining 11 sites using a flow meter. Discharge measurements were usually made within 24 hours of water quality sampling. Appendix C shows the discharge measurements at each site. As a result of the drier conditions, flow levels in 2005 were lower than in 2004 for all 11 sites. Notably, the Suttle Creek site went dry in late May and remained dry for the remainder of the year.

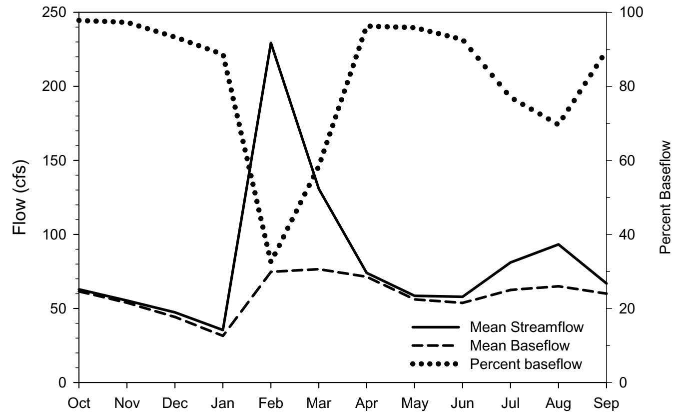


Figure 6. Mean streamflow, mean baseflow, and percent baseflow as calculated by the USGS' HYSEP program for Water Year 2005 (October 2004 through September 2005).

WATER QUALITY RESULTS

Water quality was monitored at twelve sites in the Yellow River watershed (Figure 1). The NRCS and the SWCD conducted the monitoring following methods outlined in IDNR (2005). Temperature, specific conductance, and dissolved oxygen were measured at each site using a YSI 85 meter. Turbidity samples were analyzed at each site with a Hach 2100P Turbidimeter. Samples for total suspended solids, total dissolved solids, orthophosphate, total phosphate, total Kjeldahl nitrogen (TKN), ammonia nitrogen, nitrate+nitrite nitrogen, chloride, and *Escherichia coli (E. coli)* bacteria were analyzed at the University of Iowa Hygienic Laboratory (UHL), a U.S. Environmental Protection Agency (EPA) certified lab. All the water-quality results were entered into an EPA water quality database, STORET, and can be accessed at http://wqm.igsb.uiowa.edu/iastoret/ or http://www.epa.gov/storet.

Summaries of the water quality results can be found in several of the appendices. Appendix D is a box plot summary of the data collected from April through October, 2005. Appendix E is a comparison of box plots from data collected weekly in 2004 to data collected weekly in 2005. Appendix F shows the variations in the results over time.

To augment the weekly monitoring, a YSI 6600 EDS probe was installed at the Yellow River-Ion site. This probe was operational from July 5 through November 17, 2005. The probe recorded pH, turbidity, temperature, specific conductance, and dissolved oxygen every 30 minutes. Provisional data from the probe are included in Appendix G.

Chloride

Chloride is a component of salt and can be used as an indicator of human or animal waste inputs to a stream. Potential sources of chloride to a stream include direct input from livestock, septic system inputs, and discharge from municipal wastewater facilities. During winter months, elevated chloride levels in streams may occur as a result of road salt runoff.

In 2005, chloride ranged from 4.9 to 2,600 mg/L in the Yellow River watershed. Median chloride values ranged from 5.9 mg/L (Dousman Creek site) to 910 mg/L (Hecker Creek site). Chloride data from other water monitoring stations show median chloride levels are typically below 25 mg/L across northeast Iowa. Most monitoring sites in the Yellow River watershed had median chloride levels below 25 mg/L (Appendix D).

The chloride values measured in the Yellow River watershed in 2005 were similar to those in 2004 (Appendix E). Hecker Creek, which receives wastewater effluent discharges from the City of Postville's industrial lagoon, continues to have the highest chloride values in the watershed. Dousman Creek continues to have the lowest chloride values in the watershed. Two sites, Williams Creek and the Yellow River-Ion, showed significant increases in chloride values compared to 2004. The median chloride value at the Williams Creek site increased from 23 mg/L in 2004 to 39 mg/L in 2005. The median chloride value at the Yellow River-Ion site increased from 18 mg/L in 2004 to 34 mg/L in 2005. The cause for these increases is currently unknown.

The State of Iowa currently does not have an applicable water quality standard for chloride for streams in the Yellow River watershed. However, for streams that are designated for drinking water, the State of Iowa has a water quality standard for chloride of 250 mg/L that will be used for comparison (IAC, 2002). Only chloride values at the Hecker Creek site would exceed this standard. Comparing effluent discharges reported on the City of Postville's industrial lagoon monthly operating report (MOR) with chloride concentrations at the Hecker Creek site show chloride concentrations that exceed 250 mg/L were associated with effluent discharges.

Ammonia-N

Ammonia-N is an inorganic, dissolved form of nitrogen in water. Ammonia-N is the concentration of ionized and un-ionized ammonia, both products of the decomposition of organic matter, in water. Important sources of ammonia to lakes and streams include fertilizers, and human and animal wastes.

In 2005, ammonia-N values ranged from <0.05 to 1.7 mg/L in the Yellow River watershed. Median ammonia-N values ranged from <0.05 mg/L (Bear, Hickory, and Williams sites) to 0.27 mg/L (Hecker Creek site) (Appendix D). Hecker Creek continues to have the highest ammonia-N values in the watershed. Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with ammonia-N values at the Hecker Creek site show that many high values were associated with effluent discharges. Ammonia-N was not detected at the Bear, Hickory, and Williams Creek sites for the second straight year.

Ammonia-N values measured at 3 sites (Norfolk, North Fork, and Yellow River Sub) increased from 2004 to 2005 (Appendix E). High ammonia-N detections at the Norfolk, North Fork, and Yellow River Sub monitoring sites occur on the days that also had high *E. coli* readings and high rainfall, which may indicate that both problems are caused by manure entering the stream.

The State of Iowa has an ammonia standard, which is dependent upon the water's pH (IAC, 2002). The Yellow River-Ion site was the only site in the Yellow River watershed to have both ammonia-N and pH monitored. Analysis of the data collected at the Yellow River-Ion site found no violations of the State of Iowa's ammonia standard.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is nitrogen in the form of organic proteins or their decomposition product ammonia, as measured by the Kjeldahl Method. High levels of organic nitrogen in water may indicate organic pollution from the watershed. Animal and human waste, decaying organic matter, and live organic material can contribute to organic nitrogen enrichment of water.

In 2005, TKN values ranged from <0.1 to 9.1 mg/L in the Yellow River watershed. Median TKN values ranged from 0.12 mg/L (Bear Creek site) to 4.6 mg/L (Hecker Creek site) (Appendix D). Hecker Creek continues to have the highest TKN values in the watershed. Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with TKN values at the Hecker Creek site indicate that many high values were associated with effluent discharges.

The TKN results from the Yellow River watershed are similar to results from other streams monitored throughout northeast Iowa in 2004 (Appendix D). The median TKN value from other sites in northeast Iowa is 0.35 mg/L. Five sites (Bear Creek, Dousman Creek, Hickory Creek, Norfolk Creek, and Williams Creek) had median TKN results equal to or less than 0.35 mg/L. The Yellow River-Ion site had a slightly higher median, 0.4 mg/L, than the northeast Iowa median.

Median TKN values tended to be lower in 2005 than 2004 (Appendix E). Only two sites, Hecker Creek and Yellow River Sub, had large increases in the median TKN value. The median TKN value at Hecker Creek increased from 2.0 mg/L in 2004 to 4.6 mg/L in 2005. The median TKN value at Yellow River Sub increased from 0.8 mg/L in 2004 to 1.1 mg/L in 2005.

The State of Iowa currently does not have a water quality standard for TKN. The EPA has published recommendations to assist states in adopting nutrient standards (EPA, 2000). For the subecoregion that contains the Yellow River, the EPA's TKN criteria recommendation is 0.15 mg/L (EPA, 2000). Approximately half of the TKN values at two sites, Bear Creek and Dousman Creek, were below the EPA recommendation. For the remaining sites, the vast majority of TKN samples collected were over the EPA recommendation. Four sites (Hecker Creek, North Fork, Yellow River Sub, and Upper Yellow River) did not have any samples below the EPA recommendation.

Nitrate+Nitrite as N

Nitrate+nitrite-N is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth, and includes both nitrite- and nitrate-nitrogen. Too much nitrogen in surface waters contributes to nutrient enrichment, increasing aquatic plant growth and changing the types of plants and animals that live in a stream. Sources of nitrogen include soils, human and animal wastes, decomposing plants, and fertilizer runoff from lawns and cropland.

In 2005, nitrate+nitrite-N concentrations ranged from <0.05 mg/L to 9.4 mg/L in the Yellow River watershed. Median nitrate+nitrite-N concentrations ranged from 1.7 mg/L (Hecker Creek site) to 7.1 mg/L (No Name site) (Appendix D). Most median nitrate+nitrite concentrations were lower in the Yellow River watershed than in other streams in northeast Iowa (Appendix D). The median nitrate+nitrite-N values were lower in 2005 than 2004 at all sites (Appendix E). The lower medians may be the result of drier conditions that caused lower flows in 2005 compared to 2004.

In 2004, median nitrate+nitrite-N values correlated with the amount of row crops in each watershed. However, this correlation weakened when using 2005 medians (Figure 7). The cause of the weakening is not known. Correlations of the median nitrate+nitrite-N values to the amount of row crops in watersheds across the state, and especially in northeast Iowa, strengthen from 2004 to 2005.

The State of Iowa currently does not have a water quality standard for nitrate+nitrite-N. The EPA has published recommendations to assist states in adopting nutrient standards (EPA, 2000). For the subecoregion that contains the Yellow River, the EPA's nitrate+nitrite-N criteria recommendation is 1.73 mg/L (EPA,

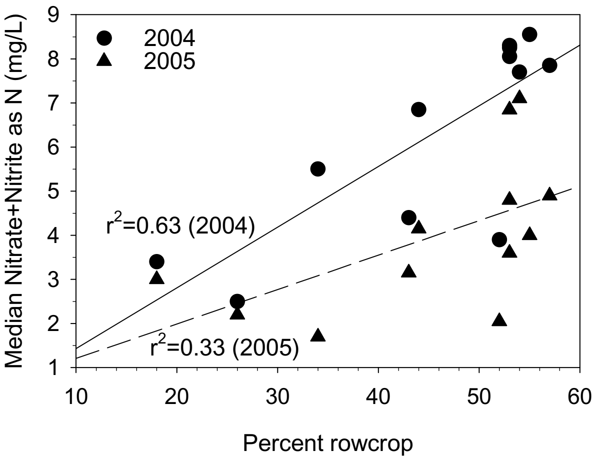


Figure 7. Comparison of the percentage of rowcrops (corn, soybeans, and other row crops) to median nitrate+nitrite as N values in 2004 and 2005.

2000). Approximately 54% of the samples from Hecker Creek and 45% of the samples from Norfolk Creek were below the EPA recommendation. A few samples at the North Fork and Yellow River Sub sites were also below the EPA recommendation. All of the samples at the remaining sites exceeded the EPA recommendation.

Total Phosphate as P

Total phosphate is the amount of phosphate, including dissolved and particulate forms, in water and is reported as phosphorus (P). Phosphorus is a necessary nutrient for plant growth and generally is limiting in the freshwater environment. Too much phosphorus in surface waters, however, can contribute to nutrient enrichment, increasing aquatic plant growth, and changing the types of plants and animals that live in a stream. Sources of phosphorus include certain soils and bedrock, human and animal wastes, decomposing plants, and runoff from fertilized lawns and cropland.

In 2005, total phosphate concentrations ranged from <0.02 mg/L to 5.1 mg/L in the Yellow River watershed. Median total phosphate concentrations ranged from 0.05 mg/L (Bear and Dousman Creek sites) to 1.9 mg/L (Hecker Creek site) (Appendix D). Hecker Creek continues to have the highest total phosphate values in the watershed. Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with total phosphate concentrations at the Hecker Creek site indicate many high total phosphate concentrations were associated with effluent discharges. High values at the remaining sites are typically associated with rainfall events. A severe thunderstorm that occurred on 8/18/2005 corresponded to the highest measured total phosphate values at most of the sites in the watershed.

Most median total phosphate values were higher in the Yellow River watershed than in other streams in northeast Iowa (Appendix D). Only Bear Creek, Dousman Creek, and Hickory Creek had total phosphate medians that were lower than other streams in northeast Iowa.

In the upper parts of the Yellow River watershed, median total phosphate values tended to be higher in 2005 than 2004 (Appendix E). For Hecker Creek, No Name, Norfolk Creek, North Fork, Williams Creek, and Yellow River Sub, concentrations increased from 2004 to 2005. The largest increase was at Williams Creek, where the median total phosphate concentration increased from 0.20 mg/L in 2004 to 0.29 mg/L in 2005.

If the Hecker Creek median is excluded, subwatersheds with higher percentages of corn, soybeans, or other row crops, as classified in the IDNR 2002 Landcover Grid, tend to have higher median total phosphate values (Figure 8). The correlation between median total phosphate values and the amount of row crop in the watershed weakened slightly in 2005 from 2004.

The State of Iowa currently does not have a water quality standard for total phosphate. The EPA has published recommendations to assist states in adopting nutrient standards (EPA, 2000). For the subecoregion that contains the Yellow River, the EPA's total phosphate criteria recommendation is 0.07 mg/L or 70 µg/L

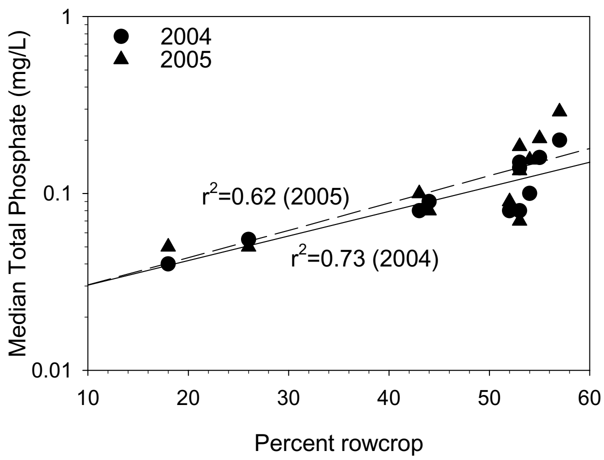


Figure 8. Comparison of the percentage of row crops (corn, soybeans, and other row crops) to median total phosphate values in 2004 and 2005.

(EPA, 2000). Only for two sites, Bear Creek and Dousman Creek, were the majority of samples below the EPA recommendation (86% and 90%, respectively). Nearly 64% of the samples at Hickory Creek were below the EPA recommendation. All of the total phosphate samples collected at the Hecker Creek, Williams Creek, Yellow River Sub, and Upper Yellow sites exceeded the EPA recommendation.

Orthophosphate

Orthophosphate is the amount of dissolved phosphate in water and is reported as phosphorus (P). Phosphorus is a necessary nutrient for plant growth and generally is limiting in the freshwater environment. Too much phosphorus in surface waters, however, can contribute to nutrient enrichment, increasing aquatic plant growth, and changing the types of plants and animals that live in a stream. Sources of phosphorus include certain soils and bedrock, human and animal wastes, decomposing plants, and runoff from fertilized lawns and cropland.

In 2005, orthophosphate concentrations range from <0.02 mg/L to 4.6 mg/L in the Yellow River watershed. Median orthophosphate concentrations ranged from 0.03 mg/L (Bear and Dousman Creek sites) to 1.1 mg/L (Hecker Creek site) (Appendix D). Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with orthophosphate concentrations at the Hecker Creek site indicate that many high orthophosphate concentrations (>1 mg/L) were associated with effluent discharges. High orthophosphate values at the remaining sites are typically associated with rainfall events. A severe thunderstorm that occurred on 8/18/2005 corresponded to the highest measured orthophosphate values at most of the sites in the watershed.

Median orthophosphate concentrations were generally higher in the Yellow River watershed compared to other streams in northeast Iowa (Appendix D). Only Bear Creek and Dousman Creek had orthophosphate median values lower than northeast Iowa.

No consistent trends were observed in median orthophosphate medians from 2004 to 2005 (Appendix E). For three watersheds (Bear, Dousman, and Hickory Creek) in the lower part of Yellow River watershed, median orthophosphate concentrations declined slightly from 2004 to 2005. The median orthophosphate values at No Name and Norfolk Creek remained unchanged. For three watersheds (North Fork, Williams, and Yellow River Sub) in the upper part of the Yellow River watershed, median orthophosphate concentrations increased from 2004 to 2005. The median orthophosphate value at the Williams Creek site increased by 0.1 mg/L, which was the largest increase in the watershed.

If the Hecker Creek median is excluded, subwatersheds with higher percentages of corn, soybeans, or other row crops, as classified in the IDNR 2002 Landcover Grid, tend to have higher median orthophosphate concentrations (Figure 9). The correlation between median orthophosphate values and the amount of row crop in the watershed strengthened in 2005 from 2004.

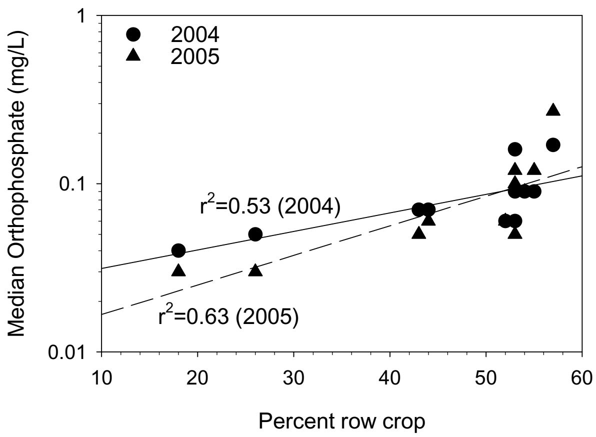


Figure 9. Comparison of the percentage of row crops (corn, soybeans, and other row crops) to median orthophosphate values in 2004 and 2005.

Escherichia coli (E. coli) Bacteria

Escherichia coli (*E. coli*) bacteria are types of coliform bacteria present in the gastrointestinal tract of warm-blooded animals. *Escherichia coli* is called an "indicator bacteria," meaning they do not cause illness, but their presence suggests that disease-causing organisms (pathogens) may be present. As the number of indicator bacteria rises in water, so does the probability that pathogens are present. The most frequent sources of pathogens are sewage overflows, malfunctioning septic systems, animal waste, polluted storm water runoff, and boating wastes. The presence of *E. coli* bacteria suggests that a pathway exists for a relatively fresh source of human or animal waste to enter the stream.

In 2005, the *E. coli* concentrations ranged from <10 to 1,200,000 colony forming units (CFU)/100mL. Median *E. coli* concentrations ranged from 140 (Yellow River-Ion site) to 10,000 CFU/100mL (Hecker Creek site) (Appendix D). Except for the Bear Creek, Williams Creek, and Yellow River-Ion sites, all sites had at least one *E. coli* concentration greater than 10,000 CFU. The highest *E. coli* results at most sites were associated with heavy rainfall. Furthermore, high *E. coli* results at the Norfolk, North Fork, and Yellow River Sub monitoring sites occurred on the days that also had high ammonia-N concentrations and high rainfall, which may indicate that both problems are caused by manure entering the stream after a runoff event.

Median *E. coli* values were higher in the Yellow River watershed than in other streams in northeast Iowa (Appendix D). No consistent trends were observed in *E. coli* medians from 2004 to 2005 despite the lower flows (Appendix E).

The Yellow River-Ion site is located on the segment of the Yellow River that is designated "Class A1 (primary contact recreational use)." According to the State of Iowa's bacteria standard for Class A1 waters, *E. coli* bacteria should not exceed the one-time standard of 235 CFU/100mL nor a geometric mean (generally calculated on not less than 5 samples equally spaced over a 30-day period) of 126 CFU/100mL (IAC, 2002). From April 5, 2005, through October 27, 2005, the Yellow River-Ion site exceeded the one-time standard 10 times, which was 33% of the samples collected, and exceeded the geometric mean standard 17 times, which was 65% of the weeks that a geometric mean could be calculated.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) are the concentration of all the dissolved chemical constituents in water. Natural waters gain dissolved chemicals by leaching minerals from soils or dissolving bedrock. Applications of road salt and effluent discharges from wastewater treatment plants, for example, also increase the amount of dissolved chemicals in streams.

The TDS concentrations ranged from 200 mg/L to 4,950 mg/L in the Yellow River watershed. Median TDS values ranged from 320 mg/L (Norfolk Creek site) to 1,980 mg/L (Hecker Creek site) (Appendix D). Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with TDS values at the Hecker Creek site indicate that many high TDS values (>1,000 mg/L) were associated with effluent discharges.

In general, the TDS values in the Yellow River watershed were higher than other streams in northeast Iowa. The median TDS value for other sites in northeast Iowa was 330 mg/L. Only three sites (Bear, Dousman, and Norfolk creeks) had median values equal to or less than 330 mg/L.

The State of Iowa's TDS standard states that TDS shall not exceed 750 mg/L in any stream with a flow rate equal to or greater than three times the flow rate of upstream point source discharges (IAC, 2002). Only two sites, Hecker Creek and Yellow River Sub, had concentrations that exceeded 750 mg/L. TDS concentrations in Hecker Creek exceeded 750 mg/L on nine occasions. Most of the values above 750 mg/L were associated with discharges from the City of Postville's industrial lagoon. The Yellow River Sub site had a single result above 750 mg/L. The cause of this high result is not known.

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is the concentration of the suspended organic and inorganic solids in water. Causes of high TSS concentration include sediment from erosion of nearby land and streambanks, and other solids that do not settle out of the water.

The TSS concentrations ranged from <1 mg/L to 3,010 mg/L in the Yellow River watershed. Median TSS values ranged from 1 mg/L (Hickory Creek site) to 41 mg/L (Hecker Creek site) (Appendix D). High TSS values (>100 mg/L) were associated with heavy rainfall in the Yellow River watershed.

In general, TSS results in the Yellow River watershed were lower than other streams in northeast Iowa. The median TSS value for other sites in northeast Iowa was 25 mg/L. Only two sites (Hecker Creek and Yellow River Sub) had median values higher than 25 mg/L.

Water Temperature

Water temperature is a measure of the thermal energy of water. Water temperature influences the type of plants that grow in the water and the types of animals that live in the water. To differentiate between cold water and warm water streams, the DNR has proposed 23.8 ºC (75 ºF) to be the maximum temperature allowed for a stream to be designated as a coldwater stream (IDNR, 2004).

Water temperatures, which were measured in the morning, ranged from 8.0 ºC to 26.0 ºC in streams throughout the Yellow River watershed. Median temperatures ranged from 13.0 ºC (Bear Creek site) to 19.6 ºC (North Fork site) (Appendix D). Large increases in the median water temperatures from 2004 to 2005 were observed at most sites (Appendix E). The warmer summer temperatures in 2005 compared to 2004 caused the increases. The Upper Yellow site, however, only had a small increase in median water temperature (increased from 13.1 ºC to 13.2 ºC). A large spring, which is located just upstream from this site, may be moderating the water temperatures.

Except for the Yellow River-Ion site, most of the water temperatures recorded were below the proposed maximum coldwater stream temperature (23.8 ºC). Three sites, Norfolk Creek, North Fork, and Yellow River Sub, had temperatures that exceeded 23.8 ºC on one date, June 23, 2005.

Daily fluctuations in water temperatures at the Yellow River-Ion site were observed in the data collected with the YSI 6600 EDS probe (Appendix G). The water temperatures collected as part of the weekly sampling exceed 23.8 ºC only two times at the Yellow River-Ion site. However, water temperatures from the probe show water temperatures exceeding 23.8 ºC for several days in July and August. The maximum temperature the probe recorded was 29.2 ºC on July 16, 2005. The probe measured daily water temperature fluctuations on the order of 2 ºC. Increases in stream flow, caused by increased runoff after thunderstorms, could also rapidly lower water temperatures at the site. Such an event occurred in late July (Appendix G).

Specific Conductance

Specific conductance is a measure of the electrical conductance of water at 25 °C and is related to the total amount of dissolved ions in the water. Sources of ions include the dissolution of limestone bedrock, the leaching of minerals from soils, fertilizers, human and animal waste, and road salt.

Specific conductance ranged from 134 µS/cm to 7,450 µS/cm in the watershed. Median specific conductance ranged from 455 µS/cm (Bear Creek site) to 2,997 µS/cm (Hecker Creek site) (Appendix D). Specific conductance values in the watershed were similar to those collected throughout northeast Iowa in 2005 (Appendix D). Median specific conductance values, however, tended to be lower in 2005 compared to 2004 (Appendix E). The lowest value (134 µS/cm) occurred at the Upper Yellow site and its cause is unknown. Comparing effluent discharges reported on the City of Postville's industrial lagoon MOR with specific conductance values at the Hecker Creek site indicate that high specific conductance values (>1000 µS/cm) at the Hecker Creek site were associated with effluent discharges.

Daily variations in specific conductance were observed at the Yellow River-Ion site with data collected by the YSI 6600 EDS probe (Appendix G). Specific conductance values collected by the probe ranged from 296 µS/cm to 996 µS/cm. The median specific conductance value of data collected with the probe was 607 µS/cm. Large decreases in specific conductance values in late July, August, and September were typically associated with increased runoff in the Yellow River.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen dissolved in water. DO levels in a stream can be affected by a number of variables, including water temperature, season of the year, time of day, stream flow, and presence of aquatic plants. Oxygen enters a stream through diffusion from the surrounding air and as a product of photosynthesis from aquatic plants. Oxygen in a stream can be consumed through respiration by aquatic plants and animals, and by the decomposition of organic matter.

The DO concentrations that were sampled weekly ranged from 1.6 mg/L to 22.7 mg/L in the Yellow River watershed. Median DO concentrations ranged from 3.7 mg/L (Yellow River Sub site) to 6.9 mg/L (Hickory Creek site) (Appendix D).

The DO concentrations for the 12 sites throughout the Yellow River watershed were typically lower than the concentrations in other northeast Iowa streams (Appendix D). Median DO concentrations were lower in 2005 at all sites compared to 2004. Part of the explanation for these low DO concentrations is the warmer water temperatures and lower flow levels that were observed in 2005. Equipment perfomance may also account for some of the DO concentrations. Two meters measured DO concentrations at the Yellow River-Ion site from July to October. Table 1 compares the differences in DO these two meters measured. The YSI 85 meter routinely measured lower DO concentrations than the YSI 6600. Thus, the YSI 85 meter, which was used at all the sites in the watershed, may be underestimating the DO concentrations.

Daily fluctuations in DO concentrations were observed at the Yellow River-Ion site with data collected by the YSI 6600 EDS probe (Appendix G). Excluding days that the DO probe's membrane failed, causing low results in mid August, late September, and late October, the DO concentrations ranged from 5.2 mg/L to 19.0 mg/L and had a median of 10.4 mg/L. The DO concentrations were typically lowest during early morning and reached maximums during late afternoon. When stream flow was relatively stable, the difference

Table 1. Comparison of dissolved oxygen values recorded at the Yellow River-Ion site using two different YSI meters. Dissolved oxygen values are in mg/L.

Date	YSI 85	YSI 6600 EDS
07/06/2005	9.2	8.4
07/07/2005	6.1	8.6
07/14/2005	3.2	6.7
07/21/2005	3.4	6.8
07/28/2005	7.5	9
08/02/2005	12.5	11.2
08/04/2005	3.9	7.7
08/11/2005	3.8	7.3
08/18/2005	3.9	8.2
08/25/2005	4.2	10.4
09/01/2005	4.8	8.7
09/05/2005	7.2	7.7
09/08/2005	6.1	8.9
09/15/2005	4.3	10.4
09/22/2005	5.2	4.2
09/29/2005	6.5	10.3

between day and night DO concentrations was approximately 5-6 mg/L. During flood events, the difference between day and night DO concentrations was approximately 2-3 mg/L.

Iowa has water quality standards for DO based on stream designation. Streams with a B(CW), cold water aquatic life, designation need a minimum of 7 mg/L, while B(LR), limited resource warm water, or B(WW), significant resource warm water, designations need a minimum of 5 mg/L (IAC, 2002). U.S. EPA guidelines for 305(b) assessments state that if no more than 10% of the DO samples violate the state standard, the water "fully supports" its designated use (John Olson, IDNR, personal communication). Williams Creek is the only site to meet the state standard using the data collected with the YSI 85. The Yellow River-Ion site meets the state standard using the data collected with the YSI 6600 EDS. The cause for the low DO concentrations throughout the watershed may be partially related to ambient conditions and partially related to equipment performance.

Turbidity

Turbidity is a measure of the optical properties of water that cause light to be reflected or scattered. Causes of high turbidity include organic matter, algae, sediment, and solids that do not settle out of the water. Turbidity tends to increase after storm events, when streams carry more sediment as a result of increased erosion.

Turbidity values ranged from 0.5 Nephelometric Turbidity Units (NTU) to >1,000 NTU in the Yellow River watershed. Median turbidity values ranged from 1.05 NTU (Bear Creek site) to 36.4 NTU (Hecker Creek site) (Appendix D). Turbidity values generally were below 10 NTU and only increased for short periods following runoff events. The highest turbidity recorded at most sites was associated with a large thunderstorm that occurred on 8/18/2005. The median turbidity value for northeast Iowa was below 10 NTU as well (Appendix D). Most of the turbidity values recorded in the Yellow River watershed were within the range of values exhibited in other northeast Iowa streams.

Median turbidity values were lower at most sites in 2005 compared to 2004 (Appendix E). The lower stream flows across that watershed are believed to be related to the lower turbidity values. For two sites, North Fork and Yellow River Sub, median turbidity values increased from 2004 to 2005. Both sites are located in grazed pastures. Cows using the streams in these pastures to cool off may have disturbed sediment or prevented sediment from settling to the bottom of the stream, causing the higher turbidity values.

Appendix E illustrates the results of the more intensive turbidity monitoring at the Yellow River-Ion site that was collected with the YSI 6600 probe. Several of the high turbidity results were associated with increased runoff caused by thunderstorms. These high results typically did not last long, generally just a few days after the thunderstorm passed.

The State of Iowa currently does not have a water quality standard for turbidity. The EPA has published recommendations to assist states in adopting a turbidity standard (EPA, 2000). For the subecoregion that contains the Yellow River, the EPA's turbidity criteria recommendation is 3.38 NTU (EPA, 2000). Several sites, Bear, Dousman, Hickory, and Williams Creek, had a significant percentage of samples below the EPA recommendation (Appendix D). Only at the North Fork site did all of the turbidity samples exceed the EPA recommendation.

pH

The pH is a measure of a water's acidity or alkalinity. Changes in pH can be caused by atmospheric deposition of acid rain, the types of soils and bedrock that the water comes in contact with, wastewater discharges, and acid mine drainage. A pH of 7 is neutral; pH values greater than 7 are alkaline, while a pH less than 7 is acidic.

Measurements of pH for this project were collected only at the Yellow River-Ion site. The pH ranged from 7.8 to 9.0 at this site. The median pH at the Yellow River - Ion site was 8.3. The median pH for streams in Iowa during 2005 was also 8.3.

Daily fluctuations in pH were observed at the Yellow River-Ion site with data collected by the YSI 6600 EDS probe (Appendix G). The pH values ranged from 7.4 to 8.6 and had a median value of 8.2. Like dissolved oxygen, pH values were typically lowest during early morning and reached maximums during late afternoon. The low pH values were typically 8.1 or 8.2, while the high pH values were typically 8.3 or 8.4. Stream flow can have an effect on the pH value. Increased flows in late July and mid August caused a temporary decrease in the pH levels at the site.

The Yellow River-Ion site is located on the segment of the Yellow River that is designated "Class A1 (primary contact recreational use)." According to the State of Iowa's pH standard for Class A1 waters, pH shall not be less than 6.5 nor greater than 9.0 (IAC, 2002). The data from this site do not violate this standard.

BENTHIC MACROINVERTEBRATE STUDY

A benthic macroinvertebrate study was conducted using field and lab methods developed by the Iowa Department of Natural Resources (IDNR, 2001) in 2004 and 2005 as an independent way to assess the water quality in the Yellow River watershed. Quantitative and qualitative benthic macroinvertebrate samples were collected at the 12 sites from August 17-20, 2004 and from 11 sites on August 23-24, 2005. The Suttle Creek site was not sampled in 2005 because of low flows. The Yellow River-Lower site was moved approximately 1 kilometer upstream to match the Yellow River-Ion site in 2005.

Three quantitative sub-samples were collected per site in riffle areas with a Surber sampler (except the Yellow River site, which was sampled with a Hess sampler due to higher flow). Qualitative samples were collected in habitats other than riffle areas to maximize the number of taxa collected. Each designated sampling area consisted of at least 150 m of stream bed length and included at least two riffle/pool sequences.

Lab procedures for the quantitative samples included identifying the macroinvertebrates from each sub-sample to the family level. Individuals from the following orders were used to calculate an index of biological integrity (IBI): Amphipoda (scuds), Coleoptera (water beetles), Diptera (flies and midges), Ephemeroptera (mayflies), Lepidoptera (moths), Megaloptera (alderflies and fishflies), Odonata (damselflies and dragonflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The immature forms of these orders of benthic macroinvertebrates live in close association with the stream water and are indicators of the amount of organic pollution in the stream water over the course of their immature development. Other invertebrates such as mussels, snails, leeches, and aquatic worms were noted, but not used in the calculation of the IBI for each site.

Hilsenhoff's (1988) family-level IBI for benthic macroinvertebrates was calculated by the following formula:

$$IBI = \frac{\text{average (number of individuals for each family x tolerance value for that family)}}{\text{total number of individuals in sub-sample}}$$

An individual family's tolerance value (TV) indicates the relative tolerance to organic pollution, on a scale of 0 to 10. Macroinvertebrate families with the least tolerance to organic pollution have a TV of 0. Macroinvertebrate families that have the most tolerance to organic pollution have a TV of 10. Macroinvertebrate families with a low TV need a higher amount of dissolved oxygen and low organic pollution. Macroinvertebrate families with a high TV can survive in conditions with a relatively lower amount of dissolved oxygen and in areas of higher organic pollution.

The IBIs for each quantitative sub-sample were averaged to establish a site IBI. IBIs were calculated for each site and each year. The average of the IBIs for 2004 and 2005 was calculated for each site.

The quantitative samples were also used to calculate percent Chironomids and percent EPT (Ephemeroptera, Plecoptera, and Trichoptera) per site. A lower percent of Chironomids and higher percent of EPT indicates higher water quality. Richness, the number of taxa per site, was calculated by totaling the number of taxa per sample from both the quantitative and qualitative samples.

An observational habitat survey (IDNR, 2001) was conducted to document the amount and types of habitats available at each site. Sedimentation and embeddedness were recorded as light, moderate, or heavy at each site. Also, the amount of turbidity and level of flow was documented after a visual assessment.

Results

There was a shift in the macroinvertebrate family dominance from 2004 to 2005 (Figures 10 and 11). In 2004, small minnow mayflies (Baetidae, 36.9%, TV = 4) and black fly larvae (Simulidae, 27.8%, TV = 6) were co-dominant families. In 2005, net-spinner caddisflies (Hydropsychidae, 50.7%, TV = 4) were the dominant macroinvertebrate family found in the quantitative samples.

Four sub-watersheds of the Yellow River were found to be in the "very good" range of water quality when the 2004 and 2005 IBIs were averaged: Norfolk, Dousman, Yellow River-Ion, and Bear (Appendix H). These sites had 5-8 macrohabitat types, higher amounts of sedimentation in 2004 than 2005 (with the exception of Dousman Creek which had moderate sedimentation for both years), and moderate turbidity in 2004 and low to moderate turbidity in 2005. Norfolk was the only site in the "very good" water quality range both years. This site had the lowest average percent of chironomids.

Dousman Creek moved from the "fair" range of water quality in 2004 (IBI = 5.47) to the "excellent" range of water quality in 2005 (IBI = 2.81). Dousman Creek had the highest number of taxa that were sensitive to organic pollution. One individual from the Corydalidae family (TV = 0) was found at Dousman Creek in 2005. Six individuals from the Glossossomatidae family (TV = 0) were found in Dousman Creek in 2005, whereas no Glossossomatidae taxa were collected in 2004. Seventy-three individuals from the Lepidostomatidae family (TV = 1) were found at Dousman Creek in 2005. Dousman Creek was the only sub-watershed that did not have fine sediments as one of the most abundant substrates for either 2004 or 2005.

Hecker Creek had the lowest water quality index for the two years and scored in the "fair" range of water quality (for the 2004 and 2005 average of IBIs), indicating "fairly substantial pollution likely." The highest number of

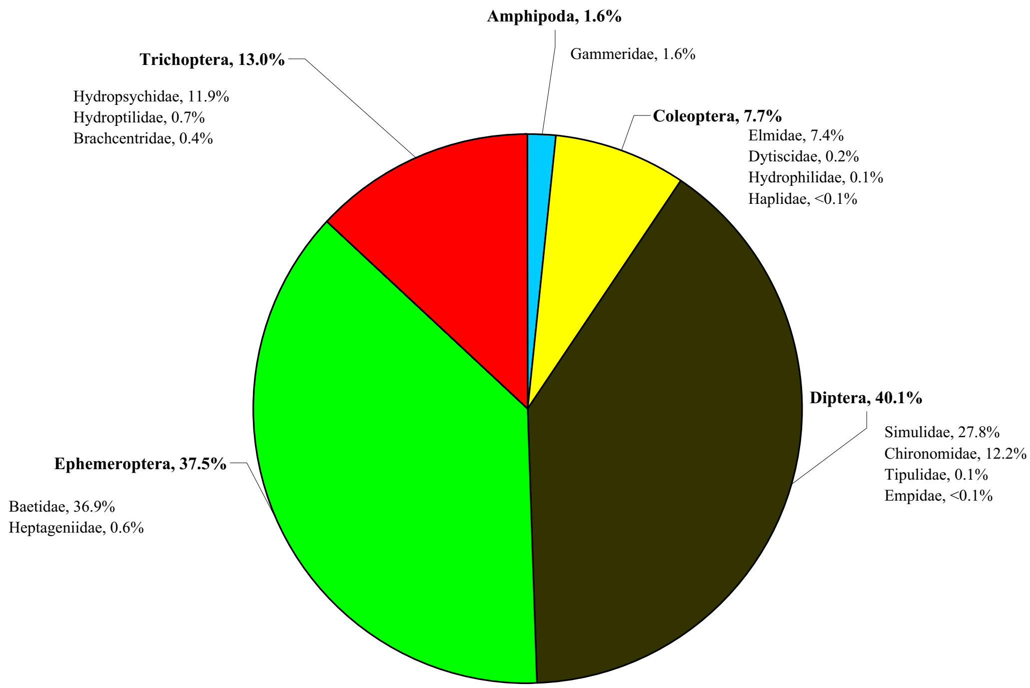


Figure 10. Relative abundance of benthic macroinvertebrate orders and families found in the Yellow River in 2004.

chironomids and lowest percent of EPT were collected in Hecker Creek. Hecker Creek had the lowest number of species richness of all 12 sites and the lowest density of macroinvertebrates collected in the quantitative samples. In 2005, only 3 benthic macroinvertebrates were collected among the 3 quantitative sub-samples. Hecker Creek had very low flow in both 2004 and 2005 during the sample period and had only standing pools in 2004. Only 5 macrohabitats were observed at this site. Coarse rock was the dominant substrate in both 2004 and 2005.

All of the remaining sub-watersheds were in the "good" range of water quality (Appendix H), indicating "some organic pollution probable." The Upper Yellow remained in the "good" range for both 2004 and 2005. All of the other sites improved in water quality from 2004 to 2005, based on the yearly IBIs. Sites in the "good" range of water quality had 6-9 macrohabitat types and generally had moderate to heavy sedimentation in 2004 and 2005. The Yellow River Sub watershed had high turbidity and moderately heavy sedimentation and embeddedness both years. North Fork Creek also had moderately heavy turbidity and heavy sedimentation and embeddedness for both years, and moderate non-filamentous algae growth. The site on North Fork Creek that was sampled is surrounded by unfenced cow pasture and has noticeable cut banks. Williams Creek's substrate was 90% covered with filamentous algae in 2004. Substantial amounts of filamentous algae were also noted in 2005. Suttle Creek, which was not sampled in 2005, had fine sediments, concrete, and garbage as the dominant substrate in 2004, with little coarse rock/cobble riffles in the sample area.

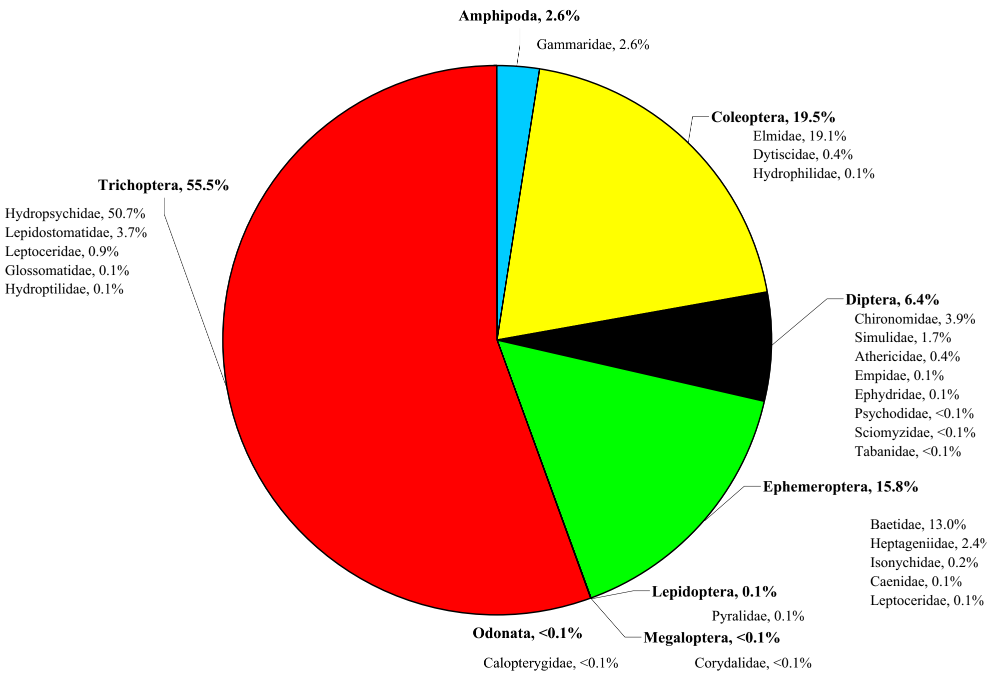


Figure 11. Relative abundance of benthic macroinvertebrate orders and families found in the Yellow River in 2005.

Discussion

The difference in macroinvertebrate family dominance between 2004 and 2005 may result from differences in rainfall patterns and subsequent flow patterns for these two years. In 2004, there were twelve 1” rainfall events from May 1, 2004 to August 16, 2004 (the day prior to the 2004 sampling). Total rainfall recorded for this time period was 27.2”. In 2005, there were six 1” rainfall events from May 1, 2005 to August 22, 2005 (the day prior to the 2005 sampling). Total rainfall recorded for this time period was 16.2”. The twelve 1” rainfall events and higher total precipitation in 2004 likely caused higher flows throughout the Yellow River watershed. High flows during the rainfall events could have flushed many of the colonizing macroinvertebrates out of their habitats in 2004. From 2004 to 2005, there was a general increase in the density of macroinvertebrates collected in the riffles areas at each site. Black fly larvae, which have a short life span and are able to colonize quickly, might have taken advantage in the reduction of competition when the other macroinvertebrates were flushed out. Also, black fly larvae have a caudal sucker that allows them to attach to substrates; this may have played an important role in the high flow periods in 2004.

Based on benthic macroinvertebrate populations, Norfolk Creek maintained “very good” water quality for both years of the study. An abundant amount of grassy area along the stream banks was observed at the Norfolk sample site. Riparian zone can play an important role in maintaining macroinvertebrate communities (Stewart et al., 2001). Stream bank plants along a stream corridor can act as a buffer zone to help control the sediment and

Table 2. Total load of various parameters calculated with two computer programs at the Yellow River-Ion site during Water Year 2005 (October 2004 through September 2005).

Parameter	Estimator (kg/yr)	Autobeale (kg/yr)
Ammonia as N	165,057	7,631
Chloride	1,755,860	1,565,629
Nitrate+Nitrite as N	225,423	247,052
Orthophosphate as P	9,389	10,126
TDS	22,815,160	25,175,844
TKN	70,906	44,136
Total Phosphate	18,098	12,787
TSS	1,633,120	1,214,822

organic pollution in runoff. Conversely, at the North Fork site, which had one of the lowest IBI scores, cut banks and unfenced cow pasture prevent the growth of riparian plants. Allowing riparian buffer zones to develop in the North Fork of the Yellow River by fencing off grazing cattle would likely improve the water quality of this area. Also, a future survey of the amount of riparian zone in each sub-watershed would be helpful in understanding the link between land use and water quality in the Yellow River watershed.

Based on the IBI score for 2005, Dousman Creek has the highest water quality of sites in the Yellow River watershed. Of special interest, is the comparatively high number of macroinvertebrate families that are intolerant of organic pollution found in this creek. The watershed of Dousman Creek is heavily forested, has little agricultural influence, and has a well-developed riparian zone. This watershed could be used as a model for land use decisions and improvements to other areas of the Yellow River.

WATER QUALITY AT EFFIGY MOUNDS

Because floodwaters from the Mississippi River could influence the water quality of the Yellow River at EFMO, a sampling site was not selected at EFMO. The Yellow River-Ion site is the closest sampling point to and immediately upstream of EFMO. The quality of water at the Yellow River-Ion site characterizes the Yellow River water quality as the water enters EFMO.

The segment of the Yellow River that flows through EFMO is listed on the State of Iowa's 303(d) list of impaired waters for high levels of indicator bacteria. Data from the Yellow River-Ion site indicates that high levels of bacteria are present in the Yellow River at EFMO. The *E. coli* concentrations at the Yellow River-Ion site exceeded the State of Iowa's one-time standard 10 times and exceeded the geometric mean standard 17 times. Heavy rainfalls, which increase stream flow, resulted in high *E. coli* counts at the Yellow River-Ion site and the other monitoring sites in the watershed, presumably at EFMO as well.

A load duration curve for *E. coli* was constructed to determine potential sources of the high *E. coli* levels (Appendix I). The *E. coli* levels at the Yellow River-Ion site exceed the State of Iowa's one-time standard during higher flow, when the flow duration is typically less than 40% (Appendix I). Point sources are attributed to values that exceed standards in the 70-100% flow duration interval, while non-point sources are attributed to values in the 0-50% flow duration interval (Bruce Cleland, America's Clean Water Foundation, personal communication, 2004). This suggests that *E. coli* exceedances at the Yellow River-Ion site are largely a non-point source problem. While manure from livestock is a potential non-point source, attempts to correlate *E. coli* levels to livestock have proven unsuccessful. An attempt by researchers at Iowa State University to correlate livestock producer's proximity to streams with *E. coli* levels in the watershed was unsuccessful because the karst topography introduced too many variables (Hillary Owen, personal communication, 2006).

The segment of the Yellow River that flows through EFMO is also subject to the

Table 3. Comparison of nutrient load during Water Year 2005 (October 2004 through September 2005) in four northeast Iowa streams. Loads were calculated using the ESTIMATOR program.

Parameter	Yellow River Allamakee Co. (kg/ha)	Bloody Run Creek Clayton Co. (kg/ha)	Turkey River Clayton Co. (kg/ha)	Upper Iowa River Allamakee Co. (kg/ha)
Nitrate+Nitrite as N	4.0	6.2	9.8	13.6
Orthophosphate as P	0.2	0.2	0.2	0.3
Total Phosphate as P	0.3	0.4	0.5	0.6

State of Iowa's ammonia, dissolved oxygen, and pH standards. Data collected from the Yellow River-Ion site indicates that no violations of the ammonia or pH standards exist at those points. Presumably, ammonia and pH should not violate the standards at EFMO either. Data collected with the YSI 6600 EDS, which had a sampling frequency of 30 minutes, shows no violation of the dissolved oxygen standard.

The State of Iowa does not have applicable standards for several parameters that were monitored during this project. Chloride concentrations at the Yellow River-Ion site were below the State of Iowa's drinking water standard, but the Yellow River is not designated for drinking water. A majority of TKN, nitrate+nitrite-N, total phosphate, and turbidity samples at the Lower Yellow site exceed EPA's recommendations for nutrient standards. Appendix I displays load duration curves for some of these parameters. A majority of the values that exceeded the EPA recommendation for TKN, nitrate+nitrite-N, and total phosphate were below the 50% flow duration interval. This suggests a majority of these high values are associated with non-point sources (Bruce Cleland, personal communication, 2004).

The types of benthic macroinvertebrates collected upstream of EFMO in the Yellow River would indicate the water quality at EFMO. The benthic macroinvertebrates collected at the Yellow River-Ion site suggests good water quality should be flowing through EFMO. A very diverse number of taxa were collected and a high percentage of mayflies, stoneflies, and caddisflies were collected at the Yellow River-Ion site (Appendix H). The IBI calculated from two years of data ranks the water as "Very good, possible slight organic pollution" (Appendix H).

Load estimations were made to estimate the total amount of various chemicals that flow by EFMO in a year (Table 2). Two computer programs, ESTIMATOR and AutoBeale, were used to estimate loads at the Yellow River-Ion site. Specific information about the computer programs used can be found in Richards (1998). For most of the parameters, the estimated loads calculated by both programs were similar. The different methods used by each program to calculate loads during floods caused the discrepancy in the ammonia as N loads. In a single event, ESTIMATOR calculated an ammonia as N load higher than the total yearly estimate made by Autobeale. Nitrate+nitrite as N, total phosphate, and orthophosphate loads per hectares of watershed were lower in the Yellow River compared to other streams in northeast Iowa (Table 3).

SUMMARY

For 2005, temperatures were warmer than normal and precipitation was slightly less than normal in the Yellow River watershed. These conditions are nearly opposite of those experienced in 2004, which had cooler than normal temperatures and significantly higher than normal precipitation. The warmer, drier conditions in 2005 caused lower stream flows than were recorded in 2004. One site, Suttle Creek, went dry in May and remained dry for the remainder of the year.

The warmer, drier conditions also had an impact on the water quality in the Yellow River watershed. Median water temperatures were higher in 2005 than in 2004. Nitrate+nitrite as N, TKN, and turbidity values were generally lower in 2005 than in 2004.

The City of Postville's industrial lagoon is impacting water quality at the Hecker Creek site. High concentrations of TDS, ammonia-N, TKN, total phosphate, orthophosphate, chloride, and specific conductance at the Hecker Creek were associated with releases of effluent from the industrial lagoon. The benthic macroinvertebrate study also indicates that the Hecker Creek site has "fairly poor" water quality, with substantial organic pollution likely.

A shift in the macroinvertebrate family dominance was observed at sites monitored throughout the Yellow River watershed. In 2004, small minnow mayflies and black fly larvae were the dominant families. In 2005, net-spinner caddisflies were the dominant family. The difference may result from differences in rainfall and stream flow between the two years. Additionally in 2005, several macroinvertebrate families that are pollution intolerant were found in Dousman Creek.

The Yellow River is listed on the State of Iowa's 303(d) list of impaired waters because of high levels of *E. coli* bacteria. *E. coli* bacteria were found at all the monitoring sites at elevated levels. Except for Bear Creek, Williams Creek, and Yellow River-Ion sites, all sites had at least one *E. coli* concentration greater than 10,000 CFU. *E. coli* concentrations at the Yellow River-Ion site exceeded the one-time standard 10 times and exceeded the geometric mean standard 17 times.

Analysis of the *E. coli* data with a load duration curve indicates that high *E. coli* concentrations are associated with non-point sources. The highest *E. coli* results at most sites are associated with heavy rainfall. Furthermore, *E. coli* results at the Norfolk, North Fork, and Yellow River Sub monitoring sites occur on the days that also have high ammonia-N concentrations and high rainfall, which may indicate that both problems are caused by manure entering the stream.

ACKNOWLEDGEMENTS

This study was a cooperative project among federal, state, and local agencies. Several organizations and individuals made key contributions to this project. They include:

- The entire staff of the USDA-NRCS (Waukon Office) and the Allamakee County SWCD who diligently collected the water quality samples and flow measurements every week.
- Dave Pals who helped collect the benthic macroinvertebrates and helped collect water quality samples.
- Corey Meyer, Richard Kittleson, Steve Scholtes, Hillary Owen, Ben Belgarde, Paul Berland, and Adam Kiel who helped collect water quality samples.
- The landowners who granted access to streams on their properties.
- Rod Rovang, Effigy Mounds National Park, who provided a secure place for water quality samples before being transported to UHL.
- Nathan Ohrt (UHL), who transported the water quality samples from Effigy Mounds National Park to UHL.
- Heartland Network, Inventory and Monitoring Program, National Park Service, which provided funding and technical support.
- Chad Fields, Bob Libra, Keith Schilling, and Lynette Seigley reviewed this report and provided editorial comments.
- Pat Lohmann oversaw the design and layout of the report.

REFERENCES

EPA, 2000. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion VII. EPA 822-B-00-018. U.S. Environmental Protection Agency. Office of Water. Washington, D.C., 20 p.

Hilsenhoff, W.L., 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society: 7(1):65-68.

IAC, 2002. Iowa Administrative Code [effective date 7/10/02]. Chapter 567-61: water quality standards. http://www.legis.state.ia.us/Rules/2003/iac/567iac/56761/56761.pdf.

IDNR, 2001. Biological sampling procedures for wadeable streams and rivers in Iowa. Iowa Department of Natural Resources, Environmental Protection Division, Water Resources Section. Des Moines, IA. 15 p.

IDNR, 2003. Surface Water Classification document [effective data 7/19/2003]. Iowa Department of Natural Resources, Environmental Protection Division, Water Quality Bureau.

IDNR, 2004. Cold Water Use Designation Assessment Protocol. Iowa Department of Natural Resources. Environmental Protection Division. Des Moines, IA. 15 p.

IDNR, 2005. Monitoring Water Quality for Purposes of Establishing a TMDL on the Yellow River as it Flows Into Effigy Mounds National Monument, Iowa. Iowa Department of Natural Resources. Water Monitoring Section. 14 p.

Prior, J.C., 1991. Landforms of Iowa, University of Iowa Press, 154 p.

Richards, R. Peter, 1998. Estimation of Pollutant Loads in Rivers and Streams: A Guidance Document for NPS Programs. Project report prepared under Grant X998397-01-0, U.S. Environmental Protection Agency, Region VIII, Denver. 108 p.

Sloto, R.A., and Crouse, M.Y., 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis: U.S. Geological Survey Water-Resources Investigations Report 96-4040, 46 p.

Stewart, J.S., Wang, L., Lyons, J., Horwatch, J.A., and Bannerman, R., 2001. Influences of watershed, riparian-corridor, and reach-scale characteristics on aquatic biota in agricultural watershed. Journal of the American Water Resources Association: 36(6):1475-1487.

Witzke, Brian J., Ludvigson, Greg A., McKay, Robert M., Anderson, Raymond R., Bunker, Bill J., Giglierano, James D., Pope, John P., Goettemoeller, Adrian E., and Slaughter, Maureen K., 1998. Bedrock geology of northeast Iowa, Digital geological map of Iowa, Phase 2: Northeast Iowa. OFM 98-7. Iowa Department of Natural Resources.

APPENDIX A.

**State of Iowa stream designations
for streams in the Yellow River watershed.**

Name	Description	A1	B (WW)	B (LR)	B (CW)	HQ	HQR
Yellow R.	Mouth (Allamakee Co.) to County Rd X-26 (S24, T96N, R5W, Allamakee Co.)	X	X				X
Yellow R.	County Rd X-26 (Allamakee Co.) to old Hwy. 51 (NE1/4, S11, T96N, R6W, Allamakee Co.)		X				X
Yellow R.	Old Hwy. 51 to confluence with N. Fk. Yellow R. (S13, T96N, R7W, Winneshiek Co.)				X		X
Yellow R.	Confluence with N. Fk. Yellow R. to confluence with an unnamed tributary (SE1/4, S8, T96N, R7W, Winneshiek Co.)			X			
Dousman Cr.	Mouth (S33, T96N, R3W, Allamakee Co.) to Allamakee-Clayton Co. line				X		X
Suttle Cr.	Mouth (S17, T96N, R4W, Allamakee Co.) to Allamakee-Clayton Co. line				X		X
Unnamed Cr. (a.k.a. Bear Cr.)	Mouth (S13, T96N, R5W, Allamakee Co.) to N. line of S12, T96N, R5W, Allamakee Co.				X		X
Hickory Cr.	Mouth (Allamakee Co.) to S. line of S28, T96N, R5W, Allamakee Co.				X	X	
Hickory Cr.	S. line of S28, T96N, R5W, Allamakee Co. to confluence with an unnamed tributary (S5, T95N, R5W, Clayton Co.)			X			
Williams Cr.	Mouth (S9, T96N, R5W, Allamakee Co.) to confluence with an unnamed tributary (S17, T96N, R5W, Allamakee Co.)			X			
Norfolk Cr.	Mouth (S6, T96N, R5W, Allamakee Co.) to confluence with Teeple Cr. (S24, T97N, R6W, Allamakee Co.)				X		X
Teeple Cr.	Mouth (S24, T97N, R6W, Allamakee Co.) to spring source in S11, T97N, R6W, Allamakee Co.)				X		X
Unnamed Cr.	Mouth (S2, T96N, R6W, Allamakee Co.) to confluence with an unnamed tributary (S33, T97N, R6W, Allamakee Co.)			X			
N. Fk. Yellow R.	Mouth (S13, T96N, R7W, Winneshiek Co.) to confluence with an unnamed tributary (S3, T96N, R7W, Winneshiek Co.)			X			

Modified from the Surface Water Classification document (IDNR, 2003).

Description of stream designations (from IAC, 2002)

A1 - Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard.

B(WW) - Waters in which temperature, flow and other habitat characteristics are suitable for the maintenance of a wide variety of reproducing populations of warm water fish and associated aquatic communities, including sensitive species.

B(LR) - Waters in which flow or other physical characteristics limit the ability of the water body to maintain a balanced warm water community. Such waters support only populations composed of species able to survive and reproduce in a wide range of physical and chemical conditions, and are not generally harvested for human consumption.

B(CW) - Waters in which the temperature, flow, and other habitat characteristics are suitable for the maintenance of a wide variety of cold water species, including nonreproducing populations of trout and associated aquatic communities.

HQ - Waters with exceptionally better quality and with exceptional recreational and ecological importance. Special protection is warranted to maintain the unusual, unique or outstanding physical, chemical, or biological characteristics which these waters possess.

HQR - Waters of substantial recreational or ecological significance which possess unusual, outstanding or unique physical, chemical, or biological characteristics which enhance the beneficial uses and warrant special protection.

APPENDIX B.

2002 landuse percentages in the Yellow River watershed.

Name	Alfalfa	Barren	Beans	Commerical/Industrial
Bear Creek	8%	0%	12%	0%
Dousman Creek	9%	0%	5%	0%
Hecker Creek	19%	1%	14%	2%
Hickory Creek	7%	0%	20%	0%
No Name	9%	0%	25%	1%
Norfolk Creek	9%	0%	22%	0%
North Fork	12%	0%	21%	0%
Suttle Creek	6%	1%	14%	1%
Upper Yellow River	12%	0%	22%	1%
Williams Creek	7%	0%	27%	1%
Yellow River Sub	13%	0%	21%	1%
Yellow River - Ion	9%	0%	18%	0%

Name	Coniferous Forest	Corn	CRP	Deciduous Forest
Bear Creek	0%	14%	5%	23%
Dousman Creek	1%	13%	2%	49%
Hecker Creek	0%	20%	3%	9%
Hickory Creek	1%	33%	1%	13%
No Name	0%	29%	1%	11%
Norfolk Creek	1%	30%	2%	11%
North Fork	0%	32%	1%	11%
Suttle Creek	0%	30%	2%	16%
Upper Yellow River	0%	31%	1%	9%
Williams Creek	1%	30%	2%	8%
Yellow River Sub	0%	34%	1%	6%
Yellow River - Ion	1%	25%	2%	16%

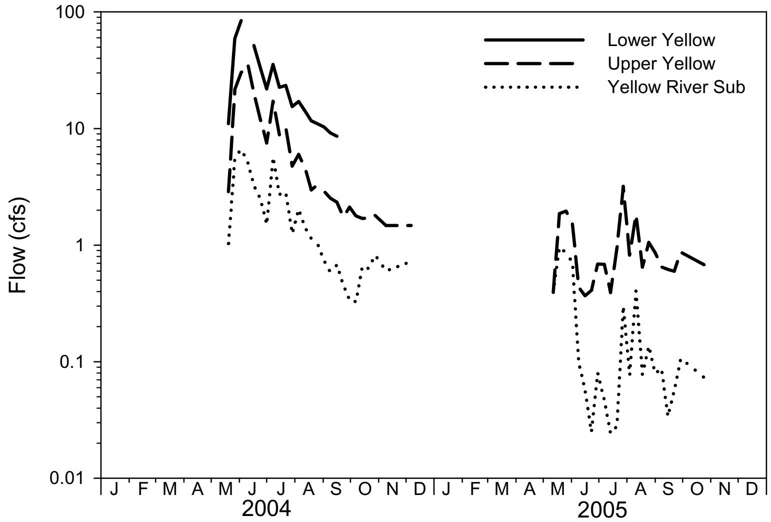
Name	Grazed grassland	Missing Data	Open Water	Other Rowcrops
Bear Creek	4%	0%	0%	0%
Dousman Creek	2%	0%	0%	0%
Hecker Creek	9%	0%	2%	0%
Hickory Creek	2%	0%	0%	0%
No Name	5%	0%	0%	0%
Norfolk Creek	6%	0%	0%	0%
North Fork	5%	0%	0%	0%
Suttle Creek	2%	0%	0%	0%
Upper Yellow River	5%	0%	0%	0%
Williams Creek	7%	0%	0%	0%
Yellow River Sub	5%	0%	0%	0%
Yellow River - Ion	5%	0%	0%	0%

Name	Residential Areas	Roads	Ungrazed Grassland	Wet Forest
Bear Creek	0%	3%	30%	0%
Dousman Creek	0%	1%	18%	0%
Hecker Creek	1%	4%	15%	0%
Hickory Creek	0%	2%	20%	0%
No Name	1%	2%	16%	0%
Norfolk Creek	1%	2%	15%	0%
North Fork	0%	2%	16%	0%
Suttle Creek	0%	2%	26%	0%
Upper Yellow River	1%	3%	16%	0%
Williams Creek	1%	3%	13%	0%
Yellow River Sub	1%	3%	15%	0%
Yellow River - Ion	1%	2%	19%	0%

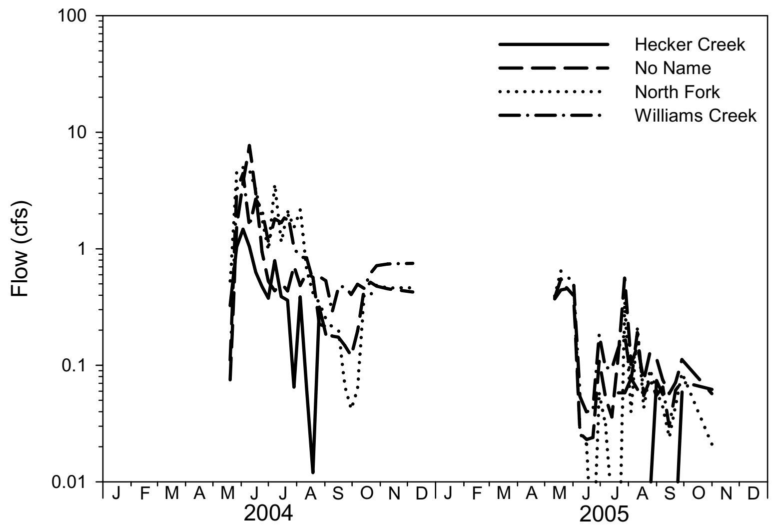
Name	Wetland
Bear Creek	0%
Dousman Creek	0%
Hecker Creek	1%
Hickory Creek	0%
No Name	0%
Norfolk Creek	0%
North Fork	0%
Suttle Creek	0%
Upper Yellow River	0%
Williams Creek	0%
Yellow River Sub	0%
Yellow River - Ion	0%

APPENDIX C.

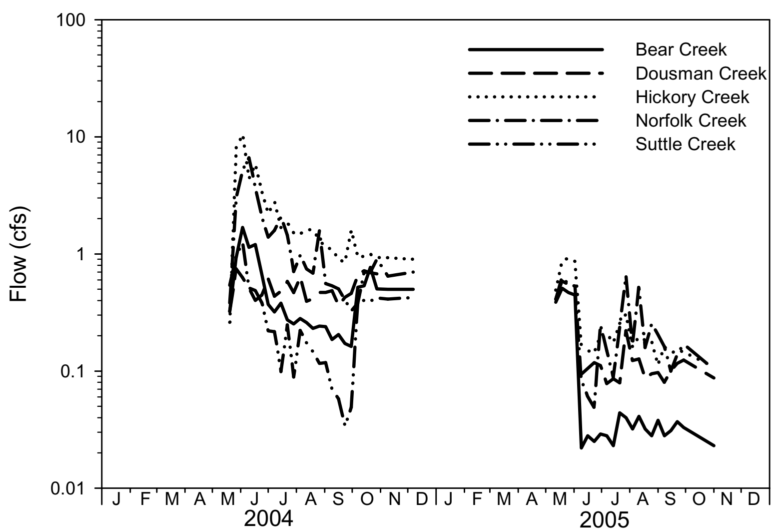
Graphs of manual flow measurements at water quality monitoring sites.



100
10
1
0.1
0.01
Flow (cfs)
Lower Yellow
Upper Yellow
Yellow River Sub
J F M A M J J A S O N D J F M A M J J A S O N D
2004
2005



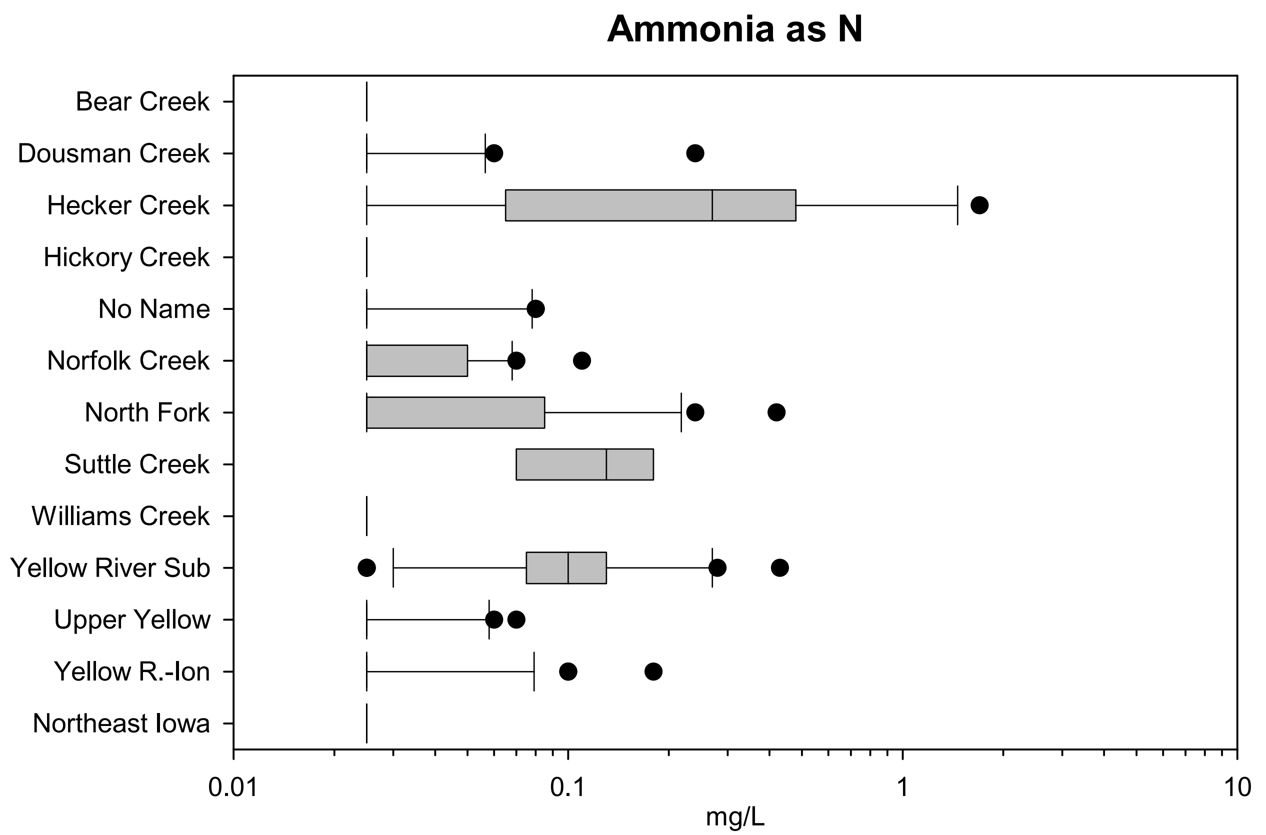
100
10
1
0.1
0.01
Flow (cfs)
Hecker Creek
No Name
North Fork
Williams Creek
J F M A M J J A S O N D J F M A M J J A S O N D
2004
2005

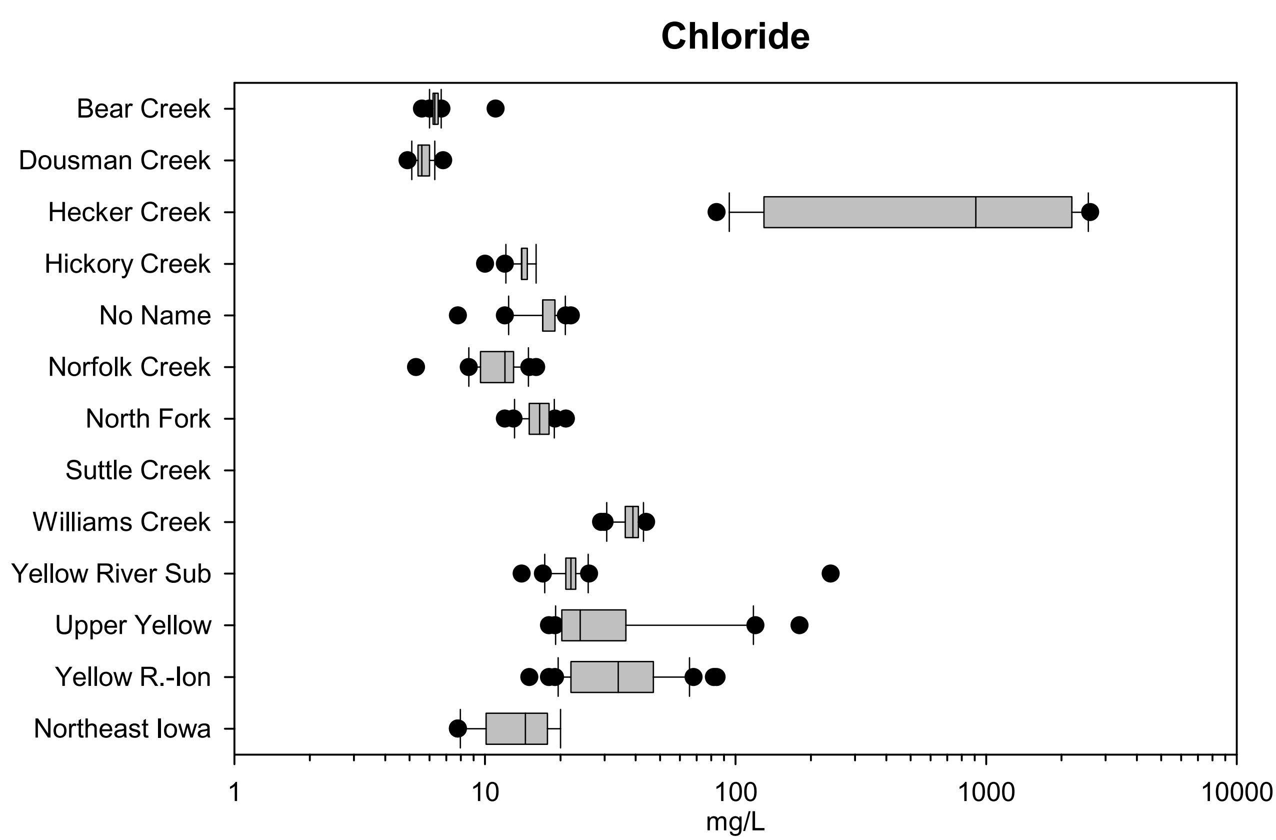


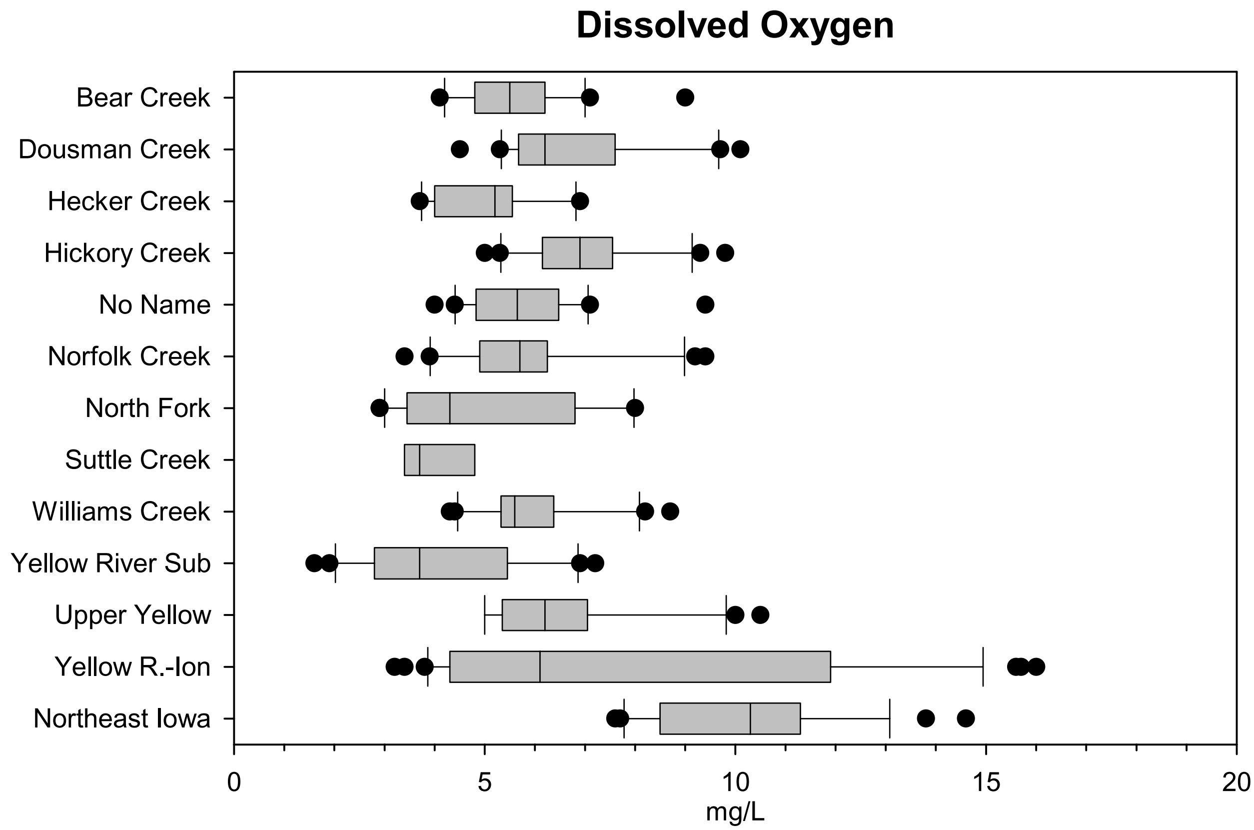
100
10
1
0.1
0.01
Flow (cfs)
Bear Creek
Dousman Creek
Hickory Creek
Norfolk Creek
Suttle Creek
J F M A M J J A S O N D J F M A M J J A S O N D
2004
2005

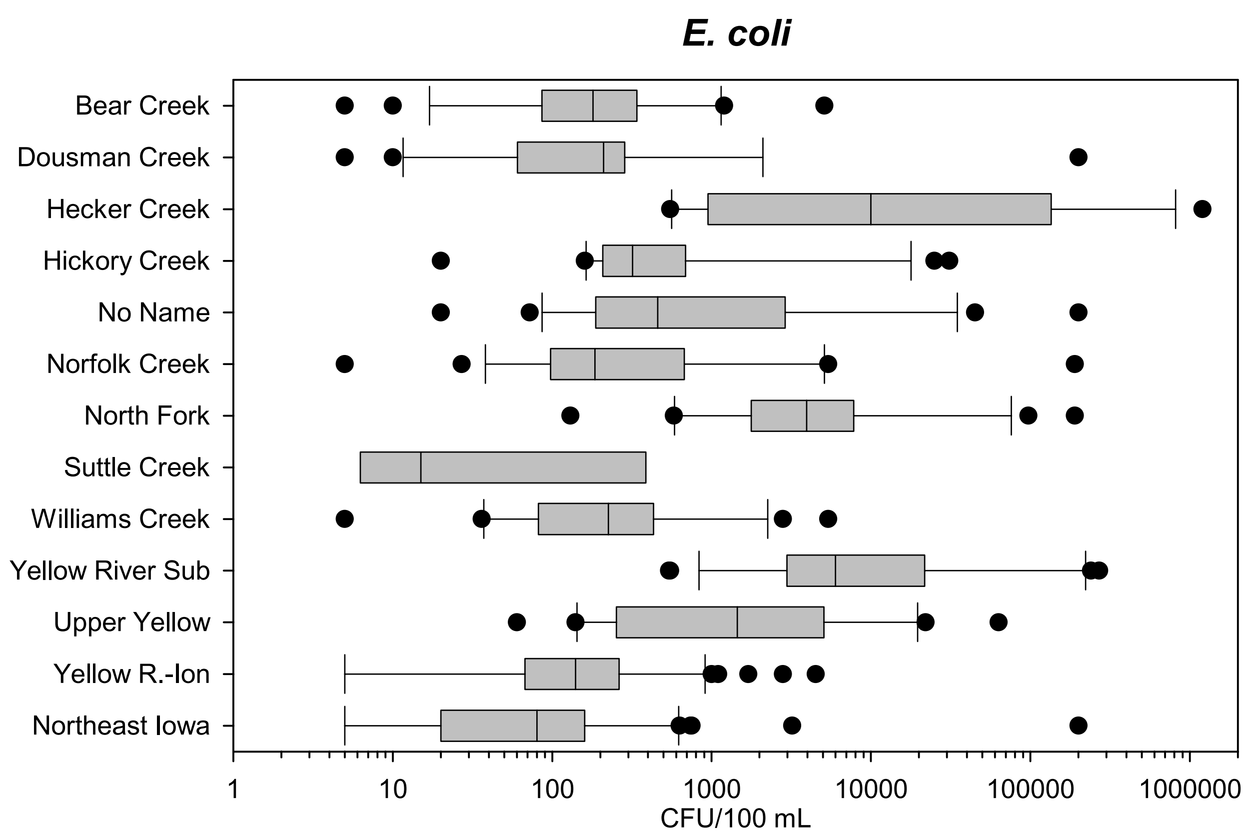
APPENDIX D.

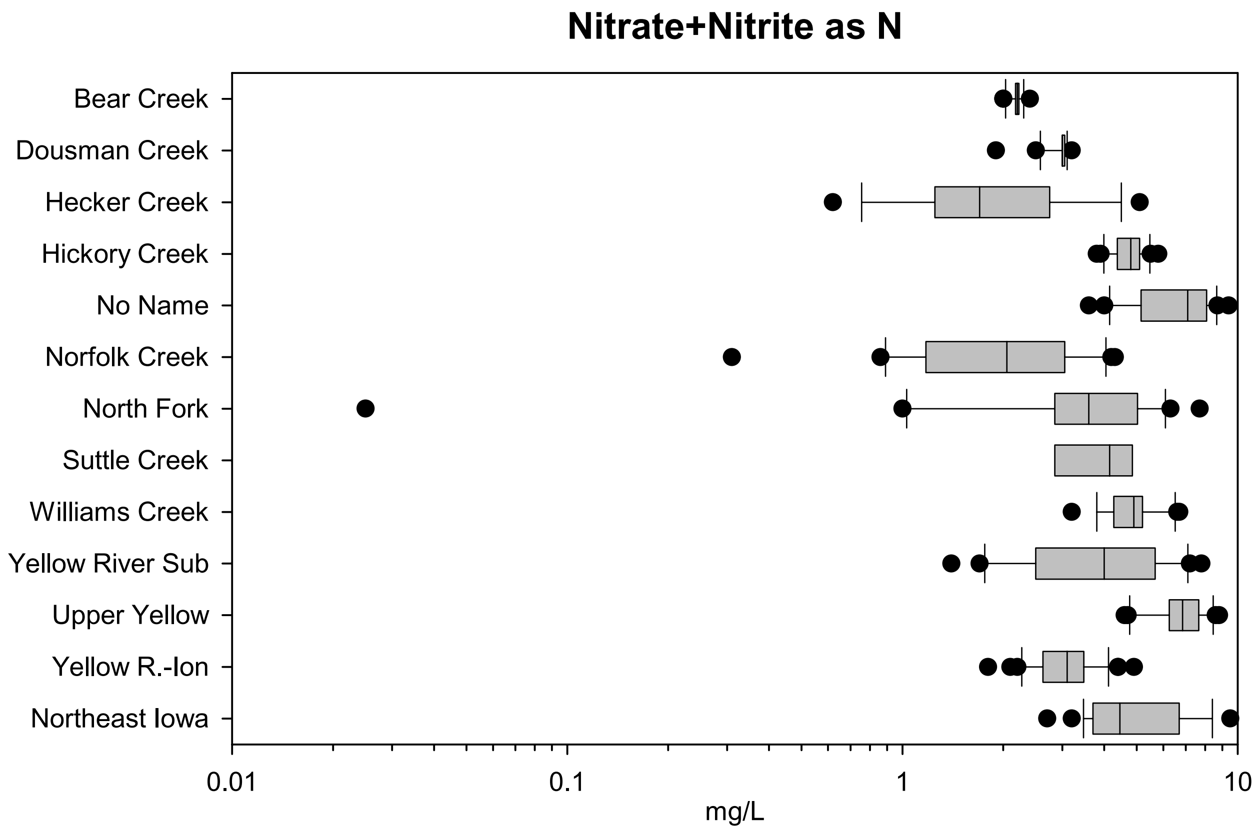
**Box plots of water quality results from April 1 through October 31, 2005.
Data for Suttle Creek is from April 1 through May 26, 2005.
The "Northeast Iowa" site represents the combined data
from the Upper Iowa River, Turkey River, Volga River,
and Bloody Run Creek.**

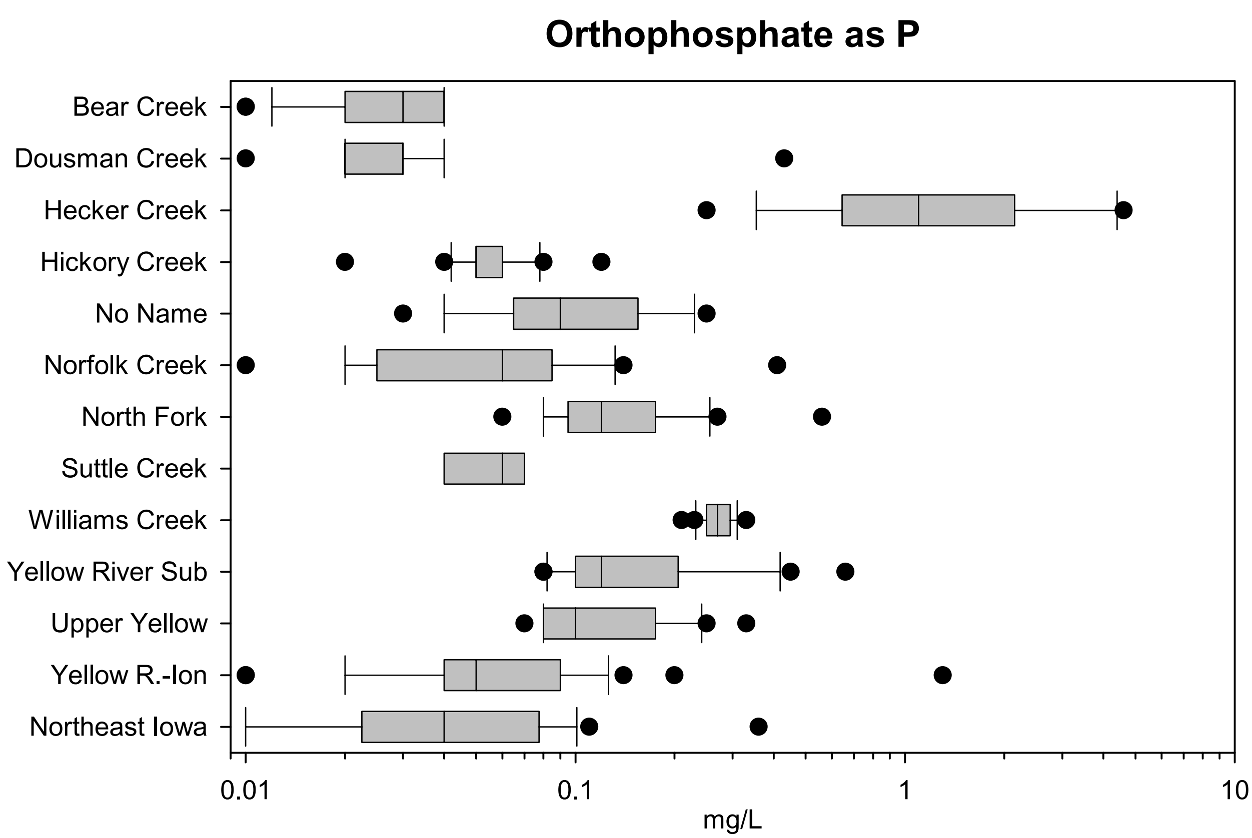

Ammonia as N
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.01
0.1
1
10
mg/L

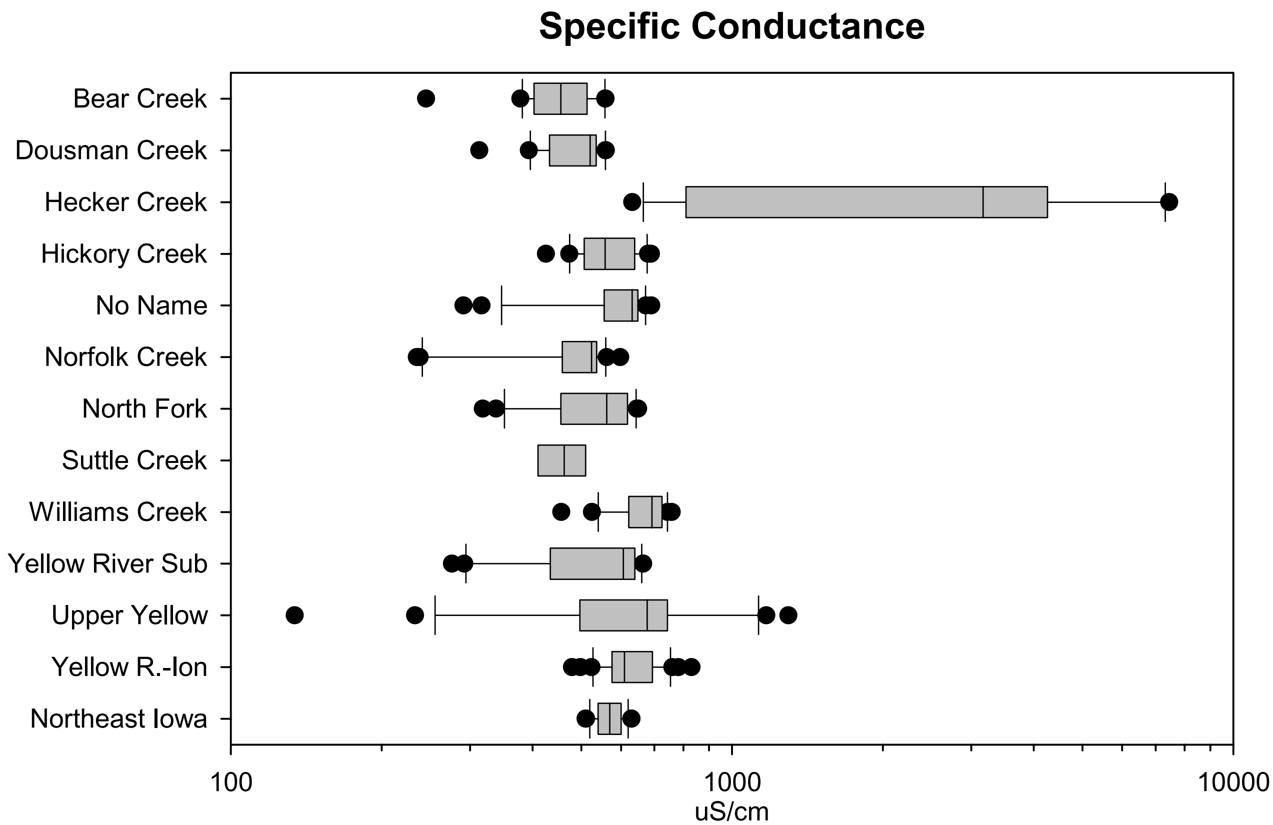

Chloride
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
1
10
100
1000
10000
mg/L

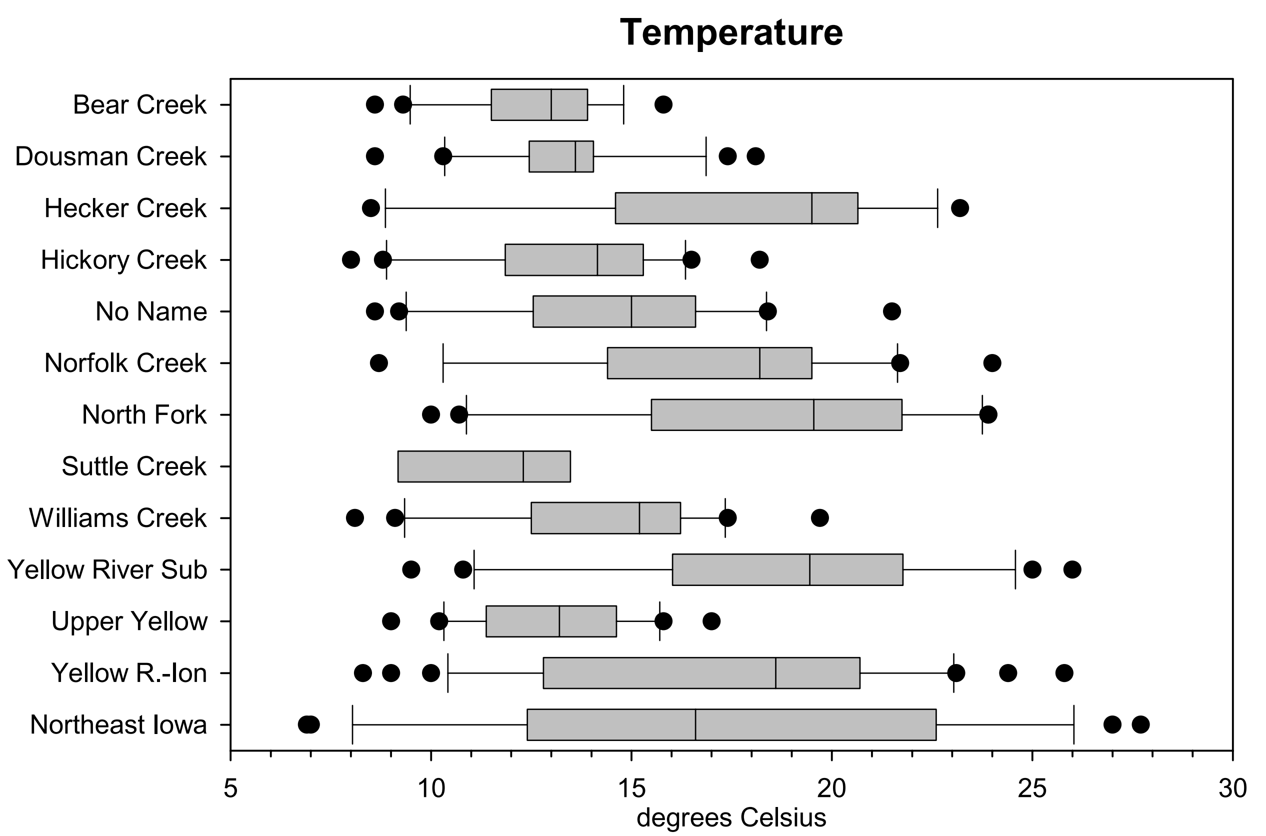

Dissolved Oxygen
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0
5
10
15
20
mg/L

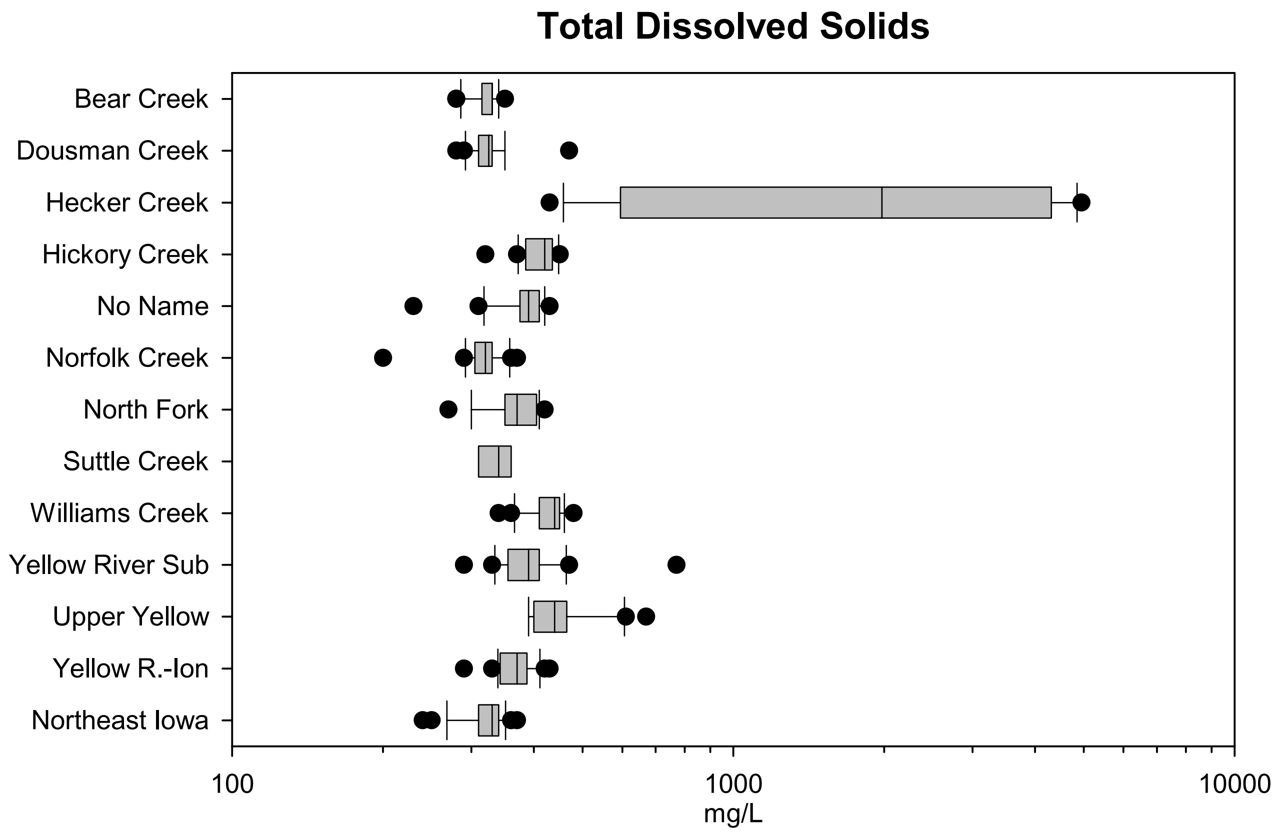

E. coli
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
1
10
100
1000
10000
100000
1000000
CFU/100 mL

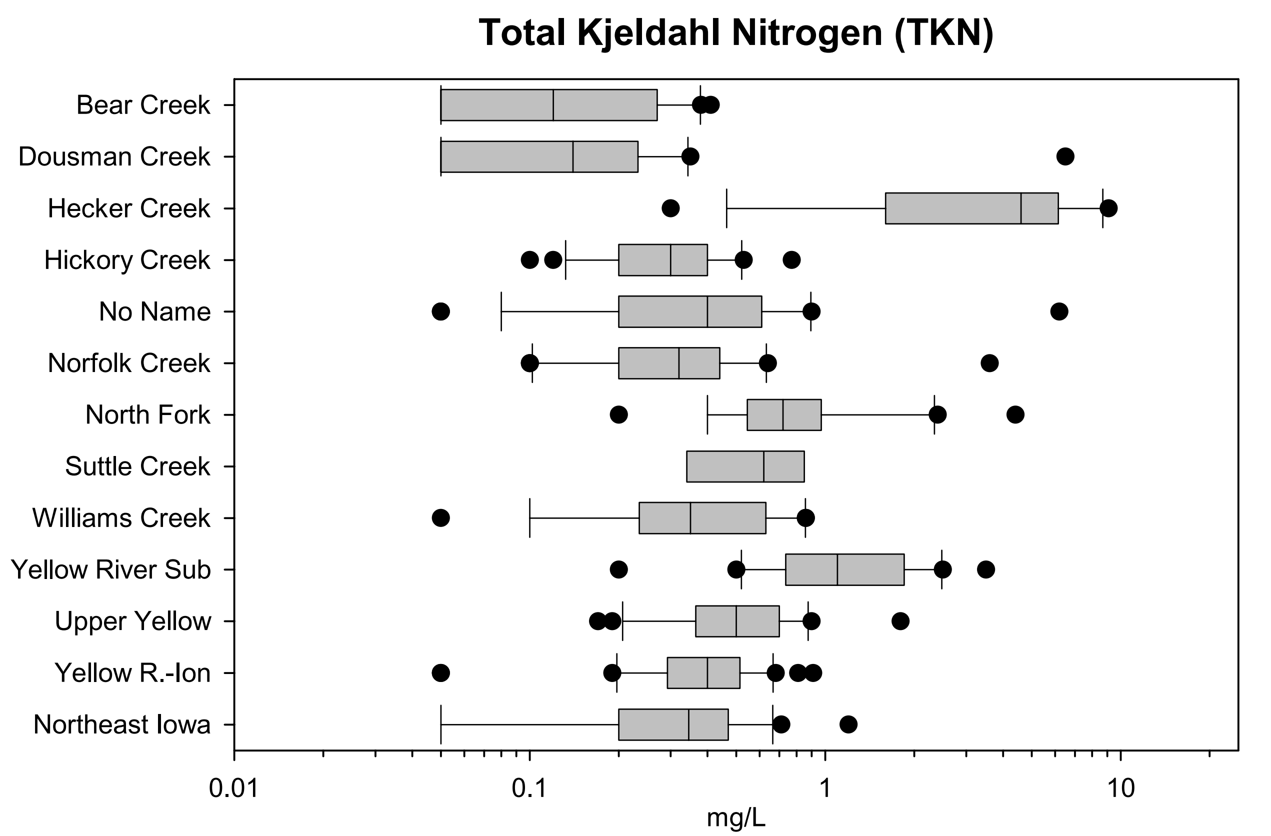

Nitrate+Nitrite as N
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.01
0.1
1
10
mg/L

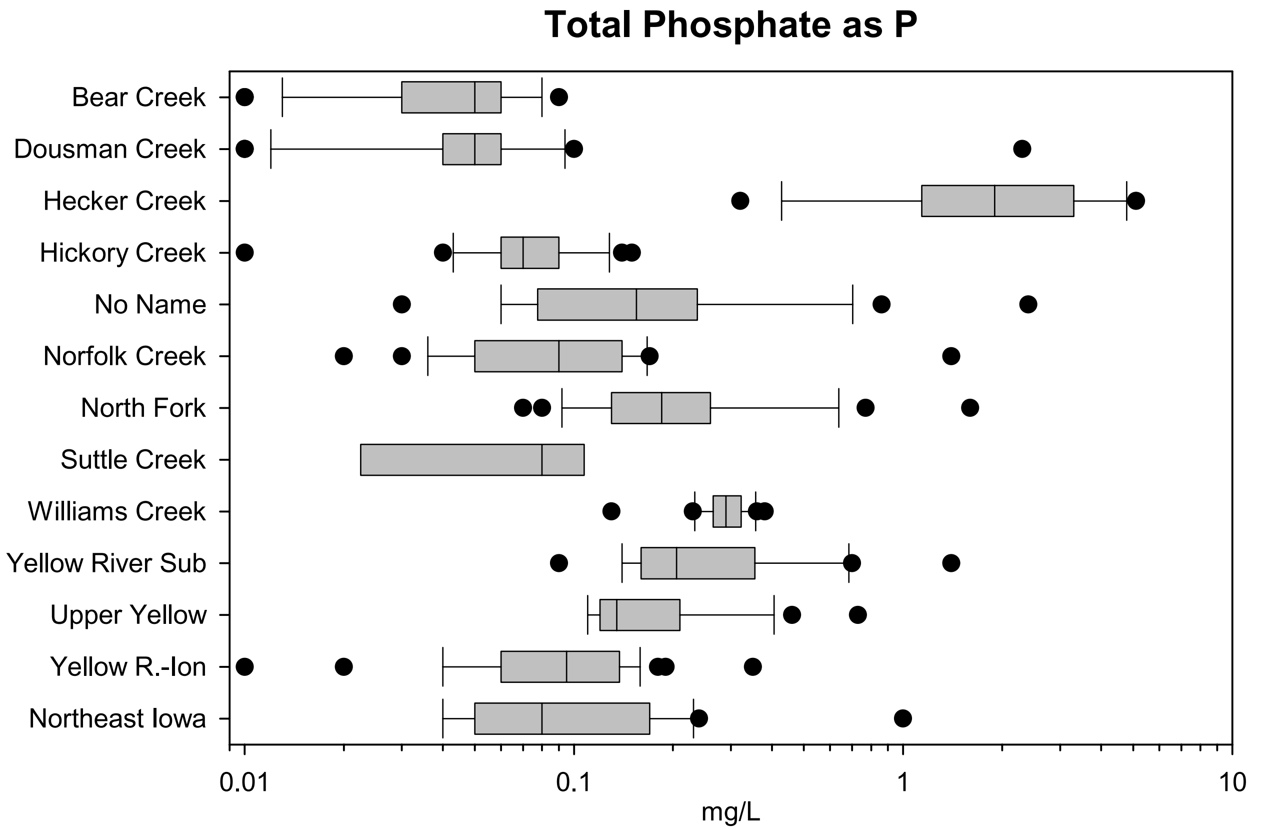

Orthophosphate as P
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.01
0.1
1
10
mg/L

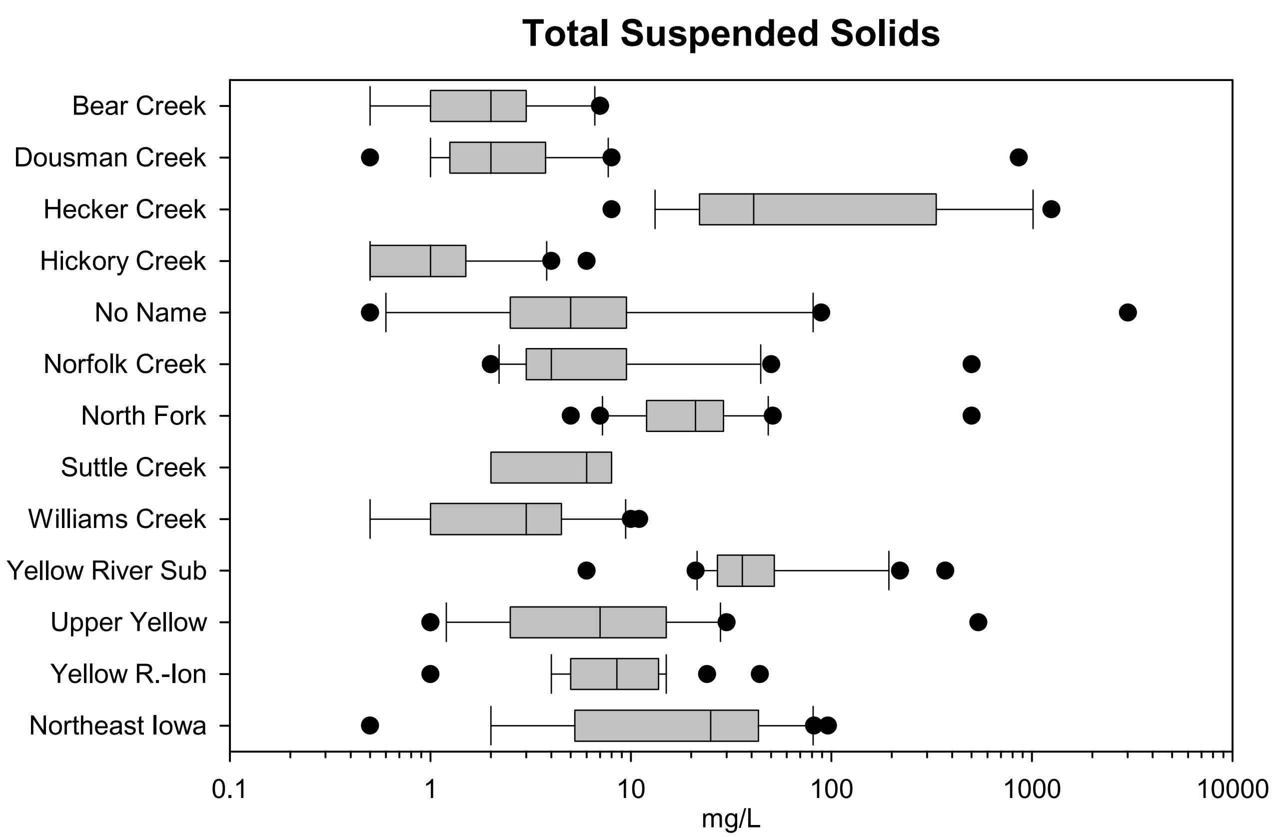

Specific Conductance
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
100
1000
10000
uS/cm

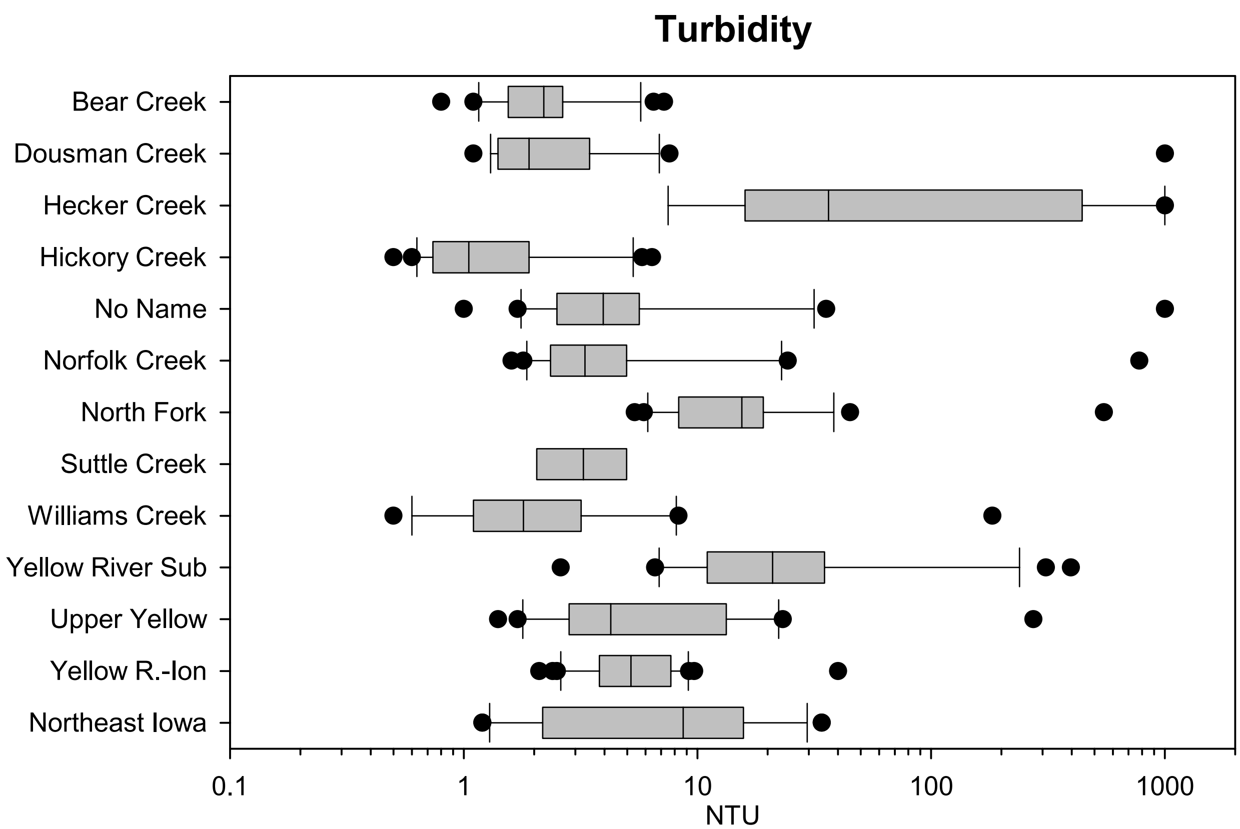

Temperature
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
5
10
15
20
25
30
degrees Celsius


Total Dissolved Solids
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
100
1000
10000
mg/L


Total Kjeldahl Nitrogen (TKN)
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.01
0.1
1
10
mg/L

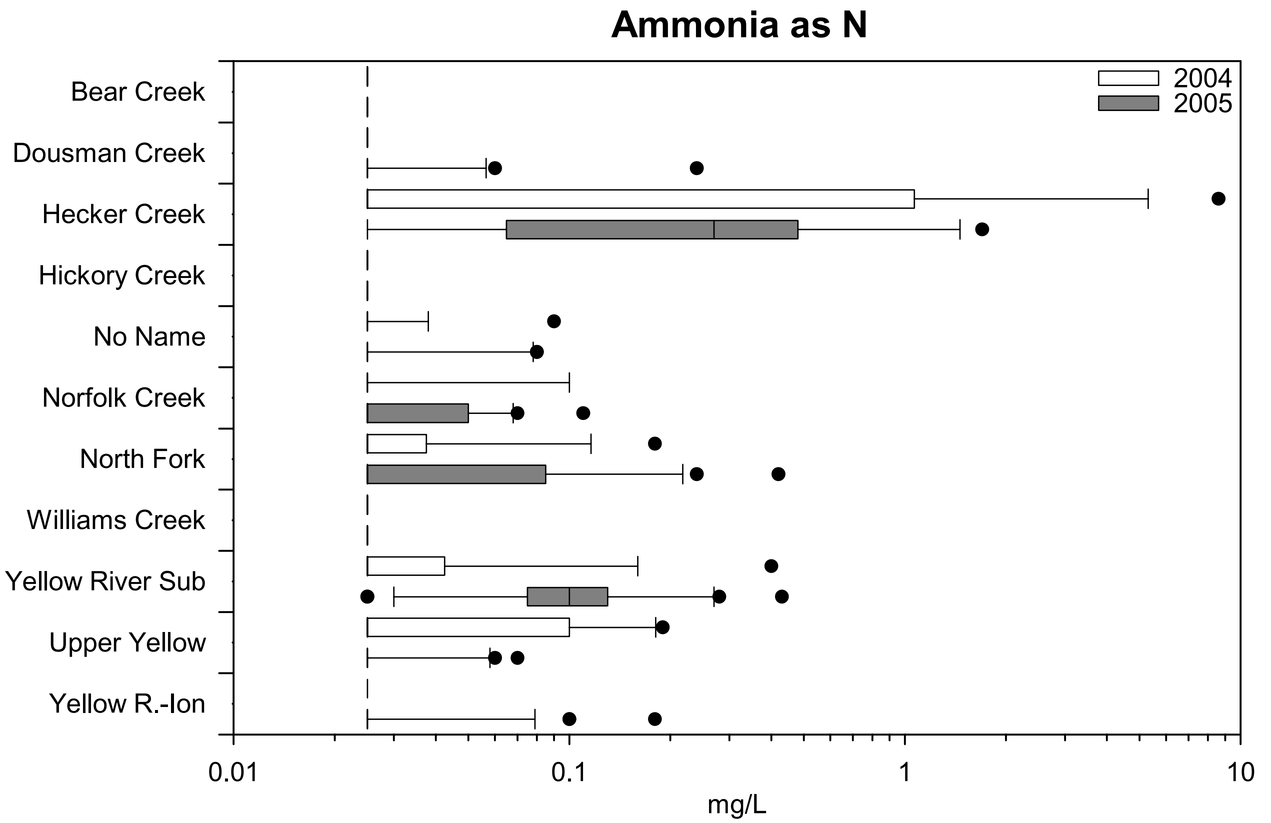

Total Phosphate as P
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.01
0.1
1
10
mg/L

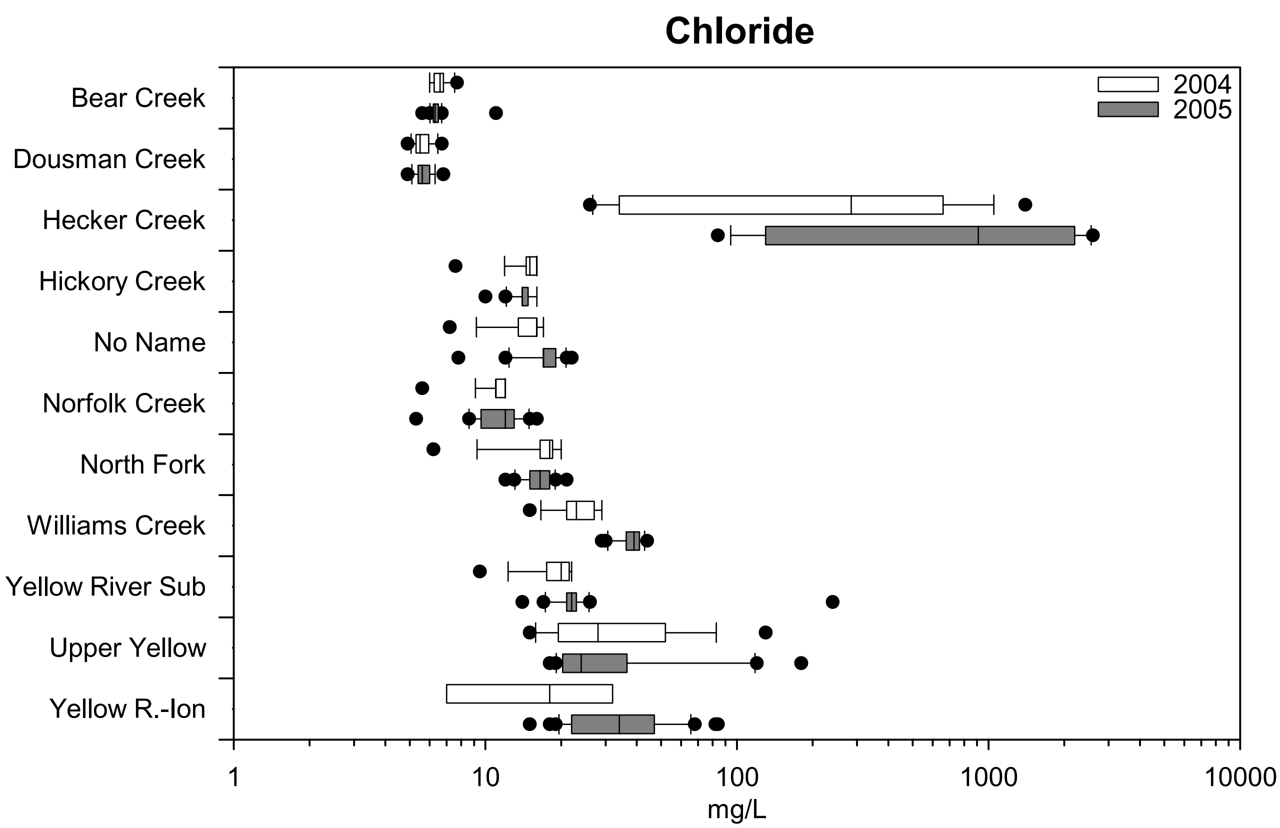

Total Suspended Solids
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.1
1
10
100
1000
10000
mg/L

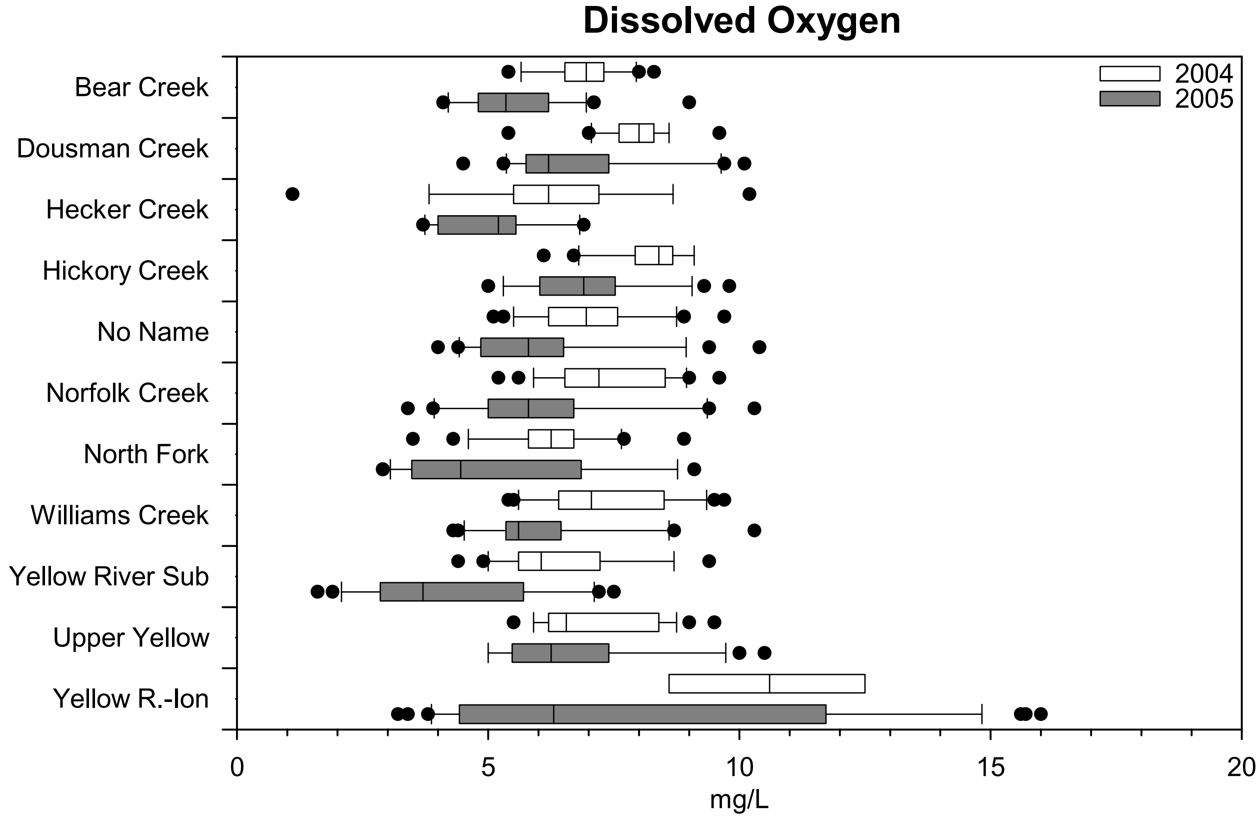

Turbidity
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Suttle Creek
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
Northeast Iowa
0.1
1
10
100
1000
NTU

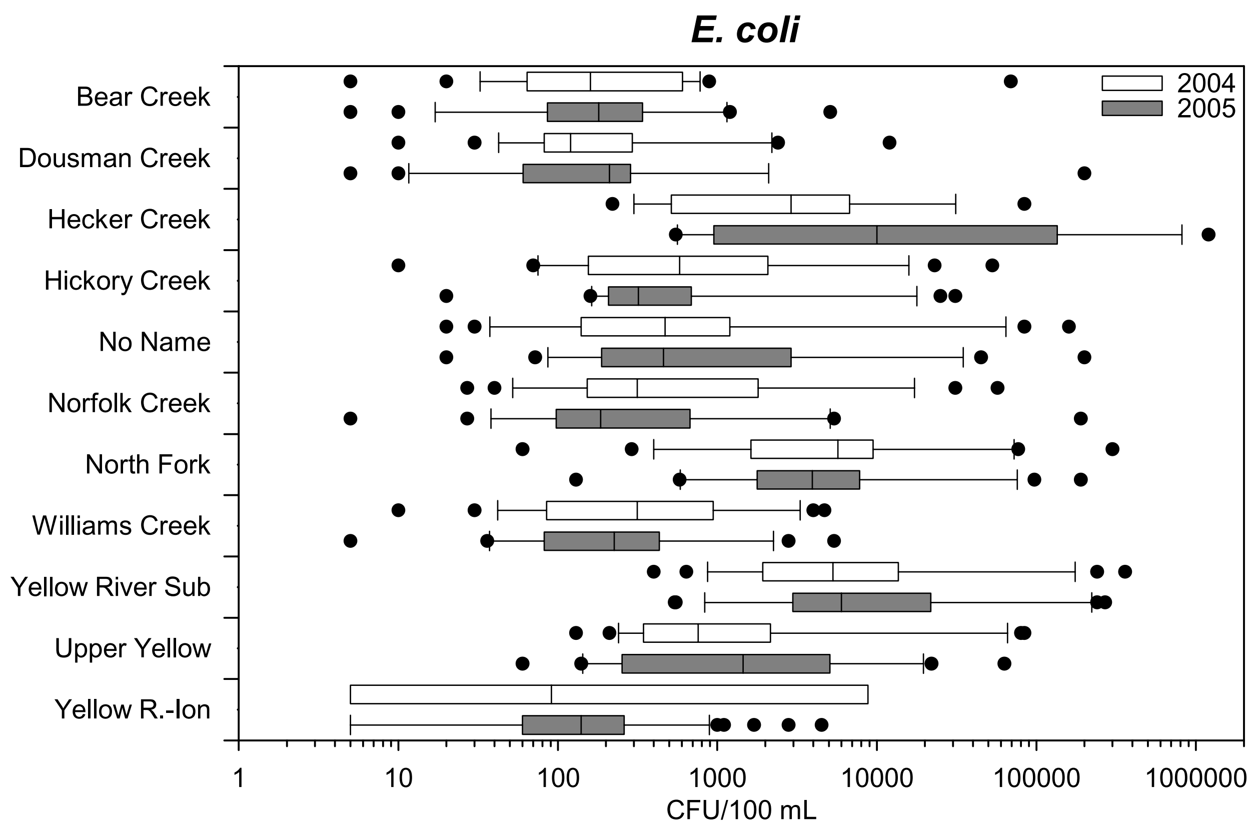
APPENDIX E.

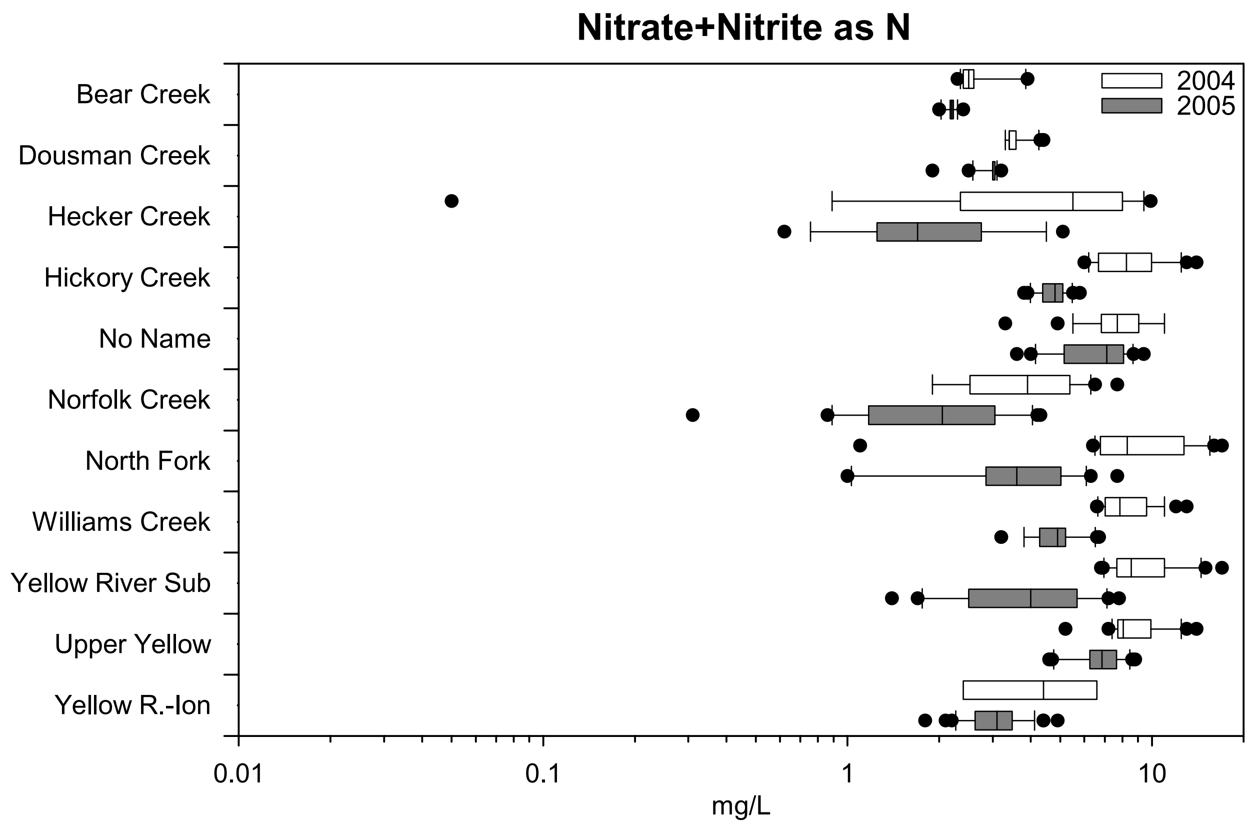
Box plots of water quality results comparing data collected weekly in 2004 to data collected weekly in 2005.

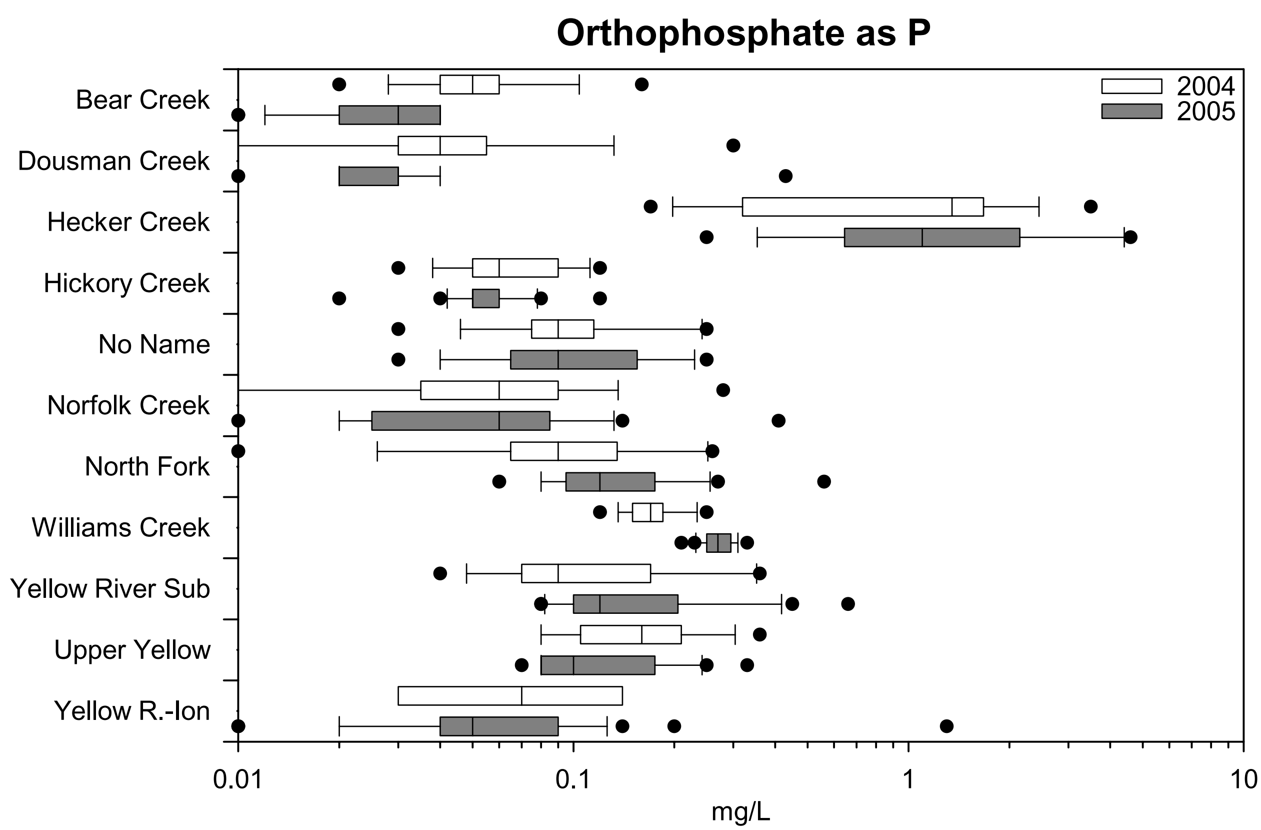

Ammonia as N
2004
2005
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
0.01
0.1
1
10
mg/L

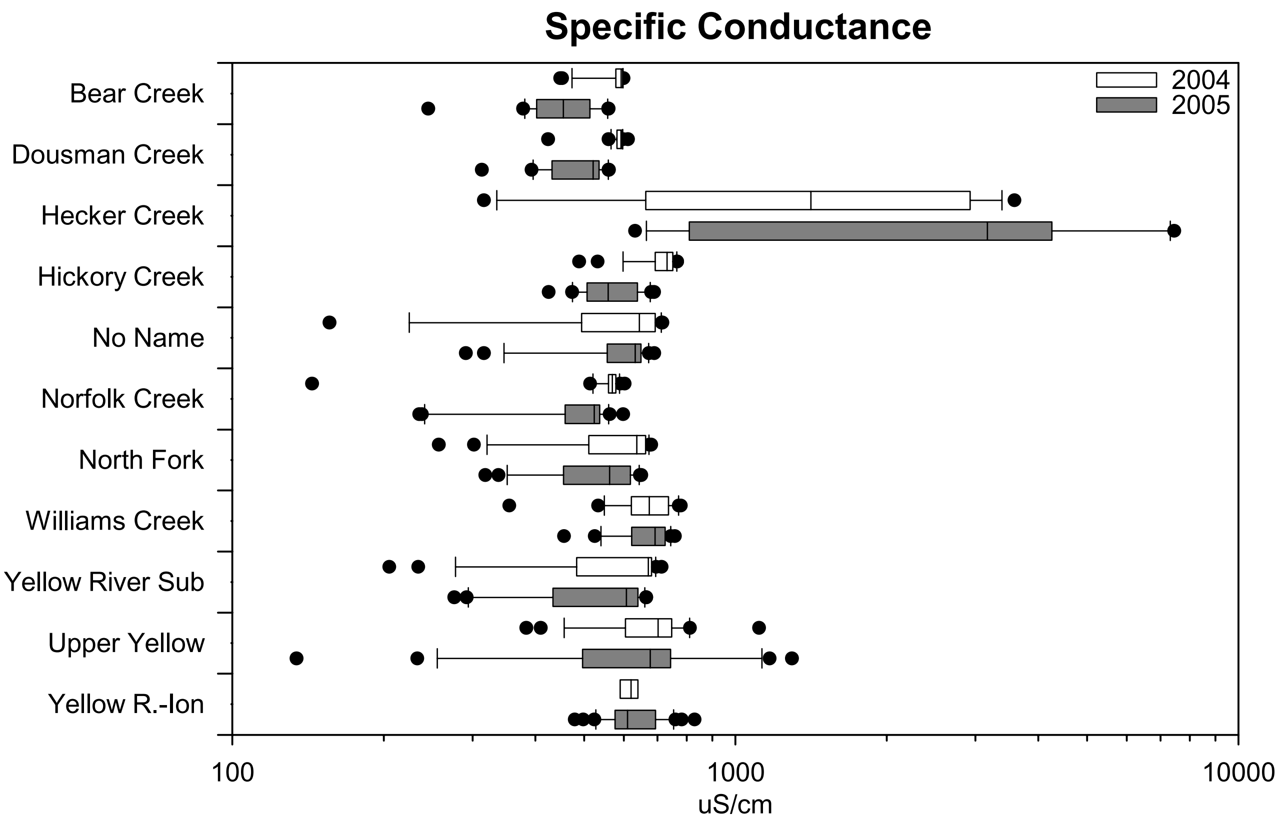

Chloride
2004
2005
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
1
10
100
1000
10000
mg/L

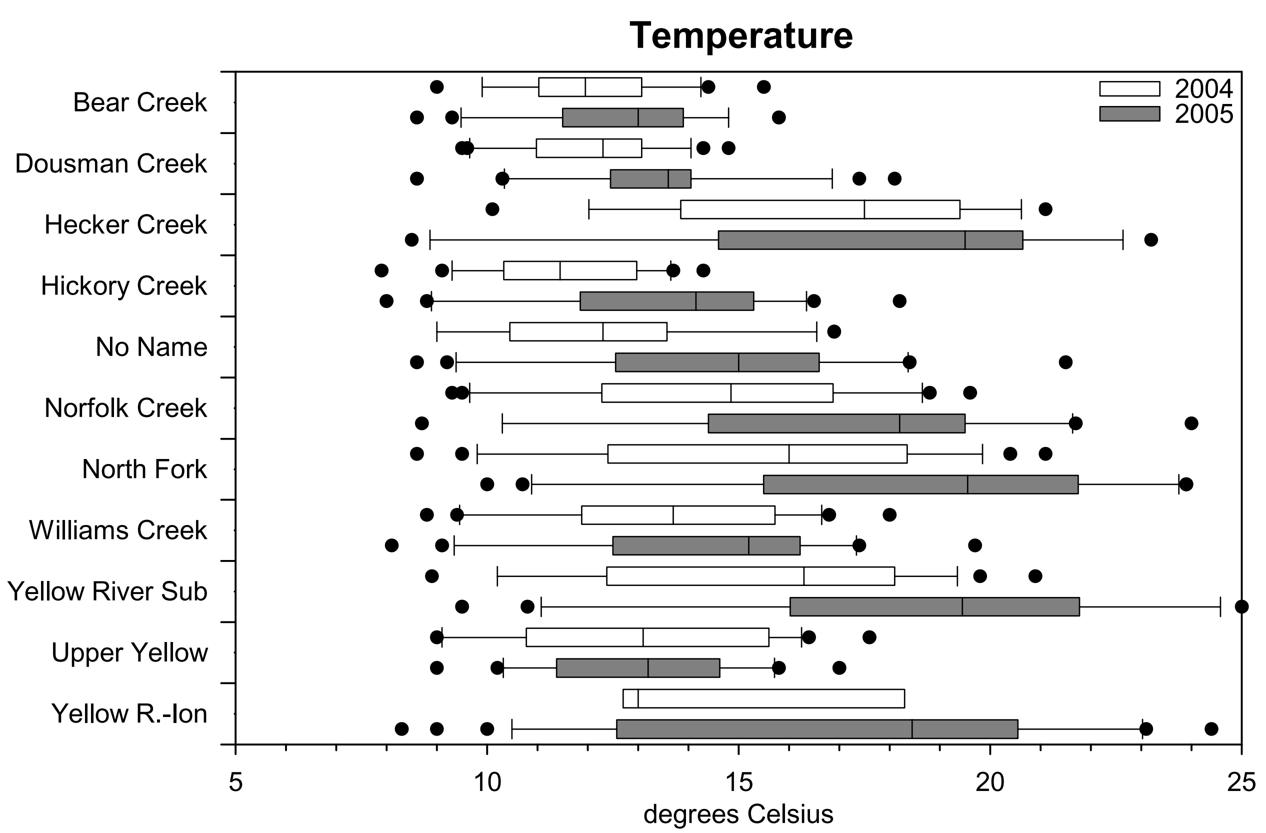

Dissolved Oxygen
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0
5
10
15
20
mg/L

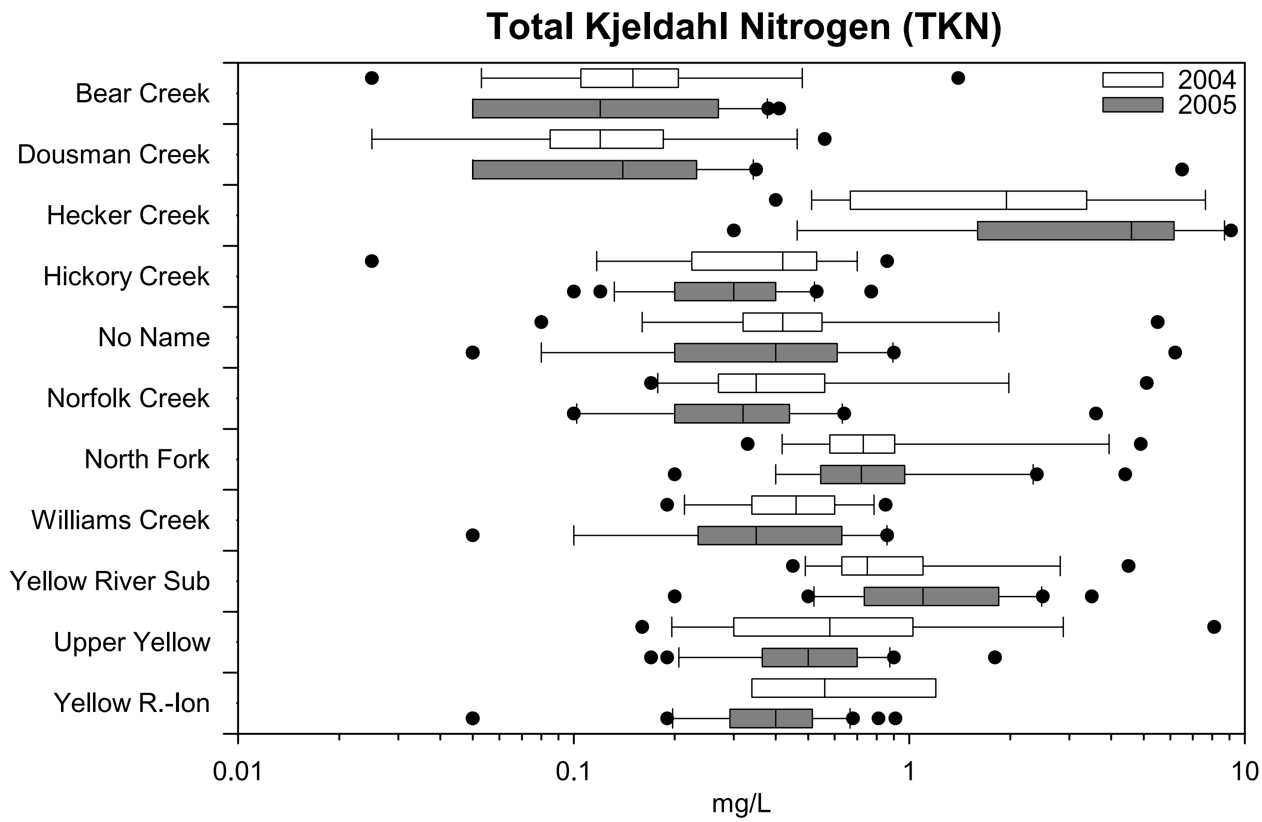

E. coli
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
1
10
100
1000
10000
100000
1000000
CFU/100 mL

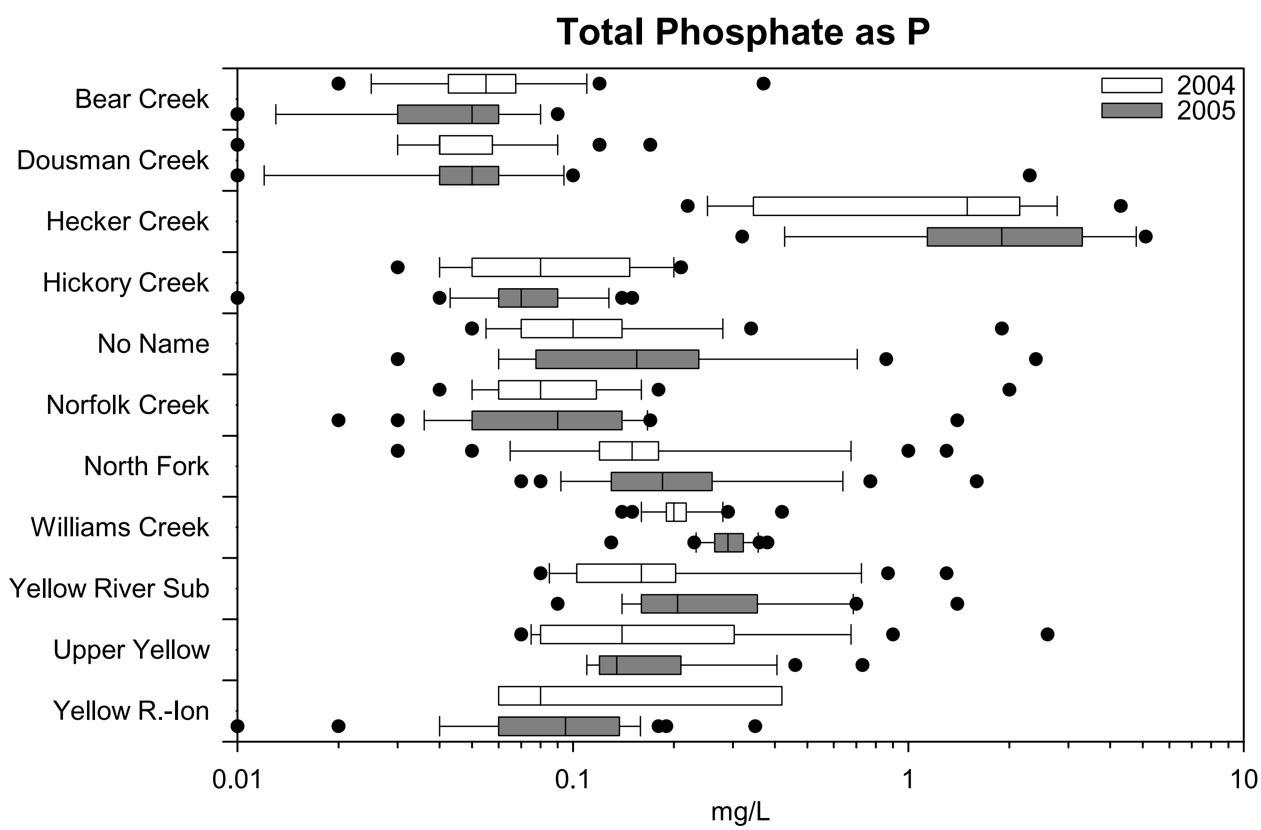

Nitrate+Nitrite as N
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0.01
0.1
1
10
mg/L

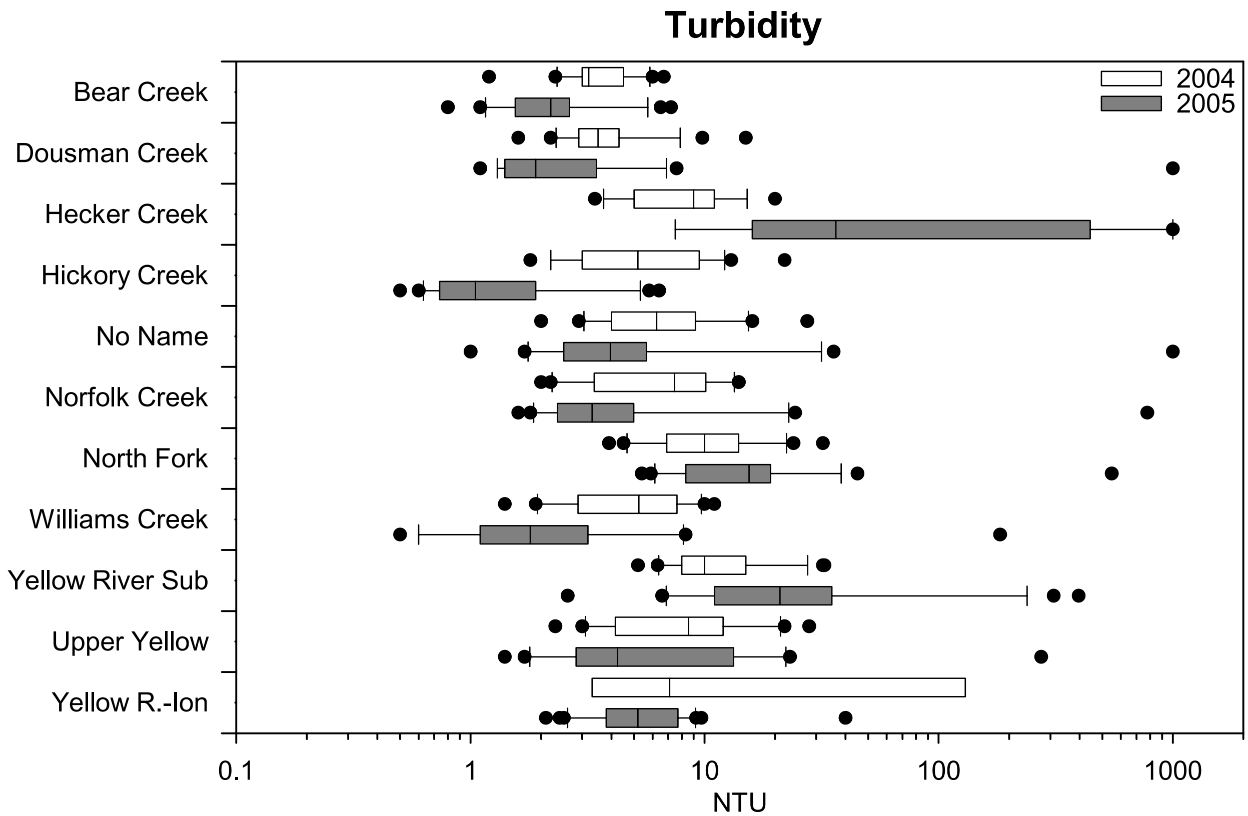

Orthophosphate as P
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0.01
0.1
1
10
mg/L


Specific Conductance
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
100
1000
10000
uS/cm


Temperature
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
5
10
15
20
25
degrees Celsius

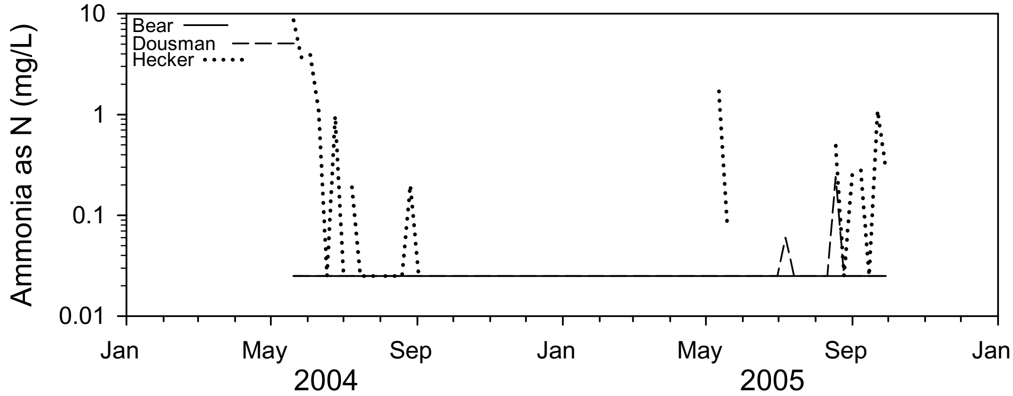

Total Kjeldahl Nitrogen (TKN)
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0.01
0.1
1
10
mg/L

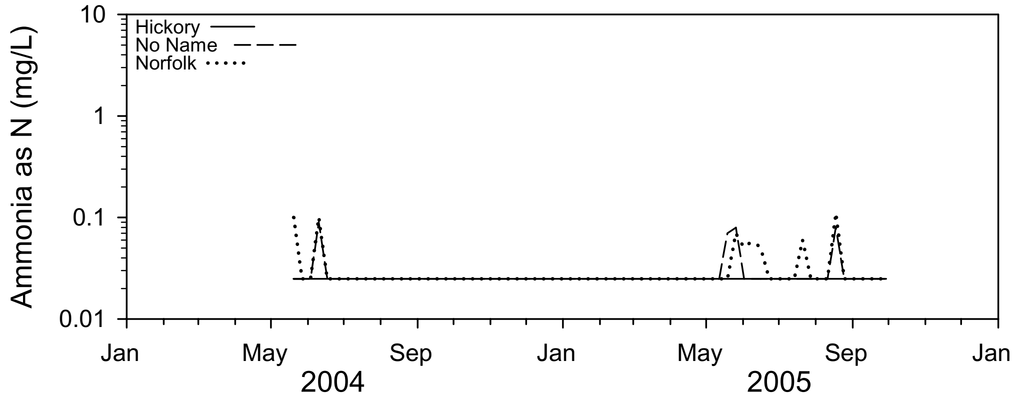

Total Phosphate as P
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0.01
0.1
1
10
mg/L

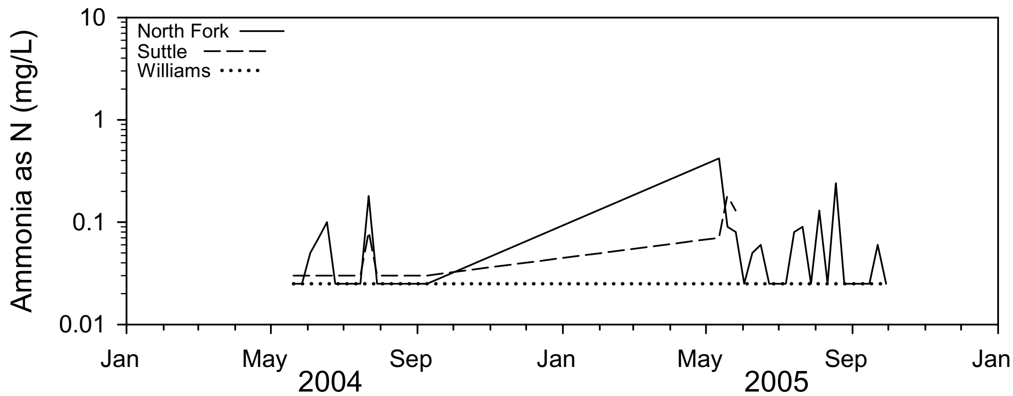

Turbidity
Bear Creek
Dousman Creek
Hecker Creek
Hickory Creek
No Name
Norfolk Creek
North Fork
Williams Creek
Yellow River Sub
Upper Yellow
Yellow R.-Ion
2004
2005
0.1
1
10
100
1000
NTU

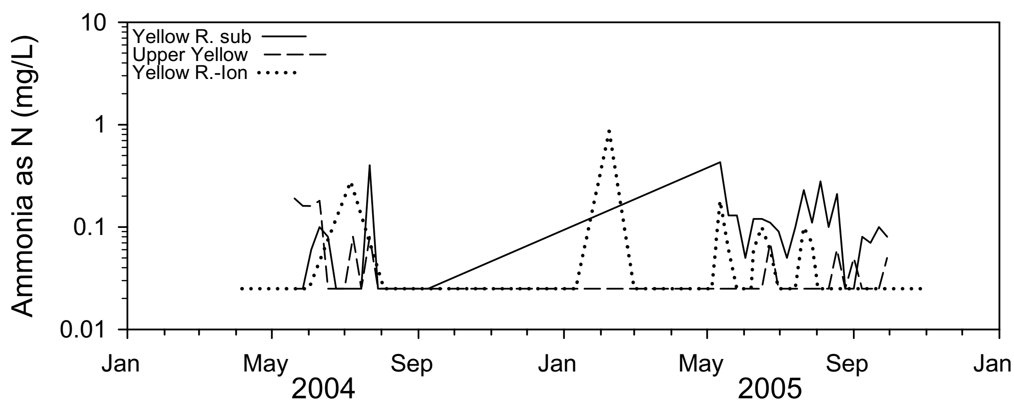
APPENDIX F.

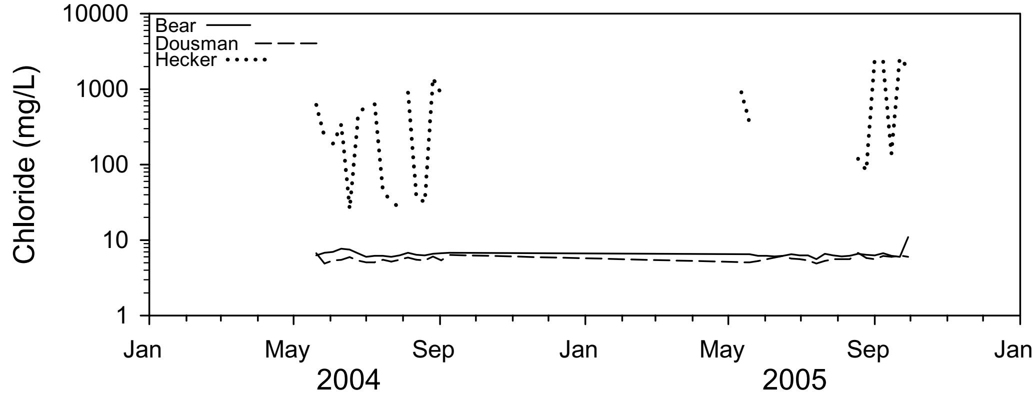
Temporal variations in water quality results from 2004 through 2005.


Ammonia as N (mg/L)
10
1
0.1
0.01
Bear
Dousman
Hecker
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

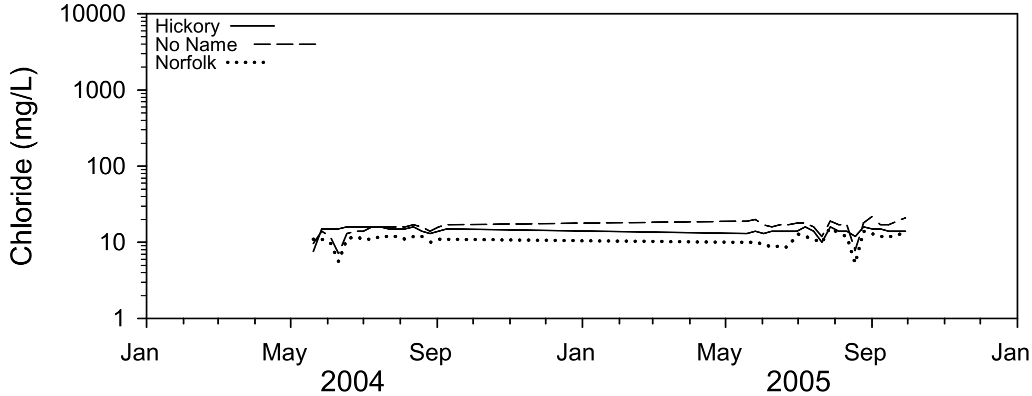

Ammonia as N (mg/L)
10
1
0.1
0.01
Hickory
No Name
Norfolk
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005


Ammonia as N (mg/L)
10
1
0.1
0.01
North Fork
Suttle
Williams
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

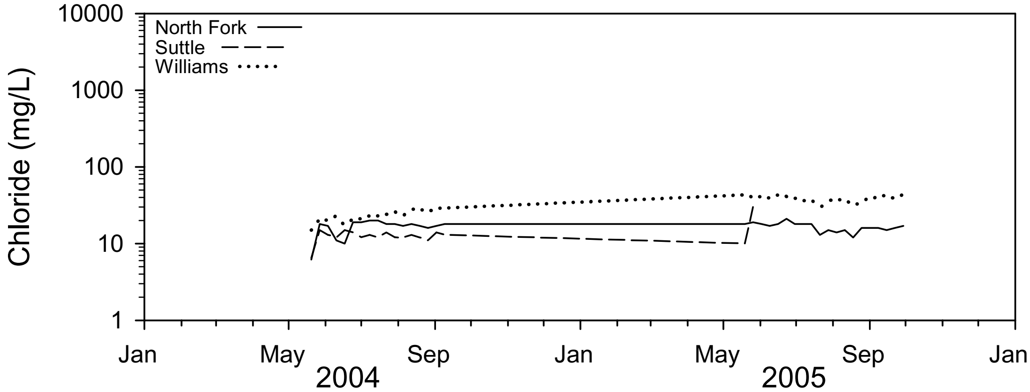

Ammonia as N (mg/L)
10
1
0.1
0.01
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005



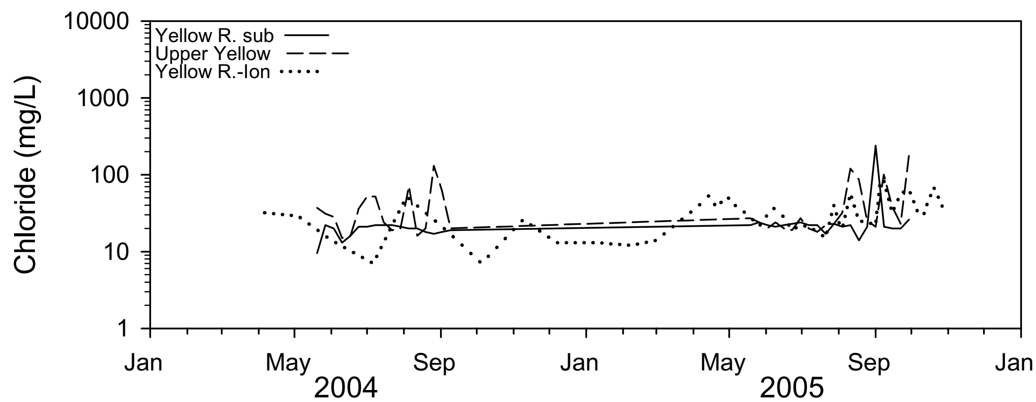
Bear
Dousman
Hecker
Chloride (mg/L)
10000
1000
100
10
1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005



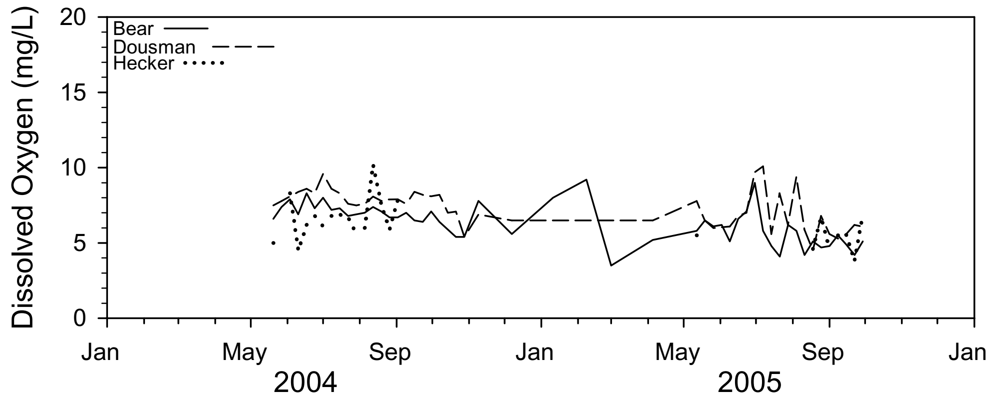
Hickory
No Name
Norfolk
Chloride (mg/L)
10000
1000
100
10
1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

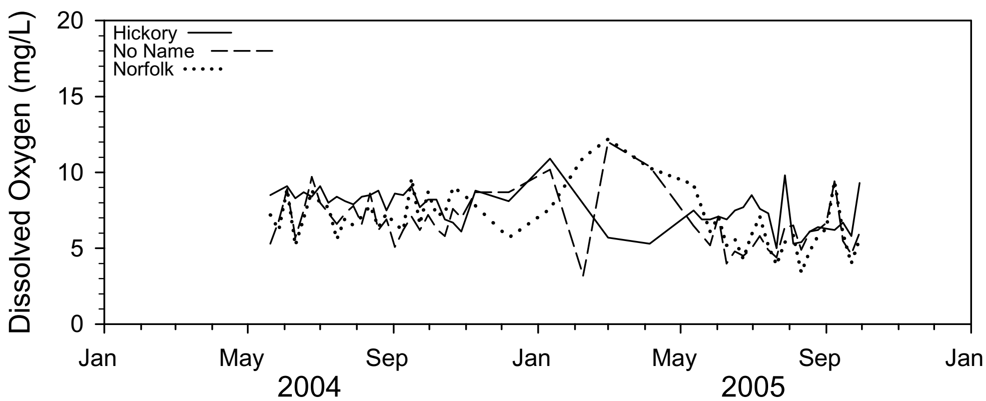


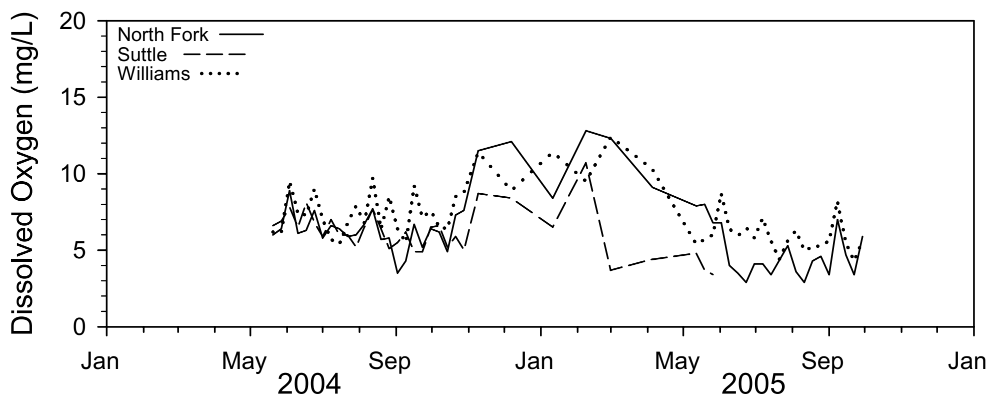
North Fork
Suttle
Williams
Chloride (mg/L)
10000
1000
100
10
1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

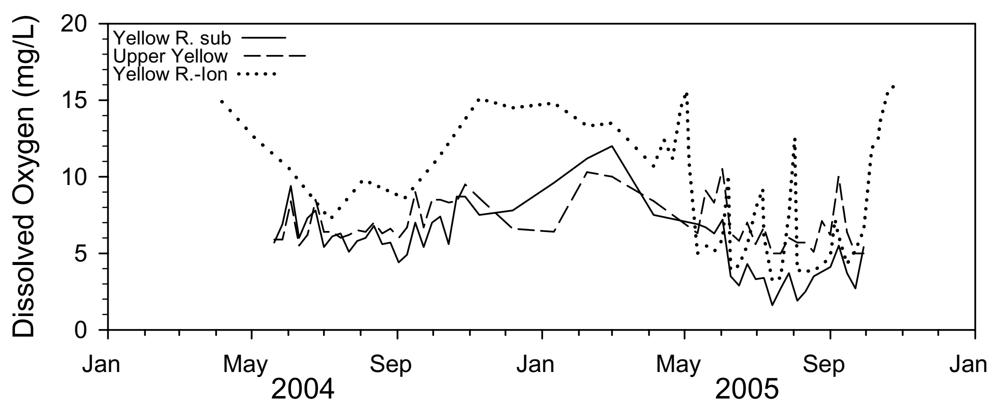


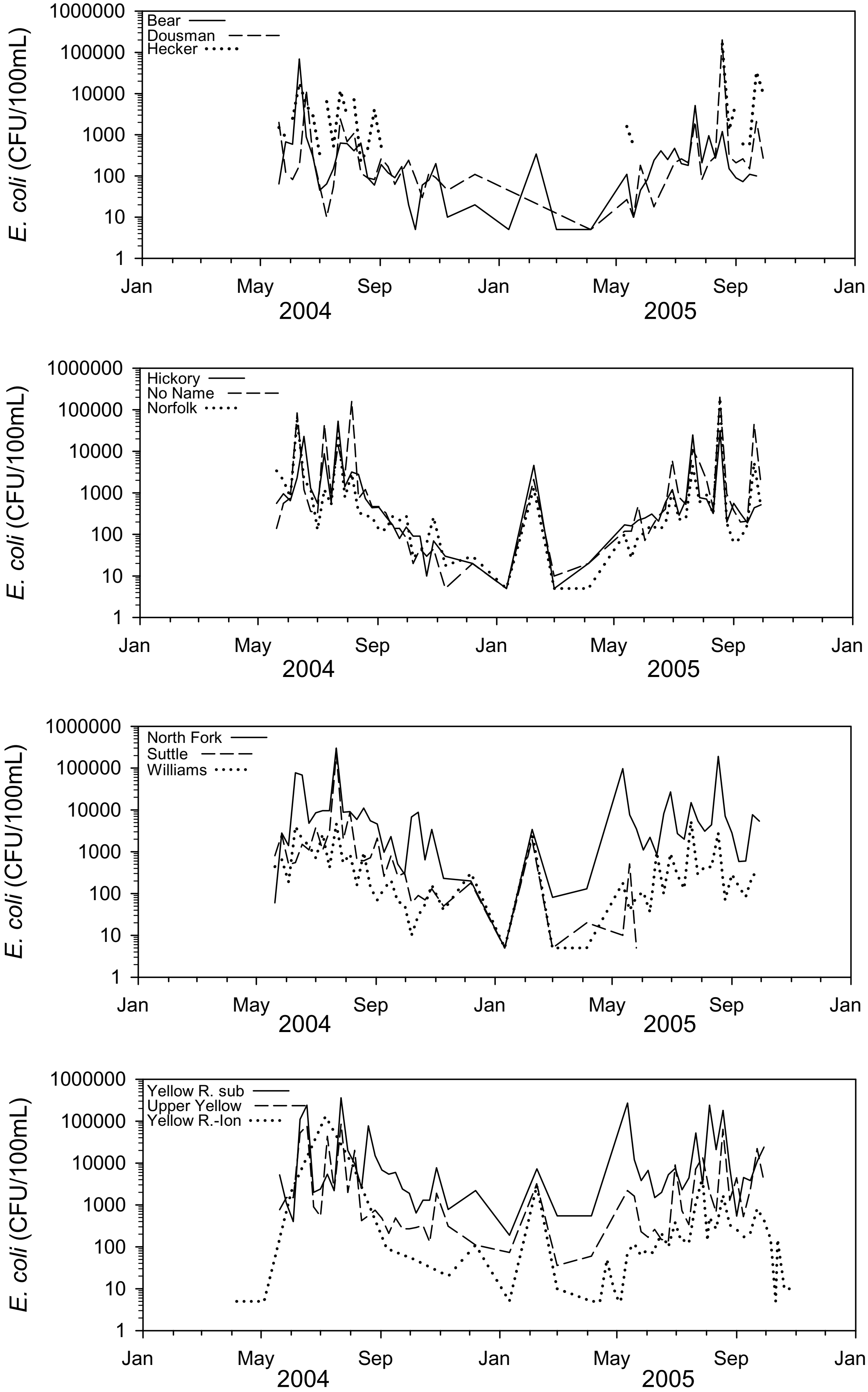
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Chloride (mg/L)
10000
1000
100
10
1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

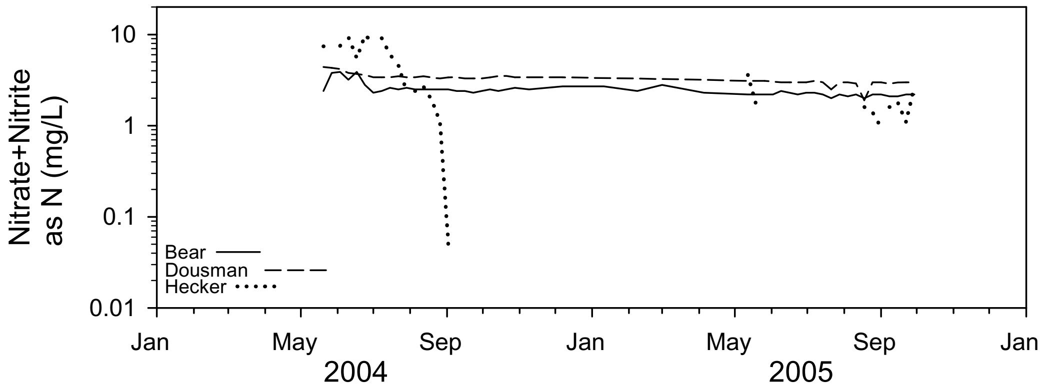

Dissolved Oxygen (mg/L)
Bear
Dousman
Hecker
0
5
10
15
20
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

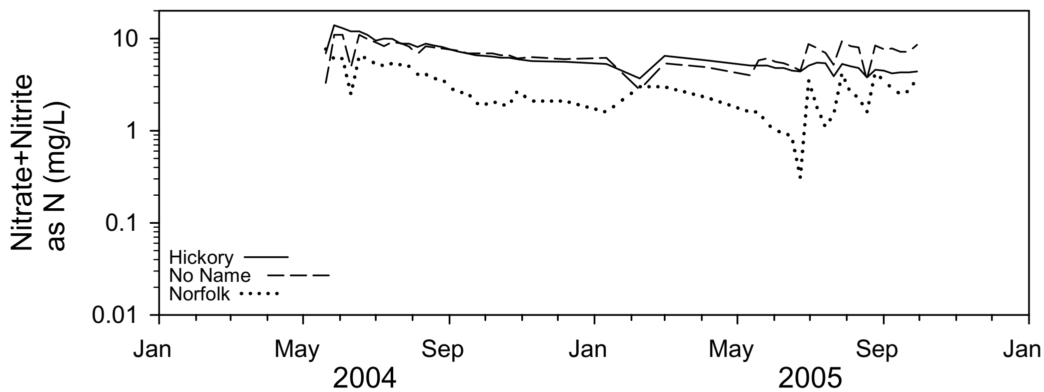

Dissolved Oxygen (mg/L)
Hickory
No Name
Norfolk
0
5
10
15
20
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

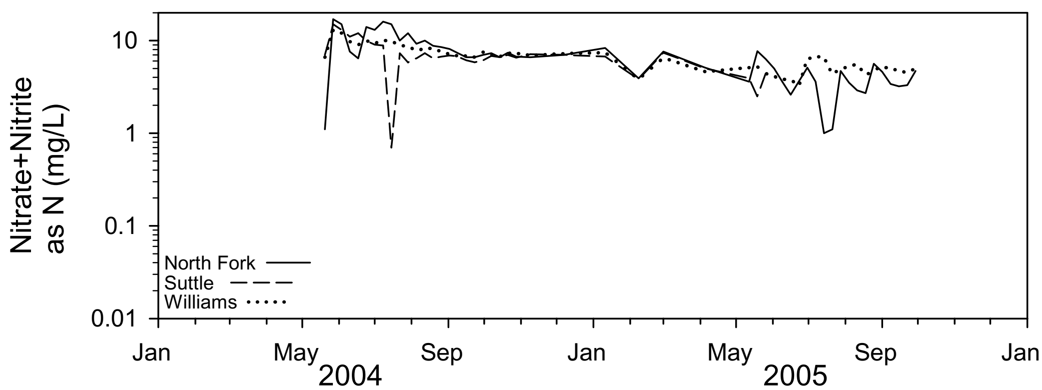

Dissolved Oxygen (mg/L)
North Fork
Suttle
Williams
0
5
10
15
20
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

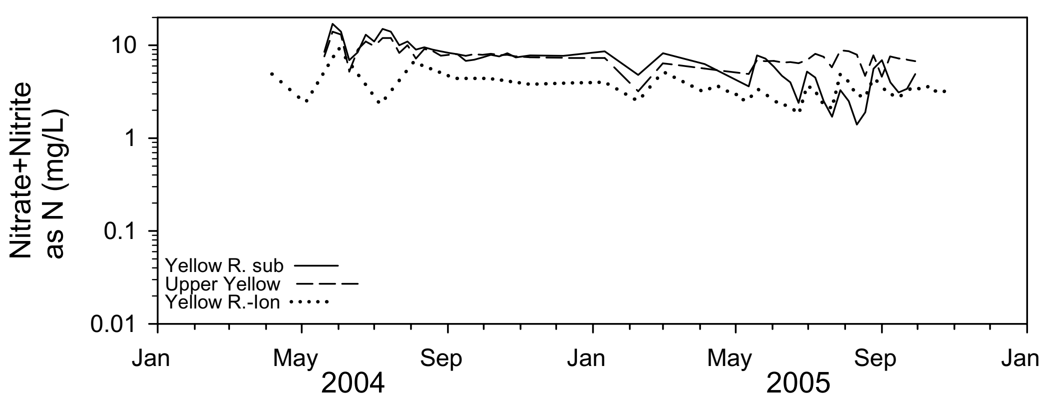

Dissolved Oxygen (mg/L)
Yellow R. sub
Upper Yellow
Yellow R.-Ion
0
5
10
15
20
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

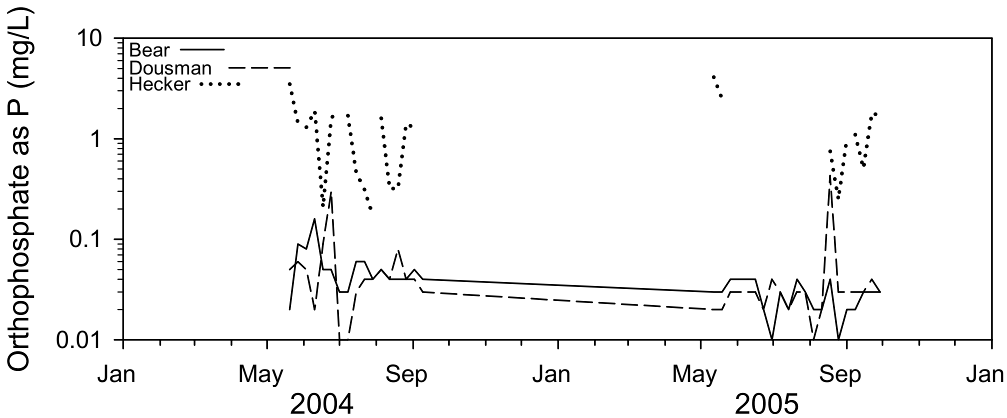

Bear
Dousman
Hecker
Hickory
No Name
Norfolk
North Fork
Suttle
Williams
Yellow R. sub
Upper Yellow
Yellow R.-Ion
E. coli (CFU/100mL)
1000000
100000
10000
1000
100
10
1
Jan
May
Sep
2004
2005

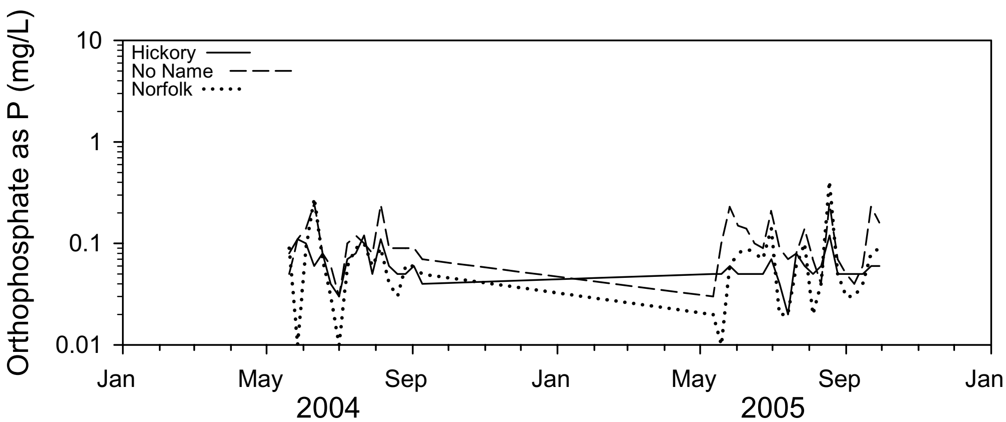

Nitrate+Nitrite as N (mg/L)
10
1
0.1
0.01
Bear
Dousman
Hecker
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

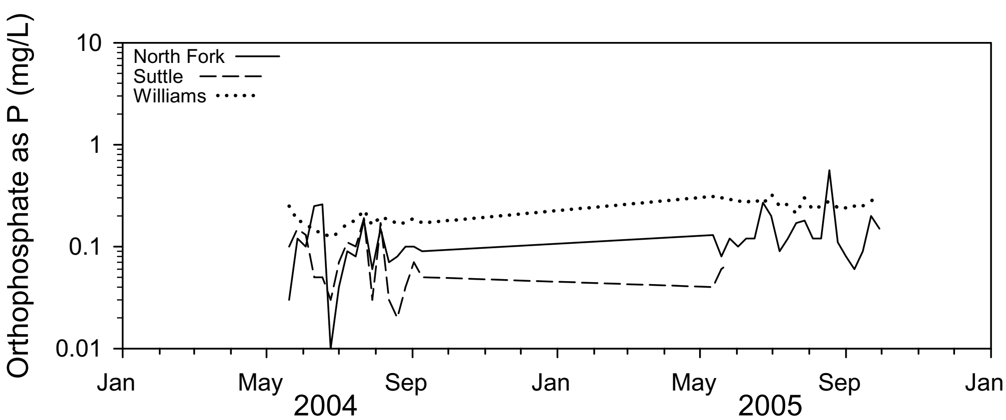

Nitrate+Nitrite as N (mg/L)
10
1
0.1
0.01
Hickory
No Name
Norfolk
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

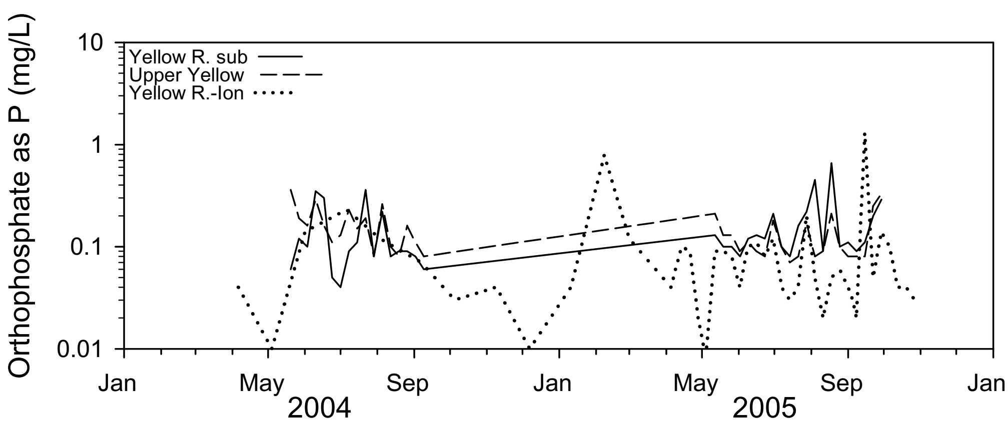

Nitrate+Nitrite as N (mg/L)
10
1
0.1
0.01
North Fork
Suttle
Williams
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

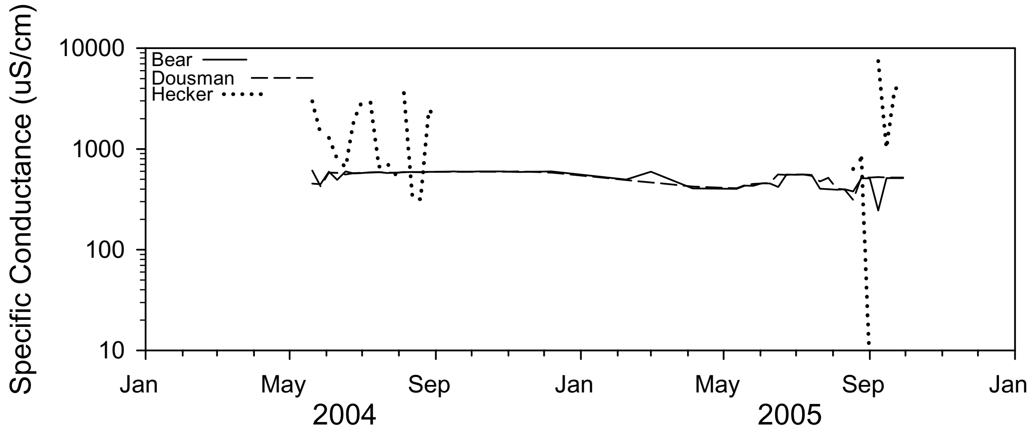

Nitrate+Nitrite as N (mg/L)
10
1
0.1
0.01
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

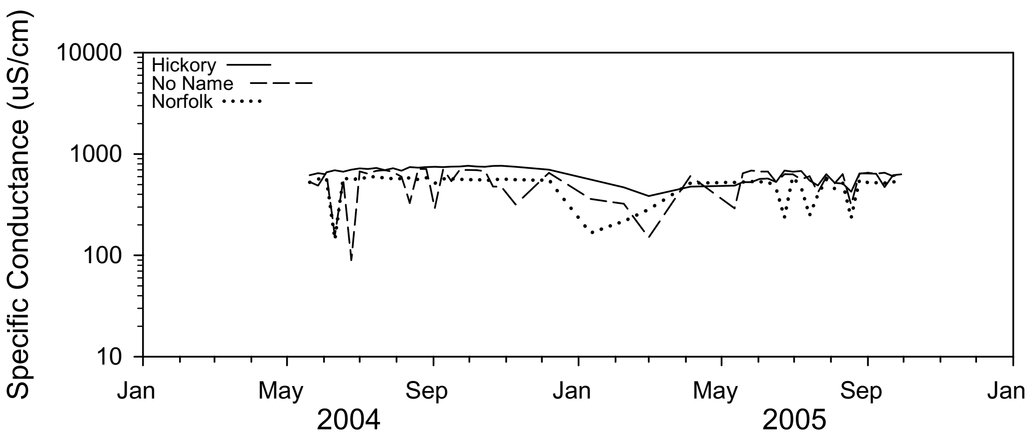

Orthophosphate as P (mg/L)
10
1
0.1
0.01
Bear
Dousman
Hecker
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

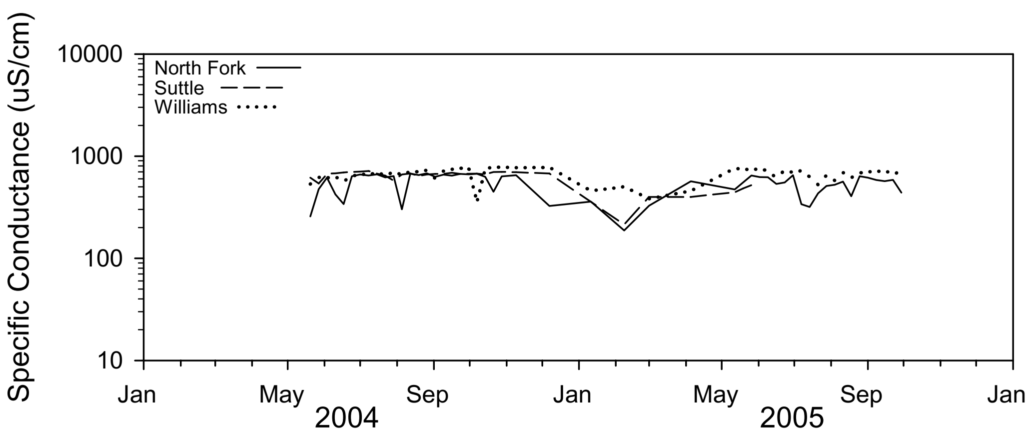

Orthophosphate as P (mg/L)
10
1
0.1
0.01
Hickory
No Name
Norfolk
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

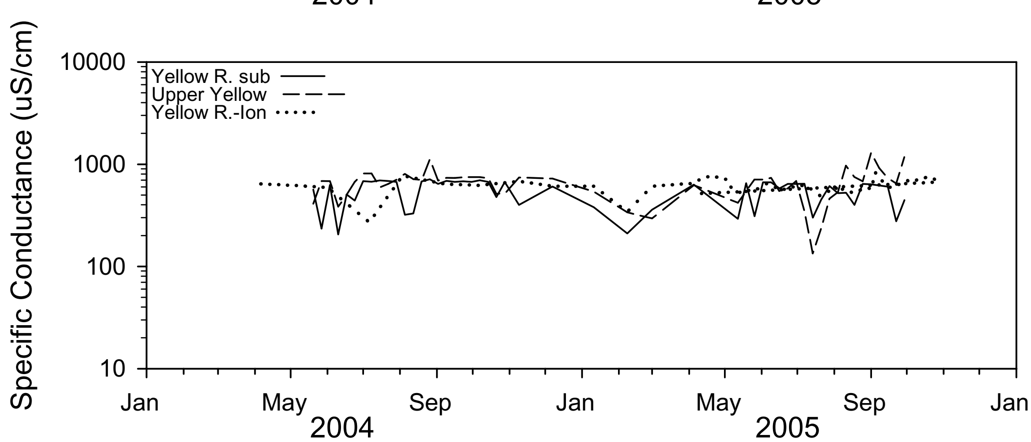

Orthophosphate as P (mg/L)
10
1
0.1
0.01
North Fork
Suttle
Williams
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

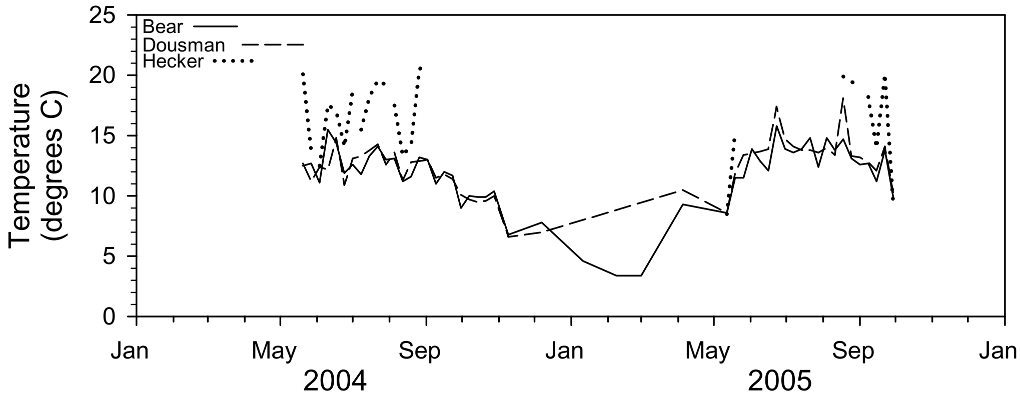

Orthophosphate as P (mg/L)
10
1
0.1
0.01
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005


Specific Conductance (uS/cm)
10000
1000
100
10
Bear
Dousman
Hecker
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

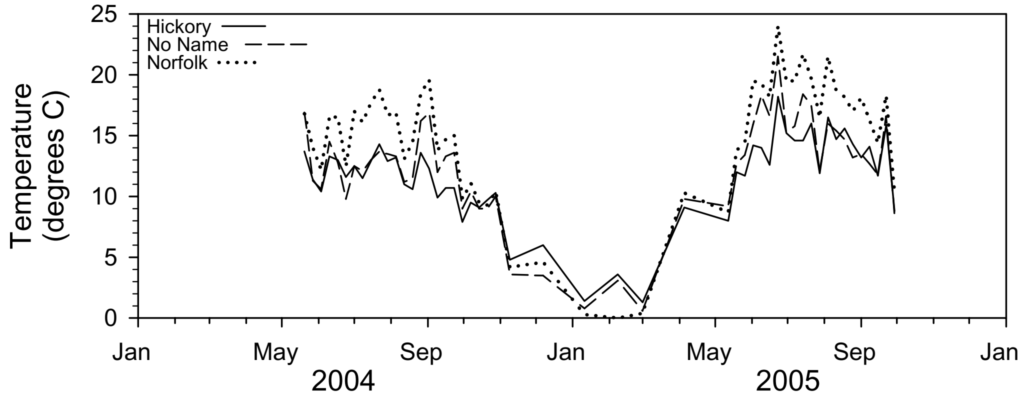

Specific Conductance (uS/cm)
10000
1000
100
10
Hickory
No Name
Norfolk
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005


Specific Conductance (uS/cm)
10000
1000
100
10
North Fork
Suttle
Williams
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

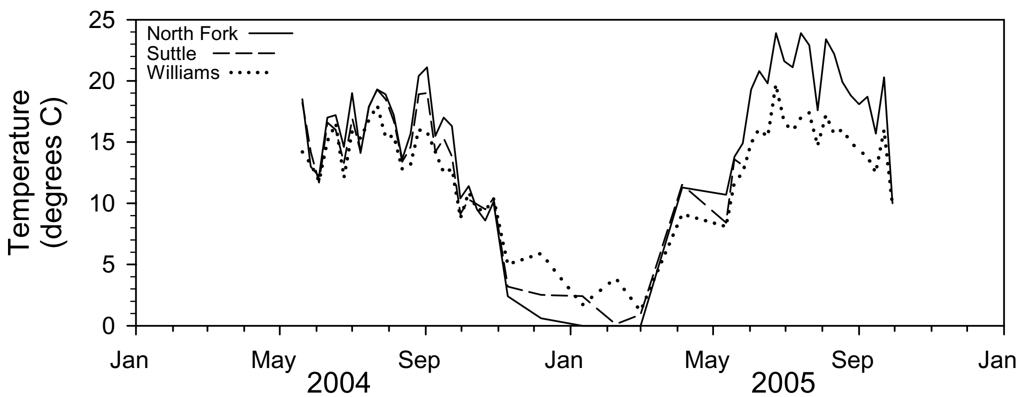

Specific Conductance (uS/cm)
10000
1000
100
10
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005



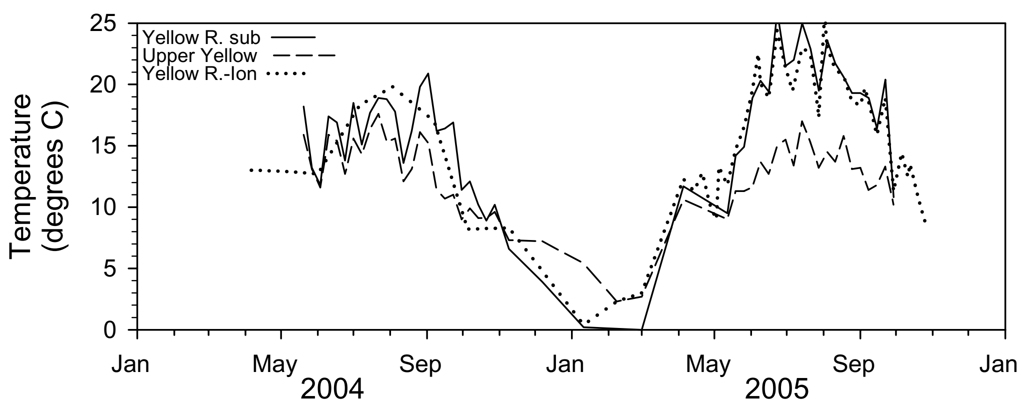
Bear
Dousman
Hecker
Temperature (degrees C)
0
5
10
15
20
25
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005



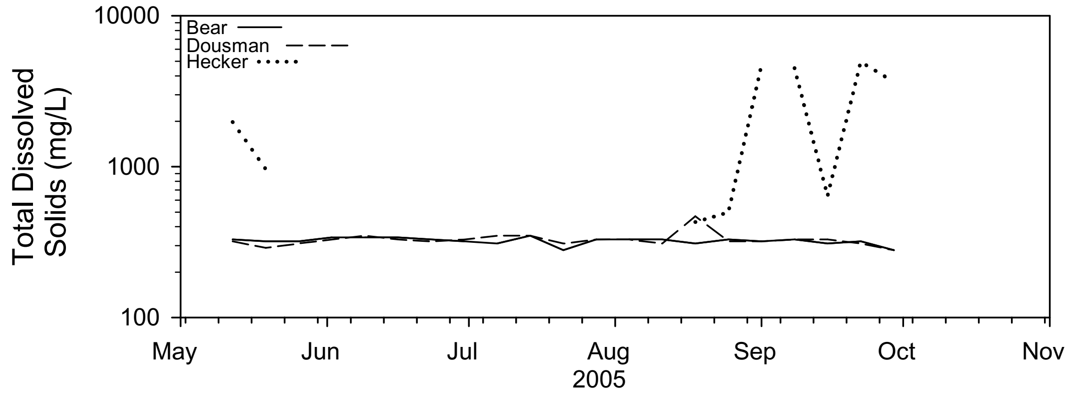
Hickory
No Name
Norfolk
Temperature (degrees C)
0
5
10
15
20
25
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

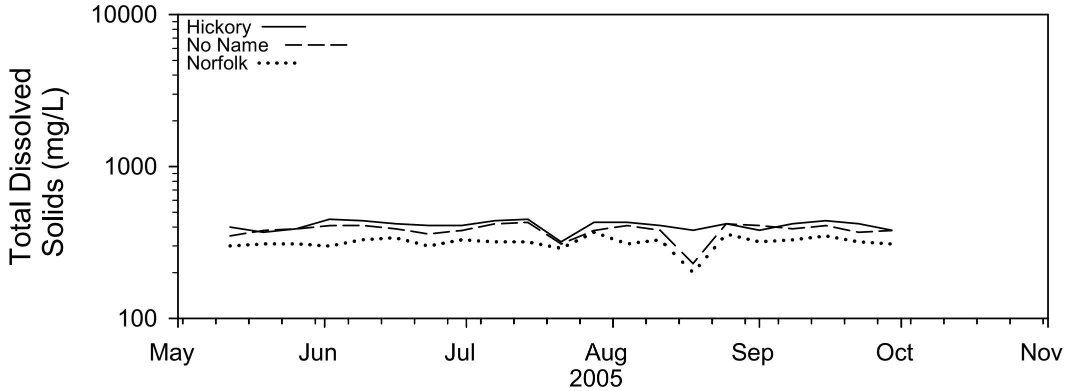


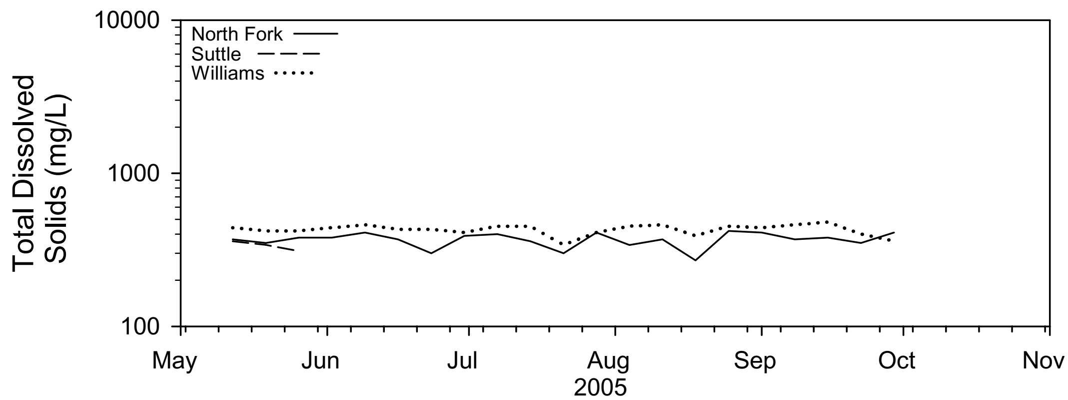
North Fork
Suttle
Williams
Temperature (degrees C)
0
5
10
15
20
25
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

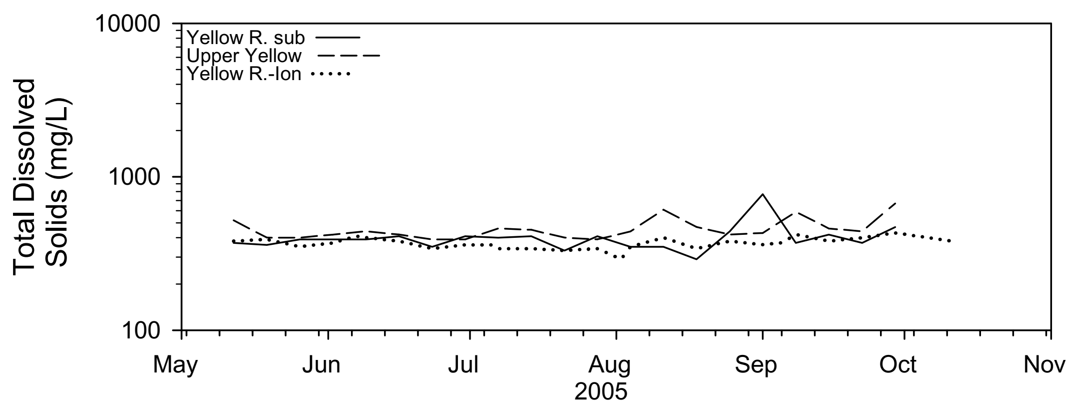


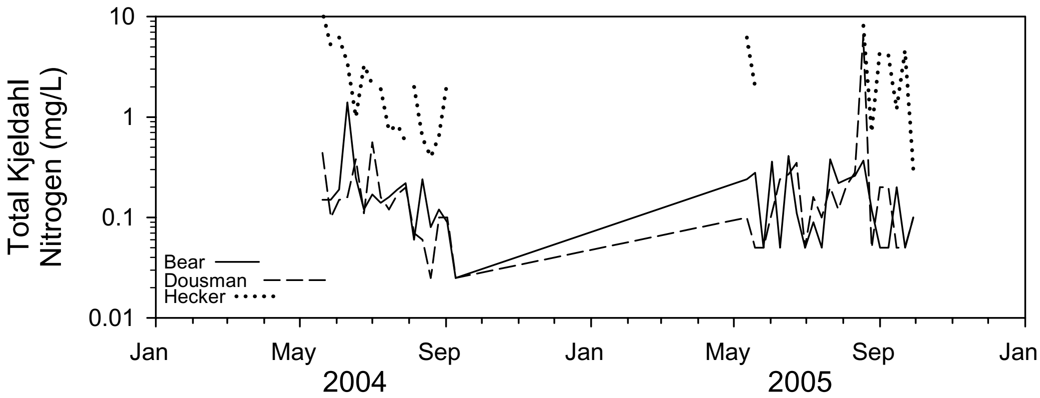
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Temperature (degrees C)
0
5
10
15
20
25
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

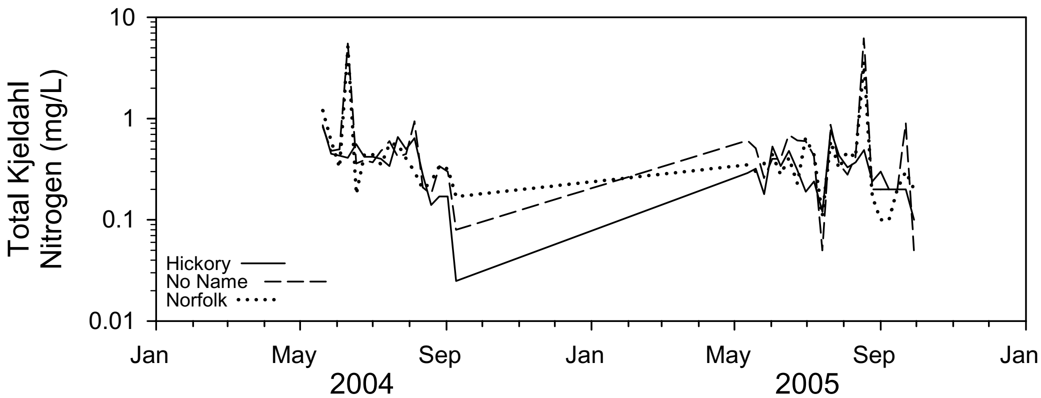

Bear
Dousman
Hecker
Total Dissolved Solids (mg/L)
10000
1000
100
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

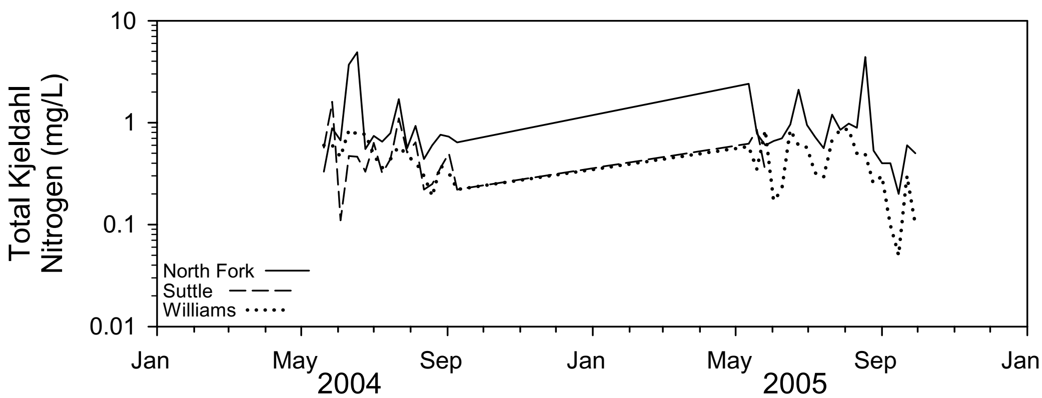

Hickory
No Name
Norfolk
Total Dissolved Solids (mg/L)
10000
1000
100
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

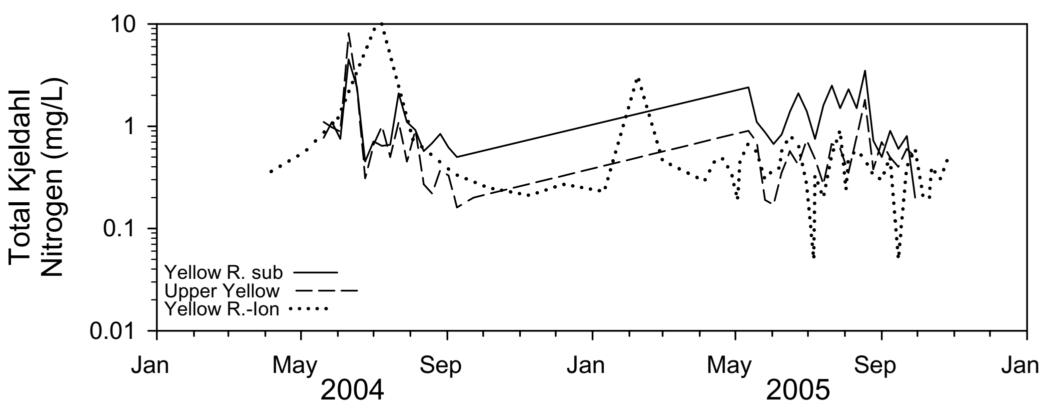

North Fork
Suttle
Williams
Total Dissolved Solids (mg/L)
10000
1000
100
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

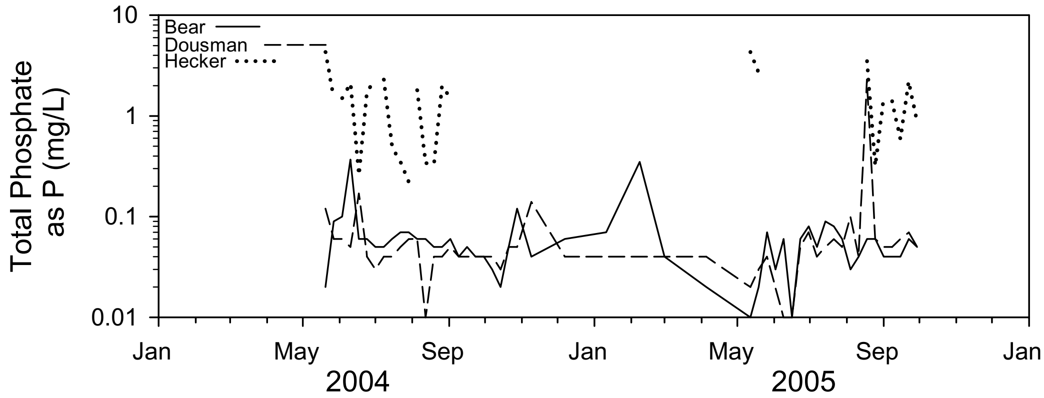

Yellow R. sub
Upper Yellow
Yellow R.-Ion
Total Dissolved Solids (mg/L)
10000
1000
100
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

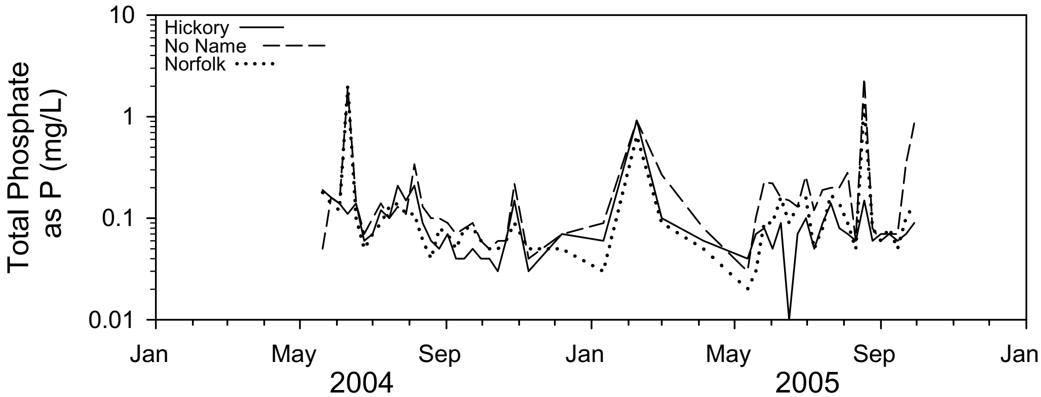

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
Bear
Dousman
Hecker
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

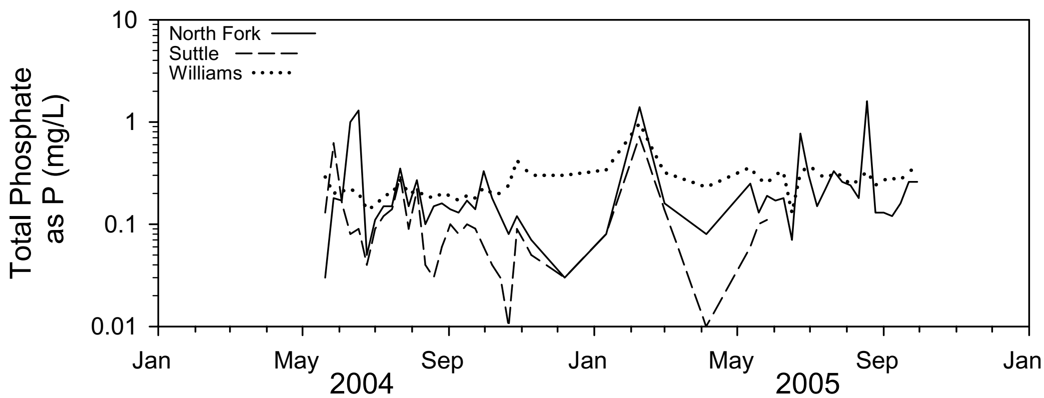

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
Hickory
No Name
Norfolk
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

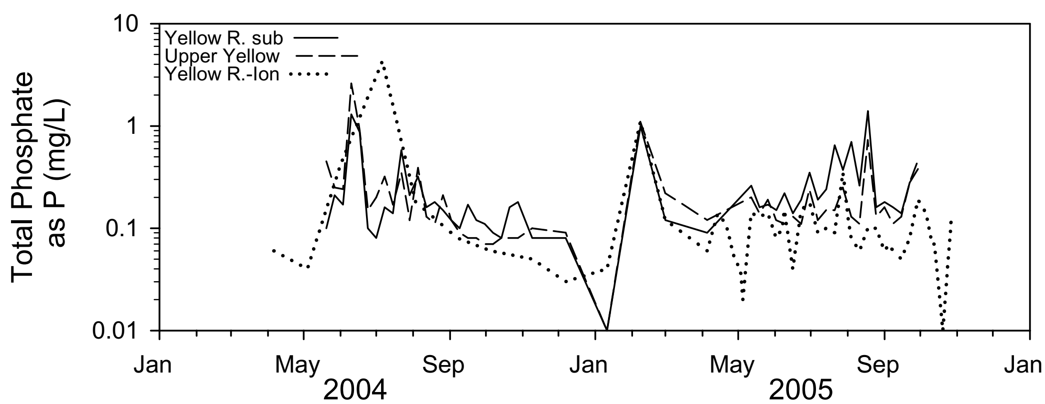

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
North Fork
Suttle
Williams
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

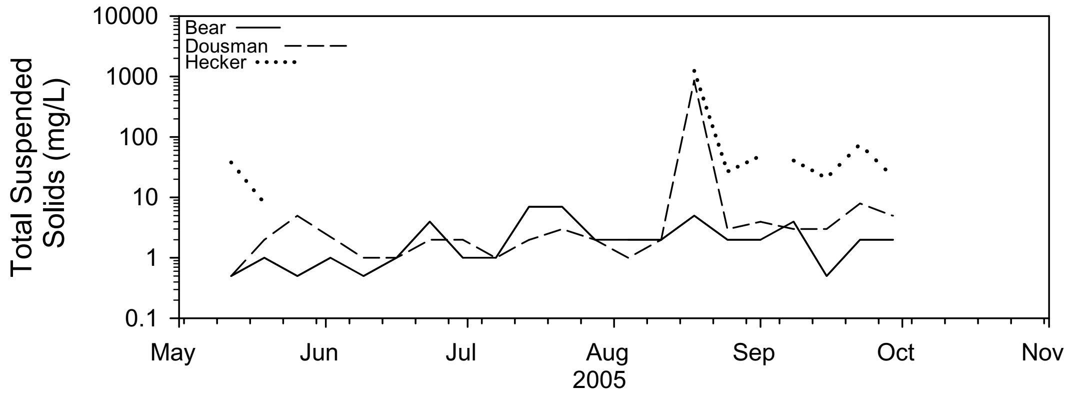

Total Kjeldahl Nitrogen (mg/L)
10
1
0.1
0.01
Yellow R. sub
Upper Yellow
Yellow R.-Ion
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

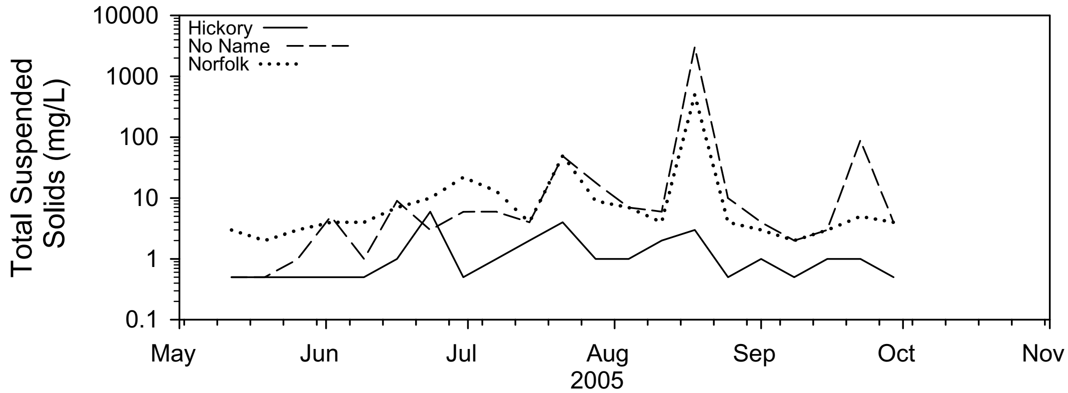

Bear
Dousman
Hecker
Total Phosphate as P (mg/L)
10
1
0.1
0.01
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

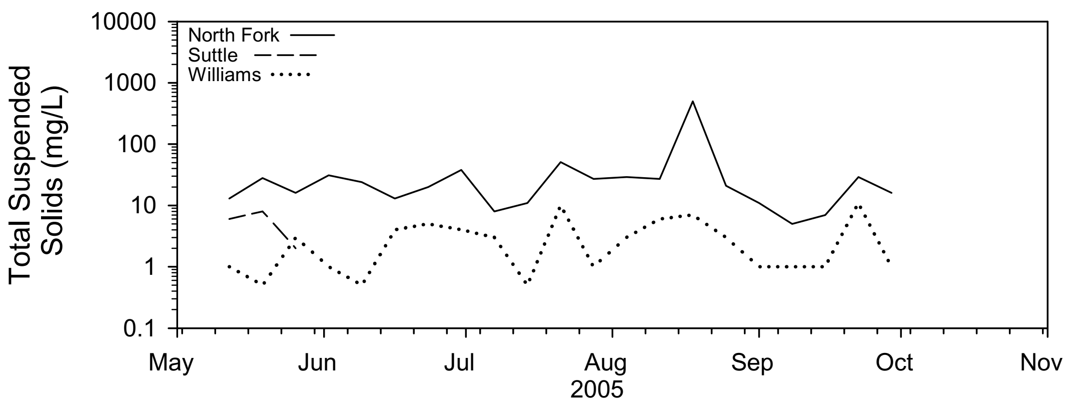

Hickory
No Name
Norfolk
Total Phosphate as P (mg/L)
10
1
0.1
0.01
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

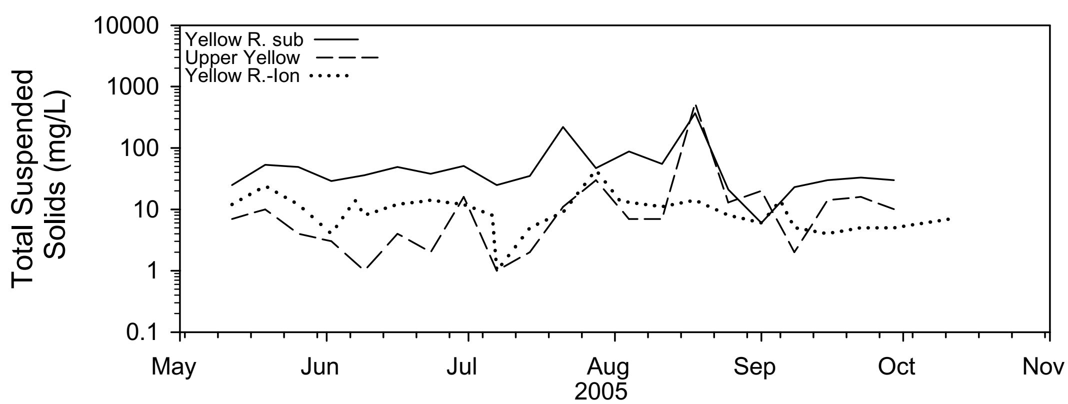

North Fork
Suttle
Williams
Total Phosphate as P (mg/L)
10
1
0.1
0.01
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

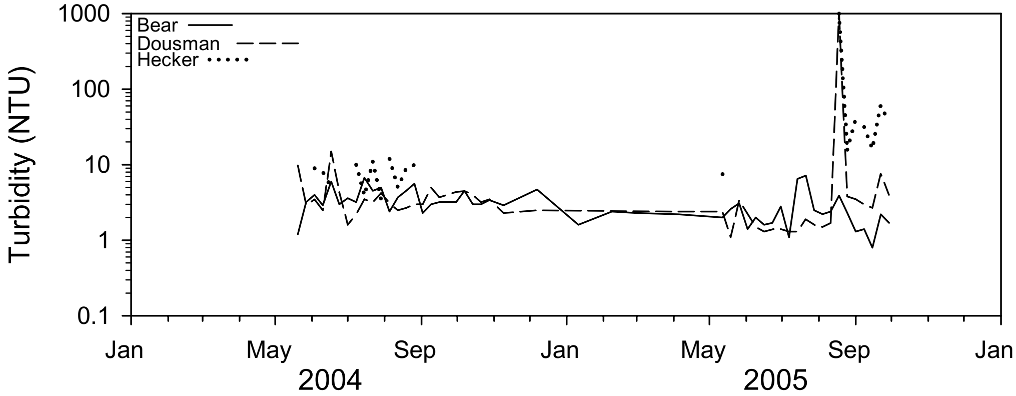

Yellow R. sub
Upper Yellow
Yellow R.-Ion
Total Phosphate as P (mg/L)
10
1
0.1
0.01
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

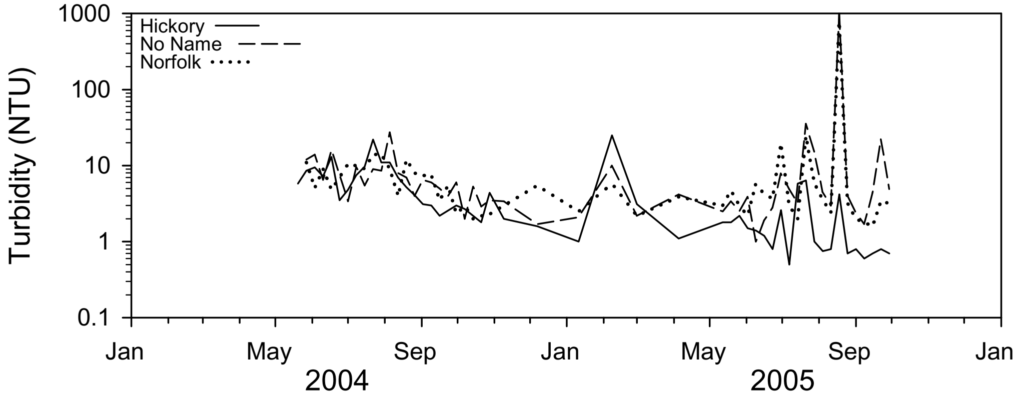

Total Suspended Solids (mg/L)
Bear
Dousman
Hecker
10000
1000
100
10
1
0.1
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

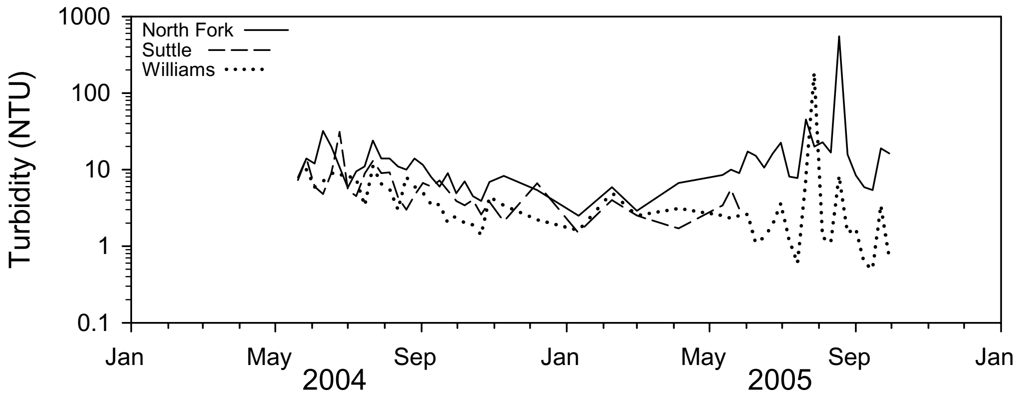

Total Suspended Solids (mg/L)
Hickory
No Name
Norfolk
10000
1000
100
10
1
0.1
May
Jun
Jul
Aug
Sep
Oct
Nov
2005

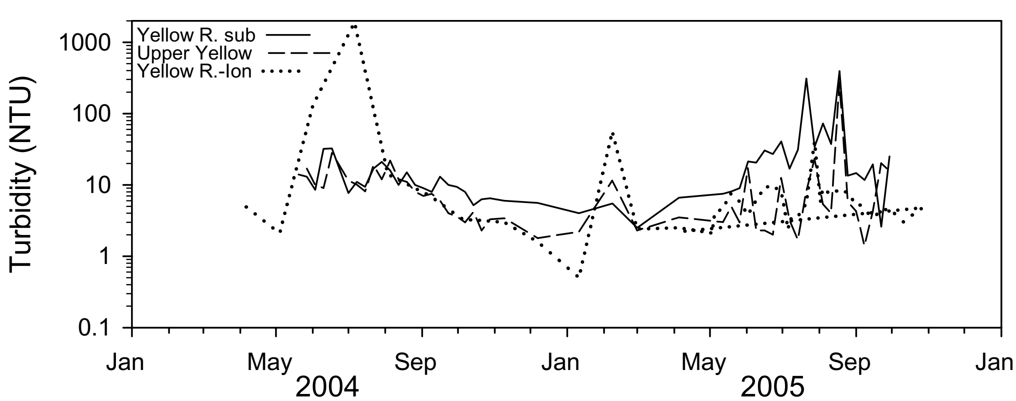

Total Suspended Solids (mg/L)
North Fork
Suttle
Williams
10000
1000
100
10
1
0.1
May
Jun
Jul
Aug
Sep
Oct
Nov
2005


Total Suspended Solids (mg/L)
Yellow R. sub
Upper Yellow
Yellow R.-Ion
10000
1000
100
10
1
0.1
May
Jun
Jul
Aug
Sep
Oct
Nov
2005


Turbidity (NTU)
Bear
Dousman
Hecker
1000
100
10
1
0.1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

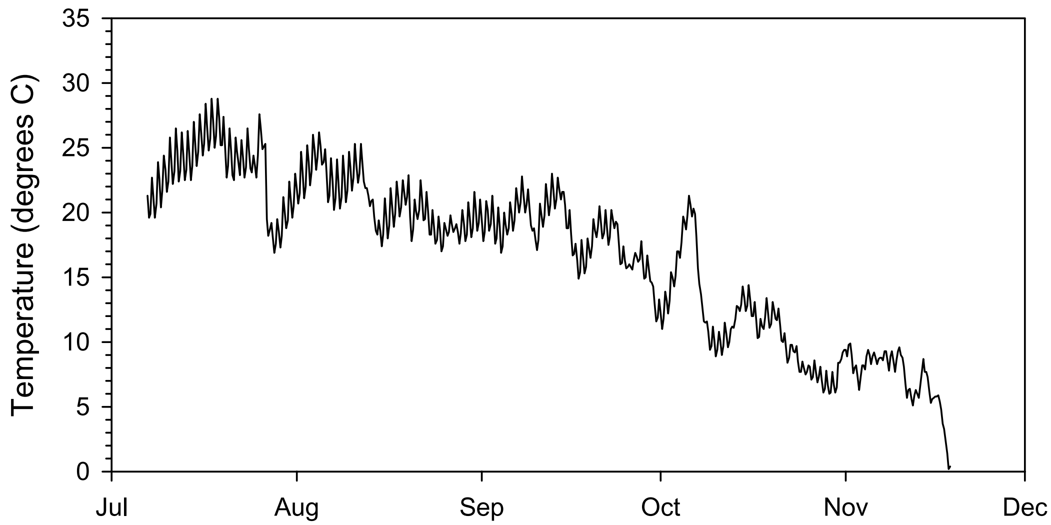

Turbidity (NTU)
Hickory
No Name
Norfolk
1000
100
10
1
0.1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005


Turbidity (NTU)
North Fork
Suttle
Williams
1000
100
10
1
0.1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

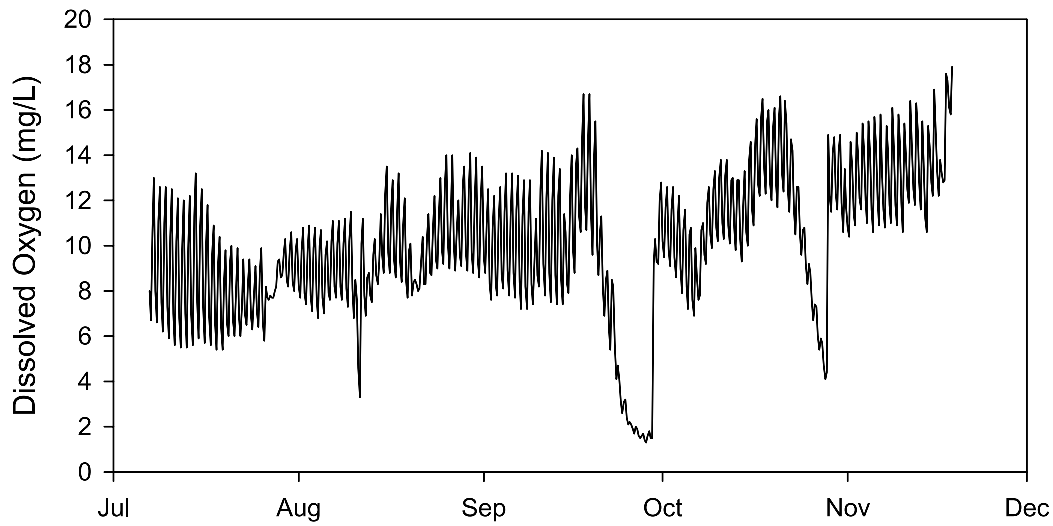

Turbidity (NTU)
Yellow R. sub
Upper Yellow
Yellow R.-Ion
1000
100
10
1
0.1
Jan
May
Sep
Jan
May
Sep
Jan
2004
2005

APPENDIX G.

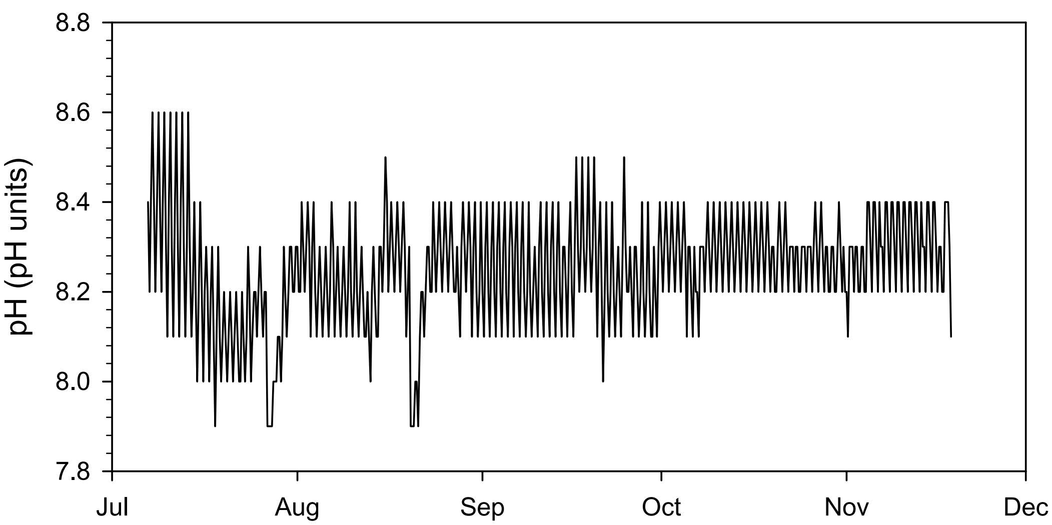
Provisional water quality data collected with a YSI 6600 EDS in 2005.



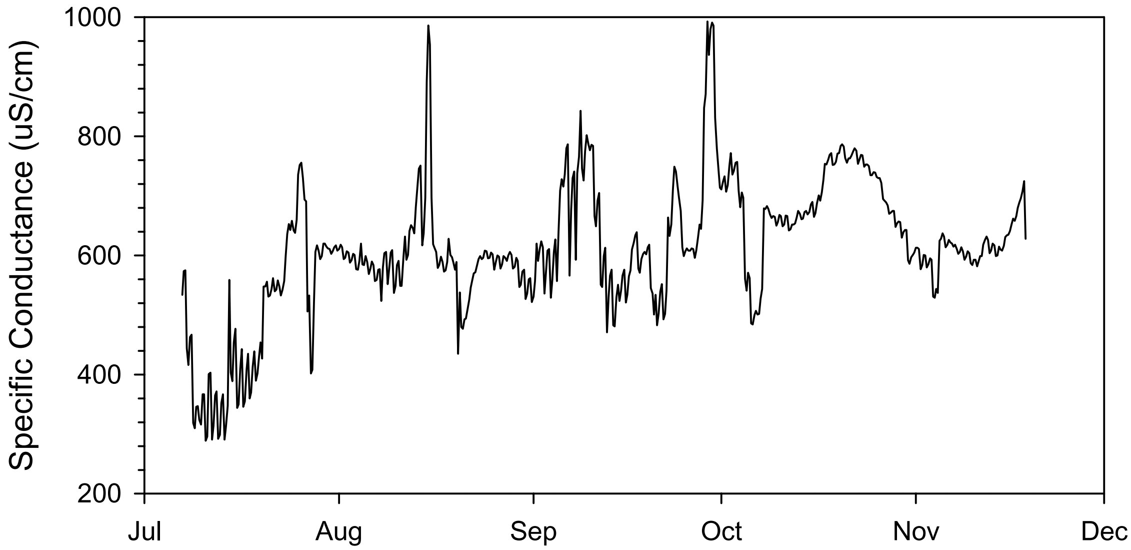
Temperature (degrees C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec



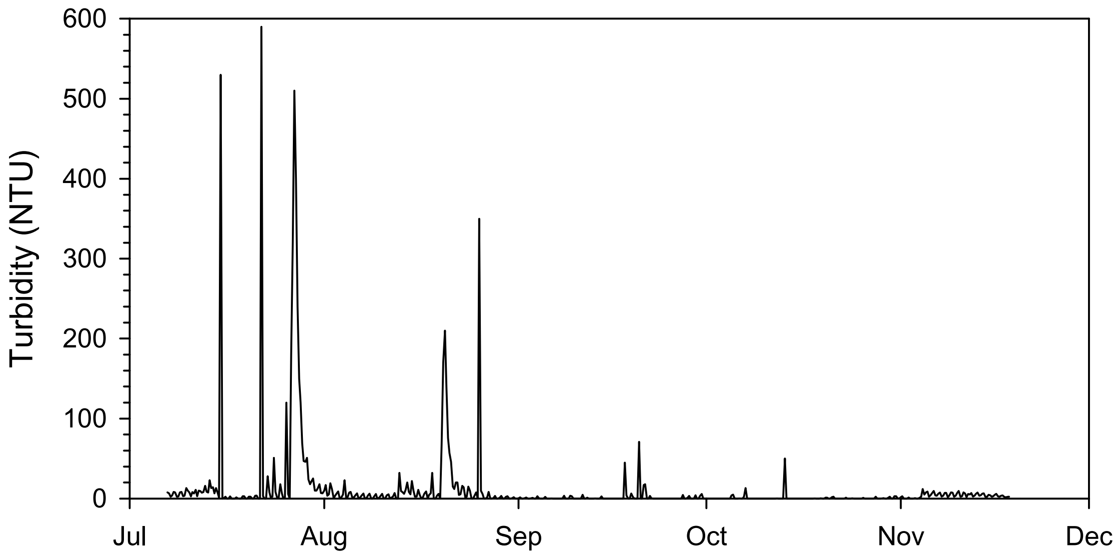
Dissolved Oxygen (mg/L)
20
18
16
14
12
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec



pH (pH units)
8.8
8.6
8.4
8.2
8.0
7.8
Jul
Aug
Sep
Oct
Nov
Dec



Specific Conductance (uS/cm)
1000
800
600
400
200
Jul
Aug
Sep
Oct
Nov
Dec



Turbidity (NTU)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec

APPENDIX H.

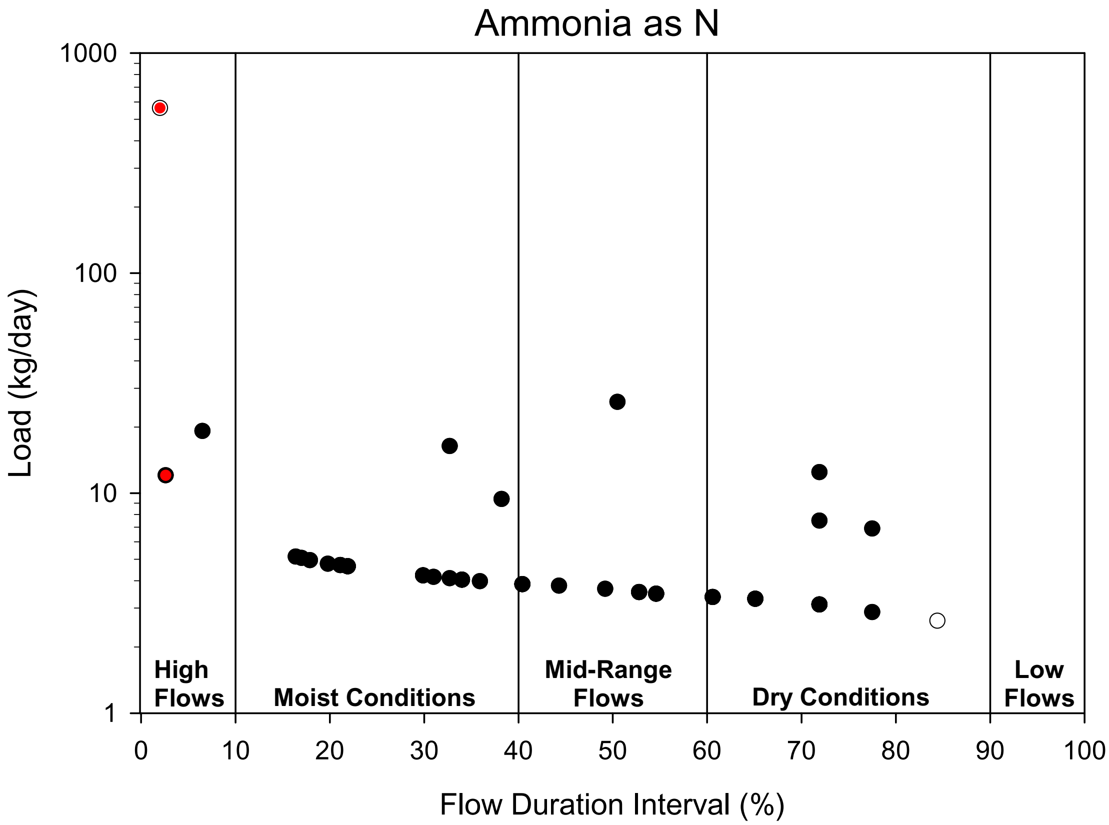
Benthic macroinvertebrate indices for the Yellow River watershed based on averages of data collected in 2004 and 2005.

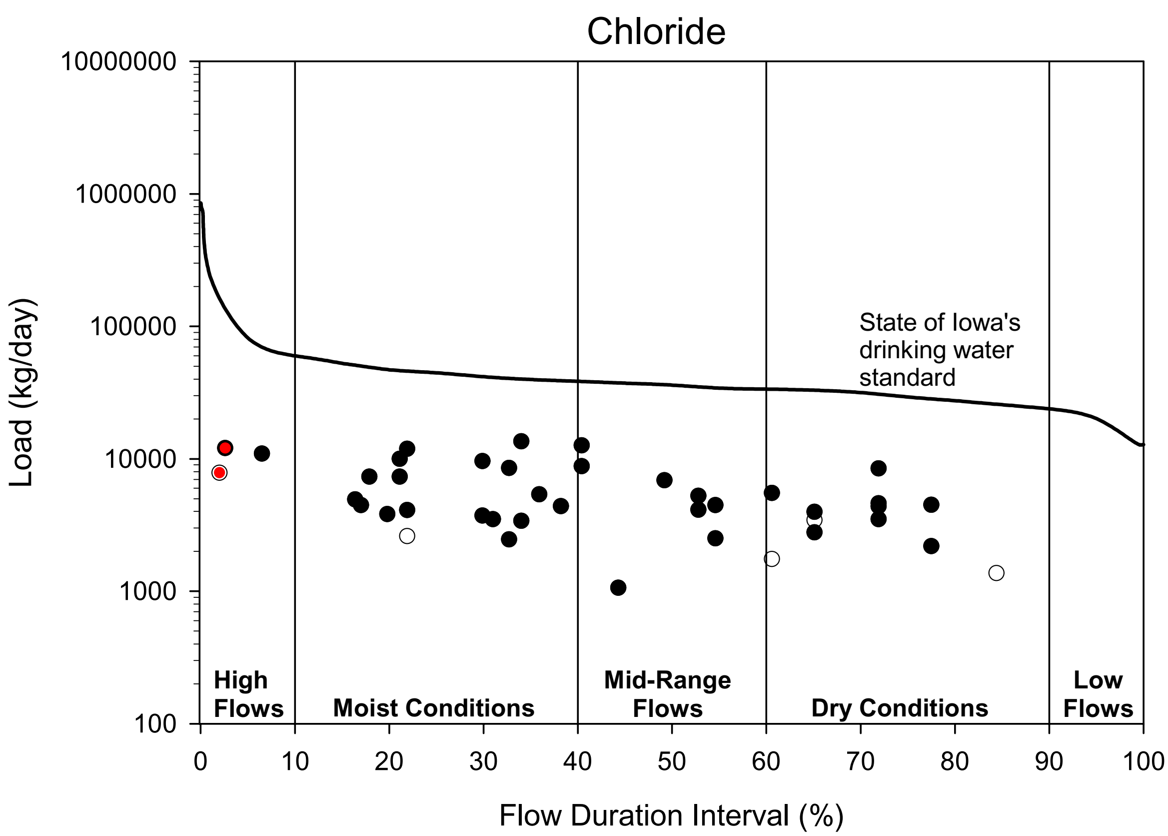
Water Quality[1] (Range of family-level IBI values)	Sub-watershed	Family-level IBI[1] (±1SE)	% EPT[2] (±1SE)	%Chironomids[3] (±1SE)	No. of Taxa[4] (±1SE)
Excellent, organic pollution unlikely (0.00-3.75)					
Very good, possible slight organic pollution (3.76-4.25)	Norfolk	4.07 (±0.00)	66.2 (±13.5)	2.2 (±1.0)	17 (±4)
	Dousman	4.14 (±1.33)	35.5 (±26.3)	23.4 (±22.5)	19 (±0)
	Yellow River-Lower/Ion	4.15 (±0.15)	56.7 (±1.8)	7.7 (±5.8)	20 (±3)
	Bear	4.17 (±0.25)	74.0 (±16.1)	5.2 (±4.0)	20 (±4)
Good, some organic pollution probable (4.26-5.00)	Yellow River-Sub	4.31 (±0.30)	48.4 (±11.2)	11.7 (±8.4)	17 (±1)
	No Name	4.39 (±0.28)	70.2 (±13.5)	2.7 (±1.8)	16 (±1)
	Hickory	4.41 (±0.23)	63.4 (±3.8)	7.6 (±6.7)	19 (±1)
	Williams	4.55 (±0.52)	63.7 (±19.7)	3.8 (±3.8)	15 (±2)
	Suttle[5]	4.55	54.4	27.4	21
	North Fork	4.57 (±0.45)	59.2 (±13.6)	11.39 (±5.5)	16 (±1)
	Upper Yellow	4.69 (±0.17)	75.9 (±4.5)	14.9 (±4.7)	16 (±2)
Fair, fairly substantial pollution likely (5.01-5.75)	Hecker	5.56 (±0.23)	21.4 (±11.9)	42.6 (±24.1)	12 (±2)
Fairly poor, substantial pollution likely (5.76-6.50)					
Poor, very substantial pollution likely (6.51-7.25)					
Very poor, severe organic pollution likely (7.26-10.00)					

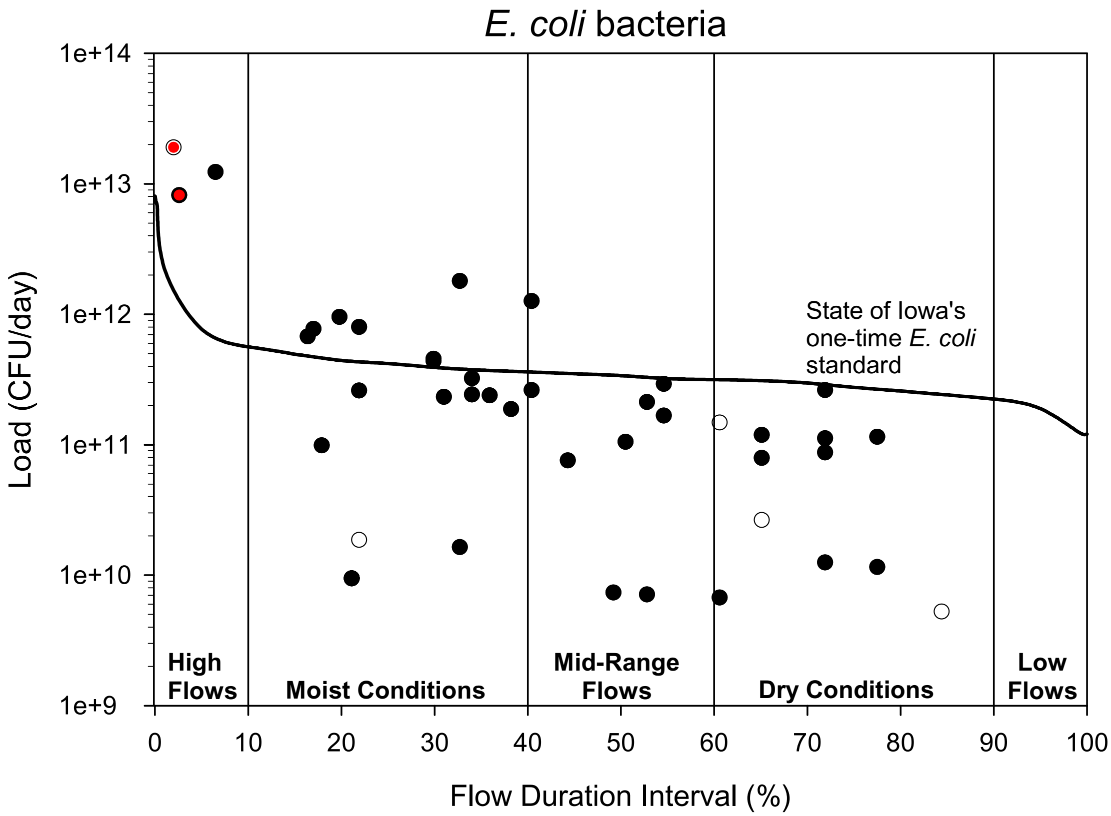
1 Based on Hilsenhoff, W.L. (1988).
2 Percentage of Ephemeroptera (mayflies), Plecotera (stoneflies), and Trichoptera (caddisflies) of each sample. A higher % EPT indicates good water quality.
3 Percentage of chironomids (blood worms) from each sample. A higher % chironomids indicates poor water quality.
4 Number of taxa is the number of macroinvertebrate families found in the qualitative sample at each site.
5 Suttle Creek was not sampled in 2005 due to low flow.

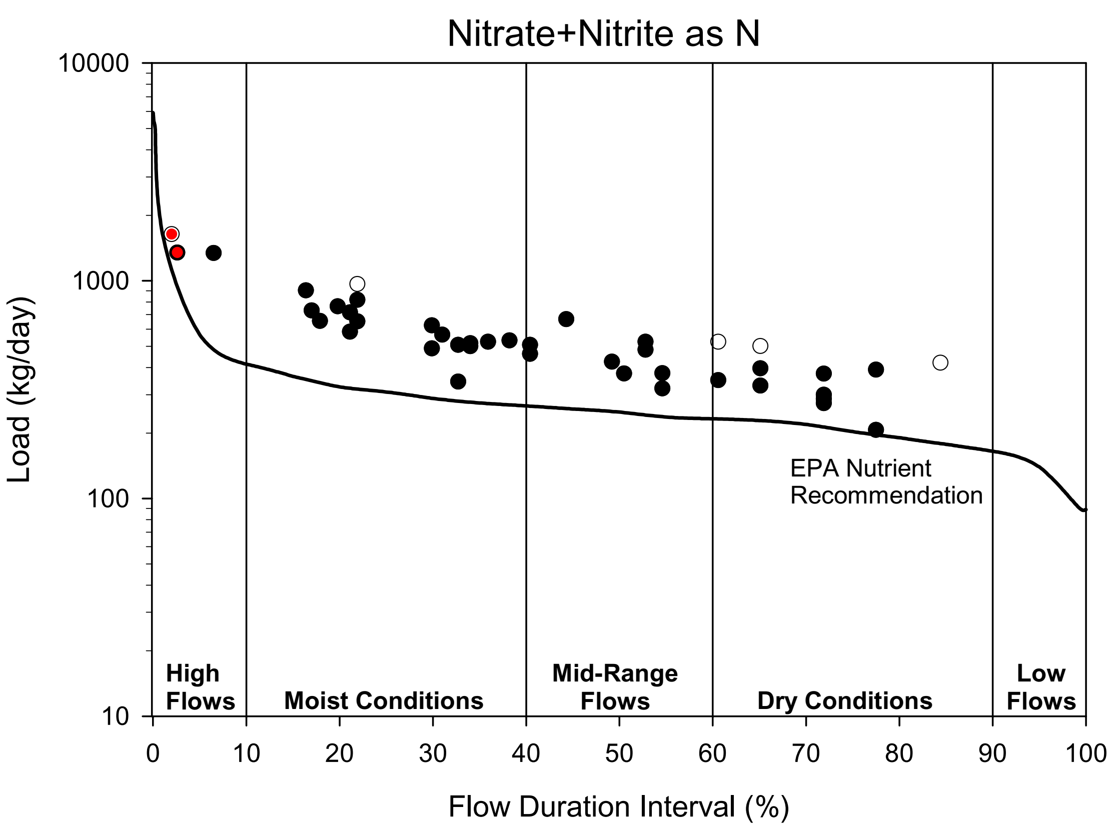
APPENDIX I.

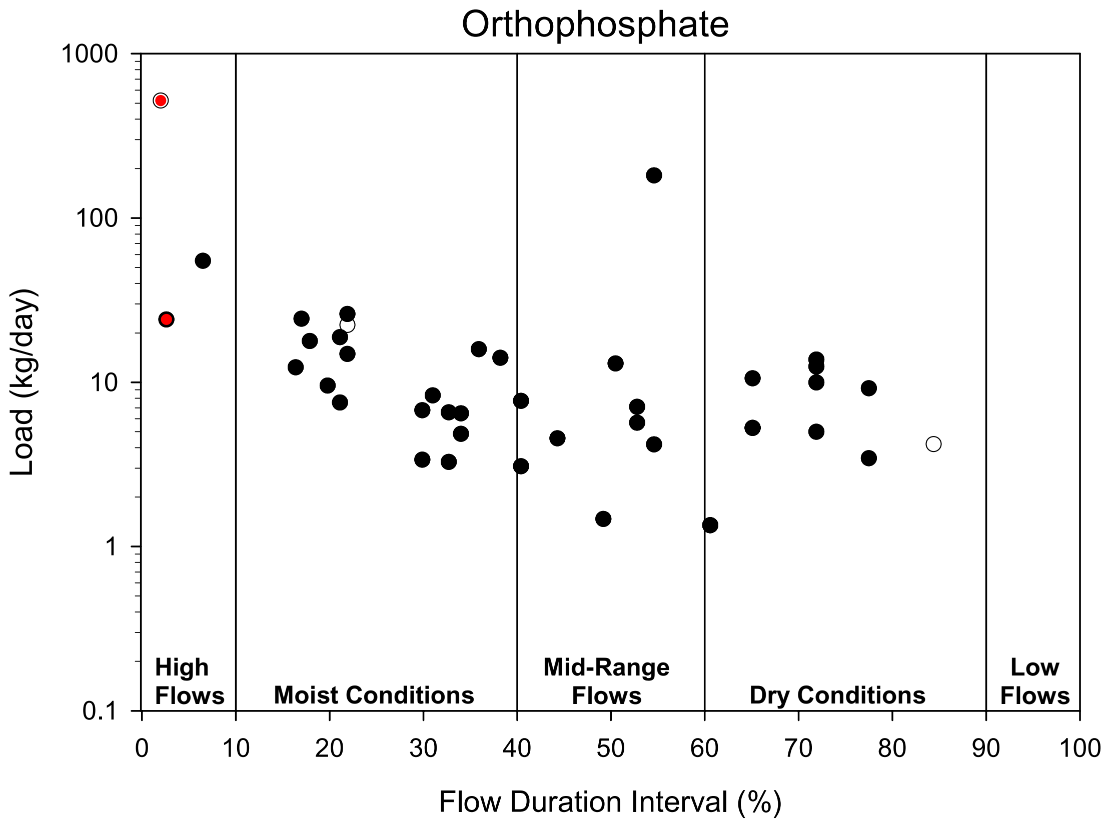
**Load duration curves for various parameters at the Yellow River-Ion site.
Black circles represent data collected from April through November.
Hollow circles represent data collected from December through March.
Red circles represent data collected during storm events.**

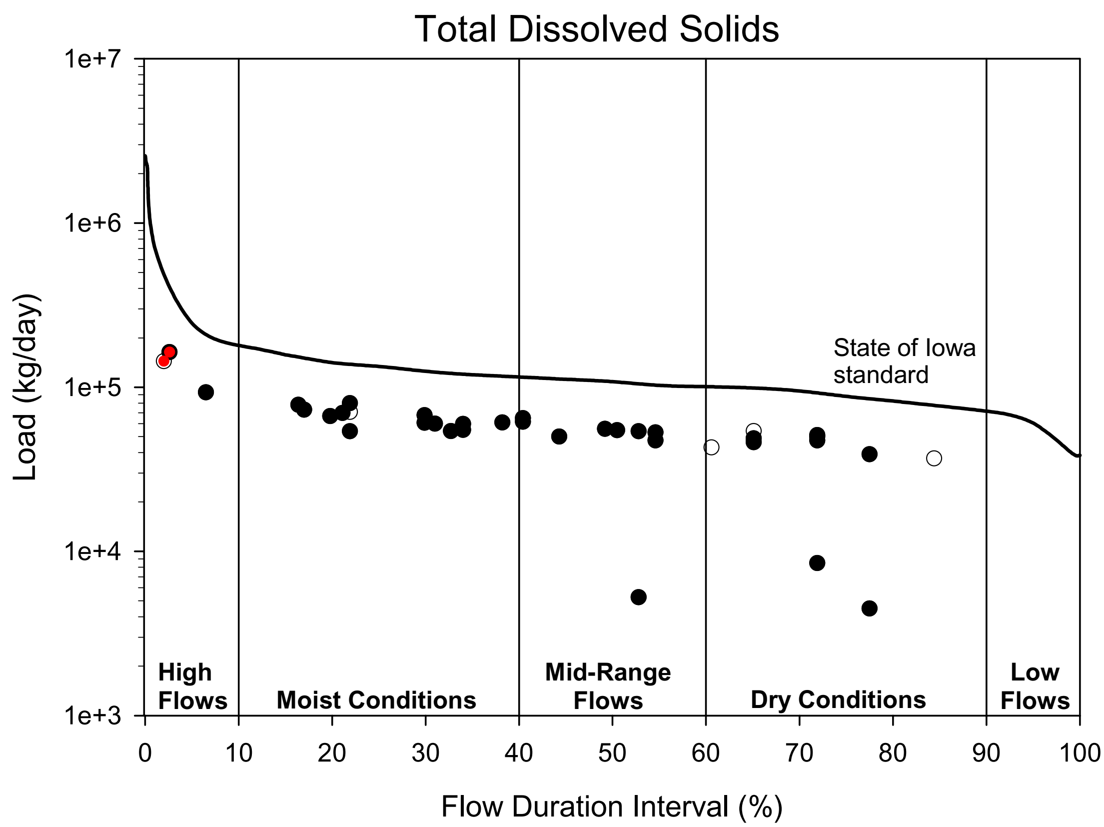

Ammonia as N
Load (kg/day)
1000
100
10
1
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)

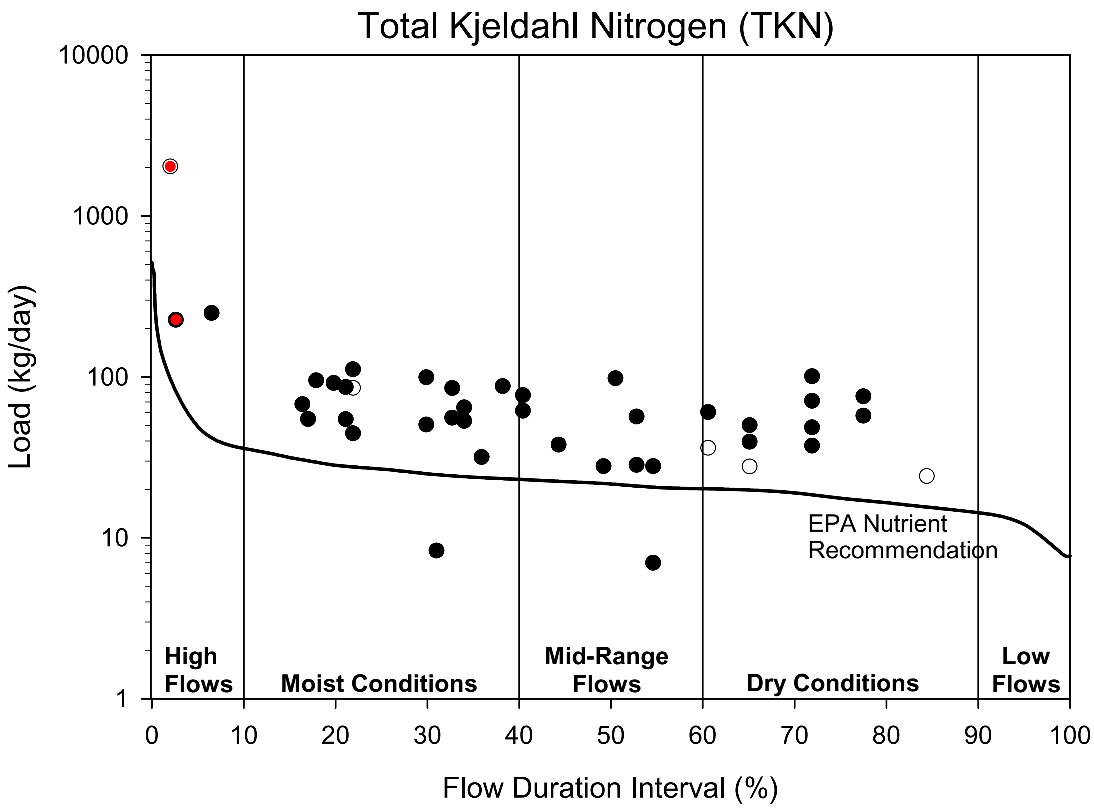

Chloride
Load (kg/day)
10000000
1000000
100000
10000
1000
100
State of Iowa's drinking water standard
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)

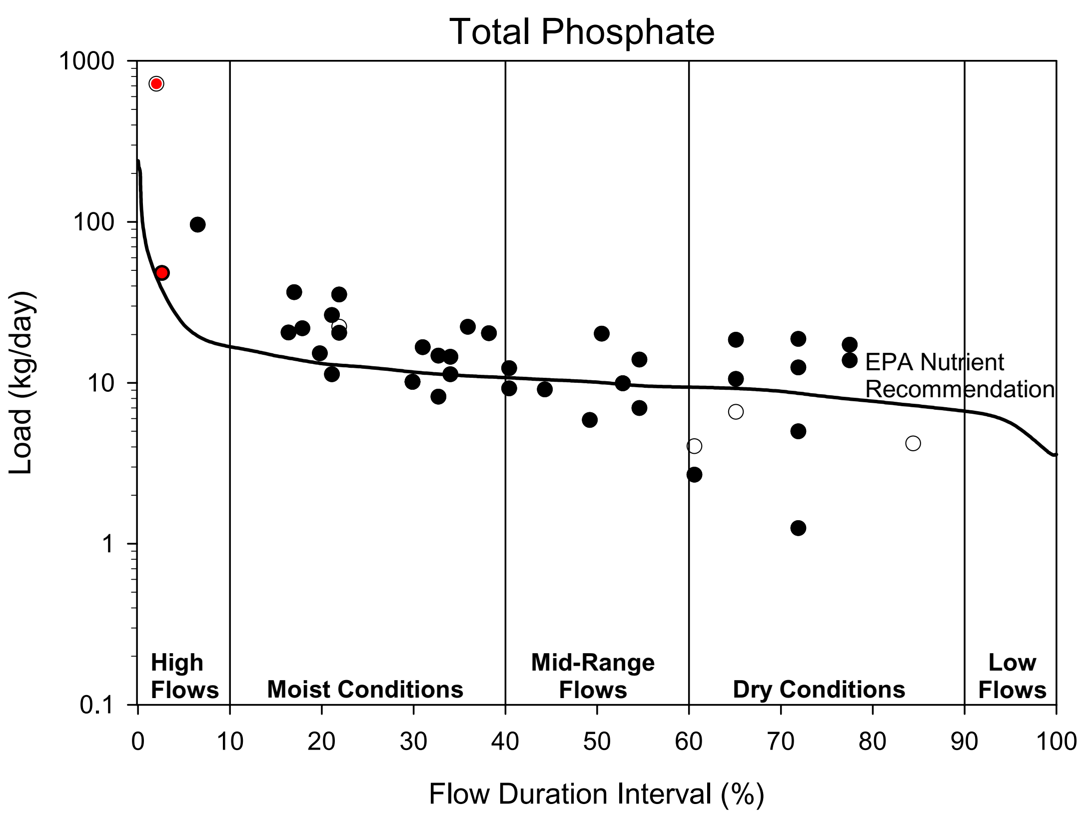

E. coli bacteria
Load (CFU/day)
1e+14
1e+13
1e+12
1e+11
1e+10
1e+9
State of Iowa's one-time E. coli standard
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)

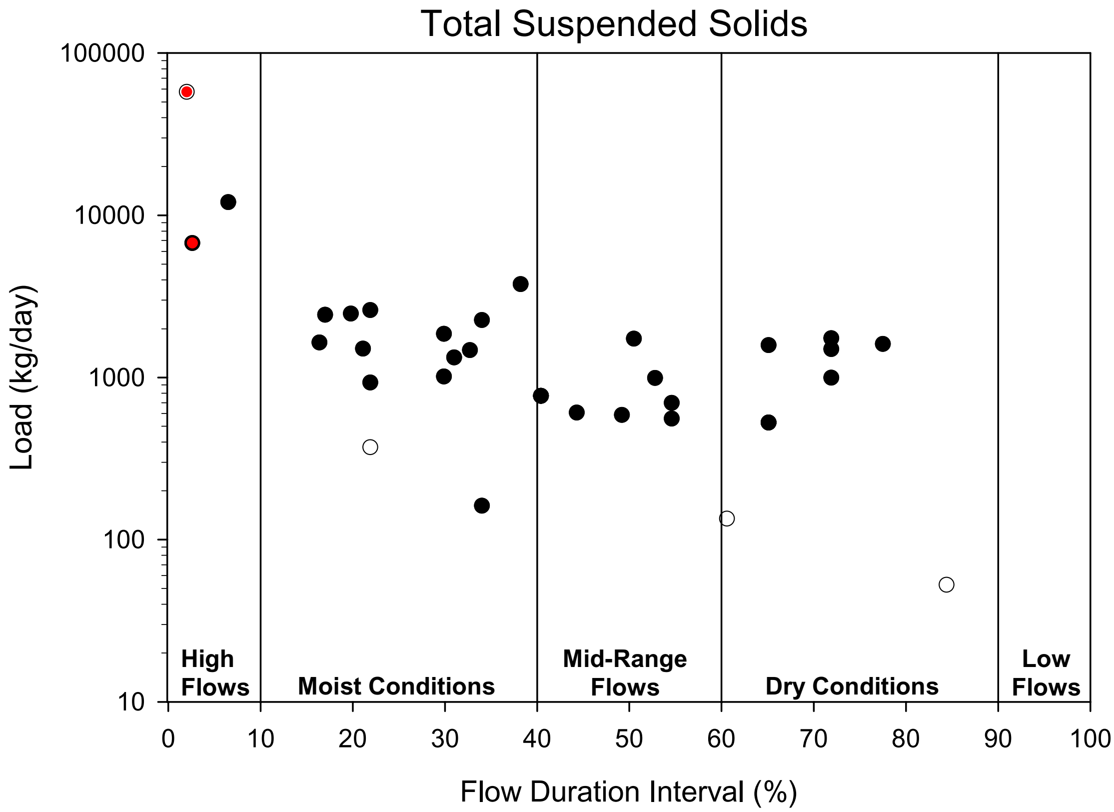

Nitrate+Nitrite as N
Load (kg/day)
10000
1000
100
10
EPA Nutrient Recommendation
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)


Orthophosphate
1000
100
10
1
0.1
Load (kg/day)
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0 10 20 30 40 50 60 70 80 90 100
Flow Duration Interval (%)


Total Dissolved Solids
1e+7
1e+6
1e+5
1e+4
1e+3
Load (kg/day)
State of Iowa standard
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0 10 20 30 40 50 60 70 80 90 100
Flow Duration Interval (%)


Total Kjeldahl Nitrogen (TKN)
Load (kg/day)
10000
1000
100
10
1
EPA Nutrient
Recommendation
High
Flows
Moist Conditions
Mid-Range
Flows
Dry Conditions
Low
Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)


Total Phosphate
Load (kg/day)
1000
100
10
1
0.1
EPA Nutrient
Recommendation
High
Flows
Moist Conditions
Mid-Range
Flows
Dry Conditions
Low
Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)


Total Suspended Solids
100000
10000
1000
100
10
Load (kg/day)
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)

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