Monitoring Water Quality on Hoover Creek as it Flows Into Herbert Hoover National Historic Site, West Branch, Iowa

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TABLE OF CONTENTS

Contents

INTRODUCTION

The unnamed tributary of the west branch of Wapsinonoc Creek that runs through the Herbert Hoover National Historic Site in eastern Iowa is referred to by project coordinators as "Hoover Creek". The Hoover Creek watershed has historically been dominated by agricultural landuse. However, in recent years, agricultural landuse has declined as the city of West Branch expands into the western section of the watershed; approximately 250 acres of agricultural land has been replaced by an urban landscape in the last 65 years. Such landuse changes have dramatically altered the water quality and stream hydrology throughout the watershed by creating more dynamic surface water flow regimes.

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. This list is known as the 303(d) list of impaired waters. Waterbodies on this list are considered "impaired" and steps to improve their water quality must be undertaken. Periodic sampling of Hoover Creek indicates that the creek has violated state standards for bacteria and nitrate-nitrogen with bacteria levels of 39,000 colony forming units (CFU) /100 ml and nitrate-nitrogen concentrations that exceed 20 mg/L.

This cooperative project involves the National Park Service, Iowa Department of Natural Resources (IDNR) – Water Monitoring Section, the University of Iowa Hygienic Lab (UHL), and the United States Geological Survey (USGS). The goal of this project is to prevent the inclusion of Hoover Creek to the list of impaired waters. Data gathered serves as baseline information to establish current trends water quality and to determine methods to improve stream quality to levels recognized as "unimpaired".

Project objectives include:

- Monitor and characterize patterns in bacteria, nutrient and total suspended solids concentrations within the creek
- Measure temperature, dissolved oxygen, and turbidity to establish baseline water quality conditions
- Determine nutrient and bacteria pollution loads
- Determine the sources of bacteria in the watershed
- Characterize the biological and physical integrity of Hoover Creek

Four monthly sampling locations were identified in the Hoover Creek watershed for water quality monitoring. All four sites are located on the western tributary of the west branch of the Wapsinonoc Creek. Sites are denoted as 1, 2, 3 and 4 (Figure 1). Monthly sampling occurred at all four sites from June 8, 2004 to October 25, 2006. The Hoover Creek watershed experienced an extreme drought in the spring and summer of 2005 that eliminated flow in all of the sampling locations, therefore, sampling did not occur between August 4, 2005 and June 5, 2006. This report summarizes all data collected from June 8, 2004 to October 25, 2006.

PROJECT SETTING

The Hoover Creek watershed is a small watershed that encompasses 1,752 acres in Cedar and Johnson counties in east-central Iowa. The Hoover Creek watershed is located within the Southern Iowa Drift Plain landform region. This landform region is composed primarily of glacial drift, with a relatively thick loess mantle. The land surface is characterized by steep rolling hills and well connected and carved drainage systems (Prior 1991).

Landuse within the watershed is agriculturally dominated. Ninety percent of the landuse is grassland or row crop while 7.5% is urban and only a small percentage is wetland, forested, and other landuses (Figure 2). The data represented in the figure 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, landuse in the upper reaches of the watershed is primarily agriculture, further downstream there is a small golf course that separates the agricultural section of the watershed from the urban part of the watershed. This urban section of the watershed (western) is expanding rapidly, such that the percentage of the watershed that is characterized as urban is steadily increasing. The bottom portion of the watershed consists of the urban park, Herbert Hoover National Park.

CLIMATIC CONDITIONS

Climate data was obtained from the Iowa State University Department of Agronomy, Iowa Environmental Mesonet (http://mesonet.agron.iastate.edu/index.phtml). Conditions in 2004 were characterized by warmer temperatures and more precipitation than normal in east-central Iowa; total precipitation was 4.0 inches higher than the average. Drought conditions impacted east-central Iowa in 2005 with above normal temperatures and 13.2 inches of precipitation below the average. Drought conditions persisted in 2006, although not as severe as the year before, with an 8 inch departure from the average amount of precipitation and higher than normal temperatures.

STREAM DISCHARGE

A USGS stream gage at the monitoring site 3 (Figure 1) provided continuous stream discharge measurements on Hoover Creek. This stream gage has been operational since April 2000 and real-time stream discharge data is available online at: http://waterdata.usgs.gov/nwis/uv?05464942.

Mean daily discharge measurements for Hoover Creek during the sampling period are illustrated in Figure 3. Long-term daily mean discharge is plotted alongside daily mean discharge to demonstrate the departure of daily mean from long-term mean discharge. This discharge graph reiterates the previously stated climatic conditions; discharge is higher than normal in 2004 and less than the long-term mean in 2005 and 2006. This trend is clearer in Figure 4 where differences in long-term and daily discharge are plotted.

In general, stream flow in Hoover Creek is flashy, with baseflow conditions interrupted by brief, high-flow events. The maximum daily discharge in 2004 was 12 cubic feet per second (cfs) on March 26, 2004, in 2005 it was 11 cfs on February 13, 2005, and 2.8 cfs was the maximum daily discharge on April 14, 2006.

WATER QUALITY RESULTS

Water quality was monitored monthly at four sites in the Hoover Creek watershed (Figure 1). Iowa Department of Natural Resources staff conducted the monitoring following methods outlined by the University of Iowa Hygienic Lab standard operating procedures (UHL 2001). The following onsite field parameters were measured: turbidity (using a Hach 2100 P Turbidimeter), dissolved oxygen, and water temperature (using YSI 55 dissolved oxygen and temperature meter). Water samples were analyzed by the University of Iowa Hygienic Laboratory, a U.S. Environmental Protection Agency (EPA) certified lab for the following parameters: total Kjeldahl nitrogen (TKN), ammonia nitrogen, nitrate+nitrite nitrogen, *Escherichia coli (E.coli)*, and total suspended solids (beginning in 2005). All water quality monitoring results were uploaded into an EPA water quality database, STORET, and can be accessed at: http://wqm.igsb.uiowa.edu/iastoret/

Summaries of the water quality results can be found in appendices A through F. Appendix A and B are tables that summarize basic statistical distribution of each monitoring parameter broken down by year and by site. Appendix C includes boxplots of the data by year. Appendix D includes boxplots of the data by site and compared to data from other eastern Iowa streams of comparable watershed size. Appendix E includes the results from the load calculations for nutrients and bacteria. Appendix F includes scatterplots illustrating the spatial and temporal trends of the data.

Nitrate+Nitrite as N

Nitrate+nitrite-N is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth, however, too much nitrogen in surface waters can contribute to nutrient enrichment. This causes excess algal growth, oxygen depletion and eutrophication, all of which negatively impact aquatic communities. Sources of nitrogen include soils, human and animal wastes, decomposing plants, and fertilizer runoff.

In 2004-2006 Nitrate+Nitrite ranged from 0.2 mg/L to 15.0 mg/L (Appendix A and C). There were generally higher values of nitrate+nitrite-N in 2004 versus 2005 and 2006. The maximum level of nitrate+nitrite-N was measured in 2004 at 15 mg/L, with an annual median of 9.0, while the lowest value of 0.2 found in 2006 with an annual median 4.4 mg/L. Potential reasons for these differences has to do with the fact that 2004 was a year with much more rain and a high potential for nitrate+nitrite-N movement across the landscape while 2005 and 2006 were much drier years. It is important to note that although 2004 and 2005 nitrate+nitrite-N data are fairly comparable, Hoover Creek was dry July 2005 until spring 2006.

Spatial patterns can be seen in the data (Appendix B and D). Nitrate+nitrite-N values decrease from upstream (site 1 - having the maximum value of 15) to downstream (site 4 - with a minimum value of 0.2 mg/L); this trend is consistent across years. There also appears to be a seasonal variation in nitrate+nitrite-N values. Nitrogen values peak in the spring and summer and tend to be lower during the winter months, when potential for nitrate+nitrite-N availability and transport is less (Appendix F).

Hoover Creek has higher nitrate+nitrite-N values than do other eastern Iowa streams (Appendix D). Although Hoover Creek's range is similar to that of eastern Iowa streams (0.2

mg/L to 15 mg/L and <0.05 mg/L to 11 mg/L, respectively), Hoover Creek has a median of almost 8 times that of eastern Iowa streams.

The State of Iowa currently does not have a water quality standard for nitrate+nitrite-N. However, the EPA has published recommendations to assist states in setting nutrient standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's nitrate+nitrite-N criteria recommendation is 1.965 mg/L. Approximately 84% of the samples from Hoover Creek are in violation of this proposed standard.

Nitrate+Nitrite Loads

Load calculations for nitrogen were unable to be calculated using traditional computer programs such as ESTIMATOR and AutoBeale due to the small size of the dataset. However, a load duration curve was calculated for nitrogen at site 3 (Figure 1) where the gaging station is located. This load duration curve is perhaps more useful than a sole load value, as it evaluates where in the hydrological cycle the highest loads are occurring. Appendix E shows the load duration curve that uses the EPA nutrient standard recommendation (as there are currently no water quality standards for nutrients) as the threshold. All sampling points above the curve shown are violating that nutrient standard (1.965 mg/L). Flows are characterized as high, moist, mid-range, dry, and low. The load duration curve suggests that much of Hoover Creek is in violation of the proposed nutrient standards. Eighty three percent of the nutrient standard exceedances occur in moist and mid-range flows, suggesting that the majority of these high values are associated with non-point sources (Bruce Cleland 2004, personal communication). This supports the previous discussion that high nutrient values in Hoover Creek are driven by high flow conditions.

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. The most common sources of ammonia include fertilizers and human and animal waste.

In 2004-2006 ammonia-N ranged from <0.05 mg/L to 0.7 mg/L. (Appendix A and C). Ammonia-N levels were generally lower in 2004 and 2005 than in 2006. The maximum level of 0.7 mg/L was measured in 2006, with multiple other detects throughout the year, while in 2004 and 2005, ammonia-N was rarely detected in Hoover Creek. Reasons for these differences could be that 2006 was a dry year; therefore, point sources of ammonia are not diluted in the stream by high flows.

There is not much variation in ammonia levels in different sections of the creek, the upper most point in the watershed (site 1) had the highest detected value of ammonia-N, otherwise, ammonia levels are relatively low in the watershed as compared to other eastern Iowa streams (Appendix D). Only one sampling event in 2006 had detections for ammonia-N at all 4 sites (Appendix F). This occurred following a strong rain storm where turbidity and bacteria numbers were also high at all sites. These elevated values, in conjunction with the large rain storm, can probably be attributed to manure entering the stream from the watershed and/or stormwater inputs.

The State of Iowa has an ammonia standard that is dependent on the pH value of the water (IAC 2002). Hoover Creek monitoring did not include monitoring for pH, thus information on violations of the state standard for ammonia is not available.

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. Sources of TKN are animal and human wastes, and decaying and live organic matter.

In 2004-2006 TKN values in Hoover Creek ranged from 0.1 mg/L to 5.4 mg/L with median values ranging from 0.3 to 0.4 mg/L. TKN values were generally higher in 2006, with a maximum level of 5.4 mg/L, than in 2004 and 2005 when maximum levels were 0.5 mg/L (Appendix A and C). Site 1 tends to have higher values of TKN, versus sites further downstream (Appendix B and F). It should be noted that TKN values throughout the stream tend to be lower than TKN values for other eastern Iowa streams (Appendix D). The highest levels of TKN occurred during high flow events in the upstream portion of the watershed where agricultural non-point source pollution is more likely.

The State of Iowa currently does not have a water quality standard for TKN. However, the EPA has published recommendations to assist states in setting nutrient standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's TKN criteria recommendation is 0.65 mg/L. Approximately 17% of the samples from Hoover Creek are in violation of this proposed standard.

Turbidity

Turbidity is a measure of the clarity of water. Causes of high turbidity include organic matter, algae, sediment, and other suspended solids in the water column. Turbidity usually increases after storm events, when streams carry more sediment as a result of increased erosion.

In 2004-2006 turbidity values in Hoover Creek ranged from 2 Nephelometric Turbidity Units (NTU) to greater than 1000 NTU (Appendix A and C). Median turbidity ranged from 11 to 17 NTU. Turbidity was generally higher in 2006 than in 2004 or 2005, potentially due to monitoring that was conducted during high flow events during 2006. In general, turbidity in the creek was relatively low (less than 25 NTU), with increases for short periods of time right after large storm events when runoff and erosion increased. The highest turbidity recorded at most sites was associated with a large rainstorm that occurred on 8/9/2006. In general, turbidity was highest at site 1 (Appendix B and D), where landuse is dominated by agriculture in a stream habitat that has a great potential for high and fast flows capable of transporting large quantities of sediment. Hoover Creek tends to have higher turbidity than the rest of streams in eastern Iowa, potentially due to the fact that it is such a flashy system.

The State of Iowa currently does not have a water quality standard for turbidity. However, the EPA has published recommendations to assist states in setting turbidity standards (EPA 2000). For the subecoregion that contains Hoover Creek, the EPA's turbidity criteria recommendation is 15 NTU. Approximately 35% of the samples from Hoover Creek are in violation of this proposed standard.

Dissolved Oxygen

Dissolved oxygen consists of oxygen gas (O_2) in water and it is crucial for the support of aquatic communities. Almost all aquatic plants and animals need dissolved oxygen in the water to survive. DO is produced by diffusion from the atmosphere, aeration of water, and is a waste product of photosynthesis. DO levels are affected by temperature, salinity, atmospheric pressure and oxygen demand from aquatic plants and animals. Oxygen in a stream can be consumed through respiration by aquatic plants and animals, and by the decomposition of organic matter.

In 2004-2006 dissolved oxygen levels ranged from 2.6 mg/L to 11.1 mg/L. Median dissolved oxygen levels ranged from 7.5 mg/L at site 1 to 8.1 mg/L at site 3 (Appendix A, B, C, D). Dissolved oxygen showed little variation from 2004-2006, however, there was a higher median value in 2005 due to the fact that samples were only collected in the winter months when dissolved oxygen levels tend to be higher. There was also very little variation in dissolved oxygen levels from upstream sites to downstream sites (Appendix D). In general, dissolved oxygen levels are relatively comparable to the rest of eastern Iowa streams, only without as many higher outlier values (Appendix D). Dissolved oxygen levels exhibit a seasonal pattern with levels highest in the winter months and lowest during the summer months (Appendix F).

The dissolved oxygen standard for the State of Iowa is a minimum of 5 mg/L in a warm water stream (IAC 2002). Hoover Creek sites violated this standard 14% of the time, usually following large rain events or during times when flow was low and water temperatures were high. Such conditions increase the biological oxygen demand and decrease available oxygen in the stream.

Water Temperature

Water temperature is a measure of the thermal energy of water. Water temperature can influence the type of plants and animals that can survive in the water.

In 2004-2006 water temperatures in Hoover Creek ranged from 1.0 to 21.9 degrees Celsius. In general, water temperatures were higher in 2006 than in 2004 and 2005, and were more variable in 2005 (Appendix A and C). Temperature did not vary much from upstream to downstream sites, with most medians similar to that of other streams in eastern Iowa (around 16 degrees Celsius) (Appendix D). As to be expected, water temperature is linked to season, with higher temperatures in the summer months than in the winter months (Appendix F).

The State of Iowa mandates that water temperatures in warm water streams do not exceed 32 degrees Celsius (89.6 degrees Fahrenheit) (IAC 2002). No exceedences of this standard occurred during the monitoring of Hoover Creek.

Total Suspended Solids (TSS)

Total suspended solids (TSS) quantify the total amount of substances that are in suspension in a stream channel. The suspended substances consist of silt, clay, and fine sand. Larger particles can be carried during floods or when water volumes and velocities are high. TSS is related to stream flow; the higher the velocity of the water, the higher the TSS. TSS is a good indicator of both land surface erosion and streambank erosion. Higher levels of TSS usually imply high velocities of water (rainfall events) which increase erosion and channel incision.

Total suspended solids were monitored from 2005 to 2006. Total suspended solids (TSS) concentrations ranged from 2 mg/L to 4400 mg/L. Median values ranged from 10 mg/L at site 3 to 29 mg/L at site 1 (Appendix A, B, C, D). In general, TSS in the creek was relatively low (less than 15 mg/L), with increases for short periods of time right after large storm events when runoff and erosion increases. The highest TSS recorded at most sites was associated with a large rainstorm that occurred on 8/9/2006 when TSS peaked at 4400 mg/L (Appendix F). In general, TSS was highest at site 1, where land use is dominated by agriculture in a stream habitat that has a great potential for high and fast flows capable of transporting large quantities of sediment (Appendix B and D). Although TSS was not a measured value in other streams in eastern Iowa, it could be predicted that Hoover Creek would have relatively higher TSS due to the fact that it is such a flashy system.

Escherichia coli (E.coli) **Bacteria**

E.coli is an indicator bacteria that is used to indicate the presence of pathogenic bacteria in water. *E.coli* is a necessary bacteria that is used to break down food in the intestine and it helps promote digestion in humans and other warm-blooded animals. A higher level of *E.coli* in water signifies greater levels of contamination from fecal matter and a greater chance that pathogenic microbes may be present in the water. Pathogenic organisms are a health risk to humans; they can cause illness in people and adversely impact aquatic ecosystems. The most frequent sources of bacteria in water are sewage overflows, malfunctioning septic systems and sewer lines, animal waste, and polluted storm water runoff.

In 2004-2006 *E.coli* values ranged from not detected to 29,000 colony forming units (CFU)/100 ml. Median concentrations ranged from 425 at site 2 to 650 at site 4 (Appendix A, B, C, D). Generally, *E.coli* was higher in 2006 than in 2004-2005, potentially due to the drier conditions in 2006 (Appendix A and C). Spatial patterns exist in *E.coli* concentrations; site 4 consistently has the highest levels of bacteria while median values are consistently lower for site 1 through 3. Site 4 has *E.coli* levels that are significantly higher than that in other eastern Iowa streams, whereas sites 1 through 3 have *E.coli* concentrations that are comparable to concentrations in other eastern Iowa streams (Appendix B and D). There are some seasonal patterns in *E.coli* concentrations, with some of the highest *E.coli* levels occurring during rain events. All sites had *E.coli* concentrations greater than 20,000 CFU/100 ml following a large rain storm on 8/9/2006.

E.coli values are relatively high throughout the entire year in Hoover Creek, with many samplings exceeding the one-time maximum standard for *E.coli* (Appendix F). The State of Iowa mandates the *E.coli* not exceed the one-time standard of 235 CFU/100 ml in Class A1 waters (IAC 2002). Although Hoover Creek is not a designated stream, this standard is used as a benchmark for evaluating bacteria contamination. Sixty-nine percent of the samples collected in Hoover Creek violated that one time maximum standard, and 85% of the samples collected at site 4 violated that one time maximum standard.

E.coli **Bacteria Loads**

To further understand patterns in bacteria in Hoover Creek, a load duration curve was generated. This load duration curve is perhaps more useful than a sole load value, as it evaluates where in the hydrological cycle the highest loads are occurring. Appendix E shows the load duration curve that uses the State of Iowa *E.coli* standard as the threshold. All sampling points above the curve shown are violating that bacteria standard (235 CFU/100 ml). Flows are characterized as high, moist, mid-range, dry, and low. The load duration curve suggests that over 60% of Hoover Creek is in violation of the bacteria standard. Sixty-two percent of the bacteria standard exceedances occur in midrange and dry conditions, suggesting the majority of these high values are likely associated with point sources of pollution (Bruce Cleland 2004, personal communication). Data suggests that Hoover Creek is impacted by both non-point source bacteria pollution and point source pollution. However, even though the highest concentrations of bacteria occurred during a high flow event, the largest load of bacteria occurred during dry conditions. This suggests that point source pollution is a likely contributor to the high bacteria levels in the creek. This conclusion is supported in the next chapter entitled "Targeted Bacteria Sampling".

BACTERIA TARGETED SAMPLING

Bacteria Source Tracking

The presence of *E. coli* as indicator bacteria suggests a relatively fresh fecal source entering the water. While current monitoring has confirmed that bacteria levels tend to be high in Hoover Creek, it does not indicate the sources of these elevated bacteria levels. Rather than conduct expensive microbial source tracking studies in the watershed, a targeted sampling approach was conducted. This approach entails taking numerous samples throughout the stretch of stream to determine the immediate areas of elevated bacteria concentration. Two sampling events occurred in August and September of 2006 during which 14-17 samples were collected and analyzed for bacteria. Fluorometry was then used to sample the levels of optical brighteners in the water. Samples were taken at a rate of one sample per 150 meters of stream length, or where tile lines were flowing (Figure 5). Additionally, a smaller sampling event was conducted on a subset of these sampling sites in October. The presence of optical brighteners and bacteria in water are good indications of a human source of bacteria via a failed or inadequate sewage treatment system.

Fluorometry

Fluorometry can be used to detect optical brighteners from laundry detergents, dishwashing detergents, and toilet papers, which fluoresce when exposed to ultraviolet radiation. Optical brighteners break down when exposed to ultraviolet radiation (UV) whereas most naturally occurring organics which fluoresce at the same wavelength do not. Optical brightener dyes are generally found in domestic waste waters because the main commercial use of these dyes is in laundry detergents and textile finishing. The brighteners can enter a waterway via leaking sewer pipes, sewer lines improperly cross-connected to storm drains, and malfunctioning onsite waste disposal systems. In the past, fluorometry did not work well in tracking potential human waste contamination when it was used alone. However, when fluorometry is combined with bacteria analysis, it is an inexpensive method to detect human waste in waterways. Table 1 shows the relationship between levels of bacteria, levels of optical brighteners, and sources of bacteria in waterways (Hartel et al 2005).

Sample Collection and Analysis

Water samples were collected in 125 ml polypropylene acid washed, sterile bottles for fluorometric analysis. Samples were stored in a cool, dark place following collection to prevent further breakdown of the optical brightening agents in the field. Bacteria samples were collected in 100 ml bottles and were analyzed by University of Iowa Hygienic Lab.

Samples were then placed in 30 ml acid washed borosilicate test tubes. Using a Turner Designs 10-AU Field Fluorometer, the level of fluorescence of each sample at 436 nm was determined and recorded. These samples were then exposed to UV for at least six hours. Samples were analyzed prior to and following UV exposure to assess the influence of background interference from organic compounds present in the water. Differences in the level of fluorescence of each sample were compared to the previous reading. The decline in fluorescence from the first reading to the second indicates the presence of optical brighteners and their concentration in each sample.

Results

Spatial patterns exist in the presence of bacteria and optical brighteners in Hoover Creek. In all three sampling events, bacteria levels generally increased from the upstream section of the stream to the downstream section (Figure 6). There are only a few exceptions to this trend, the October sampling of site 16 and September sampling of sites 8 through 10. Spatial trends in optical brighteners are more intricate. The concentration of optical brighteners generally increases from site 17 to site 10 or 11 and then start decreasing until site 7 when concentration increases and peaks at site 3 or 4 before decreasing again (Figure 7). The patterns in optical brighteners levels tend to follow landuse characteristics in the watershed (Figure 5). Optical brighteners are in relatively low numbers around site 17 in an area that is characterized by agricultural land, they increase through the golf course and then start to decrease downstream of the golf course (site 11) within residential neighborhoods. Optical brightener levels begin to increase as the stream flows through the park, peaking within the park and beginning to decrease as it flows out of Herbert Hoover National Park (site 1).

Table 1 shows the relationship between levels of bacteria, levels of optical brighteners, and sources of bacteria (Hartel et al 2005). The optical brightener concentration and bacteria levels for all three sampling events were categorized as low or high. Thresholds for these categories varied between samplings as background conditions were taken into account. As adapted from table 1, the combination of bacteria levels and optical brighteners fell into one of three potential sources of bacteria: Failing onsite waste disposal system or leaking sewer pipe/gray water from stormwater, human or other warm-blooded animals, and no evidence of fecal contamination. Table 2 summarizes the potential sources of bacteria for each site. It should be noted that some sites were consistent in their potential source of bacteria for all of the sampling events, while others had differing potential sources for events. Differences were taken into account during data analysis and interpretation.

Results show that there is no evidence of fecal pollution in the upper reaches of the watershed where landuse is dominated by agriculture (Figure 8). The one exception to this is site 16 where in one sampling it was considered that bacteria was coming from a failing onsite waste disposal system while the other sampling indicates no fecal contamination. Potential human sources of bacteria occur in the sites on the golf course and just downstream of the golf course – likely due to gray water from storm water systems. The sites within the golf course always showed relatively higher optical brightener levels, but not necessarily high bacteria concentrations. This inconsistency could indicate a chemical additive to the golf green that causes higher optical brightener levels in the stream. The sources of bacteria within Herbert Hoover National Park are likely human. Almost all sites within the park have been determined to be impacted by bacteria whose potential source is a failing onsite disposal system, leaking sewer pipe, or gray water. Sites outside of the park boundaries are characterized as having bacteria that is potentially from humans or other warm-blooded animals as well as failing waste disposal systems.

Discussion

Results from the targeted sampling suggest that some of the bacteria in Hoover Creek is likely sourced from humans. Areas that suggest potentially strong indications of human fecal contamination are sites within Herbert Hoover National Park, where sites consistently indicate that high bacteria levels are due to failing onsite waste disposal systems, leaking sewer pipes, or gray water. This is not surprising considering the large number of tile lines that are present in this section of the stream; this portion of the stream is the most impacted by urban infrastructure that has the potential to be inadequate or to fail. Other areas of concern include sites within and just downstream of the golf course, where high optical brightener values could be due in part to chemical additives applied to the golf green.

Although these fluorometry results are not completely conclusive about the exact source of bacteria, they have helped to identify areas with elevated bacteria levels. Further bacteria and fluorometric monitoring investigations would be particularly beneficial within Herbert Hoover National Park in order to expand understanding of bacteria levels and sources.

BENTHIC MACROINVERTEBRATE SAMPLING

Methods

A benthic macroinvertebrate study was conducted on all four Hoover Creek sites (Figure 1) in August of 2006 as a way of assessing the biological integrity of Hoover Creek. Sampling benthic macroinvertebrates is the most common method of assessing the biological health of a stream. As water conditions change, so does the presence and diversity of benthic macroinvertebrate communities in that stream. The number and kinds of organisms collected is a relatively good indicator of the health of the stream. This is because benthic macroinvertebrates are stable in their range (they do not migrate long distances), are easy to collect and identify, and much is known of their tolerance to different pollutants. It should be noted that only one benthic study was conducted during the study period, so the information gathered only provides a small picture of the biological integrity of the stream. In order to determine trends and changes in biological health of the stream, more frequent studies would need to be conducted.

The benthic macroinvertebrate study was conducted using IOWATER Advanced Benthic Macroinvertebrate Indexing Methods. The IOWATER method is a modified version of the Regional Environmental Monitoring and Assessment Program (REMAP) method, developed by the Iowa Department of Natural Resources in cooperation with the University of Iowa Hygienic Lab (IDNR 2001 and 2005). Three quantitative sub-samples were collected at each of the four Hoover Creek sampling sites using dip nets. Surber samplers and hess samplers were deemed inappropriate for this study due to the narrow width and shallow water depth of the stream. Benthic macroinvertebrates were collected for a period of 90 minutes utilizing a multihabitat approach (Barbour et. al 1999). Proportional abundance sampling of multiple microhabitats was conducted over a sampling area consisting of at least 100 meters of stream bed length. Observational data including clarity (transparency), dissolved oxygen, level of flow, and the number and types of macro and microhabitats sampled were recorded for each site.

Metrics

The sub-samples from each site were consolidated and macroinvertebrates were identified in the lab to family level. Five metrics were used to interpret macroinvertebrate populations in relationship to biological integrity: Macroinvertebrate Biotic Index (MBI), taxa richness, percent of families identified in Ephemeroptera, Plecoptera, and Trichoptera orders, and the percentage of the three most dominant taxa. Benthic macroinvertebrates were also classified into categories that indicate low, medium and high quality water as a way of generalizing the water quality of stream.

A family-level macroinvertebrate biotic index value was calculated using the following formula:

$$\text{MBI} = \sum \frac{(\sum \text{ of individuals for each family x tolerance value for that family})}{\text{total number of individuals collected}}$$

An individual family's tolerance value (TV) indicates their relative tolerance to organic pollution, on a scale of 0 to 10. Macroinvertebrates with the least tolerance to organic pollution have a TV of 0. These macroinvertebrates have specific habitat requirements such as high dissolved oxygen, low amount of organic pollutants, and rocky habitats. Macroinvertebrate families that have the most tolerance to organic pollution have a TV of 10. These macroinvertebrates can survive in conditions with relatively lower amounts of dissolved oxygen, areas with higher organic pollution, and habitats that are embedded with sediment. These tolerance values allow for a qualitative analysis of the water quality in the overall index score. The higher MBI value indicates water that may be more impacted by pollution, habitat destruction, or adverse environmental conditions than water that has a lower MBI.

Taxa richness represents the overall number of different taxa identified. Generally, the more diverse the taxa is, the healthier the system. The percent of organisms within Ephemeroptera, Plecoptera, and Trichoptera orders represents the percent of organisms found in orders that inhabit coarse streambed areas such as gravel and cobble. The absence of these organisms from a stream is strong evidence of a water quality or stream habitat problem. The percent three most dominant taxa provides important information on family diversity, dominant feeding groups, and can be an indicator of water quality.

Results

The benthic macroinvertebrate population in Hoover Creek is dominated by organisms that indicate mostly fair or poor water quality on a qualitative scale that ranks their relative tolerance to pollution. On a scale from poor to excellent, the poor/fair categorization suggests substantial water pollution or habitat deterioration is likely based on the benthic macroinvertebrate population (Hilsenhoff 1988).

There is not much variation in the MBI values between sites (Table 3). The MBI values range from 6.0-7.1, with site 3 having the lowest index value and site 1 having the highest value; all index values within this range indicate poor/fair water quality. Reasons for differences in MBI values most likely have to do with macro and microhabitat types. Site 1 has the least amount of micro and macrohabitats available to organisms as well as the lowest dissolved oxygen and transparency values. Site 1 was only comprised by a run and a limited number of microhabitats such as muck, silt and overhanging vegetation. Sites 2 through 4 had higher dissolved oxygen and transparency as well as significantly higher numbers of macro and microhabitats available to organisms, therefore, a lower MBI. These sites were comprised of a run and at least one other habitat type. They also had many types of high quality microhabitats such as leaf packs, fallen trees, root wads and rocks.

Although taxa richness is relatively high throughout the stream (ranging from 10-14), the diversity within the stream is low as the three most dominate taxa often comprise more than three-fourths of the population. It should be noted that the three most dominate taxa in all sections of the creek were macroinvertebrates that indicated low or medium water quality (left spiral snails, true bugs, sowbugs, beetles). The percent of EPT was very low throughout the stream, with the highest percentage found at site 4 at only 3.9% and no EPT orders found at site 1.

Organisms were categorized individually as indicating low, medium and high water quality, based on their known tolerance to pollution (Gautsch 2006, personal communication) (Table 4). All Hoover Creek sites had small quantities of high quality organisms (site 1 having no high quality organisms and site 4 having the most high quality organisms at only 4 organisms). Results are consistent with the MBI values; the majority of the macroinvertebrates in Hoover Creek are relatively pollution tolerant, indicating low or medium water quality (Figure 9). This pattern is consistent throughout the reach of the stream; however results suggest that the worst biotic integrity is in the upper reaches of the watershed.

Discussion

The high MBI values, along with visual observations from the stream, indicate a great deal of sedimentation throughout Hoover Creek. This sedimentation depletes the quality, quantity, and diversity of microhabitats. Two weeks prior to the benthic macroinvertebrate study, Hoover Creek watershed experienced a large rainfall event that significantly increased flow in the stream. This rainfall event had the potential to disturb and deteriorate the majority of macroinvertebrates and their habitats. The populations that were found in the study are populations that could have easily reestablished within a couple of weeks or are organisms that are well adapted to flashy flow regimes. Although these circumstances are specific to this particular sampling event, it should be noted that Hoover Creek has a history of flashy flows, something that has increased as landuse changes throughout the watershed have dramatically altered stream hydrology by creating more dynamic surface water flow regimes. It should be noted that stream banks are eroded at all sites, which indicates frequent high water velocity and large amounts of stream bank erosion. Such flashy flow regimes increase sedimentation within the stream and decrease the stability, quality, quantity, and diversity of microhabitats. This in turn, decreases the diversity of organisms found within the stream.

PHYSICAL ASSESSMENT

Stream Visual Assessment Protocol

A physical assessment of Hoover Creek was performed in August 2006 in order to determine the physical integrity of the stream. The Natural Resources Conservation Service's Stream Visual Assessment Protocol was used to measure the physical health of Hoover Creek (USDA 1998). This assessment provides a basic level of stream health evaluation by assessing multiple stream characteristics and combining all the assessments into an overall score that rates the physical integrity of the stream.

Fifteen stream reaches were analyzed along the stretch of Hoover Creek from monitoring site 1 to site 4 (Figure 1). A stream reach was defined as 12 times the active channel width; if conditions changed drastically within the allotted stretch of stream, the stream reach was divided further into two segments in order to capture that diversity in the assessment. Anywhere from 9 to 11 characteristics were assessed for each reach, depending on the presence of each physical characteristic. The following characteristics were assessed: channel condition, hydrologic alteration, riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, in-stream fish cover, pools, canopy cover, and riffle embeddedness. Each assessment element was rated with a value of 1 to 10 (1 indicating poorer physical health and 10 indicating better physical health). Reaches were scored based on qualitative descriptions of the conditions associated with each score for each assessment element. The overall assessment score was determined by adding values for each element and dividing by the number of elements assessed. This quantitative score was then applied to a rating scale that rates the physical integrity of the stream as either poor, fair, good, or excellent.

Results

Overall stream condition scores for Hoover Creek ranged from 2.1 to 6.1 (Table 5). All but one of the fifteen stream reaches assessed were rated as having poor physical integrity (scores less than 6.0), and that was assessed as having merely fair physical quality. There is not a significant spatial pattern to the ratings of these reaches, as scores are not variable. The assessment factors that have the most influence on the poor physical rating (the elements with the lowest scores) tend to be the accelerated amount of hydrologic alteration, absence of pools and canopy cover, and the embeddedness of the substrate within the stream. Table 5 summarizes the different scores for each of the elements.

The scores offer important information about the physical health of the stream. The stream is generally characterized as having a low diversity of in-stream habitat with most of the stream being characterized by runs. Riffle and pool habitats are less frequently found and where present, much of them are highly embedded with sediment. It is also the case that the majority of substrate is composed of mud and silt. These factors indicate that there is a lot of erosion in the stream that causes stream beds to become embedded with sediment. Many of the stream reaches are also characterized by banks that are eroding or erode on a frequent basis. Bank height ranged from 2 feet to 15 feet, with an average bank height of 6.5 feet. It should be noted that this average bank height usually characterizes vertical banks that are not stable. Further evidence of erosion was relatively wide stream channels, with the maximum channel width of 24 feet. Most of the reaches were surrounded by small riparian areas with low growing and shallow rooted plants. The lack of a large riparian area with diverse plants to help slow down and filter water and sediment increases the erosion problems both on land and in the stream.

Discussion

The rating of poor physical health for Hoover Creek indicates a stream that has extremely dynamic surface water flow regimes. This flashy flow regime is in part due to recent landuse changes that have decreased filtration potential of water and sediment before it enters the stream. The higher speed and volume of water entering the stream generally creates poor physical integrity by causing channel and stream bed erosion, sedimentation, channel widening, and destruction of macro and micro habitats. These physical characteristics of the stream have implications for degrading water quality by increasing nutrient, sediment, and bacteria loads. Flashy flow regimes, sedimentation and erosion also decrease biological integrity by decreasing quality and quantity of habitat available to aquatic life.

CONCLUSION

Through the duration of the monitoring project, the Hoover Creek watershed experienced above normal temperatures and dry conditions in 2005 and 2006. Sampling ceased for a large portion of 2005 due to the stream becoming dry. Hoover Creek can be characterized as having a very flashy flow regime with generally baseflow conditions that are interrupted by brief, high-flow events. The consequence of such a flashy system is reflected in low biological and physical integrity. A physical assessment of the stream characterized the creek as having poor physical integrity due to the accelerated amount of hydrologic alteration, absence of pools and canopy cover, and the embeddedness of the substrate within the stream. This embeddedness decreases the stability, quality, quantity, and diversity of microhabitats available to aquatic life. As such, the diversity of benthic macroinvertebrate populations found in Hoover Creek was low and most of the organisms found were pollution tolerant and able to adapt to extreme changes in their physical environment.

Water monitoring results demonstrate high nitrate+nitrite-N, bacteria, turbidity and total suspended solids values as compared to other eastern Iowa streams. Many of the results exceeded current and recommended water quality standards for these parameters. Nutrients and suspended solids were particularly high in the upstream portion of the watershed where landuse is predominately agricultural and the potential for non point source pollution is high. Nutrient load duration calculations suggest that the flashy system has a considerable impact on water quality by significantly increasing nutrient loads following large rain events.

Results from the targeted bacteria sampling suggest that some of the bacteria in Hoover Creek is likely sourced from humans. Areas that suggest potentially strong indications of human fecal contamination are sites within Herbert Hoover National Park, where sites consistently indicate that high bacteria levels are likely due to failing onsite waste disposal systems, leaking sewer pipes, or gray water. Additional sampling is suggested within the park in order to understand bacteria levels and sources.

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. Data collected as part of this project indicates that Hoover Creek, if it were a designated waterbody, would be in violation of the bacteria standard 69% of the time and in violation of the recommended nitrate+nitrite-N standard 84% of the time. Non point source and point source pollution are both contributing to these high values. Further bacteria monitoring is suggested in the watershed as well as investigations into erosion control within and around the creek.

ACKNOWLEDGEMENTS

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

- Jason McCurdy who collected and transported water quality samples as well as conducted the fluorometric investigations.
- Rick Langel, Jason McCurdy, and Jack Gilmore who helped collect the benthic macroinvertebrates and water quality samples.
- Eric O'Brien who aided in the interpretation of bacteria and fluorometry results.
- Rick Langel for providing technical support for the calculation of bacteria and nutrients loads.
- The landowners who granted the access to Hoover Creek on their property.
- Jackie Gautsch who identified the benthic macroinvertebrates and provided an interpretation of the results.
- Heartland Network, Inventory and Monitoring Program, National Park Service which provided funding and technical support.

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FIGURES

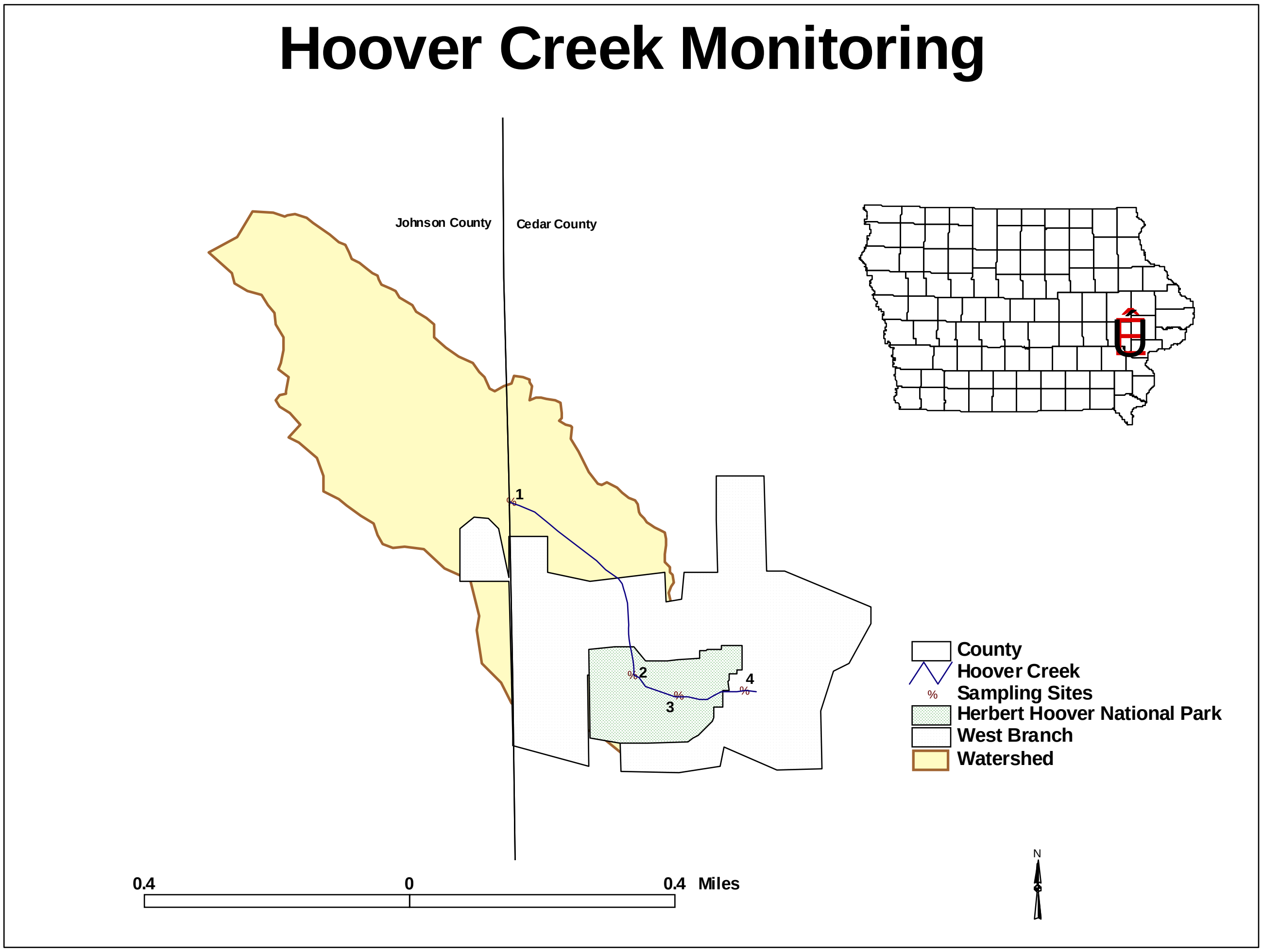


Figure 1

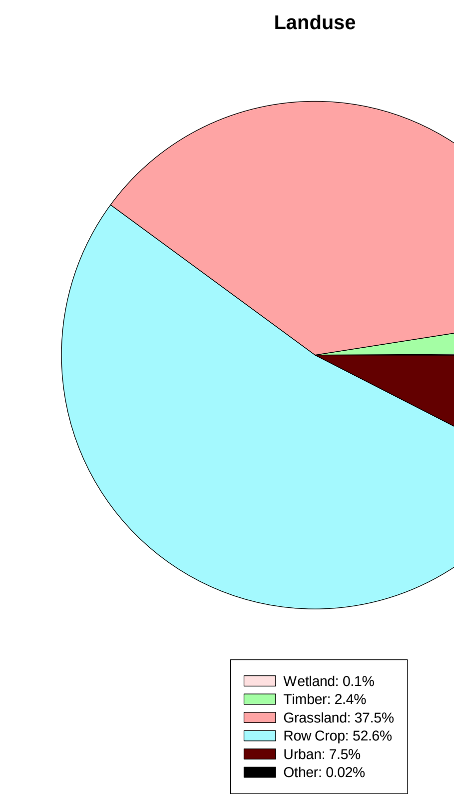

Landuse
Wetland: 0.1%
Timber: 2.4%
Grassland: 37.5%
Row Crop: 52.6%
Urban: 7.5%
Other: 0.02%

Figure 2

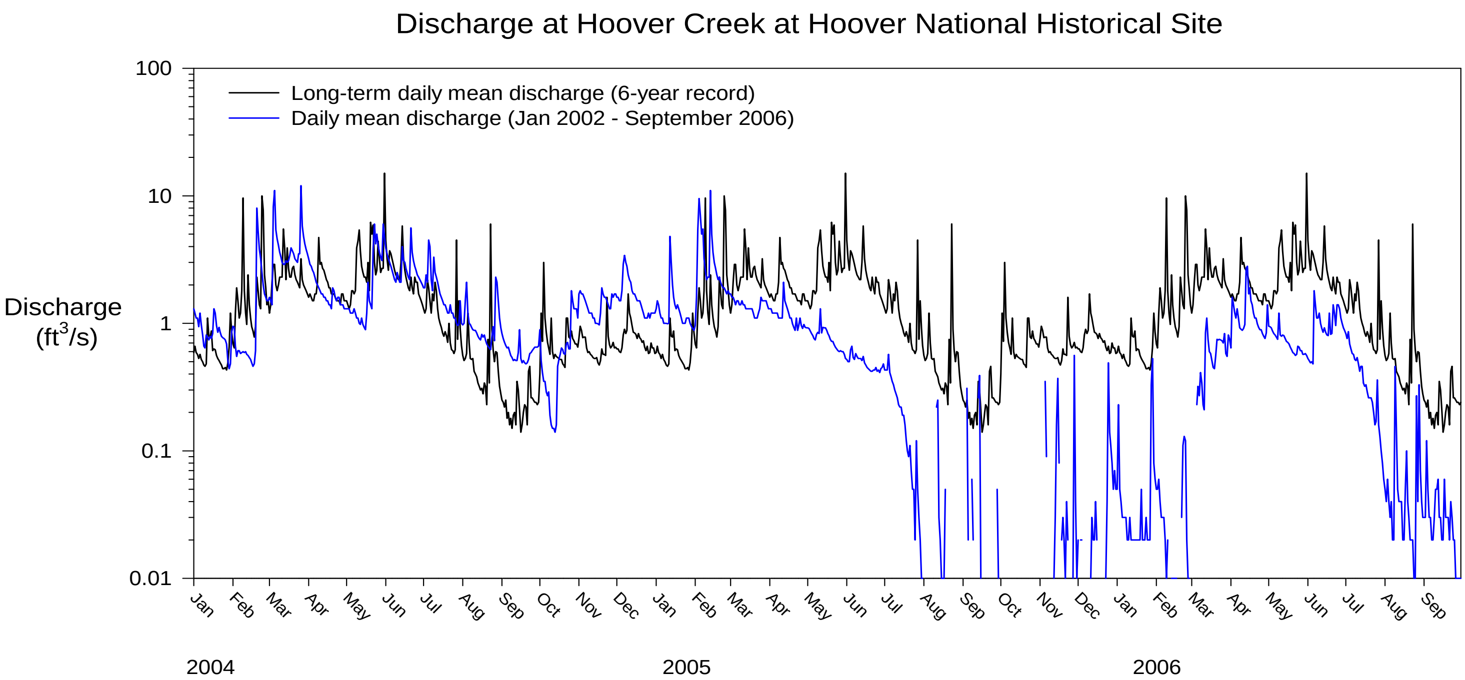


Figure 3

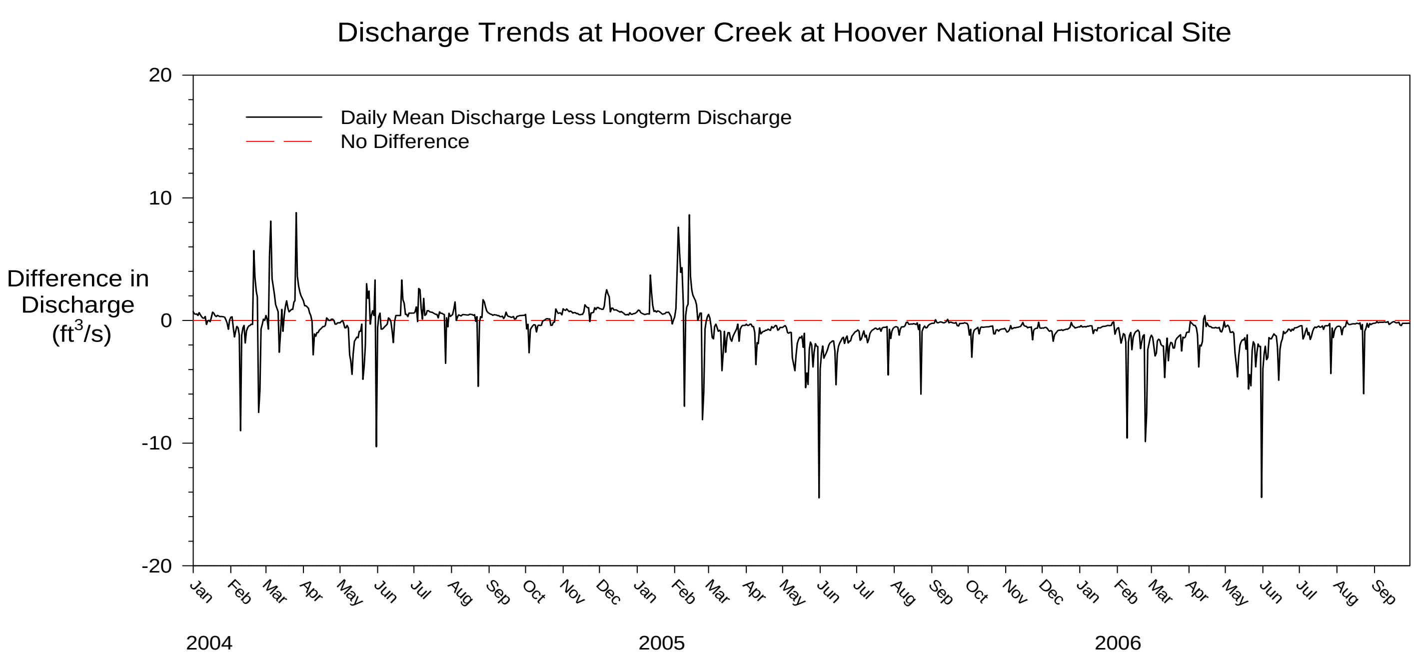


Figure 4

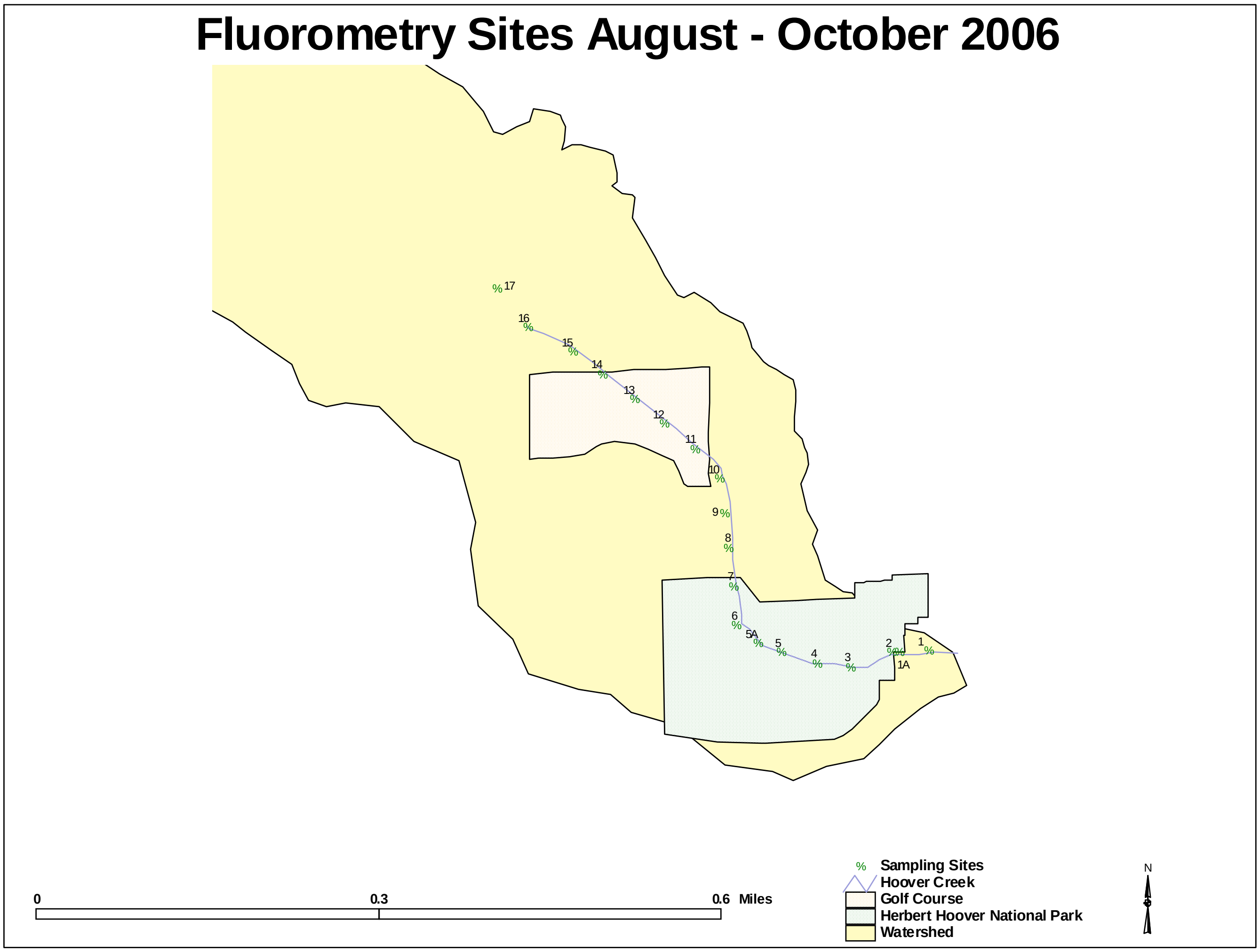

Fluorometry Sites August - October 2006
17
16
15
14
13
12
11
10
9
8
7
6
5A
5
4
3
2
1
1A
Sampling Sites
Hoover Creek
Golf Course
Herbert Hoover National Park
Watershed
0
0.3
0.6 Miles
N

Figure 5

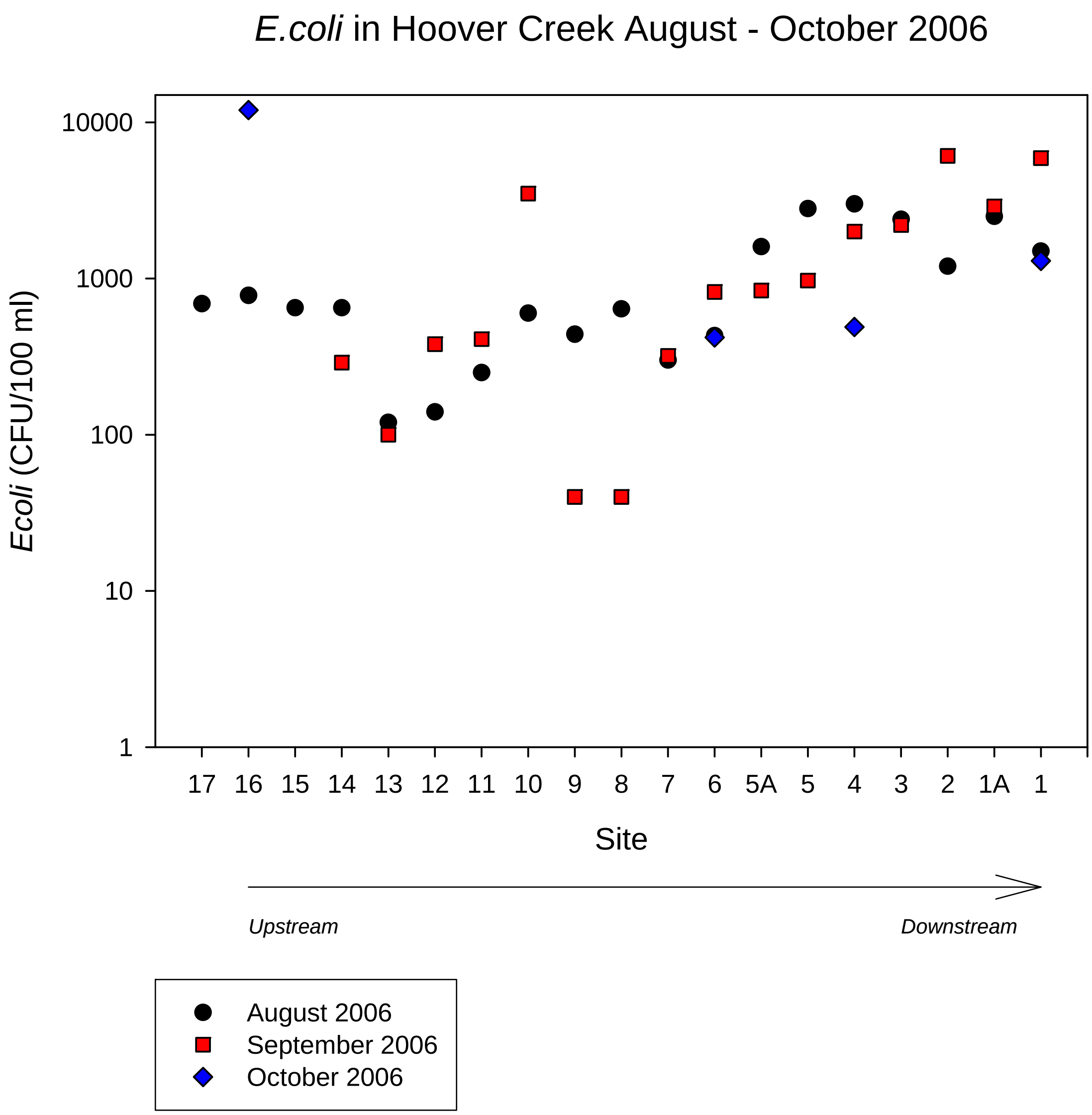

E.coli in Hoover Creek August - October 2006
Ecoli (CFU/100 ml)
10000
1000
100
10
1
17 16 15 14 13 12 11 10 9 8 7 6 5A 5 4 3 2 1A 1
Site
Upstream
Downstream
August 2006
September 2006
October 2006

Figure 6

Changes in optical brightner indicators in Hoover Creek August - October 2006

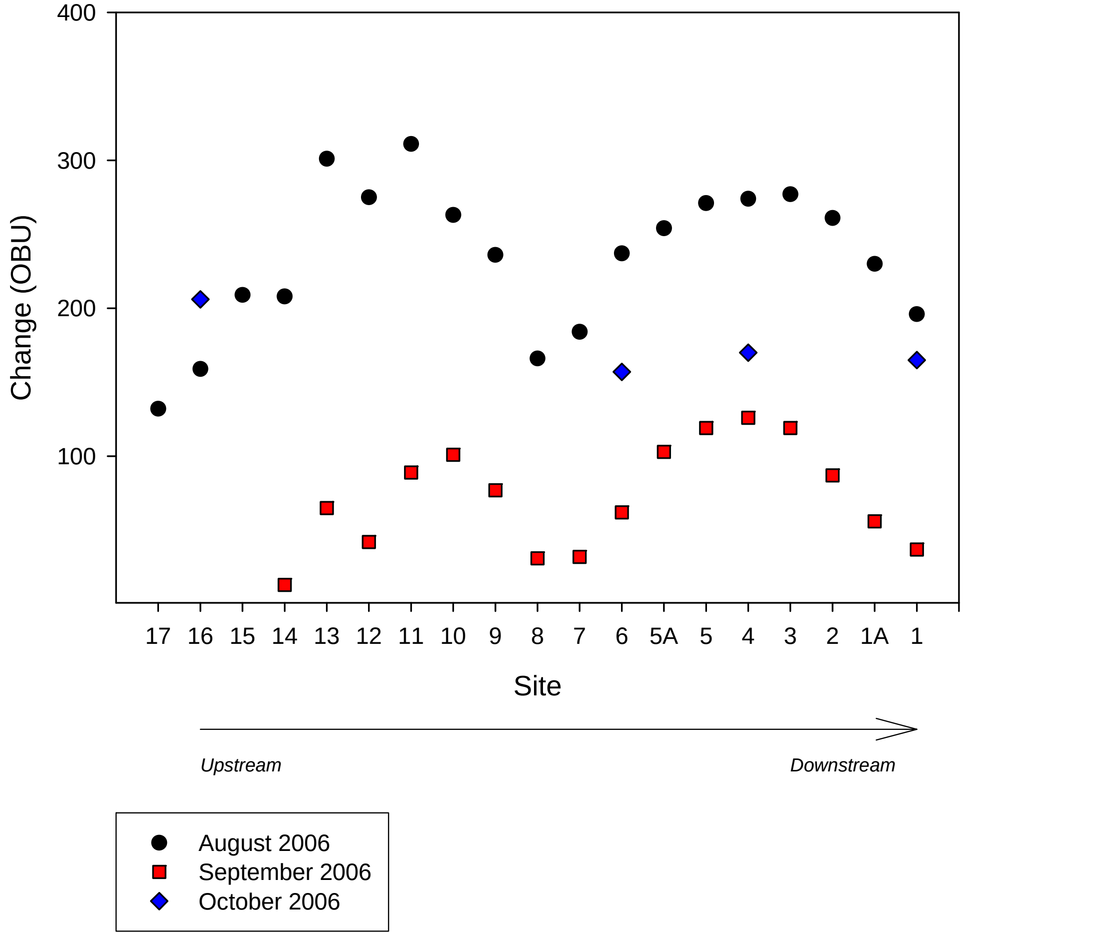


Figure 7

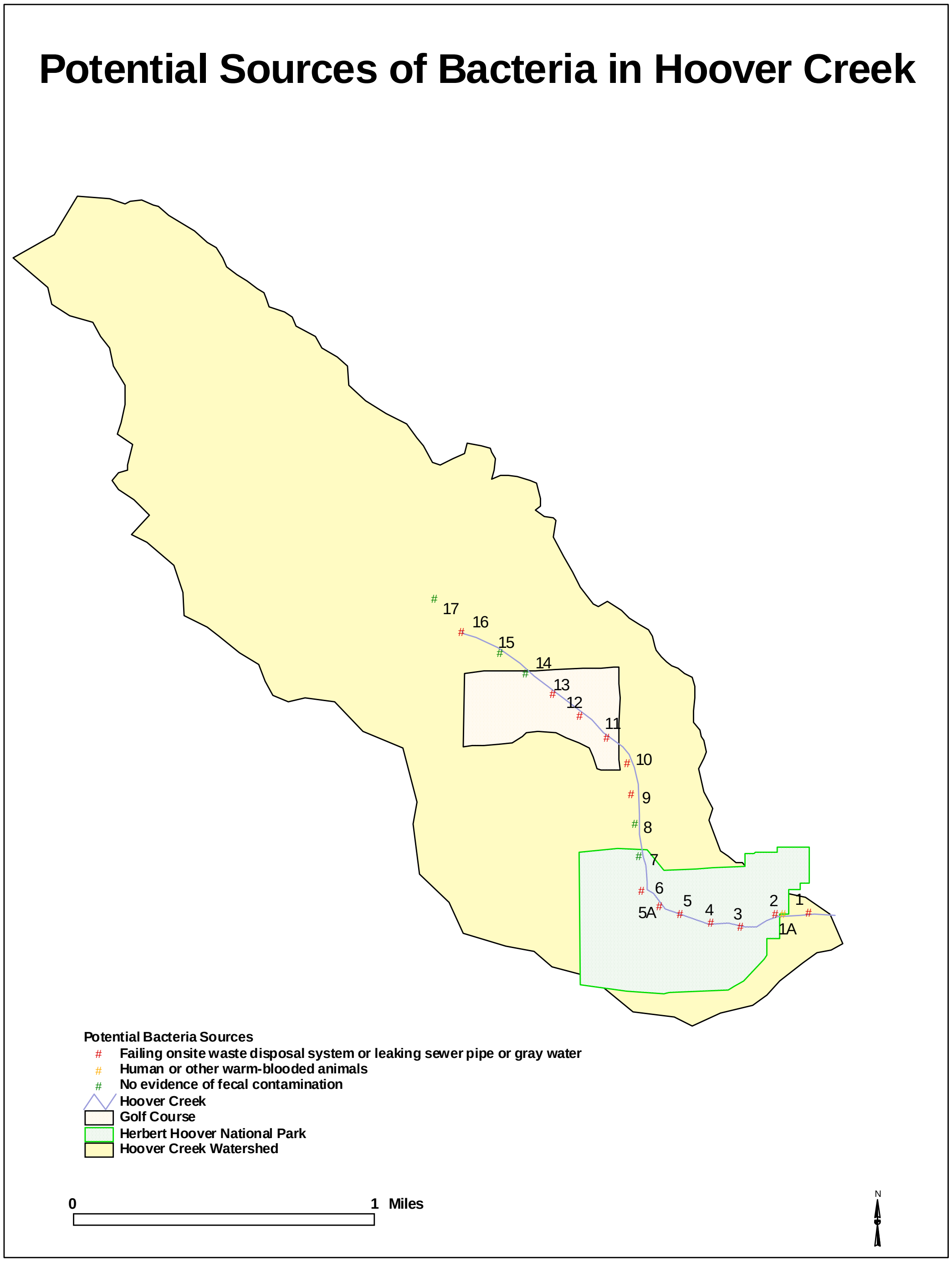
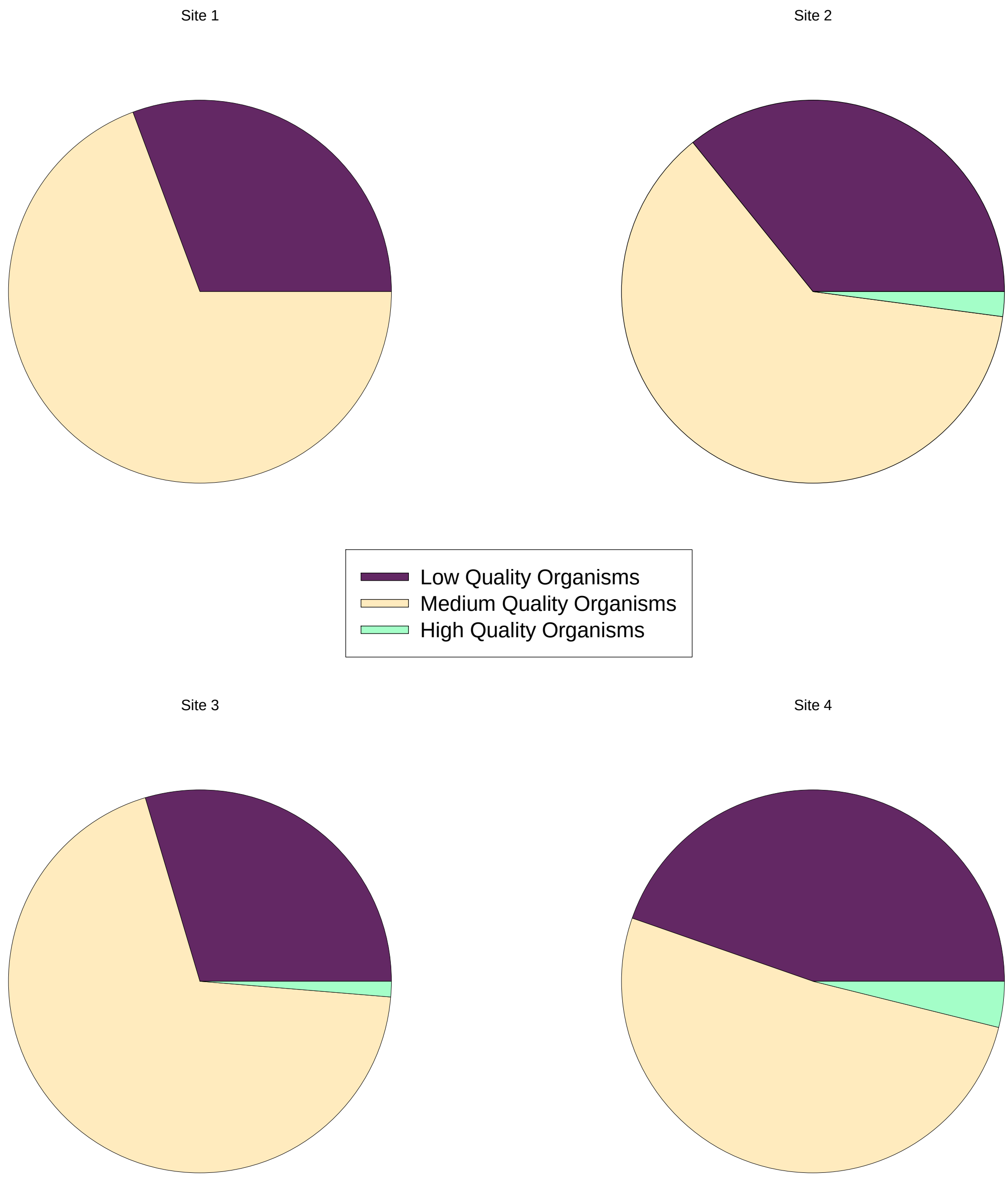

Potential Sources of Bacteria in Hoover Creek
17
16
15
14
13
12
11
10
9
8
7
6
5A
5
4
3
2
1
1A
Potential Bacteria Sources
Failing onsite waste disposal system or leaking sewer pipe or gray water
Human or other warm-blooded animals
No evidence of fecal contamination
Hoover Creek
Golf Course
Herbert Hoover National Park
Hoover Creek Watershed
0
1 Miles
N

Figure 8



Site 1
Site 2
Low Quality Organisms
Medium Quality Organisms
High Quality Organisms
Site 3
Site 4

Figure 9

TABLES

Fecal Bacterial Numbers		Optical Brightener Values		Potential Bacteria Sources
High		High		Failing onsite waste disposal system or leaking sewer pipe
High			Low	Human (e.g., outhouse) or other warm-blooded animals
	Low	High		Gray water in storm water system
	Low		Low	No evidence of fecal contamination

Table 1

Sites	Potential Sources of Bacteria
1	Failing onsite waste disposal system/human or other warm-blooded animals
1A	Human or other warm-blooded animals
2	Failing onsite waste disposal system or leaking sewer pipe
3	Failing onsite waste disposal system or leaking sewer pipe
4	Failing onsite waste disposal system or leaking sewer pipes/gray water
5	Failing onsite waste disposal system or leaking sewer pipe
5A	Failing onsite waste disposal system or leaking sewer pipes/gray water
6	Gray water/no evidence of fecal contamination
7	No evidence of fecal contamination
8	No evidence of fecal contamination
9	Gray water/no evidence of fecal contamination
10	Failing onsite waste disposal system or leaking sewer pipes/gray water
11	Gray water
12	Gray water/no evidence of fecal contamination
13	Gray water/no evidence of fecal contamination
14	No evidence of fecal contamination
15	No evidence of fecal contamination
16	Failing onsite waste disposal system or leaking sewer pipes/no evidence of fecal contamination
17	No evidence of fecal contamination

Table 2

Site	1	2	3	4
Taxa Richness (# of organisms)	11.0	13.0	14.0	10.0
EPT Taxa Richness (#of organisms)	0.0	1.0	1.0	1.0
Percent EPT	0.0	1.1	1.3	3.9
Macroinvertebrate Biotic Index	7.1	6.8	6.0	7.0
Percent 3 Most Dominant Taxa	76.7	71.6	73.7	84.5
# of Habitat Types	1	3	2	3
# of Microhabitats	4	10	8	11
Dissolved Oxygen (mg/L)	4	6	8	6
Transparency (cm)	11	52	39	24

Table 3

Site	1	2	3	4
Percentage of Low Quality Organisms	30.7	35.8	29.6	44.7
Percentage of Medium Quality Organisms	69.3	62.1	69.1	51.5
Percentage of High Quality Organisms	0.0	2.1	1.3	3.9
# of Habitat Types	1	3	2	3
# of Microhabitats	4	10	8	11
Dissolved Oxygen (mg/L)	4	6	8	6
Transparency (cm)	11	52	39	24

Table 4

Stream Characteristic	Minimum Score	Median Score	Maximum Score
Channel Condition	1	3	7
Hydrologic Alteration	1	1	1
Riparian Zone	1	3	10
Bank Stability	1	3	7
Water Appearance	3	7	7
Nutrient Enrichment	3	7	7
Barriers to fish movement	1	10	10
In-stream fish cover	1	3	8
Pools	1	1	7
Canopy Cover	1	1	10
Riffle embeddedness	1	5	5
Overall Score	**2.1**	**5.1**	**6.1**

Table 5

APPENDIX A

2004 Statistics	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	180	4.4	<0.05	0.2	7	2.6	8.7	
10th Percentile	200	5.4	<0.05	0.3	8	3.1	8.8	
25th Percentile	260	7.3	<0.05	0.3	10	3.3	9.2	
50th Percentile	460	9	<0.05	0.3	11	6.8	13.5	
75th Percentile	650	11.5	<0.05	0.4	15	8	16.5	
90th Percentile	858	13	<0.05	0.5	23	8.3	19.1	
Maximum	2900	15	0.07	0.5	31	9.4	20.1	

2005 Statistics	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	<10	6.8	<0.05	0.1	3	6.4	1	2
10th Percentile	<10	7.3	<0.05	0.2	3	6.9	2.8	4
25th Percentile	25	7.9	<0.05	0.2	6	7.9	4.5	6
50th Percentile	110	8.6	<0.05	0.3	11	8.6	16.4	9
75th Percentile	1013	9.6	<0.05	0.3	17	10	17.7	12
90th Percentile	1880	11	<0.05	0.4	27	10.8	18.9	25
Maximum	4300	11	0.1	0.5	30	11.1	20.3	47

2006 Statistics	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	50	0.2	<0.05	0.2	2	4.3	4	2
10th Percentile	343	0.4	<0.05	0.3	6	5.5	4.6	8
25th Percentile	598	0.6	<0.05	0.5	10	6.3	13.7	10
50th Percentile	1600	4.4	<0.05	0.7	18	7.5	18.7	26
75th Percentile	3475	8.6	0.1	0.9	35	9.4	20.5	42
90th Percentile	22700	9.2	0.1	2.2	887	10.5	21.1	626
Maximum	29000	12	0.7	5.4	>1000	11.1	21.9	4440

APPENDIX B

Site 1

Statistic	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	<10	0.4	<0.05	0.1	2	2.6	3.2	2
10th Percentile	9	3.4	<0.05	0.2	6	3.8	4.5	7.4
25th Percentile	160	9.1	<0.05	0.3	8	5.6	9.9	11
50th Percentile	460	10.5	<0.05	0.4	17	7.5	16.2	29
75th Percentile	1400	11.3	<0.05	0.5	26	9.6	17.8	46
90th Percentile	5040	12.1	0.03	1.7	39	10.7	20.1	570
Maximum	22000	15	0.7	5.4	>1000	11.1	21.1	4440

Site 2

Statistic	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	<10	0.6	<0.05	0.2	4	2.7	1.9	6
10th Percentile	28	1.2	<0.05	0.3	6	4.6	4.5	9
25th Percentile	175	6.4	<0.05	0.3	10	6.3	9.4	11
50th Percentile	425	8.6	<0.05	0.4	13	7.7	16.5	13
75th Percentile	760	9.6	<0.05	0.5	16	8.7	19.1	24
90th Percentile	1950	10	0.03	0.7	22	9.9	20.3	67
Maximum	24000	14	0.1	2.2	623	9.9	21.3	360

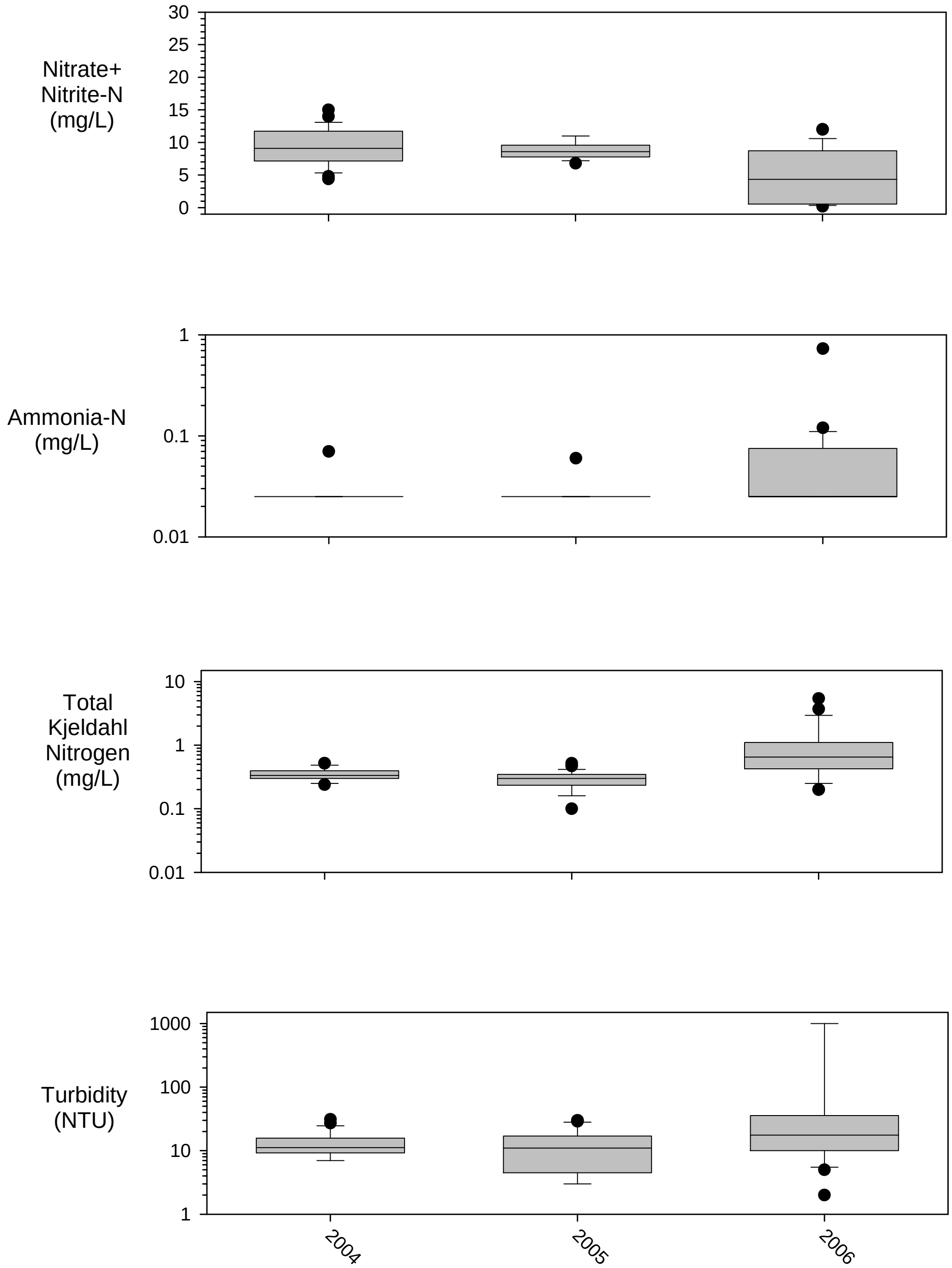
Site 3

Statistic	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	<10	0.5	<0.05	0.2	3	3.2	1.7	3
10th Percentile	53	0.6	<0.05	0.3	5	4.6	4.2	6
25th Percentile	145	5.8	<0.05	0.3	8	7	9.1	8
50th Percentile	450	7.9	<0.05	0.4	11	8.1	16.5	10
75th Percentile	1150	8.7	<0.05	0.4	17	9.3	18.6	21
90th Percentile	2520	9.8	0.1	0.5	27	10.5	20.3	105
Maximum	29000	13	0.1	2.2	>1000	11.1	21.9	810

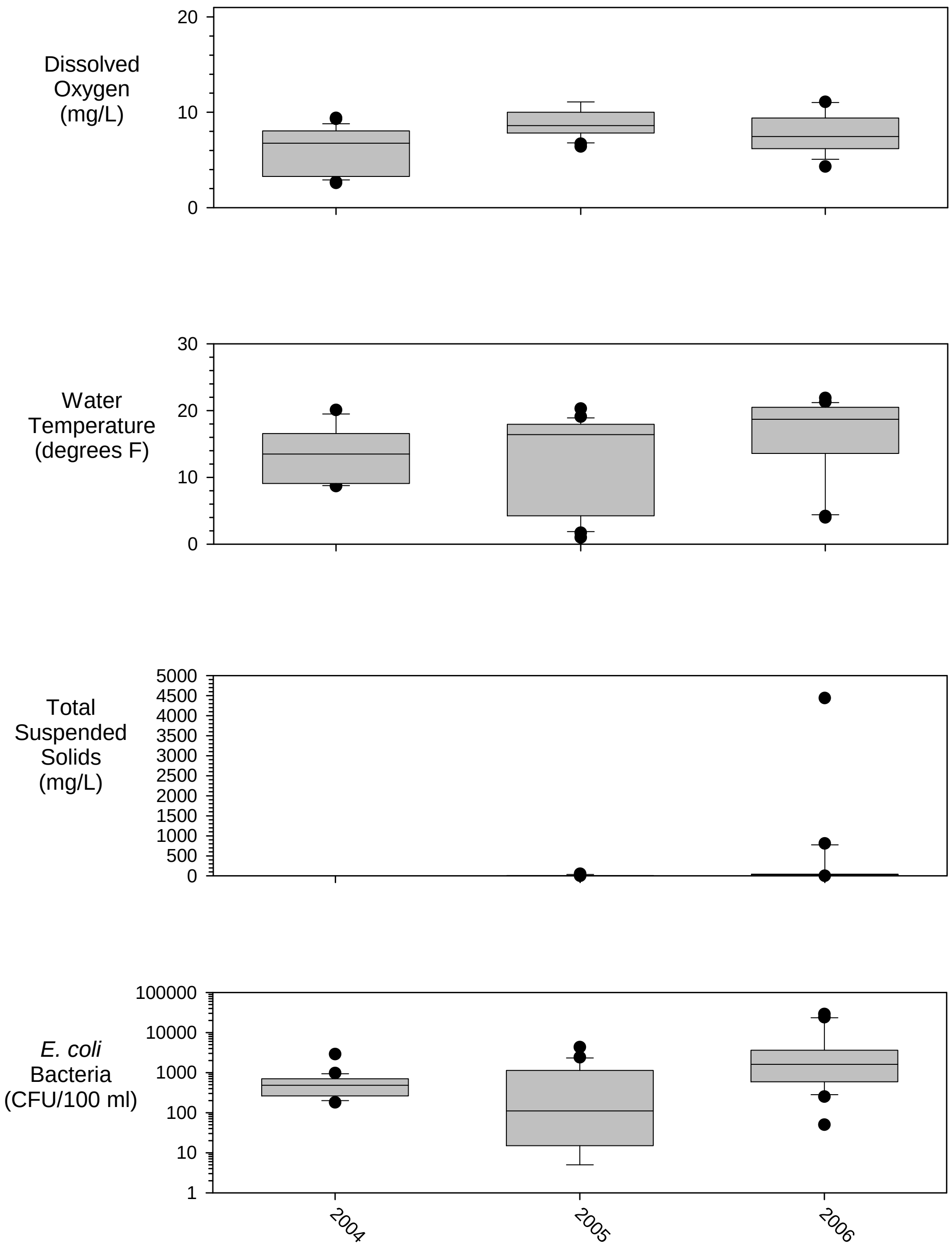
Site 4

Statistic	*E. coli* (CFU/100 ml)	Nitrate+Nitrite-N (mg/L)	Ammonia-N (mg/L)	TKN (mg/L)	Turbidity (NTU)	DO (mg/L)	Temp (°C)	TSS (mg/L)
Minimum	64	0.2	<0.05	0.2	3	3.1	1	2
10th Percentile	158	0.5	<0.05	0.2	7	4.5	4.4	5
25th Percentile	405	5.3	<0.05	0.3	9	6.8	8.7	6
50th Percentile	650	7.4	<0.05	0.3	13	8	16.3	11
75th Percentile	2600	8.3	<0.05	0.5	21	9.2	18.5	28
90th Percentile	3820	9	0.05	0.7	28	9.7	19.6	112
Maximum	23000	12	0.1	1.9	>1000	11.1	20.5	740

APPENDIX C

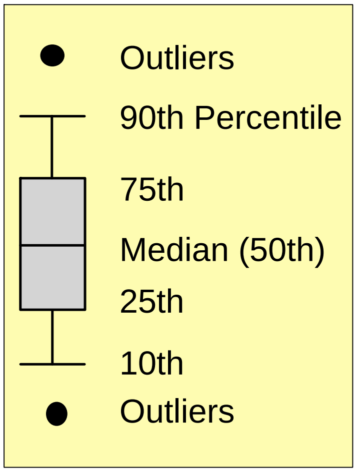


Nitrate+
Nitrite-N
(mg/L)
30
25
20
15
10
5
0
Ammonia-N
(mg/L)
1
0.1
0.01
Total
Kjeldahl
Nitrogen
(mg/L)
10
1
0.1
0.01
Turbidity
(NTU)
1000
100
10
1
2004
2005
2006

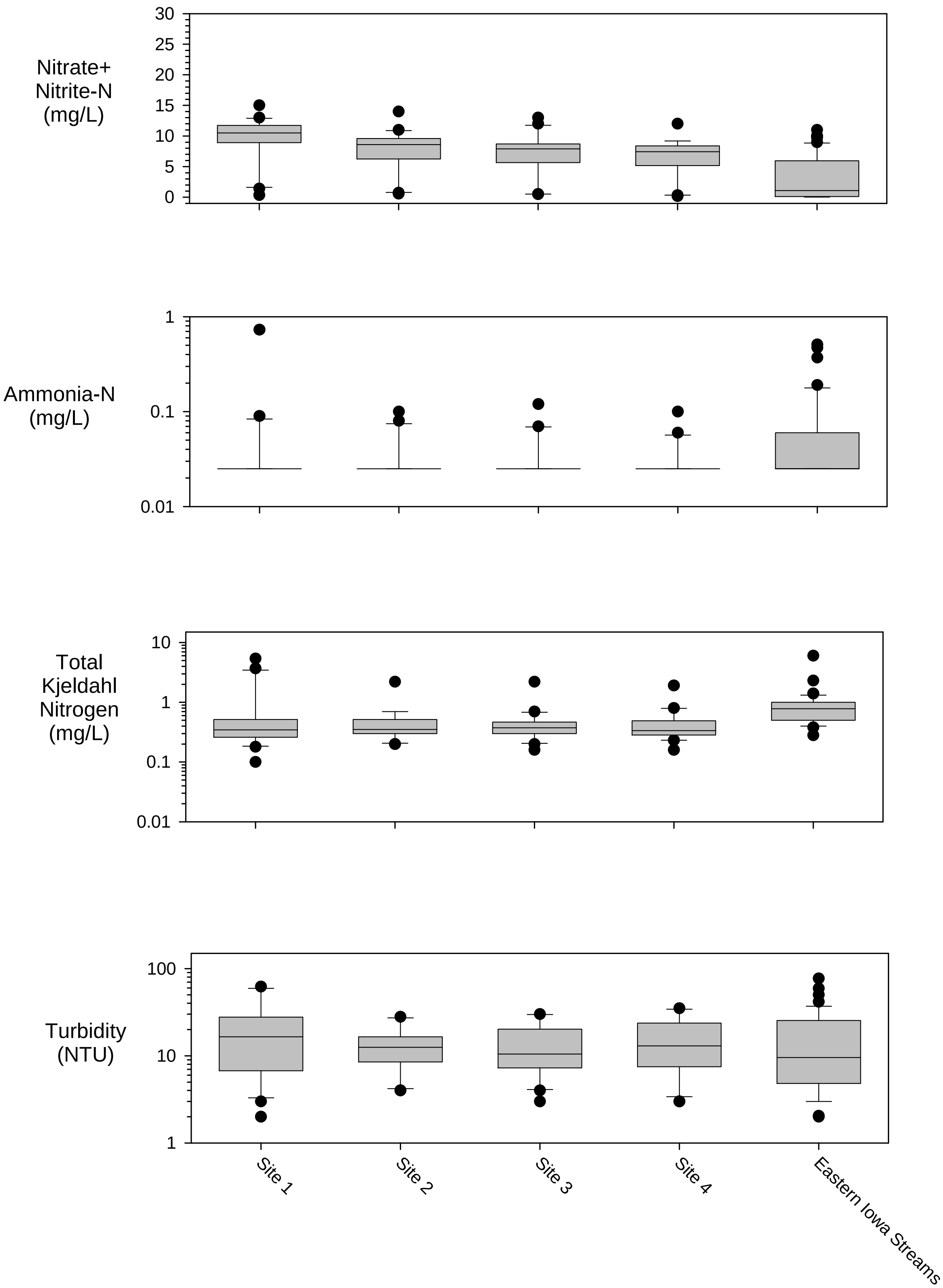


Dissolved Oxygen (mg/L)
20
10
0
Water Temperature (degrees F)
30
20
10
0
Total Suspended Solids (mg/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
E. coli Bacteria (CFU/100 ml)
100000
10000
1000
100
10
1
2004
2005
2006

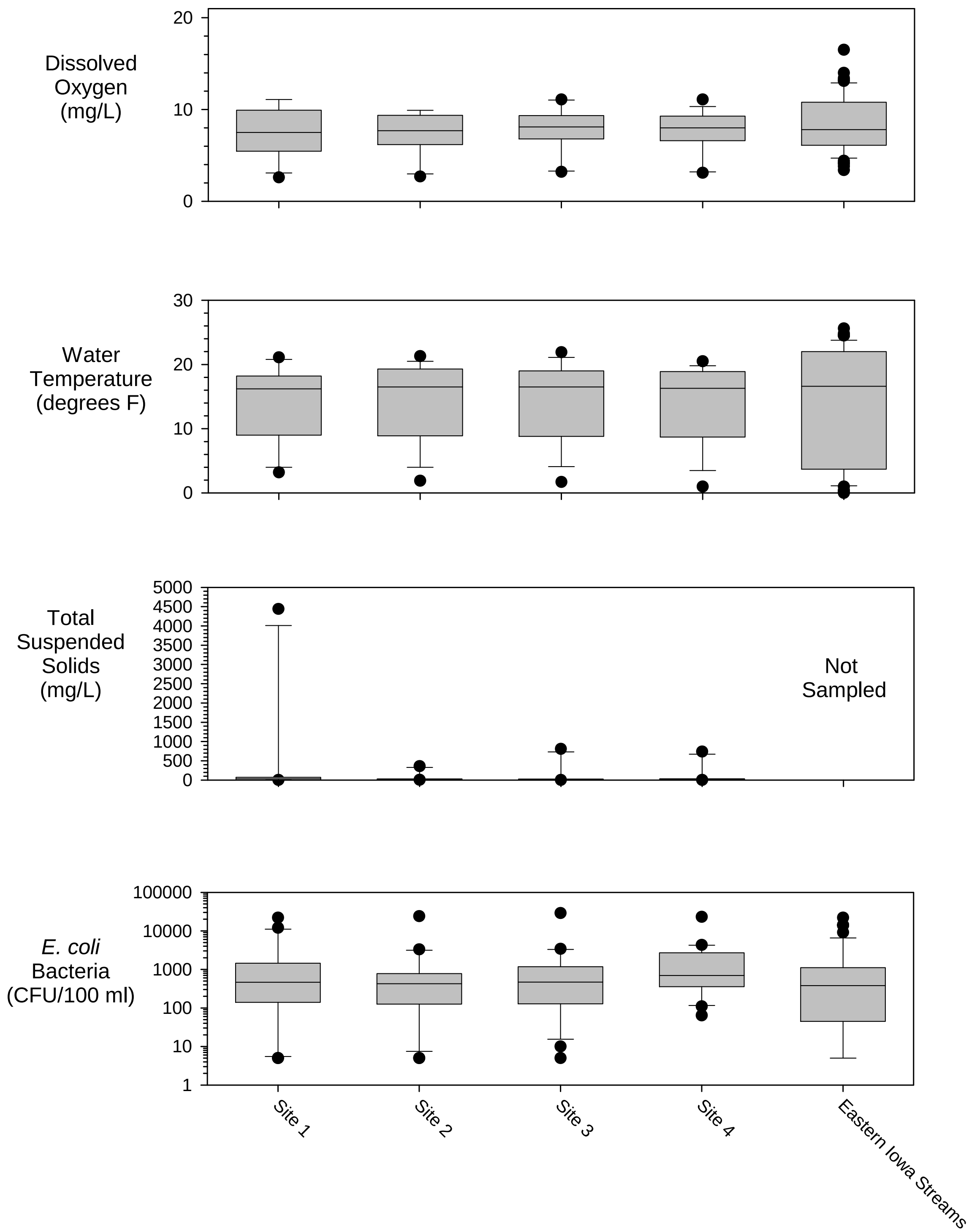
Explanation of a Box Plot



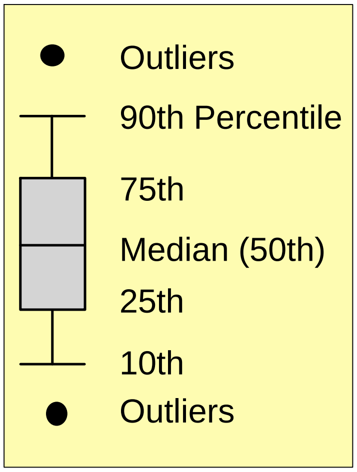
APPENDIX D



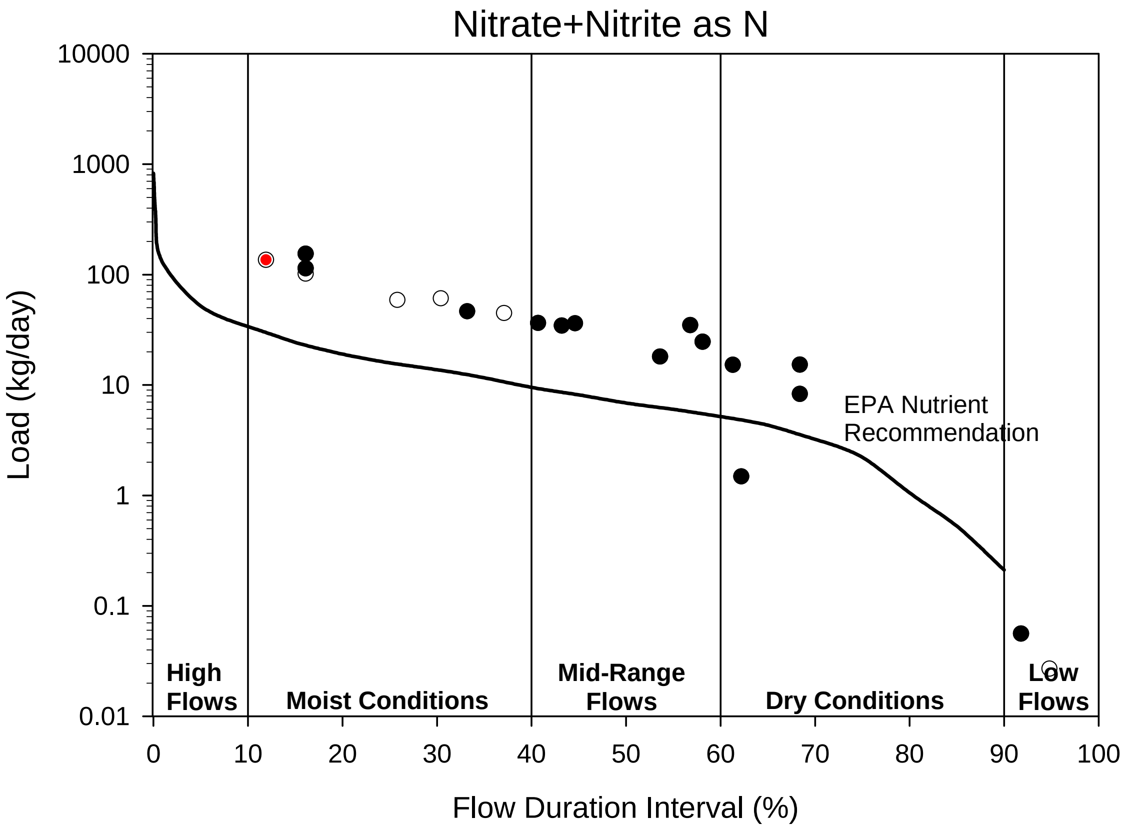
Nitrate+
Nitrite-N
(mg/L)
30
25
20
15
10
5
0
Ammonia-N
(mg/L)
1
0.1
0.01
Total
Kjeldahl
Nitrogen
(mg/L)
10
1
0.1
0.01
Turbidity
(NTU)
100
10
1
Site 1
Site 2
Site 3
Site 4
Eastern Iowa Streams


Dissolved Oxygen (mg/L)
20
10
0
Water Temperature (degrees F)
30
20
10
0
Total Suspended Solids (mg/L)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Not Sampled
E. coli Bacteria (CFU/100 ml)
100000
10000
1000
100
10
1
Site 1
Site 2
Site 3
Site 4
Eastern Iowa Streams

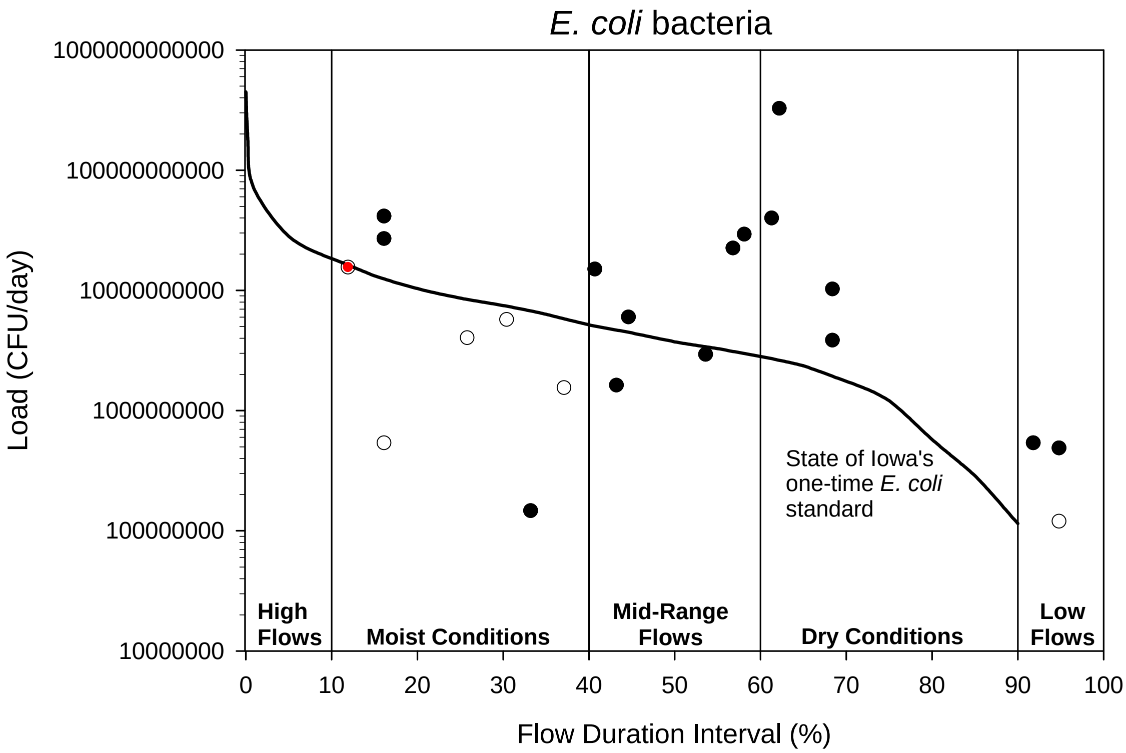
Explanation of a Box Plot



APPENDIX E

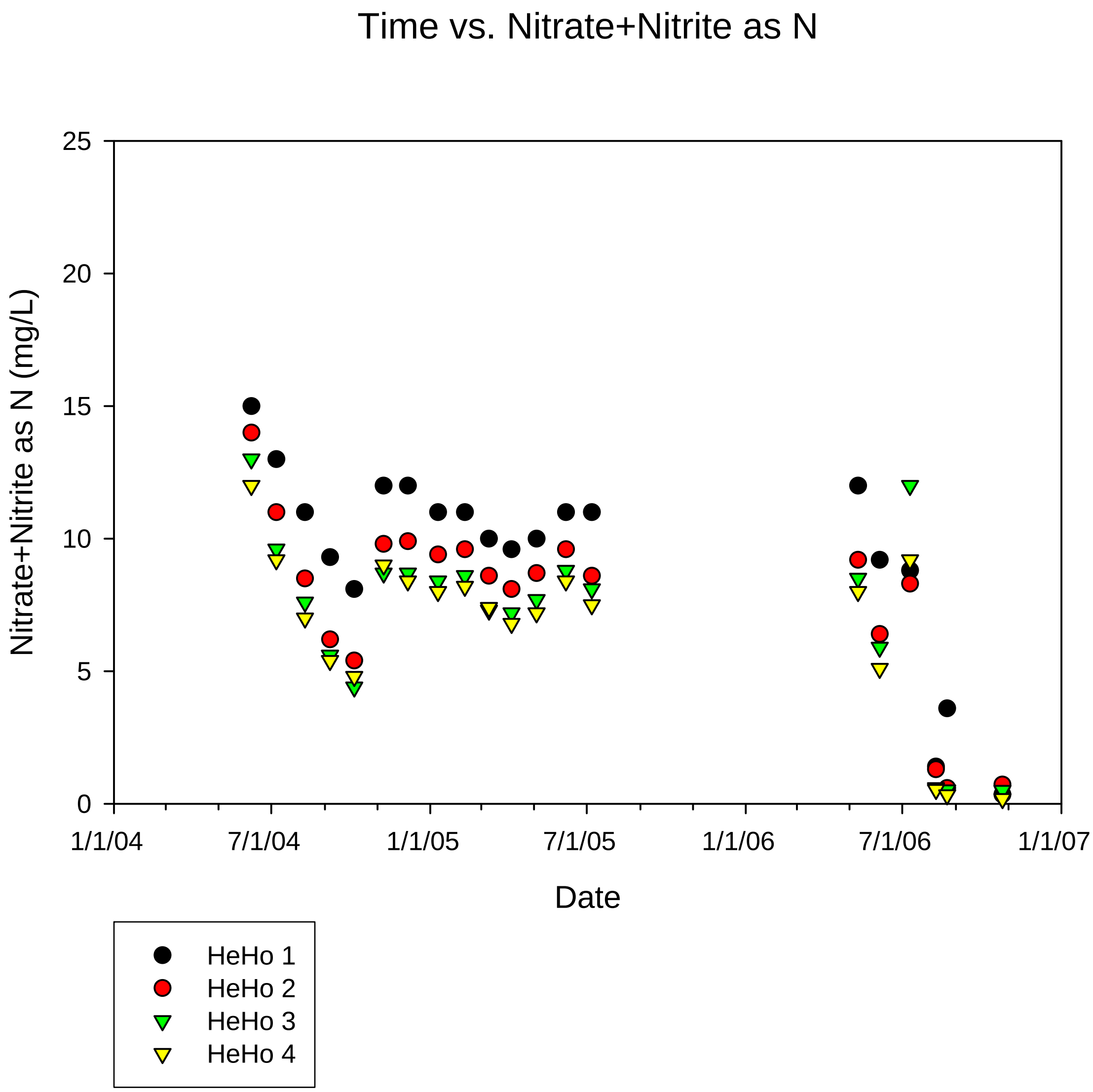


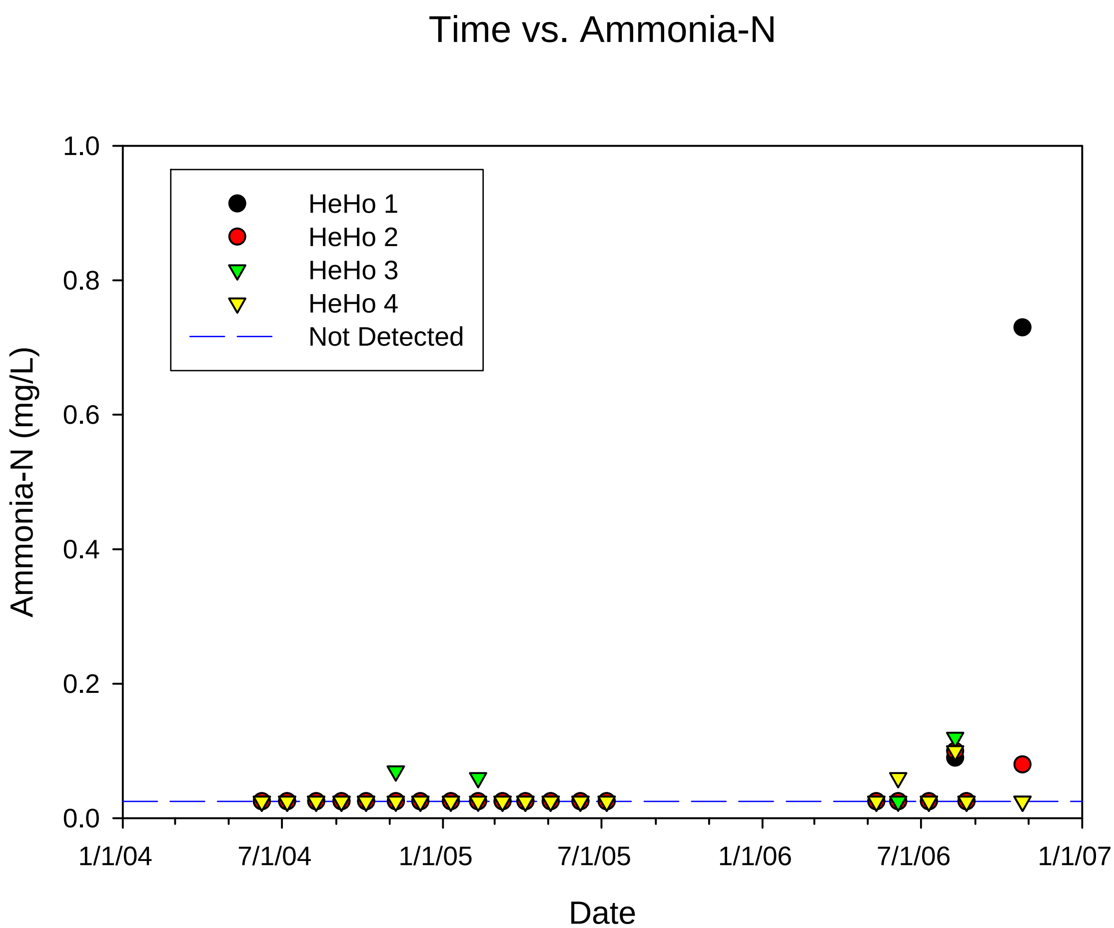
Nitrate+Nitrite as N
10000
1000
100
10
1
0.1
0.01
Load (kg/day)
EPA Nutrient Recommendation
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
Flow Duration Interval (%)



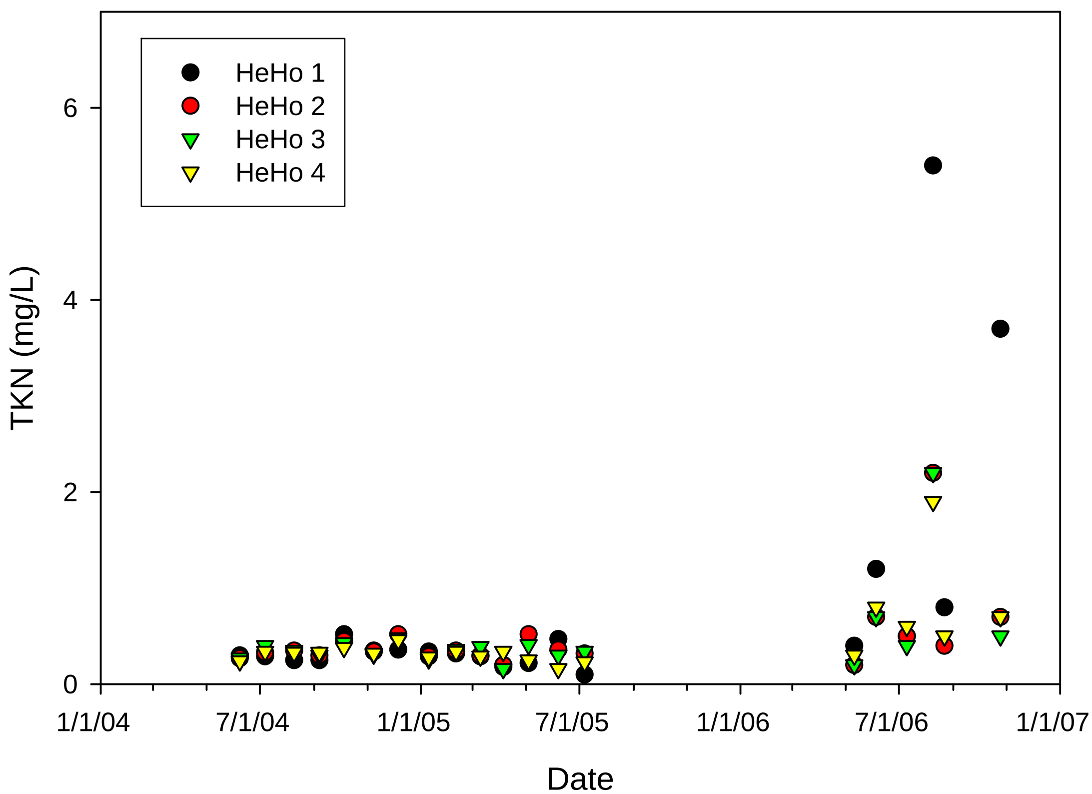
E. coli bacteria
Load (CFU/day)
1000000000000
100000000000
10000000000
1000000000
100000000
10000000
Flow Duration Interval (%)
0
10
20
30
40
50
60
70
80
90
100
High Flows
Moist Conditions
Mid-Range Flows
Dry Conditions
Low Flows
State of Iowa's one-time E. coli standard

APPENDIX F

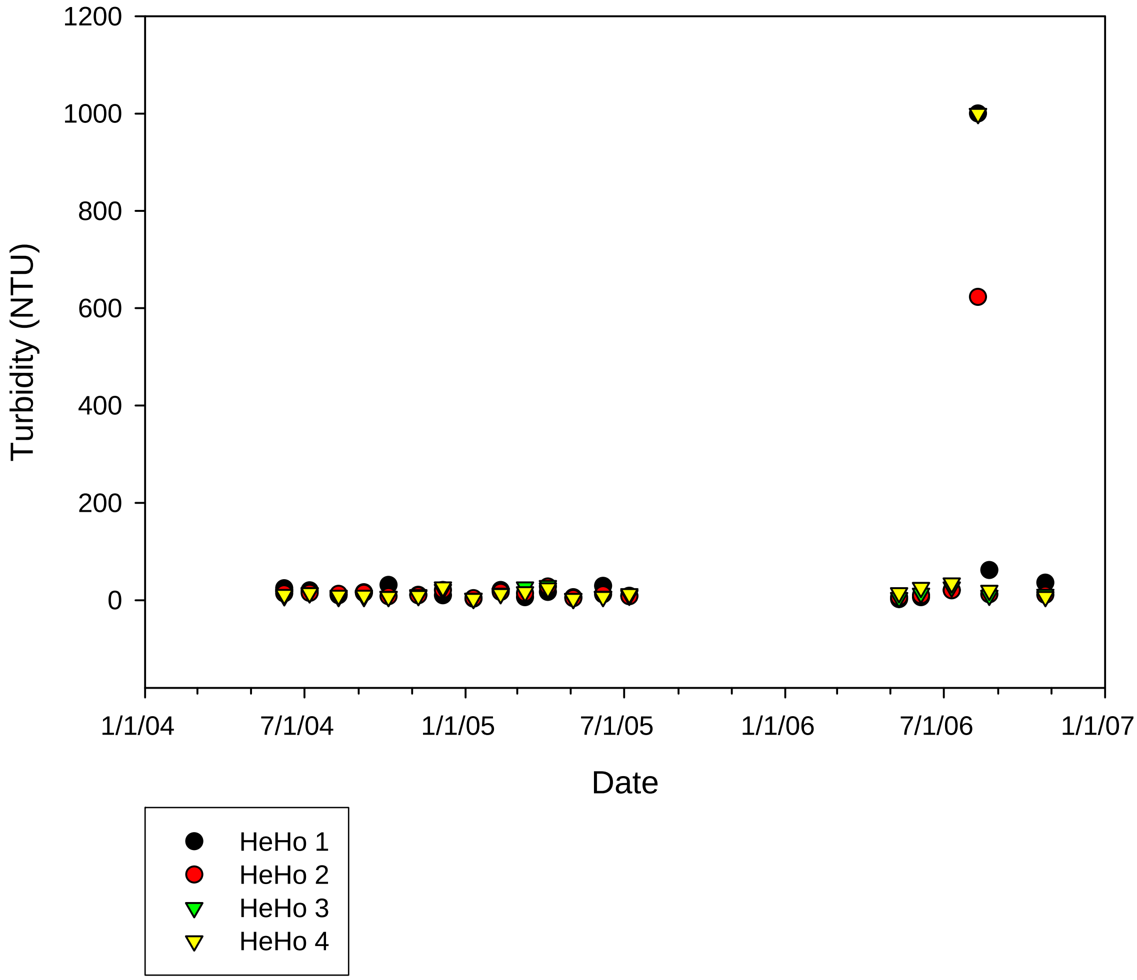

Time vs. Nitrate+Nitrite as N
Nitrate+Nitrite as N (mg/L)
25
20
15
10
5
0
1/1/04
7/1/04
1/1/05
7/1/05
1/1/06
7/1/06
1/1/07
Date
HeHo 1
HeHo 2
HeHo 3
HeHo 4

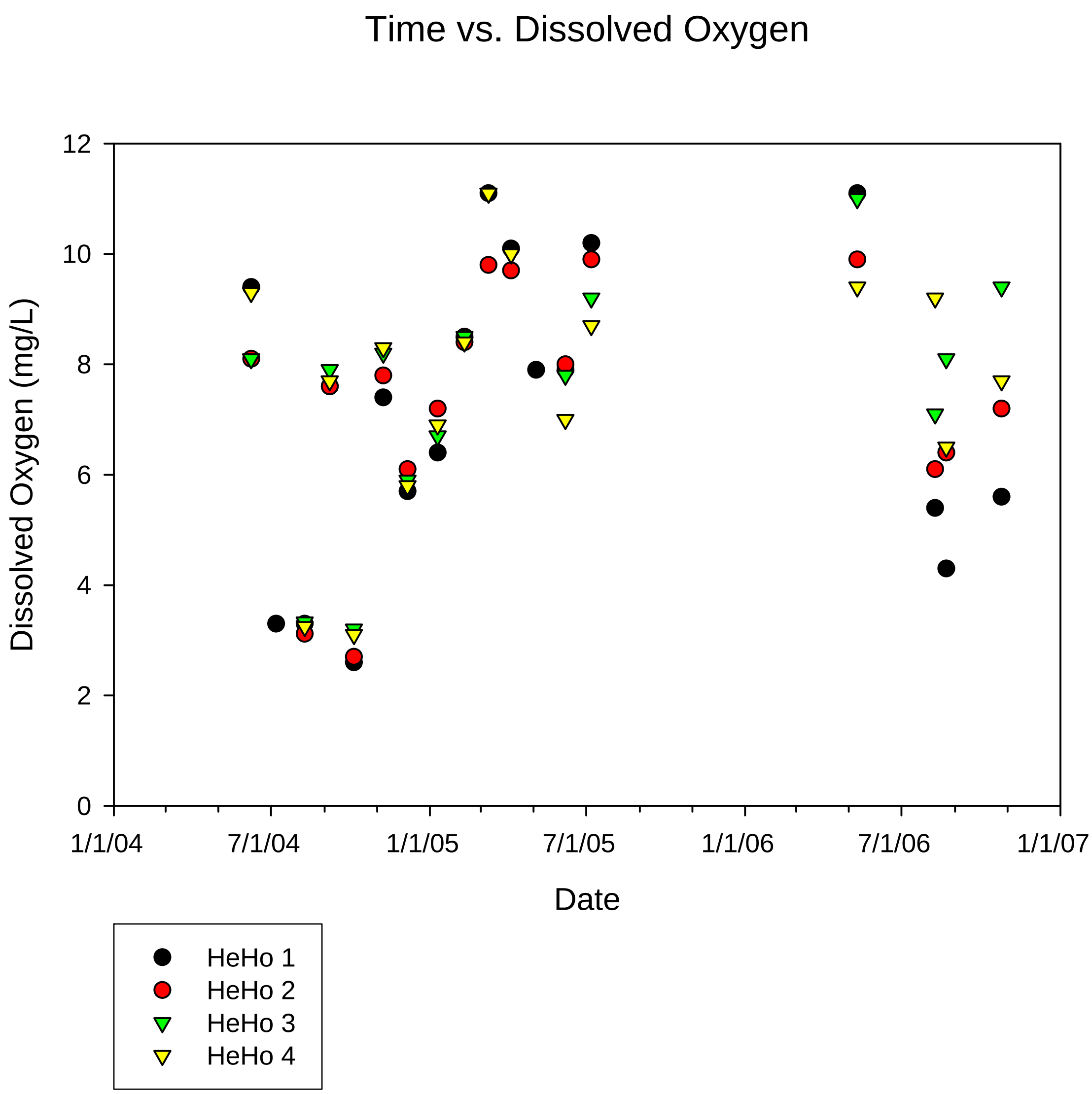

Time vs. Ammonia-N
HeHo 1
HeHo 2
HeHo 3
HeHo 4
Not Detected
Ammonia-N (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
1/1/04
7/1/04
1/1/05
7/1/05
1/1/06
7/1/06
1/1/07
Date

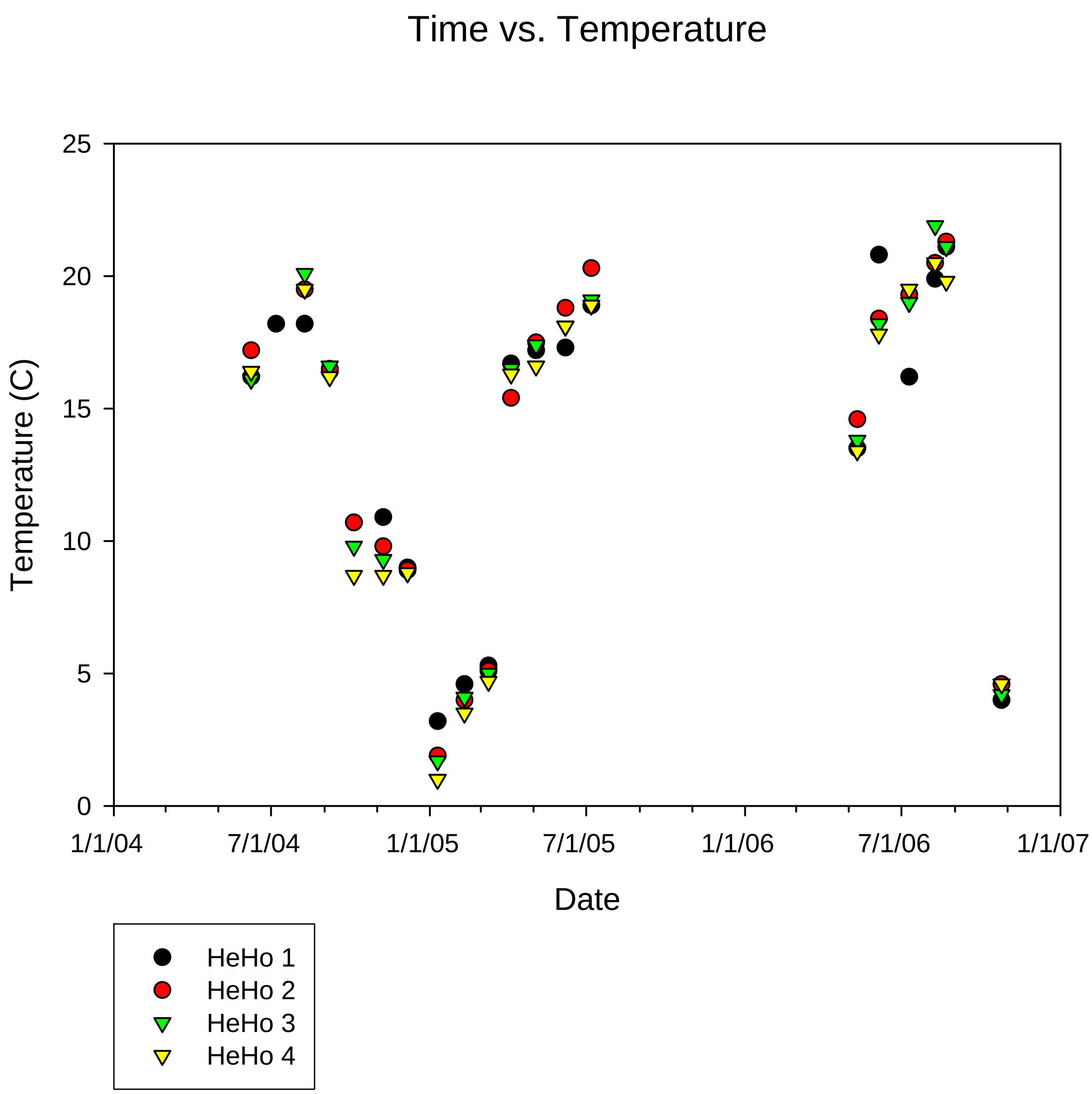
Time vs. Total Kjeldahl Nitrogen



Time vs. Turbidity

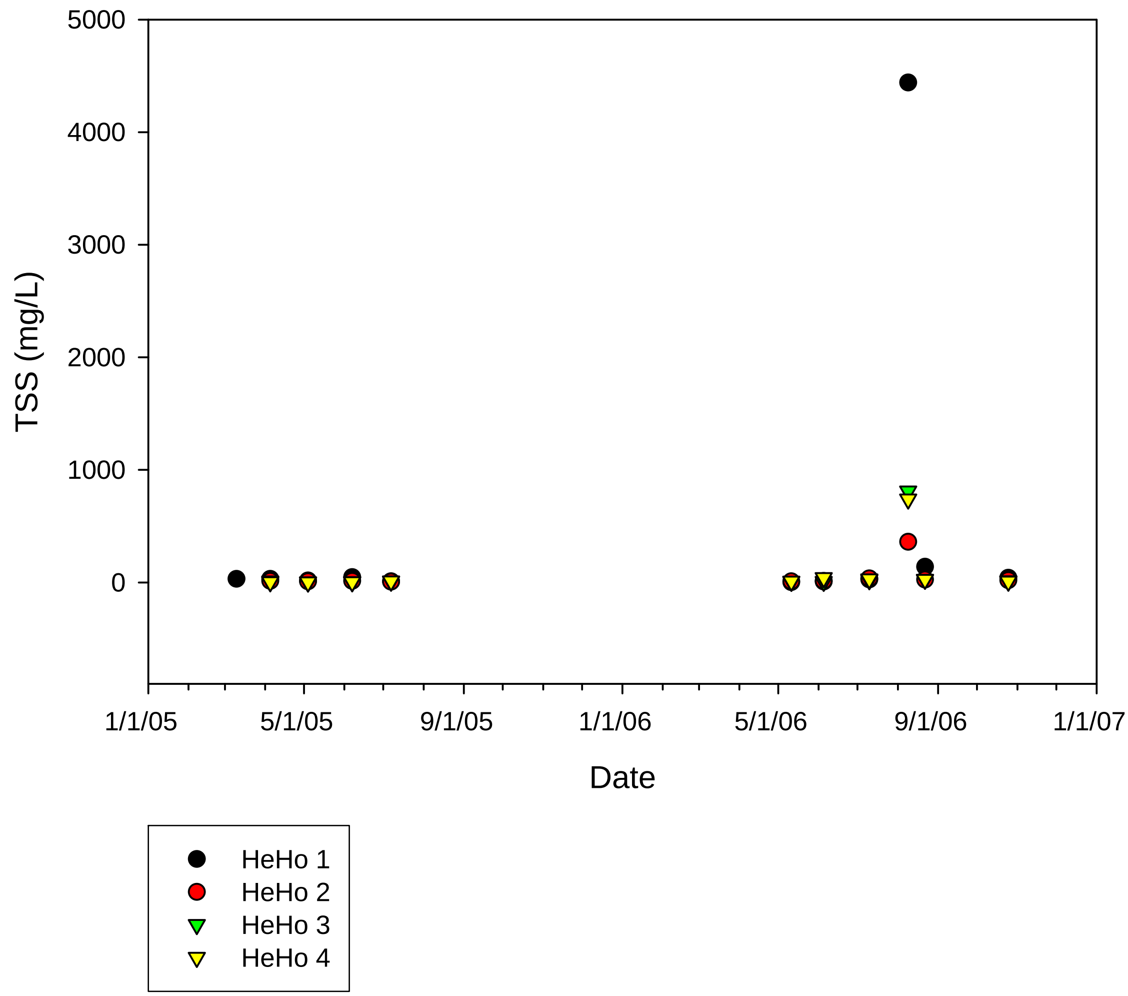



Time vs. Dissolved Oxygen
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
1/1/04
7/1/04
1/1/05
7/1/05
1/1/06
7/1/06
1/1/07
Date
HeHo 1
HeHo 2
HeHo 3
HeHo 4



Time vs. Temperature
Temperature (C)
25
20
15
10
5
0
1/1/04
7/1/04
1/1/05
7/1/05
1/1/06
7/1/06
1/1/07
Date
HeHo 1
HeHo 2
HeHo 3
HeHo 4

Time vs. Total Suspended Solids



Time vs. *E.coli*