Hinkston Creek Watershed Assessment and Management Plan

Prepared for:

Kentucky Energy and Environment Cabinet
Department for Natural Resources
Division of Conservation
Frankfort, Kentucky

SOIL CONSERVATION DISTRICTS of KENTUCKY
The Soil is in our Hands

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1 Introduction

1.1 THE WATERSHED

The Hinkston Creek watershed is located in the Outer Bluegrass region of Kentucky, in the headwaters of the South Fork Licking River just east of Lexington. Hinkston Creek originates in the southern and western portions of Montgomery County, flows through the city of Mt. Sterling, and then proceeds northward through Bourbon County, where it joins with Stoner Creek to form the South Fork Licking River (Figure 1-1).

Approximately 70 percent of the watershed is covered with pasture, hay, and fallow fields and 2 percent is cultivated crops (i.e., 72 percent of the watershed is devoted to agricultural uses). Low intensity development comprises 7 percent of the watershed, while higher intensity development makes up only 0.5 percent of the watershed and is limited to areas in Mount Sterling, Carlisle, Millersburg, and Sharpsburg. Forested land and areas covered by shrubs act as natural filters within the landscape to treat water quality; these areas make up approximately 20 percent of the watershed. Approximately 21,000 people live in the Hinkston Creek watershed. The population is generally located in developed areas and is sparse throughout the remainder of the watershed.

The 2010 Integrated Report to Congress on the Condition of Water Resources in Kentucky identified several lengths of waterways within the Hinkston Creek watershed as impaired to some degree for fecal coliform, sedimentation/siltation, and/or nutrient/eutrophication biological indicators (KDOW, 2010a). When waterways are designated as impaired, this means these particular waterways are not supporting their designated use such as activities like fishing, wading, and swimming. The South Fork Licking River receives waters from the Hinkston Creek watershed which are then used as a drinking water source and a recreational resource by communities in Harrison and other counties, making good water quality in the Hinkston Creek watershed a public health concern not just for local residents but also for those that live outside of the watershed.

In an effort to proactively address the identified waterway impairments and improve water quality, the Kentucky Division of Conservation and the Kentucky Division of Water have initiated the development of a Hinkston Creek Watershed Based Plan. Throughout this plan document, the Hinkston Creek watershed will be divided into six reporting units (Figure 1-1) for the purposes of reporting existing watershed conditions and developing best management practices (BMPs) to improve water quality. For detailed assessments required for the evaluation of existing conditions, such as constructing models, performing the loading analysis, and assessing riparian status, the watershed was divided into 34 assessment subwatersheds.

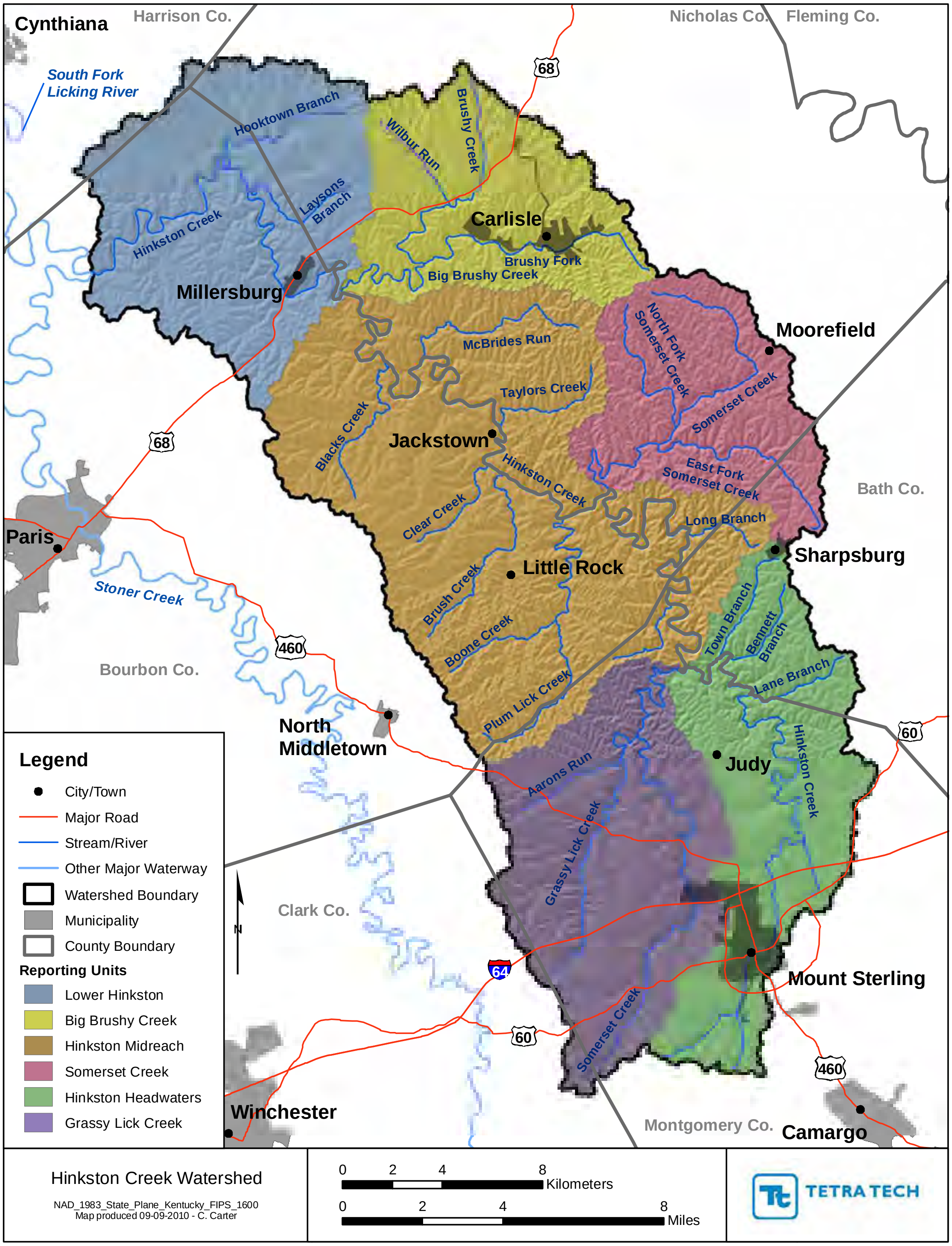


Figure 1-1. Reporting Units within the Hinkston Creek Watershed

1.2 PARTNERS AND STAKEHOLDERS

The Hinkston Creek Watershed Project was developed by Tetra Tech staff, with the approach based on observations and involvement with watershed management projects in Kentucky (Clark and Rowan counties), Arkansas, and other areas. Because land use in the watershed is 70 percent pasture/hay land and 20 percent forest/shrub – and less than 8 percent developed – the stakeholder approach adopted is focused on working with landowners, land managers, and resource specialists, largely in the agricultural sector. The presence of active county soil and water conservation boards in the watershed counties provides an opportunity to work with existing organizations that have a long-term relationship with landowners/managers and resource staff, and with the Kentucky Division of Conservation, which is providing primary support for development of the watershed assessment and management plan.

Project staff meets quarterly with the Montgomery County Conservation District, which covers the two reporting units identified as the initial focus areas for implementation of best management practices (BMPs). Staff have also met with and provided project orientation sessions to the Bourbon, Nicholas, and Bath County Conservation District Boards, and will be working with these boards in the future to help secure funding for BMP implementation in those counties.

Besides the county conservation districts, project staff have also worked with and consulted the partners listed in Table 1-1 below in developing the watershed assessment and management plan.

Table 1-1. Project Partners, Roles, and Contact Information

Partner	Organization	Role	Contact Info
Gary Williamson	Mayor City of Mt. Sterling	Consultation on flooding issues in Mt. Sterling	859-498-8725
Floyd Arnold	Judge-Executive Montgomery County	Consultation on project implementation	859-498-8707
Steve Lane	Public Works Director City of Mt. Sterling	Consultation on flooding issues in Mt. Sterling	859-498-8744
Edsel Boyd	US Department of Ag NRCS Field Office	Consultation on ag BMPs and other issues	859-498-8907
Ron Catchen	UK Ag Extension Services	Consultation on ag practices and other issues	859-498-8741
Faye Ferrell	Montgomery County Conservation District	Ag BMP cost share funding and signup procedures	859-498-5654
David Pearce	Director, Mt. Sterling Water & Sewer System	Consultation on WWTP operations	859-497-0481
Greg Gilvin	Mt. Sterling – Montgomery Rails-Trails	Consultation on joint trail and creek planning	859-498-8732
Emily Anderson	Fleming County Conservation District	Consultation on ag practices, funding, BMPs	606-845-9387
April Haight	Morehead State University IRAPP	Water quality monitoring and watershed assessment	606-783-2455
Crystal Renfro	KY Division of Conservation	Working with county conservation districts	859-987-2311
Angie Wingfield	KY Division of Conservation	Project coordination and management	502-573-3080
James Roe	KY Division of Water NPS Section	Project coordination and management	502-564-3410

Partner	Organization	Role	Contact Info
Jamie Vinson	Mt. Sterling Advocate Newspaper	Public awareness newspaper columns	859-498-2222
Lajuanda Haight-Maybriar	Licking River Watershed Coordinator	Consultation on watershed planning	859-948-3263

The rationale for the approach outlined above is two-fold:

1. The low status of many Kentucky waterbodies among the public at large; i.e., streams and small rivers that drain mostly agricultural and forest land lack the “star power” of major recreational lakes, world-class fishery rivers, marine beaches, and cold-water “fly fishery” streams. In many cases, small creeks and rivers are viewed – and mostly treated – as urban/rural storm sewers, intended primarily to drain precipitation away as quickly as possible.

2. The overarching reality that polluted runoff is the predominant pollution cause and source – rather than high profile, easy-to-target point sources – and that a relatively small group of landowners and land managers in each watershed should be the real stakeholders and target audiences for many of our nonpoint source pollution control efforts because they can affect significant changes in water quality. Except in rare cases (e.g., large new subdivisions, new strip-type developments, industrial facilities with large materials storage/handling yards, etc.), there is little that the average property/home owner can do to address the big nonpoint pollution sources in the 90-plus percent of the Hinkston Creek watershed that is rural. Most of the water quality issues are related to pasture management, cattle access to streams, hydromodification (largely on agricultural lands), removal of riparian vegetation, and scattered row crop plots. Few residential property owners have been observed applying significant quantities of fertilizer to their yards, due to the cost, the general lack of need (i.e., soil fertility in most of Central Kentucky is fair to good), and the absence of any sort of a “yard farmer” culture. There is a need for targeted implementation of green infrastructure subdivision design, industrial and construction stormwater management practices, and better vegetation along urban/suburban streams, but these apply to a very small percentage of the watershed.

2 Hinkston Creek Watershed

2.1 INTRODUCTION

The Hinkston Creek watershed encompasses 260 square miles of rolling pasture-land in east-central Kentucky, northeast of Lexington. Hinkston Creek joins with Stoner Creek – with a watershed of 284 square miles – to form the headwaters of the South Fork of the Licking River. The South Fork Licking River then flows generally northward toward Covington, KY to drain into the Licking River, which discharges shortly thereafter into the Ohio River.

The Hinkston Creek watershed includes the northern third of Montgomery County, the eastern half of Bourbon County, and the western half of Nicholas County. There is a small portion in Bath County and very small areas within the borders of Harrison and Clark counties. The largest community in the watershed is Mt. Sterling (pop. 6,000); other communities include Millersburg (842), Carlisle (1,917), and Sharpsburg (295). With the exception of Mt. Sterling, which has more than a dozen manufacturing operations employing around 3,500 workers, most of the watershed can be described as rural pasture-land populated by low-to-moderate income citizens who are about 90 percent white and 10 percent African-American and Hispanic.

As noted previously, the watershed lies in the Outer Bluegrass region, and is dominated by beef cattle production, hay and tobacco, manufacturing (processed food products, metal plating and fabrication, automotive plastics and rubber molding, parts assembly), retail and restaurant businesses, and services in the local towns (education, health care, social services, etc.).

Hinkston Creek is about 70 miles long. In general, the stream network in the watershed consists of a classical dendritic drainage pattern, with primary mainstem tributaries measuring about five miles in length, with secondary tributaries one mile in length. Average land slope lengths range from 500 to around 1,500 feet. With land use/cover consisting of about 70 percent pasture/hay fields, 20 percent forest/brush, and about 10 percent developed, water quality impacts are mostly linked to agricultural practices, with localized heavy impacts on stream reaches in Mt. Sterling, Carlisle, and Millersburg. Tobacco production in the watershed peaked during 1998 – 2002, and has fallen by approximately two-thirds since then, a fairly significant development with ramifications involving sediment runoff from row crop land (probably less), livestock impacts to waterways (probably greater), and regional agricultural economic output (probably less, but partially offset by greater cattle production).

Among the permitted dischargers are four sewage treatment plants, three are permitted at less than 1 MGD and one is permitted for over 1 MGD of discharge. The land cover in the watershed is dominated by agriculture.

2.2 WATER RESOURCES

2.2.1 Watershed Boundary and Hydrology

Hinkston Creek originates in the southern and western portions of Montgomery County, flows through the city of Mt. Sterling, and then proceeds northward through Bourbon County, where it joins with Stoner Creek to form the South Fork of the Licking River. The creek drains much of western Nicholas County, and a portion of western Bath County. A small fraction of the watershed lies in Harrison and Clark counties. Major tributaries of the watershed include Boone Creek, Grassy Lick Creek, Black's Creek, Somerset Creek, Big Brushy Creek, and Taylor's Creek, among others (Figure 1-1). The Hinkston Creek watershed includes the municipalities of Sharpsburg, Carlisle, Millersburg, and Mount Sterling and covers a total drainage area of approximately 166,464 acres (260.1 square miles).

The United States Geological Survey (USGS) maintains a monitoring station in the Hinkston Creek watershed. Among the parameters observed and reported is daily average stream flow. The monitoring station identification number is 03252300 and it is named Hinkston Creek near Carlisle, KY. The location is shown in Figure 2-1 and Table 2-1 presents summary information about the reported daily average flow values. The period of record reflected in the table is from 1991 to 2010, with provisional data for water year 2010. The study area is influenced by karst features (Section 2.3.2) however there was no quantification of the source/sink connectivity of the karst features with the stream flow.

Table 2-1. USGS Station 03252300 Daily Average Flow Summary Statistics (1991 – 2010)

Parameter	Value
Drainage Area (mi^2)	154
Maximum (cfs)	7520
75th Percentile (cfs)	174
Median (cfs)	55
25th Percentile (cfs)	11
Minimum (cfs)	0
Average (cfs)	200
Specific Discharge (cfs/mi^2)	1.3

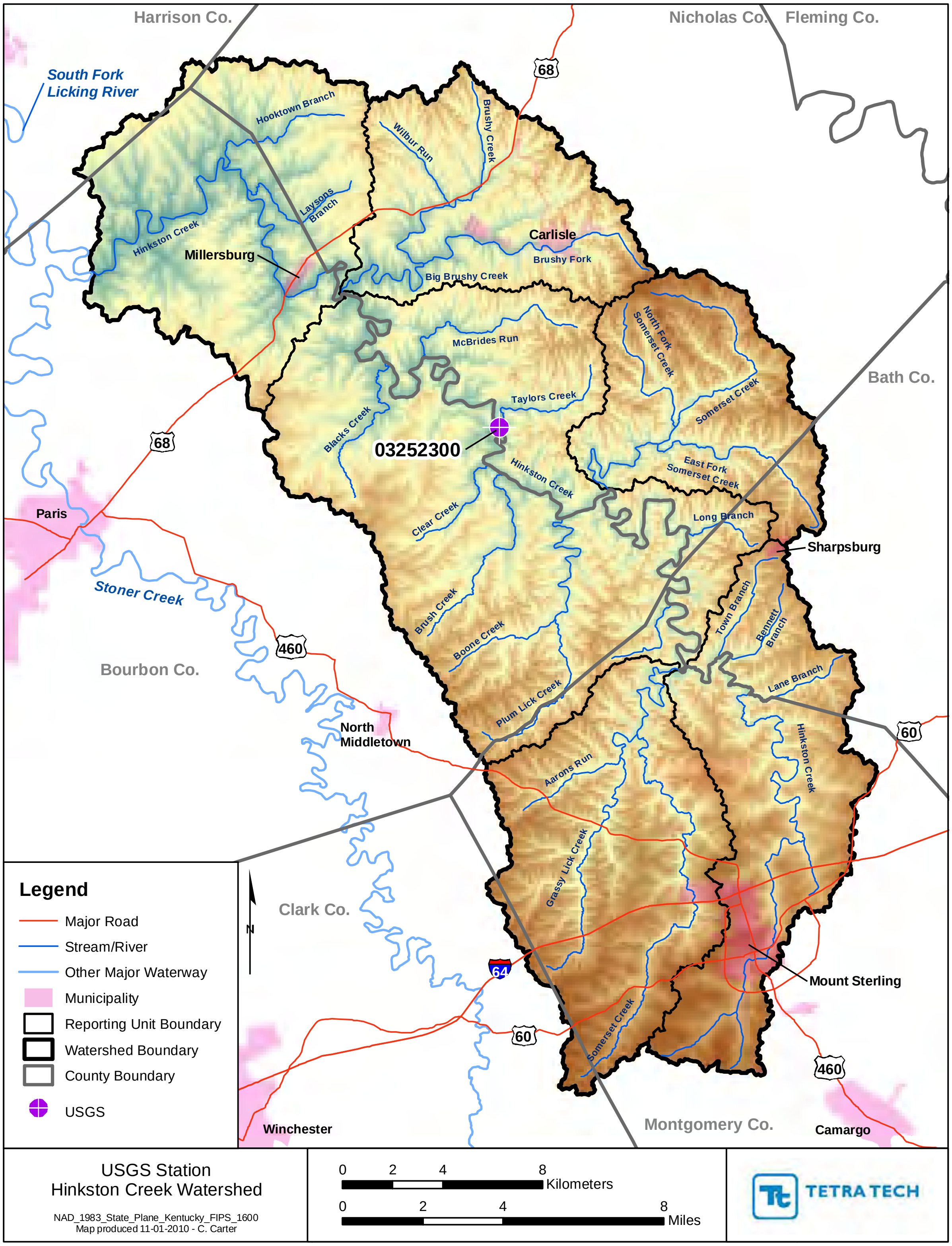


Figure 2-1. **USGS Station Location**

The daily average flow record was developed into 30-day moving averages and presented for the period of record (1991-2010; Figure 2-2) and the study period (2000-2010; Figure 2-3). The two monitoring periods were 2004-2005 and 2009-2010, however the simulation period was selected as 2000-2010. This was because typical modeling practice for watershed model applications is 10-years. A Soil and Water Assessment Tool (SWAT) application was developed for this watershed to assist in addressing objectives of the study such as estimating loading magnitudes and sources. The use of a 30-day moving average helps to reveal wet and dry periods in a record. From the period of record figure (Figure 2-3), it can be seen that the lowest 30-day moving average appears in late 2010. Alternatively, the wettest period appears to have been in early 1997. The 30-day moving average value is near 1 cfs approximately six times in the period of record. The daily average flow value was reported as zero 19 times in the period of record.

Table 2-2 presents the median daily average flow values by water year (October 1 to September 30), they are ordered from lowest to highest median value. Furthermore, water year 2010 contains provisional records. While the table was developed on a water year basis, it is still useful to assess wet/dry periods for the period of record at the USGS monitoring station. The Kentucky Division of Water (KDOW) monitoring data spans March 2004 to February 2005, while the data collected by Morehead State University spans November 2009 to October 2010 (refer to Section 3.1 for more detailed information on monitoring). The KDOW period is not coincident to a water year but the MSU monitoring period is essentially water year 2010. The KDOW monitoring period was divided across water year 2004 and water year 2005. Water year 2004 was the highest median value for the period of record. The years that overlap or encompass the KDOW and MSU monitoring periods are indicated with the use of bold font.

Table 2-2. Median Daily Average Flow by Water Year, October 1st – September 30th

Water Year (Oct 01 to Sep 30)	Median (cfs)
2000	15
1999	17
2006	22
2001	36
2002	40
1992	49
1993	50
2008	53
2009	56
2007	57
1995	58
2005	79
1998	81
2010	84
1994	89
1997	93
1996	94
2003	104
2004	107

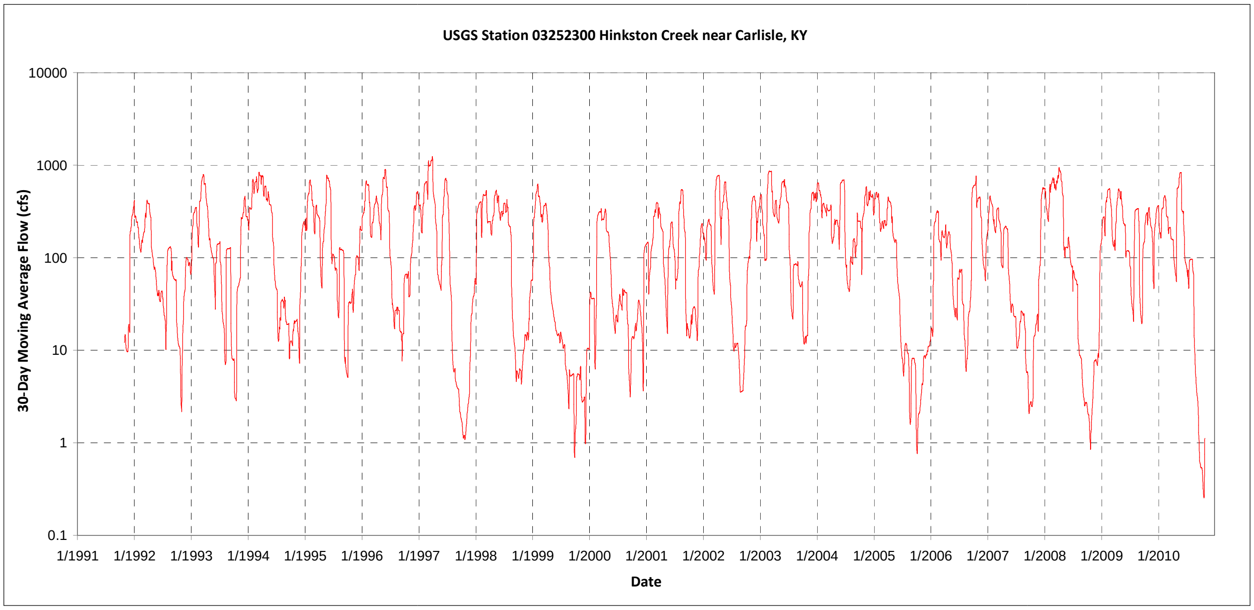


Figure 2-2. **USGS Station 03252300 30-Day Moving Average of Daily Average Flow (cfs), 1991-2010**

Figure 2-3 shows the 30-day moving average of daily average stream flow for the study period (2000-2010). The KDOW and MSU monitoring periods are also highlighted on Figure 2-3. The KDOW monitoring period was wetter than the MSU monitoring period. Table 2-3 presents summary statistics of the daily average flow for the two monitoring periods to further investigate the respective flow regimes. All of the statistical comparisons except the maximum value indicate that that the KDOW sampling period was wetter than the MSU monitoring period.

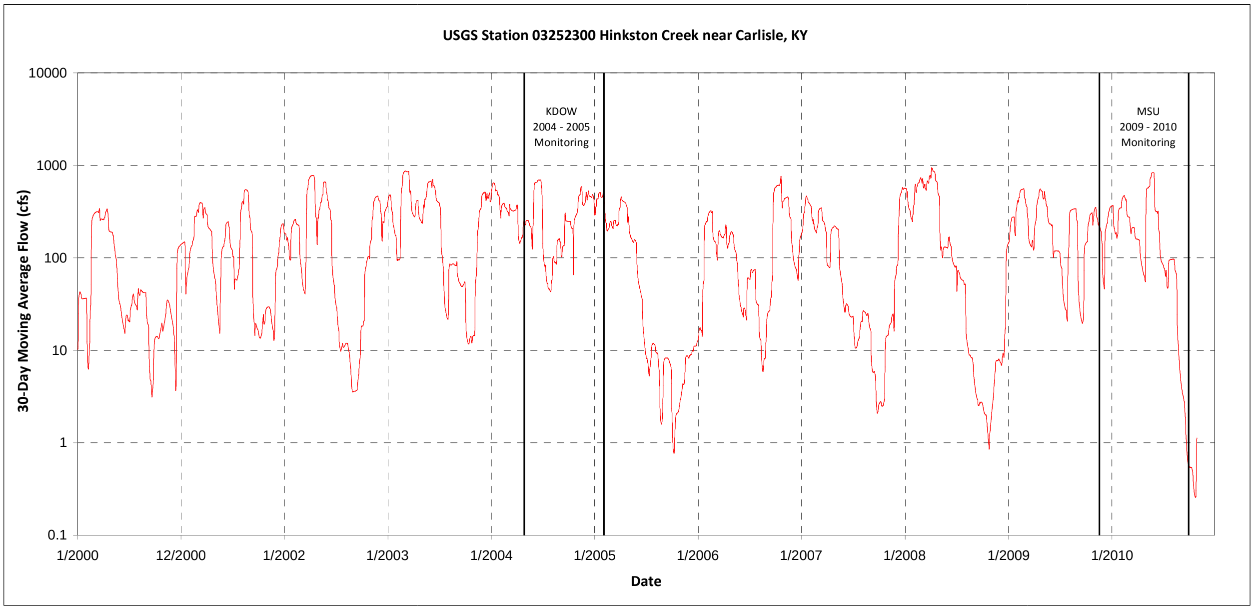


Figure 2-3. **USGS Station 03252300 30-Day Moving Average of Daily Average Flow (cfs), 2000-2010**

Table 2-3. USGS Station 03252300 Daily Average Flow Summary Statistics

Parameter	KDOW Monitoring Period 4/27/2004 – 2/3/2005	MSU Monitoring Period 11/20/2009 – 10/1/2010
Maximum (cfs)	4640	6120
75th Percentile (cfs)	271	164
Median (cfs)	101	77
25th Percentile (cfs)	36	24
Minimum (cfs)	11	0
Average (cfs)	311	212

A SWAT watershed model was constructed as part of this work. Rainfall records were obtained in the study area which were needed to drive the watershed model. Figure 2-4 shows the locations of four rainfall gages located in the study area.

Table 2-4 presents annual (calendar year) totals of the patched records. The raw records were reviewed for impaired periods and then patched using a normal ratio patching method. Calendar year 2010 is a partial record. Bold font was used to highlight the maximum and minimum values in the patched records for the complete calendar years of 1998-2009. It can be seen that at two of the four stations, 2004 had the highest annual totals, immediately followed in 2005 with the lowest annual totals.

Table 2-4. Patched Calendar Year Rainfall Totals (in/year)

Year	155640 Mt Sterling	156170 Paris	150804 Blue Lick Springs	154746 Lexington Bluegrass AP
1998	49.29	48.95	50.70	49.63
1999	35.99	34.20	38.90	31.87
2000	37.96	45.30	48.82	42.10
2001	40.60	54.84	49.85	38.97
2002	55.14	52.95	55.78	49.31
2003	55.21	50.31	61.66	53.39
2004	62.32	60.77	64.62	62.44
2005	35.32	32.39	45.86	33.52
2006	50.68	48.53	56.14	52.79
2007	36.06	46.46	32.79	43.71
2008	45.82	48.00	40.35	47.46
2009	50.76	57.86	60.52	54.01
2010 (partial year)	36.31	38.53	38.72	29.88

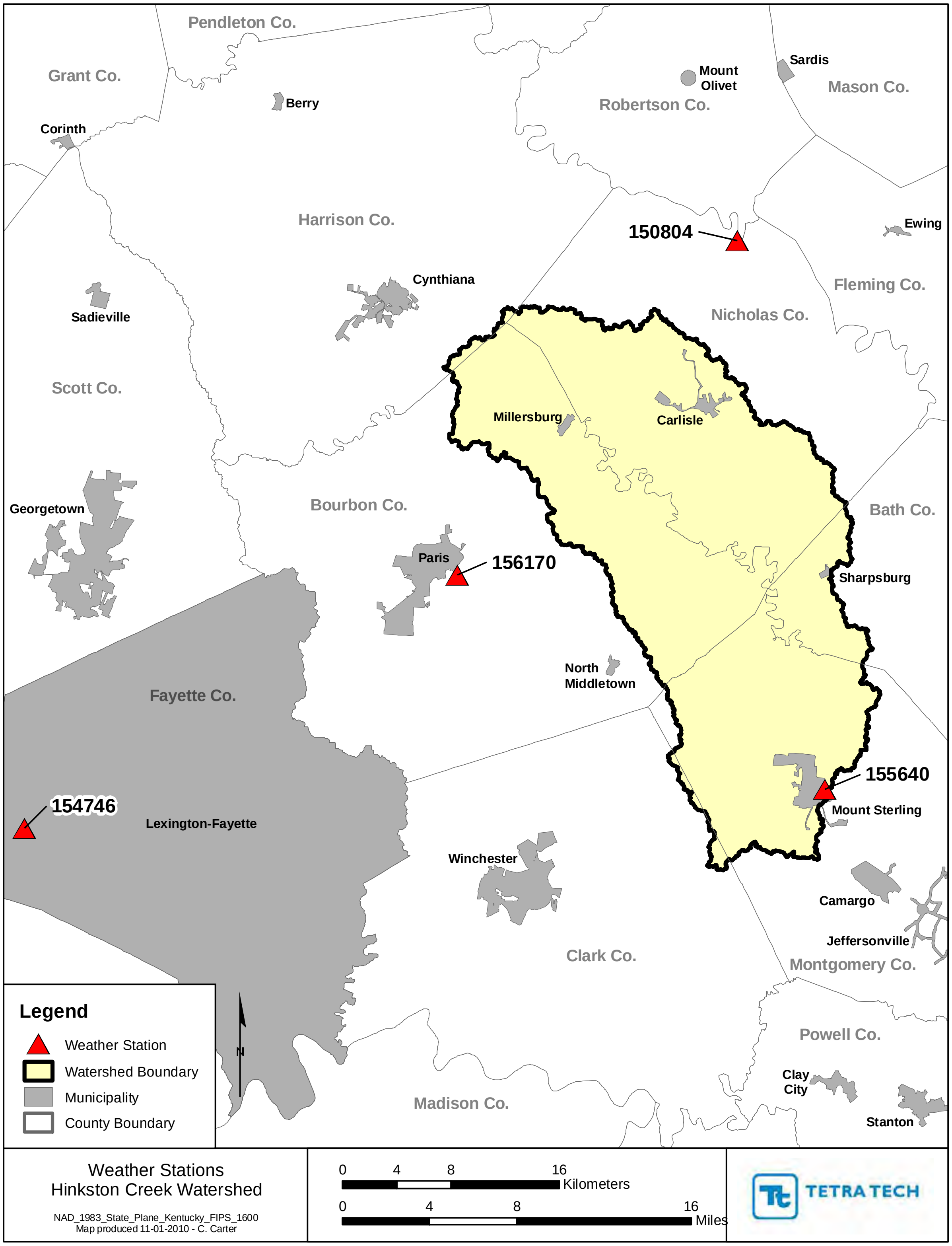


Figure 2-4. Weather Stations Used for Precipitation in the Hinkston Creek Watershed

Figure 2-5 through Figure 2-8 show the annual totals on a measured (raw) and processed (patched) comparison. The measured rainfall was obtained from National Climatic Data Center (NCDC) Summary of the Day (SOD) observation stations. The SOD data came with flags to indicate missing and/or deleted impaired periods. The impaired periods had to be processed, or patched, to repair the impaired periods. There is also an annual indication of the percent of the record which was impaired. Year 2010 is a partial year and this fact is reflected in the indication of the percent impaired.

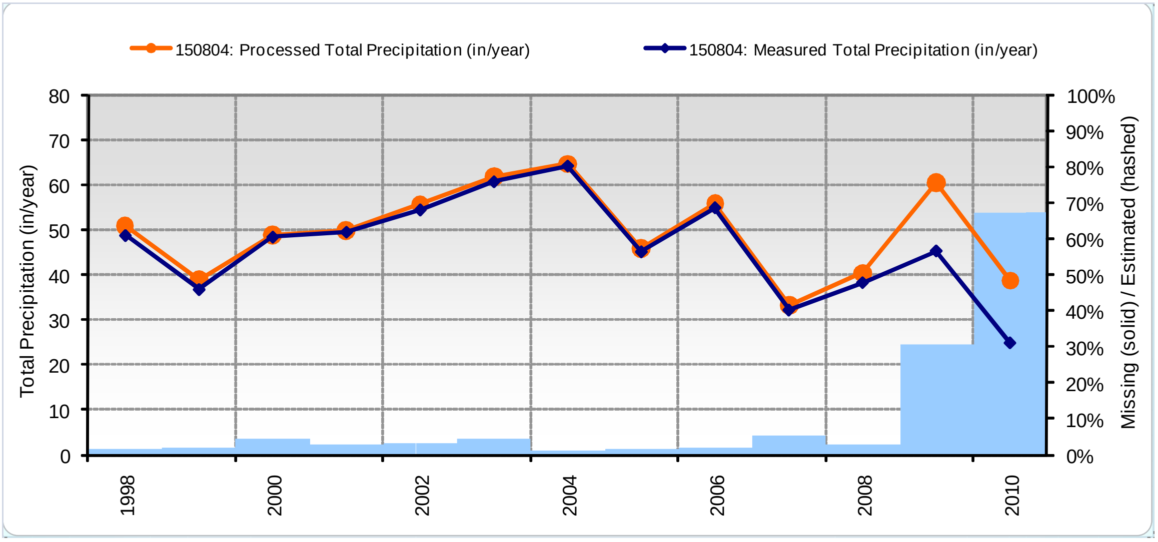


Figure 2-5. **Total Precipitation at Blue Lick Springs (150804), 1998-2010 (2010 is a Partial Year)**

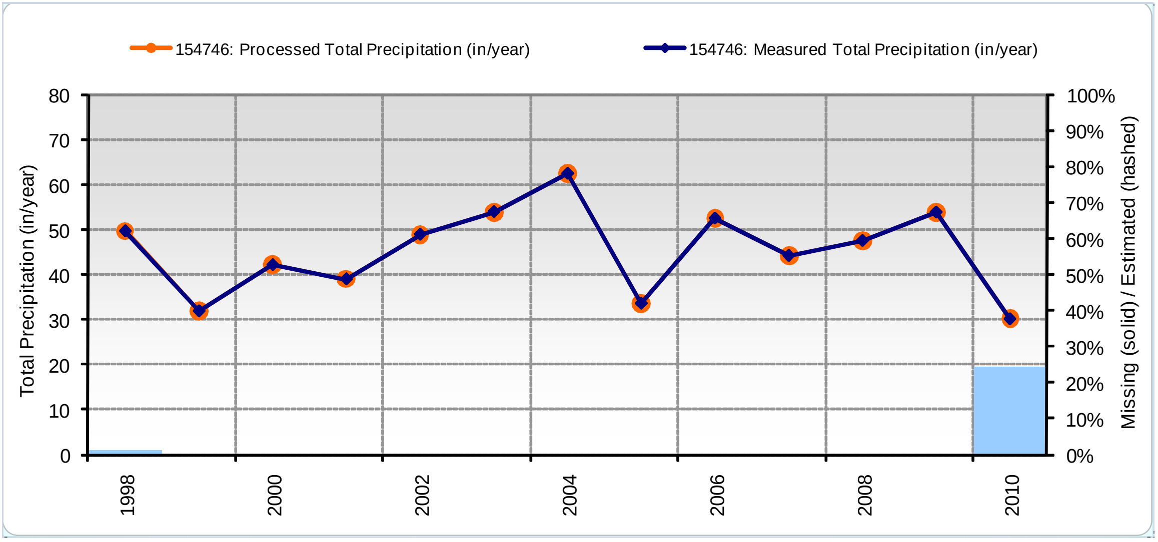


Figure 2-6. **Total Precipitation at Lexington Bluegrass AP (154746), 1998-2010 (2010 is a Partial Year)**

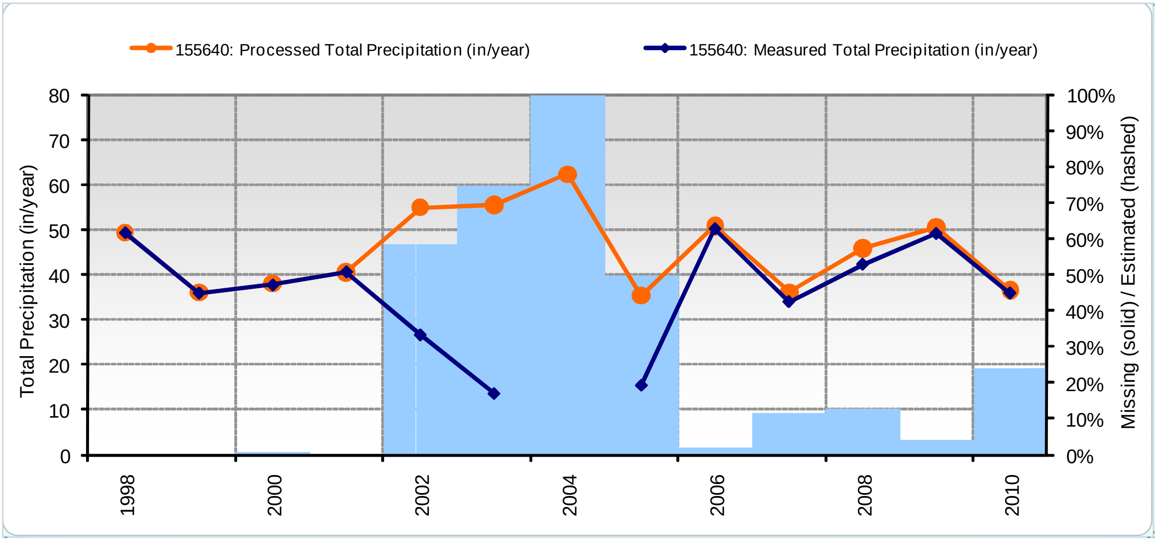


Figure 2-7. Total Precipitation at Mt Sterling (155640), 1998-2010 (2010 is a Partial Year)

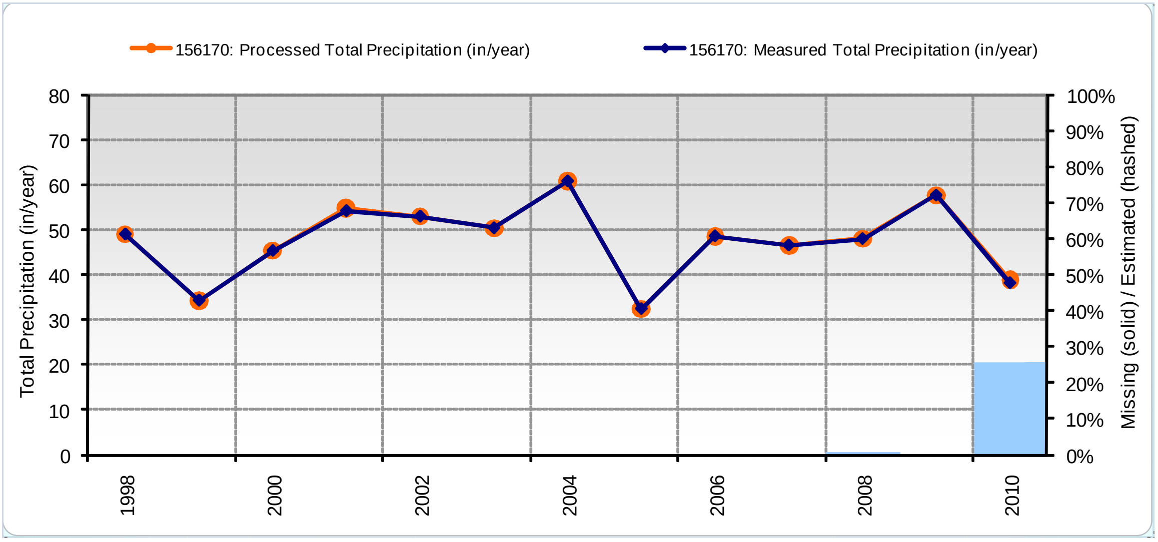


Figure 2-8. Total Precipitation at Paris (156170), 1998-2010 (2010 is a Partial Year)

2.2.2 Groundwater-Surface Water Interaction

The geologic composition of portions of the Hinkston Creek watershed is predominately made up of limestone. Limestone is a soluble rock that allows for the formation of karst topography as it is slowly dissolved away by weak acids found naturally in rain and soil water. Common landscape features found in areas having high potential for karst development are caves, springs, sinkholes, and aquifers (Cobb et al., 2004). While a full analysis covering the interactions between groundwater and surface water within the Hinkston Creek watershed was beyond the scope of this plan, the presence of areas with high potential for karst development within the watershed allows for some interpretation regarding these interactions and will help inform the selection, design, and cost of BMPs. In areas having high potential for karst development, it is likely that aquifers have developed. Aquifers provide a reliable supply of water to a number of homes throughout Kentucky through springs and wells. Springs are sites where groundwater emerges from aquifers to become surface water; these typically occur along creeks and rivers where the water table meets the land surface. Sinking streams can also develop in karst areas, further promoting the interaction between ground and surface waters (Cobb et al., 2004). Water quality among karst topography can be greatly influenced by these landscape features. Water flowing from aquifers to the surface via springs is typically much cooler in temperature than surface waters. In karst areas it is also likely for runoff from streams and the ground to enter aquifers quickly, transporting unfiltered contaminants that can pollute groundwater and potentially resurface at a downstream location. The Kentucky Geological Survey (KGS) and KDOW have collaborated to produce a compilation of digitized karst basins within the state of Kentucky. The Kentucky Karst Atlas is the product of their efforts and is an ongoing development to provide published maps of karst basins delineated through tracer tests. As of yet, the atlas does not include published maps for the Hinkston Creek watershed area. The point of contact for this work is James Currens (current@uky.edu, http://www.uky.edu/KGS/about/biographies/currensbio.htm)

The extent of karst and groundwater interactions is unknown in areas throughout the Hinkston Creek watershed; however, as the potential for karst development increases, there is an expected increase in the prevalence of landscape features that promote ground and surface water interactions. Refer to Section 2.3.2 of this plan for a description and map of the potential for karst development within the watershed.

2.2.3 Flooding

Hinkston Creek is a major tributary of the South Fork Licking River, and has been the subject of two flood management issues:

1. Flooding along the South Fork Licking River in Cynthiana and the downstream end of Hinkston Creek in Millersburg, just upstream from the South Fork confluence; and

2. Flooding in the Hinkston Creek headwaters, in and around the city of Mt. Sterling.

The US Army Corps of Engineers (USACE) has been involved in several years of study to develop remediation plans for both flooding locations. Initial plans for both situations involve the construction of dry bed detention basins, which would fill during storms and slowly release water afterwards. The section below summarizes the two projects.

South Fork Licking and Lower Hinkston

The project recommended by USACE would reportedly reduce flood damages in the communities of Cynthiana, Millersburg, and Paris, in the Licking River Basin in Kentucky, by the construction of two dry bed detention basins on tributaries of the South Fork of the Licking River. The two basins would be created by constructing roller compacted concrete dams on the Hinkston Creek and Strodes Creek tributaries (Figure 2-9). The Hinkston Creek detention structure, located just upstream of the Town of Millersburg, would have a height of about 30 feet, a length of about 680 feet, and would create a pool with a maximum volume of about 8,188 acre-feet given an occurrence of the 0.2 percent chance (500-year) flood. The detention facility would include a 200-foot-long spillway, a 16-foot-wide by 12-foot-high gravity outlet, and a 1,500-foot-long access road. (The Strodes Creek detention structure, located about 16 miles upstream of the town of Paris, Kentucky, would have a height of about 25 feet, a length of about 700 feet, and would create a maximum pool of about 3,923 acre-feet during the 0.2 percent chance flood.)

Mitigation for unavoidable environmental impacts associated with the proposed project would consist of 90 acres of hardwood plantings on project lands to offset the impacts of the detention structures on the existing riparian hardwood corridors in the vicinity of the proposed project. The estimated first cost of the recommended plan is about $17,460,000. Cost sharing for the initial project would be 65 percent

($11,350,000) federal and 35 percent ($6,110,000) non-federal. The non-federal sponsor, the City of Cynthiana, represents a consortium of local and State interests. Further, the non-federal sponsor would be responsible for 100 percent of the operation, maintenance, repair, replacement, and rehabilitation of project features, a cost currently estimated at $25,000 per year. Average annual flood damage reduction benefits associated with the recommended plan are estimated at $3,350,000. With annual costs of $1,096,000, the resulting benefit-to-cost ratio would be 3.1 to 1. Net benefits would total $2,254,000. The proposed project would reduce expected annual damages from flooding in the communities of Cynthiana, Millersburg, and Paris, Kentucky by about 86 percent.

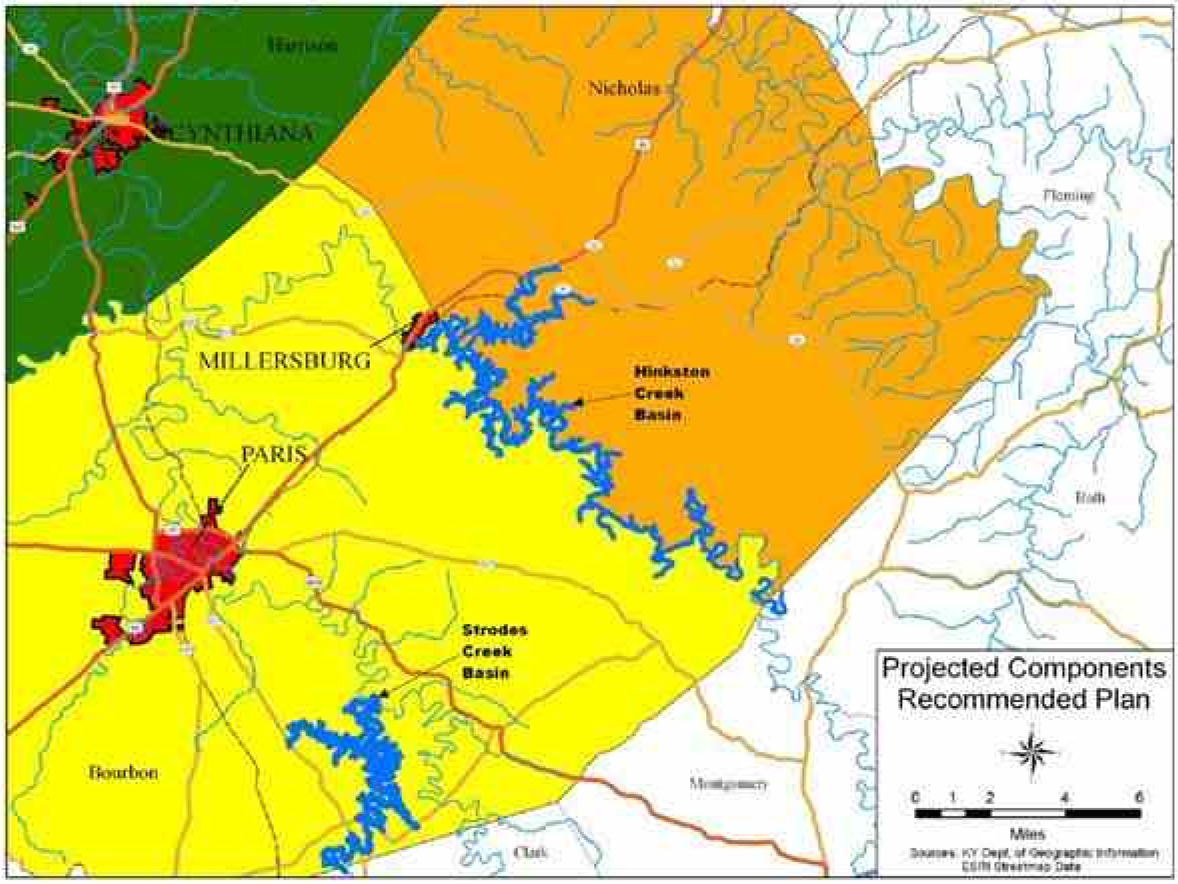


Figure 2-9. Lower Hinkston and Strodes Creek Dry Detention Dam Proposed Locations

Upper Hinkston Creek at Mt. Sterling

The project under study by the USACE would address flooding in downtown Mt. Sterling, in a portion of the Hinkston Creek subwatershed that has been extensively developed over the past 20 years. Homes, businesses, and the police station are flooded during heavy rains. Approximately 80 residential and some commercial structures are in the floodplain, some of which are not being presently used due to a variety of structural, maintenance, and other conditions. The drainage area contributing to flooding is approximately 7 square miles. A preliminary assessment of flooding problems was completed in 2002, and a preliminary assessment was produced the same year. It appears that at least some of the backup of the creek might be caused by the relatively small opening under the US 60 (East Main Street) bridge in Mt. Sterling – i.e., most of the flooding occurs due to ponded water immediately upstream of this area.

The initial USACE recommendation involves the construction of two detention basins and the relocation of two commercial structures at a cost of approximately $4,000,000. The city of Mt. Sterling's share would be $1,400,000. The estimated benefits-to-cost ratio is 2.1 to 1. The project stopped in 2007 due to lack of payment/documentation of "Work In Kind" by the city of Mt. Sterling for the local share. USACE cannot work on a project if the funding is not in balance. Also, the USACE project manager left and the Planning Branch had little to no staff at that time due to reallocation of funds to military projects. After recent payments and documentation of "Work In Kind by the City," the funding is now in balance and USACE has resumed working. The Feasibility Study should be done in 6 to 9 months, depending on the duration of the Independent Technical Review. After the Feasibility Study is completed, design will take about six months and contracting will require more time. However, there is some question regarding whether or not the city will be able to secure an easement for the detention basin along Calk Road (Figure 2-10). USACE has advised that property acquisition is the responsibility of the city, including any condemnation actions, funding, etc.

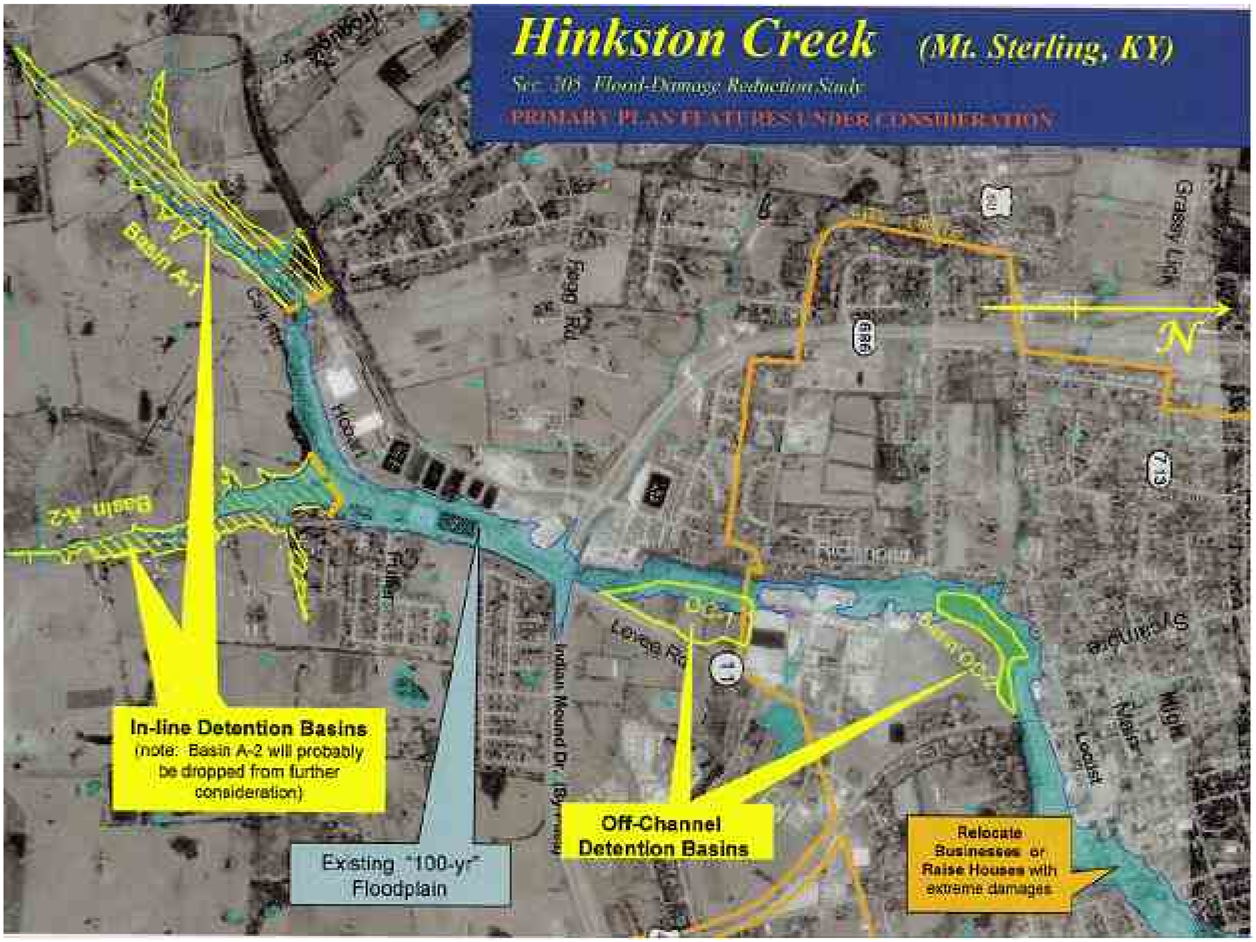


Figure 2-10. USACE Preliminary Detention Basin Plan for Upper Hinkston Creek in Mt. Sterling

Status of Flood Control Projects

At present, implementation of the two flood control projects summarized above does not appear to be imminent. Cost-share funding from both cities might be difficult, given the present economic conditions, and no major activities have been undertaken for the past two or three years. Discussions regarding the projects are ongoing, and some meetings have been held, but there are no indications that construction will begin prior to 2013, at the earliest.

For the upper Hinkston project in Mt. Sterling, there has been discussion of purchasing some of the flood-prone structures and moving two others to create a permanent greenway/floodway, which would store floodwaters during high flows without building detention basins. That approach – along with replacing the US 60 bridge with a larger span – could address the issues at a substantially lesser cost.

2.2.4 Regulatory Status of Waterways

The 2010 Integrated Report to Congress on Condition of Water Resources in Kentucky identified several lengths of waterways within the Hinkston Creek watershed as impaired for fecal coliform, sedimentation/siltation, and/or nutrient/eutrophication biological indicators (KDOW, 2010a).

There are six segments of waterways identified as impaired within the Hinkston Creek watershed (KDOW, 2010a). Four of these segments are along the mainstem of Hinkston Creek with the other two along the tributaries of Blacks Creek and Boone Creek (Table 2-5 and Figure 2-11). Two reach segments are not supporting Primary Contact Recreation (PCR) and one is only partially supporting PCR. One reach segment is not supporting Warm Aquatic Habitat (WAH) and three others are only partially supporting WAH. The cause(s) of non- and/or partial support of these segments are one or more of the following:

- Fecal Coliform
- Sedimentation/Siltation
- Nutrient/Eutrophication Biological Indicators

In five of the waterway segments, KDOW identified agricultural related land uses as the source of impairment (e.g., agricultural practices, livestock grazing, and feeding operations). In the remaining segment, Hinkston Creek from mile 0.0 to mile 12.6, KDOW was unable to determine the cause of the fecal coliform impairment.

Water quality criteria, typically determined by state governments, were created for the different uses and pollutants that may impair designated uses of waterways. However, for the impaired waterways within the Hinkston Creek watershed, only recreational waters have established numeric water quality criteria to address Fecal Coliform. These criteria are designed to help protect humans from becoming ill due to exposure to pathogens. A summary of waterbody impairments, identified uses, and related numeric water quality criteria for the Hinkston Creek watershed can be found in Table 2-5 and Table 2-6. The tables also list dissolved oxygen (DO) standards, as DO is affected by algal growth associated with nutrient loads.

Table 2-5. Waterways Listed as Impaired with Causes and Identified Sources (KDOW, 2010a)

Segment	Length (mi)	Impairment	Cause(s)	Source
Hinkston Creek 0.0 to 12.6	12.6	Primary Contact Recreation - Not Supporting	Fecal Coliform	Source Unknown
Hinkston Creek 20.8 to 31.0	10.2	Primary Contact Recreation - Partially Supporting	Fecal Coliform	Livestock (grazing or feeding operations)
Hinkston Creek 41.8 to 49.1	7.3	Primary Contact Recreation - Not Supporting	Sedimentation/Siltation; Fecal Coliform	Agriculture
		Warm Aquatic Habitat - Partially Supporting	Sedimentation/Siltation; Fecal Coliform	Agriculture

Segment	Length (mi)	Impairment	Cause(s)	Source
Hinkston Creek 51.5 to 65.9	14.4	Warm Aquatic Habitat - Not Supporting	Sedimentation/Siltation; Nutrient/Eutrophication Biological Indicators	Grazing in Riparian or Shoreline Areas
Blacks Creek 0.0 to 3.4	3.4	Warm Aquatic Habitat - Partially Supporting	Sedimentation/Siltation; Nutrient/Eutrophication Biological Indicators	Livestock (grazing or feeding operations)
Boone Creek 0.0 to 5.0	5	Warm Aquatic Habitat - Partially Supporting	Sedimentation/Siltation; Nutrient/Eutrophication Biological Indicators	Livestock (grazing or feeding operations)

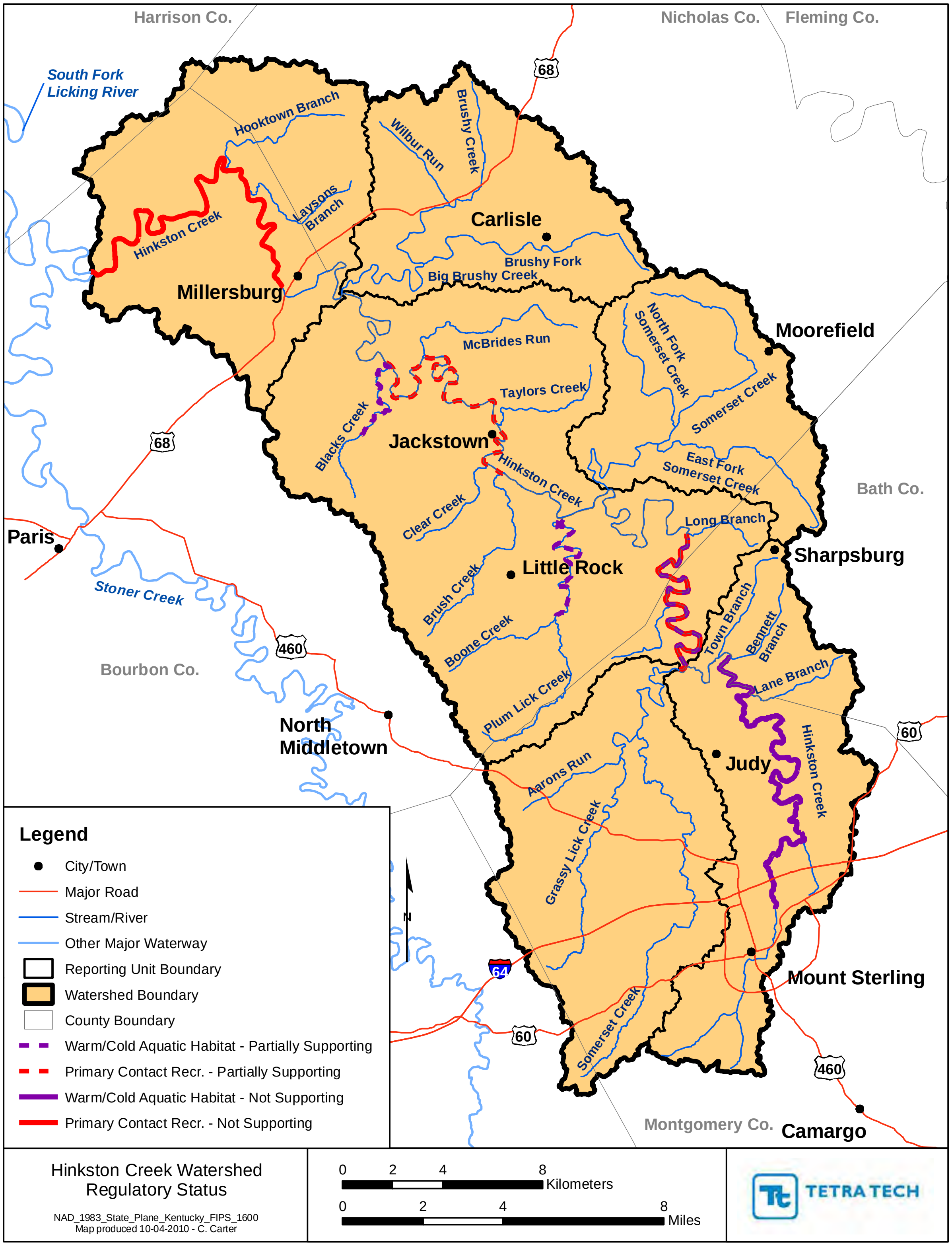


Figure 2-11. Impaired Waterways Located within the Hinkston Creek Watershed

Table 2-6. Related Kentucky Water Quality Standards (KNREPC, 2010)

Cause of Impairment	Warm Water Aquatic Habitat	Primary Contact Recreation
Bacteria	Not applicable	May 01-October 31 Fecal Coliform/*E. coli* (respectively): Not to exceed 200/130 colonies per 100mL as a geometric mean (>5 samples in 30 days) Fecal Coliform/*E. coli* (respectively): Not to exceed 400/240 colonies per 100mL in less than 20% samples in 30 days 401 KAR 10:031, Section 7 (1) (a) November 01-April 30 Fecal Coliform: Not to exceed 1000 colonies per 100mL as a geometric mean (>5 samples in 30 days) Fecal Coliform: Not to exceed 2000 colonies per 100mL in less than 20% samples in 30 days 401 KAR 10:031, Section 7 (2) (a)
Nutrients	Narrative 401 KAR 10:031, Section 1 and Section 2	Narrative 401 KAR 10:031, Section 1
Sedimentation/Siltation	Narrative 401 KAR 10:031, Section 4 (1) (f), (g), and (h)	Not applicable
Dissolved Oxygen	5.0 mg/L daily average minimum 4.0 mg/L instantaneous minimum 401 KAR 10:031, Section 4 (1) (e)	Not applicable

2.2.5 Water Chemistry and Habitat Assessment

Detailed analyses and discussion of water quality and habitat assessment data are provided in Chapters 3 and 4 of this report. The following text provides a brief summary of these data.

2.2.5.1 Water Chemistry

Benchmark values for concentration and unit area loading rates were established throughout this watershed plan for the following water quality impairment indicators: total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and bacteria (*E. coli*). Where measurable numeric criteria were not available, narrative standards and bioregion reference reach mean values were used as reference points for deciding appropriate benchmark values. These values then served as reasonable measures against which to evaluate observed and modeled water quality data reflecting existing conditions (Table 4-1 and Table 4-2).

The Hinkston Creek watershed assessment was performed using water quality data collected by KDOW (10 stations), Morehead State University (MSU, 12 stations), and flow data reported by MSU and one US

Geological Survey (USGS) flow gage positioned in the center of the watershed. Licking River Watershed Watch (LRWW, 7 stations) data were also incorporated into the analysis but only included summer measurements *E. coli* and fecal coliform. A more detailed description of the data and its sources is provided in Chapter 3.

For summarization purposes, the average and median concentrations for each of the parameters of interest were calculated using data from all dates and all station locations throughout the entire watershed (Table 2-7). The reported average TSS concentration is not flow weighted in Table 2-7 but flow weighted average values are presented in later sections of this report. Data is further analyzed by reporting unit and at the station level in Chapter 4.

Table 2-7. Average and Median Parameter Concentrations for the Entire Hinkston Creek Watershed

Parameter	Average Concentration	Median Concentration
TN (mgN/L)	2.25	2.12
TP (mgP/L)	0.178	0.106
TSS (mg/L)	13.19	7.20
Summer *E. coli* (cfu/100mL)	1,172	300
Winter *E. coli* (cfu/100mL)	565	130

2.2.5.2 Habitat

In-stream habitat quality was assessed using total habitat and individual habitat parameter scores measured in 1999 and 2004. Habitat survey stations were not equally distributed throughout the entire watershed; stations were located along the mainstem of Hinkston Creek within the Hinkston Headwaters and Lower Hinkston reporting units and along tributaries in the Hinkston Headwaters reporting unit. All station locations during both years were found to have poor or marginal scores under bank stability, bank vegetative protection, and riparian vegetative protection. Stations having the lowest total habitat scores tended to have poor or marginal scores under parameters reflecting physical habitat and sediment deposition.

KDOW established tentative habitat criteria in 2008 and designated total habitat scores less than 114 as non-supporting in wadeable streams (for drainage areas greater than 50 square miles). The majority of total habitat scores along the mainstem of the Hinkston Creek headwaters were less than 114, thus reflecting its designation of non-supporting aquatic habitat.

2.2.6 Geomorphology

Tetra Tech's Hinkston Creek watershed assessment team performed a rapid visual assessment of three aspects relating to stream geomorphology within the Grassy Lick Creek and Hinkston Headwaters reporting units. Field surveys were conducted throughout the winter months of 2010 and 2011 and included observations of stream channel erosion status, riparian buffer vegetation status, and access of cattle to streams. While landowner permission proved to be a restriction for accessing all stream reaches within the two southern reporting units, segments along Aaron's Run, Grassy Lick Creek, Town Branch, and the mainstem of Hinkston Creek within and upstream of the City of Mount Sterling were surveyed.

The survey was conducted by divid
manageable segments for assessme
interest. Scores for each aspect ran
representing very good conditions.
observations and were used to prior
visual assessment are presented and

2.3 NATURAL FEATURE

2.3.1 Ecoregions

The Hinkston Creek watershed, loc
Lexington, falls within two ecoregi
(Figure 2-12 and Figure 2-13). Eco
type, quality, and quantity of enviro
on terrain texture, rock type, and ge
includes roughly 70 percent of the H
rivers, and intermittent and perenni
is higher than in the Hills of the Blu
cropland. Mean stream density wit
ecoregion and concentrations of sus
Bluegrass ecoregion. The Hills of t
Creek watershed and consists of upl
general, the Hills of the Bluegrass h
density, and is more erosion-prone t
the Bluegrass is wooded land, pastu
agriculture. Stream nutrient levels i
Bluegrass and upland streams are o

Figure 2-12. Ecoregions and Ur

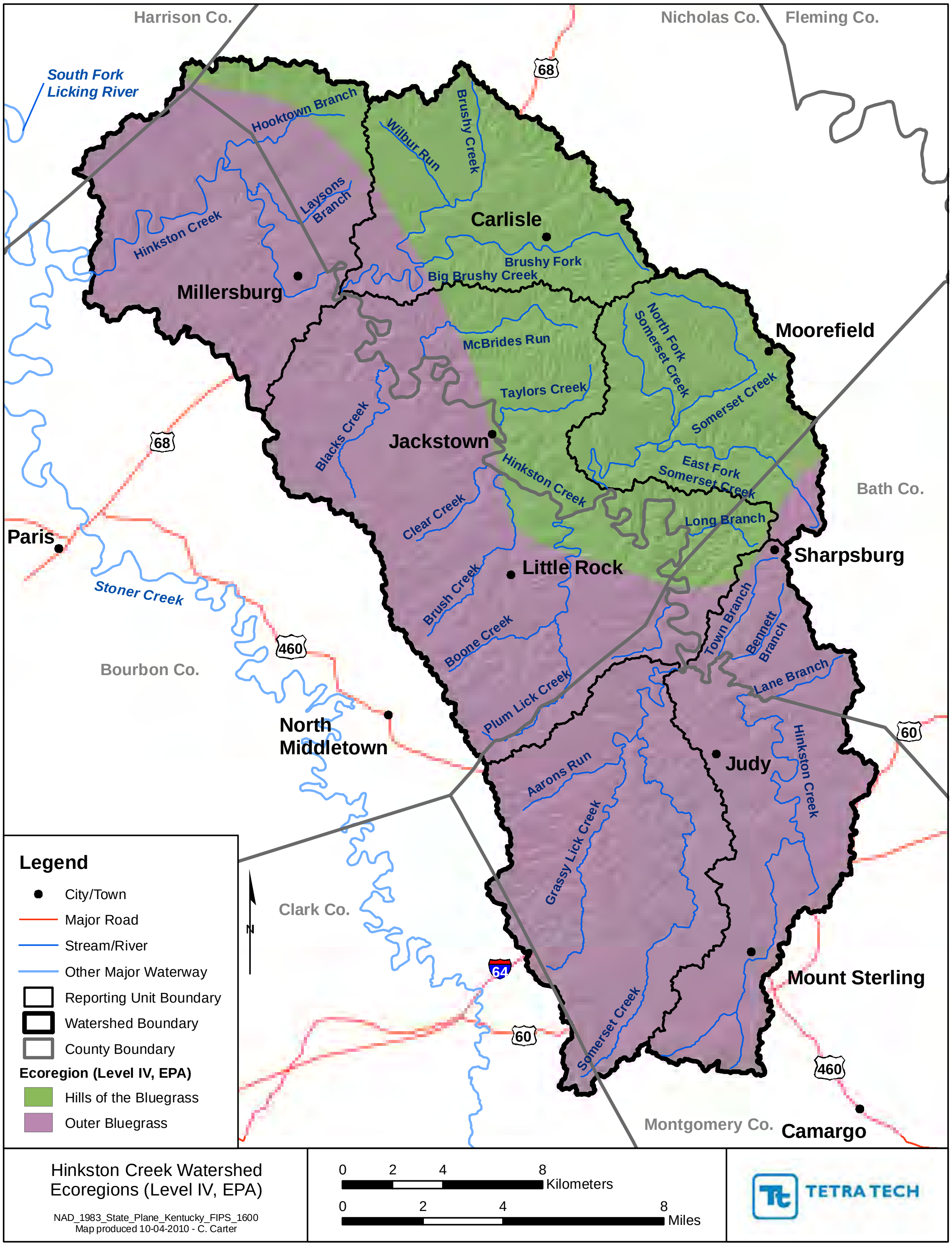


Figure 2-13. Level IV Ecoregion Boundaries in the Hinkston Creek Watershed

2.3.2 Geology and Topography

Topography of the Hinkston Creek watershed is varied throughout, ranging from 1,135 feet to 732 feet above sea level, with highest elevations in the eastern and southern portions of the watershed (Figure 2-14). The elevation of Mount Sterling is approximately 970 feet, Sharpsburg's elevation is 1,014 feet, Carlisle has an elevation of 879 feet, and Millersburg's elevation is roughly 803 feet. Areas of the watershed near Sharpsburg and Moorefield are hilly to very hilly while the remaining portions of the watershed have a terrain that is rolling and moderately hilly. Areas within Bourbon County have differences in elevation between valley flats and adjacent uplands ranging from 60 to 120 feet, with the greatest reliefs found adjacent to major streams such as Hinkston Creek. Areas within Nicholas County have a more moderate relief and contain many flat-topped ridges.

Much of the Hinkston Creek watershed is underlain by limestone (see Figure 2-12) which creates fertile soils upon weathering. Phosphate minerals from limestone serve as natural fertilizers to create highly productive fields and streams naturally rich in nutrients (USDA-NRCS, 2008). Due to the presence of limestone throughout the watershed, the Hinkston Creek watershed has been divided into three sections based on the potential for karst development (Figure 2-15). Karst landscapes of Kentucky most commonly develop on limestone and have been formed over hundreds of thousands of years. As water moves underground, from hilltops toward a stream through tiny fractures in the limestone bedrock, the rock is slowly dissolved away by weak acids found naturally in rain and soil water. Due to this activity, karst landscapes are typically identified by the presence of sinkholes, sinking streams, caves, and springs (Cobb et al., 2004). While Kentucky is one of the most famous karst areas of the world, the Hinkston Creek watershed only shows high potential for karst in areas located within Bourbon and Nicholas counties where limestone is most abundant. Areas of the watershed where there is low potential for karst development are dominated by siltstone instead of limestone.

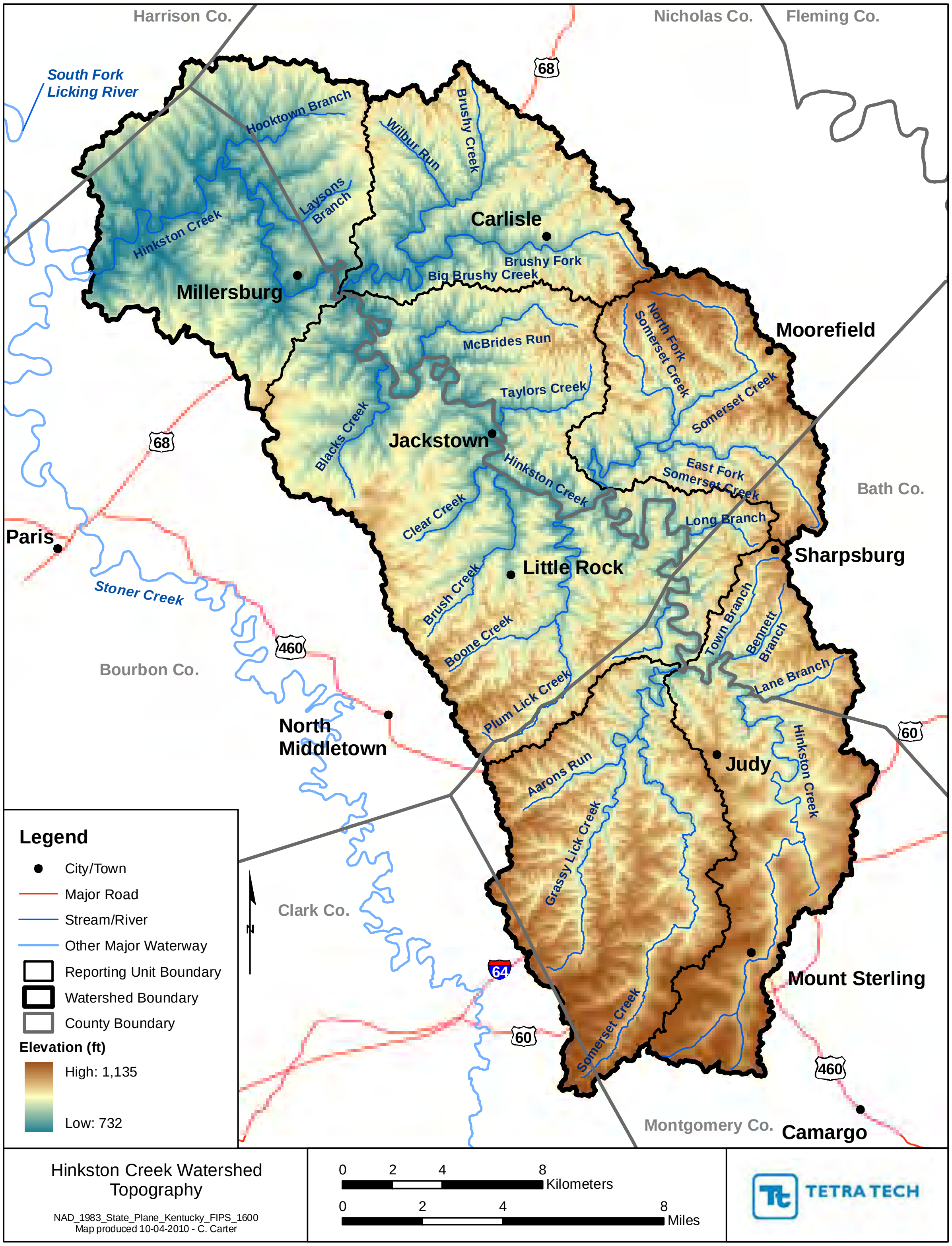


Figure 2-14. Topography in the Hinkston Creek Watershed

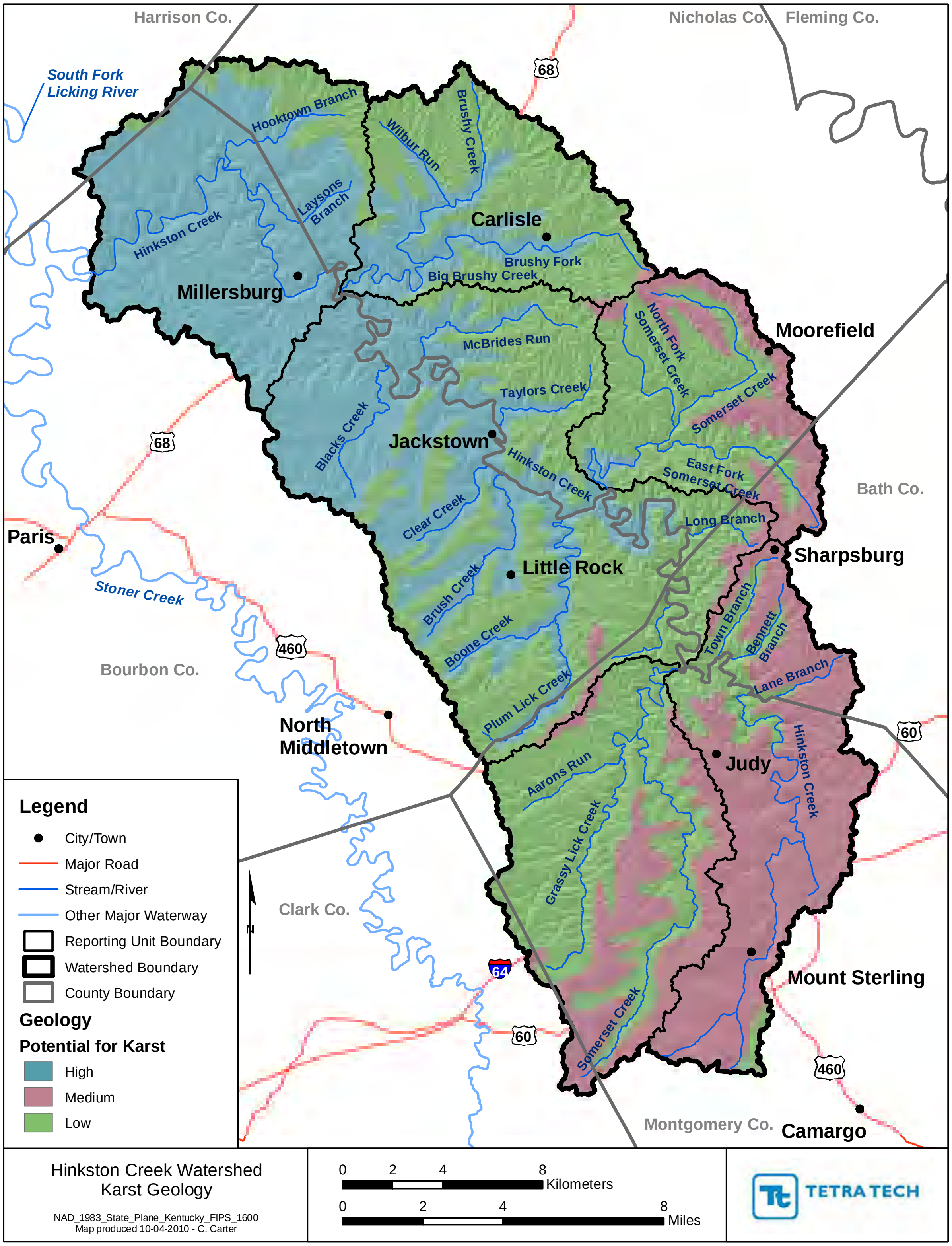


Figure 2-15. Potential for Karst in the Hinkston Creek Watershed

Percent slope identifies the rate of maximum change in elevation and can be used to identify areas of high erosion risk leading to increased potential for sediment transport to or within streams. High percent slope (~59 percent) is spread throughout the Hinkston Creek watershed in areas adjacent to stream channels (Figure 2-16). However, there is a more interesting pattern of high percent slope stretching across the area of the watershed that lies within the Hills of the Bluegrass Ecoregion and sections of the Outer Bluegrass Ecoregion to the south. These areas of high percent slope, where the terrain is at its steepest, correspond heavily with areas that have very low potential for karst topography. The Big Brushy Creek, Somerset Creek, and portions of the Hinkston Midreach, Grassy Lick Creek, and Hinkston Headwaters reporting units have the greatest occurrence of high percent slopes.

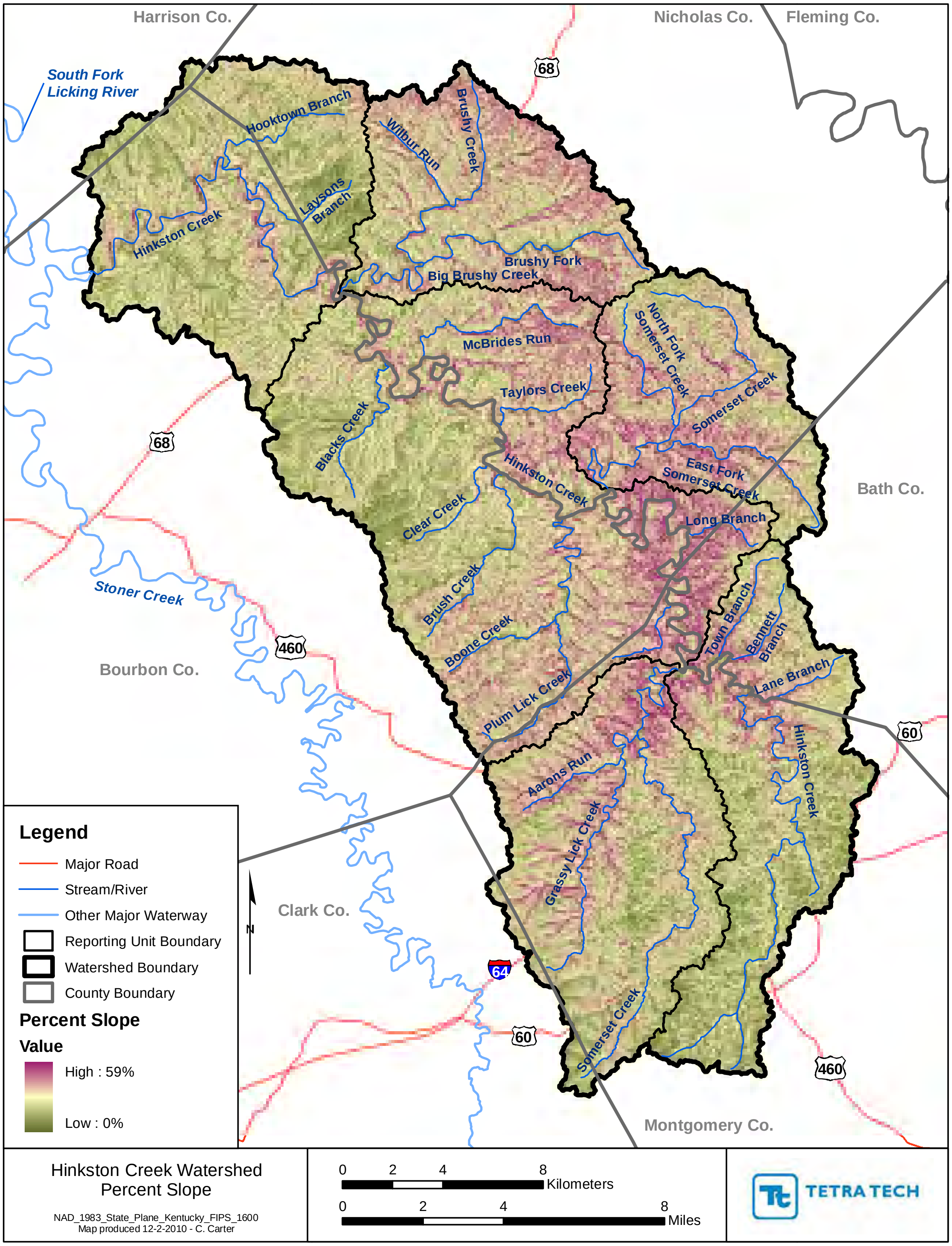


Figure 2-16. Percent Slope In the Hinkston Creek Watershed

2.3.3 Soils

Soils of the Hinkston Creek watershed are dominated by four series – Eden, Faywood, Lowell, and Crider (Figure 2-17). Common characteristics among these soil series are that they are moderately deep to very deep, well drained, and have moderately slow permeability. Due to slow permeability, these soils are characteristic of medium to rapid runoff. Most of these series are known to have been formed in association with limestone; however, Eden soils have a dominant association with siltstone. The following provides a brief description of each soil type:

- Faywood and Lowell soils are found on upland ridgetops and sideslopes and occur on slopes ranging from 2 to 60 (65 for Lowell) percent. Faywood and Lowell soils are commonly used for growing hay and for pasture but are also used for growing crops.
- Eden soils are found on hillsides and narrow ridgecrests and occur on slopes ranging from 2 to 70 percent but are most dominant on slopes ranging from 20 to 30 percent. Eden soils are used for pasture and hay; steep slopes are generally forested or brushy pasture.
- Crider soils are found on nearly level to moderately steep uplands and occur on slopes ranging from 0 to 12 percent. Crider soils are widely used for growing crops and for pasture.

Soil data were retrieved on a per county basis from the Soil Survey Geographic (SSURGO) Database provided by the Natural Resources Conservation Service (NRCS; http://soils.usda.gov/survey/geography/ssurgo/). The composition of this data is based on data collected by soil scientists during the course of preparing the soil maps. General patterns present in the soil data layers appear to be guided by county boundaries; this is potentially caused by variations in individual interpretations of soil characteristics on a per county basis as well as the fact that several of these soil series are considered competing series characterized by minute differences. Spatial distributions of soil series within county boundaries allow for a more robust interpretation of soil patterns that may govern water quality within the Hinkston Creek watershed. The percent of each reporting unit covered by the most dominant soil series through the Hinkston Creek watershed is reported in Table 2-8.

Table 2-8. Percent of Reporting Unit Covered by the Dominant Soil Series

Soil Series	Lower Hinkston	Big Brushy Creek	Hinkston Midreach	Somerset Creek	Hinkston Headwaters	Grassy Lick Creek
Crider	0%	0%	0%	0%	14%	4%
Eden	2%	35%	19%	47%	0%	0%
Faywood	38%	32%	33%	18%	1%	2%
Faywood-Lowell	0%	0%	3%	3%	25%	50%
Lowell	32%	6%	14%	19%	27%	14%
Other	28%	27%	31%	13%	33%	30%

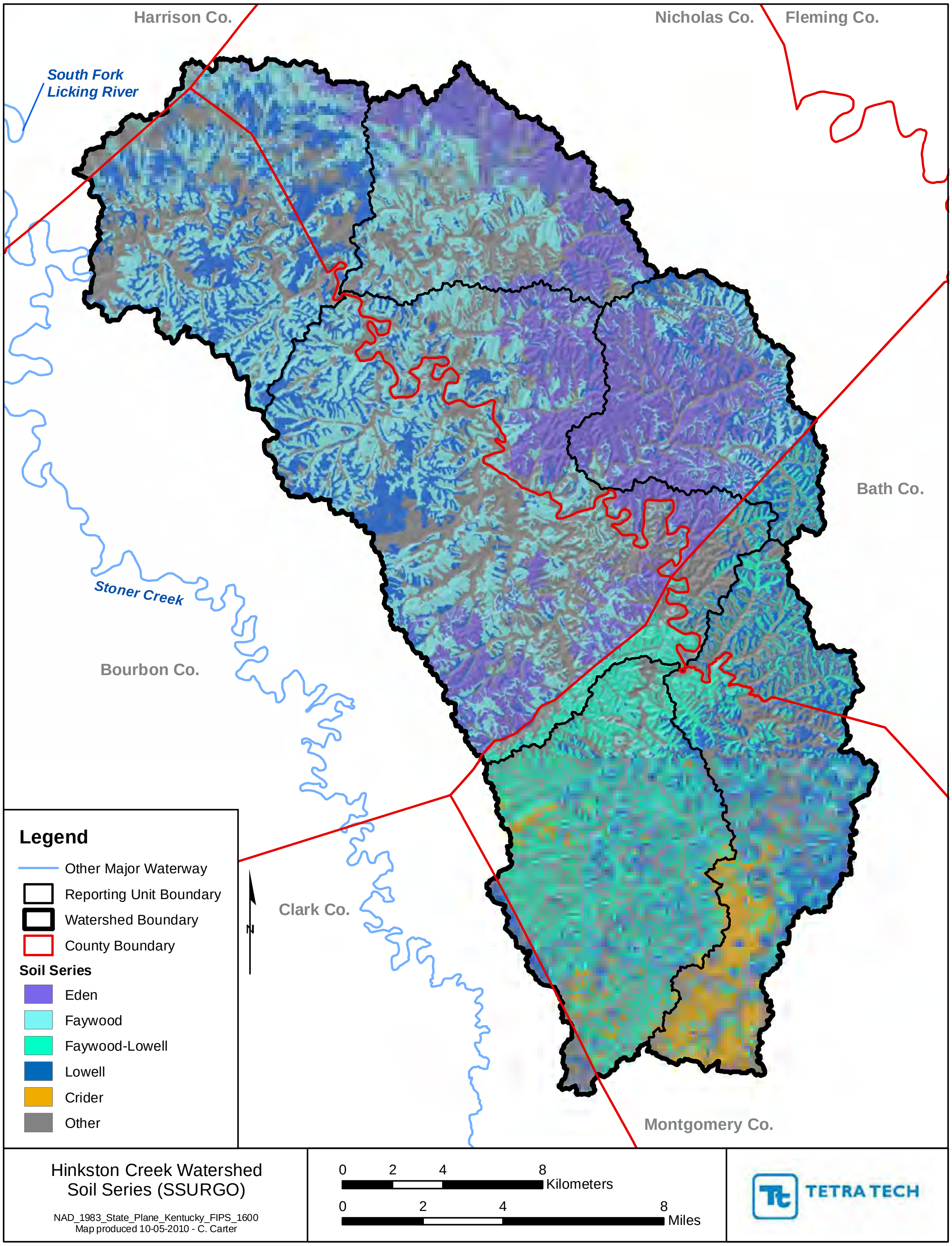


Figure 2-17. Dominant Soil Series in the Hinkston Creek Watershed

2.4 RIPARIAN/STREAMSIDE VEGETATION

The riparian density along stream corridors and the edge of waterbodies such as reservoirs and lakes is important for slowing overland water velocities as well as filtering detritus and improving water quality. Lack of riparian vegetation along streams can be closely related to stream channel erosion and instability. Within the Hinkston Creek watershed, typical riparian species are hardwood tree species, including sycamore, Osage orange, maple, river birch, walnut, box elder, oak, and willow, as well as grasses such as Johnson grass and some areas of native cane.

A riparian deficiency analysis was performed as part of this watershed plan to serve as a method for identifying riparian areas throughout the watershed that are either intact or impacted. The stream layer used for this analysis was the high resolution streams data layer created by the United States Geological Survey (USGS) as part of the National Hydrography Dataset (NHD; USGS, 2007). These streams were buffered to create polygons representing riparian buffer areas for this analysis. A 100-foot buffer was created along each side of the mainstem of Hinkston Creek downstream from the Grassy Lick/Hinkston confluence. A 50-foot buffer was created along each side of Hinkston Creek upstream from the Grassy Lick/Hinkston confluence and along all tributaries within the Hinkston Creek watershed.

To maintain aquatic habitat, a literature review on effective riparian buffer width indicates that 35 to 100 feet of native forested riparian buffers should be preserved or restored along all streams (Wenger, 1999). Therefore, this analysis considers riparian buffers as any lands within 100 feet of the Hinkston Creek mainstem and within 50 feet of the Hinkston Creek headwaters and tributaries as identified by the NHD high-resolution dataset. Buffer widths of 50 feet and 100 feet are typical widths used for both voluntary and regulatory riparian buffer restoration and protection. Applications of these widths vary by jurisdiction, but when both are used, the 50-foot widths tend to be applied to intermittent streams, and the 100-foot widths tend to be applied to perennial streams. These widths tend to be used because they roughly coincide with the land that has a direct hydrologic connection to the stream through wetlands or floodplain areas. Based on a consideration of farming practices and the relative drainage area of the headwater streams, Tetra Tech estimated that 50 feet represents a reasonable width that farmers may consider converting to restored riparian buffer. Farming practices were given priority over other land use types as approximately 71 percent of land use in the watershed is related to agriculture and just over 20 percent of the watershed is forested; this leaves less than 10 percent of the watershed for additional land uses (Section 2.6.2). For the Hinkston Creek mainstem, which is expected to have wider floodplain areas, Tetra Tech estimated 100 feet as a reasonable buffer width to consider for potential restoration. These widths were used in the riparian buffer deficiency analysis so that the results of the analysis could directly inform the management recommendations.

A Multi-Resolution Land Characteristics Consortium (MRLC) geospatial dataset known as the Landscape Fire and Resource Management (LANDFIRE) map, that provides vegetation and wildland fuel maps was obtained to determine riparian buffer health status (impacted vs. intact). The advantage of this particular MLRC coverage over the traditional National Land Cover Database 2001 (NLCD 2001) dataset is that while it has the same Land Use Land Cover (LULC) classes as the NLCD (e.g., Pasture/Hay), its processing goes a step further for vegetated LULC classes (tree cover, shrub cover, and herbaceous cover) and breaks them down into 10 equal intervals based on percent coverage (e.g., “Tree Cover ≥ 30 and < 40 percent”). Using methodology from a recent study (Roy et al., 2005), any vegetated layers with less than 30 percent coverage were lumped together with other impacted riparian habitat LULCs (e.g., developed, open space, pasture/hay, etc.). The percent buffer deficiency within each assessment subwatershed was estimated using GIS (Figure 2-18).

The riparian buffer deficiency, at the assessment subwatershed level, ranges from 45 percent to100 percent throughout the Hinkston Creek watershed. The riparian buffer deficiency for the entire watershed is 75 percent; this means that 75 percent of riparian areas within 100 feet of the mainstem of Hinkston

Creek, and within 50 feet of the Hinkston headwaters and tributaries, are impacted and do not have sufficient vegetation needed to effectively protect water quality and aquatic habitat. Areas of greatest concern are within the Big Brushy Creek reporting unit near Carlisle, within the Hinkston Midreach reporting unit, and within the Hinkston Headwaters reporting unit near Sharpsburg and Mount Sterling. Riparian buffer status is reported on an assessment subwatershed level in Appendix A.

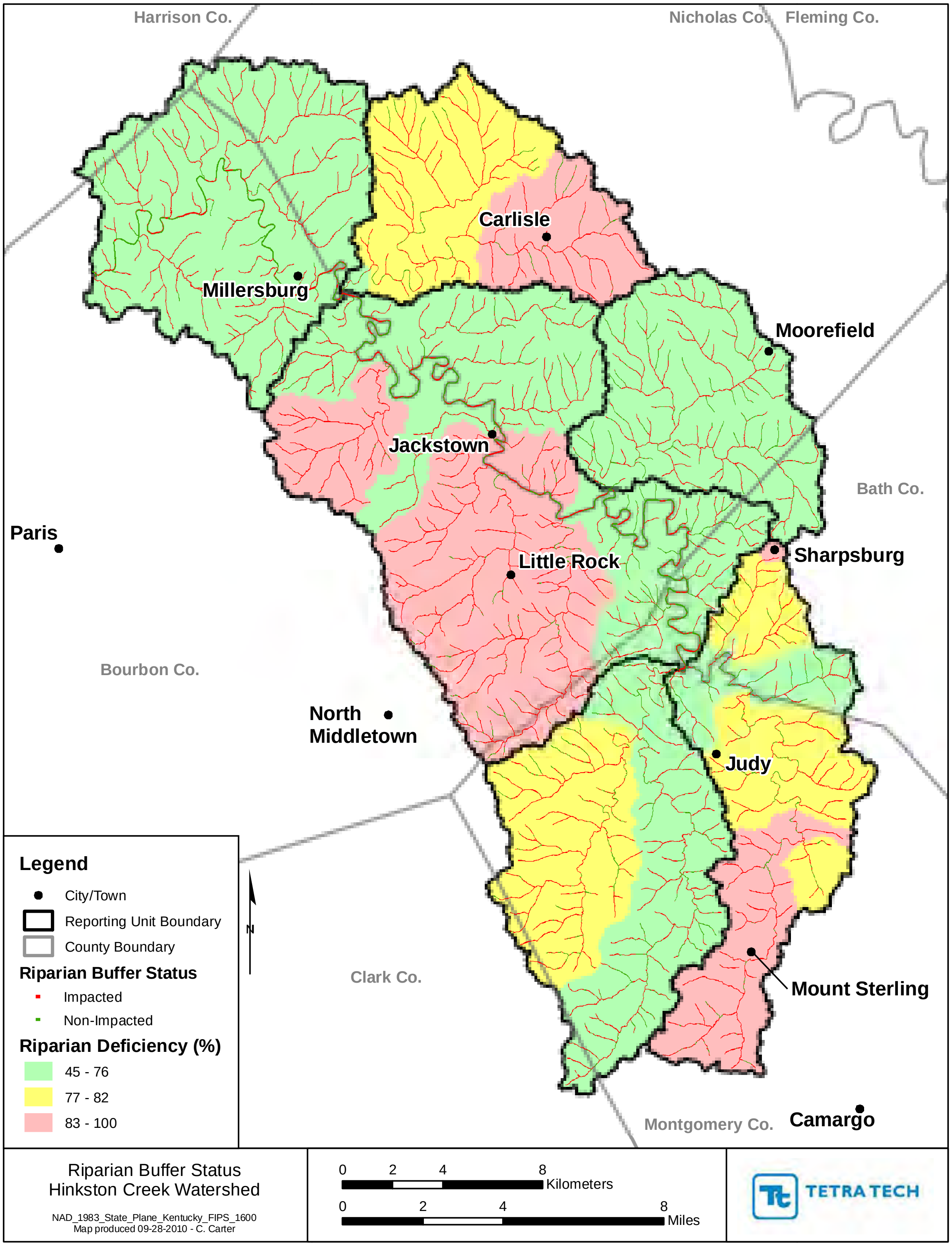


Figure 2-18. Riparian Buffer Status within the Hinkston Creek Watershed

2.5 RARE AND EXOTIC/INVASIVE PLANTS AND ANIMALS AND ENVIRONMENTALLY SENSITIVE AREAS

2.5.1 Invasive Plant Species

Invasive plant species recorded in at least one of the counties of the Hinkston Creek watershed are listed in Table 2-9. Of these species, yellow sweet clover is the only plant to have been recorded in all six of the Hinkston Creek watershed counties. Japanese stiltgrass, fescue, Japanese honeysuckle, bush honeysuckle, multiflora rose, and Johnson grass are also widespread throughout the watershed. All of these plants have been reported by the Kentucky Exotic Plant Pest Council (http://www.se-eppc.org/ky/list.htm) as severe threats because they possess characteristics of invasive species and spread easily into native plant communities with the potential to displace native vegetation. For example, invasive species like multiflora rose have been known to encroach on pasture grasses causing a decrease in productivity (personal communication, E. Boyd, Montgomery County Natural Resources Conservation Service, to H. Fisher, October 7, 2010).

As riparian areas become dominated by invasive species, soil erosion may increase and bank stability may decrease relative to a more native, diverse plant community. These impacts are largely species-specific, and the species that pose the most risk are those that have shallow roots or tend to overgrow and kill beneficial trees and shrubs. These species may include Japanese honeysuckle, oriental bittersweet, fescue Japanese stiltgrass, and garlic mustard.

In addition to the potential increase in soil erosion, invasion of nitrogen fixing (N-fixing) species such as autumn olive have the potential to add excess nitrogen to soil in the form of ammonium (NH_4^+). Once nitrogen is available in the soil, microbial-mediated nitrification occurs as NH_4^+ is converted to nitrate (NO_3^-), a highly soluble and mobile form of nitrogen that can easily be leached from soils to ground or surface waters (Goldstein & Williard, 2008). While native N-fixing species do exist, invasive species tend to dominate an area, which could lead to an excessive amount of N-fixation compared to a diverse, native canopy.

While some invasive species provide reasonable protection from erosion, or they could provide nitrogen to nitrogen-deprived areas, a balance should be considered between the negative and positive effects of the invasive species when making management decisions.

Table 2-9. Invasive Plant Species Recorded within Counties of the Hinkston Creek Watershed

Scientific Name	Common Name	County Where Recorded
Ailanthus altissima	tree-of-heaven	Bourbon, Nicholas, Harrison
Alliaria petiolata	garlic mustard	Bourbon, Harrison
Carduus nutans	musk thistle	Nicholas, Montgomery
Celastrus orbiculata	oriental bittersweet	Bath, Nicholas, Harrison
Conium maculatum	poison hemlock	Bourbon, Clark
Dioscorea oppositifolia	Chinese yam	Bourbon, Clark, Montgomery
Elaeagnus umbellata	autumn olive	Nicholas, Harrison
Euonymus alatus	winged euonymus, burningbush	Bourbon, Bath, Nicholas, Harrison
Euonymus fortunei	winter creeper	Bourbon, Clark, Nicholas, Harrison

Scientific Name	Common Name	County Where Recorded
Festuca arundinacea (=Lolium arundinaceum)	Kentucky 31 fescue	Bourbon, Bath, Clark, Nicholas, Harrison
Lespedeza cuneata	sericea lespedeza	Bath, Clark, Nicholas, Montgomery
Ligustrum sinense; L. vulgare	privet	Clark, Harrison; Bath, Nicholas
Lonicera japonica	Japanese honeysuckle	Bath, Clark, Nicholas, Montgomery, Harrison
Lonicera maackii; L. morrowi	amur/bush honeysuckle; Morrow.s	Bourbon, Clark, Nicholas, Montgomery, Harrison;
Melilotus officinalis	yellow sweet clover	Bourbon, Bath, Clark, Nicholas, Montgomery, Harrison
Microstegium vimineum	Japanese stiltgrass	Bath, Clark, Nicholas, Montgomery
Rosa multiflora	multiflora rose	Bath, Clark, Nicholas, Montgomery, Harrison
Sorghum halapense	Johnson grass	Bourbon, Bath, Clark, Montgomery, Harrison

2.5.2 Threatened and Endangered Species

Federally-listed mammal, plant, and mussel species are found within the counties of the Hinkston Creek watershed and are listed by county in Table 2-10. Because these species have been recorded by county, there is potential for them to occur within suitable habitat in one of the Hinkston Creek watershed counties, but outside of the watershed boundary. Kentucky state-listed species are not included in this list but can be found on the Kentucky State Nature Preserves Commission (KSNPC) webpage (http://naturepreserves.ky.gov).

Table 2-10. Federally-listed Species Located within Counties of the Hinkston Creek Watershed

County	Species Type	Species Name	Federal Status
Bath	Freshwater Mussels	Northern Riffleshell	Endangered
	Freshwater Mussels	Pink Mucket	Endangered
	Freshwater Mussels	Sheepnose	Candidate
	Freshwater Mussels	Clubshell	Endangered
	Mammal	Virginia Big-eared Bat	Endangered
	Mammal	Indiana Bat	Endangered
Bourbon	Plant	Running Buffalo Clover	Endangered
	Plant	Globe Bladderpod	Candidate
Clark	Plant	Globe Bladderpod	Candidate
	Plant	Running Buffalo Clover	Endangered
	Mammal	Gray Myotis	Endangered
Harrison	Plant	Running Buffalo Clover	Endangered
	Freshwater Mussels	Fanshell	Endangered
	Freshwater Mussels	Clubshell	Endangered
	Freshwater Mussels	Rabbitsfoot	Candidate
Montgomery	Plant	Running Buffalo Clover	Endangered

County	Species Type	Species Name	Federal Status
Nicholas	Plant	Short's Goldenrod	Endangered
	Freshwater Mussels	Fanshell	Endangered
	Freshwater Mussels	Sheepnose	Candidate

2.5.3 Wetlands

Wetlands serve as important landscape features because they provide a multitude of ecological, economic, and social benefits. Wetlands hold and slowly release flood water, recharge groundwater, act as natural filters, recycle nutrients, and provide recreation and wildlife viewing opportunities for people (NWI: http://www.fws.gov/wetlands/). Wetland and deepwater habitats documented by the US Fish and Wildlife Service (USFWS) and mapped as part of the National Wetlands Inventory (NWI) program, as well as hydric soils identified by the NRCS SSURGO dataset, are displayed in Figure 2-19.

Hydric soils are “soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part (NRCS: http://soils.usda.gov/use/hydric/intro.html). Under natural conditions, these soils are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophytic vegetation. Through the NWI program, the USFWS provides information to the public on the extent and status of wetland habitat throughout the US.

2.5.4 Efforts to Preserve and Protect

2.5.4.1 National Resources Conservation Service

The NRCS has developed a suite of programs promoting conservation of natural resources and protection of wildlife habitat throughout the state of Kentucky. A full list of these programs as well as a description of each is provided on the NRCS website, http://www.ky.nrcs.usda.gov/programs/. One program supported by NRCS is the Wetlands Reserve Program (WRP). The WRP provides technical and financial assistance to help landowners with their wetland restoration efforts. Through this voluntary program, the NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. The WRP offers landowners an opportunity to establish long-term conservation, wildlife habitat, and wetland protection. Approximately 5 to 10 percent of the properties in the Hinkston Creek watershed have some portion of the land managed or preserved under Environmental Quality Incentives Program (EQIP), Conservation Reserve Program (CRP), or other conservation-related program (personal communication, E. Boyd, Montgomery County Natural Resources Conservation Service, to H. Fisher, December 08, 2010). EQIP provides cost-share funding for agricultural BMPs and CRP provides payments to landowners for setting aside vegetated riparian buffers (undisturbed vegetation along streams).

2.5.4.2 Kentucky Department of Fish and Wildlife Resources

The KDFWR provides several recommendations for wildlife habitat improvement throughout Kentucky. A list of programs and recommendations is available on their website, http://www.kdfwr.state.ky.us/. Included in this list is a wetland and stream mitigation program that was initiated to address the continued loss of wetland and stream habitat in both quality and quantity. In addition, the KDFWR has developed the Kentucky Comprehensive Wildlife Conservation Strategy (CWCS) to identify and conserve Kentucky's Species of Greatest Conservation Need and to comply with the requirements of the congressionally authorized State and Tribal Wildlife Grants (STWG) Program. The CWCS represents a proactive plan for sustaining the diversity of species and habitats found in Kentucky. Upon completion of the CWCS, Priority Conservations Areas (PCAs) were identified by the KDFWR for several species (mussels, fish, lamprey, birds, mammals, reptiles, and amphibians). Of these species, the PCA for grassland birds falls within the boundaries of the Hinkston Creek watershed; the boundary of the Outer Bluegrass ecoregion within the watershed forms the PCA boundary for grassland birds.

2.5.4.3 Kentucky State Nature Preserves Commission

"The Kentucky State Nature Preserves Commission (KSNPC) participates in an international network of programs that monitor biodiversity. The 1976 Kentucky legislature created the commission to protect the best remaining natural areas in the state, not only to preserve our natural heritage, but also in recognition of the dependence of the public's well-being on healthy ecosystems (KSNPC, 2010)." While the KSNPC has successfully established a multitude of state preserves and natural areas throughout Kentucky, none exist within the Hinkston Creek watershed boundary. In addition, the KSNPC has developed a useful database through the Kentucky Natural Heritage Program which provides records of rare plants, animals and high quality ecological communities within the state including descriptions of habitat preferred by these rare species.

2.5.4.4 Licking River Watershed Watch

The mission of the Licking River Watershed Watch (LRWW) is to protect, improve, and restore the waters of the Licking River Basin by promoting water quality monitoring, public education, and citizen action (http://lrww.org). The LRWW was established in 1998 as part of the Kentucky Watershed Watch Program, and is a 501(c)(3) non-profit organization that spans 19 counties from eastern Kentucky to northern Kentucky. As a volunteer citizen-based organization, the LRWW monitors streams and collects data on various water quality parameters. Water quality information collected by LRWW is then used by the state and others to improve the health of streams. LRWW volunteers and leadership also work to improve watershed conditions through cleanups, restoration projects, public involvement and advocacy. There are seven LRWW stream monitoring locations within the Hinkston Creek watershed.

2.6 HUMAN INFLUENCES AND IMPACTS

2.6.1 Water Use

The Kentucky Division of Water's (KDOW) water withdrawal program governs all withdrawals of water greater than 10,000 gallons per day from any surface, spring or groundwater source. The following water withdrawals are not regulated by KDOW's water withdrawal program: withdrawals for domestic purposes (needs for one household), agricultural withdrawals (including irrigation), withdrawals for steam-powered electrical generating plants having a certificate of environmental compatibility, and withdrawals for injection underground operations for the production of oil and gas (KDOW, 2010b). The KDOW Watershed Management Branch has documented three permitted water withdrawals within the Hinkston Creek watershed (Figure 2-20), two are for municipal water supply and are located near Millersburg and Carlisle. The Millersburg Municipal Water Works withdraws its water from Hinkston Creek and services 2 wholesale, 1 commercial, and 492 residential connections. The Carlisle Water Department derives its water supply from two sources. While the more significant source lies outside of the Hinkston Creek watershed, the secondary source consists of two small municipal lakes, one downstream of the other, on a fork of Brushy Fork Creek on the city's southwest side. The Carlisle Water Department services 2 wholesale, 86 commercial, 1,133 residential, and 101 industrial connections. The third permitted water withdrawal is Tree Point Inc.; information regarding this withdrawal was limited and records indicated that no water had been withdrawn by Tree Point Inc. from 2005 through 2010. Permitted withdrawal rates by month and reported average monthly withdrawal rates for 2002 through 2010 are presented in Table 2-11 and Table 2-12, respectively.

Water withdrawals for agricultural irrigation are not reported for the Hinkston Creek watershed; however, it is expected that very few agricultural withdrawals for irrigation are in existence as the majority of land use in the watershed is not cropland, but pasture, and cattle have direct access to surface water for drinking.

Table 2-11. Permitted Withdrawal Rates (MGD) by Month

Month	Carlisle Water Department (WWD 0488)	Millersburg Municipal Water Works (WWD 0036)	Tree Point Inc. (WWD 1561)
Jan	0.9	0.11	0
Feb	0.95	0.1	0
Mar	0.85	0.117	0
Apr	0.9	0.117	0
May	0.95	0.117	0
Jun	1.1	0.127	0.24
Jul	1	0.127	0.24

Month	Carlisle Water Department (WWD 0488)	Millersburg Municipal Water Works (WWD 0036)	Tree Point Inc. (WWD 1561)
Aug	1	0.127	0.24
Sep	0.9	0.127	0.24
Oct	1.1	0.127	0.24
Nov	1.15	0.1	0
Dec	1.1	0.1	0

Table 2-12. Average Water Withdrawal (MGD) by Month for 2002 through 2010

Month	Carlisle Water Department (WWD 0488)	Millersburg Municipal Water Works (WWD 0036)	Tree Point Inc[1] (WWD 1561)
Jan	0.530	0.124	0
Feb	0.528	0.129	0
Mar	0.486	0.110	0
Apr	0.492	0.108	0
May	0.587	0.110	0
Jun	0.575	0.113	0
Jul	0.617	0.112	0
Aug	0.547	0.111	0
Sep	0.450	0.110	0
Oct	0.420	0.106	0
Nov	0.482	0.107	0
Dec	0.464	0.117	0

[1] Tree Point Inc. records indicated that no water was withdrawn.

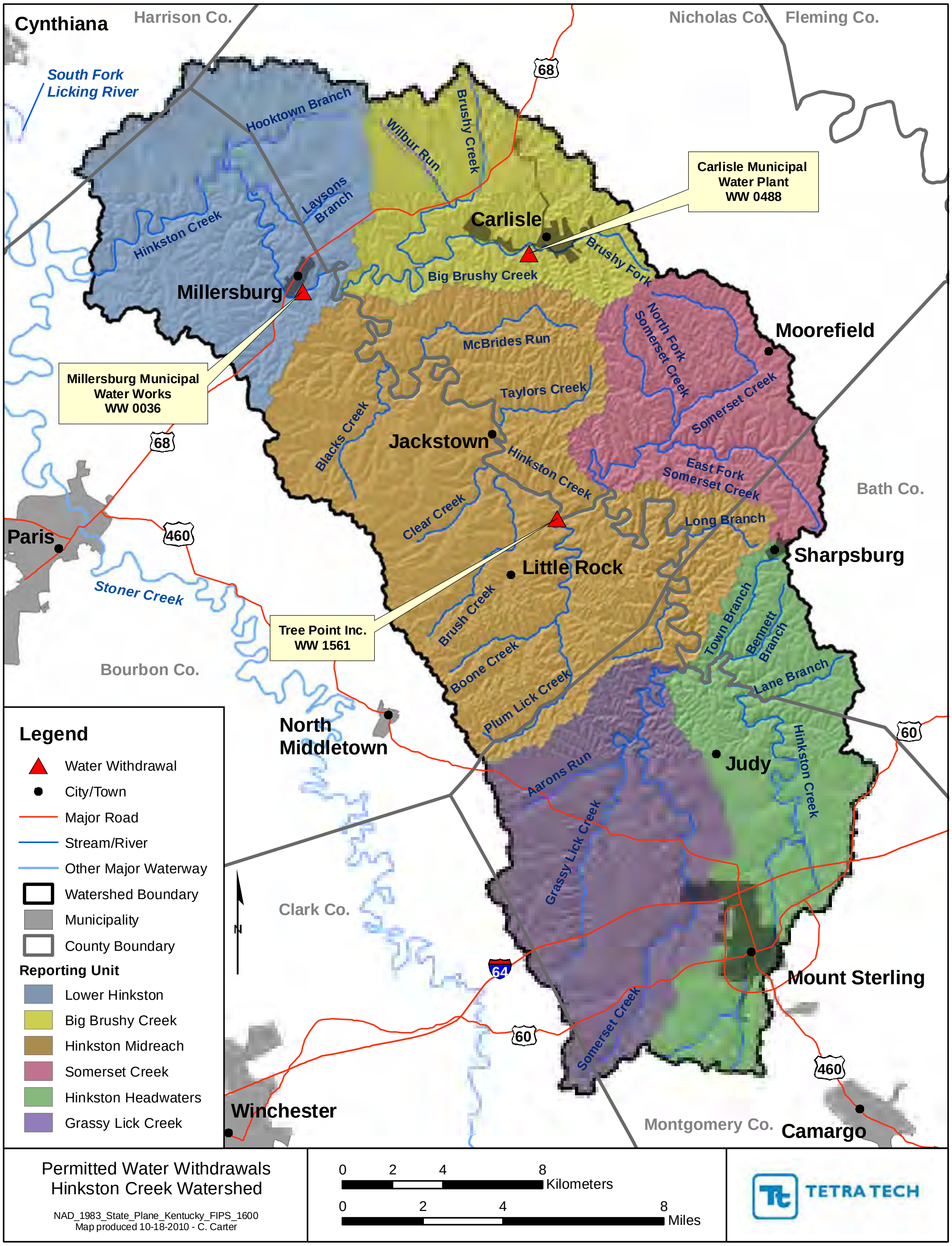


Figure 2-20. Permitted Water Withdrawals in the Hinkston Creek Watershed

2.6.2 Land Use and Land Cover

The land cover of a watershed is a critical feature with complex interactions. A long established native land cover may have any combination of vegetation and root structure. The development of these lands results in removal of the native vegetation and disturbances to the soil and root structures, which collectively may result in altering the rainfall-runoff response both overland and subsurface.

Land use and land cover for the Hinkston Creek watershed were analyzed using the NLCD for 2001 (Figure 2-21). The largest land cover category throughout the watershed is pasture/hay/fallow fields (70 percent of total watershed area). The remaining primary land covers are forest/shrub (20 percent), low intensity development (7 percent), and cultivated crops (2 percent). Low intensity development also includes developed open space such as recreation fields and common areas. There are portions of the study area used for medium and high intensity development (0.5 percent total) and there are small portions covered by open water and wetlands (0.2 percent, Figure 2-22).

Land use and land cover distributions throughout the Hinkston Creek watershed appear to be influenced by the underlying geology. The Somerset Creek reporting unit is covered by the greatest percentage of forest/shrub land cover (29 percent) when compared to all other reporting units. In general the Hills of the Bluegrass ecoregion, which has low potential for karst topography and is mostly underlain by siltstone, appears to have more forest cover when compared to areas that lie within the Outer Bluegrass ecoregion. The Lower Hinkston reporting unit contains the greatest percentage of pasture/hay/fallow fields (76 percent) and croplands (4 percent) when compared to all other reporting units. The Lower Hinkston reporting unit is almost entirely located within the Outer Bluegrass ecoregion which is expected to have more productive soils when compared to soils of the Hills of the Bluegrass ecoregion. The Hinkston Headwaters reporting unit has the greatest percentage of both low density development (14 percent) and high density development (3 percent) when compared to levels of development among the other reporting units. This also reflects the greatest levels of imperviousness being found within the Hinkston headwaters reporting unit.

The effects of impervious area on hydrologic, biologic, and water quality have been studied and many relationships between imperviousness and resulting water quality response are documented (i.e., Sutherland et al., 2002 and Brabec et al., 2002). A detailed publication on this topic is available from the Center for Watershed Protection (http://www.cwp.org/). It is generally accepted that negative impacts on water quality will be observed when the impervious area is 10 percent or more of the total watershed area. Impervious areas promote water quality degradation because they channel rainfall quickly into streams, causing bank erosion and sediment inputs.

Impervious area in the Hinkston Creek watershed was assessed using a 30-meter resolution raster grid from the National Land Cover Database (NLCD) for 2001 (http://www.mrlc.gov/). The impervious coverage for the watershed is shown in Figure 2-23. Each grid cell in the geospatial dataset describes the percent impervious area between 0 and 100 percent. The areas of highest imperviousness are located in the Hinkston Headwaters reporting unit (4.2 percent impervious) near Mount Sterling. In the downstream portions of the Hinkston Creek watershed, impervious areas are concentrated near Carlisle and Millersburg. There are approximately 1,834 acres of impervious area in the entire watershed, which represents 1.1 percent of the total watershed area.

The breakdown of land use and land cover as well as percentage of imperviousness for each reporting unit within the Hinkston Creek watershed is shown in B.

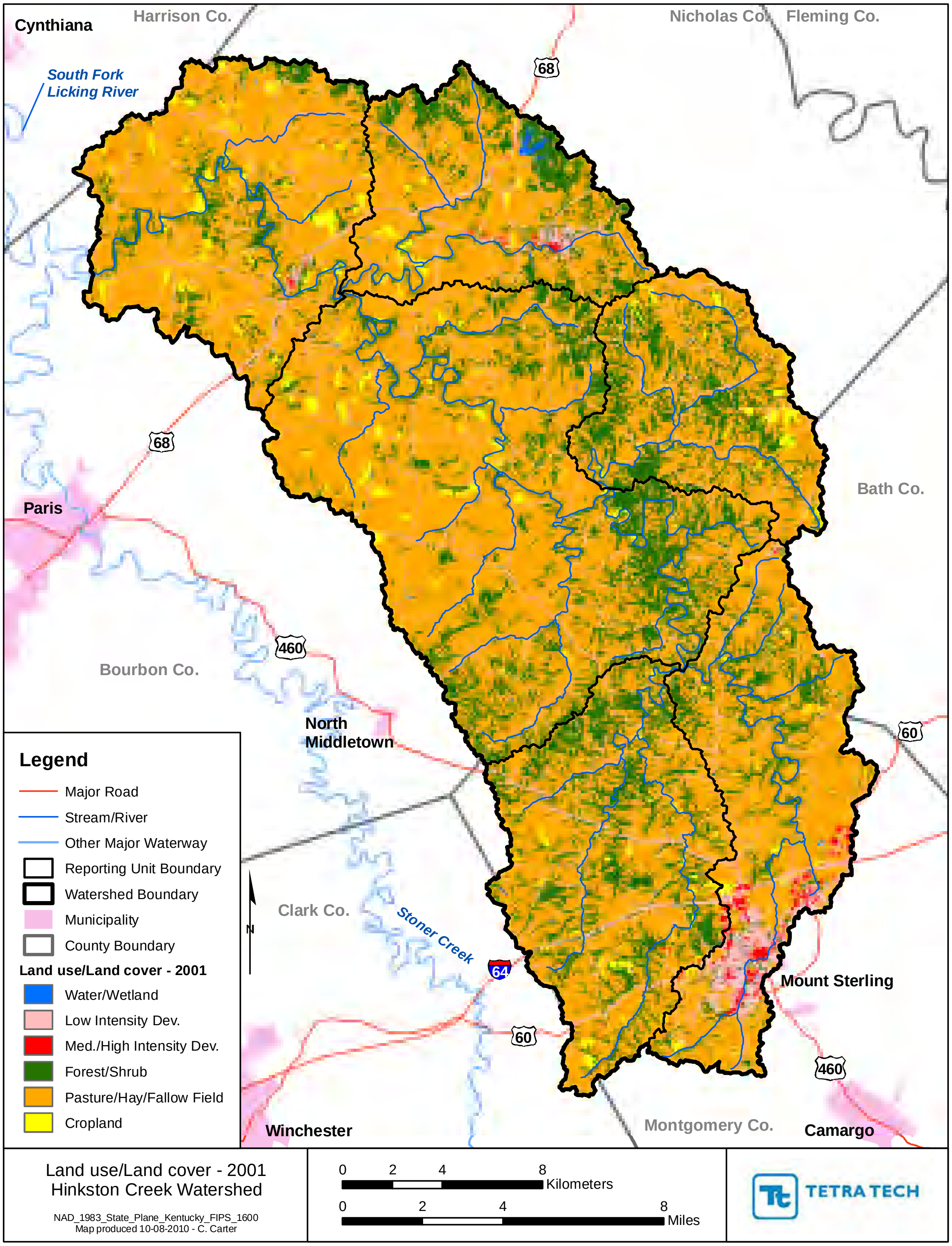


Figure 2-21. Land Use and Land Cover for the Hinkston Creek Watershed

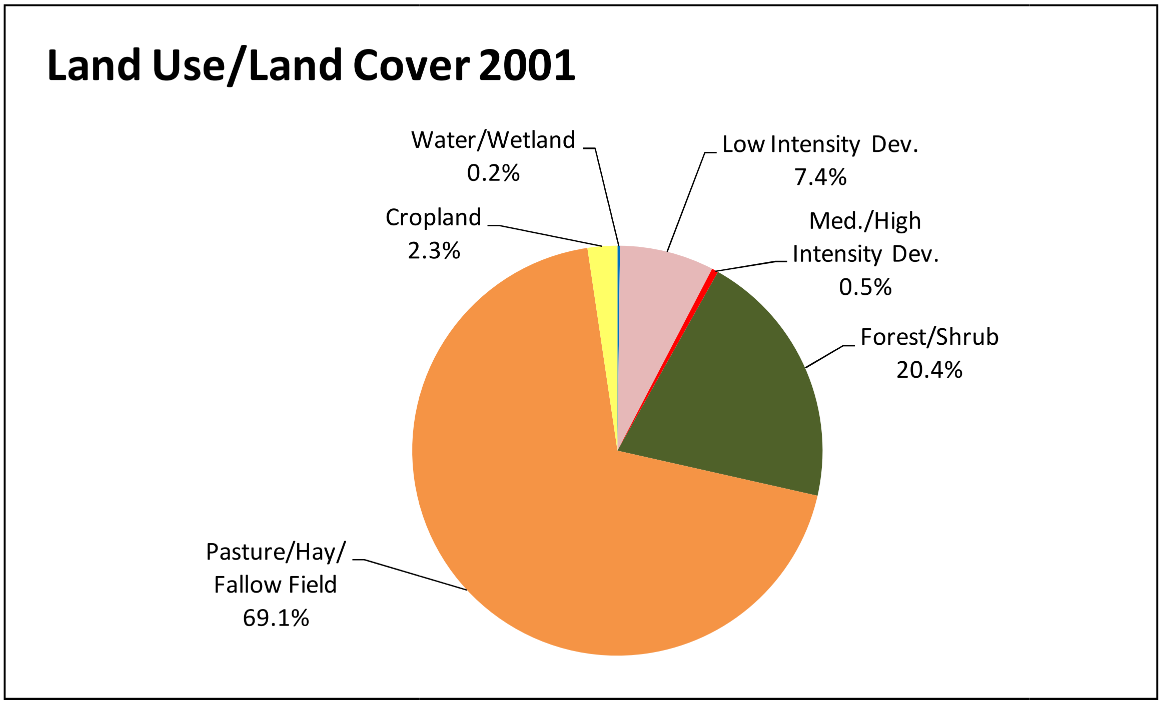


Figure 2-22. Proportions of Land Use and Land Cover in the Hinkston Creek Watershed

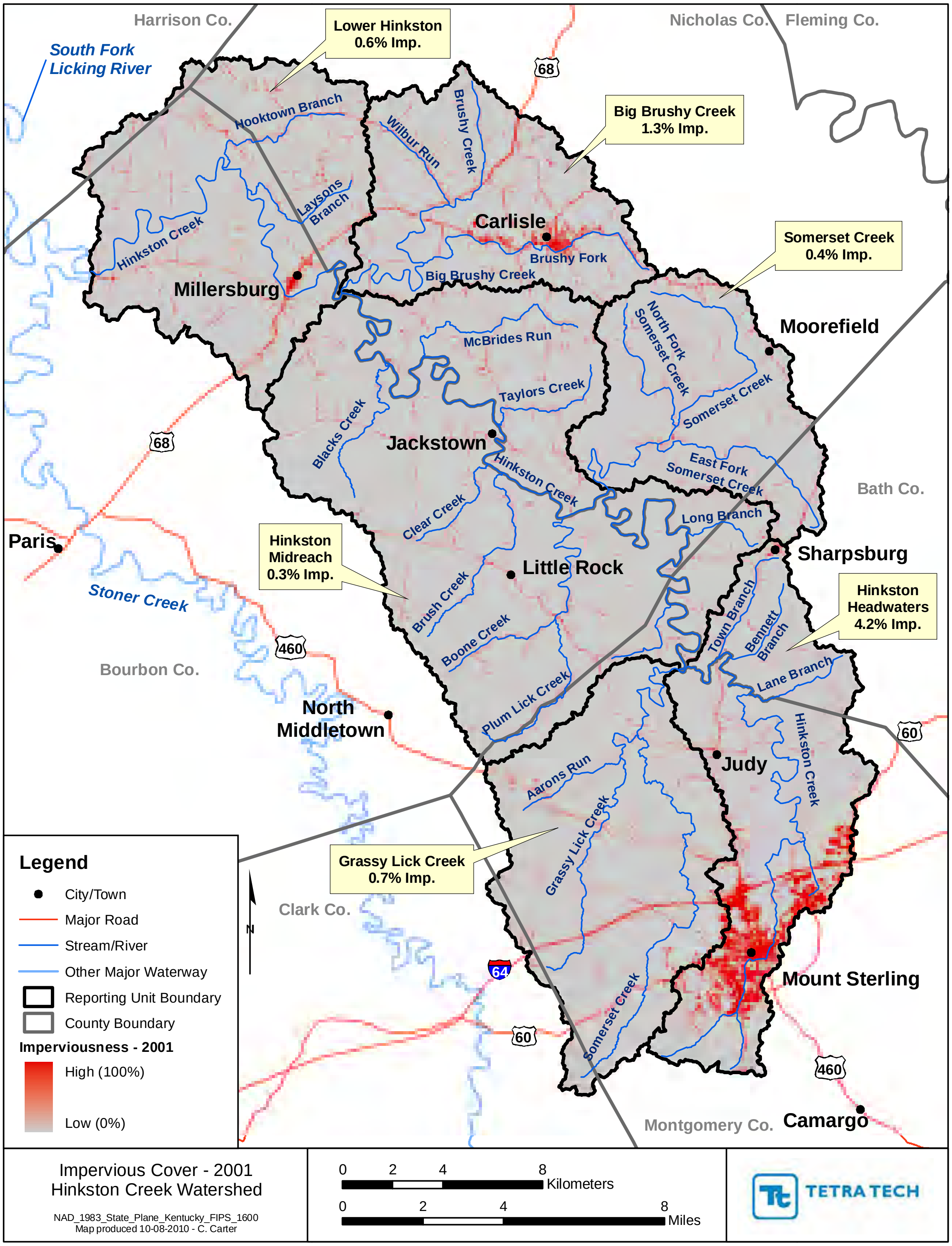


Figure 2-23. Imperviousness in the Hinkston Creek Watershed

2.6.3 Point Source Dischargers

The National Pollutant Discharge Elimination System (NPDES) was established through the Clean Water Act and is managed by the US Environmental Protection Agency (USEPA). NPDES is a system used to regulate point sources of pollution. Examples of point sources within the Hinkston Creek watershed include:

- Industrial facilities (including manufacturing and service industries).
- Municipal governments and other government facilities (such as sewage treatment plants (STPs) and water supply facilities).

In 1983, the Kentucky Natural Resources and Environment Protection Cabinet (NREPC) received regulatory responsibilities from the USEPA for the NPDES permit program under Section 402 of the Clean Water Act. The Kentucky Division of Water now administers the program, and the program is known as the Kentucky Pollution Discharge Elimination System (KPDES).

Twenty-seven KPDES locations are within the Hinkston Creek watershed. The majority of these dischargers are permitted for the discharge of storm water runoff either from parking lots or from construction activities. Among the twenty-seven dischargers, two are permitted for the discharge of treated sanitary wastewater (KY0077232 and KY0092282) and five are identified as sewage treatment plants (STP), one of which is residential. Due to limited data availability, only dischargers identified as municipal STPs will be included in the loading analysis portion of this watershed plan. A full list of permitted point source dischargers and corresponding maps are provided in the appendix.

Municipal STPs for Mount Sterling, Sharpsburg, Carlisle, and Millersburg discharge into Hinkston Creek and its tributaries (Figure 2-24). Data for each of the wastewater treatment plants was obtained from the United States Environmental Protection Agency (USEPA) Permit Compliance System (PCS) and additional sub-monthly data were obtained directly from the Mt. Sterling STP. These data were used to develop approximate loading values on an annual basis for the period of data. Summary information for the dischargers is presented in Table 2-13 through Table 2-15 and this information is presented in graphical form in Figure 2-25 through Figure 2-28, to aid in interpretation the y-axis was set at a constant range for three of the figures.

The largest point source discharger in the watershed is the Mt Sterling STP, with a monthly average permitted discharge value of 3 million gallons per day (MGD); this is more than four times the sum of the other municipal STPs (Table 2-13) Mount Sterling's STP outfall was previously permitted as KPDES ID KY0020044, shown in Figure 2-24, however the discharge location was moved almost 4 miles downstream in December 2003 and assigned a new KPDES ID of KY0104400, which became active in January 2004. The new location has approximately 14.2 square miles of upstream drainage area. There is approximately 11.1 square miles of drainage area upstream of the Carlisle STP outfall and approximately 0.3 square miles upstream of the Sharpsburg STP outfall. The upstream areas are relatively small and contribute to low or dry receiving water conditions for these outfalls during periods of limited precipitation.

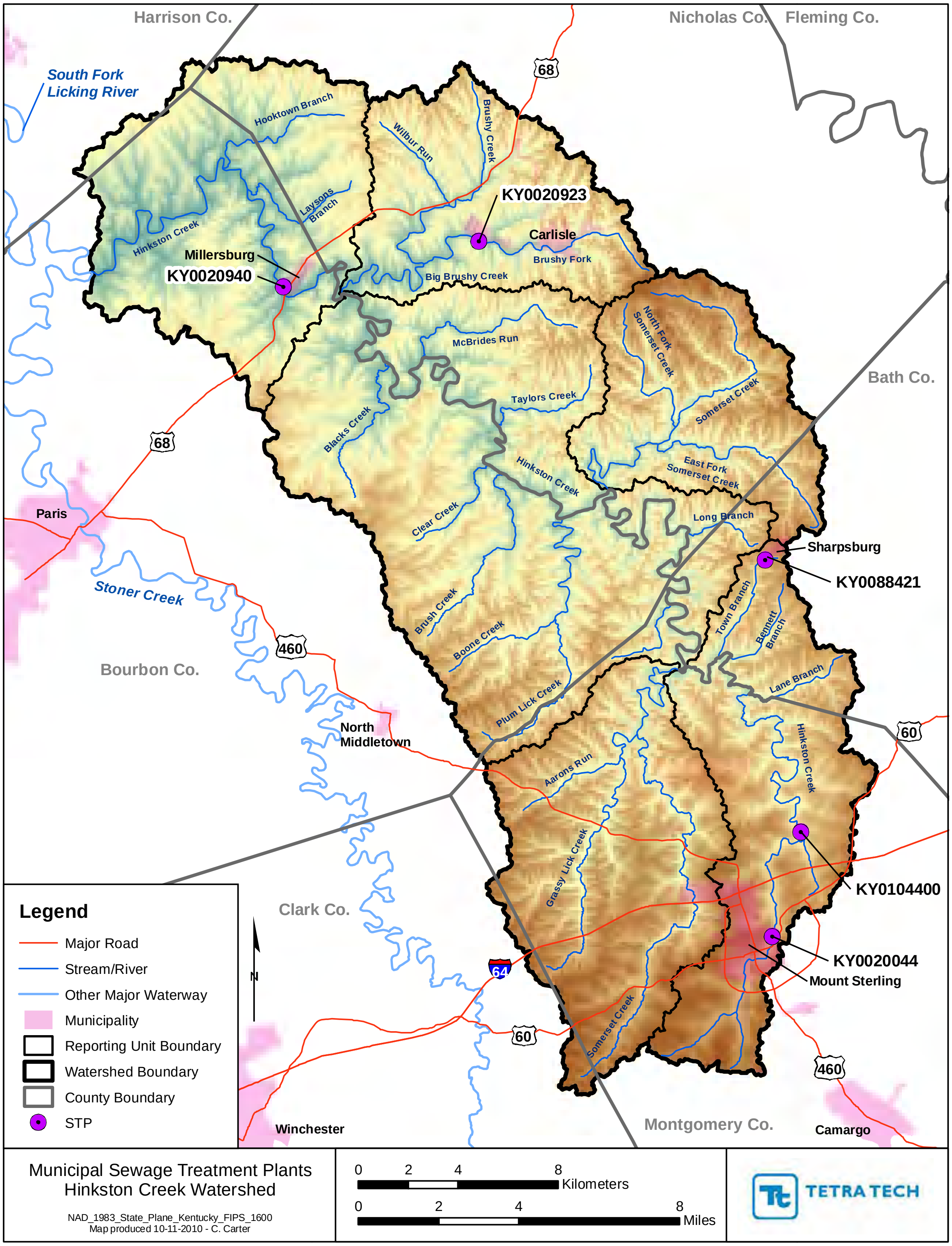


Figure 2-24. Municipal Sewage Treatment Plants within the Hinkston Creek Watershed

Table 2-13. Point Source Discharger Information

NPDES ID	Name	Latitude (NAD83)	Longitude (NAD83)	Receiving Stream	Monthly Average Permitted Flow (MGD)	Monthly Average Reported Flow (MGD)	Permit Expiration
KY0020923	Carlisle STP	38.314722	-84.062778	Brushy Fork of Big Brushy Creek	0.35	0.27	10/31/2014
KY0020940	Millersburg STP	38.299444	-84.152778	Hinkston Creek	0.20	0.11	4/30/2014
KY0088421	Sharpsburg STP	38.197778	-83.934444	Town Branch	0.07	0.03	12/31/2014
KY0104400	Mt. Sterling STP	38.099444	-83.920556	Hinkston Creek	3.00	2.0	11/30/2014

Table 2-14. Point Source Discharger Current Monthly Average Water Quality Permit Limits

NPDES ID and Name	Min. DO (mg/L)	CBOD5 (mg/L)	CBOD5 (lb/d)	NH3 (mgN/L)	NH3 (lbN/d)	TP (mgP/L)	TSS (mg/L)
KY0020923 Carlisle STP	7	10	29.2	2 (May-Oct) 6 (Nov-Apr)	5.84 (May-Oct) 17.6 (Nov-Apr)	No Limit	30
KY0020940 Millersburg STP	7	10	16.7	2 (May-Oct) 8 (Nov-Apr)	3.34 (May-Oct) 13.3 (Nov-Apr)	No Limit	30
KY0088421 Sharpsburg STP	7	25	14.6	4 (May-Oct) 10 (Nov-Apr)	2.3 (May-Oct) 5.8 (Nov-Apr)	No Limit	30
KY0104400 Mt. Sterling STP	7	15	375	4 (May-Oct) 10 (Nov-Apr)	100 (May-Oct) 250 (Nov-Apr)	1 (Nov-Apr) 2 (Nov-Apr)	20

Table 2-15. Point Source Discharger Annual Loading (lb/y) Based on Current Monthly Average Permit Limits

NPDES ID and Name	NH3 (lbN/y)	TN (lbN/y)	TP (lbP/y)
KY0020923 Carlisle STP	4,260	Report Concentration	Report Concentration
KY0020940 Millersburg STP	3,022	Report Concentration	Report Concentration
KY0088421 Sharpsburg STP	1,473	Report Concentration	Report Concentration
KY0104400 Mt. Sterling STP	63,650	Report Concentration	13,670
Total	72,405	-	-

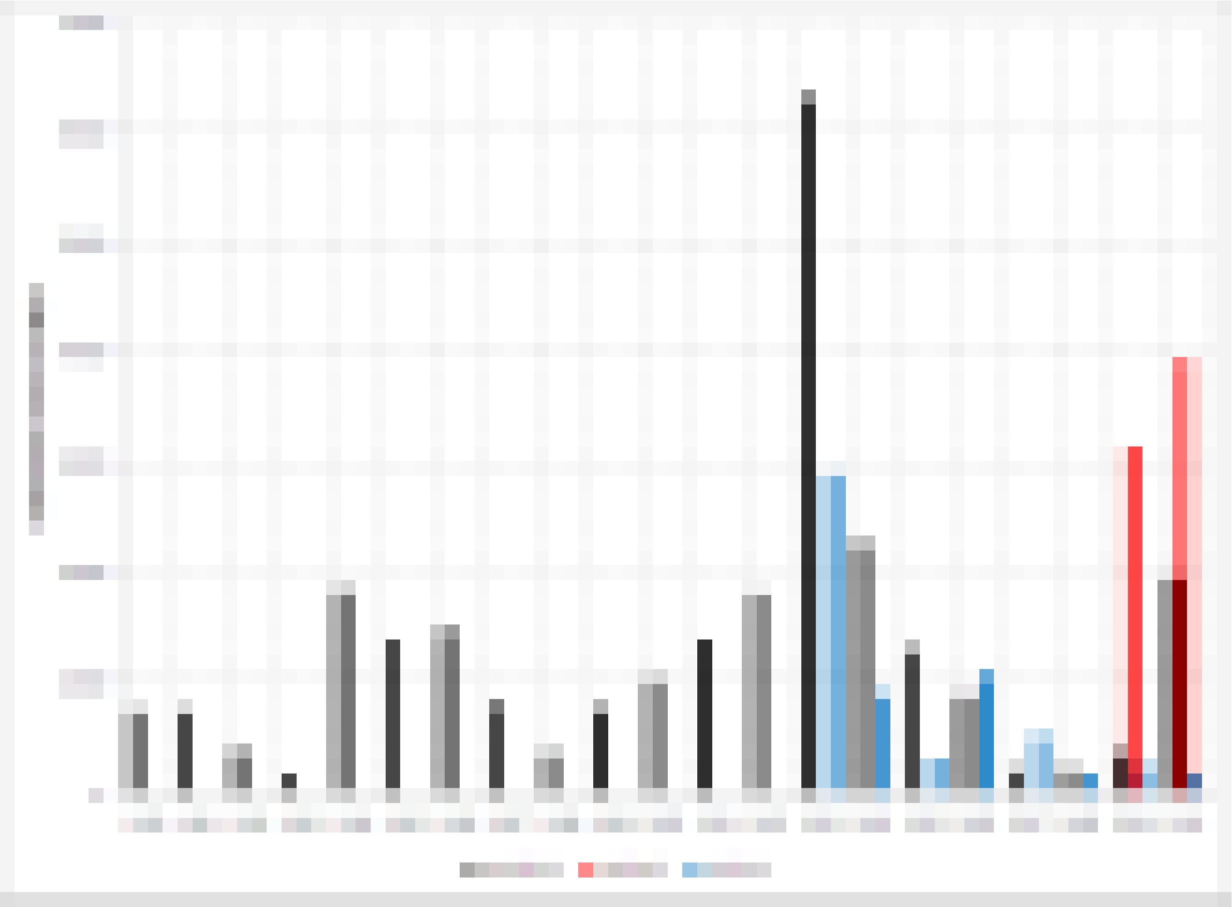


Figure 2-25. Approximate Annual Loading Values of NH3, TN, and TP for Mt. Sterling STP

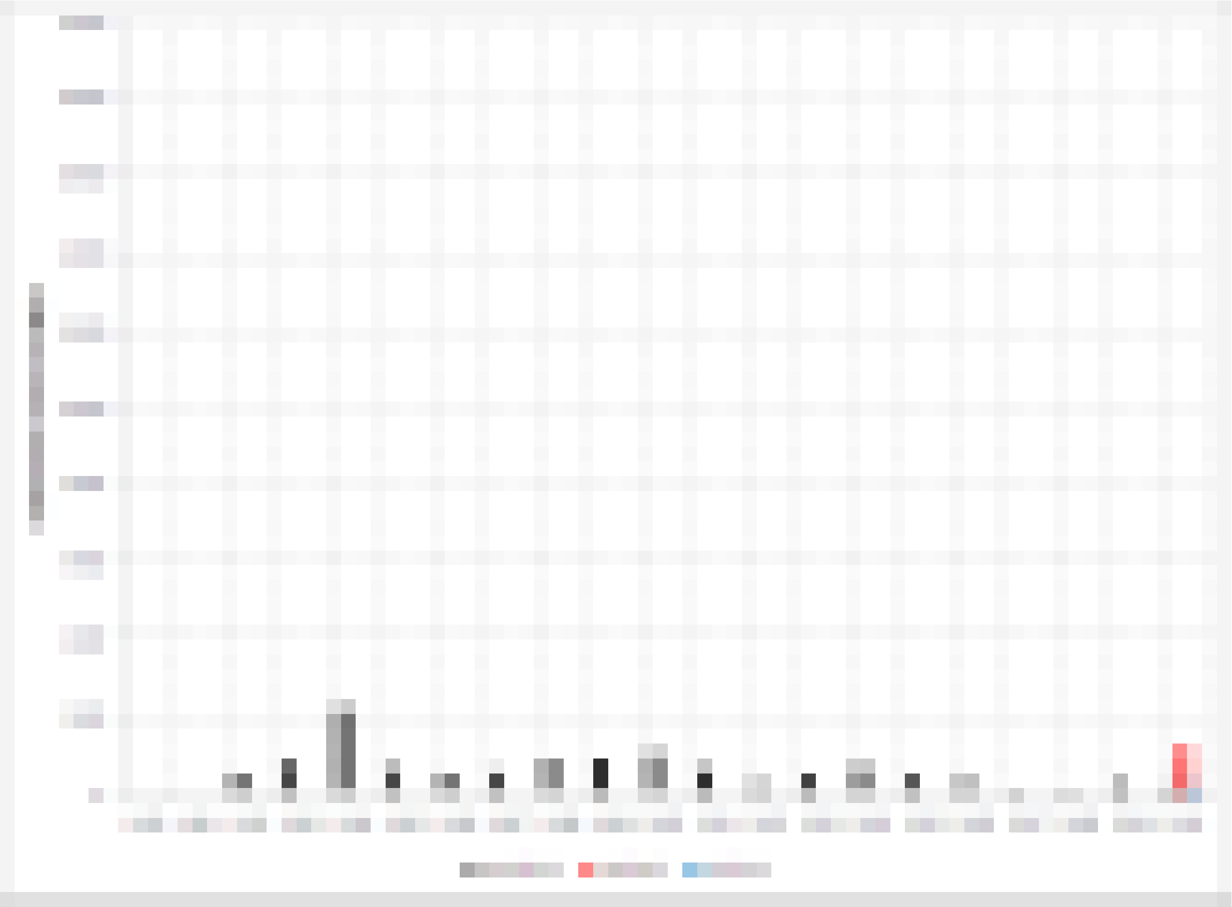


Figure 2-26. **Approximate Annual Loading Values of NH3, TN, and TP for Sharpsburg STP**

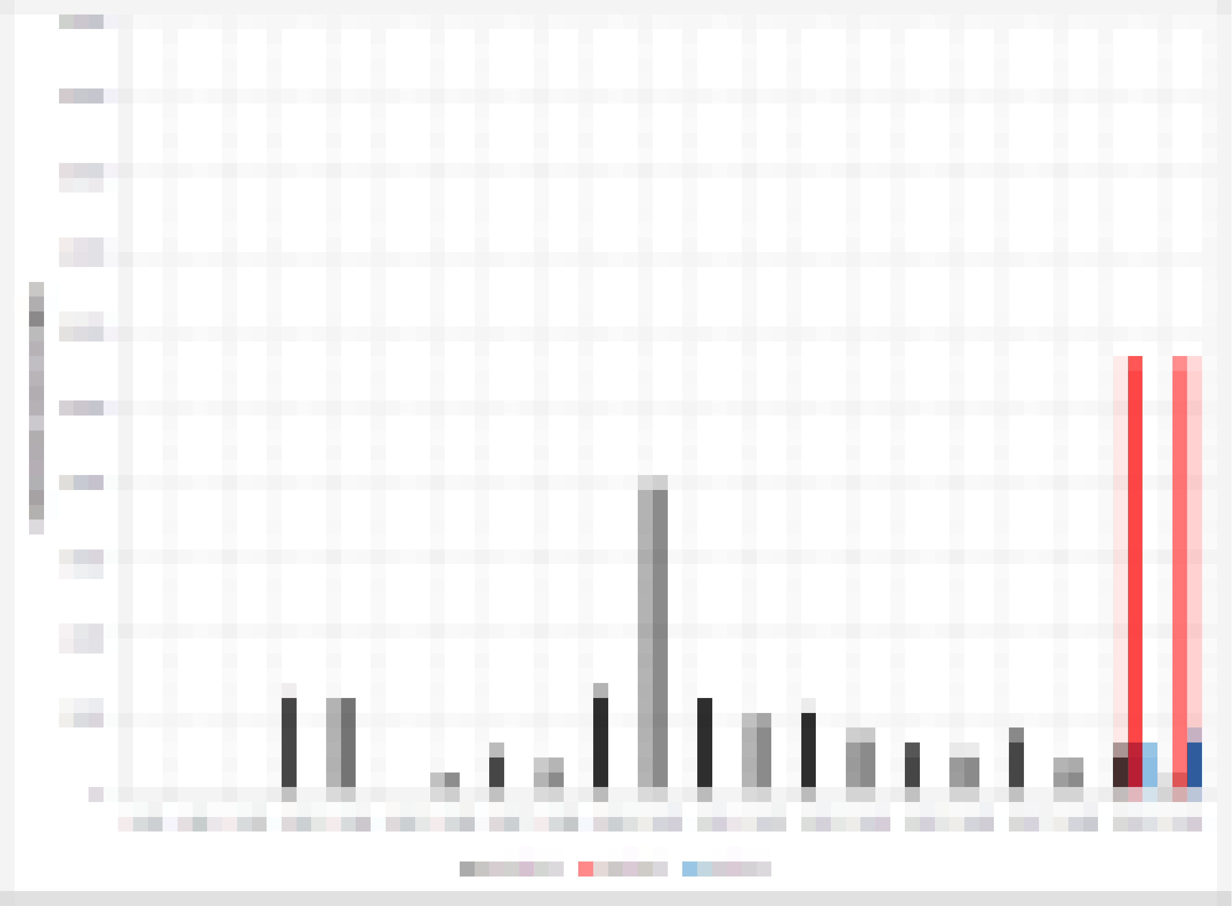


Figure 2-27. Approximate Annual Loading Values of NH3, TN, and TP for Carlisle STP

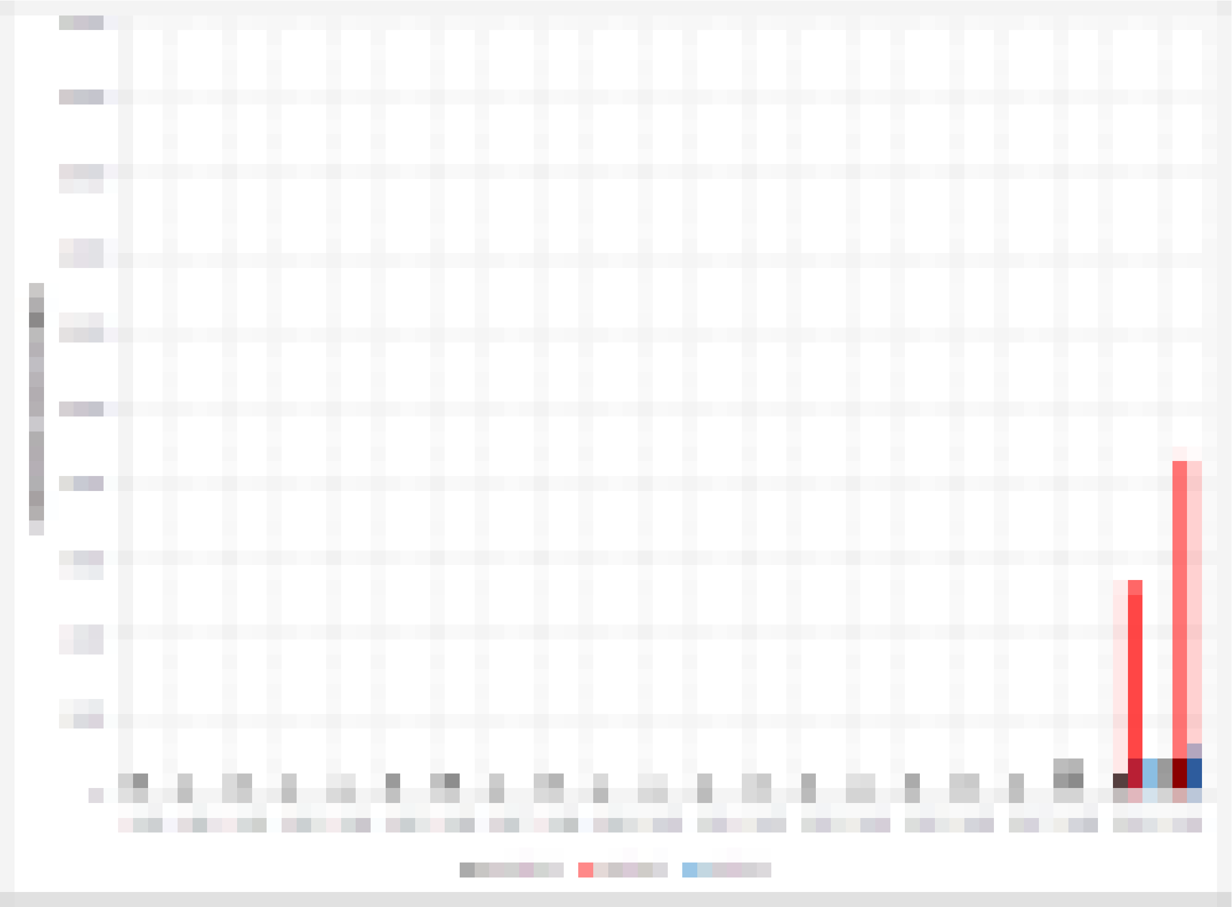


Figure 2-28. Approximate Annual Loading Values of NH3, TN, and TP for Millersburg STP

The figures provide historical perspective on pollutant loading from these dischargers. The data suggest that Mt. Sterling STP has been the largest contributor among these dischargers of pollutant loading. In 2009, except for Sharpsburg STP which began in 2010, the dischargers began to report TN-N and TP-P monthly average effluent concentrations. These reported values were used to approximate an annual load and are presented in Table 2-16 through Table 2-18. The 2009-2010 approximate annual loading values suggest that Mt. Sterling STP is the primary contributor of nitrogen and Carlisle STP is the next largest contributor. There is less discrepancy between their total phosphorus values than their values for other parameters.

Table 2-16. Approximate Annual NH_3 (lbN/y) Loading for the Domestic Waste Dischargers

Year	Mt Sterling STP	Sharpsburg STP	Carlisle STP	Millersburg STP
2009	3,681	262	1,093	467
2010	19,403	175	252	891

Table 2-17. Approximate Annual TN (lbN/y) Loading for the Domestic Waste Dischargers

Year	Mt Sterling STP	Sharpsburg STP	Carlisle STP	Millersburg STP
2009	31,496	-	11,271	5,464
2010	39,444	1,219	11,227	8,650

Table 2-18. Approximate Annual TP (lbP/y) Loading for the Domestic Waste Dischargers

	Mt Sterling STP	Sharpsburg STP	Carlisle STP	Millersburg STP
2009	2,405	-	1,248	909
2010	1,555	179	1,376	1,048

2.6.4 Other Water Disturbances

In addition to point source pollution, discussed in Section 2.6.3, nonpoint source pollution (NPS) is a source for water quality disturbance within the Hinkston Creek watershed. NPS pollution is generally caused by rainfall or snowmelt moving over and through the ground; as the water moves, it picks up and carries pollutants which are then deposited into lakes, rivers, wetlands, and aquifers. The Kentucky Division of Water (KDOW) recognizes NPS as the top contributor to water pollution in Kentucky as it accounts for approximately two-thirds of the water quality impairments in Kentucky's streams and lakes. KDOW has developed a NPS Pollution Control Program with goals to protect the quality of Kentucky's surface and groundwater from NPS pollutants, abate NPS threats, and restore degraded waters to the extent that water quality standards are met and designated uses are supported (http://water.ky.gov). KDOW is achieving these goals through federal, state, local, and private partnerships that promote NPS pollution control initiatives at both statewide and watershed levels. The primary methods for controlling NPS pollution are the implementation of practical and cost-effective land management practices known as best management practices (BMPs) which can be structural or non-structural (e.g., codes or ordinances) and serve to reduce or prevent NPS while allowing for everyday activities.

Sources for NPS that are of primary concern in the Hinkston Creek watershed are urban runoff, agriculture, and failing septic systems. Urban runoff is of greatest concern in areas having highly connected impervious surfaces where water can flow directly into streams before it has the chance to be filtered by the ground; impervious surfaces within the Hinkston Creek watershed are discussed in Section 2.6.2.

Nonpoint source pollution from agricultural fields can come from the wash off of topsoil from cultivated fields, the wash off of applied fertilizers and pesticides, and improperly managed livestock waste. When topsoil enters streams it increases the amount of suspended sediment and impairs aquatic habitat. Sediment entering the stream also carries with it any attached nutrients or fecal coliform, which can further impair water quality. Pesticides and fertilizers that wash into streams raise nutrient levels and increase the concentrations of harmful chemicals. Improperly managed livestock waste affects streams and lakes as it causes increased fecal and nutrient loading which can greatly reduce the level of oxygen available in these waters. As discussed in Section 2.6.2, pasture and cropland comprise greater than 71 percent of the watershed.

Water quality impacts from malfunctioning septic systems are of greatest concern in areas that are not serviced by a public sewer system, where the household density is greater than one household per acre, and where surface waters are nearby. Throughout the Hinkston Creek watershed, there are four areas serviced by public sewer systems – the municipalities of Millersburg, Carlisle, Sharpsburg, and Mount Sterling. All other areas within the watershed manage waste through the use of individual wastewater treatment systems, nearly all of which are conventional gravity flow septic systems. When these systems are inappropriately designed, installed, maintained, or poorly located, pathogen-containing waste may emerge at the surface where it can be washed into streams by rain, or it can seep directly into near-surface groundwater.

During the development of this watershed plan, areas of high density housing that are dependent on septic systems were prioritized to estimate their potential to contribute NPS pollution to streams and groundwater. Prioritization was based on level of household density, closeness to streams, and closeness to karst topography (to account for impacts to groundwater). Publicly serviced areas with centralized wastewater treatment were eliminated from prioritization based on data obtained from the Water Resources Information System, which is supported by the Kentucky's Area Development Districts and KDOW (WRIS, 2010). Household density was calculated for areas outside of public sewer line boundaries that were surrounding the municipalities – within 2 miles of publicly serviced areas in Mount Sterling and within 1 mile of publicly serviced areas for all other municipalities. Household density was not calculated across the entire watershed because septic failure impacts to water quality were assumed to be low in agricultural areas where household density is less than 1 house per acre. Data for calculating household density was obtained from the U.S. Census Bureau's 2000 Census Block data (downloaded from http://kygeonet.ky.gov/). Closeness to streams was calculated using the 1:24,000 streams data layer created by the United States Geological Survey (USGS, 2007). Closeness to karst was calculated using a geologic data layer developed by the Kentucky Geological Survey (downloaded from http://kygeonet.ky.gov/). Only areas having a household density greater than one household per acre were considered and household density, closeness to streams, and closeness to karst geology received equal weights throughout the prioritization process.

Eight census blocks within the Hinkston Creek watershed received prioritization ratings at levels of medium priority (7 blocks) and high priority (1 block). All other census blocks included in the prioritization analysis received ratings of low priority due to low levels of household density (<1 house per acre). The areas prioritized throughout this analysis are displayed in Figure 2-29 along with the census block identification number. Subdivisions located in census blocks adjacent to those highlighted through this analysis should not be disregarded for further investigation. Due to data availability, the resolution of this analysis was at the census block level and it was possible for high density subdivisions that are located within large census blocks to be overlooked while similar subdivisions located within smaller census blocks are given priority since not all census blocks are the same size.

The purpose for prioritizing septic areas for this watershed plan was to highlight areas within the watershed that have the highest potential to contribute NPS pollution to streams and/or near-surface groundwater if septic systems are not properly maintained. Near-surface groundwater is a concern because during dry weather, streams in the watershed maintain flow by pulling groundwater from the surrounding soil and rock layers, which can transfer groundwater bacteria into surface waters. The level of septic system function and maintenance in these highlighted areas is unknown, and the threat of bacteria contribution could be very low. Subsequent analyses of the highlighted areas may include consideration of septic system age and soil class suitability as these are important factors that often influence septic system function and ease of contamination transfer to groundwater, respectively. In addition, low-flow bacteria sampling in the streams surrounding these areas might provide evidence as to whether these areas require further investigation of septic system failure or implementation of septic system BMPs (upgrades, repairs, or replacements).

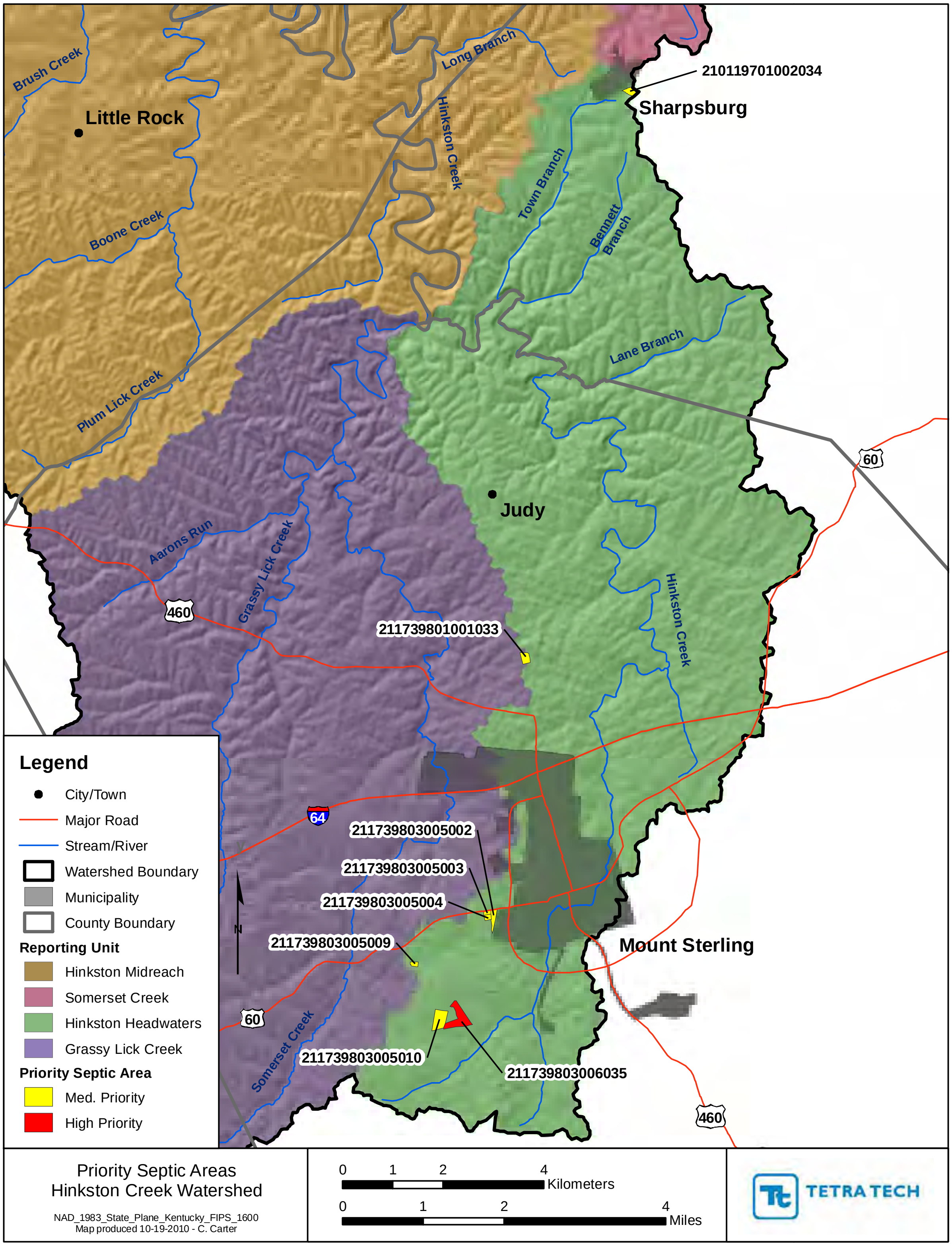


Figure 2-29. Priority Septic Areas within the Hinkston Creek Watershed

2.6.5 Land Disturbances

Land disturbances within the Hinkston Creek watershed from construction activity and/or road building are minimal and were considered negligible for the development of this watershed plan (Barry Tonning, local resident, personal communication with Greg Sousa, Tetra Tech, October 18, 2010).

2.6.6 Hazardous Materials

The EPA list of superfund sites (http://www.epa.gov/region4/waste/npl/index.htm#KY) indicated 20 open sites within the state of Kentucky. None of these 20 sites are located within the Hinkston Creek watershed.

2.7 CATTLE

The number of beef cattle within the Hinkston Creek watershed was estimated by reporting unit using cattle counts recorded for each county in the years from 1998 to 2010 (USDA-NASS, 2010). The Hinkston Midreach reporting unit has the highest average cattle count compared to other reporting units. The Lower Hinkston, Big Brushy Creek, and Hinkston Midreach reporting units have the highest cattle density (Table 2-19).

Table 2-19. Cattle Count and Density Estimates by Reporting Unit

Reporting Unit	Annual Average Cattle Count	Cattle Density (cattle/hectare)
Lower Hinkston	7,187	1.1
Big Brushy Creek	4,338	1.1
Hinkston Midreach	13,871	1.1
Somerset Creek	4,061	1.0
Hinkston Headwaters	5,517	0.9
Grassy Lick Creek	5,886	1.0

2.8 DEMOGRAPHICS AND SOCIAL ISSUES

The total population for Hinkston Creek watershed was estimated using GIS and 2000 Census Block data obtained from the U.S. Census Bureau. Several census blocks crossed the boundary of the watershed and only a proportion of their total recorded population was considered. For this estimation, an area weighted calculation was applied to determine the proportion of total population within the watershed boundary and the assumption of uniform population distribution throughout these census blocks was applied. The estimated total population for the Hinkston Creek watershed for the year 2000 was 20,957 people.

Although Mount Sterling has extra territorial jurisdiction authority which it can use for planning subdivisions and developments within the 5 miles radius of Mount Sterling, the growth area for the City (i.e. where the City is likely to extend its boundaries and provide city services such as water and sewer in the near term) is estimated to be within a half mile from the current city limits (correspondence with Jeff Prater, MTGCO, October, 21, 2010).

2.9 TEAM OBSERVATIONS

Tetra Tech's Hinkston Creek watershed assessment team observed characteristics of stream and water quality degradation from impacts related to both agricultural and developed land uses throughout the watershed. Most obvious of these characteristics were widespread erosion along banks leading to channel incision, little riparian cover or buffers along waterways (Figure 2-30), relatively unrestricted cattle access to sensitive bank areas (Figure 2-31), bedrock or hardpan stream bottoms (Figure 2-31), and poor manure management throughout the Hinkston Creek watershed. These characteristics are common throughout the watershed but were specifically noted during a geomorphology field survey conducted in the Grassy Lick Creek and Hinkston Headwaters reporting units. Results from the geomorphology survey are described in more detail in Section 2.2.6. Information from a survey and mapping program undertaken by the Gateway District Health Department as part of a five-county nonpoint program provides similar observations from within the Hinkston Creek watershed (GDHD, 1994, 1996, 1998).

Figure 2-30. Mainstem of Hinkston Creek located in downtown Mount Sterling, west of KY 11 and south of West Locust Street. Note: very little riparian cover and poor bank conditions. (Photo taken by Greg Sousa, Tetra Tech, September 22, 2010)

Figure 2-31. Plum Lick Creek, at tributary of Boone Creek in the Hinkston Midreach reporting unit. Note: little to no riparian cover, cattle access to stream, pasture land abutting stream, and hardpan stream bottom. (Photo taken by Greg Sousa, Tetra Tech, September 22, 2010)

2.10 INTERIM CONCLUSIONS

The Hinkston Creek watershed has widespread need for water quality management efforts. The main goal of this report is to provide recommendations for key areas to focus attention to ensure that initial restoration and BMP implementation efforts are effective as first steps to improving the water quality of Hinkston Creek. Throughout this report, benchmark values and in-stream data were utilized to perform a two-phase prioritization process. Each of these is briefly summarized in the following text and explained in greater detail in Chapters 4 and 6.

2.10.1 Phase 1 Prioritization

An initial prioritization (Phase 1) was performed on reporting units to select the one or two areas of greatest priority for water quality management. Three key elements were included in the ranking of reporting units. The first and second elements were based on observed water quality data and simulated loading estimates, respectively. The final element was based on administrative effectiveness. Each element is further defined in Section 4.2. The Phase 1 prioritization resulted in the Hinkston Headwaters reporting unit receiving the highest priority ranking for management efforts and the adjacent Grassy Lick Creek reporting unit was ranked as second priority.

2.10.2 Phase 2 Prioritization

A second prioritization (Phase 2) was performed to identify focus areas within the Hinkston Headwaters and Grassy Lick Creek reporting units. The Phase 2 prioritization included an assessment of observed water quality concentrations, riparian buffer status, habitat assessment scores, and results from the geomorphic visual assessment. Results of this prioritization indicated key areas for potential management efforts. These areas are Town Branch, Bennett Branch, the headwaters of Hinkston Creek (south of Calk

Road), and Grassy Lick Creek. The Phase 2 prioritization provides a useful stepping-stone to aid in the process of BMP planning and development and is outlined in detail in Section 6.1.

3 Monitoring

3.1 STREAM WATER QUALITY MONITORING

Monitoring data used throughout the development of this watershed plan was derived from four sources – the Kentucky Division of Water (KDOW), the Licking River Watershed Watch (LRWW), Morehead State University (MSU) and the United States Geological Survey (USGS). All data was compiled into a single database using the Water Resources Database (WRDB) software program.

Ten KDOW monitoring locations are located within the Hinkston Creek watershed. All of these locations are within the Hinkston Creek mainstem and tributaries of the Hinkston Headwaters subwatershed draining Mount Sterling and Sharpsburg (Figure 3-1). Location descriptions for each of these stations are listed in Table 3-1. KDOW observations at these locations were collected between March 2004 and February 2005 on a monthly basis. Data collected at KDOW locations included physical and chemical observations and stream flow (Tonning 2010).

Seven LRWW monitoring locations are located within the Hinkston Creek watershed. LRWW stations are widely distributed throughout the watershed; however, none are located within the Somerset Creek (Grassy Lick) or Grassy Lick Creek subwatersheds (Figure 3-1). Location descriptions for each of these stations are listed in Table 3-2. Data collected by LRWW consists of nutrient concentration records dated between 1999 and 2008. The time period for which data was collected at LRWW stations varies between stations and some stations have very limited data available. Station L225 in Figure 3-1 has records from May 2003 to October 2008, while all other stations have records available from 1999 through 2004 or 2008. The monitoring frequency for LRWW stations was once per year, always in the month of September. LRWW monitoring was performed by volunteers and resulting data were posted on the LRWW website (www.lrww.org).

Morehead State University monitored 12 stream locations throughout the Hinkston Creek watershed (Figure 3-1). Location descriptions for each of these stations are listed in Table 3-3. At these locations, nutrient data and stream flow were collected on a monthly basis from November 2009 through October 2010. Sampling events occurred during the first week of each month. Due to the highly variable rainfall and flow conditions in east-central Kentucky, the monitoring schedule was expected to capture a range of flow conditions from low flow (e.g., during the fall sampling period) to moderate and high flows (e.g., during the late winter and spring; Tonning, 2010). Monitoring by MSU was specifically planned to support development of this watershed plan. Water quality sampling sites were selected to capture the impacts from segments of the Hinkston Creek mainstem and the principal tributaries. The sites selected will help to screen segments of the mainstem and tributary drainage areas that appear to be supporting instream use designations from those where impairments may exist. The rationale for selecting which parameters to record was based on the impairment causes listed by KDOW in its *Integrated Report on Water Quality* entries for Hinkston Creek, which identifies nutrients, sediment, bacteria, and low dissolved oxygen as potential causes for impairment (Tonning, 2010).

Stream flow was recorded at a USGS gage positioned in the center of the Hinkston Creek watershed, downstream of Clear Creek's confluence with Hinkston Creek in the Hinkston Midreach reporting unit (Figure 3-1). Daily stream flow has been reported for the station since October 1, 1991 and the station monitors flow draining from 154 square miles of the watershed.

Table 3-1. KDOW Station Descriptions

Station ID	Location Description	Latitude	Longitude	River Mile	Drainage Area (mi^2)
05016020	Hinkston Creek off KY 11 downstream of Calk Road bridge	38.034800	-83.952300	69.15	4.17
05016021	Unnamed Tributary to Hinkston Creek off KY 1991	38.095700	-83.919500	67.00	2.17
05016022	Lane Branch at private drive	38.149200	-83.927000	54.20	2.74
05016023	Bennett Branch off gravel road near county line	38.162600	-83.950600	52.45	2.59
05016024	Town Branch at private drive past KY11 bridge	38.165600	-83.956000	52.00	2.54
05016025	Hinkston Creek at Hinkston Pike (KY 1991)	38.095900	-83.921400	63.05	12.03
05016026	Hinkston Creek off private drive	38.107200	-83.922900	61.75	15.21
05016027	Hinkston Creek at Tipton Road	38.141100	-83.929700	56.45	23.73
05016028	Town Branch Downstream from Sharpsburg	38.197700	-83.934900	54.72	0.30
05016029	Hinkston Creek off KY11	38.161400	-83.959100	51.70	35.19

Table 3-2. LRWW Station Descriptions

Station ID	Location Description	Latitude	Longitude	River Mile	Drainage Area (mi^2)
L225	Hinkston Creek at KY 1940 bridge in Ruddell's Mill	38.304600	-84.238100	0.00	260.36
L40	Hinkston Creek off Rogers Mill Road	38.166620	-83.976050		79.12
L61	Hinkston Creek off KY 11 downstream of Calk Road bridge	38.035600	-83.951700	69.15	2.54
L62	Hinkston Creek off Hinkston Road	38.076300	-83.934500		9.02
L79	Hinkston Creek at Steel Ford bridge	38.339169	-84.171447		235.50
L89	Brushy Fork Creek off Miller Station Road	38.309040	-84.081591		13.05

Table 3-3. MSU Station Descriptions

Station ID	Location Description	Latitude	Longitude	River Mile	Drainage Area (mi^2)
HKC-01	Hinkston Creek at KY 1940 bridge in Ruddell's Mill	38.304444	-84.239167	0.00	260.36
HKC-02	Hinkston Creek downstream of US 68 bridge in Millersburg	38.296389	-84.152778	12.74	223.67
HKC-03	Big Brushy Creek at KY 386 bridge	38.304722	-84.113333	17.13	28.92
HKC-04	Blacks Creek at Stoker Road bridge	38.268333	-84.111389	21.55	8.46
HKC-05	Hinkston Creek at KY 13 bridge near Jackstown	38.247222	-84.055556	29.03	154.65
HKC-06	Boone Creek at Soper Road bridge NE of Little Rock	38.213611	-84.026944	33.45	15.55

Station ID	Location Description	Latitude	Longitude	River Mile	Drainage Area (mi^2)
HKC-07	Somerset Creek at KY 57 bridge SW of East Union	38.231111	-84.005278	37.49	25.21
HKC-08	Grassy Lick Creek NW of Aaron's Run Road bridge	38.134722	-83.994722	54.15	18.83
HKC-09	Somerset Creek NW of Aaron's Run Road bridge	38.134722	-83.994722	54.65	18.81
HKC-10	Hinkston Creek off KY 11	38.163056	-83.957222	51.70	35.19
HKC-11	Hinkston Creek upstream of SR 1991	38.098889	-83.920278	62.22	15.21
HKC-12	Hinkston Creek off KY 11 downstream of Calk Road bridge	38.035000	-83.951944	69.15	2.54

Of the aforementioned water quality monitoring data, records for sediment, phosphorus, nitrogen, fecal coliform/bacteria, and dissolved oxygen (DO) will be used throughout the development of this watershed plan. Water quality data from each of the monitoring groups (KDOW and MSU) will be combined for analysis because these groups used comparable methods for collection and processing. Only bacteria data collected by LRWW will be considered in this watershed plan.

Data was obtained for the four sewage treatment plants located within the Hinkston Creek watershed from the United States Environmental Protection Agency (USEPA) Permit Compliance System (PCS). Summary information for the dischargers is presented in Table 2-13 and Table 2-14 their locations are shown in Figure 2-24. The data analyzed for this watershed plan were measured between 1989 and 2010. The largest sewage treatment plant in the watershed is the Mount Sterling Sewage Treatment Plant. Mount Sterling was previously permitted as NPDES ID KY0020044, shown in Figure 2-24, but the discharge location was moved in December 2003 and assigned a new NPDES ID of KY0104400.

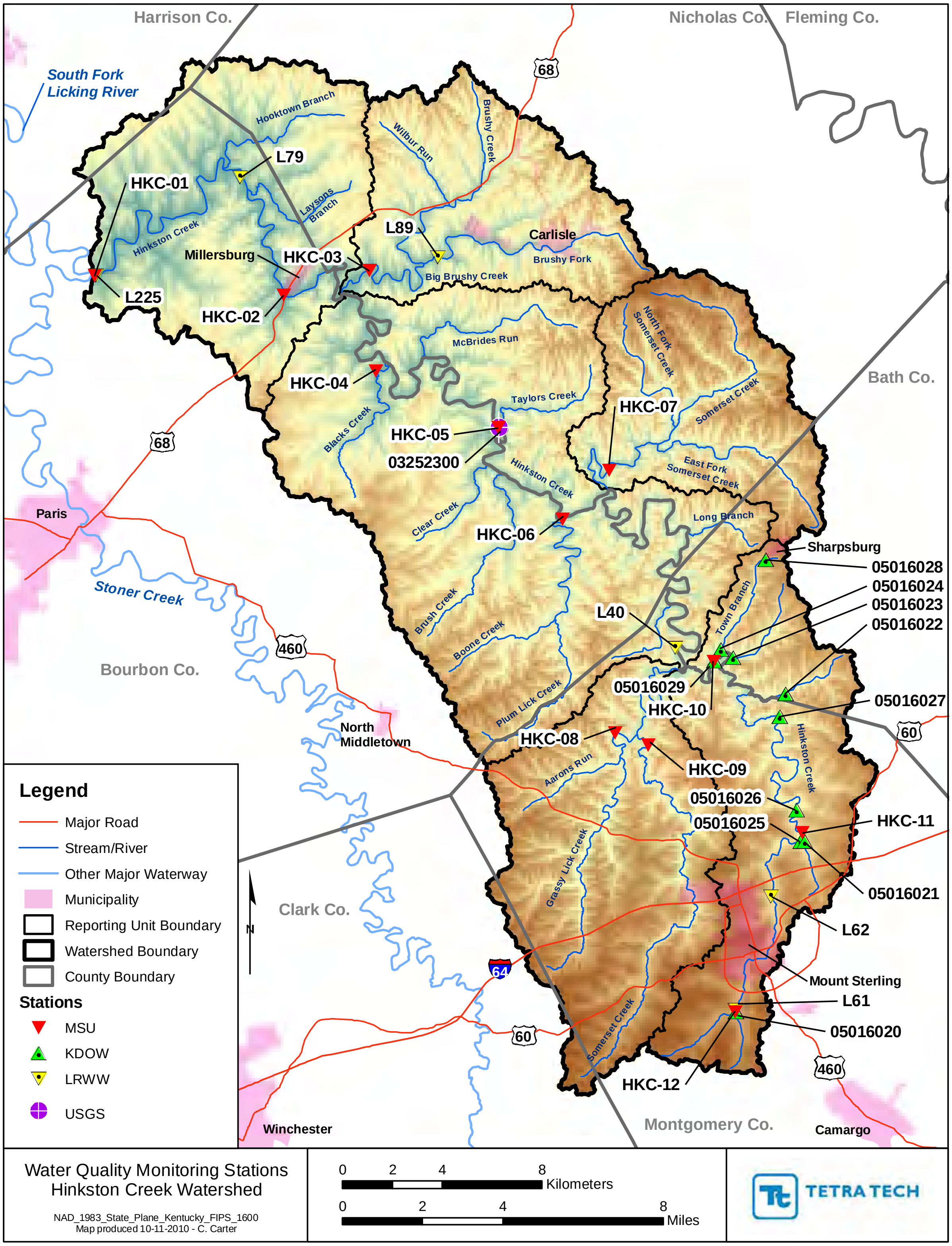


Figure 3-1. **Monitoring Station Locations within the Hinkston Creek Watershed**

3.2 STREAM ASSESSMENT MONITORING

KDOW performs stream assessments to evaluate how well a waterbody is supporting aquatic life. Assessments are performed according to KDOW (2008) and include measures of stream physical characteristics, aquatic habitat, algae, periphyton, macroinvertebrates, and fish (Figure 3-2). For macroinvertebrate data, collection methods differed between 2004 and previous sampling years and, therefore, these data are not being used to assess use support. KDOW considered aquatic habitat scores when evaluating use support in the Hinkston Creek watershed. These data are considered in this watershed plan along with substrate composition and other stream characterization measures. Observations during a single sampling event were recorded at four locations in 1999 and eight locations in 2004. Only one sampling event was recorded for each station, either in 1999 or 2004. Habitat scores were recorded for both years while substrate composition and other physical characteristics were only recorded in 2004.

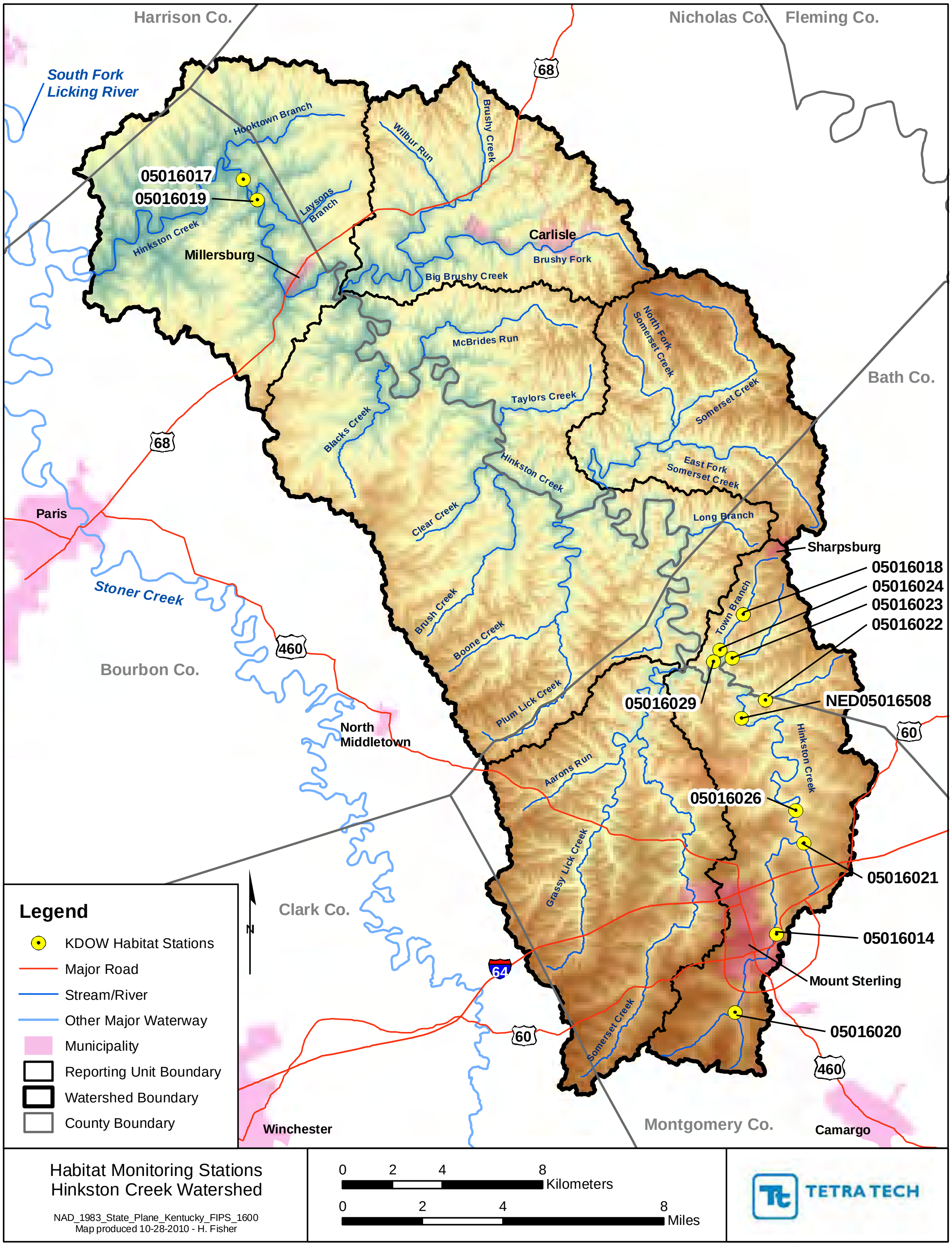


Figure 3-2. Stream Assessment Monitoring Station

4 Habitat and Water Quality Data Analysis

4.1 PHASE 1 – ANALYSIS

The two primary monitoring periods were each approximately one year long, KDOW monitored for 2004 – 2005 and MSU monitored for 2009 – 2010. The watershed model developed in support of this study was set to simulate 2000 – 2010. This section discusses the constituents of interest by data collection agency which reflects different 1 year collection periods along with model simulation output for a 10 year period. Since a 10-year period better represents each high, low and average flow periods than a 1-year period, these varying periods are important to note because they generate different average flow and water quality results.

4.1.1 Benchmarks

Benchmark values can be used as indicators of desired conditions when evaluating observed and modeled water quality data reflecting existing conditions, and when evaluating the adequacy and effectiveness of proposed BMPs. Some proposed benchmarks are not regulatory in nature, and are not recommended as future standards for regulations or as absolute targets. Rather, they are proposed as reasonable measures against which to evaluate progress in achieving improvement in water quality.

The water quality standards set forth in Kentucky's regulations – which do provide a basis for regulation of point sources - were used as a starting point in the development of water quality benchmarks. These standards must be attained by law and so establish a minimum level of performance. However, measurable numeric criteria are not available for every constituent of concern, and where narrative standards exist, it is necessary to develop measurable surrogates for desired conditions. Additionally, stakeholders can adopt more stringent benchmarks than Kentucky's minimum standards. Therefore, non-regulatory information was also considered in the development of benchmarks, such as the bioregion reference reach mean values adopted by Kentucky.

Water quality criteria or non-regulatory benchmarks need to be identified for current impairment indicators: bacteria (fecal coliform or *E. coli*), total nitrogen (TN), total phosphorus (TP), and suspended sediment. Hinkston Creek is designated for uses as warm water aquatic habitat and primary/secondary contact recreation. The relevant water quality standards established in Kentucky water quality regulations are summarized in Table 2-6. (The table also lists dissolved oxygen (DO) standards, as DO is affected by algal growth associated with nutrient loads). Elevated levels of fecal coliform and *E. coli* have been observed in Hinkston Creek. However, monitoring has occurred once a month, thus the water quality standards for fecal coliform and *E. coli* (which require evaluation of statistics on multiple samples within a 30-day period) cannot be directly compared with the observed data. The water quality standards for nutrients and sediment are narrative only and do not specify numeric criteria, therefore numeric benchmark values are needed to assess desired conditions and to perform the BMP evaluation.

The Commonwealth of Kentucky has developed bioregion reference reach mean concentrations for nutrients and sediment which can provide important benchmark reference points for desired conditions in the absence of numeric criteria. These bioregional data represent typical concentrations in reference streams, that is, those in which use support has been judged not to have been adversely affected by nutrients. The relevant reference reach mean values for Hinkston Creek in the Bluegrass bioregion were presented in the Quality Assurance Project Plan (QAPP) for this study (Tetra Tech 2009). Key values from that document related to this study are summarized below, and the basis for these proposed benchmarks are discussed in more detail in the following sections.

- TNH_3 = 0.044 mgN/L
- NO_3+NO_2 = 0.656 mgN/L
- TKN = 0.320 mgN/L
- TN = 0.976 mgN/L
- TP = 0.132 mgP/L
- TSS = 9.82 mg/L

The bioregion reference values should represent, by definition, average concentrations which are consistent with attaining designated uses. They therefore represent appropriate benchmarks; however, it is possible that uses could still be achieved at somewhat higher concentrations.

Bacteria

The listing for impairment due to bacteria in the Hinkston watershed is for fecal coliform. The recent monitoring only collected *E. coli* data, although historically fecal coliform and *E. coli* have been observed. The bacterial criteria contain a geometric mean (5 samples in 30 days) and an upper bound concentration that is not to be exceeded more than 20 percent of the time. The upper bound concentration criterion for *E. coli* of 240 colonies per 100mL was proposed as a summer benchmark to ensure that the regulatory standard is met. A winter criterion upper bound for fecal coliform is presented in the regulations as 5 times the summer value. This factor was adopted to propose a winter benchmark concentration for *E. coli* of 1,200 colonies per 100mL. These benchmarks should be interpreted as applicable to individual measurements

Nutrients and DO

Organic enrichment refers to excess organic matter (nutrients) entering a waterbody. The organic enrichment may be due to point source dischargers, animal operations, agriculture, urban development, or other cause. The result of the additional input may be adverse impacts on dissolved oxygen, stimulated algal productivity, or both. Organic enrichment is a concern in the Hinkston Creek watershed. More monitoring data that includes algae and diurnal DO are required to better assess the dynamics of the nutrient balance in the water column. However, the non-regulatory bioregion reference reach mean values adopted by Kentucky are proposed as appropriate benchmarks for this study for TN (0.976 mgN/L) and TP (0.132 mgP/L). In addition, nutrient-induced algal growth should not result in excursions of the criteria minimum of 4 mg/L for DO (KNREPC, 2010).

Sediment

Sediment concerns in the waterbody are dynamic and complex. Excess sediment loads degrade aquatic habitat, reduce recreational opportunities, and also promote the loading and transport of sorbed pollutants. Generally, high flow events create the critical condition as far as detaching and mobilizing sediment from the land surface, stream banks, and/or stream bed. The Bluegrass bioregion reference reach mean value for TSS is one potential benchmark, although as a measure of average conditions it may not serve adequately to evaluate individual high flow observations when concentrations are expected to be elevated.

To test the applicability of the bioregion reference value for TSS, two station locations of interest in the study area were observed during each the KDOW TMDL monitoring (2004 - 2005) and the MSU watershed plan monitoring (2009 – 2010). Those stations were 05016029/HKC-10 which is on the mainstem just downstream of the Town Branch and 05016020/HKC-12 which is just south of Mt.

Sterling. The paired observations of flow and concentrations were calculated as loads and plotted against the observed flow (Figure 4-1 and Figure 4-2). A power regression was fit to the observed data to perform a cursory assessment of correlation. The Bluegrass bioregion mean TSS concentration was also used with the observed flows to calculate loads, which are presented in the figures. The downstream station (05016029/HKC-10) figure suggests that current observed loads are approximately consistent with the Bluegrass bioregion mean concentration, and supports the use of the bioregion mean value for this study as a benchmark for TSS through the range of observed flows. The upstream station (05016020/HKC-12) suggests a need for sediment reduction in that portion of the study area, which corresponds with visual observations of this reach (i.e., heavy livestock pasture use, with free access and visible channel degradation – see analysis later in this section). The sediment benchmark value should be applied only on a flow-weighted annual average basis, and not to individual observations.

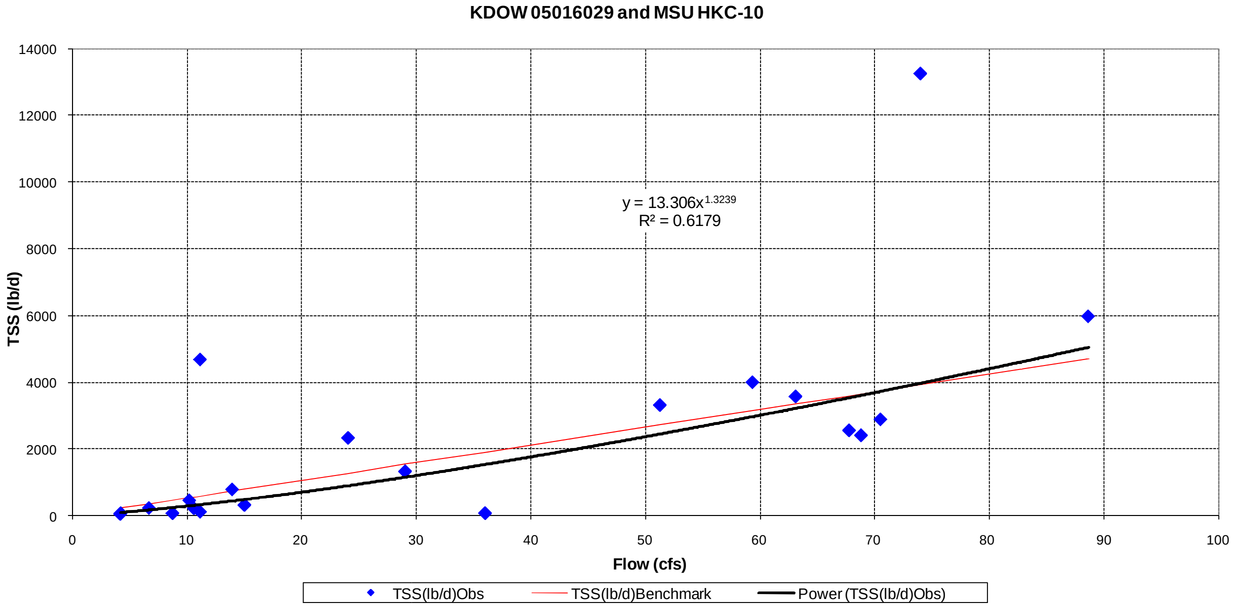


Figure 4-1. TSS Load vs. Flow at Station KDOW 05016029 (MSU HKC-10)

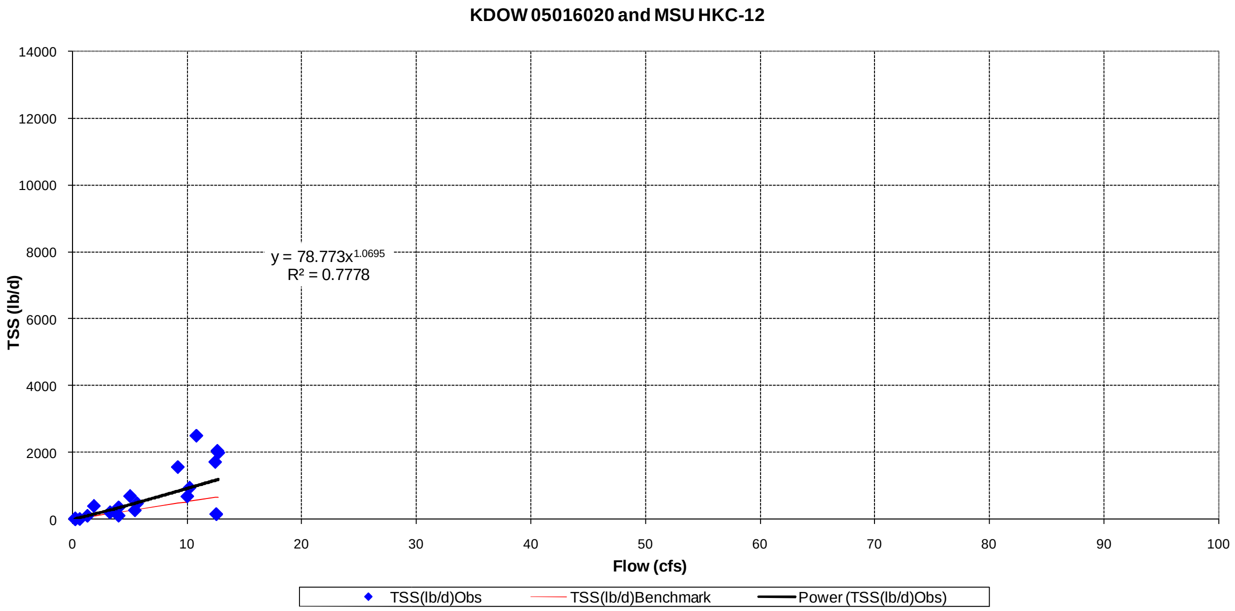


Figure 4-2. TSS Load vs. Flow at Station KDOW 05016020 (MSU HKC-12)

Habitat Assessment

KDOW (2008) has established a tentative total habitat criteria in which a total habitat score less than 114 is considered not supporting aquatic life use in wadeable streams (drainage areas greater than 50 square miles). The total habitat score of 114 was selected as a benchmark for assessment of habitat.

A summary of the benchmarks proposed for this study is presented in Table 4-1. Even though the table indicates that benchmarks established for TN, TP, and TSS are applicable to seasonal or annual mean values, the average values of observed data presented throughout this report are averages from one (or two discontinuous) years of data collected during either the MSU or KDOW monitoring periods (or both periods) and should not be interpreted as averages across many years.

Table 4-1. Benchmark Values for the Hinkston Creek Watershed

Indicator	Value	Comment
E. coli	Summer 240 col/100mL	More stringent than the criterion, which allows 20% excursions. Applicable to individual samples and means
	Winter 1,200 col/100mL	Proposed as 5 times the summer value, which is the same factor used in the water quality standards for fecal coliform. Also more stringent than the criterion which allows 20% excursions. Applicable to individual samples and means.
TN	0.976 mg N/L	Kentucky Bluegrass bioregion reference reach mean value; applicable as a seasonal or annual mean.
TP	0.132 mg P/L	Kentucky Bluegrass bioregion reference reach mean value; applicable as a seasonal or annual mean.
DO	4 mg/L	401 KAR 10:031, Section 4 (1) (e), applicable as an instantaneous minimum standard (KNREPC, 2010).
TSS	9.82 mg/L	Kentucky Bluegrass bioregion reference reach mean value, applicable as an annual flow-weighted average
Habitat	114	KDOW's (2008) tentative habitat criteria, total habitat scores less than 114 are considered not supporting in wadeable streams.

The average flow from the USGS flow station (03252300 Hinkston Creek near Carlisle, KY) for that period (2000 – 2010) is 208 cfs. The summer (May through October) and winter (November through April) averages for that same period are 200 cfs and 216 cfs, respectively. Table 4-2 presents the benchmark loading based on the reported mean stream flow for the simulation period, the proposed Bluegrass bioregion reference reach mean values for TN, TP, and TSS. The area draining to that USGS flow station location is 154 square miles. Table 4-2 also presents average unit area loading rates consistent with the benchmark concentrations. These can be area-weighted for use at locations other than the USGS gage or applied to the analysis of individual BMPs on a unit-area basis. However, load duration curves will be used for *E. coli* and an average unit loading value will not be presented here.

Table 4-2. Proposed Benchmark Mean (2000 – 2010) Loads for the Hinkston Creek Watershed at USGS Gage 03252300 and Unit Area Loads

Indicator	Load	Unit Area Load
TN-N	399,669 lb/y	4.1 lb/ac/y
TP-P	54,054 lb/y	0.5 lb/ac/y
TSS	2,011 tons/yr	40.8 lb/ac/y (0.0204 tons/ac/y)

4.1.2 KDOW Stream Habitat Assessment Data

KDOW (2008) documents the standard methods used for aquatic habitat scores and stream assessment data. For each aquatic habitat parameter, a score from 0 to 20 is assigned, with the following classifications: Poor (0 to 5), Marginal (6-10), Suboptimal (11-15), Optimal (16-20). These methods were originally based on Barbour et al. (1999). Definitions of each habitat parameter can be found in KDOW (2008).

The total habitat and individual parameter scores measured in 1999 and 2004 are displayed in Table 4-3. All locations during both years had poor or marginal scores for bank stability, bank vegetative protection, and riparian vegetative protection. This is consistent with extensive cattle access to streams and lack of vegetated cover along streams throughout the watershed. The stations with the lowest total scores (less than 114) tended to have poor to marginal scores under frequency of riffles or bends, embeddedness, epifaunal substrate/ available cover, and sediment deposition. Scores varied considerably under velocity/depth regime, channel flow status (degree to which the channel is filled with water), and channel alteration (large-scale changes to the channel shape).

Overall, the habitat scores point to the bank conditions as being a major factor in habitat quality for all stations, and for stations with lower scores, the poor condition or absence of physical habitat also appears to be an important impact. Embeddedness and sediment deposition scores suggest that sites with poorer habitat tend to be more impacted by sediment loading.

The 2004 substrate composite data and other stream measures are displayed in Table 4-. Among these measures, percent fines is an additional indicator of potential sediment impacts. Stations with the lowest percent fines (10 percent) were two of the higher scoring stations in the habitat data (stations 05016014 and 05016026 with total habitat scores of 132 and 117 respectively). In contrast, station 05016020, with the lowest total habitat score (67), has the highest proportion of fines (70 percent). The latter station also has low habitat diversity with 90 percent of the reach classified as “run.” Generally, the substrate composition and other stream measures suggest that sediment loading to the stream channels is a major factor in habitat impairments. The poor to marginal habitat scores under the bank measures suggest that cattle access and lack of riparian vegetation could be major sources of sediment loading to the streams. In addition, KDOW has noted that bank failure is a significant source of sediment loading to streams under increased flow conditions as incised banks are susceptible to sediment detachment caused by repeated freeze/thaw patterns of bank soils in winter months. Note: A comparison of WWTP discharge locations and poor habitat scores indicates that these point source discharges are not a major source of impact to habitat. In urban areas, increased stormwater flow, including duration, volume, and velocity, is likely a strong contributing factor in habitat degradation.

Table 4-3. KDOW Aquatic Habitat Assessment Scores

Station ID	Date	Bank Stability		Bank Vegetative Protection		Channel Flow Status	Channel Alteration	Embeddedness	Epifaunal Substrate/ Available Cover	Frequency of Riffles (or Bends)	Riparian Vegetative Zone Width		Sediment Deposition	Velocity/ Depth Regime	Total Score
		Left Bank	Right Bank	Left Bank	Right Bank						Left Bank	Right Bank			
05016508	8/11/1999	5	4	3	3	10	18	6	8	8	4	3	5	12	89
05016017	7/8/1999	4	4	4	4	14	11	10	13	3	7	3	8	13	98
05016018	7/15/1999	5	2	6	3	8	12	8	5	11	6	2	8	2	78
05016019	7/16/1999	5	5	4	6	16	18	14	13	0	4	8	13	8	114
05016014	3/23/2004	8	8	6	6	15	15	13	14	10	4	4	15	14	132
05016020	3/23/2004	4	4	3	3	15	9	8	6	2	1	1	4	7	67
05016021	5/6/2004	4	5	4	4	15	16	8	9	11	1	1	8	14	100
05016022	3/23/2004, A	7	6	1	1	15	16	16	13	16	1	1	13	9	115
	3/23/2004, B	4	4	1	1	15	16	10	7	10	0	0	12	8	88
05016023	3/23/2004	5	5	4	4	15	16	14	10	7	7	2	6	14	109
05016024	3/23/2004	4	4	5	5	15	15	14	13	16	6	4	8	17	126
05016026	6/29/2004	9	7	7	7	15	16	10	11	10	3	2	12	8	117
05016029	6/29/2004	4	3	4	4	15	16	7	10	10	3	3	8	13	100

Table 4-4. KDOW Substrate Composite and Other Site Characterization Measures

Station ID	Date	%Bedrock	%Boulder	%Cobble	%Fines	%Gravel	%Pool	%Riffle	%Run	Stream Width (feet)
05016014	3/23/2004	5	15	30	10	30	15	10	75	15
05016020	3/23/2004		10	10	70	10	5	5	90	12
05016021	5/6/2004	10	10	10	30	40	15	20	65	15
05016022	3/23/2004, A	25	20	15	25	18	20	15	65	10
05016022	3/23/2004, B	25	20	15	25	15	10	15	75	12
05016023	3/23/2004		5	15	50	30	20	10	70	20
05016024	3/23/2004		5	15	40	40	20	20	60	10
05016026	6/29/2004	25	25	20	10	20	10	30	60	25
05016029	6/29/2004	0	5	20	35	40	30	30	40	20

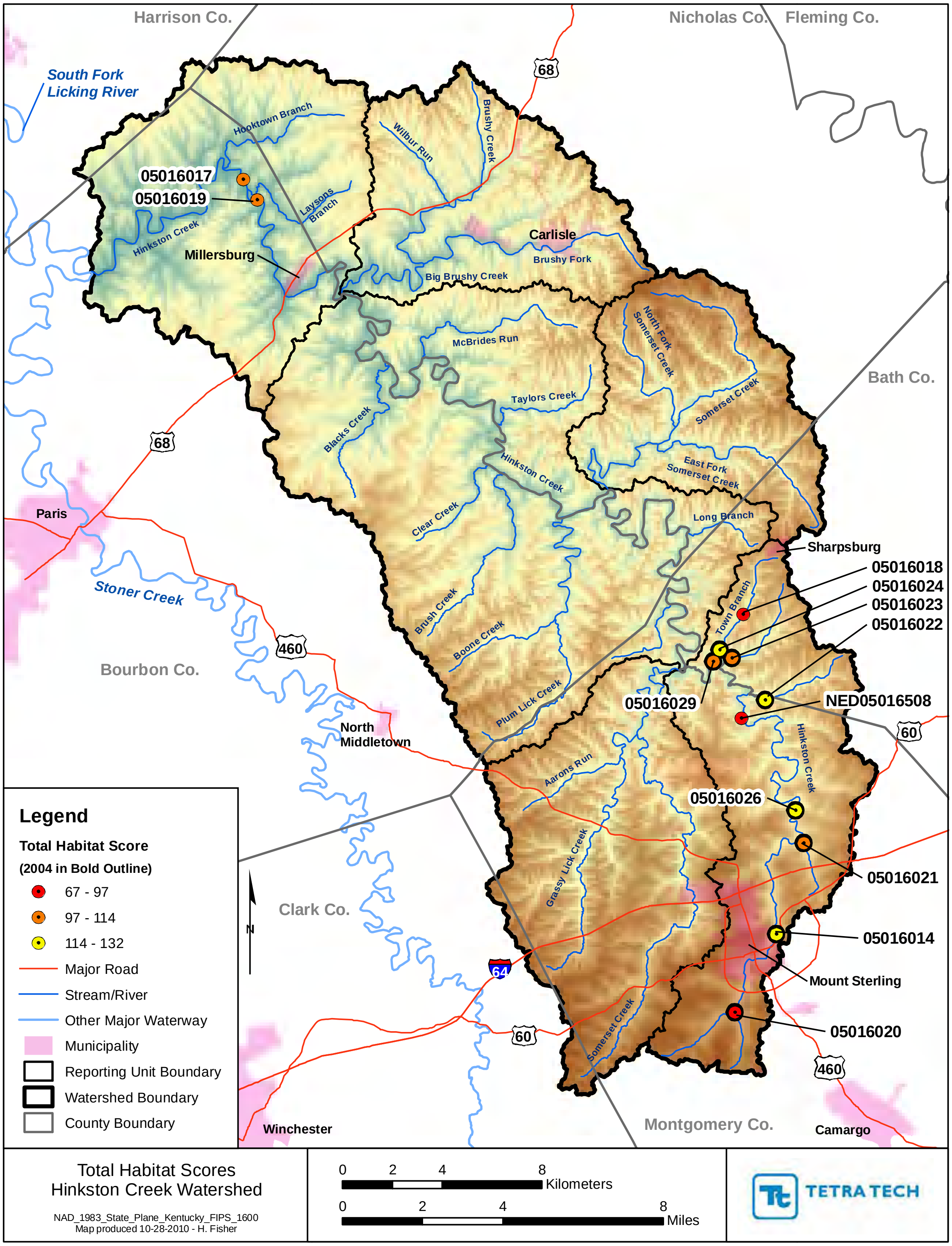


Figure 4-3. **KDOW Total Habitat Scores**

Figure 4-3 displays the total habitat scores by station location in the watershed. Ranges for total habitat scores in this figure were selected to highlight areas having a total habitat score greater than the selected benchmark of 114, representing optimal overall habitat. Subsequent ranges were arbitrarily selected using natural breaks in the data. All samples in 2004 and most samples in 1999 were taken in the Hinkston Headwaters reporting unit. The two remaining stations are located in the Lower Hinkston reporting unit. Given this limited spatial distribution, insufficient data are available to prioritize reporting units based on habitat scores. However, the discussion above supports riparian buffer deficiency and sediment loading as key indicators of habitat degradation, and these indicators can be used to prioritize reporting units for habitat restoration.

According to KDOW's tentative habitat criteria (KDOW, 2008), total scores less than 114 are considered not supporting in wadeable streams (drainage areas greater than 50 square miles). The majority of total habitat scores (four out of six) along the mainstem of the Hinkston Creek headwaters reflect its designation of not-supporting aquatic habitat.

4.1.3 Nitrogen

Nitrogen is an essential component of proteins in plants and animals and is naturally a dominant constituent of the atmosphere. However, excess amounts of nitrogen can promote undesirable plant growth in waterways. Nitrogen enters the watershed in rainfall, through the application of chemical fertilizer, and in imported food and forage. The transformation of organic nitrogen and ammonium (NH_4) to nitrite (NO_2) and then nitrate (NO_3) consumes oxygen. The inorganic forms of nitrogen (NH_4 and NO_3) can be consumed by algae. Organic enrichment is a concern in the Hinkston Creek watershed and therefore nitrogen will be evaluated along with other related parameters.

4.1.3.1 Concentration Time Series Comparisons

The KDOW (2004 – 2005) and MSU (2009 – 2010) monitoring data reported key nitrogen species such that a total nitrogen value could be determined. KDOW observed nitrate (NO_3) and total kjeldahl nitrogen (TKN) which were summed to total nitrogen. KDOW did not observe nitrite (NO_2) which is generally an order of magnitude lower than nitrate (NO_3) concentrations. The MSU monitoring reported nitrite (NO_2), nitrate (NO_3), and total kjeldahl nitrogen (TKN) which were summed to total nitrogen. TKN was used in calculations for total nitrogen is equal to the sum of organic nitrogen and total ammonia (Chapra, 1997).

The concentration data from each of the monitoring periods were developed into time series figures along with the benchmark value in the D. The TN benchmark (0.976 mgN/L) is consistently exceeded at all KDOW and MSU stations through time, except KDOW tributary stations (05016021 and 05016022). Section 4.1.3.2 below provides a comparison of average TN values to the benchmark. The KDOW data suggest the most elevated total nitrogen values in the headwaters of the mainstem (05016020), Bennett Branch (05016023) and Town Branch (05016024 and 05016028). The MSU observations reported higher total nitrogen concentrations at most locations compared to the KDOW monitoring period. The MSU monitoring period was dry compared to the KDOW monitoring period with the last three months of sampling resulting in insufficient flow for measurement. However, water quality samples were taken at these times. Typically, the highest values of total nitrogen reported by MSU were in the early part of 2010.

4.1.3.2 Plan View Mean Concentration

Average total nitrogen concentrations were calculated for each KDOW and MSU station. These values were developed into plan view maps (Figure 4-4) to convey spatial location along with the magnitude of concentration. Benchmark concentrations are indicated by the smallest circles, and only stations 05016021 and 05016022 have average concentrations which meet the TN benchmark.

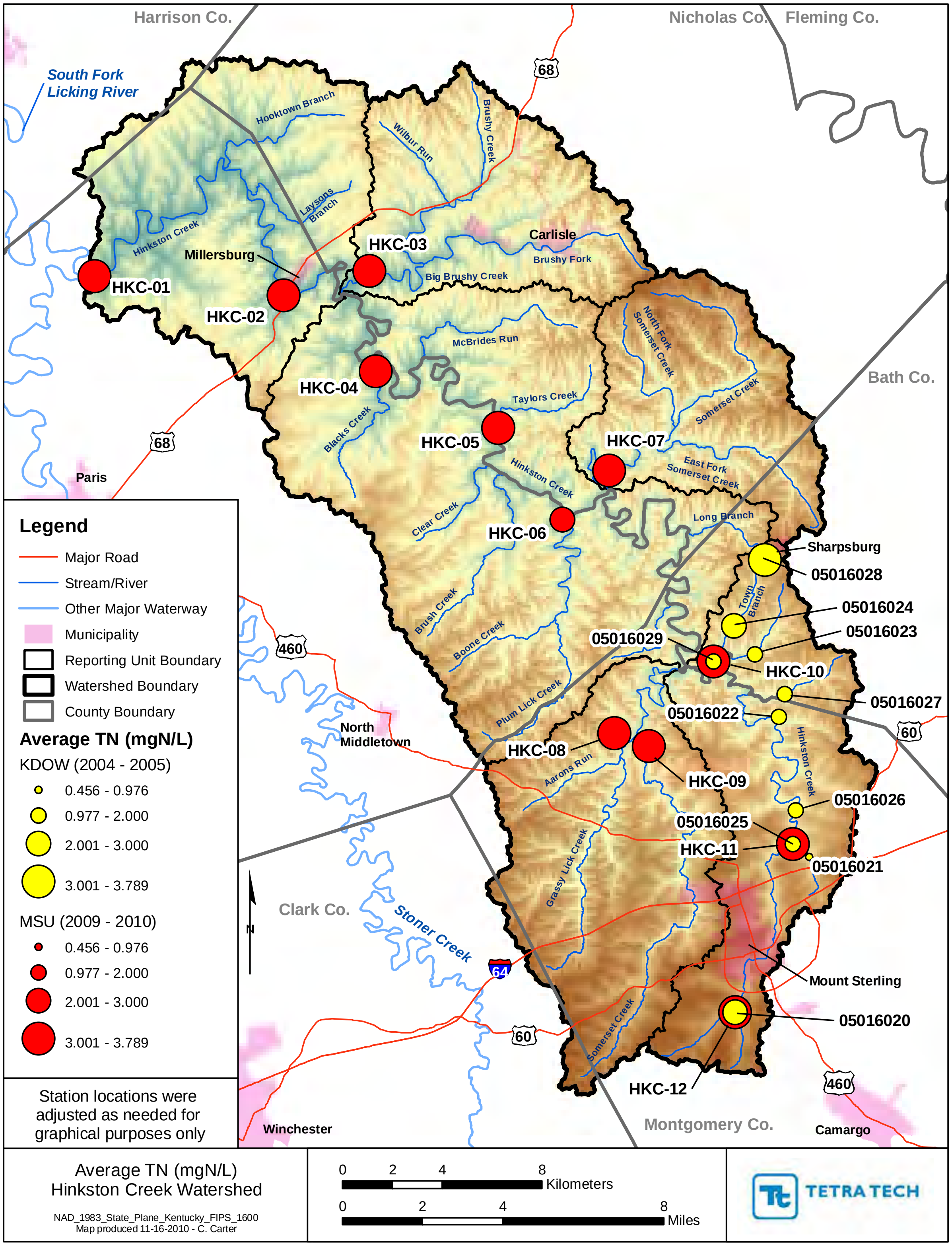


Figure 4-4. Average Total Nitrogen Concentration Measured at Each Water Quality Station

4.1.3.3 Longitudinal Profile Concentration

The observed data were developed into longitudinal profile figures. The use of longitudinal profile figures enables interpretation of trends in the observations and points of interest. The x-axis of the figures is river mile based upon the mainstem, Hinkston Creek. Tributary stations are also assigned river miles that are developed from connection with the mainstem. The figures show the data with box-and-whisker plots that show maximum, 75th percentile, median, 25th percentile, and minimum values. If there is more than one station on the same reach, a solid line is drawn which connects the median values.

Table 4-5 lists each the KDOW and MSU station river mile assignments. Figure 4-5 and Figure 4-6 present these stations with the river miles noted. The river mile for station KDOW 05016028 is discussed for illustration. It is located on Town Branch, 3 miles upstream of the confluence of Town Branch with Hinkston Creek. Therefore station KDOW 05016028 is assigned a river mile of 54.7.

Table 4-5. Monitoring Station Summary with River Miles

KDOW Station ID	MSU Station ID	River Mile	Reach Name
-	HKC-01	0.0	Hinkston Creek
-	HKC-02	12.7	Hinkston Creek
-	HKC-03	17.1	Big Brushy Creek
-	HKC-04	21.6	Blacks Creek
-	HKC-05	29.0	Hinkston Creek
-	HKC-06	33.5	Boone Creek
-	HKC-07	37.5	Somerset Creek
-	HKC-08	54.2	Grassy Lick Creek
-	HKC-09	54.2	Somerset Creek (Grassy)
05016029	HKC-10	51.5	Hinkston Creek
05016024	-	52.0	Town Branch
05016023	-	52.5	Bennett Branch
05016022	-	54.2	Lane Branch
05016028	-	54.7	Town Branch
05016027	-	56.5	Hinkston Creek
05016026	-	61.8	Hinkston Creek
-	HKC-11	62.2	Hinkston Creek
05016025	-	63.1	Hinkston Creek
05016021	-	67.0	Twin Oaks Subdivision/Industrial Park
05016020	HKC-12	69.2	Hinkston Creek

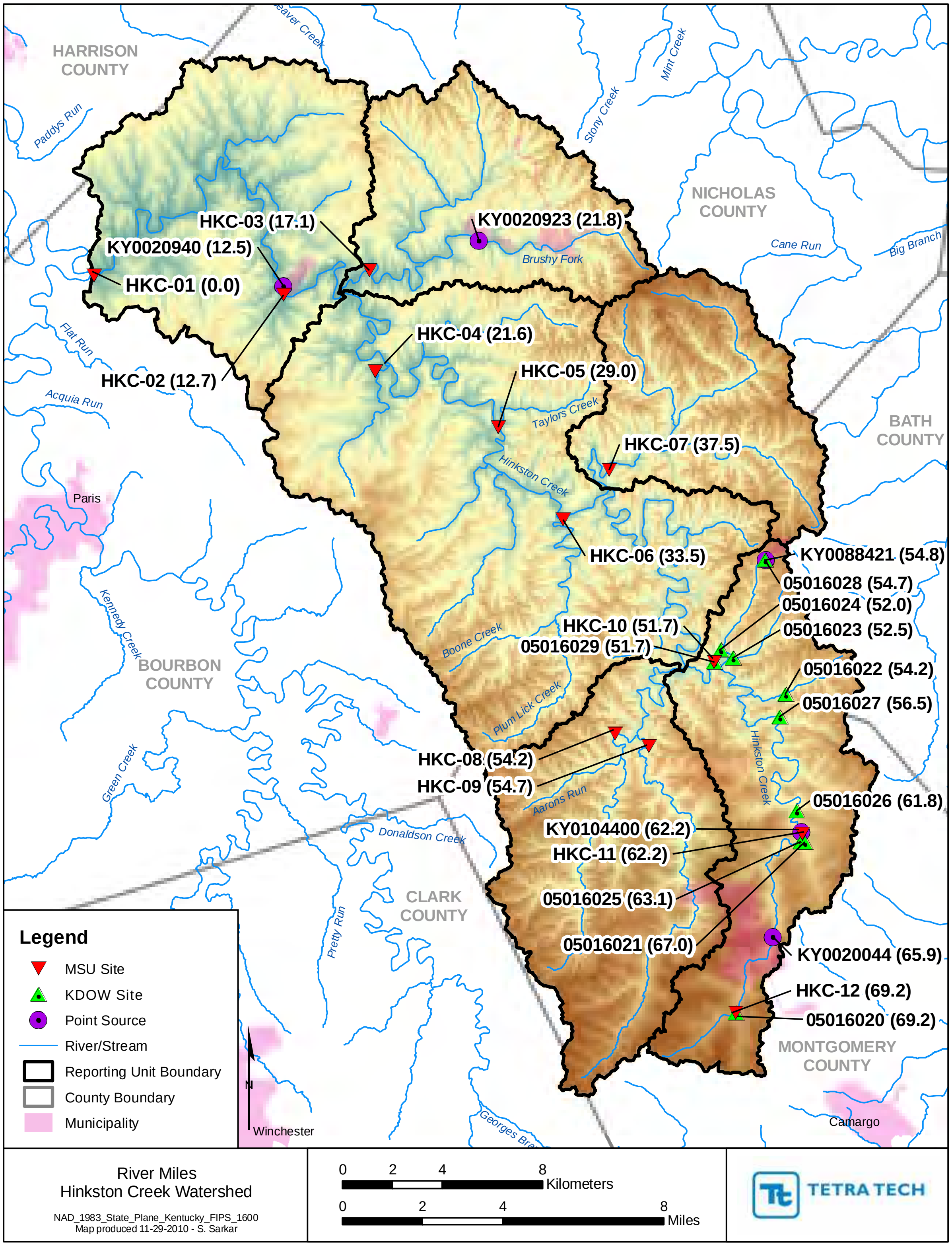


Figure 4-5. River Miles for Locations of Interest

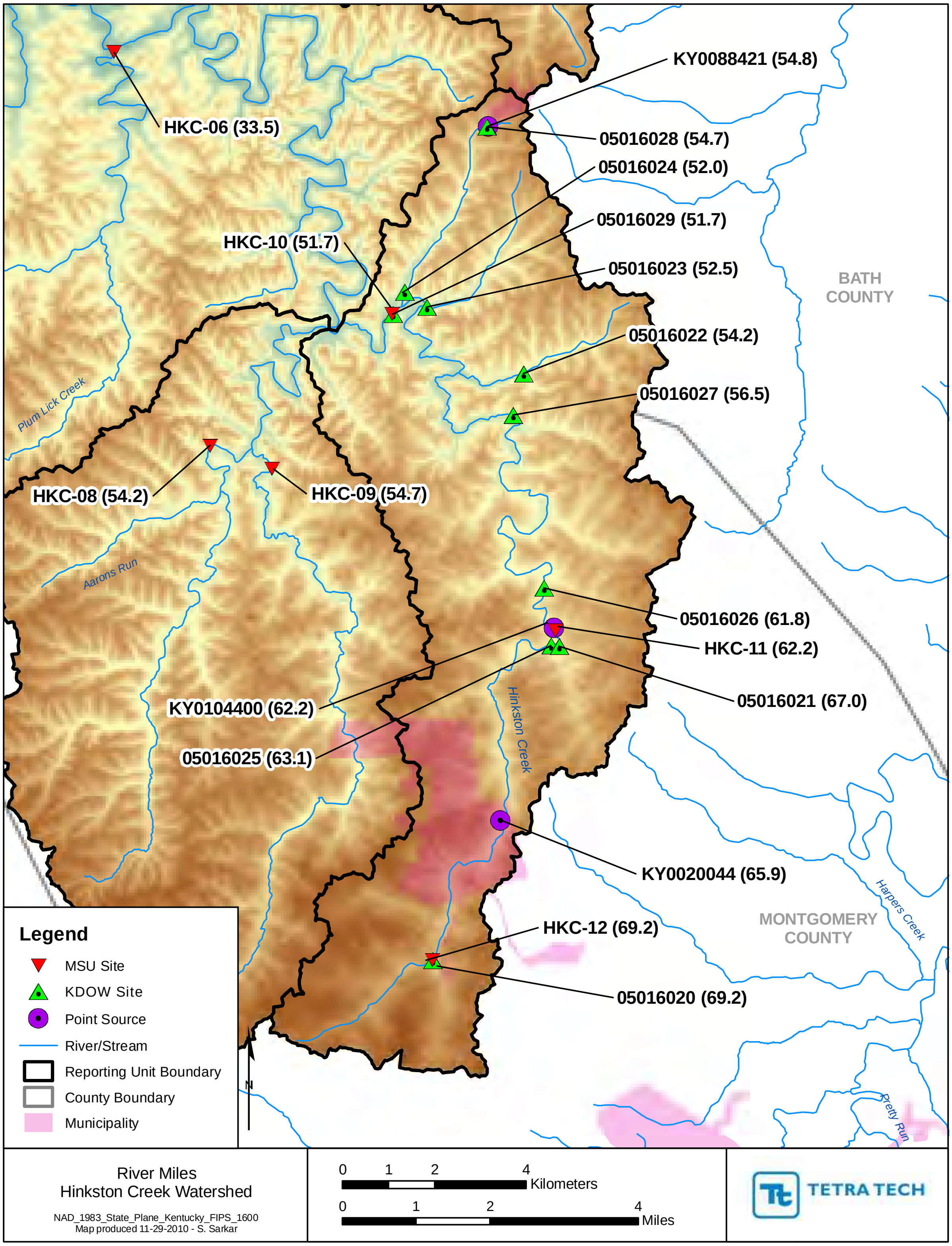


Figure 4-6. **River Miles for Locations of Interest (Hinkston Headwaters and Grassy Lick Reporting Units)**

Again, total nitrogen observations above the benchmark value were common in each of the monitoring periods (Figure 4-7 and Figure 4-8). However, the MSU sampling (2009 – 2010) reported total nitrogen mainstem median values around 2.5 – 3.0 mgN/L, consistently higher than found during the KDOW sampling (2004 – 2005), where mainstem median values were around 1.5 – 2.0 mgN/L. The Town Branch stations reported elevated total nitrogen concentrations. The MSU sampling tended to suggest similar behavior of total nitrogen concentrations in tributaries which did not receive domestic waste effluent except for Boone Creek. Somerset Creek presented the highest statistics on the reported total nitrogen concentrations. The median value of total nitrogen increased by 0.5 mgN/L from HKC-02 to the mouth (HKC-01), the Millersburg STP outfall is located downstream of HKC-02 though it is a relatively small discharge.

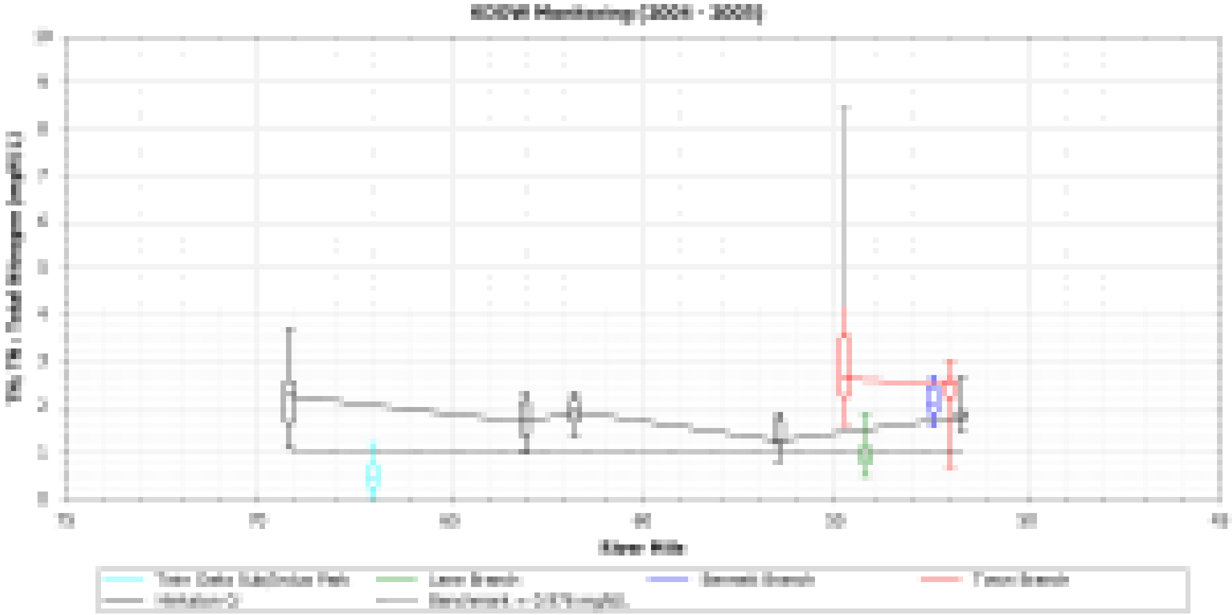


Figure 4-7. Longitudinal Profile of Total Nitrogen, KDOW (2004 – 2005)

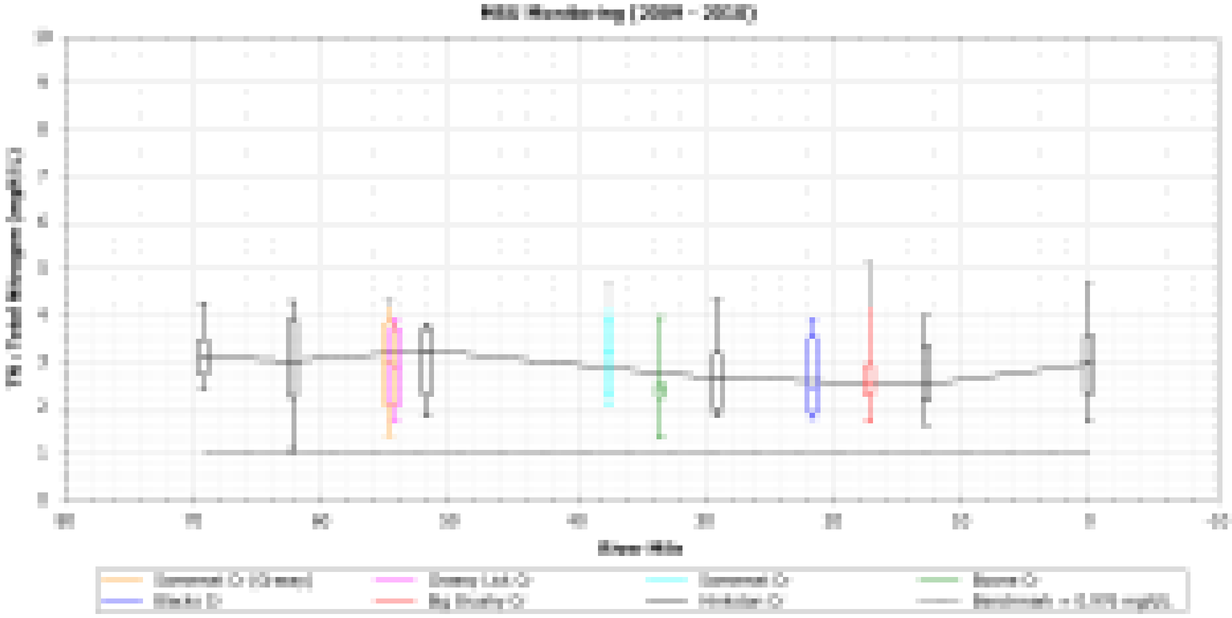


Figure 4-8. Longitudinal Profile of Total Nitrogen, MSU (2009 – 2010)

Nitrate (NO_3) is being reviewed because of its relevance in algal productivity. NO_3 concentrations in the KDOW TMDL monitoring observations (Figure 4-9) were generally the highest at the most upstream location (river mile 69.2, 05016020). The median value continued to decrease moving downstream along the mainstem past the Mt. Sterling STP outfall. The 2004 – 2005 monitoring period was wetter than the 2009 – 2010 monitoring period. The nitrate concentrations on Town Branch are higher and increase moving downstream along Town Branch. This is likely due in part to the conversion of the ammonium to nitrate. The Bennett Branch tributary reported values suggests elevated nitrate values coming from that drainage area. The median mainstem nitrate concentration in the KDOW monitoring observations is above 1 mgN/L, which is above the total nitrogen benchmark value.

The MSU monitoring data (Figure 4-10) continue to suggest higher nitrate concentrations are upstream of river mile 69 (HKC-12). Furthermore, the MSU data suggest that higher nitrate concentrations are more common to the area in the southeast portion of the Hinkston Creek watershed, upstream of river mile 51 (05016029, HKC-10). The tributaries between river miles 0 and 51 suggest elevated nitrate contributions, all of those tributaries are primarily nonpoint source. However, the reported nitrate values from Boone Creek are lower than the other tributaries which do not receive a domestic waste discharge.

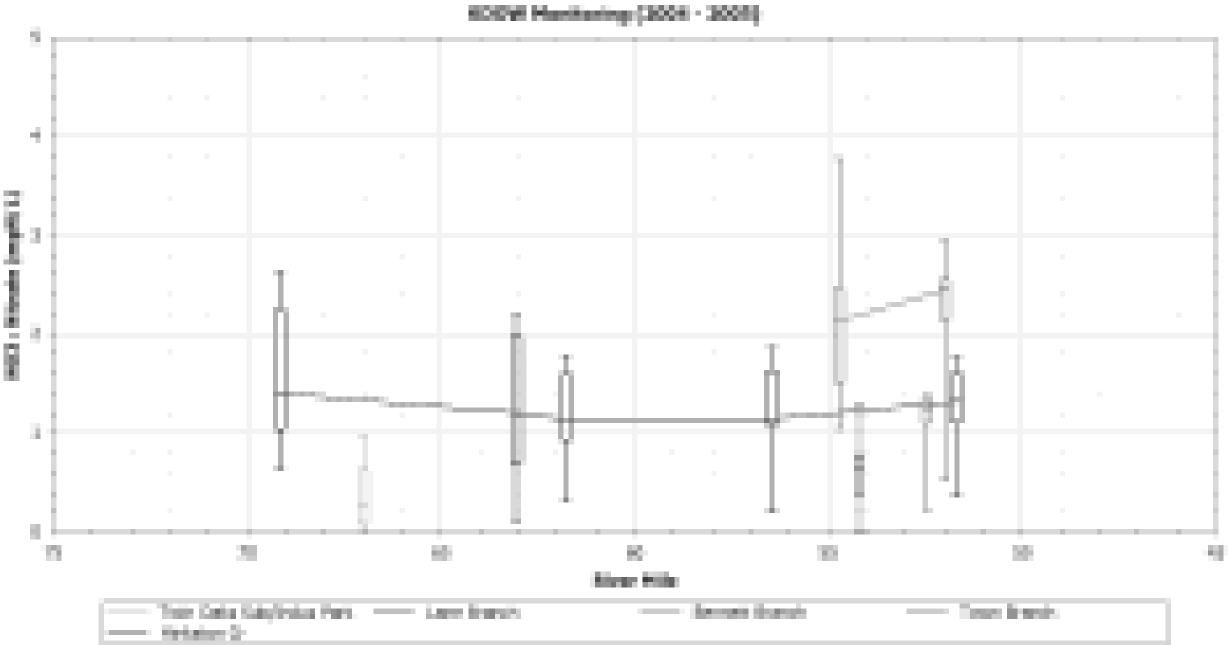


Figure 4-9. Longitudinal Profile of Nitrate, KDOW (2004 – 2005)

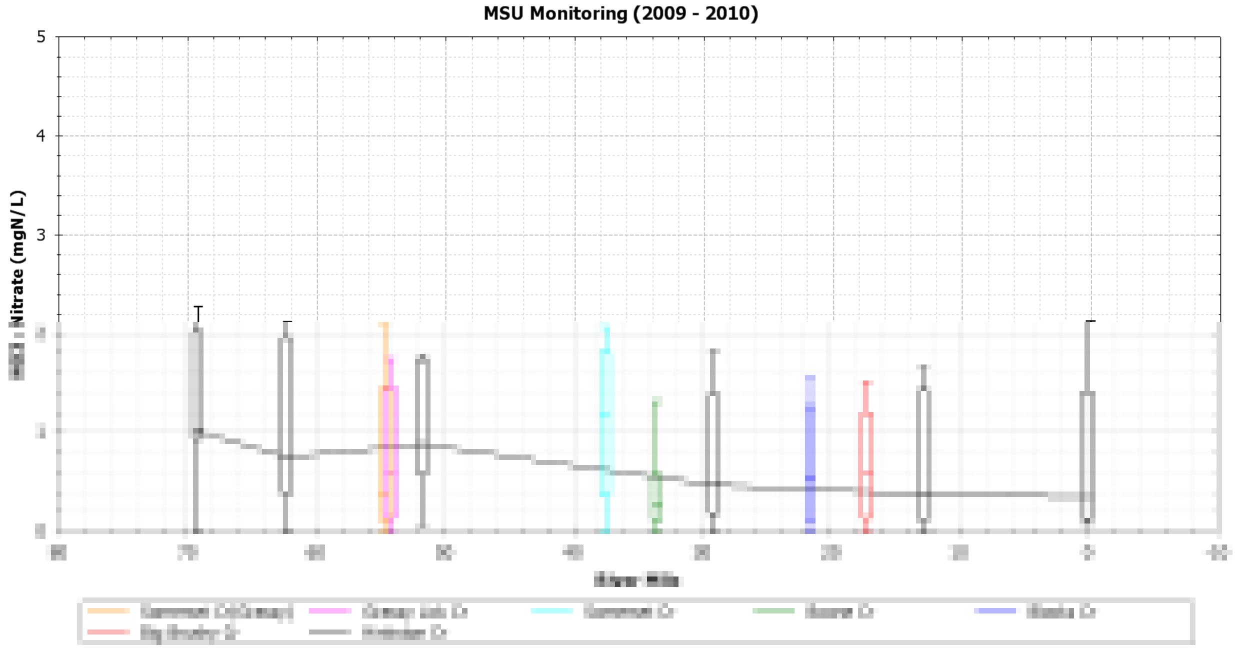


Figure 4-10. Longitudinal Profile of Nitrate, MSU (2009 – 2010)

4.1.3.4 Monitoring Data Loads

The KDOW and MSU observations of flow and concentration were used to calculate load. These are in-stream calculations of load, with no separation of point and nonpoint source contributions. These loads were averaged for each monitoring station and then converted to unit-area loads (D). These values were developed into a plan view map (Figure 4-11) to convey spatial location along with the magnitude of loading.

The benchmark unit area load for total nitrogen is 4.1 pounds per acre per year (Section 4.1.1). The headwater portion of Hinkston Creek (05016020) and Town Branch each result in a unit area load of approximately 10 pounds per acre per year, the highest of the KDOW monitoring period. The MSU data provided a similar unit area loading for the headwater of Hinkston Creek (HKC-12) of 11.4 pounds per acre per year. However, the largest unit area loading from the MSU monitoring was attributed to Blacks Creek at almost 17 pounds per acre per year. Visual assessments for both Blacks Creek and Town Branch indicate heavy livestock pasture operations along the channels, with free cattle access to the streams, which could be linked to elevated TN loading in these reaches. In addition, the MSU data show an increase in the mainstem of unit area loading moving downstream, which suggests elevated nitrogen loading contributions in the lower portion of the drainage area.

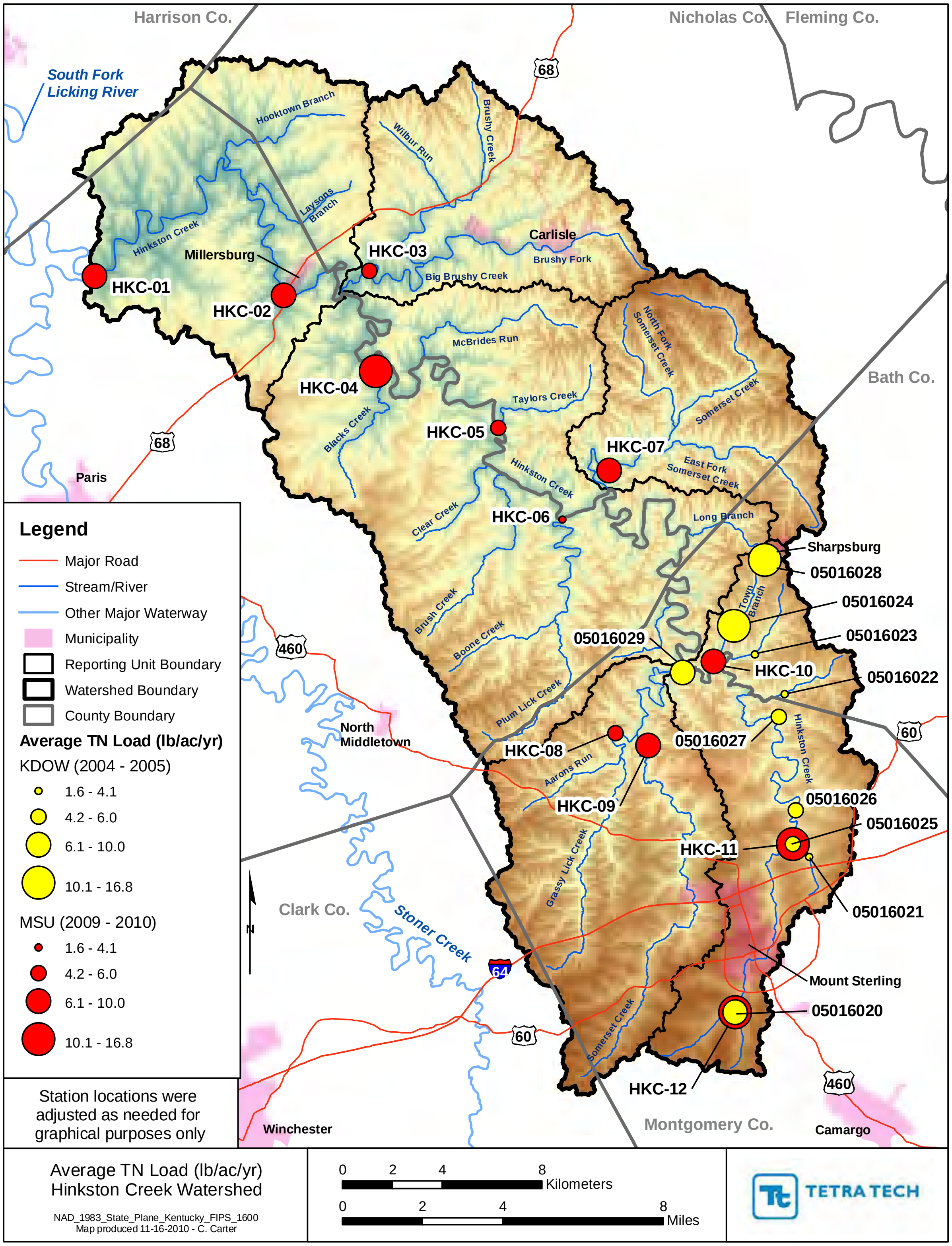


Figure 4-11. Average Total Nitrogen Loading at Each Water Quality Station

4.1.3.5 SWAT Loads

A watershed model was developed for this study to aid in assessing pollutant sources by land category and domestic waste discharge (E). The Soil and Water Assessment Tool (SWAT) watershed model was constructed to simulate 2000 to 2010 for TN, TP, and TSS. SWAT is used to represent the rainfall-runoff process on the land which includes representing high, average, and low flow hydrologic events. The SWAT model output will be used to support the BMP component of this work and to assist in prioritizing reporting units. Figure 4-12 presents the annual average nitrogen loading by nonpoint land category along with the permitted waste discharges (STP), if present, by reporting unit. The figure suggests that pasture lands are the primary nonpoint source of nitrogen, which is generally consistent with pasture land being the dominant land cover in all six reporting units. The figure also conveys the magnitude of point source contribution, primarily in the Hinkston Headwaters reporting unit where Mt. Sterling STP and Sharpsburg STP are located.

Figure 4-13 shows a plan view of the study area with model output nonpoint unit area loading rates by reporting unit. While the values are generally similar, 10 – 12 lb/ac/year, they are all at least two times greater than the benchmark unit area loading value of 4.1 lb/ac/year.

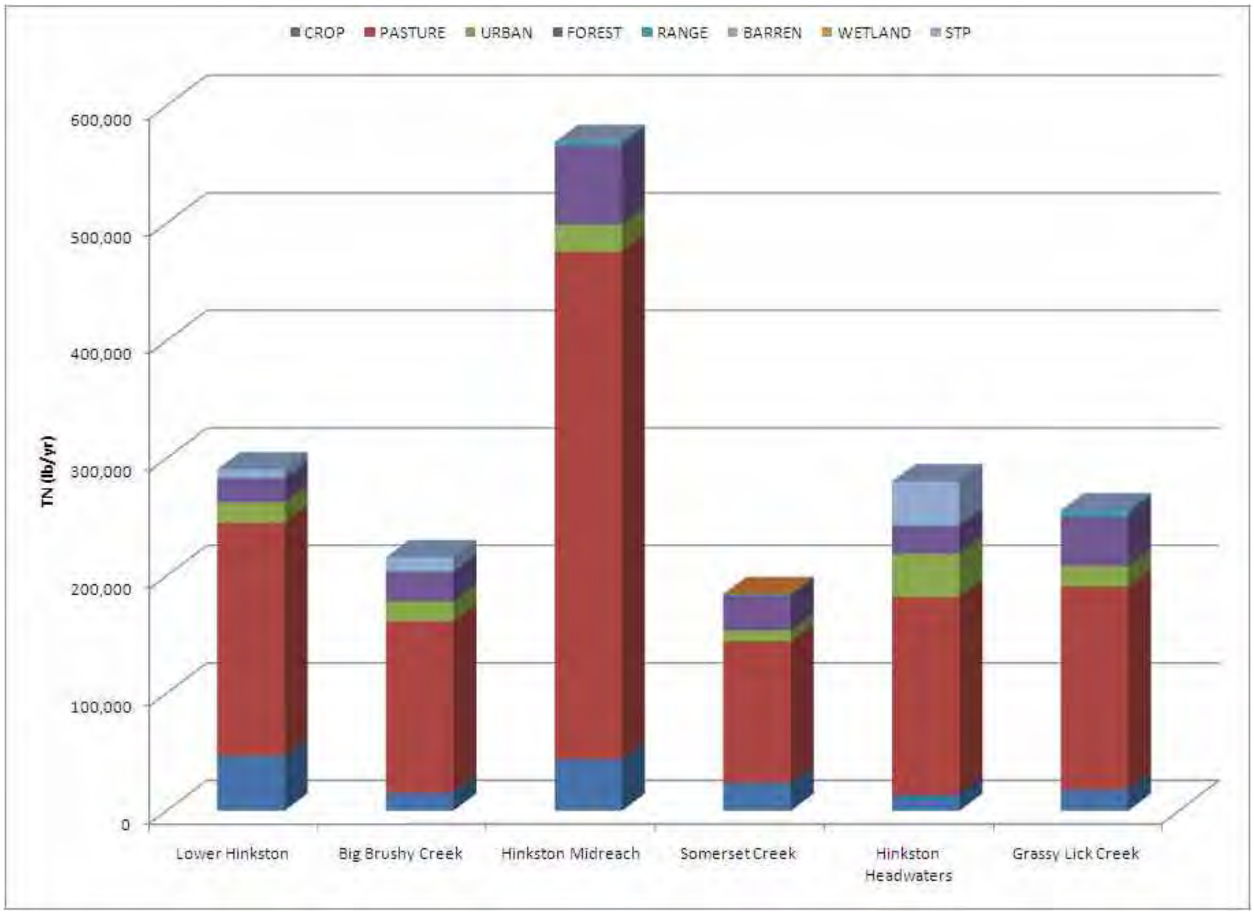


Figure 4-12. SWAT (2000 - 2010) Total Nitrogen Output Annual Average Loading by Reporting Unit for Point and Nonpoint Sources

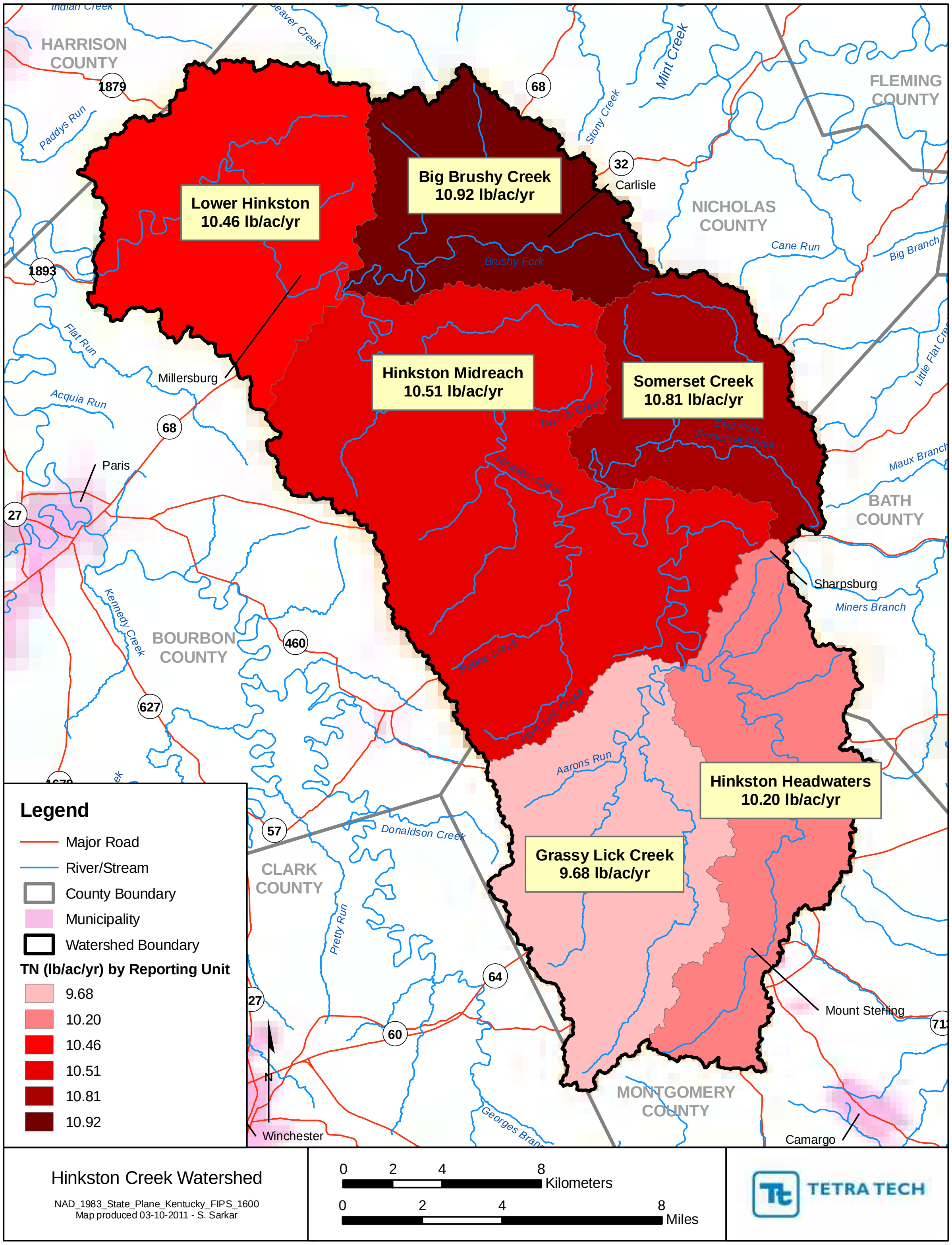


Figure 4-13. SWAT (2000 - 2010) Total Nitrogen Output Annual Average Unit Loading by Reporting Unit for Nonpoint Source

4.1.4 Phosphorus

Like nitrogen, phosphorus is an essential nutrient for plant and animal growth, but can cause problems when present in excess. Phosphorus is naturally present in sand and rock but is also added in fertilizer. Phosphorus is typically present in natural systems sorbed to particles with a limited dissolved fraction. The decay of organic matter results in organic phosphorus being released in the stream.

4.1.4.1 Concentration Time Series Comparisons

Total phosphorus was measured directly and reported during each of the KDOW and MSU monitoring periods. These data are presented in time series format along with the benchmark value in D. Only one station, 05016028, consistently exceeded the benchmark. Section 4.1.4.2 provides a comparison of the average TP values to the TP benchmark (0.132 mgP/L). Both KDOW and MSU data suggest the most elevated total phosphorus values were observed during summer months from June through September for both 2004 and 2010 sampling. During these summer months, the KDOW data further suggest elevated total phosphorus observations at mainstem stations downstream from the Mount Sterling STP (05016026, 05016027, and 05016029) relative to total phosphorus observed at mainstem stations upstream from the STP (05016020 and 05016025). KDOW data also suggest that elevated total phosphorus was observed during the 2004 – 2005 time period for both Bennett Branch (05016023) and the section of Town Branch directly downstream from the Sharpsburg STP (05016028). The MSU data show a similar pattern to KDOW along the mainstem downstream (HKC-01, HKC-02, HKC-05, and HKC-10) and upstream (HKC-11 and HKC-12) of the Mount Sterling STP. Elevated total phosphorus was also observed during the MSU sampling time period for Big Brushy Creek (HKC-03), Grassy Lick Creek (HKC-08), and Somerset Creek (HKC-09; tributary to Grassy Lick Creek). The MSU monitoring period was dry compared to the KDOW monitoring period with the last three months of sampling resulting in insufficient flow for measurement. However, water quality samples were taken at these times.

4.1.4.2 Plan View Mean Concentrations

Average total phosphorus concentrations were calculated for each KDOW and MSU station. These values were developed into plan view maps (Figure 4-14) to convey spatial location along with the magnitude of concentration in comparison to benchmark values (smallest red and yellow circles). Average concentrations at several stations do appear below the benchmark (05016020, 05016021, 05016025, 05016027) and there are a number of stations just above the benchmark (HKC-12, HKC-11, HKC-10, HKC-08, HKC-09, HKC-07, HKC-06, HKC-04, 05016029, 05016024, and 05016023).

In general, the figure reveals that elevated total phosphorus concentrations are present on the mainstem within the Hinkston Headwaters reporting unit directly downstream from the Mount Sterling STP and along Town Branch directly downstream from the Sharpsburg STP. The figure also reveals elevated total phosphorus concentrations at locations along the mainstem throughout the Hinkston Midreach and Lower Hinkston reporting units and at the Big Brushy Creek station location.

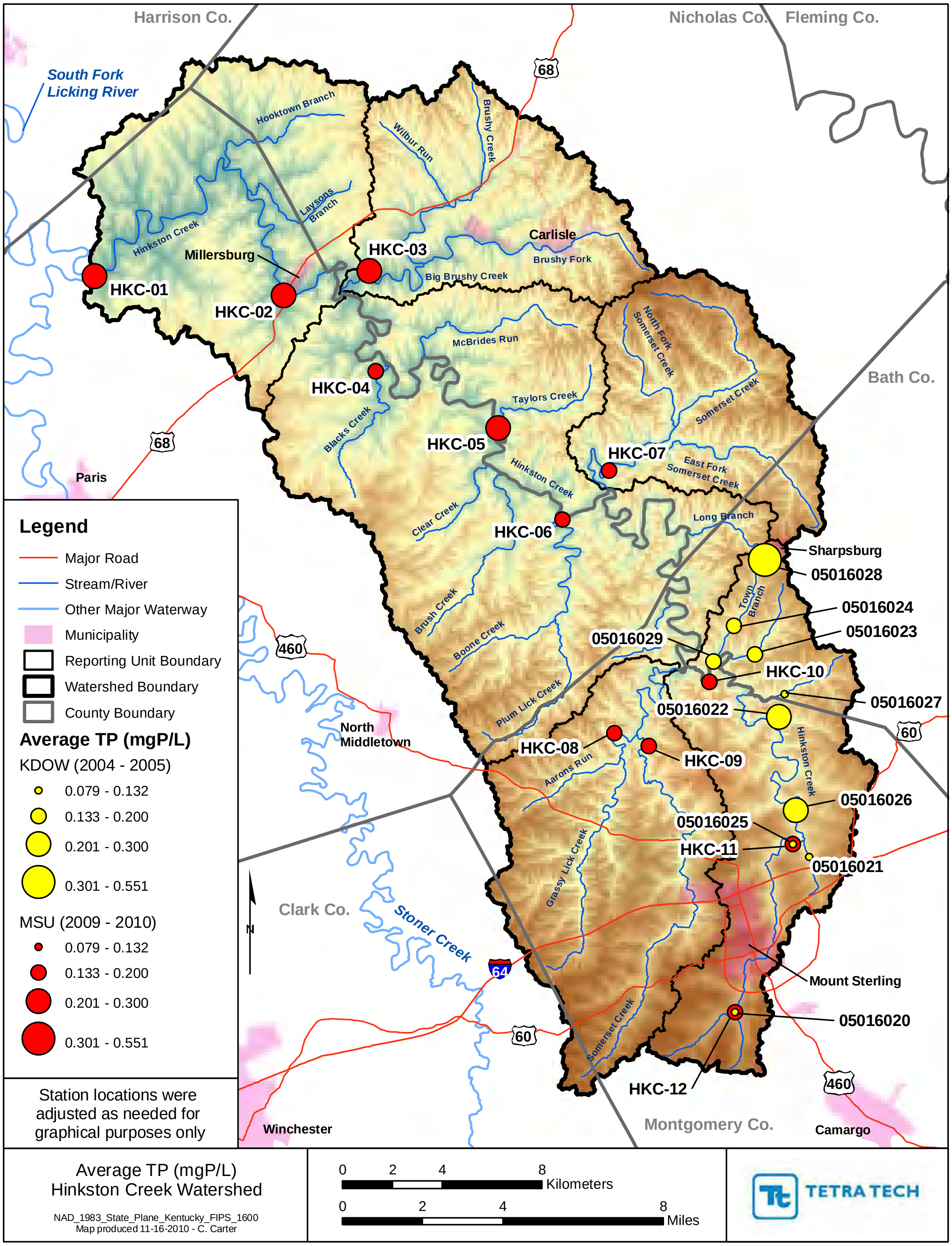


Figure 4-14. Average Total Phosphorus Concentration Measured at Each Water Quality Station

4.1.4.3 Longitudinal Profile Concentration

Total phosphorus concentrations are shown in Figure 4-15and Figure 4-16. The KDOW monitoring was limited to upstream of approximately river mile 51. The KDOW data show a notable increase in phosphorus values downstream of the Mt. Sterling STP outfall (Figure 4-15). There also appears a notable elevation in total phosphorus values at river mile 54.5 on Town Branch, which is downstream of the Sharpsburg STP outfall. Across each of the two monitoring periods, the 75th percentile total phosphorus value at river mile 54.5 (05016028) on Town Branch is the highest for that statistic. The MSU observations do not show the mainstem total phosphorus concentration elevating around the Mt Sterling STP outfall as the KDOW observations (Figure 4-16). The Carlisle STP effluent is discharged to Big Brushy Creek and the monitoring station on that tributary reports elevated total phosphorus values. There are two tributaries which suggest elevated total phosphorus values that do not have domestic waste discharge, they are Grassy Lick Creek and Bennett Branch.

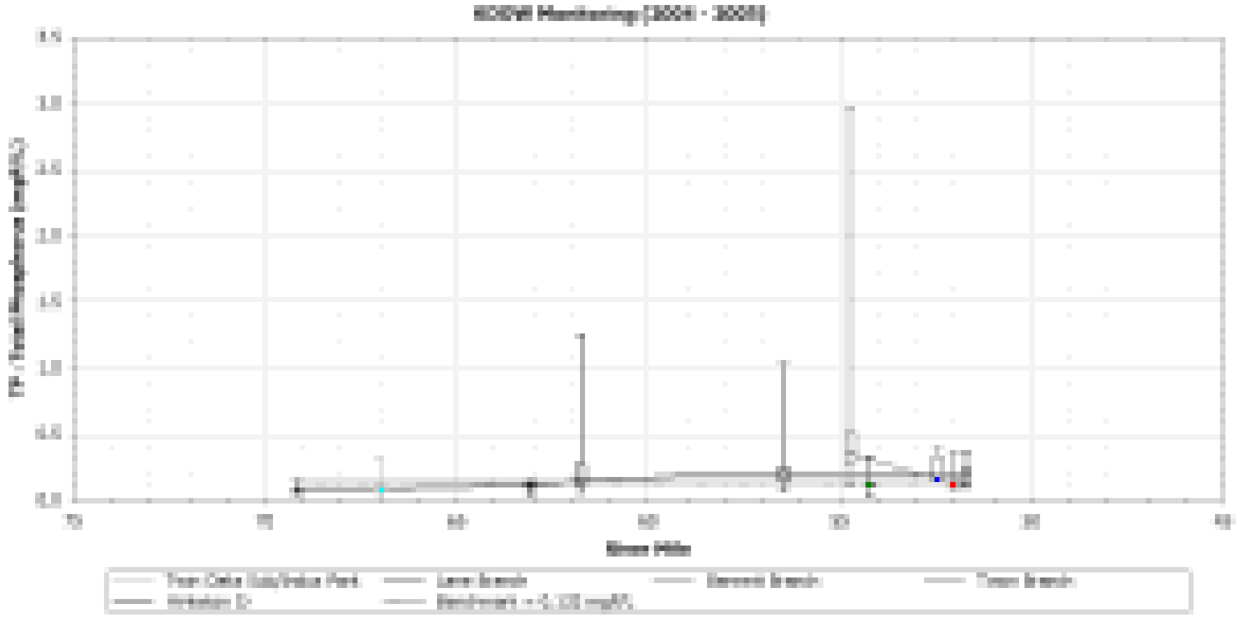


Figure 4-15. Longitudinal Profile of Total Phosphorus, KDOW (2004 – 2005)

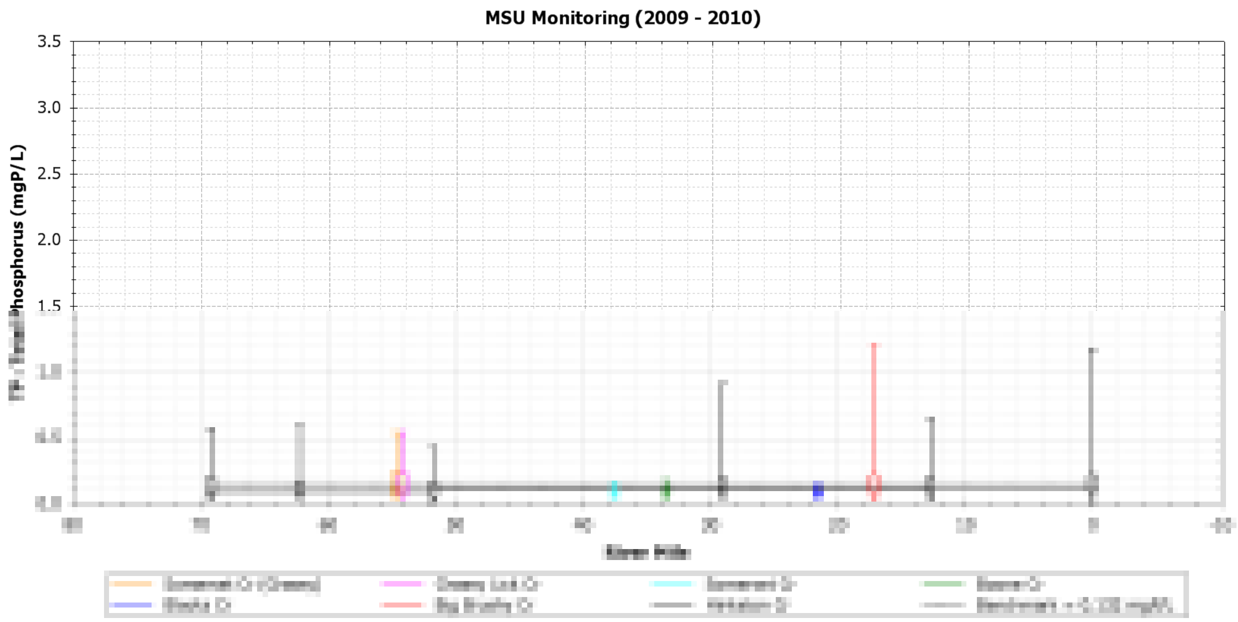
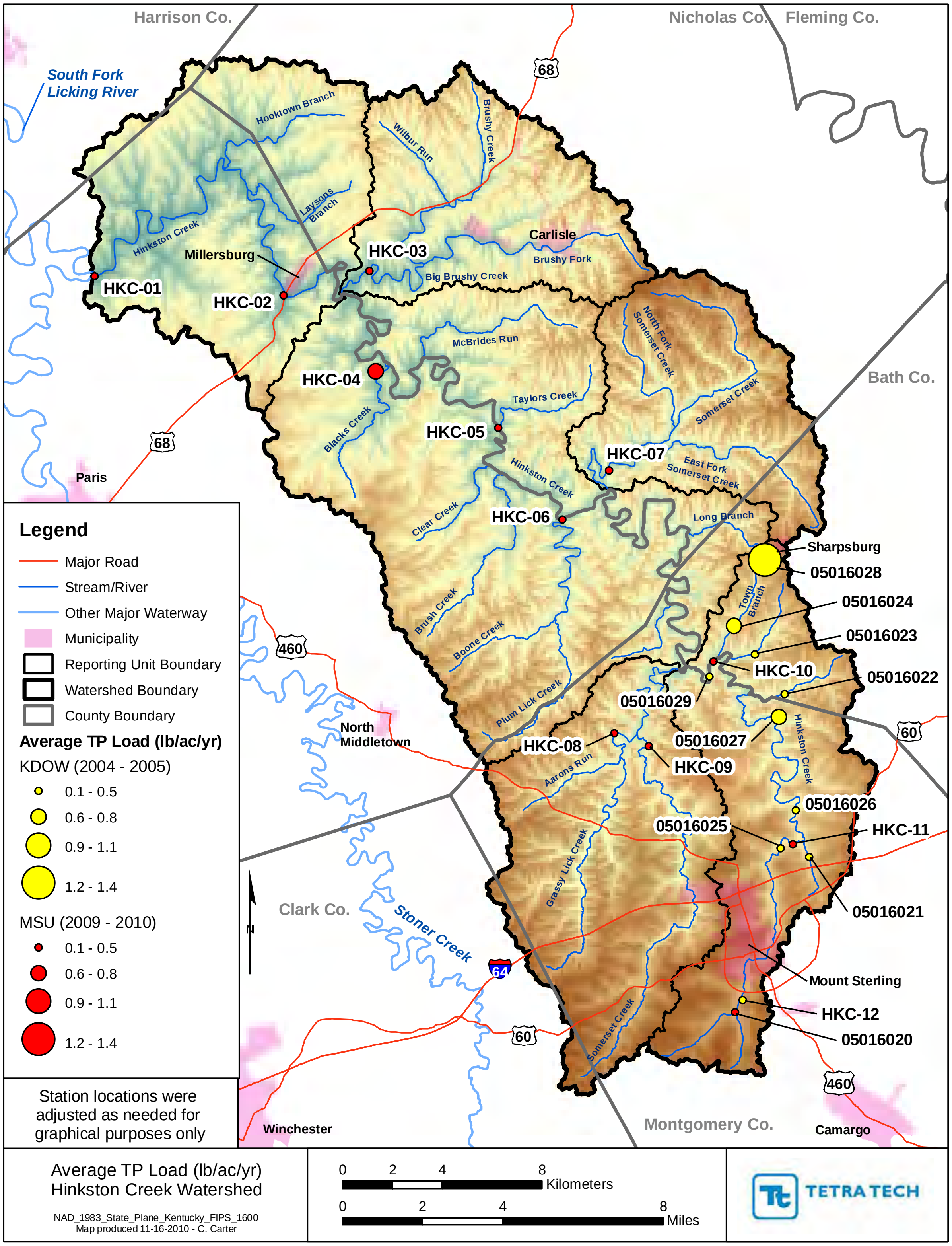


Figure 4-16. Longitudinal Profile of Total Phosphorus, MSU (2009 – 2010)

4.1.4.4 Monitoring Data Loads

The KDOW and MSU observations of flow and concentration were used to calculate load. These are in-stream calculations of load, with no separation of point and nonpoint source contributions. These loads were averaged for each monitoring station and then converted to unit-area loads (D). These values were developed into a plan view map (Figure 4-17) to convey spatial location along with the magnitude of loading, and to convey the relationship to the TP loading benchmark.

The benchmark unit area load for total phosphorus is 0.5 pounds per acre per year. Town Branch monitoring stations (05016028 and 05016024) resulted in the highest unit area load of the KDOW monitoring period with loadings of approximately 1.4 and 0.57 pounds per acre per year, respectfully. One location along the mainstem of Hinkston Creek downstream from the City of Mount Sterling (05016027) also exceeded the benchmark value with a loading of approximately 0.57 pounds per acre per year. The largest unit area loading from the MSU monitoring was once again attributed to Blacks Creek (HKC-04) at almost 0.56 pounds per acre per year; all other MSU monitoring stations were below the benchmark value.



Station locations were adjusted as needed for graphical purposes only

Average TP Load (lb/ac/yr)
Hinkston Creek Watershed

NAD_1983_State_Plane_Kentucky_FIPS_1600
Map produced 11-16-2010 - C. Carter

Figure 4-17. Average Total Phosphorus Loading at Each Water Quality Station

4.1.4.5 SWAT Loads

Because watershed assessments conducted on the basis of observed (monitored) water quality data represents only a brief time period and a limited range of conditions (e.g., flow), Tetra Tech supplemented the assessment with modeled data based on the Soil and Water Assessment Tool (SWAT). The nonpoint simulation of phosphorus produced unit area loadings which were greater than the benchmark for all six reporting units. Figure 4-18 summarizes the model nonpoint output as a yearly average over the simulation period (2000 – 2010) along with the domestic waste dischargers each in units of mass per time. The Hinkston Midreach reporting unit produced the highest annual average phosphorus loading with Hinkston Headwaters as the second highest. Recall that generally pasture was the dominant land cover for all reporting units (62 to 76 percent), therefore in the model environment the pasture land cover is anticipated to be a primary contributor of constituent mass. The Hinkston Midreach is more pronounced on this figure because it is the largest drainage area of the six reporting units. The contribution of phosphorus from the point sources is relatively larger for phosphorus (Figure 4-18) than for nitrogen (Figure 4-12).

When the mass of phosphorus was considered as nonpoint unit area loading, variations across the reporting units were relatively small (Figure 4-19). Compared to nitrogen and suspended sediment, the simulated nonpoint source contribution of phosphorus was slightly larger than the benchmark by approximately 0.1 to 0.2 lb/ac/year, representing approximately 30 percent more than the benchmark.

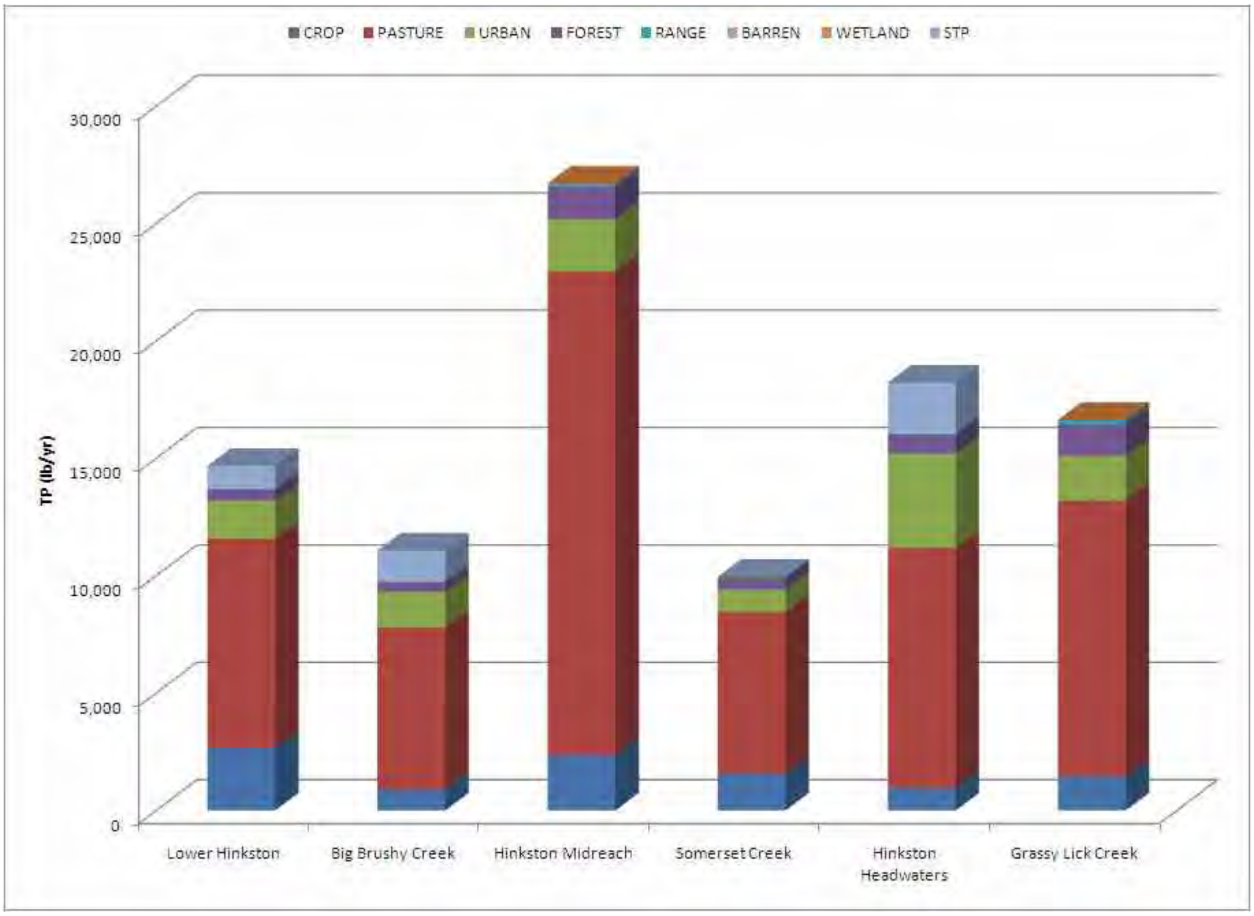


Figure 4-18. SWAT (2000 - 2010) Total Phosphorus Output Annual Average Loading byReporting Unit for Point and Nonpoint Sources

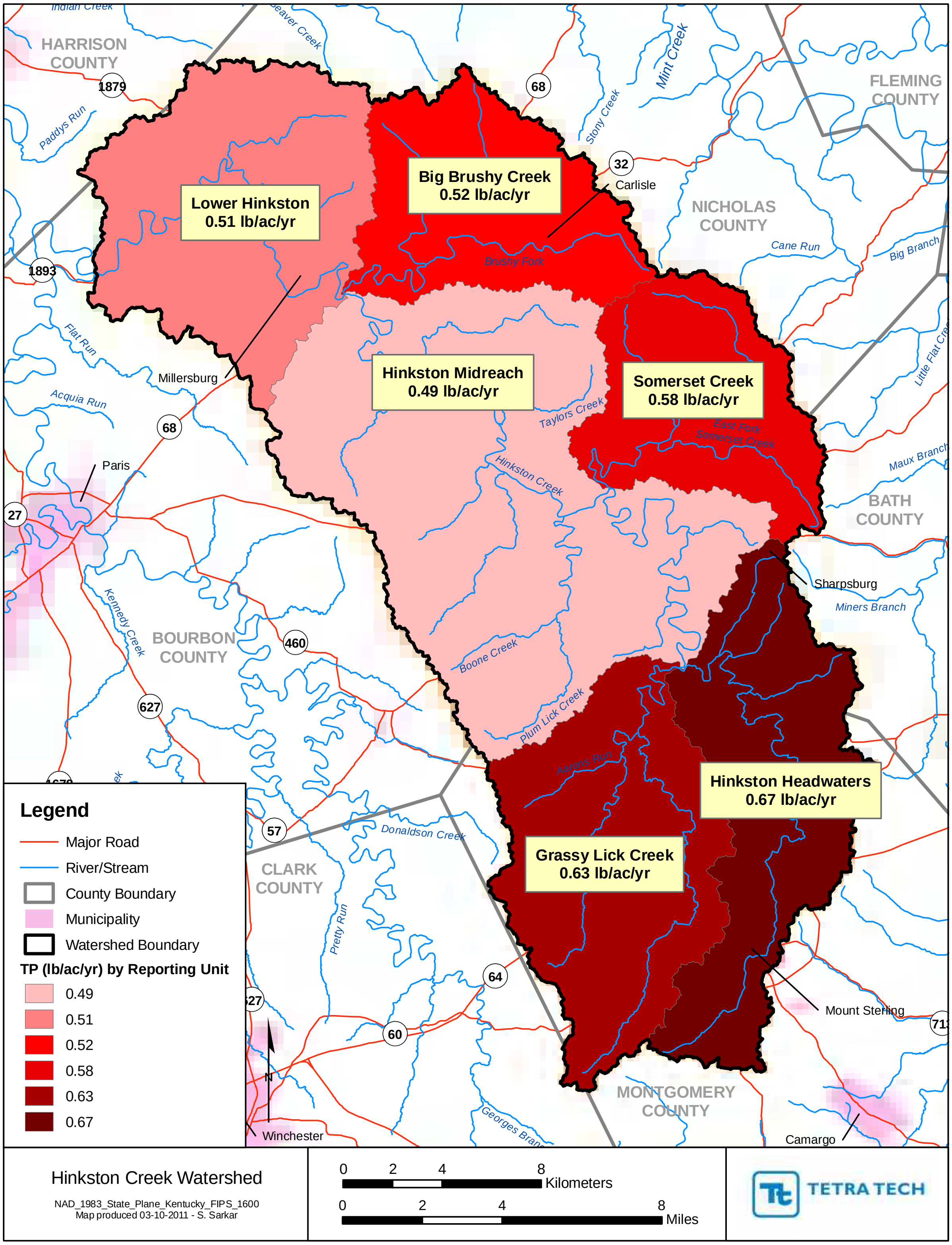


Figure 4-19. **SWAT (2000 - 2010) Total Phosphorus Output Annual Average Unit Loading by Reporting Unit for Nonpoint Source**

4.1.5 Suspended Solids

Total suspended solids (TSS) is one measure to assess sediment concentration and load. TSS is a water column parameter, it does not reflect the sediment that moves along the bottom of a stream, the bed load. A better understanding of the water column sediment would be achieved through storm sampling, as 2 – 4 storm events per year may move 40 – 70 percent of the sediment load. The evaluation of sediment is complex not only regarding transport but also in characterizing sources. The available data does not facilitate adequate determination of magnitudes attributable to stream-based or land-based sediment generation.

4.1.5.1 Concentration Time Series Comparisons

Total suspended solids (TSS) was measured directly and reported during each of the KDOW and MSU monitoring time periods. These data are presented in time series format along with the benchmark value in D. Several stations consistently approached or exceeded the TSS benchmark value of 9.82 mg/L: 05016020, HKC-01, 05016024, 05016028. Section 4.1.5.2 below provides a comparison of the average TSS values to the TSS benchmark. The KDOW data suggest the most elevated TSS values were observed in the headwaters of the mainstem (05016020 and 05016029), Bennett Branch (05016023), an unnamed tributary (Twin Oaks Subdivision/Industrial Park) to Hinkston Creek near Mount Sterling (05016021), and Town Branch (05016024 and 05016028). The MSU observations suggest the most elevated TSS concentrations in the headwaters of the mainstem (HKC-12) and at the mouth of Hinkston Creek (HKC-01). Individual concentration records were reported above the benchmark value at each of the tributaries except for Boone Creek (HKC-06) with the greatest measurement above the benchmark observed at Blacks Creek (HKC-04). The MSU monitoring period was dry compared to the KDOW monitoring period with the last three months of sampling resulting in insufficient flow for measurement. However, water quality samples were taken at these times. Typically, the highest values of TSS reported by KDOW were in June and July of 2004 and by MSU were in May of 2010.

4.1.5.2 Plan View Mean Concentration

Average TSS concentrations were calculated for each KDOW and MSU station. These values were developed into a plan view map (Figure 4-20) to convey spatial location along with the magnitude of concentration and the relationship to the benchmark value (shown in the smallest circles). Less than half of the stations had average TSS values that met the benchmark: HKC-11, 05016025, 05016026, 05016022, HKC-05, and HKC-06. The figure reveals that the most elevated TSS concentrations were observed at the tributaries of Town Branch and Bennett Branch within the Hinkston Headwaters reporting unit. The figure also reveals average TSS concentrations exceeding the benchmark value at various locations along the mainstem and tributaries throughout the entire Hinkston Creek watershed.

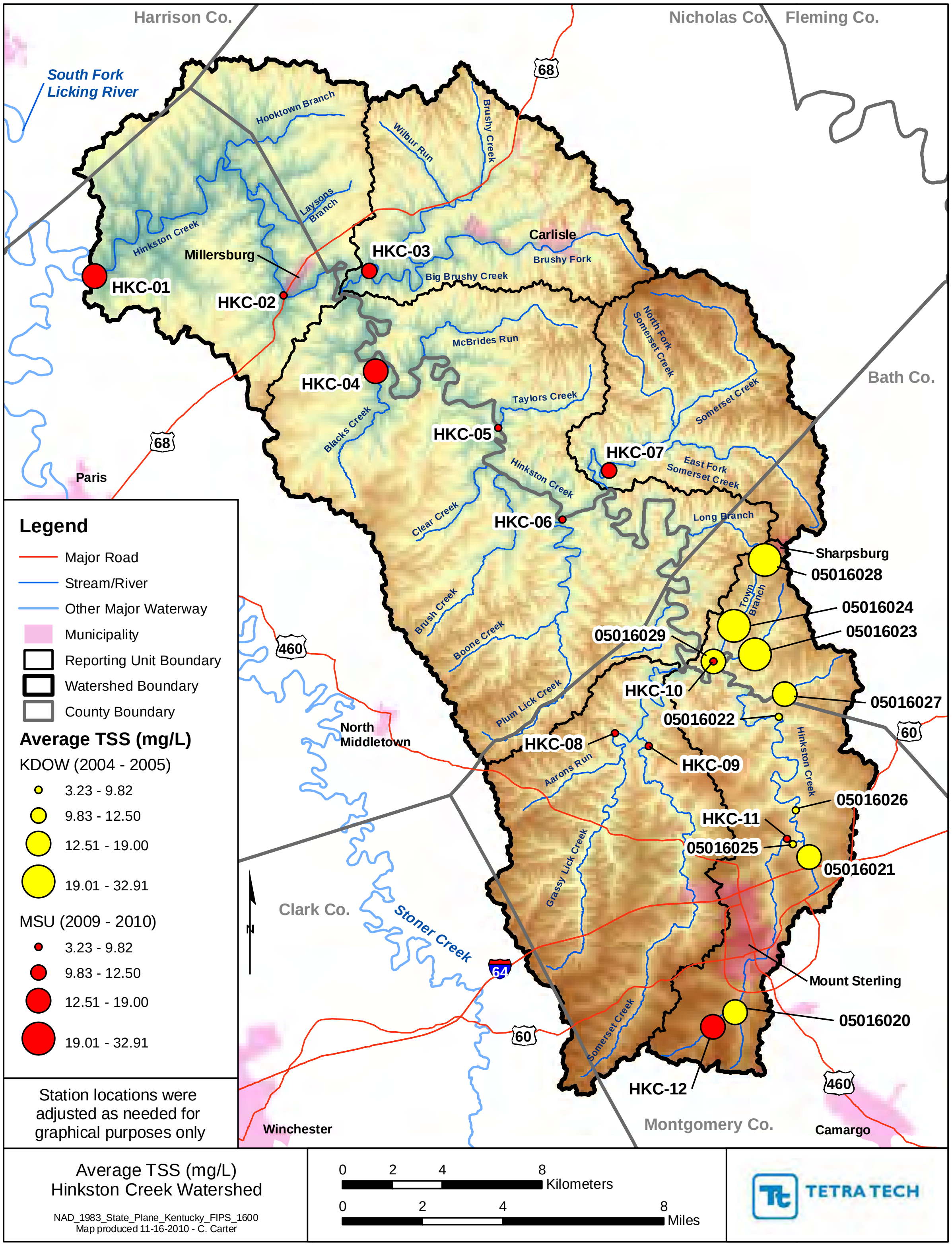


Figure 4-20. **Average Total Suspended Solids Concentration Measured at Each Water Quality Station**

4.1.5.3 Longitudinal Profile Concentration

Both the KDOW and MSU monitoring indicate that elevated TSS values occur at river mile 69.2 (05016020/HKC-12). The KDOW data resulted in median values for Bennett Branch and Town Branch (Figure 4-21) higher than the remaining stations. The MSU data indicate the median value at river mile 69.2 (HKC-12) was higher than all other median values for that data set. The statistics for the Grassy Lick Creek and Blacks Creek tributaries suggest elevated sediment generation (Figure 4-22). The statistics from station HKC-01 indicate there may be some incremental contributions along the mainstem downstream of HKC-02.

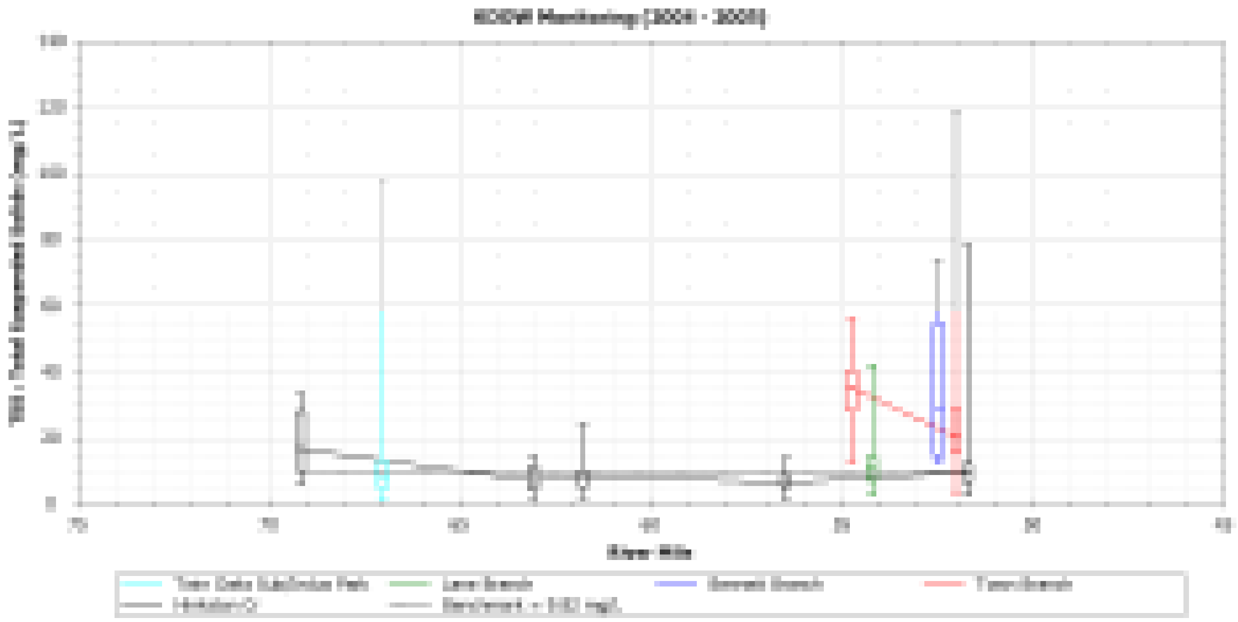


Figure 4-21. Longitudinal Profile of Total Suspended Solids, KDOW (2004 – 2005)

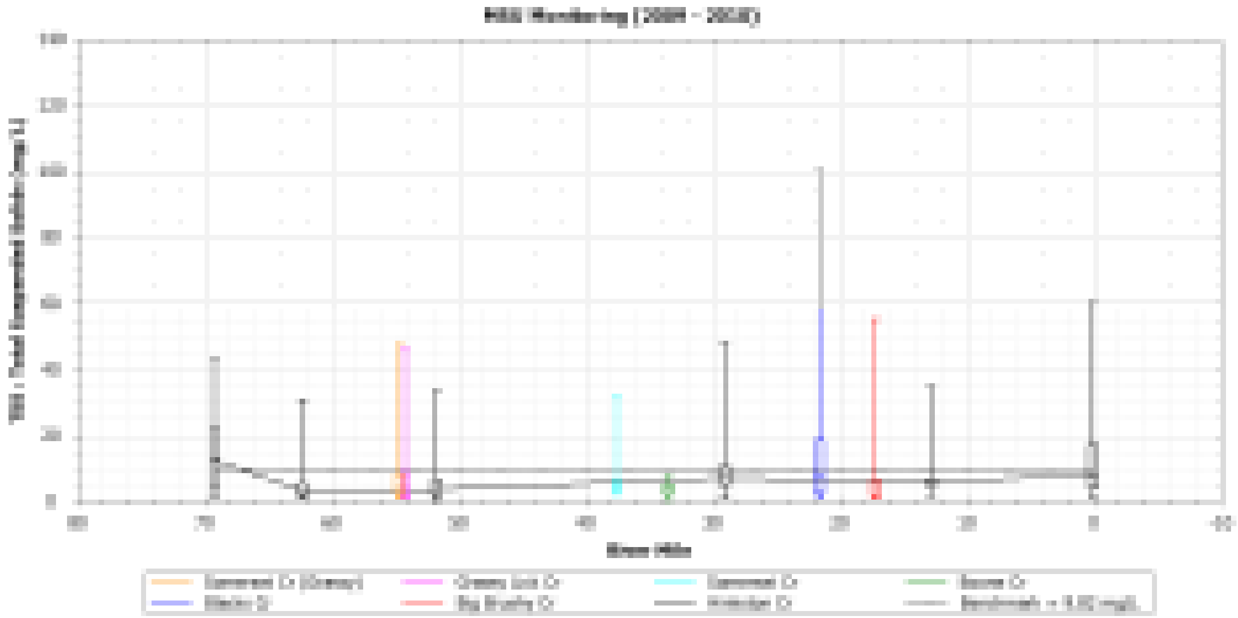


Figure 4-22. Longitudinal Profile of Total Suspended Solids, MSU (2009 – 2010)

4.1.5.4 Monitoring Data Loads

The KDOW and MSU observations of flow and concentration were used to calculate load. These are instream calculations of load, with no separation of point and nonpoint source contributions. These loads were averaged for each monitoring station and then converted to unit-area loads (D). These values were developed into a plan view map (Figure 4-23) to convey spatial location along with the magnitude of loading. The monitoring data did not capture storm flow events which should be noted when reviewing the information in this section compared with that in the next section from the SWAT simulation. The results from the SWAT simulation include high flow events.

The benchmark unit area load for total suspended solids is 40.8 pounds per acre per year. Town Branch monitoring stations (05016028 and 05016024) resulted in the highest unit area load of the KDOW monitoring period with loadings of approximately 145 and 115 pounds per acre per year, respectively. Additional locations that exceeded the benchmark value during the KDOW monitoring period were the headwater portion of Hinkston Creek (05016020), the Twin Oaks Subdivision/Industrial Park Tributary to Hinkston Creek downstream from the City of Mount Sterling (05016021), and Bennett Branch (05016023). The largest unit area loading from the MSU monitoring was the headwater portion of Hinkston Creek (HKC-12) at approximately 64 pounds per acre per year. The stations located at the mouth of Hinkston Creek (HKC-01) and along Blacks Creek (HKC-04) also exceeded the benchmark value during the MSU monitoring time period. A comparison of the estimated monitoring data loads and the total habitat scores suggests a low correlation between the two except in the Hinkston Headwaters watershed above Mt. Sterling and Town Branch.

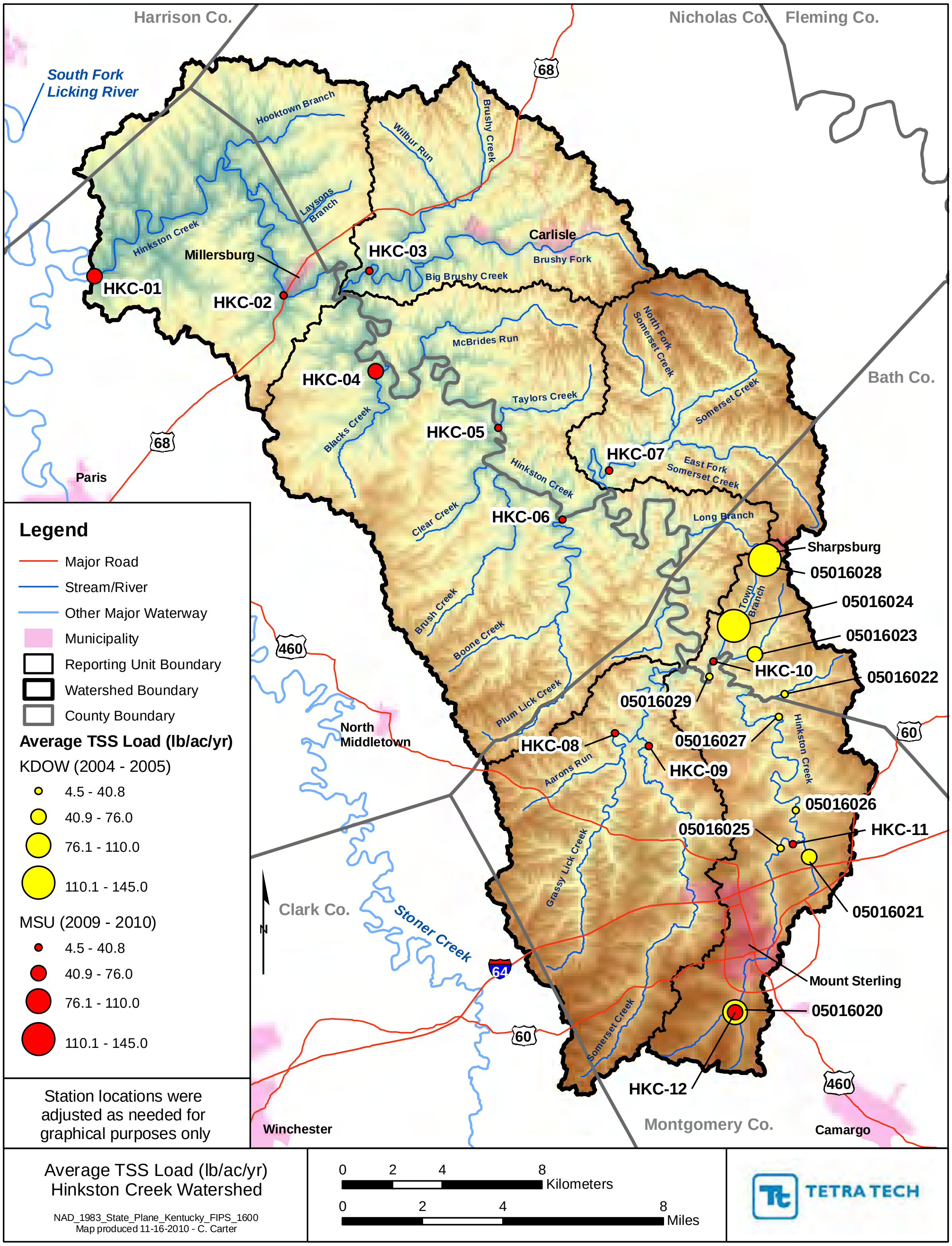


Figure 4-23. Average Total Suspended Solids Loading at Each Water Quality Station

4.1.5.5 SWAT Loads

Figure 4-24 presents the simulated nonpoint source loading along with the contributions from the domestic waste dischargers in the study area. As seen with nitrogen and phosphorus, the Hinkston Midreach reporting unit produces the highest loading in mass per time of all the reporting units primarily due to the incremental drainage area. This figure also conveys that the primary focus of sediment contribution is from nonpoint sources, as the point source magnitudes are indiscernible in this figure, their magnitudes are very small.

The unit area loading figure of simulation output again shows general similarity across the reporting units with values ranging from 0.7 to 1.2 tons/ac/year (Figure 4-25). However, the simulated nonpoint unit area loading rates are 30 to 50 times greater than the benchmark value of 0.02 tons/ac/year, which is much different when compared to nitrogen and phosphorus. The simulation captures the range of hydrologic events, whereas the observed data did not capture significant high flow events which are more informative regarding sediment characteristics in the study area.

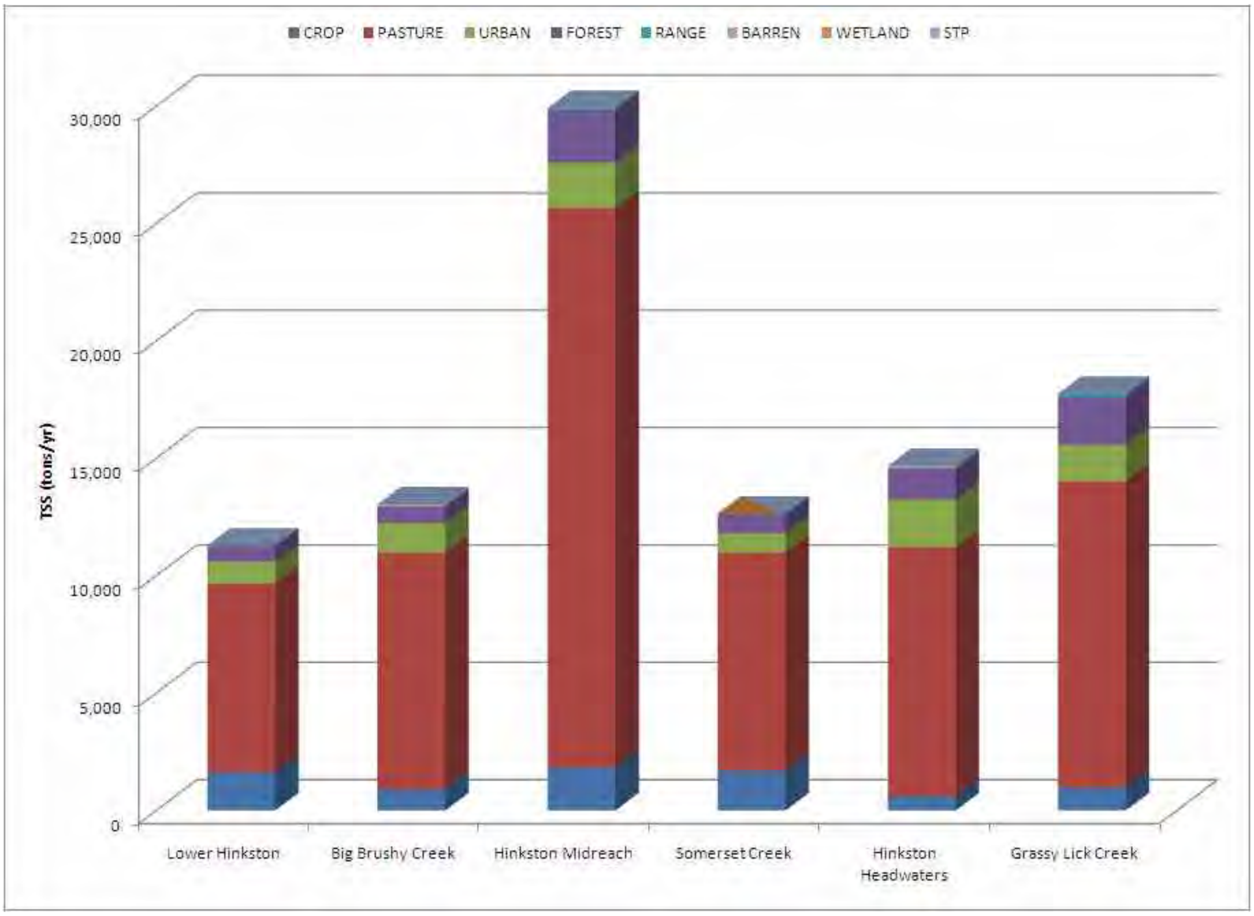


Figure 4-24. SWAT (2000 - 2010) Total Suspended Solids Output Annual Average Loading by Reporting Unit for Point and Nonpoint Sources

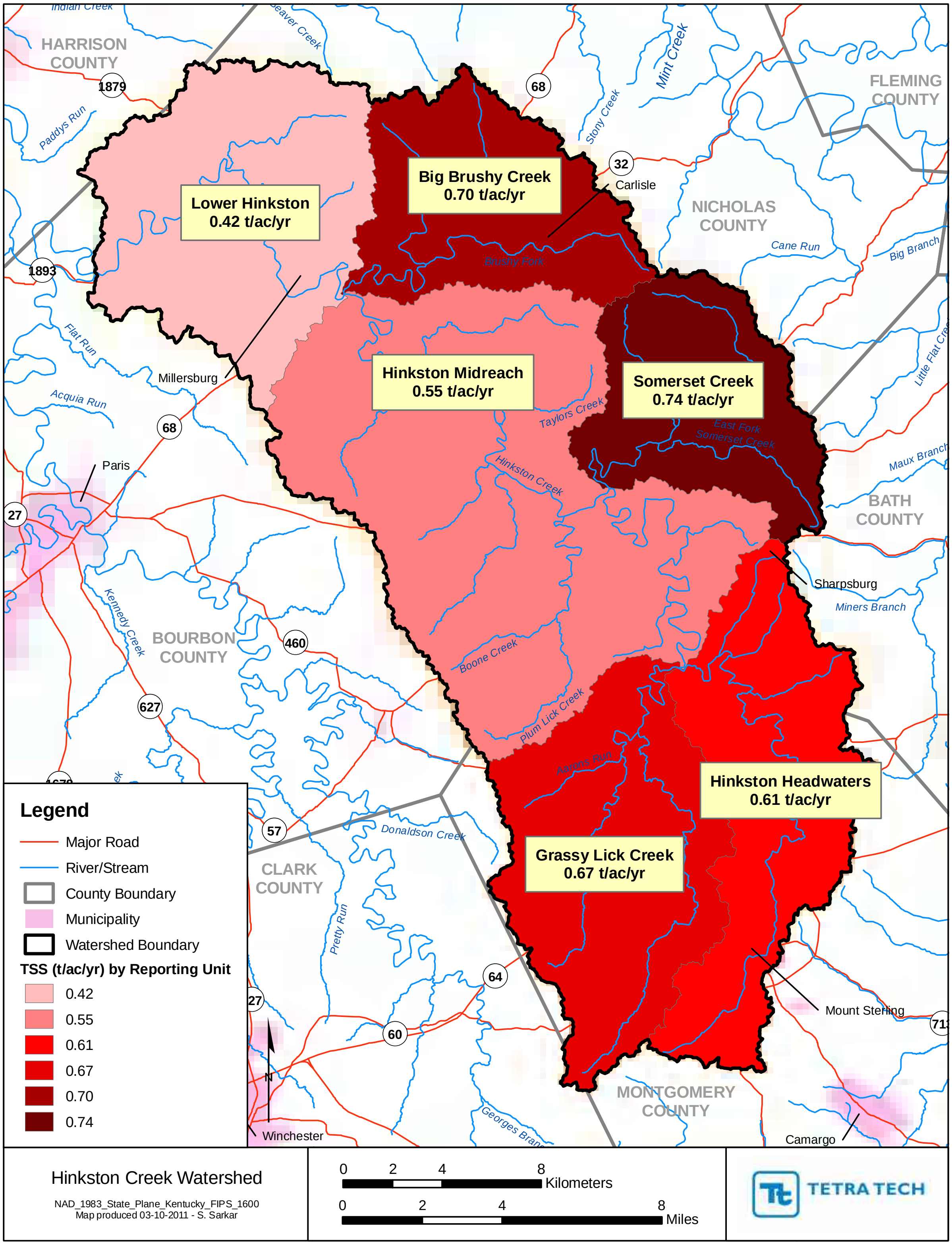


Figure 4-25. **SWAT (2000 - 2010) Total Suspended Solids Output Annual Average Unit Loading by Reporting Unit for Nonpoint Source**

4.1.6 Dissolved Oxygen

4.1.6.1 Concentration Time Series Comparisons

Dissolved oxygen was measured directly and reported during each of the KDOW and MSU monitoring time periods. Data presented in this report was measured from grab samples collected once between approximately 9:00am and 3:00pm on days when sampling occurred; it is likely that these methods did not capture the daily minimum dissolved oxygen level. The amount of dissolved oxygen in stream water is influenced by patterns of plant and animal respiration in response to available sunlight and the daily minimum dissolved oxygen level is expected to occur generally before sunrise. In order to capture daily minimum dissolved oxygen levels, continuous measurements of dissolved oxygen are required but were not available at this time. The available dissolved oxygen data are presented in time series format along with the minimum criteria value in D. As stated in Section 4.1.1 discussing benchmark values established for nutrients, nutrient-induced algal growth should not result in excursions below the minimum criterion of 4 mg/L for dissolved oxygen. The KDOW data did not suggest a concern for dissolved oxygen levels within the Hinkston Headwaters reporting unit as all observed measurements for dissolved oxygen were reported above the minimum criteria. The MSU data reflect a similar pattern except for the months of August through October in 2010. During this time, most MSU measurements for dissolved oxygen were below the minimum criteria; however, it was during this time that flow measurements were reported as less than 0.01 cubic feet per second (cfs). Even though the last three months of the MSU sampling period resulted in insufficient flow for measurement, water quality samples were still taken at these times.

4.1.6.2 Plan View Minimum Concentration

Minimum dissolved oxygen concentrations were selected for each KDOW and MSU station. These values were developed into a plan view map (Figure 4-26) to convey spatial location along with the magnitude of concentration. The figure reveals that several MSU sampling locations throughout the entire watershed have minimum values of dissolved oxygen below the instantaneous minimum criterion of 4 mg/L. MSU samples measured below this criterion were collected during the months of August and October of 2010, a period of very low flow (Figure 2-3). All 10 KDOW locations have minimum values of dissolved oxygen above the criterion of 4 mg/L. The color ramp scale on Figure 4-26 show that the minimum values of dissolved oxygen at MSU and KDOW water quality stations were 0.6 mg/L and 4.3 mg/L, respectively. In the figure, smaller circles represent higher dissolved oxygen of water based solely on observed concentrations.

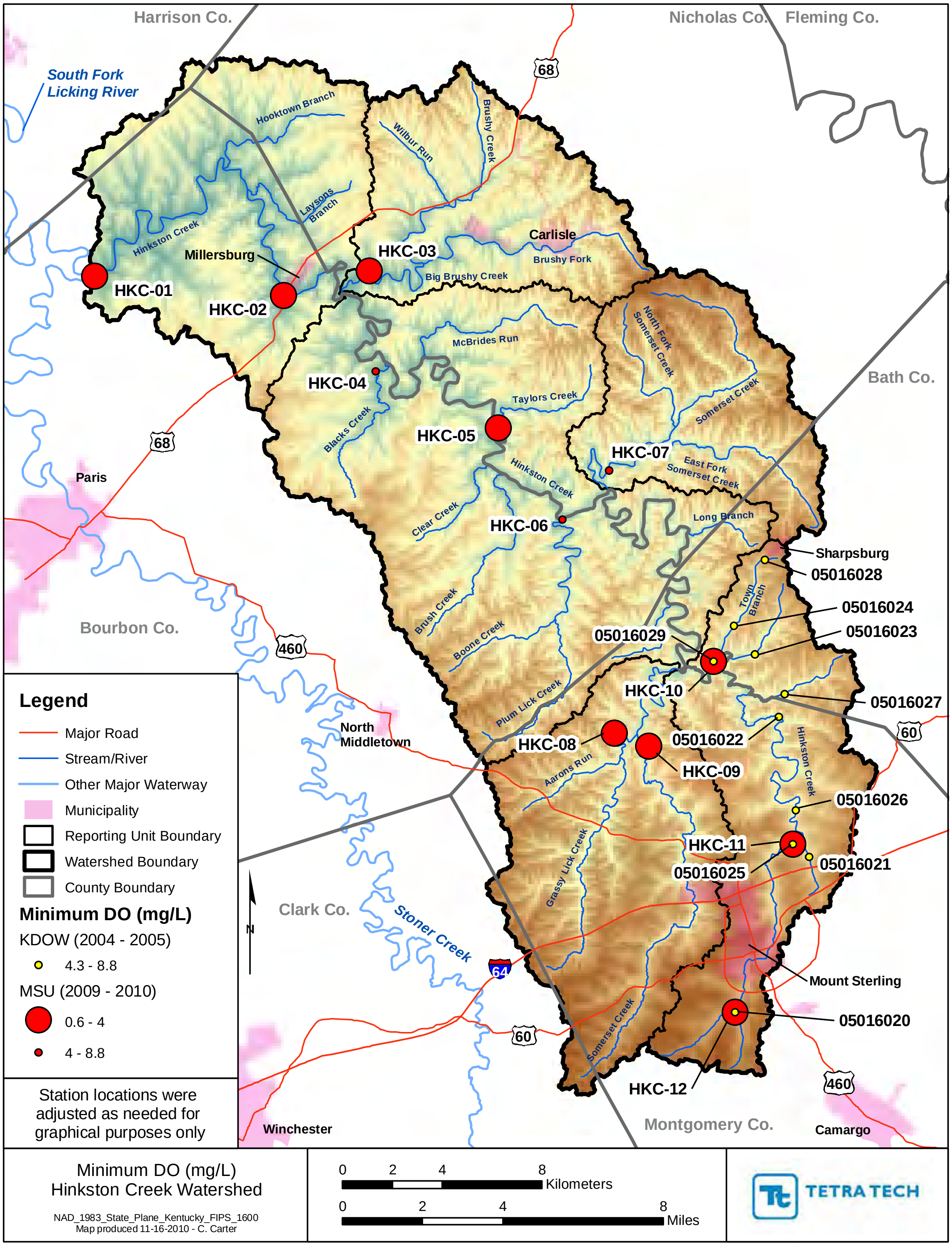


Figure 4-26. Minimum Dissolved Oxygen Concentration Measured at Each Water Quality Station

4.1.6.3 Longitudinal Profile Concentration

Figure 4-27 shows the longitudinal profile of dissolved oxygen for the KDOW 2004 - 2005 monitoring period. Mt. Sterling STP effluent is discharged to Hinkston Creek at river mile 62.1. The median value of observed DO is lower at river mile 61.8 (05016026) compared to river mile 63.1 (05016025) while the range is increased. Sharpsburg STP effluent is discharged on Town Branch at river mile 54.8. The headwater station (RM 54.7, 05016028) on Town Branch indicates lower DO values relative to the downstream station (RM 52.0, 05016024).

The MSU monitoring (Figure 4-28) data reported DO values less than the water quality standard of 4 mg/L (instantaneous). However, all of these DO violations were observed when there was no measurable flow, which is when the water was essentially stagnant. There were no instantaneous violations of the DO standard when the flow of water was measurable, which suggests that though there is concern regarding organic enrichment, the algal activity is not sufficient to suppress DO levels.

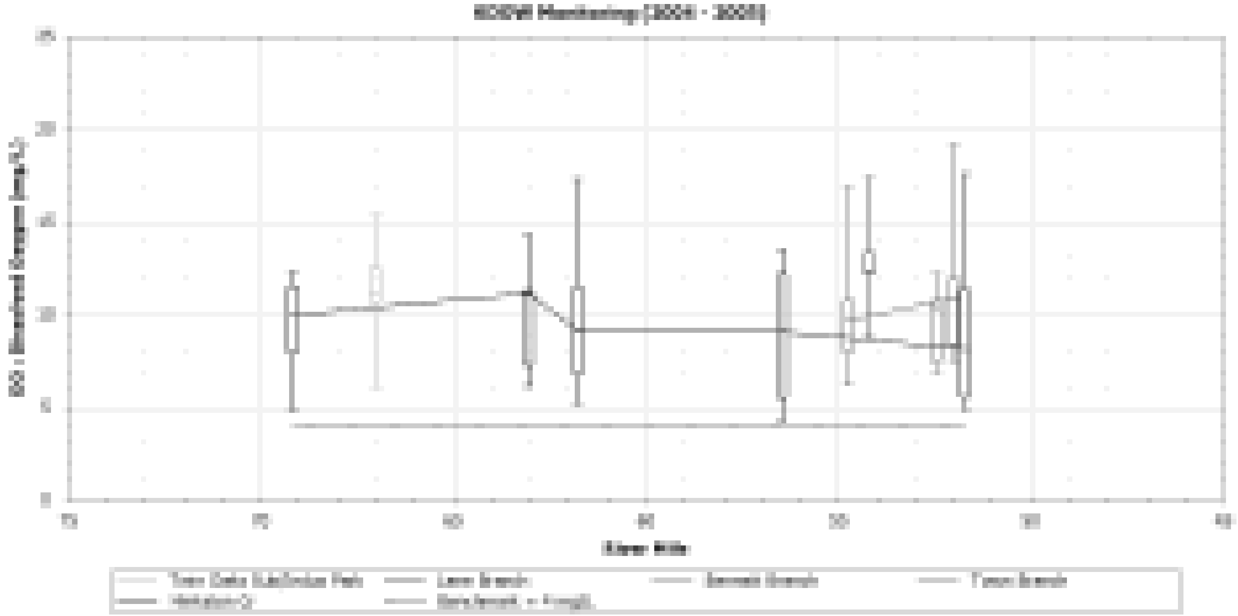


Figure 4-27. Longitudinal Profile of Dissolved Oxygen, KDOW (2004 – 2005)

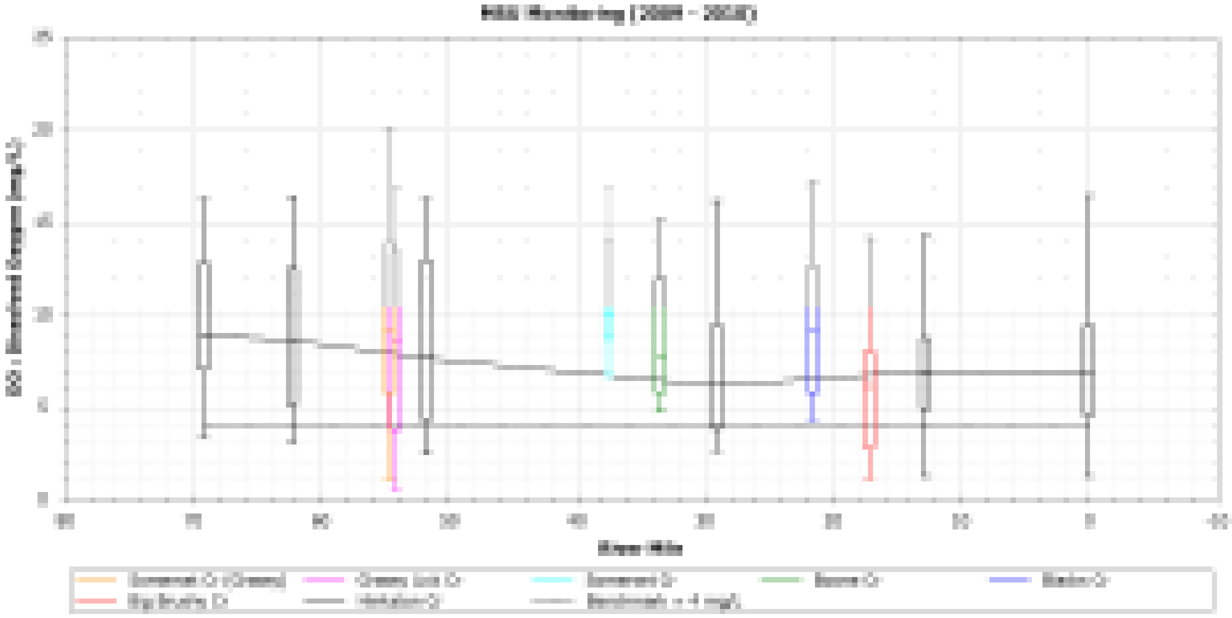


Figure 4-28. Longitudinal Profile of Dissolved Oxygen, MSU (2009 – 2010)

4.1.7 Bacteria

4.1.7.1 MSU and LRWW Monitoring Data

Both fecal coliforms and *Escherichia coli* (*E. coli*) are groups of obligate anaerobic bacteria that are used as indicators of potential contamination by fecal matter and possible risk of human pathogens. Fecal coliforms and *E. coli* were measured and used as indicators of surface water bacteria contamination in the development of this watershed plan. Fecal coliform and *E. coli* loading may be due to malfunctioning septic or sewer systems as well as improperly managed livestock waste. Loads may also be due to wildlife and waterfowl loading.

The LRWW monitored *E. coli* throughout the watershed from May 13, 2006 through May 8, 2010; they also monitored fecal coliform from May 13, 2006 through September 9, 2006. During the monitoring period for fecal coliform, three samples were collected at each of the LRWW stations except L40; no monitoring of bacteria (either fecal coliform or *E. coli*) was performed at station L40. The LRWW data suggest the most elevated fecal contamination was observed along the mainstem in the Lower Hinkston reporting unit (L225 and L79) and in the Hinkston Headwaters reporting unit directly upstream (L61) and directly downstream (L62) of the City of Mount Sterling. Elevated fecal coliform values were also observed in May and July of 2006 in the Big Brushy Creek reporting unit along the Brushy Fork tributary downstream from Carlisle (L89).

MSU monitored *E. coli* throughout the watershed from November 11, 2009 through October 1, 2010. MSU did not monitor fecal coliform. The MSU data suggest the most elevated *E. coli* values were observed along the mainstem in the Lower Hinkston reporting unit (HKC-01) and in the Hinkston Headwaters reporting unit directly upstream from the City of Mount Sterling (HKC-12), which is consistent with observations from LRWW. MSU data also suggest elevated *E. coli* values were observed along Big Brushy Creek (HKC-03) and Blacks Creek (HKC-04), particularly in the late summer months of 2010. In contrast, MSU data for Boone Creek (HKC-06), Somerset Creek (HKC-07), Grassy Lick Creek (HKC-08), and Somerset Creek as a tributary off Grassy Lick Creek (HKC-09) suggest elevated *E.*

coli values in the early summer months of 2010 with a decline below the benchmark value (240 cfu/100mL) in late summer months. These data are presented in time series format along with the benchmark values in D.

4.1.7.2 Plan View Mean Concentrations

Average summer and winter *E. coli* and fecal coliform measurements were calculated for each LRWW and MSU station where bacteria were monitored. These values were developed into plan view maps (Figure 4-29 through Figure 4-31) to convey spatial location along with the magnitude of bacteria and to communicate the relationship between the monitored values and the respective benchmark (indicated by the smallest circles). The summer figures indicate concentration exceedances throughout the Hinkston watershed. The winter exceedances are fewer and primarily observed at the mouth (HKC-01) and headwaters of Hinkston Creek (HKC-12).

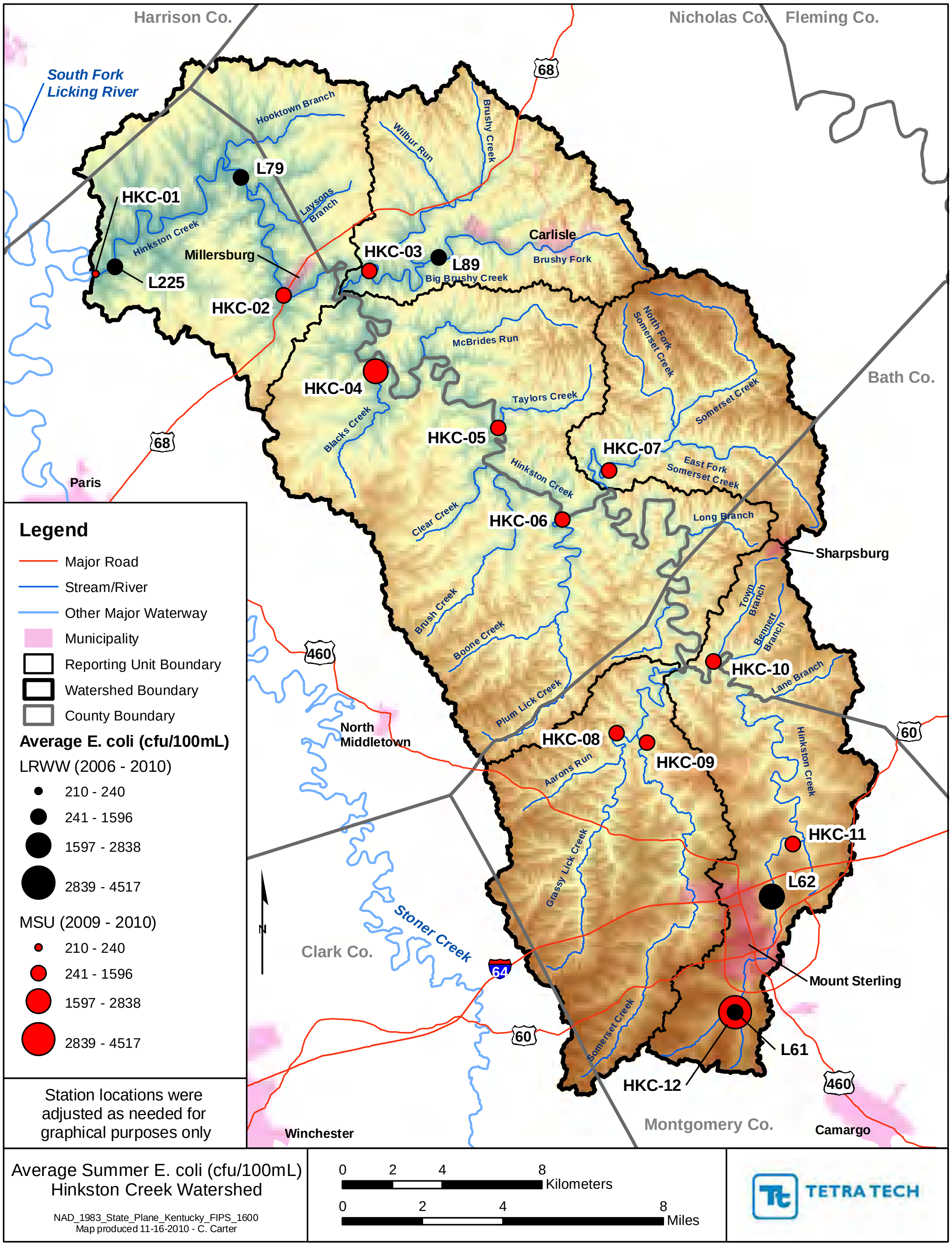


Figure 4-29. Average *E. coli* Measured in Summer at MSU and LRWW Water Quality Stations

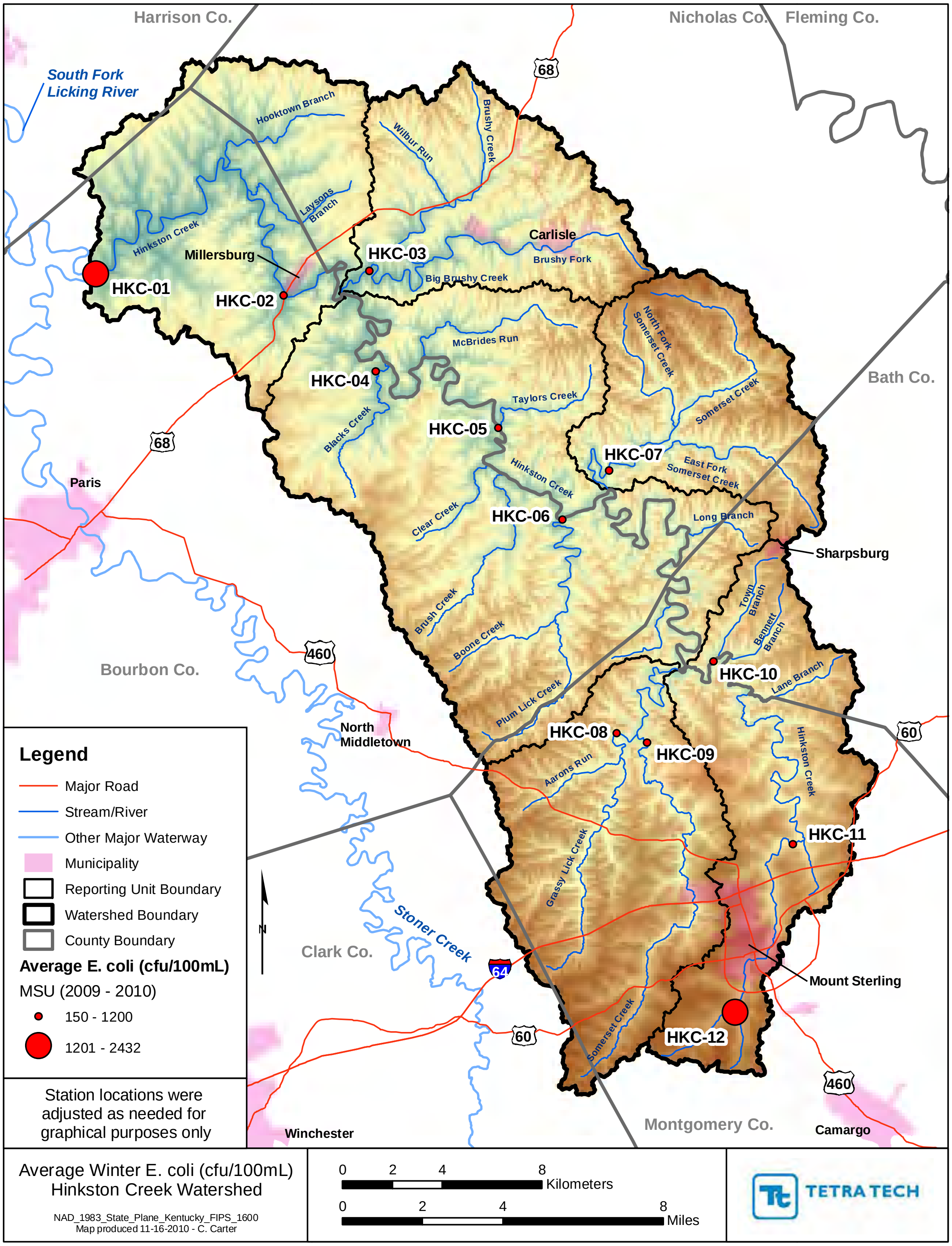


Figure 4-30. Average *E. coli* Measured in Winter at MSU Water Quality Stations

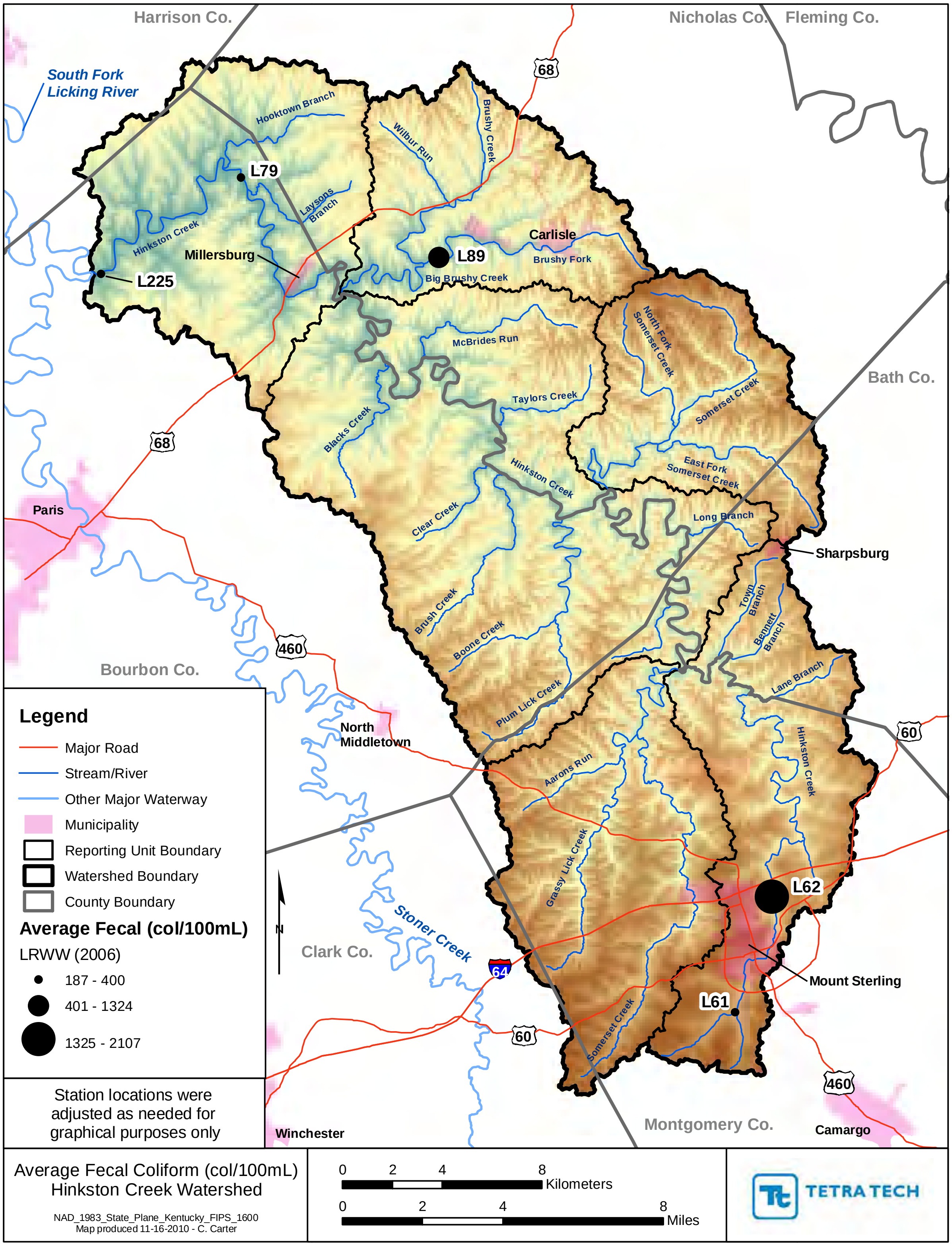


Figure 4-31. **Average Fecal Coliform Measured at LRWW Water Quality Stations (Only Measured in Summer)**

4.1.7.3 Longitudinal Profile Concentration

E. coli was observed during the MSU monitoring only. The *E. coli* sampling produced results which indicated relatively higher contributions of *E. coli* in the headwaters, upstream of river mile 51; this includes the headwaters of Hinkston Creek and Grassy Lick Creek (Figure 4-32 and Figure 4-33). Within Grassy Lick Creek, there was a slight indication that Somerset Creek (HKC-09) may contribute more to the elevated *E. coli* values due to the higher 75th percentile value than station HKC-08 during the summer months. Moving downstream, the median value for Blacks Creek was higher relative to most other stations. Note: The y-axis scale in the following figures was purposefully set to exclude the maximum value for the Hinkston Creek headwaters (16,500 cfu/100mL) while providing ease in interpretation of distributions for other stream reaches.

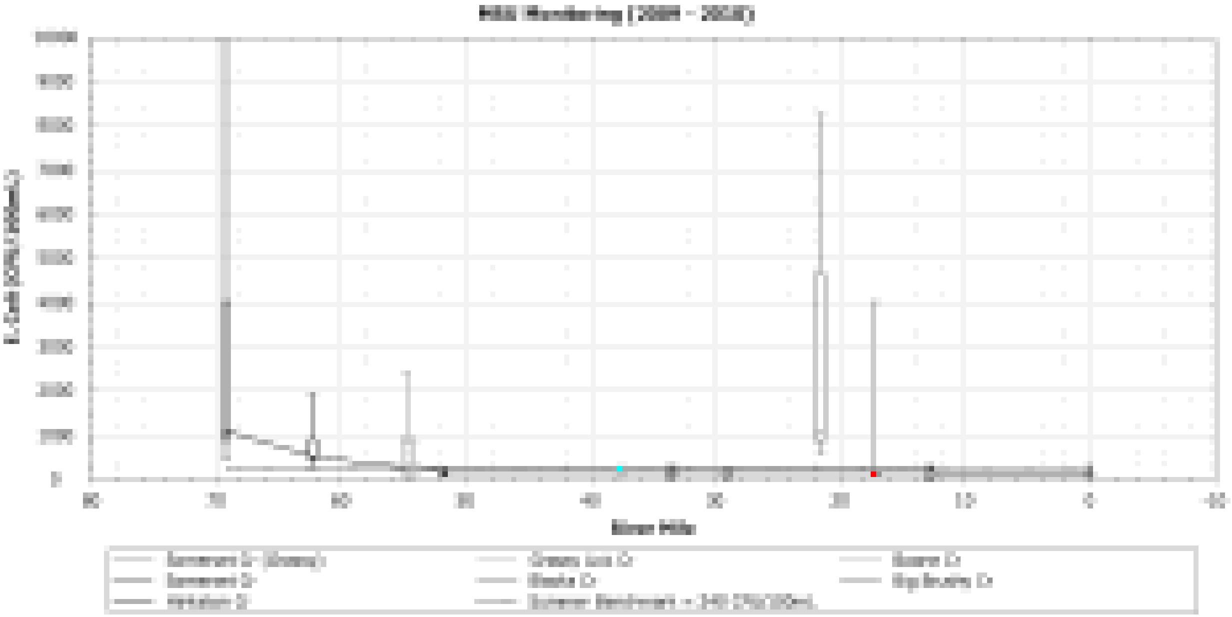


Figure 4-32. Longitudinal Profile of *E. coli* in Summer, MSU (2009 – 2010)

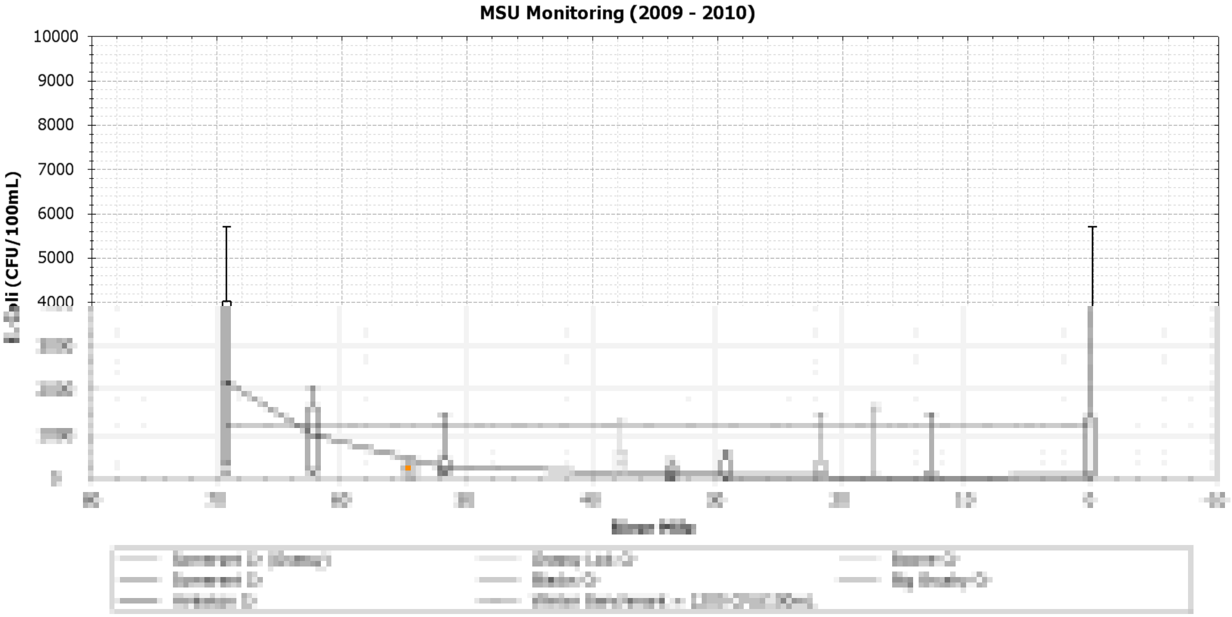


Figure 4-33. Longitudinal Profile of *E. coli* Winter, MSU (2009 – 2010)

4.1.7.4 Monitoring Data Loads

The MSU observations of flow and *E. coli* measurements were used to calculate summer and winter load. These are in-stream calculations of load, with no separation of point and nonpoint source contributions. These loads were averaged for each monitoring station and then converted to unit-area loads (Appendix). These values were developed into a plan view map (Figure 4-34 and Figure 4-35) to convey spatial location along with the magnitude of loading.

The summer loading was highest for the Somerset Creek tributary to Grassy Lick Creek and the upper portion of Hinkston Headwaters reporting unit (HKC-11 and HKC-12). However, four other stations also reported elevated summer average loading. The winter average benchmark loading was exceeded only in the Hinkston Headwaters (HKC-12) reporting unit.

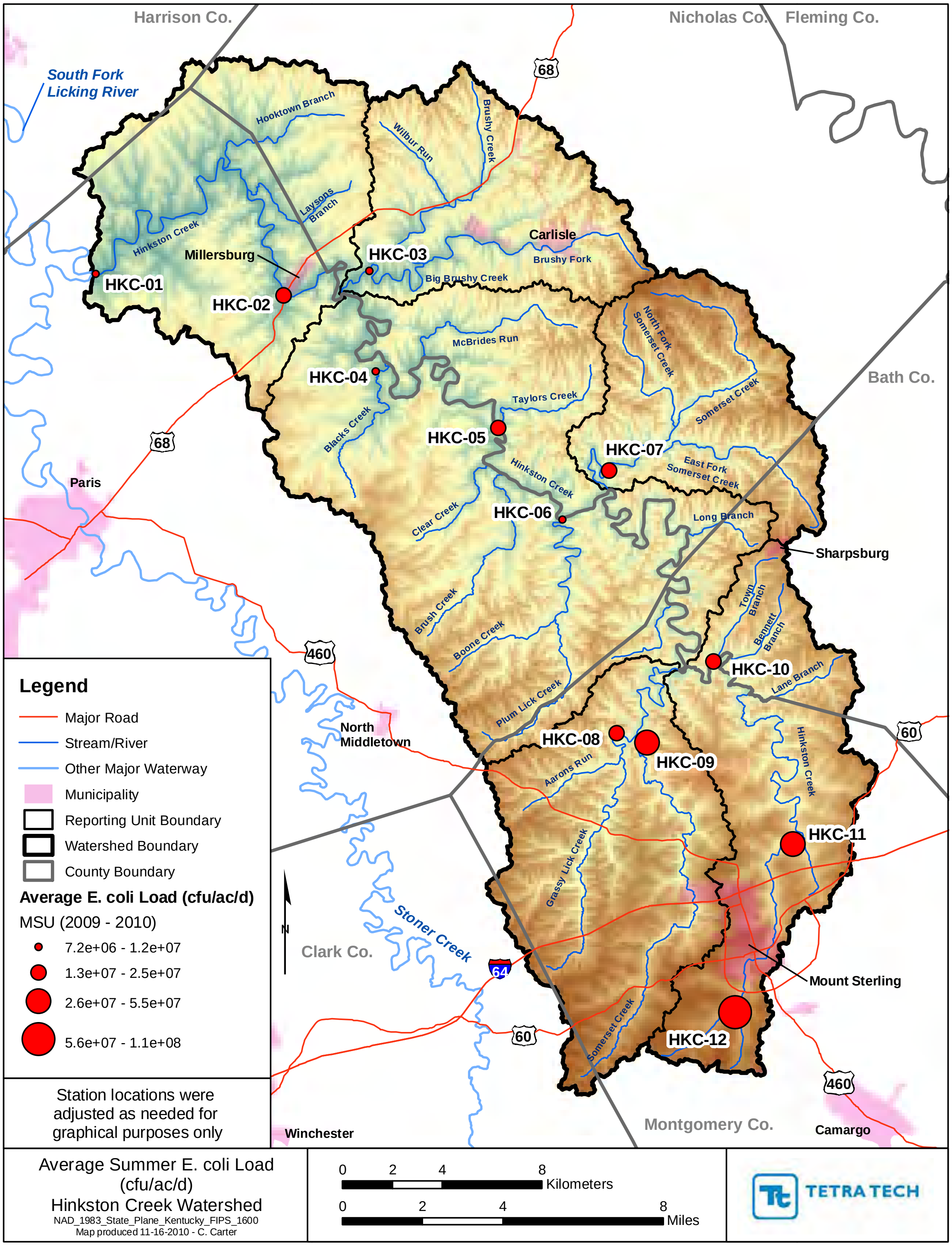


Figure 4-34. Average Summer *E. coli* Loading at MSU Water Quality Stations

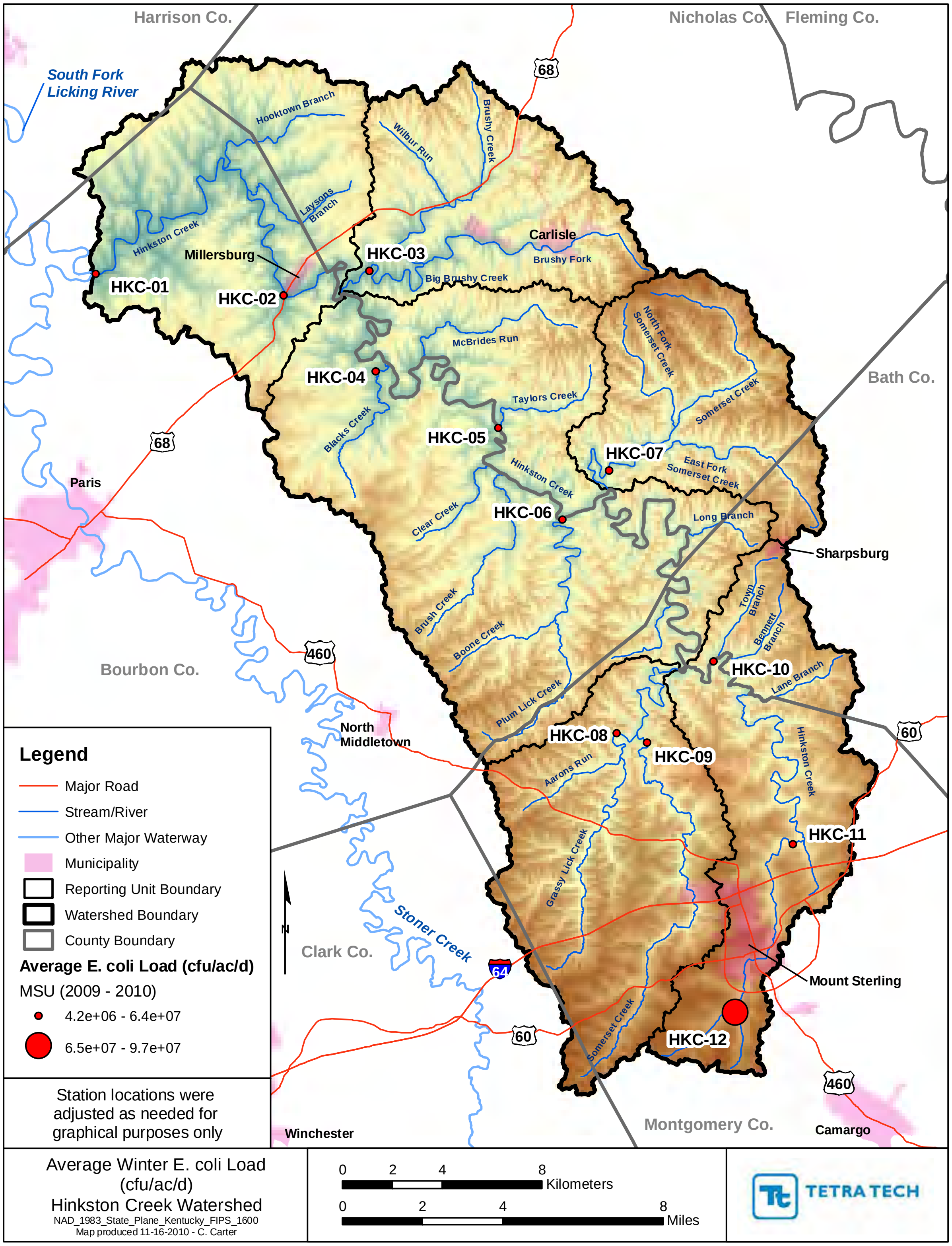


Figure 4-35. Average Winter *E. coli* Loading at MSU Water Quality Stations

4.1.7.5 Load Duration Curves

Load duration curves are a useful way to review monitoring data. The general indication of flow condition, that is high flow or low flow, can be assessed which may lead or help lead to source identification. This is important when considering BMP controls to affect water quality.

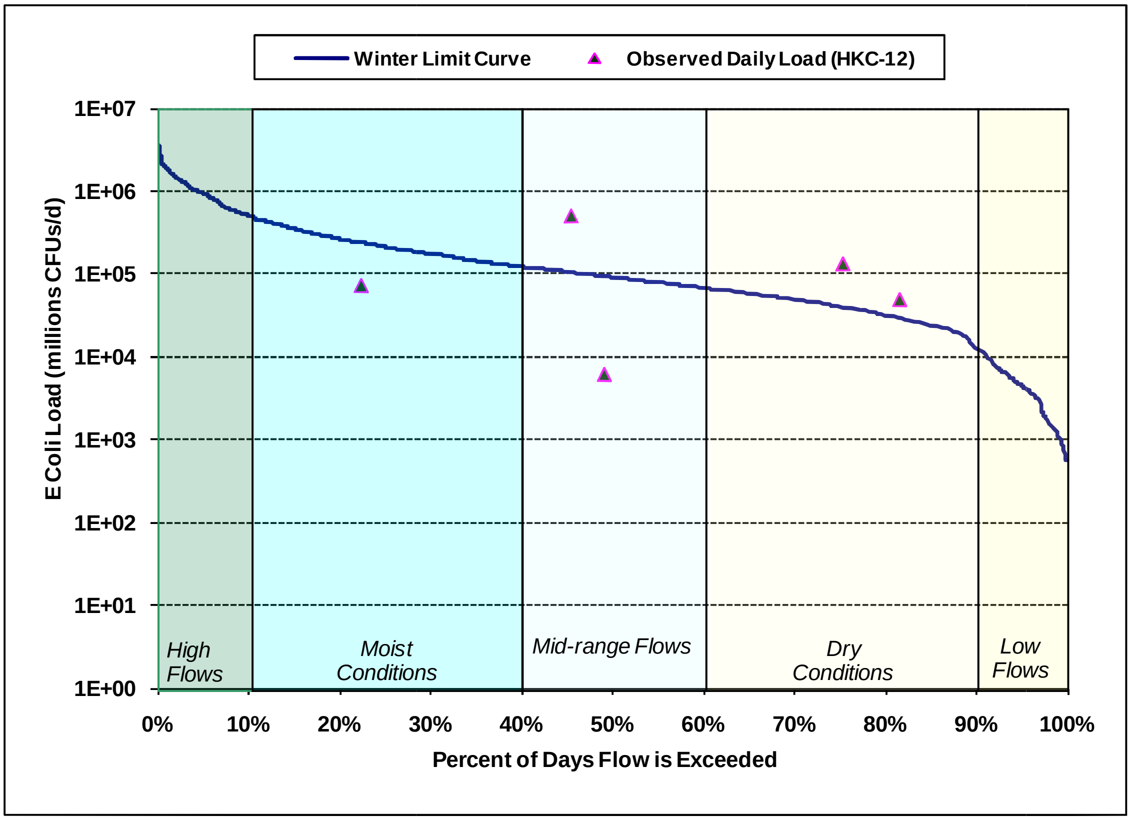
Load duration curves were generated for the observed *E. coli* data to assess seasonal characteristics as well as the nature of any excursions. These will be useful to help characterize when excursions occur and possibly inform whether they may be more related to causes such as septic systems, cattle in the stream, and/or runoff events. Winter and summer load duration curves were generated for each of the 12 MSU monitoring stations used for this project. The daily average flow record from USGS gage 03252300 was area-weighted to 11 water quality station locations to obtain an estimate of the daily average flow record at a specific station, one station (HKC-05) was coincident to the USGS station. The area-weighted flow records were developed for 2000 through September 2010, to coincide with the period selected for the SWAT watershed model simulation which was used for TN, TP, and TSS. The related figures are presented in F. The load duration curves have breaks to generally indicate flow condition, that is higher or lower flows. Section 2.2.1 discussed the historical context of the hydrology during the 2009 – 2010 monitoring period as being more dry than the 2004 – 2005 monitoring period. The observed data provide an adequate starting location to assess *E. coli* in the Hinkston Creek watershed, but further understanding would likely be achieved through sampling by storm chasing, bacterial source tracking, and other methods.

The proposed benchmark was described as a not-to exceed target but can also be used against mean values. The load duration curves afford the opportunity to assess a magnitude of the limit curve and the excursion, as well as characterize the flow condition. The flow conditions were categorized by the percent of days a given flow is exceeded and are shown in Table 4-6.

Table 4-6. Flow Condition Definitions

Percent of Days Flow is Exceeded	Flow Condition
0 – 10th	High
10th – 40th	Moist
40th – 60th	Middle
60th – 90th	Dry
90th – 100th	Low

Appendix F contains the load duration figures for all 12 MSU stations, the figures for station HKC-12 are repeated in this section (Figure 4-36) to provide context for discussion. The figures were reviewed by station and by season and the excursion requiring the greatest reduction was noted. This summary is presented in Table 4-7.



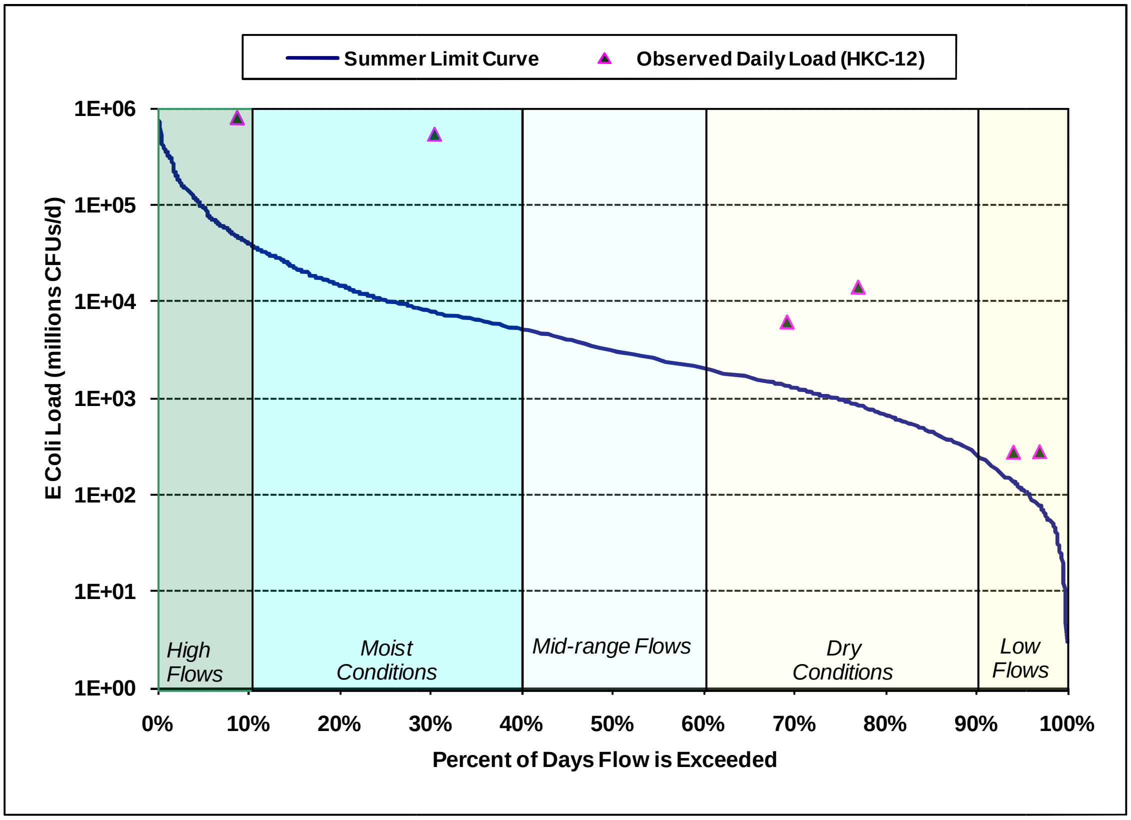


Figure 4-36. Load Duration Curve for Area Upstream of Calk Road (HKC-12)

Table 4-7. Summary of Maximum *E. coli* Load Excursions by Station

Station	Season	Flow Condition	Observed (million CFU/d)	Benchmark (million CFU/d)	Needed Reduction
HKC-01	Winter	Mid-range	3.1E+07	6.5E+06	79%
HKC-02	Summer	High	8.9E+06	2.4E+06	73%
HKC-03	Summer	Low	8.7E+03	5.2E+02	94%
HKC-04	Summer	Dry	9.3E+04	2.7E+03	97%
HKC-05	Summer	High	1.2E+07	1.8E+06	86%
HKC-06	Summer	High	6.9E+05	1.7E+05	76%
HKC-07	Summer	High	1.6E+06	2.7E+05	83%
HKC-08	Summer	High	1.9E+06	2.1E+05	89%
HKC-09	Summer	High	3.3E+06	2.1E+05	94%
HKC-10	Summer	High	2.9E+06	3.8E+05	87%
HKC-11	Summer	Low	3.6E+03	4.5E+02	87%
HKC-12	Summer	Moist	5.3E+05	7.7E+03	99%

The greatest excursions by station in the Lower Hinkston reporting unit (HKC-01 and HKC-02) occurred once in the summer and once in the winter, for high and mid-range flow conditions, respectively. Only one station was used for the Big Brushy reporting unit (HKC-03) and the greatest excursion occurred in summer during low flow condition. The Hinkston Midreach reporting unit consisted of three monitoring stations, two on tributaries (HKC-04 and HKC-06) and one on the mainstem (HKC-05). The greatest excursions all occurred during summer with two in high flow condition and one in dry flow condition. The Somerset Creek (HKC-07) reporting unit was represented with one monitoring station which had the greatest excursion in summer during high flow condition. The Grassy Lick reporting unit (HKC-08 and HKC-09) excursions were each for summer high flow conditions. The three Hinkston Headwaters reporting unit stations (HKC-10, HKC-11, and HKC-12) reported their greatest excursions across high, moist, and low flow conditions, but all were in summer. The greatest excursion occurred at HKC-12, for reference see Figure 4-36 in this section. There is one observed value in the moist flow condition bin, which is the data presented in Table 4-7 for HKC-12.

The needed reductions presented in Table 4-7are not for further use in the BMP evaluation portion of this report. The reductions are presented here only as another means of reviewing the observed data and providing some interpretation. Later chapters in this report will provide the analysis and development of loading regarding bacteria for use with BMP evaluation.

4.1.8 Pollutant Load Reduction Needs Based on Observed Data

The MSU data were used to estimate needed pollutant load reductions (i.e., in order to meet benchmarks) by reporting unit. In later sections for BMP evaluation, a similar exercise is also performed, however the starting point for loading values is SWAT simulation output for TN, TP, and TSS and a regression for *E. coli*. The KDOW data were not used in the exercise of this section as that monitoring was contained within only one reporting unit, Hinkston Headwater. The unit area loading values for the MSU stations within a reporting unit were combined, whether they were on the mainstem or not. However, the average unit area loading from the observations is an average of typically 12 discrete samples, it does not account for the full range of flows at a particular station. The difference from the benchmark unit loading rate and reduction are also noted in the tables (Table 4-8 through Table 4-10).

At the reporting unit level, total nitrogen loading exceeds the benchmark value (4.1 lb/ac/y) at all reporting units. This is consistent with other analyses conducted in chapter 4, which further suggests that nitrogen is a concern in the watershed. The mean unit loads for total phosphorus noted in the table show no exceedance of the benchmark loading rate of 0.5 lb/ac/y. This result may not be useful, but is still informative. The primary contributions of phosphorus is anticipated to come from point source dischargers. That contribution will show up more during low flow conditions rather than average conditions. The TSS values only present an exceedance of the benchmark value (40.8 lb/ac/y) at the Lower Hinkston reporting unit. Each of the monitoring periods were conducted on a monthly basis without storm sampling. Sediment observations are typically different during high flow events and while the limited data did not reveal a strong relationship of TSS to flow it is still reasonable to note that storm sampling may have plausible benefit to better understanding sediment. The use of the SWAT simulation output is expected to be more useful when assessing the impacts of BMPs. The *E. coli* benchmarks are being developed as a limit curve using load duration curves. Therefore *E. coli* will not be a part of this section.

Table 4-8. Pollutant Load Reductions Based on Observed Data, Total Nitrogen

Reporting Unit	Representative Station	Average Observed Load (lb/ac/y)	Difference from Benchmark (lb/ac/y)	Reduction to Average Observed Load (Percent)
Lower Hinkston	HKC-01, HKC-02	7.0	-2.9	42%
Big Brushy Creek	HKC-03	4.2	-0.1	3%
Hinkston Midreach	HKC-04, HKC-05, HKC-06	8.6	-4.5	52%
Somerset Creek	HKC-07	9.3	-5.2	56%
Hinkston Headwater	HKC-10, HKC-11, HKC-12	10.4	-6.3	61%
Grassy Lick Creek	HKC-08, HKC-09	6.5	-2.4	37%

Table 4-9. Pollutant Load Reductions Based on Observed Data, Total Phosphorus

Reporting Unit	Representative Station	Average Observed Load (lb/ac/y)	Difference from Benchmark (lb/ac/y)	Reduction to Average Observed Load (Percent)
Lower Hinkston	HKC-01, HKC-02	0.21	0.29	0%
Big Brushy Creek	HKC-03	0.10	0.40	0%
Hinkston Midreach	HKC-04, HKC-05, HKC-06	0.28	0.22	0%
Somerset Creek	HKC-07	0.24	0.26	0%
Hinkston Headwater	HKC-10, HKC-11, HKC-12	0.20	0.30	0%
Grassy Lick Creek	HKC-08, HKC-09	0.16	0.34	0%

Table 4-10. Pollutant Load Reductions Based on Observed Data, Total Suspended Solids

Reporting Unit	Representative Station	Average Observed Load (lb/ac/y)	Difference from Benchmark (lb/ac/y)	Reduction to Average Observed Load (Percent)
Lower Hinkston	HKC-01, HKC-02	43.8	-3.7	8 %
Big Brushy Creek	HKC-03	12.0	28.1	0 %
Hinkston Midreach	HKC-04, HKC-05, HKC-06	28.8	11.3	0 %
Somerset Creek	HKC-07	24.8	15.3	0 %
Hinkston Headwater	HKC-10, HKC-11, HKC-12	39.6	0.5	0 %
Grassy Lick Creek	HKC-08, HKC-09	25.3	14.8	0 %

4.2 PHASE 1 – PRIORITIZATION

Taking key assessment indicators from previous sections of this chapter, and guidance from KDOW, a ranking scheme was developed to prioritize the reporting units for BMP implementation, both for the initial, or near term phase of project selection and implementation and for latter phases. This ranking scheme has three key elements:

1. Stream water quality data, concentrations. Average concentration values were compared to benchmark values. KDOC/KDOW has provided guidance that monitoring data in the watershed should be given more weight (than modeling output) in the prioritization and BMP selection. Therefore this prioritization element is given a weight of 2.
2. Reporting unit simulated nonpoint unit area loads. While element number 1 is based on actual monitoring data, and given the highest weight, there are limited monitoring stations in the watershed. The reporting unit simulated loading estimates help provide a fuller view of potential watershed impacts. For this element, annual average unit area loads based on SWAT analyses, were compared to the benchmark values. This prioritization element is given a weight of 1.
3. Administrative Effectiveness. KDOC/KDOW has indicated a desire to begin BMP implementation in the southern portions of the Hinkston Creek watershed to ensure that investment in restoration and BMP projects downstream are not undermined by ongoing upstream issues. The southern areas, which are the farthest upstream areas along the mainstem, include the Grassy Lick and Hinkston Headwaters reporting units. This element is assigned a weight of 1.

The first element was assessed by combining MSU observation stations by reporting unit. The MSU data was used because it was a component of this study along with being the only observed dataset with at least one station in each of the six reporting units. The monitoring period was for one year, 2009 – 2010. The observed concentrations were compared to five benchmark values, shown in Table 4-11. The table also indicates which MSU stations were used to generate the average or maximum of observed values. Maximum observed values, as opposed to average values, were used as a conservative approach to assess *E. coli* levels for the watershed based on the understanding that health risks associated with exposure to bacterial contamination pose a greater threat to humans than do elevated levels of nutrients or TSS. The adopted benchmark values of TN, TP and TSS were based on average bioregion values, thus the observed data for this study were assessed as average values.Table 4-12 is populated with a 1 if the value from Table 4-11 was above the benchmark and a zero if it was not. The score for element 1 reflecting its weight is shown in the table.

Table 4-11. Observed Values Used for Prioritization

Reporting Unit	MSU Stations	Maximum E. coli (CFU/100mL) Summer	Maximum E. coli (CFU/100mL) Winter	Average TN (mgN/L)	Average TP (mgP/L)	Flow Weighted Average TSS (mg/L)
Benchmark	Not Applicable	240	1,200	0.976	0.132	9.82
Lower Hinkston	HKC-01 HKC-02	880	5,700	2.746	0.190	22.03
Big Brushy Creek	HKC-03	4,000	1,620	2.643	0.260	9.31
Hinkston Midreach	HKC-04 HKC-05 HKC-06	8,220	1,480	2.465	0.128	15.28
Somerset Creek	HKC-07	1,400	1,320	2.939	0.085	8.76

Reporting Unit	MSU Stations	Maximum E. coli (CFU/100mL) Summer	Maximum E. coli (CFU/100mL) Winter	Average TN (mgN/L)	Average TP (mgP/L)	Flow Weighted Average TSS (mg/L)
Hinkston Headwaters	HKC-10 HKC-11 HKC-12	16,500	5,700	2.867	0.144	10.75
Grassy Lick Creek	HKC-08 HKC-09	3,880	480	2.740	0.158	12.64

Table 4-12. Contribution of Instream Water Quality Data, Concentrations, Element 1 to Prioritization Score

Reporting Unit	Maximum E. coli Summer	Maximum E. coli Winter	Average TN	Average TP	Flow Weighted Average TSS	Element 1 Score
Lower Hinkston	1	1	1	1	1	(5 / 5) * 2 = 2
Big Brushy Creek	1	1	1	1	0	(4 / 5) * 2 = 1.6
Hinkston Midreach	1	1	1	0	1	(4 / 5) * 2 = 1.6
Somerset Creek	1	1	1	0	0	(3 / 5) * 2 = 1.2
Hinkston Headwaters	1	1	1	1	1	(5 / 5) * 2 = 2
Grassy Lick Creek	1	0	1	1	1	(4 / 5) * 2 = 1.6

Element 2 was used to represent the simulated nonpoint watershed unit area load, the simulation period was 10 years (2000 – 2010). All reporting units simulated nonpoint unit area loading values above the benchmarks for TN, TP, and TSS, thus the element 2 score for all reporting units was 1 (Table 4-13) with one exception. The Hinkston Midreach simulated a unit area loading value for TP of 0.49 lb/ac/year, just 0.01 lb/ac/year below the benchmark. Unit area loading was not simulated for *E. coli*. The third element was used to represent the directive from Kentucky to address the study area from the upstream portion first. The third element adopts a top-down approach of beginning implementation in headwater areas first. Finally, the prioritization score was calculated as shown in Table 4-13 and a rank was assigned to each reporting unit based on the prioritization score.

Table 4-13. Phase 1 Prioritization Score and Rank

Reporting Unit	Instream Water Quality Data, Concentrations Element 1 Score	Reporting Unit Simulated Nonpoint Unit Area LoadsElement 2 Score	Administrative Effectiveness Element 3 Score	Prioritization Score	Rank
Lower Hinkston	2.0	1	0	3 / 4 = 0.75	3
Big Brushy Creek	1.6	1	0	2.6 / 4 = 0.65	4
Hinkston Midreach	1.6	0.67	0	2.27 / 4 =0.57	5
Somerset Creek	1.2	1	0	2.2 / 4 =0.55	6
Hinkston Headwaters	2.0	1	1	4 / 4 = 1.00	1
Grassy Lick Creek	1.6	1	1	3.6 / 4 = 0.90	2

Figure 4-37 shows a plan view of the study area with the prioritization scores noted by reporting unit. The outcome was that the Hinkston Headwaters reporting unit received a rank of 1, and Grassy Lick was ranked second. Lower Hinkston received a rank of 3 and it is noted that each of the monitoring stations in that reporting unit were along the mainstem. Therefore the observed data (element 1) reflect the upstream contributions as well as the reporting unit specific nonpoint contributions. This also applies to Hinkston Midreach (rank 4), though that reporting unit contains two tributary stations (Blacks Creek and Boone Creek) and one on the mainstem. The remaining two reporting units are each headwaters, Big Brushy Creek (rank 4) and Somerset Creek (rank 5). The exercise of creating rankings was intended to help distill various pieces of information to aid the decision making process. While Somerset Creek resulted in the lowest ranking, problems still exist in that reporting unit such as cattle access to streams.

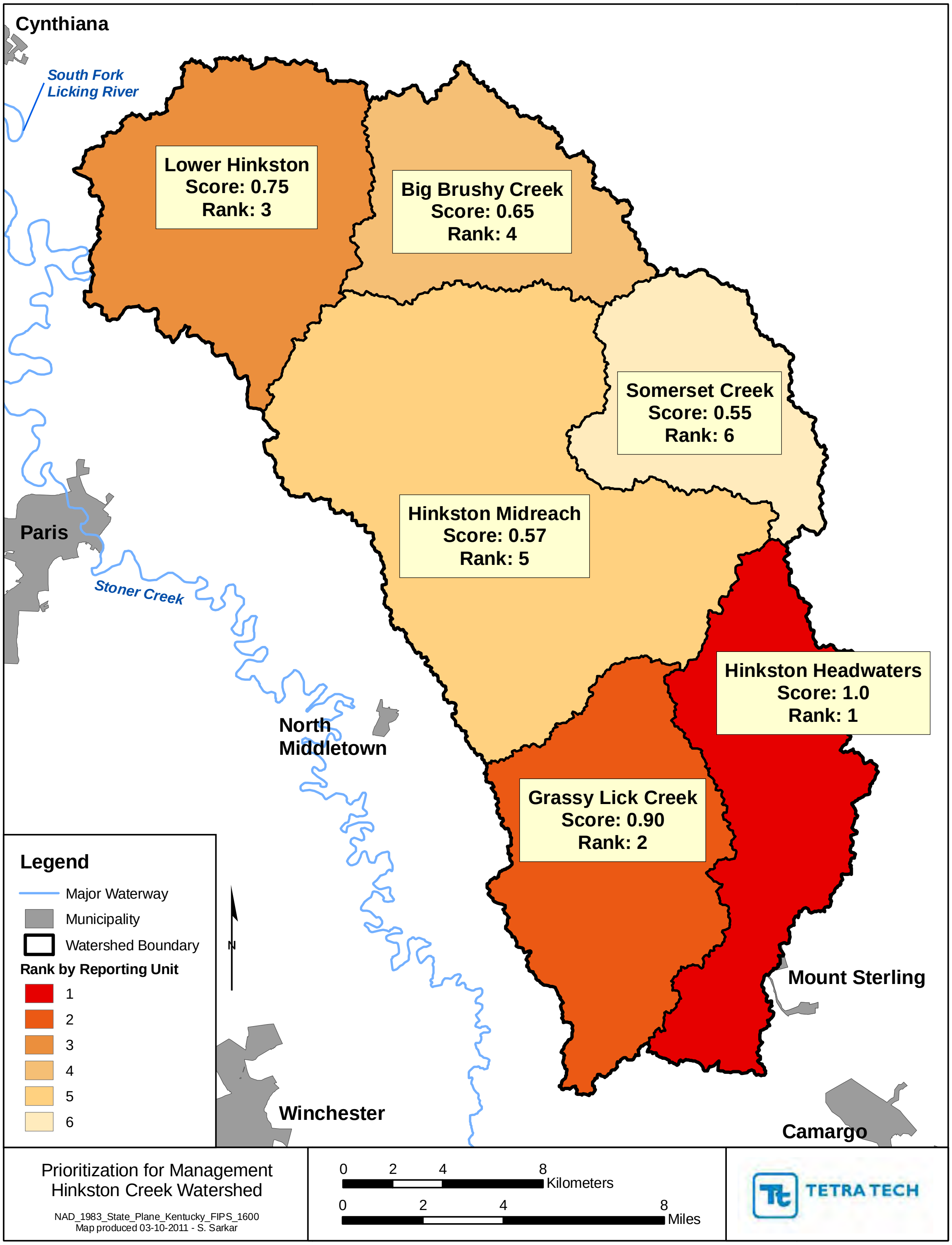


Figure 4-37. Hinkston Watershed Phase 1 Prioritization Score and Rank by Reporting Unit

5 Recommended BMPs

The previous chapters have documented existing conditions in the Hinkston Creek watershed and the potential stressors and sources that have led to impairment of designated uses within the watershed. In particular, disturbance of stream channels and banks from cattle access and vegetation removal have likely caused bank instability, leading to erosion and sedimentation throughout the watershed. This finding is not unexpected, given that approximately 70 percent of the watershed is devoted to production of pastured cattle that generally have free access to stream channels. Cattle access and pasture land uses have contributed to elevated nutrient, bacteria, and sediment concentrations in streams. Permitted wastewater discharges and on-site wastewater systems have also contributed to elevated concentrations of nutrients and bacteria at select locations in the watershed. Other land uses, such as row crops and urban development, are less influential from a whole watershed perspective but may be contributing locally to stream impairments.

The primary purpose of this plan is to develop recommendations for best management practices (BMPs) to address the major sources and stressors associated with the impairments. The first step in these recommendations was to identify the types of BMPs that would best address the existing stressors. Then watershed-wide estimates of available opportunities were developed based on available GIS data. The opportunities were measured in terms of stream length or land area in each reporting unit. Although the plan is focused on addressing existing stressors, increases in development and other future stressors could reverse efforts to address impairments. Therefore, management strategies to address future stressors are also discussed in this chapter. These preliminary considerations provide a foundation for more detailed recommendations within the Grassy Lick Creek and Hinkston Headwaters reporting units, which are addressed in Chapter 6.

5.1 BMPS TO ADDRESS EXISTING STRESSORS

The BMP selection process involved review of potential BMP types and identification of BMPs that would best address the major stressors associated with watershed impairment. Then, the selected BMPs were categorized in groups that corresponded to how they will likely be implemented. These steps are described in more detail in the following sections.

5.1.1 Selected BMP Types

The selection of potential BMPs began with a review of BMPs recommended for agricultural practices in Kentucky by the USDA NRCS (USDA, 2011). Urban stormwater BMP retrofits , stormwater treatment devices that treat existing urban development, were also considered in addition to agricultural BMPs. Based on observations of current agricultural practices in the watershed, a subset of BMPs was selected that would target the major stressors of concern. BMPs were sought that could address stream impacts from cattle and reduce erosion and pollutant concentrations in runoff from agricultural land due to land management practices. Detailed BMP methods specific to agricultural practices in the vicinity of the watershed were considered as well.

Based on these watershed concerns, the following BMPs were selected to represent the major strategies to be used during plan implementation. For the purposes of evaluating the costs and benefits of the plan, it was assumed that these BMPs generally represent the type, scope, and cost of the anticipated watershed management. Site-specific needs may call for different or additional strategies. Where applicable, the same terms used by the USDA (2011) are used below for consistency. The BMPs are defined as follows:

Pasture Renovation

Pasture renovation in the vicinity of the Hinkston Creek watershed involves both planting and soil measures. In general, seeds are drilled into the soil during the winter when the ground is frozen. This practice helps aerate the soil and augment the vegetative cover. This practice primarily addresses nutrient and sediment loading from pasture land. Once a pasture is renovated, this practice may not need to be repeated if the pasture is managed according to standard recommended methods.

Prescribed Grazing

This practice involves controlling the length of time and location of grazing animals, managed with the intent to achieve relatively uniform impacts to soil and vegetation. This practice may involve the rotation of animals among different grazing areas to allow for regrowth of grass, termed rotational grazing. The major water quality benefit of this practice is the reduction of nutrient and sediment loading from pasture land.

Use Exclusion

The goal of this practice is to minimize impacts to streams by restricting or excluding livestock access. Cattle exclusion is of particular interest in the Hinkston Creek watershed. The following components are typically used within the vicinity of the watershed (E. Boyd, NRCS Montgomery Office, personal communication to H. Fisher and P. Cada, November 2010):

- Fencing: Fencing along the length of the stream to prevent cattle access.
- Stream Crossing: A stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles. A ford crossing is typically used in the watershed vicinity at a gap in the exclusion fencing. The banks and channel are stabilized with rip rap or other stabilizing materials, and fencing is placed across the stream to prevent cattle access upstream and downstream of the gap.
- Water Access: A source of drinking water for cattle as an alternative to unlimited stream access. For the Hinkston watershed, the ford crossing will provide an alternative water source since this will allow the cattle limited access to the stream.

This practice is expected to provide reduction in nutrient, sediment, and bacteria loading and prevent further degradation of stream banks and channels.

Riparian Bank and Buffer Restoration

The recommended practices for restoring riparian buffers and stream banks are:

- Streambank and Shoreline Protection: Management practices used to stabilize and protect banks of streams or constructed channels, and shorelines of lakes, reservoirs, and other waterbodies.
- Riparian Forest Buffer Restoration: The restoration of natural vegetation along streambanks to a specified distance from a stream. Restoration of grass, tree, and shrubs were considered, although grass is likely to be the preferred vegetation for most landowners.

The major benefits of these practices include reduction of nutrient and sediment loading and improved function and stability of stream banks and channels. Stream stabilization/restoration in particular is expected to provide reduction in sediment and phosphorus loading from stream bank erosion. Riparian buffers provide filtering of sediment, nutrients, and bacteria as well as protecting near-stream land from erosion. Figure 5-1 provides an example of a restored riparian buffer applied along with use exclusion and prescribed grazing.

Grassed Waterways

A grassed waterway is a shaped or graded channel that is established with suitable vegetation to carry surface water at a non-erosive velocity to a stable outlet. This BMP was selected to reduce nutrient and sediment concentrations in runoff from both pasture and row crop land uses. This practice also reduces sediment loading by converting erosive drainage ditches to more stable, protected drainage pathways. Figure 5-2 provides an example of a grassed waterway on crop land.

Urban Stormwater Retrofits

Urban stormwater impacts are less pervasive than agricultural impacts in the Hinkston Creek watershed. However, this plan recommends application of urban stormwater control and treatment where appropriate. Besides water quality improvements, urban stormwater controls have the added benefit of reducing the rapid delivery of runoff to local streams, which can help to reduce flooding. For areas currently experiencing stormwater impacts, retrofits that detain, retain, infiltrate, and/or treat stormwater are recommended. Many potential types of BMPs may be considered. Devices that provide treatment of relatively large drainage areas (greater than 5 acres) include wet detention ponds, dry detention ponds, and constructed wetlands. Figure 5-3 provides an example of a wet detention pond. More distributed devices (e.g. rain gardens) that treat and/or infiltrate rooftop runoff or parking lots should also be considered. Riparian buffer restoration, similar to the above practice for agricultural settings, is also a viable option for the urban areas within Hinkston Creek. Removal of damaged, low-value structures in the floodplain in the flood prone area of Mt. Sterling and restoring floodplain water storage and other functions can reduce flood impacts and warrant further investigation as well.

The above list represents the BMPs that are likely to be cost-effective and feasible towards achieving pollutant load reduction, more stable streams, and ultimately reversing the impairment of designated uses. The benefits and costs of these BMPs are quantified for the Phase 1 priority areas in Chapter 6-1. Other BMPs that should be considered during implementation but were not quantified include septic tank inspection and management and education and outreach. The high-priority septic system impact areas (see Figure 2-29) were not found to be significant at the watershed or reporting unit levels, but do warrant further investigation to determine whether or not localized impacts might be degrading water quality within specific stream reaches.

Figure 5-1. **Example of restored riparian buffer, use exclusion, and prescribed grazing (photo courtesy of NRCS)**

Figure 5-2. Example of a grassed waterway (photo courtesy of NRCS)

Figure 5-3. Example of a wet detention pond (photo courtesy of H. Fisher)

5.2 BMP GROUPS

Once the individual BMPs were identified, they were categorized into groups towards achieving cumulative benefits and feasible implementation. Each grouping is defined below with an explanation for why the BMPs would provide the greatest benefits if implemented together.

Group 1: Pasture renovation, prescribed grazing, and use exclusion

This first BMP group is recommended as the most basic management strategy for pasture land where cattle currently have unlimited access to a stream. Cattle use exclusion, including a ford crossing with limited access for drinking water, will address instream stressors. Pasture renovation and prescribed grazing are recommended to address upland stressors. It is anticipated that many opportunities exist for implementation of these practices throughout the watershed, both in terms of the need to improve current land management practices as well as the potential for landowner interest in participation. The upland BMPs in this group can provide enhanced pasture productivity, and use exclusion is the least burdensome among the BMPs that address stream bank and buffer impacts.

Group 2: Pasture renovation, prescribed grazing, cattle exclusion, and riparian bank and buffer restoration -- 50-foot buffer

Group 2 builds on the first group by adding the riparian buffer and bank restoration BMP. This group of BMPs includes a 50-foot restored riparian buffer and stream bank stabilization and/or restoration.

Group 3: Pasture renovation, rotational grazing, cattle exclusion, and riparian bank and buffer restoration -- 100-foot buffer

Group 3 is identical to Group 2 except for the increase in restored riparian buffer width from 50 to 100 feet. It is anticipated that fewer landowners will be interested in this group compared to the above two groups. Where landowner interest exists, this additional width will provide greater reduction in pollutant loading from agricultural runoff.

Group 4: Grassed waterways

Grassed waterways are recommended separately from other BMPs since this BMP type applies to both pasture and row crop land uses. If a property has opportunities for pasture renovation, prescribed grazing, and grassed waterways, then these practices can be combined to achieve cumulative pollutant reduction. However, some properties may only have opportunities to convert ditches to grassed waterways, especially properties that do not have stream access or only contain row crop land use.

Group 5: Urban Retrofit BMPs

Similar to grassed waterways, urban retrofit BMPs are considered in a separate group because they apply to different land uses than the other BMPs. These BMPs are grouped together because the type of retrofit appropriate for a particular site is uncertain. Although BMP retrofit costs and pollutant removal can vary considerably, for evaluation purposes it will be assumed that a stormwater wet detention pond represents this BMP group in terms of relative cost and pollutant removal benefits.

Overall, the BMP groups provide a succinct method for evaluating the benefits and costs of the recommended watershed management while considering realistic application of BMPs to sites within the watershed. Groups 1 through 3 represent differing levels of effort and cost and theoretically could be applied to any reach with cattle access, deficient vegetation, and landowner interest in that particular BMP group. Group 4 is limited to land draining to small ditches, and Group 5 is limited to highly impervious, or urban, drainage areas. The following section estimates the available lengths and areas of opportunity for these BMPs across the watershed.

5.3 BMP OPPORTUNITIES

The available extent of BMP opportunities was estimated using geospatial (GIS) data and land use assumptions considering typical agricultural practices in the watershed. Areas of pasture and row crops and impervious areas were identified using the 2001 National Land Cover Dataset (NLCD) created by the Multi-Resolution Land Characteristics Consortium (MLRC). Riparian buffers were created in a GIS from the National Hydrography Dataset (NHD) flowlines which represent perennial and intermittent waterways.

Groups 1 through 3

The pollutant removal benefits of pasture renovation and/or prescribed grazing BMPs are expected to diminish with distance from streams and only properties that intersect streams are expected to have opportunities for use exclusion. Therefore, only pasture lands directly connected to near stream area were considered for potential BMP implementation under groups 1, 2, and 3. To select these areas, the near stream area was defined as 50 feet from NHD flowlines. This width is different from the recommended restored buffer widths (50 or 100 feet from streams), and the near stream area assumption is only used to approximate the pasture land area that is directly connected to streams. All contiguous areas of land under pasture management connected to the near stream area (50 feet from streams) were identified and totaled for each reporting unit regardless of how far the pasture land was from the near stream area (Table 5-1). As noted above, land was identified as pasture using the 2001 NLCD. Since parcel boundaries were not available, selecting pasture land contiguous with the near stream area allowed for an approximation of properties that would likely have stream access. Within the land selected, cattle existing on any portion of the land could theoretically have access to a stream reach.

The approximate number of landowners in Table 5-1 is based on the assumption that, on average, approximately 60 acres of pasture land is owned by one particular individual, or group of individuals (personal communication, Edsel Boyd, NRCS Montgomery Office, to H. Fisher and P. Cada, November 2010). The use exclusion length estimates in Table 5-1 are based on the length of flowlines (streams) that have pasture lands within the near stream area. Riparian buffer restoration opportunities were considered those areas that are lacking healthy riparian forest cover (areas with less than 40 percent canopy coverage, see Section 2.4 for more details) coincident with the pasture lands identified under BMP Group 1. Corresponding to Groups 2 and 3, 50-foot and 100-foot buffer restoration opportunities were estimated. It is estimated that one stream crossing, on average, would be required for each property with cattle access to streams, and this number is represented by the number of landowners in Table 5-1.

Group 4

Since grassed waterway BMPs are not dependent on proximity or intersection with streams or the near stream area, all areas of pasture and row crop within the Hinkston Creek watershed were considered for this BMP group. A geospatial coverage of drainage ditches was not available at the time of this study so assumptions of total waterway length per landowner was made based on information from Montgomery County NRCS. Within the watershed, drainage ditches frequently run parallel to the nearby stream with other ditches forming a larger diversion ditch that directs flow to a stream or creek. Often, these larger drainage ditches are found flowing perpendicular to the receiving stream’s flow direction (personal communication, Edsel Boyd, NRCS Montgomery Office, to H. Fisher and P. Cada, November 2010).

A typical property under pasture management that is assumed to be 60 acres in size with a rectangular shape, an estimated length of 1,500 feet, and an estimated width of 1,700 feet (i.e., average property size assumed to be 58.5 acres, or 1,700 feet by 1,500 feet). Another assumption, typical of practices within the watershed, is that each property has one diversion ditch flowing perpendicular to hill slopes with an approximate length of 1,500 feet that then flows into two diversions ditches per property (on average) each with a length of 1,700 feet. These two 1,700 feet ditches are assumed to drain to an adjacent property or road ditch system, or a nearby stream (personal communication, Edsel Boyd, NRCS Montgomery Office, to Heather Fisher and Peter Cada, November 2010). These assumptions lead to an estimated total of 4,900 linear feet of drainage ditches per property that could be converted to grassed waterways. The length of potential grassed waterways in pasture lands for each reporting unit (Table 5-1) was determined by multiplying 4,700 feet by the estimated number of landowners (determined by dividing total pasture area in acres in each reporting unit by 58.5 acres/property).

For areas with row crops, an average individual property is assumed to be 100 acres (personal communication, Edsel Boyd, NRCS Montgomery Office, to H. Fisher and P. Cada, November 2010). As with properties under pasture management, the total area of row crop land uses in each reporting unit was divided by 100, yielding an approximate number of landowners. Next, the approximate number of properties under row crop management was multiplied by the perimeter of a rectangular 100 acre property (8,342 feet). Table 5-1 shows the approximate length of drainage ditches available for implementation of the grassed waterway BMP.

Group 5

Existing areas of urban development that may be appropriate for the BMPs within this group were estimated by buffering existing municipal boundaries by ½ mile in all directions to capture any recent developments on the fringes of current urban areas. Impervious surface drainage area within the buffered municipal areas were estimated using the NLCD 2001 dataset (Urban Area Retrofit BMPs in Table 5-1).

Across all BMP groups, the areas and lengths in Table 5-1 provide a perspective on the extent that watershed management opportunities exist throughout the watershed. These estimates also provide a foundation for estimating the benefits and costs of recommended BMPs in the Phase 1 priority areas, which is addressed in Chapter 6.

Table 5-1. Preliminary BMP Opportunity Statistics

Reporting Unit	Approx. Number of Pasture Land Owners	Approx. Number of Row Crop Land Owners	BMP Groups 1, 2, and 3				BMP Group 4		BMP Group 5
			Pasture Renovation and Prescribed Grazing	Use Exclusion	50-foot Riparian Buffer and Bank Rest.	100-foot Riparian Buffer and Bank Rest.	Grassed Waterways		Urban Area Retrofit BMPs
			Area (acres)	Length (feet)	Length (feet)	Length (feet)	Length in pasture (feet)	Length in row crops (feet)	Impervious Drainage Area (acres)
Hinkston Headwaters	266	4	14,008	339,208	339,145	62	1,252,092	17,173	5,964
Grassy Lick Creek	280	5	14,967	377,060	376,989	71	1,317,405	22,911	481
Hinkston Midreach	653	10	36,281	956,137	876,834	79,303	3,067,422	47,448	9
Somerset Creek	180	5	9,863	272,423	272,423	0	844,314	24,015	27
Big Brushy Creek	208	4	11,031	288,172	288,122	50	978,889	17,926	1,594
Lower Hinkston	352	11	19,262	445,150	415,790	29,359	1,656,222	53,349	431
Watershed Total	1,940	39	105,412	2,678,149	2,569,303	108,846	9,116,344	182,822	8,506

5.4 BMPS TO ADDRESS FUTURE STRESSORS

The major focus of this watershed plan is to address existing stressors that are linked to watershed impairments. However, consideration of future changes in land uses and watershed conditions is essential to the success of plan implementation and ultimate watershed improvement. The most likely future change in land use is the conversion from agricultural to urban land uses, and this change is likely to be concentrated within and near the municipal boundaries of Mount Sterling, Millersburg, and other incorporated entities within the watershed.

Urban development can be a major source of water quality stressors. In areas with urban development, runoff from impervious surfaces increases the speed of runoff and decreases the amount of soil infiltration, which leads to an increase in both the volume and velocity of storm flows. This runoff carries pollutants from roads, driveways, rooftops, lawns, and other land into surface waters. The increase in flow erodes stream banks and channels beyond their natural capacity, leading to unstable, degraded streams. Point sources, including municipal wastewater treatment plants, further contribute to these stressors by introducing additional pollutant loads and flow to the system. If the existing urban areas continue to develop and expand, these processes may contribute to further water quality and habitat degradation.

If urban areas and densities increase, local governments may enact stricter stormwater control and treatment requirements, or they may be required by KDOW to develop municipal stormwater management programs as part of EPA's Phase II stormwater requirements. Whether through requirements, incentives, or voluntary means, development techniques are available that help minimize watershed impacts from development sites. The most promising techniques include:

- Low Impact Development (LID) Site Planning– Development site planning that mimics the pre-development natural hydrology of a site. An important component of LID site planning is an evaluation of the pre-development conditions of a site. During this evaluation, areas that provide infiltration or other natural amenities are selected to be preserved while more impacted areas are selected for development. The location of BMPs on the site is also evaluated to take advantage of existing flow patterns and high infiltration areas. Figure 5-4 shows an example site evaluation.

- Water Re-Use – Integrating stormwater storage facilities within a development and using that water for landscaping irrigation and other uses. Facilities used to harvest stormwater include ponds and cisterns. These applications are most successful with an automatic harvesting system to ensure that the water is used prior to the next large storm event. Figure 5-4 shows an example of a cistern.

- Disconnection of Impervious Surface and Permeable Pavement – Grading parking lots and other impervious surface so that runoff drains to natural or engineered infiltration areas. Permeable pavement can also be used for low-traffic areas to provide additional infiltration and reduction in runoff. These techniques are related to LID in that they can be used to achieve a more natural water budget on a development site. Figure 5-4 shows examples of permeable pavement and impervious surface disconnection.

LID and water re-use provide cost savings and profitability benefits as well as enhanced water quality protection. In particular, natural area preservation can increase property values by enhancing the natural beauty of a site, and reduced impervious surface and stormwater infrastructure can provide cost savings. For example, in the Gap Creek subdivision in Sherwood, AR, an increase in open space from 1.5 to 23.5 acres resulted in a sale price increase of $3,000 per lot and a development cost savings of $4,800 per lot, achieving $2.2 million additional profit for the developer. More examples of cost savings and increased profits through LID are provided in NCSU (2009) and NCSU (2010).

These techniques are provided for reference and for consideration if significant changes in development occur or are expected to occur in the future. As current agricultural practices are the most widespread concern relating to watershed impairments, the evaluation of BMPs in this plan is focused on addressing the existing stressors.

Figure 5-4. Examples of innovative stormwater design (clockwise from top left): Low Impact Development site planning, pervious pavement, parking lot draining to a bioretention cell, and cistern used for rain water harvesting (Source: NCSU (2009) and Heather Fisher, Tetra Tech)

6 Strategy for Success

The Hinkston Headwaters and Grassy Lick reporting units were identified in Section 4.2 as the highest priority for management within the Hinkston Creek watershed. In Section 4.2 three elements were used for Phase 1 Prioritization which were observed concentration, simulated loading (i.e., via the SWAT model), and administrative effectiveness. With the exception of *E. coli* concentrations in Grassy Lick during the winter months, all observed concentration and SWAT simulated loading values exceeded the respective benchmark within these two reporting units. In addition to these concerns, beginning implementation within the upper watershed, which is encompassed by these reporting units, will help ensure that management efforts succeed and are not impacted by upstream conditions. These reporting units contain extensive management opportunities. The majority of the land is in pasture, which affords many opportunities to work with landowners on limiting cattle access, restoring riparian buffers, and enhancing pasture management. A small but significant area of row crop exists as well, and several municipalities are present, including Mount Sterling. Overall, the Hinkston Headwaters and Grassy Lick reporting units provide substantial opportunities for addressing watershed impairments.

The strategy for successfully addressing watershed impacts and restoring designated uses involves a finer consideration of impacts within the reporting units and an evaluation of BMP benefits, costs, and feasibility. First, in the Phase 2 Prioritization, the reporting units are divided into reaches and prioritized to determine the areas with the greatest management need. Since impacts are known to be widespread, these priority areas will be used to guide BMP implementation, but BMPs will not be limited to these priority reaches.

Next, a cost-benefit analysis is presented that compares the pollutant load reduction benefits and costs across the BMP groups and two reporting units. This analysis helped determine the likely extent of BMPs that are feasible and cost-effective as well as the achievable pollutant load reduction. The estimated unit loads with BMPs are compared to the benchmarks to illustrate the progress that can be achieved through BMP implementation efforts. It should be noted that the water quality benchmarks selected for TN, TP, and TSS are based on Bluegrass bioregion reference reach data and, hence, represent fairly aggressive objectives for the heavily impacted Hinkston Creek watershed. The BMP implementation strategies described in this section acknowledge the “high bar” that has been set through the adoption of these benchmarks and recognize that adjustments might be necessary as plan implementation rolls out via the adaptive management approach described in Chapter 7.

Finally, the recommended implementation actions and schedule are outlined in light of the prioritization and cost-benefit analysis results. These recommendations seek to provide a strategy for successful BMP implementation and to lay a foundation for overall watershed improvement.

6.1 PHASE 2 PRIORITIZATION

As the first step of the Phase 2 Prioritization, the Hinkston Headwaters and Grassy Lick Creek reporting units were divided into nine areas for management prioritization based on the location of KDOW and MSU water quality monitoring stations. Major tributaries that did not have an associated monitoring station were assigned to one of the nine areas included in the prioritization process (e.g., Aaron’s Run is upstream from HKC-08 and is therefore included in the Grassy Lick Creek drainage area specified below). These nine areas (and their corresponding stations) are as follows:

1. Town Branch (05016024 and 05016028)
2. Bennett Branch (05016023)

3. Lane Branch (05016022)
4. Unnamed Tributary to Hinkston Creek (Twin Oaks Subdivision/Industrial Park; 05016021)
5. Upstream of Calk Road (05016020 and HKC-12)
6. Somerset Creek (HKC-09)
7. Grassy Lick Creek (HKC-08)
8. Hinkston Creek (Mainstem Portion)
9. Grassy Lick Creek (Downstream Portion)

Seven (numbered 1 through 7) of these nine areas were ranked using in-stream water quality data, riparian buffer deficiency status, habitat data, and results from the geomorphic visual assessment survey. The two remaining areas (numbered 8 and 9) were not formally ranked but were included in the final prioritization for Phase 2 which involved categories of high, medium, and low priority. The decision to not formally rank the mainstem portion of Hinkston Creek and the downstream portion of Grassy Lick Creek was for one of two reasons – either a monitoring station was not located in the reach (Grassy Lick downstream portion), or the monitoring stations that were located in the reach received water draining from one or more headwater reaches already accounted for in the ranking process (Hinkston mainstem portion). Ranking and prioritization methods for the Phase 2 prioritization are discussed in the following paragraphs.

Water Quality

The Phase 1 prioritization used only the MSU data set because it had greater spatial coverage than the KDOW data set and at least one station was located in each of the six reporting units. Furthermore, the MSU monitoring (2009-2010) was part of the current Hinkston watershed project. The KDOW monitoring data will now also be considered as an element for ranking in the Phase 2 prioritization. The KDOW monitoring was conducted only in the Hinkston Headwaters reporting unit in 2004-2005 with 10 water quality station locations. The concentration values were reviewed against the adopted benchmark values to determine if that element of the Phase 2 prioritization received a score of zero (acceptable) or one (concern).

Riparian Buffer Deficiency Analysis

The riparian buffer deficiency analysis was used as an element to rank reaches in the Phase 2 prioritization. Figure 2-17 was used to assign a score for this element to a drainage area within the two priority reporting units. The figure presented the riparian deficiency results divided into three categories. These three categories were assigned scores of 0.33 (lowest concern), 0.67, and 1.0 (highest concern).

Water quality data, except for *E. coli*, and riparian buffer status were available for each of the seven reaches included in the ranking portion of the Phase 2 prioritization. For this reason, scores from these two elements were combined to rank stream reaches (

Table 6-1). For all ranked areas, reaches were first assigned scores where the highest score indicated highest concern. Following the scoring process, each reach was ranked so that the highest scoring reach received the rank of highest priority and was represented by the rank of 1. The highest combined score (i.e., Upstream of Calk Road, 0.90) received the highest priority ranking with a rank of 1 and the lowest combined score (i.e., Lane Branch, 0.50) received the lowest priority ranking with a rank of 6. In later steps of the prioritization process, these rankings will be used with habitat data and results from the geomorphic visual assessment to further prioritize reaches into the three categories of high, medium, or low priority.

Table 6-1. Water Quality Data (Concentration) and Riparian Buffer Deficiency Scores and Ranking

Description	Town Branch (05016024 and 05016028)	Bennett Branch (05016023)	Lane Branch (05016022)	Twin Oaks/Industrial Park (05016021)	Upstream of Calk Road (05016020 and HKC-12)	Somerset Creek (HKC-09)	Grassy Lick Creek (HKC-08)
Water Quality Individual Parameter Scores							
Nitrogen	1	1	1	1	1	1	1
Phosphorus	1	1	0	0	0	1	1
TSS	1	1	1	1	1	1	1
E. coli (summer)	NA	NA	NA	NA	1	1	1
E. coli (winter)	NA	NA	NA	NA	1	0	0
Element Scores							
Water Quality Monitoring Data Score (Weight = 1)	3 / 3 = 1.0	3 / 3 = 1.0	2 / 3 = 0.67	2 / 3 = 0.67	4 / 5 = 0.80	4 / 5 = 0.80	4 / 5 = 0.80
Riparian Buffer Deficiency Analysis Score(Weight = 1)	0.67	0.67	0.33	0.67	1	0.33	0.67
Total Scores and Ranking							
Water Quality and Riparian Buffer Deficiency Score	0.84	0.84	0.50	0.67	0.90	0.57	0.74
Rank	2	2	6	4	1	5	3

In addition to water quality data and riparian buffer deficiency, some of the reaches had data available from a habitat assessment conducted by KDOW and/or a geomorphic visual assessment performed by Tetra Tech. Results from each assessment are discussed in the following paragraphs.

Habitat Scores

Habitat scores were developed by Kentucky at few stations in the Hinkston watershed and only in the Hinkston Headwaters of the two priority reporting units; Grassy Lick Creek and Somerset Creek were not included in this assessment. Several reaches were found to have scores below the 114 benchmark value (KDOW's (2008) tentative habitat criteria), but the lowest scoring reach was the area upstream of Calk Road (Table 6-2). The resulting ranks based on habitat scores (1 = highest priority, 6 = lowest priority) will be used in later steps of the prioritization process.

Table 6-2. Habitat Scores and Ranking

Description	Town Branch A 05016018	Town Branch B 05016024	Bennett Branch 05016023	Lane Branch A 05016022	Lane Branch B 05016022	Twin Oaks/ Industrial Park 05016021	Upstream of Calk Road 05016020
Habitat Score	78	126	109	115	88	100	67

Date	7/15/1999	3/23/2004	3/23/2004	3/23/2004	3/23/2004	5/6/2004	3/23/2004
Rank	NA[1]	6	4	5	2	3	1

[1] The habitat score for Town Branch A was not included in ranking because it was the only score reported in 1999.

Geomorphic Visual Assessment

The geomorphic visual assessment survey was an important component of the Hinkston Creek watershed project. The protocol for the assessment was based on three parameters from the NRCS *Stream Visual Assessment Protocol* (NRCS, 1998). Staff were deployed on-the-ground to walk stream segments and perform an assessment. This effort was dependent on willing landowners providing permission to access the stream. Several of the reaches included in the Phase 2 prioritization were unable to be assessed due to unreached landowners. The reaches where landowners were not able to be contacted should be evaluated at a later date when landowner permission is obtained.

The geomorphic survey consisted of three parameters which are described as follows.

1. Stream channel erosion status.
2. Riparian buffer vegetation status.
3. Access of cattle to streams.

A scoring system from one (concern) to 10 (acceptable) was used for each of the three parameters (Figure 6-1 through Figure 6-3).

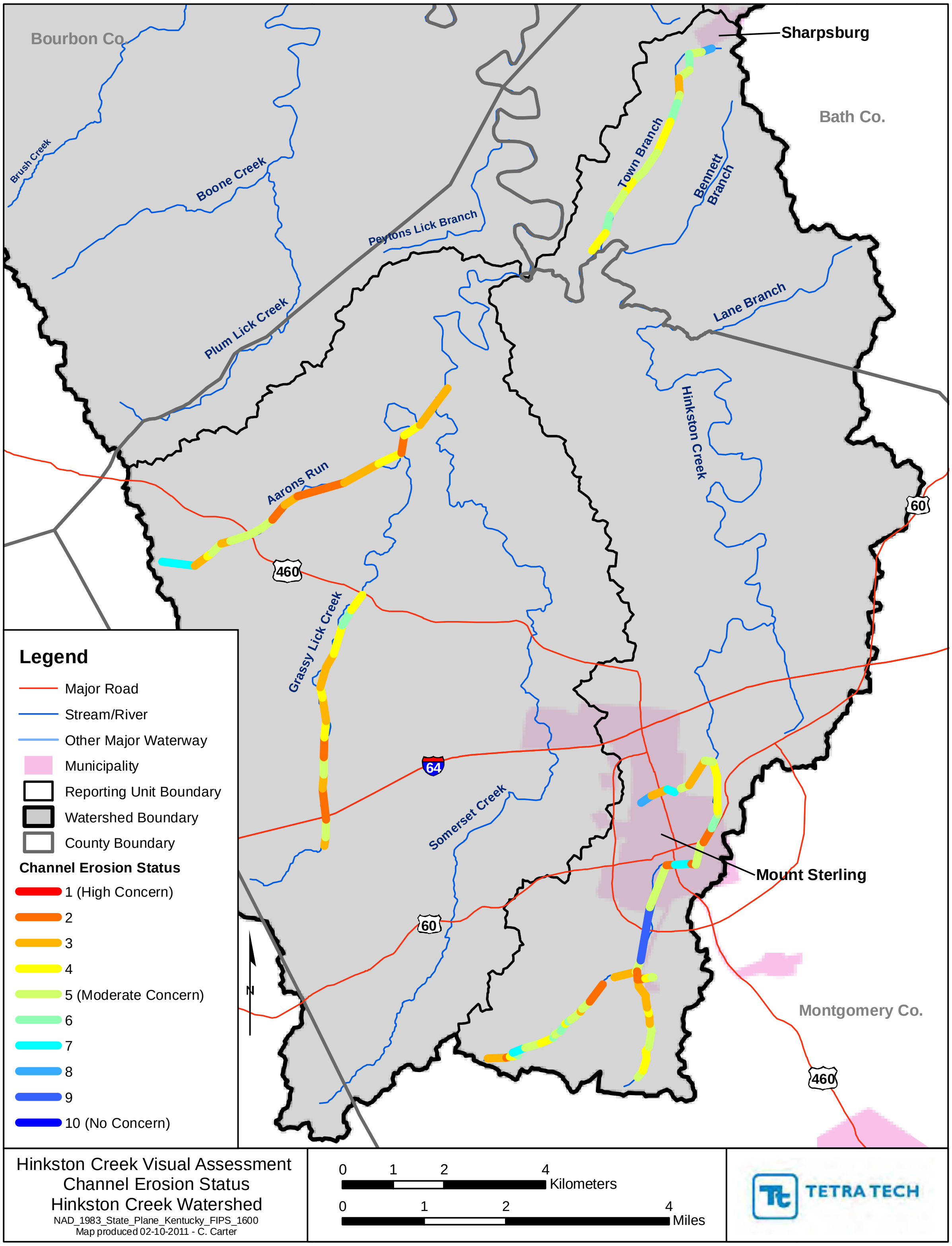


Figure 6-1. **Stream Channel Erosion Status**

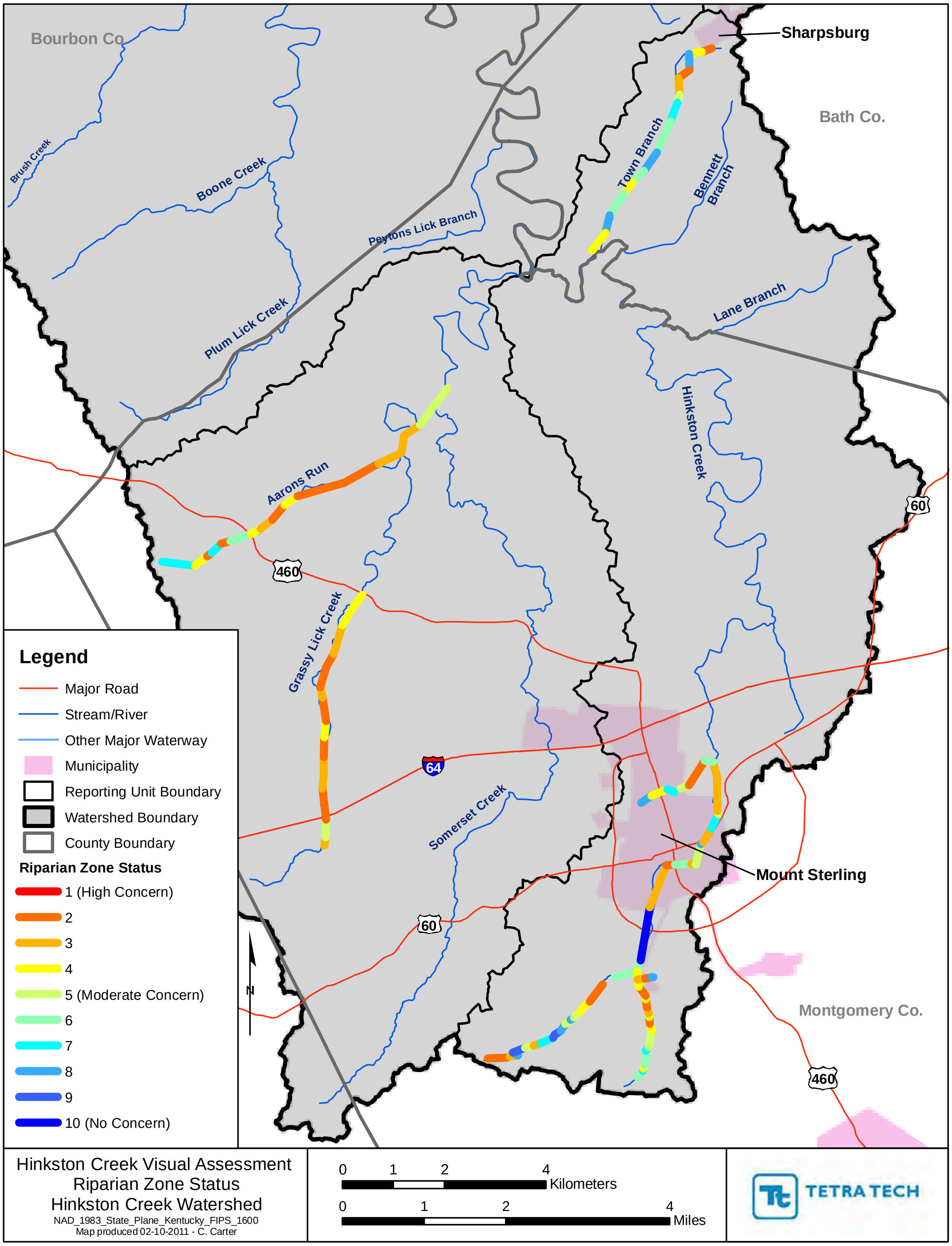


Figure 6-2. Riparian Buffer Vegetation Status

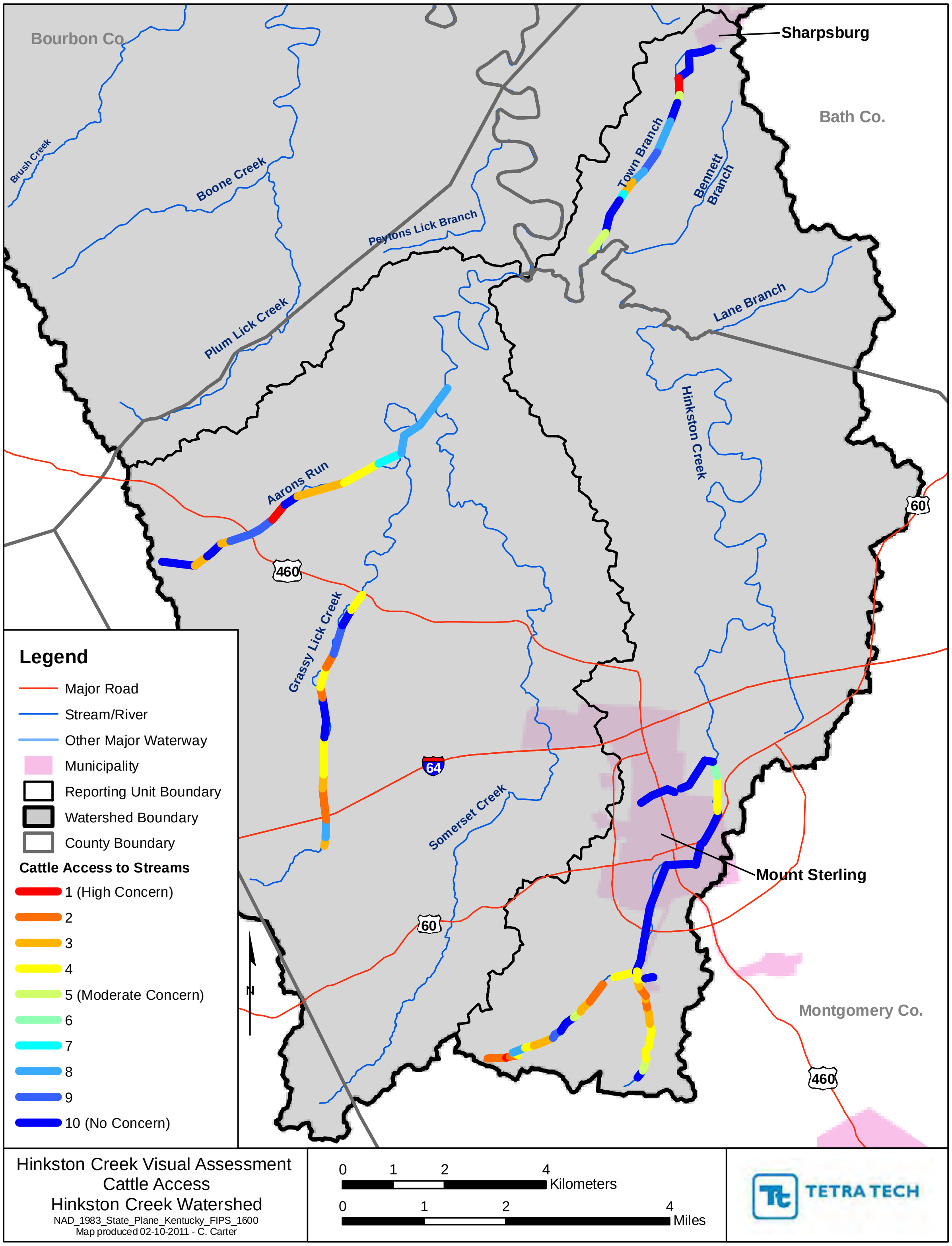


Figure 6-3. Cattle Access to Streams

The average field survey score was converted to an element score for ranking reaches as part of the Phase 2 prioritization (Table 6-3). The conversion to an element score was done to achieve consistency with other element scores where zero meant acceptable and one was used to indicate a concern. The conversion was performed as noted in the following equation.

Element score = 1 – (average field score / 10)

Table 6-3. Geomorphic Field Survey Element Scores and Ranking

Description	Town Branch	Bennett Branch	Lane Branch	Twin Oaks/Industrial Park	Upstream of Calk Road	Somerset Creek	Grassy Lick Creek
Individual Parameter Scores							
Stream Channel Erosion Status	0.5	NA	NA	NA	0.6	NA	0.6
Riparian Zone Status	0.5	NA	NA	NA	0.5	NA	0.7
Access of Cattle to Streams	0.2	NA	NA	NA	0.5	NA	0.4
Total Scores and Ranking							
Geomorphic Field Survey Score	1.2	NA	NA	NA	1.6	NA	1.7
Rank	3	NA	NA	NA	2	NA	1

Ranking Results

Phase 2 prioritization consisted of three separate rankings for seven of the nine indentified reaches located in the Hinkston Headwaters and the Grassy Lick Creek reporting units (Table 6-4; rank of 1 = highest priority). The first ranking was based on water quality data and riparian buffer deficiency (Table 6-4). The second ranking was based on habitat scores (Table 6-4), and the third ranking was based on results from the geomorphic visual assessment survey (Table 6-4). The three separate rankings cannot be directly combined to quantitatively prioritize reaches due to the lack of data for some of the reaches analyzed; however, a brief summary of each of the three rankings is provided below. These rankings will be used in the next step of the prioritization process to aid in qualitatively prioritizing all nine reaches.

Table 6-4. Phase 2 Prioritization Rankings

Description	Town Branch	Bennett Branch	Lane Branch	Twin Oaks/ Industrial Park	Upstream of Calk Road	Somerset Creek	Grassy Lick Creek
Water Quality and Riparian Buffer Deficiency Rank	2	2	6	4	1	5	3
Habitat Rank[1]	6	4	5 and 2[2]	3	1	NA	NA
Geomorphic Field Survey Rank	3	NA	NA	NA	2	NA	1

[1] Habitat rank is based solely on habitat scores reported in 2004.

[2] Lane Branch's habitat rank has two values; this is because two habitat assessments were conducted for Lane Branch on the same date in 2004.

Town Branch received a rank of 2 based on water quality data and riparian buffer status, received the lowest priority rank for the 2004 habitat assessment, as well as the lowest priority rank of the three reaches surveyed during the geomorphic visual assessment. Town Branch receives effluent from the Sharpsburg STP (KY0088421) in its headwaters. While a relatively small discharge (monthly average permitted flow 0.07 mgd) the drainage area upstream of the outfall is approximately 0.3 square miles (192 acres). Furthermore, even with the regular effluent waste stream, Town Branch still typically goes dry before the confluence with Hinkston Creek. Town Branch was monitored with two stations by KDOW (05016024 and 05016028) which collectively indicated concern with sediment, nitrogen, and phosphorus levels. By comparing the phosphorus monitoring at the other stations in the Hinkston Creek watershed (Table 6-5), it is reasonable to consider the point source discharge as a primary contributor of phosphorus.

Table 6-5. Phosphorus Monitoring Results

Description	Average TP (mgP/L)	Median TP (mgP/L)
Town Branch (05016028)	0.526	0.336
Town Branch (05016024)	0.141	0.121
Town Branch (both stations)	0.334	0.158
Bennett Branch (05016023)	0.220	0.175
Lane Branch (05016022)	0.112	0.122
Twin Oaks/Industrial Park (05016021)	0.101	0.083
Calk Road (05016020, HKC-12)	0.117	0.080
Somerset Creek (HKC-09)	0.158	0.098
Grassy Lick Creek (HKC-08)	0.158	0.094

The drainage upstream of the outfall is dominated by urban land cover (26 percent low intensity development and 3 percent high intensity development, Table 6-7). The remaining drainage area of Town Branch is dominated by pasture (75 percent). The riparian buffer GIS analysis indicates particular concern in the Town Branch drainage and even though Town Branch received the lowest rank for the geomorphic assessment results, this reach still received only moderate scores for both channel erosion status and riparian zone status. The habitat survey results from 1999 further indicate stream degradation.

Bennett Branch received a rank of 2 (along with Town Branch) based on water quality data and riparian buffer status, and a rank of 4 for habitat assessment. Bennett Branch was not surveyed during the geomorphic survey due to lack of landowner permission. However, the riparian buffer deficiency analysis helps to establish concern regarding the lack of riparian buffers. Furthermore, the habit survey indicated poor condition (<114) and the water quality monitoring indicated concern for each nitrogen, phosphorus, and sediment. The urban land cover (3 percent low intensity development and no high intensity development, Table 6-7) is relatively small in that tributary while pasture land cover is significant (73 percent).

The Lane Branch tributary received a rank of 6 based on water quality data and riparian buffer status and was a concern for nitrogen and sediment, but not phosphorus. The habitat survey indicated an acceptable condition of the stream bed (ranked fifth and second in priority, Table 6-4). A geomorphic field survey could not be performed in Lane Branch, but the riparian buffer deficiency indicated some concern in that tributary. The pasture land cover was 69 percent (Table 6-7).

The Twin Oaks/Industrial tributary received a rank of 4 based on water quality data and riparian buffer status and was a concern for nitrogen and sediment and the habitat survey revealed poor stream bed condition (ranked third). The riparian buffer deficiency analysis indicates more concern in this drainage when compared to Lane Branch. A geomorphic survey could not be performed in the Twin

Oaks/Industrial tributary. This tributary contains an industrial park (30 percent low intensity development and 11 percent high intensity development, Table 6-7), impervious area (14 percent, Table 6-8), and pasture land cover (53 percent).

The drainage upstream of Calk Road was of highest concern (rank 1) based on the scoring conducted with water quality data and riparian buffer deficiency status as well as the comparison between habitat scores. Nitrogen and sediment monitoring values were above the benchmark and were relatively high for both constituents when compared to the other monitored reaches (Table 6-6). The habitat survey indicated poor stream bed conditions while also noting the most impaired score (67).

Table 6-1 shows that this drainage scored a 1 for riparian buffer deficiency, and was the only drainage presented in that table to score a 1. The geomorphic visual assessment indicated concern for bank conditions as the average stream channel erosion received a score of 4, indicating poor to moderate conditions. This drainage is comprised of pasture land (77 percent, Table 6-7) and urban land cover (11 percent low intensity development and almost zero percent high intensity development).

Table 6-6. TN and TSS Observed Concentration Values

Description	Average TN (mgN/L)	Flow Weighted Average TSS (mg/L)
Town Branch (05016028)	3.07	36.9
Town Branch (05016024)	2.16	29.6
Bennett Branch (05016023)	1.93	47.6
Lane Branch (05016022)	0.95	16.3
Twin Oaks/Industrial Park (05016021)	0.46	16.9
Calk Road (05016020, HKC-12)	2.57	21.8
Somerset Creek (HKC-09)	2.79	12.8
Grassy Lick Creek (HKC-08)	2.68	12.4

Somerset Creek (Grassy Lick) and Grassy Lick Creek each scored a 0.8 for water quality with concern noted for each of the four water quality constituents. In general, these reaches received ranks of 5 and 3, respectively, based on water quality data and riparian buffer status. The riparian buffer deficiency analysis indicated concern in each of the drainages, with more concern in the Grassy Lick Creek tributary. These drainages did not have any habitat surveys performed on them. The geomorphic field survey could only be performed in Grassy Lick Creek tributary and the results indicated primary concern for bank and riparian zone conditions rather than cattle access to streams.

The two unranked reaches included the remaining portions of the Grassy Lick reporting unit downstream of the confluence of Somerset Creek and Grassy Lick Creek and the majority of the mainstem portion of Hinkston Creek in the Hinkston Headwaters reporting unit. The downstream portion of the Grassy Lick reporting unit not discussed previously could reasonably be approached for BMP implementation with an assumption of similar concerns as noted in the upstream tributaries of Grassy Lick Creek and Somerset Creek. The mainstem portion in the Hinkston Headwaters reporting unit is more complex because of the urban component of Mount Sterling (20 percent urban considered with 63 percent pasture, Table 6-7), the Mount Sterling STP, and the significant stream reaches which were not part of the geomorphic survey. BMPs will still be suggested for these areas.

Table 6-7. Percent Land Use/Land Cover in the Drainage Area for Each Reach

Description	Water/ Wetland	LID[1]	HID[2]	Forest/ Shrub	Pasture/Hay/ Fallow Field	Cropland	Total Area (acres)
Town Branch (05016028)	0%	26%	3%	12%	59%	0%	191
Town Branch (05016024)	0%	8%	0%	14%	75%	2%	1,434
Bennett Branch (05016023)	0%	3%	0%	23%	73%	1%	1,659
Lane Branch (05016022)	0%	5%	0%	26%	69%	0%	1,759
Twin Oaks/Industrial Park (05016021)	1%	30%	11%	4%	53%	1%	1,392
Calk Road (05016020, HKC-12)	0%	11%	0%	9%	77%	2%	2,943
Somerset Creek (HKC-09)	0%	7%	0%	23%	67%	3%	12,041
Grassy Lick Creek (HKC-08)	0%	7%	0%	28%	65%	1%	12,054
Grassy Lick Creek, Downstream Portion	0%	6%	0%	40%	52%	2%	2,348
Hinkston Creek, Mainstem Portion [3]	0%	16%	4%	15%	63%	2%	14,592

[1] LID = Low Intensity Development

[2] HID = Medium and High Intensity Development

[3] Mainstem Hinkston Creek calculations include land use data along the mainstem of Hinkston Creek upstream from the Grassy Lick Creek confluence (HKC-10 and 05016029, 05016027, 05016026, and HKC-11 and 05016025).

Table 6-8. Percent Imperviousness in the Drainage Area for Each Reach

Description	Area of Imperviousness (acres)	% Impervious
Town Branch (05016028)	10	5.1
Town Branch (05016024)	7	0.5
Bennett Branch (05016023)	3	0.2
Lane Branch (05016022)	4	0.2
Twin Oaks/Industrial Park (05016021)	199	14.3
Calk Road (05016020, HKC-12)	35	1.3
Somerset Creek (HKC-09)	122	1.0
Grassy Lick Creek (HKC-08)	67	0.6
Grassy Lick Creek, Downstream Portion	7	0.3
Hinkston Creek, Mainstem Portion1	761	5.2

[1] Mainstem Hinkston Creek calculations include land use data along the mainstem of Hinkston Creek upstream from the Grassy Lick Creek confluence (HKC-10 and 05016029, 05016027, 05016026, and HKC-11 and 05016025).

Prioritization Results

The Phase 2 prioritization provides a tool for assessing the relative management needs of the Hinkston Headwaters and Grassy Lick Creek reporting units. Given that management opportunities exist within all nine reaches of these reporting units, plan implementation should focus on the higher ranking reaches but not limit implementation to these reaches only. The Phase 2 prioritization rankings were used to place reaches into three priority categories: high, medium, and low. The rankings point towards the reaches of Town Branch, Bennett Branch, Upstream of Calk Road, and Grassy Lick Creek as the high priority reaches for implementation. These reaches generally have the highest riparian buffer deficiency and greatest nutrient and sediment concentrations, on average, than the remaining reaches considered in the prioritization. Among the reaches with available E. coli data, Upstream of Calk Road appears to have the greatest concern for bacteria loading as well. The unranked mainstem portions of the Hinkston Headwaters reporting unit are considered medium priority because relatively high riparian buffer deficiency occurs in this area (Figure 2-18) as well as a relatively large area of agricultural land (Table 6-7). The remaining reaches of Lane, Twin Oaks, and Somerset are placed in the low priority category. The Twin Oaks/Industrial tributary could be considered a higher priority due to its poor habitat score, but this reach drains a lower percentage of agricultural area than the other priority reaches and is best grouped with Lane Branch and Somerset Creek in terms of priority. The unranked downstream portions of the Grassy Lick Creek reporting unit are considered in the low priority category because upstream BMPs should generally be implemented first. These prioritization categories are used along with the load reduction and cost data, to select recommended implementation targets for the watershed plan. Figure 6-4 displays the Phase 2 prioritization results for each of the nine reaches.

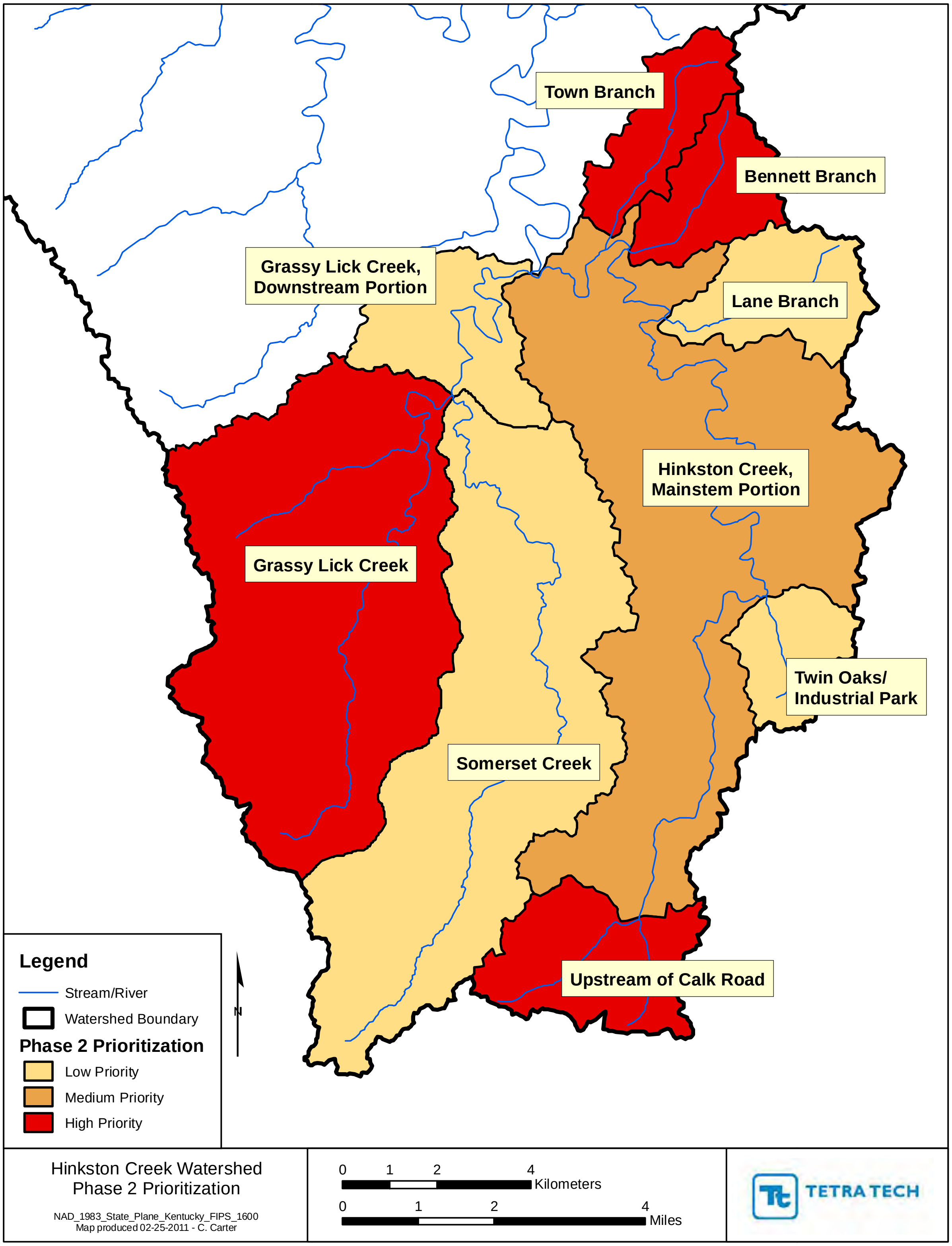


Figure 6-4. Phase 2 Prioritization

6.2 BMP COST-BENEFIT ANALYSIS

The pollutant load reduction benefits and costs of the BMP groups were compared in a cost-benefit analysis. This process included a refinement of previous BMP opportunity estimates (Section 5.3), development of assumptions for BMP load reduction efficiencies, and compilation of available cost data. A regression of *E. coli* on flow interval was developed to estimate annual summer *E. coli* load reduction by BMPs. For stream bank erosion, an approximate range of load reduction estimates was derived to estimate the benefits of stream bank stabilization/restoration. Preliminary results were reviewed to recommend the percent of opportunity area (or reach length) that would be feasible to implement while making reasonable progress towards meeting the loading benchmarks. The resulting costs, benefits, and cost-effectiveness ratios are compared by BMP group and reporting unit for TSS, TN, TP, *E. coli*, and stream bank erosion.

6.2.1 BMP Quantities

An important consideration for the cost-benefit analysis was the BMP quantities to be implemented. In Chapter 5, preliminary estimates of areas and lengths of opportunities were derived for the entire watershed. These estimates were used as a foundation for estimating the quantities used to evaluate the costs and benefits of the recommended BMP groups. Several adjustments were made to the preliminary methods to provide a more detailed estimate of opportunities for the Hinkston Headwaters and Grassy Lick reporting units. Where BMP groups may potentially overlap, it was assumed that these groups would treat separate drainage areas to provide a conservative perspective on pollutant load reduction. Table 6-9 outlines these more detailed assumptions, and

Table 6-10 presents the adjusted quantities. For Groups 1 through 3, the drainage area of the restored riparian buffer was estimated as within 250 to 300 feet (depending on buffer width) from the buffer's upland edge. Beyond this distance, the parallel ditch, described in Chapter 5, is typically present and concentrated flow, as opposed to sheet flow, is expected to dominate the drainage patterns between this land and the stream. The upland area was estimated by multiplying the length of reach opportunity by the expected property width of 1700 feet. This is approximate and does not account for stream sinuosity; however, this method provides a reasonable, conservative estimate given that the resulting areas are slightly less than estimated in Chapter 5 (Table 5-1). The estimate of eligible landowners is also slightly less than the preliminary estimates given these more conservative assumptions. Lengths of 100-foot wide riparian buffer opportunities were assumed to be negligible since less than 100 feet of opportunity (longitudinal length along streams) were estimated in each reporting unit.

For Group 4 on pasture land, the drainage area applied to grassed waterways was assumed to be different from the area draining to Groups 1 through 3. An approximate drainage area of 15 acres was assumed per property with a typical width of 30 feet across both sides. In addition to grassed waterways, it was assumed that pasture renovation was applied to the drainage area because this practice would likely be applied to the entire property. For Group 4 on row crop land, 70 percent of the crop land was assumed as a drainage area for grassed waterways, reflecting an estimate of the properties that likely have a need for this practice (E. Boyd, NRCS Montgomery Office, personal communication to H. Fisher and P. Cada, November 2010). The grassed waterway dimensions for pasture were also assumed for row crop, and multiple drainage areas of 15 acres were assumed on larger row crop properties.

Drainage area estimates for Group 5 were also refined. The impervious area estimates in Chapter 5 represent all types of impervious surface, including roads. Although roads represent a potential opportunity, BMP retrofits may provide the greatest benefit where impervious surface is most concentrated, mainly within the center or downtown of the municipality. Using an area calculation tool in GIS, approximate impervious areas in concentrated urban areas were estimated and used as the approximate drainage area of BMP treatment opportunity.

In the resulting detailed quantity estimates (

Table 6-10), slightly fewer landowners and slightly less pasture area was estimated compared to the preliminary estimates. The small amount of 100-foot buffer restoration in the preliminary estimates was added to the 50-foot buffer restoration quantities. The grassed waterway length in pasture dropped considerably because of the assumption that 15 acres per property (25% of pasture property area) would drain to grassed waterways. Finally, the urban BMP area decreased because the estimate focused on concentrated impervious area instead of all impervious area throughout the reporting unit.

Table 6-9. Detailed Quantity Assumptions for Cost-Benefit Analysis

Assumption	Value
Reach length within pasture property (feet)	1500
Total width of riparian buffer drainage areas, including buffer area (one side, feet)	300
Total pasture property width	1700
Grassed waterway width (includes both sides, feet)	30
Grassed waterway length per property (feet)	600
Grassed waterway drainage area per property(acres)	15

Table 6-10. Detailed BMP Quantities for Cost-Benefit Analysis

			BMP Groups 1, 2, and 3				BMP Group 4		BMP Group 5
			Pasture Renovation and Prescribed Grazing	Use Exclusion	50-foot Riparian Buffer and Bank Rest.	100-foot Riparian Buffer and Bank Rest.	Grassed Waterways		Urban Area Retrofit BMPs
Reporting Unit	Approx. Number of Pasture Land Owners	Approx. Number of Row Crop Land Owners	Area (acres)	Length (feet)	Length (feet)	Length (feet)	Length in pasture (feet)	Length in row crops (feet)	Impervious Drainage Area (acres)
Hinkston Headwaters	226	3	9,846	339,208	339,208	Negligible	135,683	3	250
Grassy Lick Creek	251	3	10,945	377,060	377,060	Negligible	150,824	3	20

6.2.2 Cost Estimate Methods

The cost estimates were derived from available cost data on the major components of each BMP group. Cost data are available for all EQIP-funded practices from USDA (2011), and the cost estimates are primarily based on these data. Since landowner participation will be voluntary and implementation is likely to be funded largely by either federal or state funding sources, the costs are estimated from the perspective of the federal and state government. Where necessary, costs were adjusted to reflect 2011 dollars and local costs. The major cost estimate assumptions are provided in Table 6-11 with the applicable BMP groups and data sources noted.

The majority of the cost estimates reflect upfront costs to implement each practice. Except for prescribed grazing (which takes place over several years) annual operation and maintenance costs of agricultural practices were not included and assumed to be covered by the landowner or tenant. Operation and maintenance costs for urban BMPs were assumed to be covered by either the local governments or the property owner and were also not included in the cost estimates. It was assumed that property owners would receive payments from the Conservation Reserve Program (CRP) for the 50 and 100-foot restored buffers. Estimated annual CRP payments for riparian buffer restoration were included in the cost estimates, assuming a 20-year lifetime for the practice. For the annual costs that were considered (prescribed grazing and CRP payments), the present value of these costs over the lifetime of the practice was calculated by assuming a discount rate of 2 percent (OMB, 2011).

For the EQIP practices, two costs were estimated to indicate the range of potential costs depending on the source of cost-share funds. The first estimate "EQIP Cost" represents the cost of the practice if the landowner agrees to fund the entire cost-share. The second cost "Full Cost" represents the full cost of the practice and would be applicable if other state or federal grants or other funding were obtained to cover the additional cost-share. The intent during plan implementation is to pursue landowner cost-share opportunities first and then supplement with other funding where landowners are not willing or able to provide the cost-share match. As noted in Table 6-11, this is not applicable for the CRP payments and urban retrofit BMPs.

Table 6-11. Cost Estimate Assumptions

Component	BMP Groups	EQIP#	Unit	EQIP Cost	Full Cost	Source
Pasture Renovation: Native Grasses Seeding, No Till	1,2,3	512	per acre	$343	$440	NRCS (2011)
Prescribed Grazing (Years 1-3)	1,2,3	528	per acre	$281	$382	NRCS (2011)
Use Exclusion: Typical Containment Fence Installation	1,2,3	382	per foot	$2.08	$3	NRCS (2011)
Stream Crossing - 6 to 10 Foot Deep Stream	1,2,3	578	lump sum	$2,118	$2,824	NRCS (2011)
Streambank and Shoreline Protection: Stream Restoration Streambank Treatments from 8' up to 10' Bank Height Protection	2,3	580	per foot	$78	$103	NRCS (2011)
Riparian Buffer Conservation Reserve Program Payments (20-year present value cost)	2,3	NA	per acre	NA	$906	Kentucky USDA FSA[1]
Riparian Forest Buffer: Native Grass Planting, No Till	2,3	391	per acre	$129	$172	NRCS (2011)
Riparian Forest Buffer: Tree and Shrub Establishment	2,3	391	per acre	$417	$557	NRCS (2011)
Grassed Waterway: Erosion Control Blanket on 40 Percent	4	412	per acre	$3,666	$4,888	NRCS (2011)
Urban Retrofit BMPs: Wet Detention Ponds as Representative BMP (Design, Engineering, and Construction; Public or Donated Land)	5	NA	per impervious area acre	NA	$3,872	Schueler (2007), ENR (2010), RS Means (2011)

[1] F. Brown, Kentucky Farm Services Agency Conservation Reserve Program, personal communication to H. Fisher, March 2011.

The stream crossing assumed in Group 1 would provide a limited cattle access to streams for drinking water. This approach would be feasible for most pasture operations; however, a few operations may require an alternative water source, which is likely to have a full cost of $21,000 per pasture property and an EQIP cost of $16,000 per pasture property (assuming 4 tanks or troughs, 5000 feet of typical pipe, and typical spring development).

6.2.3 Pollutant Load Reduction Methods

To estimate the pollutant load reduction benefits of the recommended BMPs, available literature was reviewed for estimates of the percent load reduced by each practice. Values estimated within the southeast U.S. were used to the extent available. SWAT output was used to estimate TSS and nutrient load generated from surface runoff and cattle sources. Literature values were used to provide an approximate estimate of reduced stream bank erosion, and a separate load reduction analysis was used to determine *E. coli* load reduction benefits. These methods are described in more detail below.

BMP Reduction Efficiencies

Table 6-12 provides the assumptions and references used for BMP reduction efficiency. As noted in Table 6-12, some pollutant removal efficiencies were not directly reported in the literature but could be estimated based on similar studies or conditions. Table 6-12 also indicates that literature values on pollutant removal efficiencies were not available for all constituents across all BMPs. Pasture renovation may provide some bacteria removal benefits, but literature values were not readily available and these benefits were expected to be negligible compared to the bacteria removal benefits of cattle use exclusion and buffer restoration. Similarly, bacteria removal by grassed waterways can be variable and is not well studied. Coyne et al. (1995 and 1998) found that although between 55 and 95 percent of bacteria mass was removed from runoff using grass filter strips (a similar practice), bacteria concentrations remained high and continued to exceed standards. Results within the Hinkston watershed will depend on how the upland areas are being managed in terms of crop or pasture uses. Since several more promising bacteria removal BMPs are available, bacteria load reduction from grassed waterways was not estimated. Bacteria load reduction from urban retrofit BMPs is also highly variable, and source reduction techniques – such as septic tank management, good housekeeping practices (e.g., pet waste reduction), etc. – would provide

Table 6-12. BMP Pollutant Reduction Efficiency Assumptions

Best Management Practice	Pollutant Removal Efficiency (%)				References
	TSS	TP	TN	E. coli	
Load reduction applied to surface and cattle sources					
Pasture renovation	65	40	55	NA[1]	ADEQ (2004a)
Prescribed grazing, and cattle exclusion	54	79	33	83	Larsen et al. (1994)
Riparian bank and buffer restoration -- 50-foot buffer	65[2]	50[2]	60[2]	71[3]	Larsen et al. (1994)
Riparian bank and buffer restoration -- 100-foot buffer	80	75	87[2]	71[3]	Larsen et al. (1994)
Grassed waterways	68	29	24	NA[1]	Winer (2000), Lee (1999)
Urban retrofit BMPs (wet ponds)	80	50	30	NA[1]	CWP (2007), Hirschman et al. (2008)
Load reduction applied to bank erosion					
Bank restoration	70	70[2]	NA	NA[1]	Sheffield (2007), ADEQ (2004b), Jessup (2003)

[1] NA – Literature values were not available or reductions thought to be variable or negligible. See text for more explanation.
[2] Estimated based on references but not directly reported in literature.
[3] Combined with use exclusion, Larsen et al. (1994) estimates that a 95 percent reduction could be achieved.

promising bacteria reduction methods in addition to the variable benefits of urban retrofit BMPs. Finally, benefits from bank restoration were estimated for TSS and TP, which are the most relevant constituents for this practice.

TSS and Nutrients from Surface Runoff and Cattle Sources

To estimate load reductions for sediment and nutrients, the pollutant load from the applicable drainage area (or reach length in the case of bank restoration) was estimated using SWAT simulated output loading rates. This load was multiplied by the BMP removal efficiencies to calculate load removed. For BMP groups with BMPs in series, this calculation was performed for the upland BMPs first. For example, load removal calculations for BMP Group 1 were performed in the following order: pasture renovation, prescribed grazing, and cattle exclusion.

E. coli from Surface Runoff and Cattle Sources

To estimate *E. coli* loads and load reductions due to BMPs, a log-linear regression was performed using summer *E.coli* daily unit load estimates (from observed data for the five monitoring stations within the Hinkston Headwaters and Grassy Lick reporting units) as the dependent variable and percent of days flow exceeded (flow interval percent) as the independent variable. The regression was based on summer load as this is the most relevant load relating to meeting the current water quality standards. The following equation was estimated:

$$y = e^{(-9.54359x+20.01731)}$$

Where y is *E. coli* daily unit load in CFUs/acre/day and x is the flow interval in percent. The flow interval variable represents about 84 percent of the variability in *E.coli* daily unit loads (R^2=84 percent). The probability that either coefficient is zero is extremely low ($p<1.0x10^{-12}$). These results suggest that the regression equation provides a reliable method for estimating *E. coli* summer loads. To compare to the predicted load curve, the summer limit curves derived in Section 4.1.7.5 were converted to CFUs/acre/day. The predicted load and limit curves are shown in Figure 6-5.

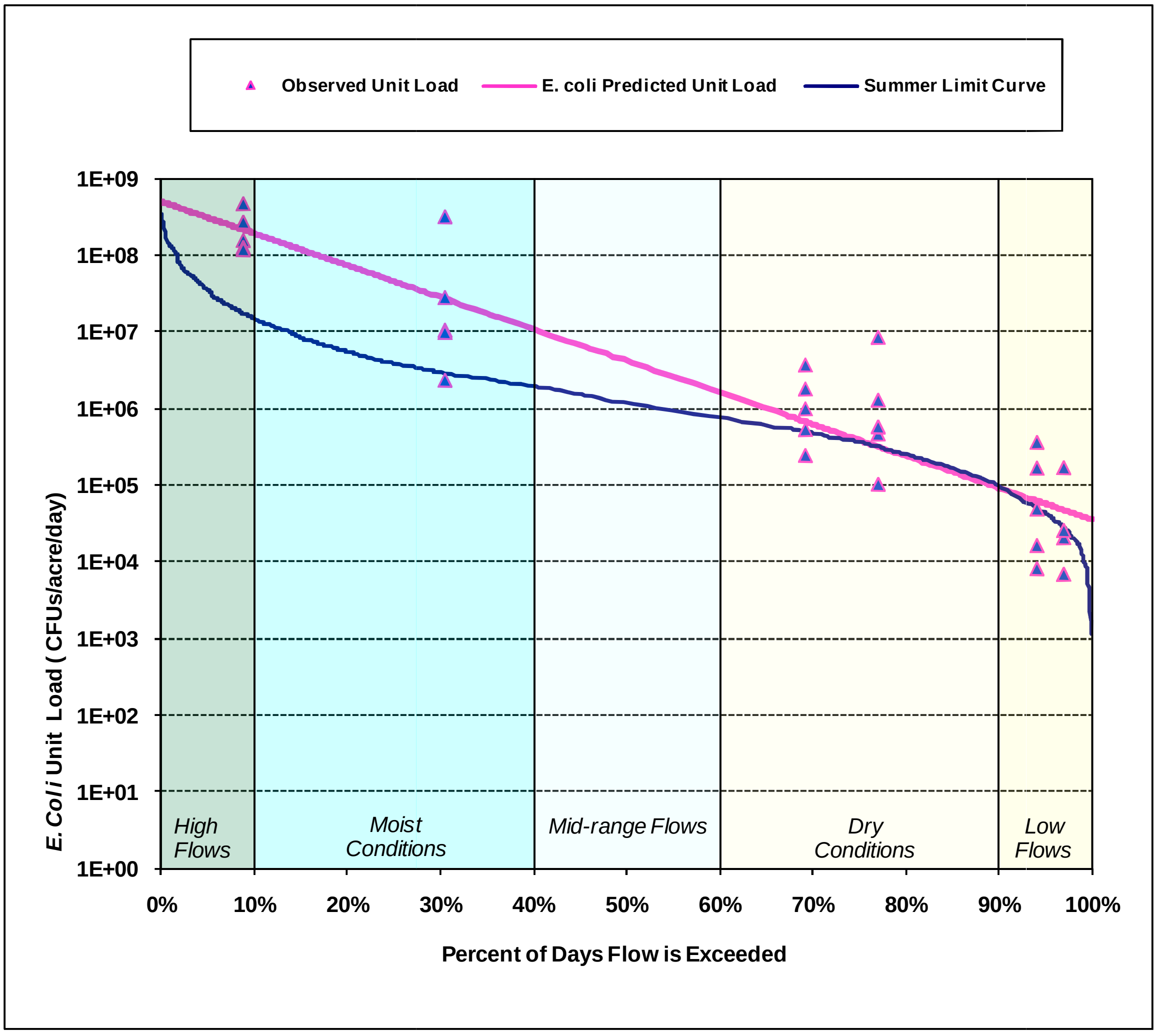


Figure 6-5. **Results of *E. coli* Regression Analysis (Stations HKC-08 through HKC-12)**

To estimate approximate annual summer load and load reduction, the average predicted daily load was calculated from the regression line for each flow regime. Then, this load was multiplied by the number of days represented by the flow regime to calculate the total annual load for the summer season. This method was also used to estimate a summer unit load benchmark based on the summer load limit curve.

The *E. coli* BMP reduction efficiencies were applied to the estimated annual summer load, and then this estimated load reduction was scaled down based on the percent of opportunities targeted for implementation (see Section 6.2.4 Preliminary Implementation Targets). The percent of opportunities implemented was reduced by 5 percent to provide a conservative estimate of the load reduction provided.

Bank Erosion Load Reduction

Sediment is among the most complicated parameters to represent in a watershed modeling environment. The SWAT watershed application was developed for TSS; however the model was not adequate to specify bank erosion vs. land based sediment generation. Furthermore, there were no observed data to inform the model parameters to separate bank erosion from land based sediment generation. The application was developed without bank erosion and the instream simulated output was calibrated to the observed TSS values.

Measured bank erosion rate studies were not available for the Hinkston Creek watershed. To estimate a range of load reduction due to stream bank stabilization/restoration, erosion rates attributed to streams with differing degrees of erosion hazards were used, based on literature values as described in G. An approximate range of 200 to 2000 tons per mile was estimated to represent the likely range of annual sediment loading from bank erosion in the Grassy Lick and Hinkston Headwaters reporting units. The midpoint of 1,100 tons per mile was used for the purposes of the cost-benefit analysis.

The length of stream reach recommended for restoration was multiplied by 1,100 tons per mile and by the load reduction efficiencies noted in Table 6-12 to calculate a range of potential annual reduction in sediment from bank erosion. The phosphorus load due to bank erosion was estimated by multiplying the sediment load reduction by 0.75, which is the ratio of phosphorus (lbs) to sediment (tons) assumed in the SWAT model.

Stream erosion rates and load reductions due to stream restoration can vary widely. This loading estimate is provided for reference purposes and should not be considered an absolute estimate of bank and channel erosion in the Hinkston Creek watershed or substitute for watershed-specific field measurements. An obvious compromise regarding this approach to bank erosion is that the estimated magnitude of generation exceeds the values simulated by SWAT which were calibrated to instream observations. This compromise is being accepted because the contribution of sediment from bank erosion is considered very important and some effort, even if estimated, should be applied to addressing this source of concern. It should be noted that analyses of stream bank erosion rates – and related sediment loading – are recommended as a component of future updates of the watershed assessment and/or watershed plan. Such analyses typically involved bank pin studies, measurements of mass wasting, and other approaches.

6.2.4 Preliminary Implementation Targets

Costs were divided by load reduction estimates to calculate cost-effectiveness ratios for the relevant pollutants. The preliminary results were reviewed to determine the BMP groups with the greatest cost-effectiveness. For TSS, TN, and TP from surface loading and cattle, Group 4 was most cost-effective, followed by Group 1, across all BMP groups. The *E. coli* cost-effectiveness ratios also confirmed that Group 1 was more cost-effective than Group 2. Along with consideration of feasibility, the preliminary cost-effectiveness results were used to recommend the percent of BMP opportunity area or length to achieve through plan implementation (Table 6-13).

As a starting point, it was assumed that about 50 percent implementation may be feasible for all BMP groups considering uncertainty in landowner interest at this point. To take advantage of cost-effectiveness, percentages for Groups 1 and 4 were set at the maximum expected to be achievable. The sum of groups 1 and 2 was limited to 50 percent of available opportunities. Group 3 was not included because few opportunities for 100-foot riparian buffer restoration are expected to exist in the small drainage areas of the Grassy Lick and Hinkston Headwaters reporting units. The Group 4 implementation target was set at 60 percent, anticipating that landowners will be interested in the benefits provided by the conversion of eroding gullies and ditches into more stable grassed waterways.

The implementation target for Group 5 was set at 33 percent, reflecting uncertainty of landowner interest and construction feasibility of stormwater BMP retrofits. This group is not as cost-effective as the other groups. The total available drainage area is small, and 33 percent of this area would represent a much smaller area and cost of opportunity compared to the other BMP groups. Therefore, a 33 percent implementation target for Group 5 reflects feasibility as well as the need to focus funding towards more cost-effective BMPs.

The preliminary loading rates with BMPs were also reviewed against the loading benchmarks, and it was observed that most benchmarks could not be achieved even with 100 percent implementation. As noted, the water quality benchmarks selected for TN, TP, and TSS are based on Bluegrass bioregion reference reach data and hence represent fairly aggressive objectives for the heavily impacted Hinkston Creek watershed. Adjustments in the approach will be made through the adaptive management approach described in Chapter 7. To target the greatest magnitude of pollutant reduction, equal percent implementation is recommended across the priority areas. The Phase 2 priorities can be addressed by targeting implementation efforts in order of the priority so that implementation occurs in the high priority area as soon as possible.

In the future, the project team will work with stakeholders to adjust these preliminary implementation targets based on overall feasibility of implementation. For example, over the next 20 years, other BMPs may be substituted for portions of these recommended BMPs as new BMPs become available or as certain BMPs prove more popular than others and targets are adjusted accordingly.

Table 6-13. Percent Implementation Targets by BMP Group

BMP Group	Percent of Opportunities Targeted for Implementation
Group 1	35%
Group 2	15%
Group 3	0%
Group 4	60%
Group 5	33%

6.2.5 Results

Table 6-14 presents the results of the cost-benefit analysis by BMP group. Annual loads reduced are provided with the cost-effectiveness ratios (cost per unit load removed) in parentheses. These results are organized by type of pollutant, either 1) surface and cattle sources or 2) bank erosion. The 20-year and annualized costs are provided as both “Full Cost” and “EQIP Cost.”

As noted above, Group 4 is estimated to provide the greatest pollutant load reduction per dollar spent for TSS, TN, and TP from surface runoff and cattle sources. Group 1 is the next most cost-effective group for surface and cattle sources (TSS, TN, TP, and *E. coli*), which is an expected outcome since use exclusion, rotational grazing, and pasture renovation are relatively inexpensive practices. In addition, the act of limiting cattle access to streams should provide a large reduction in pollutant loading because of the direct nature of this impact. Groups 1 and 4 combined provide a cost-effective approach that could be applied to many properties with interested landowners. Group 1 would be applied to land draining directly to stream reaches with cattle access, and Group 4 would be applied to land draining to ditches that outlet to stream reaches. Rotational grazing could be added to the Group 4 drainage areas, as appropriate, to achieve additional pollutant reduction.

Under load reduction from bank erosion, Group 2 is the only applicable group and therefore direct cost-effectiveness comparisons are not applicable across BMP groups. However, the Group 2 bank stabilization/restoration is estimated to provide a large reduction in loading from bank erosion, and the cost-effectiveness results suggest that a substantial value would be provided by this practice. Although TSS from surface and cattle loading and sediment from bank erosion are different measures, the cost per ton reduced by bank erosion is within the lower range of the surface and cattle loading results for TSS, suggesting that bank stabilization/restoration is among the more cost-effective measures recommended.

Stream bank stabilization ($41/ton sediment reduced) may be more cost-effective than Group 4 ($37/ton TSS reduced). A similar cost-effectiveness may be gained for total phosphorus depending on how much bank erosion contributes to instream phosphorus concentrations.

The riparian buffer restoration in Group 2 contributes to the higher cost-effectiveness ratios compared to Groups 1 and 4. Coupled with the bank stabilization/restoration benefits, Group 2 is expected to be a promising strategy. Since buffer restoration will require some removal of land from pasture, fewer landowners will likely be interested in this option, but where implemented, this BMP group will provide reasonable value for the investment.

Group 5 was estimated as the least cost-effective BMP group. Urban BMPs are often more expensive per pollutant load removed as they require more structural components and more detailed design than agricultural BMPs. Due to the anticipated costs, Group 5 BMPs should be targeted in strategic locations where stormwater runoff flow is severely degrading stream channels or causing flooding hazards to residents and property.

Table 6-14. BMP Load Reduction Estimates by Group (Cost per Load Reduced in Parentheses)

Benefit or Cost	Group 1	Group 2	Group 4	Group 5	Total
Load reduction applied to surface and cattle sources					
TSS (tons/year)	4,711 ($151)	2,402 ($270)	3,391 ($37)	37 ($464)	10,541 ($142)
TN (lbs/year)	54,090 ($13)	28,316 ($23)	33,316 ($4)	243 ($71)	115,966 ($13)
TP (lbs/year)	4,420 ($161)	2,066 ($313)	2,010 ($63)	44 ($394)	8,540 ($176)
E. coli (million summer CFU/year)	8.868E+7 ($0.01)	3.383E+7 ($0.02)	NA	NA	1.225E+8 ($0.01)
Load reduction applied to bank erosion					
Sediment (tons/year)	NA	15,668 ($41)	NA	NA	15,668 ($41)
TP (lbs/year)	NA	11,751 ($55)	NA	NA	11,751 ($55)
Cost estimate (Present Value)					
20-Year Full Cost ($)	$14,227,000	$24,064,826	$2,518,000	$345,000	$41,154,826
Annualized Full Cost ($)	$711,350	$1,203,241	$125,900	$17,250	$2,057,741
20-Year EQIP Cost ($)	$11,163,000	$19,209,351	$1,945,000	$345,000	$32,662,351
Annualized EQIP Cost ($)	$558,150	$960,468	$97,250	$1,199,000	$2,814,868

Table 6-15 and Figure 6-6 compare the unit loads under existing conditions and with BMPs for TSS, TN, TP, and *E. coli* to the applicable benchmarks by reporting unit. The percent reduction in load refers to the percent of the total reporting unit load reduced. Cost-effectiveness ratios are also provided by reporting unit across all BMP groups. Cost-effectiveness between the two reporting units is similar. The slight variations are due to differences in loading rate and/or distributions of BMP opportunities. For example, implementation in Grassy Lick is estimated to be more cost-effective for TSS reduction because the TSS unit load is higher and the reporting unit is estimated to have a greater proportion of cost-effective BMPs (i.e., Group 4 compared to Group 5).

Table 6-15. Unit Load Estimates and Cost-Effectiveness by Reporting Unit

Reporting Unit	Existing	Benchmark	With BMPs	% Reduction	Cost per Unit Removed
TSS (tons/acre/year)					
Hinkston Headwaters	0.61	0.02	0.42	30.8%	$160
Grassy Lick	0.67	0.02	0.44	34.0%	$130
TN (lbs/acre/year)					
Hinkston Headwaters	10.20	4.10	7.85	23.0%	$12.9
Grassy Lick	9.68	4.10	7.39	23.6%	$13.0
TP (lbs/acre/year)					
Hinkston Headwaters	0.67	0.50	0.51	24.3%	$185
Grassy Lick	0.63	0.50	0.45	28.0%	$168
E. coli (million summer CFUs/acre/year)					
Hinkston Headwaters	7,070	1,154	4,637.6	34.4%	$0.01
Grassy Lick	7,070	1,154	4,389.0	37.9%	$0.01

[1] Reflects full cost, not EQIP cost share, for all BMPs; ratios based on EQIP costs are about 15 to 25% less than ratios based on full costs.

The recommended BMPs (applied according to the percent implementation targets in Section 6.2.4) provide substantial progress towards meeting the loading benchmarks. Percent reduction in load ranges from about 23 to 38 percent. The recommended BMPs are estimated to meet the TP loading target. For TSS, TN, and E. coli, additional reduction would likely be needed to achieve the benchmarks. Since these are estimates, the results suggest that the recommended BMPs should provide progress towards addressing impairments, and once BMPs are implemented, conditions in the watershed can be re-assessed to determine actual reductions and where additional improvement is needed.

The estimated reduction in bank erosion was not directly applicable to the comparison in Table 6-15 because TSS and bank erosion are separate measures. TSS loading, as estimated by SWAT, represents the load delivered to the stream that contributes to suspended sediment concentrations. The bank erosion loading estimates represent sediment delivered to the stream that contributes to both bed load and suspended sediment. Despite these differences, the bank erosion reduction estimates warrant consideration towards meeting the TSS benchmark because bank materials are mostly clays and silts, with small particle sizes easily mobilized by stream flows, and thus likely significant contributors to measured TSS values. Bank erosion is expected to be a major contributor to sediment loading in the watershed, and stabilization/restoration is likely to provide considerable load reduction towards meeting the TSS benchmark for drainage areas where the majority of reaches are restored.

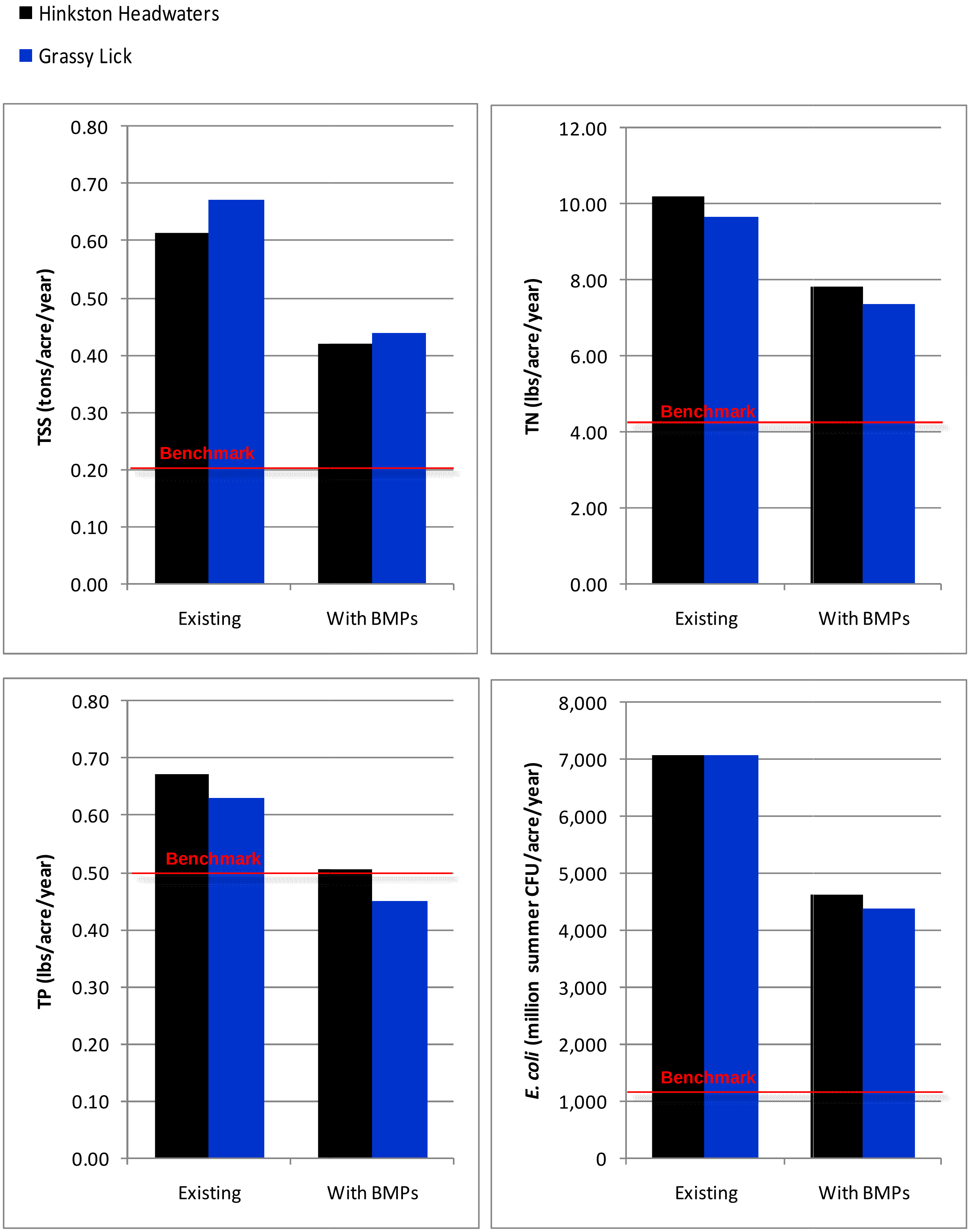


Figure 6-6. **Unit Loading Rates by Reporting Unit for Existing Conditions and Recommended BMP Implementation Compared to Benchmarks**

6.3 IMPLEMENTATION ACTIONS AND RECOMMENDED TIMEFRAME

The BMPs recommended for the Hinkston Creek watershed reflect the practices that can best address existing stressors and take advantage of opportunities to improve land management. The BMP groups represent the most likely groupings of BMPs on typical properties within the watershed. The estimated opportunities for these groups were reduced to potentially feasible quantities, and the cost-benefit analysis provided estimates of load reduced and cost as well as measures of cost-effectiveness. The recommended quantities of BMPs, based on the implementation targets in Section 6.2.4, are summarized by group in Table 6-16. The cost-benefit analysis estimated that if these quantities are implemented, annual pollutant load could be reduced by 23 to 38 percent for Hinkston Headwater and Grassy Lick reporting units.

Table 6-16. Recommended BMP quantities for plan implementation

BMP Measure	Units	Target Value
Group 1		
Pasture renovation and prescribed grazing	Acres of pasture	7,277
Use exclusion	Miles	47
Group 2		
Pasture renovation and prescribed grazing	Acres of pasture	3,119
Use exclusion, riparian buffer restoration (50-feet), streambank stabilization or restoration	Miles	20
Group 4		
Pasture renovation	Acres of pasture	4,298
Grassed Waterways in Pasture	Miles	33
Grassed Waterways in Row Crop	Miles	3
Group 5		
Urban stormwater retrofits	Acres of impervious drainage area	94

While the recommended BMP groups represent a major effort towards watershed improvement for Hinkston Creek, additional management practices are recommended beyond these BMP groups. On a voluntary basis, it is recommended that owners and managers of industrial and urban areas, as well as construction sites, improve how these areas are managed to protect water quality, stream stability, and other watershed functions. Improved wastewater management is also recommended, with particular focus on investigating potential impacts from the septic tank hot spots identified in Section 2.6.4. Plan implementation should involve extensive outreach and education across all sectors to encourage improved management efforts. The following list summarizes the overall actions recommended for watershed plan implementation:

- Improved management of agricultural land (BMP groups 1-4)
- Installation of urban retrofit BMPs (BMP Group 5)
- Improved stormwater management for industrial and urban areas
- Improved management of construction sites
- Improved wastewater management
- Outreach and education supporting all of the above

The targeted quantities for implementation are specified for the entire area of the two reporting units Hinkston Headwaters and Grassy Lick. The Phase 2 prioritization indicated that implementation should begin first in upstream of Calk Road, along the mainstem of Grassy Lick Creek, and along Town and Bennett Branches. Then, efforts should be focused along the Hinkston Creek mainstem second, and the remaining reaches third. Since it is uncertain how many interested property owners exist within these priority areas, this order should be used as guidance during implementation with the intent of achieving the recommended quantities across the entire two reporting units, regardless of priority area. As noted above, these recommendations reflect a starting point or snapshot in time. In the future, as new BMPs or technologies become available, other BMPs may be substituted for these core BMPs recommended, or if some BMPs on the menu prove more difficult and others easier to implement than anticipated, the targeted participation rate can be adjusted.

A 20-year timeframe is recommended for implementing the recommended BMP quantities in the Grassy Lick and Hinkston Headwater reporting units. On an annual basis, implementation progress should be reviewed to evaluate effectiveness and determine whether or not adjustments in the approach are required. Tracking against interim annual and 5-year implementation targets is recommended. A more detailed outline of implementation actions and schedule is provided in Chapter 7.

As outlined in this chapter, the overall strategy for success is based on technical information, locally-based cost data, and preliminary estimates of feasibility from a property owner perspective. While implementation will be an adaptive process, the recommended implementation targets provide a firm foundation for adapting the overall watershed improvement strategy to changing conditions and new information. The evaluations in this chapter indicate that available BMP opportunities will provide a substantial progress towards successful watershed improvement.

7 Making it Happen

7.1 ORGANIZATION OF IMPLEMENTATION EFFORT

The Hinkston Creek Watershed Plan was developed by Hinkston Creek Project staff with assistance and input from local resource managers, technical experts, and other stakeholders. The plan will be implemented through the actions of project partners, watershed landowners, residents, and local organizations, assisted and supported by public and private entities involved in natural resource management, regulatory compliance assistance, outreach, and education. Table 7-1 below lists key project partners that will be involved at various levels in the watershed plan implementation effort.

As noted in this document, land use in the watershed is 70 percent pasture/hay land, 20 percent forest/shrub, and less than 8 percent developed (i.e., residential, commercial, industrial, institutional). The stakeholder approach adopted by the Hinkston project (i.e., watershed management through the soil and water conservation boards) has focused on working with landowners, land managers, and resource specialists, largely in the agricultural sector.

Implementation of the watershed plan will be coordinated by Hinkston Creek project staff, in cooperation with the county soil and water conservation boards, local government, and project partners. This approach was selected because more than 90 percent of the land use is classified as agriculturally-related, most of the water quality threats or impairments are linked to agricultural and/or land management sources, and most of the recommended management practices focus on agricultural/or and land management issues.

The presence of long-term active organizations directly involved with both landowners and water quality issues – such as the county soil and water conservation boards, producer associations, etc. – provides an excellent venue for watershed plan implementation. The county soil and water conservation boards have a history of assisting producers with resource conservation measures, vast knowledge of what works and what does not, and excellent relationships with producers, local governments, and other watershed stakeholders.

The initial BMP implementation focus areas for the watershed plan are the two uppermost reporting units – the Grassy Lick and the upper Hinkston Headwaters reporting units, nearly all of which lie in Montgomery County. Project staff has been meeting quarterly with the Montgomery County Conservation District, which covers the two reporting units identified as the initial BMP focus areas. Staff have also met with and provided project orientation sessions to the Bourbon, Nicholas, and Bath County Conservation District Boards, and will be working with these boards in the future to help secure funding and other support for BMP implementation in those counties. Besides the county conservation districts, project staff have also worked with and consulted the partners listed in Table 7-1 in developing the watershed assessment and management plan.

Table 7-1. Project Partners, Roles, and Contact Information

Partner	Organization	Role	Contact Info
Gary Williamson	Mayor, City of Mt. Sterling	Consultation on flooding issues in Mt. Sterling	859-498-8725
Wallace Johnson	Judge-Executive, Montgomery County	Consultation on project implementation	859-498-8707
Steve Lane	Public Works Director, City of Mt. Sterling	Consultation on flooding issues in Mt. Sterling	859-498-8744

Partner	Organization	Role	Contact Info
Edsel Boyd	US Department of Ag NRCS Field Office	Consultation on ag BMPs and other issues	859-498-8907
Ron Catchen	UK Ag Extension Services	Consultation on ag practices and other issues	859-498-8741
Faye Ferrell	Montgomery County Conservation District	Ag BMP cost share funding and signup procedures	859-498-5654
David Pearce	Director, Mt. Sterling Water & Sewer System	Consultation on WWTP operations	859-497-0481
Greg Gilvin	Mt. Sterling – Montgomery Rails-Trails	Consultation on joint trail & creek planning	859-498-8732
Emily Anderson	Fleming County Conservation District	Consultation on ag practices, funding, BMPs	606-845-9387
April Haight	Morehead State University IRAPP	Water quality monitoring & watershed assessment	606-783-2455
Crystal Renfro	KY Division of Conservation	Working with county conservation districts	859-987-2311
Angie Wingfield	KY Division of Conservation	Project coordination and management	502-573-3080
James Roe	KY Division of Water, NPS Section	Project coordination and management	502-564-3410
Lajuanda Haight-Maybriar	Licking River Watershed Coordinator	Consultation on watershed planning	859-948-3263
Jamie Vinson	Mt. Sterling Advocate Newspaper	Public awareness newspaper columns	859-498-2222
Barry Tonning	Watershed Plan Coordinator	Support for plan development and implementation	859-585-0370

7.1.1 Key Roles in Watershed Plan Implementation

As noted, Tetra Tech staff have provided watershed plan development and plan implementation support, and will continue in that role. The county Soil and Water Conservation Boards in Montgomery, Bourbon, and Nicholas counties will also play key roles in promoting agricultural BMPs to their constituents, with the focus on the Montgomery County SWCB initially because the initial BMP focus watersheds lie mostly within Montgomery County.

The watershed coordinator will conduct a variety of presentations and training sessions intended to raise awareness, improve knowledge, and promote action (i.e., BMP implementation) in the two focus watersheds during 2011. These presentations and training sessions (Table 7-2) will be extended to other groups – and other areas of the larger Hinkston Creek watershed – as resources allow (see next subsection).

Watershed partners will continue to provide input, advice, and support for watershed plan development, implementation, and updating through periodic feedback to the watershed coordinator, county soil and water conservation board meetings, responses and discussion at outreach and education events (Table 7-2), and other venues.

7.1.2 Promotion and Incentive

Another tool to promote implementation of BMPs recommended in the watershed plan is the Kentucky Agricultural Water Quality Act, which was passed by the Kentucky General Assembly in 1994. The goal of the act is to protect surface and groundwater resources from pollution as a result of agriculture and silviculture activities. The Agriculture Water Quality Act requires all landowners with 10 or more acres that are being used for agriculture or silviculture operations to develop and implement a water quality plan based upon guidance from the Kentucky Agriculture Water Quality Plan. It is the sole responsibility of each landowner to develop, implement and revise when needed, a water quality plan for their individual operations.

The Kentucky Agriculture Water Quality Plan is a compilation of BMPs from six different areas, and includes BMPs recommended by the Hinkston Creek Watershed Plan. Technical assistance and cost-share funding is provided through local conservation district offices with assistance from the Natural Resources Conservation Service, Cooperative Extension Service and others, to landowners in developing and implementing site-specific plans. After identifying the BMPs, landowners/land users implement these practices on their land. Assistance to implement the plan can be provided through local conservation district offices with assistance from the Natural Resources Conservation Service and a variety of technical agencies.

Sponsors of the Hinkston Creek Watershed Plan will work with the Kentucky Division of Conservation, county conservation boards, producer associations, and farmers in the watershed to promote updates of Agricultural Water Quality Plans that incorporate the BMPs listed in the watershed plan. This activity will occur within the context of education, outreach, BMP cost share, and other programs undertaken by Hinkston Creek Project staff and partners.

7.2 PRESENTATIONS AND OUTREACH EFFORTS

A number of presentations have been held regarding the watershed plan, and more will be scheduled as the implementation phase begins. The workshops and presentations will focus on building awareness of the watershed plan, and providing technical training on targeted topics – i.e., those areas/issues related to addressing pollutant sources. Specifically, the following types of presentation and outreach events are included in this plan (Table 7-2):

1. Overview of the watershed assessment and management plan
2. Training on construction site and industrial facility stormwater management
3. Presentations on polluted runoff control (general)
4. Presentations on agricultural and other best management practices

Table 7-2. Planned Outreach Presentations, Technical Workshops, Events, and Reports.

Activity Type	Purpose	Target Group	Frequency
Watershed plan overview	Awareness of plan, build support for implementation	Mt. Sterling City Council	Semi-annually
Watershed plan overview	Awareness of plan, build support for implementation	Montgomery County Fiscal Court	Semi-annually
Watershed plan overview	Awareness of plan, build support for implementation	Montgomery County High School classes and organizations	Quarterly and as needed

Activity Type	Purpose	Target Group	Frequency
Watershed plan overview	Awareness of plan, build support for implementation	Montgomery County civic, educational, and other groups	Quarterly and as needed
Watershed plan progress report	Report on activities and future actions	Montgomery County SWCB, Mt. Sterling City Council, Montgomery County Fiscal Court	Annually
Watershed plan progress report	Report on activities and future actions	Local news media,	Annually
Industrial stormwater permit compliance	Technical training for KPDES stormwater permittees on permit compliance	KPDES industrial stormwater permit holders	Once, in Mt. Sterling
Construction site erosion and sediment control	Technical training for construction site personnel on reducing polluted runoff	Construction site contractors and subcontractors	Once, in Mt. Sterling
Farm field days for agricultural BMPs	Awareness and demonstration of pasture, livestock, and other ag BMPs	Crop and livestock producers	Once or annually, in Montgomery County
Urban runoff control	Awareness and technical training on good housekeeping and illicit discharge management	City and county public works personnel	Bi-annually
Volunteer water quality monitoring	Awareness and technical training on basic water quality parameter monitoring	High school students, local citizen volunteers	Annually, and as needed
Storm drain labeling	Install “Do Not Dump – Drains to Waterway” medallions on curb and other inlets	Civic, scout, or youth groups in Mt. Sterling, Carlisle, and Millersburg	Once in each town

Because polluted runoff is the predominant pollution cause and source – rather than high profile, easy-to-target point sources, presentations and workshops will target the relatively small group of landowners and land/facility managers that can implement practices that result in significant changes in water quality. As noted in this plan, most of the water quality issues appear to be related to pasture management, cattle access to streams, hydromodification (largely on agricultural lands), removal of riparian vegetation, and other more minor factors (stormwater runoff from Mt. Sterling, erosion from scattered row crop plots, etc.). In addition, there is a need to engage contractors, consultants, and others involved in the development of large, new subdivisions, new strip-type developments, industrial facilities with large materials storage/handling yards, public works employees, and members of civic, educational, and other groups with an interest in water quality for the purpose of awareness-building and education.

Most of the materials needed for the outreach presentations and technical workshops are on hand, or have already been developed for US EPA, the Kentucky Division of Water, or other entities, so it is expected that sufficient resources for these events are available. The biggest need for watershed plan implementation support will likely be additional funding for cost-share dollars to support agricultural BMPs.

The project has been seeking to develop greater interest in agricultural BMPs through its outreach program, and the project team expects to solicit approximately 10 to 15 landowners annually for BMP implementation on pasture, row crop, or other lands. Outreach to landowners and land managers will occur directly, through personal contact and/or presentations conducted by project staff, partners, or stakeholders, or indirectly, through newspaper articles, notices, printed materials, or other indirect means.

Cost share funding for the installation of cattle exclusion fencing, alternate water sources, and pasture renovation is expected to be a key need as plan implementation proceeds. The next section provides information on how plan sponsors intend to seek this support.

7.3 FUNDING FOR WATERSHED PLAN IMPLEMENTATION

Implementation of BMPs recommended by this report will be supported by a variety of projects, programs, volunteer efforts, and financial and other resources. Most of the implementation effort will be geared toward two major categories of activities: the awareness, educational, and motivational presentations and workshops described in the preceding section, and the solicitation of cost-share and other funds to implement agricultural and streambank stabilization management practices in high-priority areas. In addition, there will be some follow-up water quality monitoring in the watershed and post-BMP implementation operation/maintenance monitoring, to gage whether or not management practices are working properly and to document any water quality improvements.

It is expected that a total of about $40 million is required to fund implementation of BMPs in the two priority upper watershed reporting units. Sufficient funding for full BMP implementation is not available in the near term. However, there is $120,000 in short-term funding available (i.e., until September 30, 2011) through the current Hinkston Creek Project.

In addition, other sources of funding – the Kentucky Nonpoint Source Pollution Grant Program, authorized under Section 319 of the Clean Water Act; US Department of Agriculture cost-share programs; the federal Mississippi River Basin Initiative; the Kentucky Wetland and Stream Mitigation Fund; and other sources. Table 7-3 summarizes these programs, and lists proposed amounts to be sought from each funding source over the next five years to support BMP implementation in the upper watershed priority areas.

Table 7-3. Funding Sources for BMP Implementation.

Funding Source	Description	BMP Types Funded	Amount
Landowners & Land Managers	Self-implemented BMPs on residential, commercial, institutional, and industrial properties	Lot-level nutrient and ditch management, stormwater BMPs	TBD
Hinkston Creek Project	Funded KDOC CWA Section 319 Program; expires September 30, 2011	All types of nonpoint source BMPs	$120,000
KY DOW NPS CWA 319 Program	Statewide grant program for nonpoint source pollution projects	All types of nonpoint source BMPs	$350,000
USDA NRCS Environmental Quality Incentive Program	Federally funded cost-share program for agricultural sector BMPs that protect soil and water quality	Full range of agricultural sector BMPs	$2.5 million plus
USDA NRCS Wetland Reserve Program	Federally funded program to protect, restore, and enhance wetlands	Wetland protection and restoration	$1 million plus
USDA FSA Conservation Reserve program	Federally funded cost-share program for agricultural sector practices that protect soil and water quality	Conservation practices on erodible lands, habitat enhancement, stream protection	$1 million plus
Mississippi River Basin Healthy Watersheds	Federally funded program for restoring water quality in the Mississippi River watershed	Full range of agricultural sector BMPs	TBD

Funding Source	Description	BMP Types Funded	Amount
Initiative			
Kentucky DFWR / USACE Stream and Wetland Mitigation Fund	Fee-in-lieu-of mitigation fund, supported by CWA 404 permittees whose activities result in significant impacts to surface waters	Streambank stabilization and restoration	$750,000
City and county infrastructure and public works	Funding for city and county road departments, sewage collection and treatment, stormwater management	Wastewater treatment, stormwater management	TBD
University of Kentucky Extension Service	Outreach and education programs	Outreach and education	TBD

7.4 MONITORING SUCCESS

Monitoring implementation of the watershed plan involves two separate but related activities: monitoring the implementation of activities and BMPs listed in the plan – including those in this section, and monitoring whether or not water quality in Hinkston Creek measurably improves.

The first set of monitoring tasks, tracking activity measures, will consist of documenting the planning, execution, and outcome of the various work items listed in the watershed management plan, e.g., presentation of workshops, awareness building events, reports to local officials, and other activities. These actions are extremely important for building awareness of water quality issues in the Hinkston Creek watershed, increasing understanding of the technical aspects of recommended management practices, building support for BMP implementation, and providing overall support for water quality improvement. Table 7-2 listed the primary outreach, education, and other events to be held, and Table 7-4 was used to develop a checklist that can be filled in as activities are completed.

Table 7-4. Checklist for Watershed Plan Educational Activities and Other Events.

Activity Type	Purpose	Frequency	Completion
Watershed plan overview	Awareness of plan, build support for implementation	Semi-annually	
Watershed plan overview	Awareness of plan, build support for implementation	Semi-annually	
Watershed plan overview	Awareness of plan, build support for implementation	Quarterly and as needed	
Watershed plan overview	Awareness of plan, build support for implementation	Quarterly and as needed	
Watershed plan progress report	Report on activities and future actions	Annually	
Watershed plan progress report	Report on activities and future actions	Annually	
Industrial stormwater permit compliance	Technical training for KPDES stormwater permittees on permit compliance	Once, in Mt. Sterling	
Construction site erosion & sediment	Technical training for construction site personnel on reducing polluted runoff	Once, in Mt. Sterling	

Activity Type	Purpose	Frequency	Completion
control			
Farm field days for agricultural BMPs	Awareness and demonstration of pasture, livestock, and other ag BMPs	Once, in Montgomery County	
Urban runoff control	Awareness and technical training on good housekeeping and illicit discharge management	Bi-annually	
Volunteer water quality monitoring	Awareness and technical training on basic water quality parameter monitoring	Annually, and as needed	
Storm drain labeling	Install “Do Not Dump – Drains to Waterway” medallions on curb and other inlets	Once in each town	

NOTE: Last column to be filled out upon completion of each activity.

Besides activity and event tracking/monitoring, a key part of project evaluation will be documenting the implementation of BMPs in the watershed. As noted throughout this plan, because most of the threats to water quality are linked to riparian zone, pasture, and livestock management, the key BMPs to be implemented address these pollutant sources. Table 7-5 summarizes the annual BMP implementation goals for the 20-year implementation timeframe and provides information on how implementation will be measured and reach lengths or land areas to be targeted each year, for the first five years, and for the entire 20-year timeframe. Although a minimum 50-feet width for riparian buffer restoration is recommended, buffer widths are likely to vary depending on landowner interest and therefore the actual width is expressed within the 25 to 50 foot range. To achieve these implementation targets, it is estimated that project staff will need to coordinate with about 13 interested pasture landowners and four interested crop landowners per year. The targeted area for urban stormwater retrofits represents about one centralized BMP retrofit project (e.g., wet detention pond) every few years or several smaller, distributed retrofits projects (e.g. bioretention.) every year.

Table 7-5. Structural BMP Measures and Target Values for Implementation in the Grassy Lick and Hinkston Headwaters Reporting Units.

BMP Measure	Units	Annual Target	5-Year Target	20-Year Target
Pasture renovation and prescribed grazing	Acres of pasture	735	3,673	14,693
Use exclusion	Miles	3.4	17	68
Riparian buffer restoration (25-50 feet)	Miles	1.0	5	20
Streambank stabilization or restoration	Miles	1.0	5	20
Grassed waterways in pasture	Miles	1.6	8	33
Grassed waterways in row crop	Miles	0.1	1	3
Urban stormwater retrofits	Acres of impervious drainage area	5	24	94
Improved stormwater management for industrial & urban areas	Identification of poor practices	Observed reduction in poor practices		
Improved management of construction sites	Identification of poor practices	Observed reduction in poor practices		

Monitoring improvements in water quality as implementation of the watershed plan rolls out will be handled under the existing Hinkston Creek *Quality Assurance Project Plan* (Tetra Tech 2009) which specifies monitoring parameters and sampling locations throughout the watershed. Monitoring frequency will be adjusted to better reflect both the expected level of resources available for this activity and the need to capture broad water quality trends, rather than assessment information.

Monitoring sites within the two priority reporting units will be visited at least three times annually – during the late spring (May), mid-summer (July), and early fall (September). Other sites in the downstream portion of the watershed will be visited at least annually. As watershed plan implementation moves into those areas, monitoring will be increased to the May/July/September schedule, to better refine understanding of waterbody conditions. Sampling site locations are indicated in Figure 7-1 and described in Table 7-6. Table 7-7 provides details on the planned water quality monitoring activities. It should be noted that project staff propose to further refine the understanding of the magnitude of sediment loads contributed by streambank erosion vs. upland erosion processes via stream bank erosion studies in the future. Plans to implement stream bank erosion studies (i.e., through bank pin analyses) will be forwarded to KDOC and KDOW when they are completed.

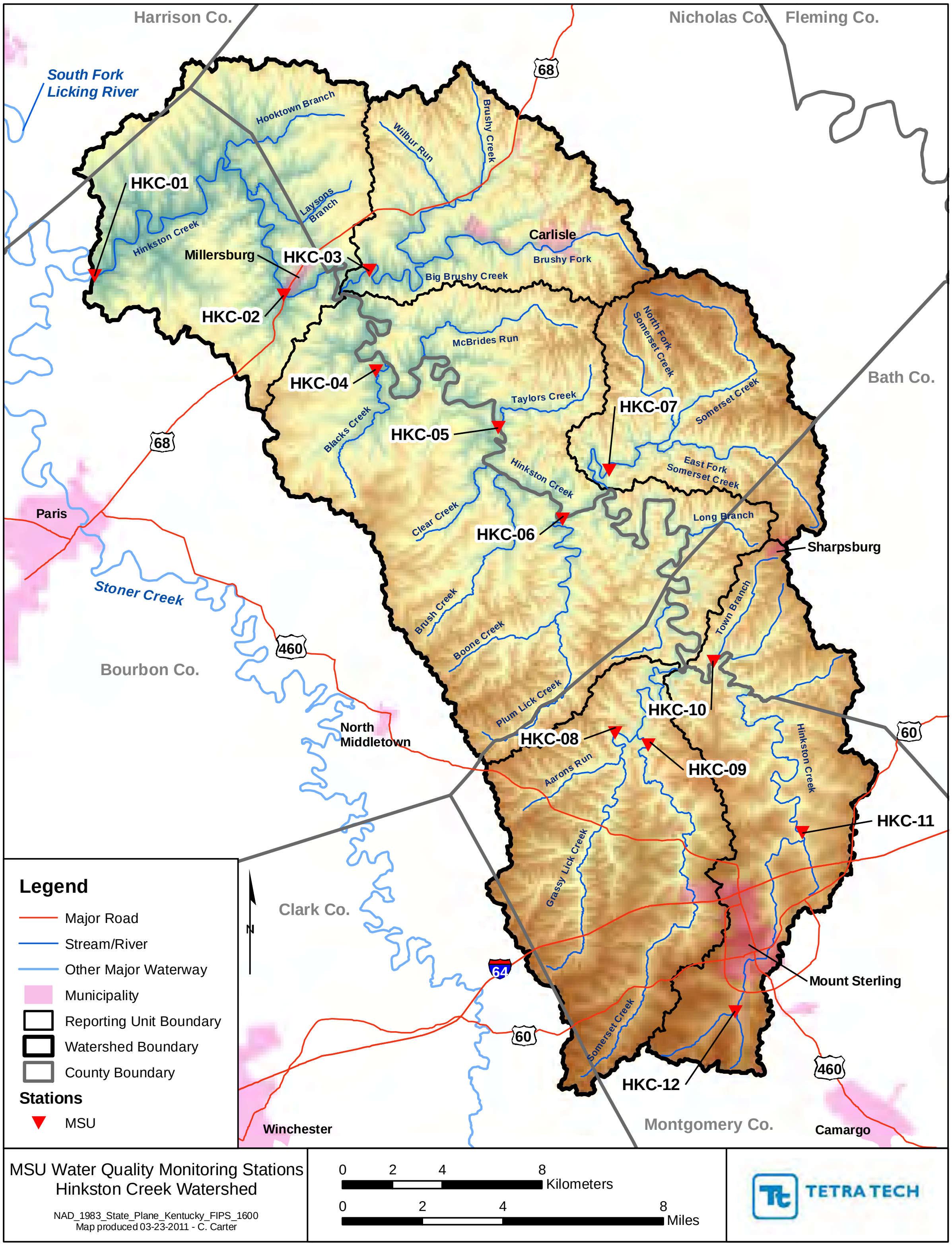


Figure 7-1. Map of Long-Term Hinkston Watershed Sampling Sites

Table 7-6. Locational Information for Long-Term Sampling Sites.

Site	Lat/Long	Description of Sampling Location	Location Notes
HKC-08	38 08 05 N 83 59 41 W	Grassy Lick Creek mainstem just upstream from the Somerset Creek confluence north of Aaron's Run Road in Montgomery County. Site is located west of Judy, just NW of the Aaron's Run Road bridge over Somerset Creek near the Fiddlers Hill Farm at 3002 Aaron's Run Road.	Near 3002 Aarons Run Rd; Jerry Lansdale, owner – he wants to know sampling results. Sample both Grassy Lick & Somerset from this location.
HKC-09	38 08 05 N 83 59 41 W	Somerset Creek mainstem just upstream from the Grassy Lick Creek confluence north of Aaron's Run Road in Montgomery County. Site is located west of Judy, just NW of the Aaron's Run Road bridge over Somerset Creek near the Fiddlers Hill Farm at 3002 Aaron's Run Road.	Near 3002 Aarons Run Rd; Jerry Lansdale, owner – he wants to know sampling results. Sample both Grassy Lick and Somerset from this location.
HKC-10	38 09 47 N 83 57 26 W	Hinkston Creek mainstem at the Montgomery – Bath county line near KY 11. Site is located near the new KY 11 bridge over Hinkston Creek.	Earl Donaldson, owner; lives just downstream on Rogers Mill Rd
HKC-11	38 05 56 N 83 55 13 W	Hinkston Creek mainstem north of Mount Sterling. Site is located about 50 yards upstream of the Hinkston Pike (KY 1991) bridge over Hinkston Creek, near the entrance to the Twin Oaks subdivision in Montgomery County.	Pull off lane after entering Twin Oaks; sample on right
HKC-12	38 02 06 N 83 57 07 W	Hinkston Creek mainstem, just downstream of the confluence of the two headwaters segments that join to form Hinkston Creek. Site is located south of Mt. Sterling and just west of KY 11, downstream of the Calk Road bridge near several old manufacturing plants.	Sample ~ 50 ft downstream from culverts under Calk Ave, after both flows are well mixed

Table 7-7. Monitoring Parameters for Long-Term Sampling Sites.

Parameter	Link to Impairment	Monitoring Frequency
Dissolved oxygen	Organic enrichment	Spring/Summer/Fall
Conductivity	Organic enrichment (e.g., septic systems, sewage)	Spring/Summer/Fall
Turbidity	Sedimentation	Spring/Summer/Fall
pH	Biological indicator support	Spring/Summer/Fall
Temperature	Biological indicators support	Spring/Summer/Fall
Flow	Screening out nonpoint from point sources	Spring/Summer/Fall
Nitrite-Nitrate	Nutrients	Spring
Ammonia	Nutrients, biological indicators	Spring
TKN	Nutrients	Spring
Total Phosphorus	Nutrients	Spring
E. coli	Bacteria; primary/secondary contact recreation	Spring/Summer/Fall

7.5 EVALUATING AND UPDATING THE WATERSHED PLAN

Land use in the Hinkston Creek watershed is mostly established and very stable – i.e., there is little residential, commercial, industrial, or other development, and agricultural lands are typically managed for the same uses over time. In light of the relatively fixed and stable land uses in the watershed, frequent evaluations of and updates to the watershed plan are not anticipated. Project staff are planning for triennial watershed plan reviews, with any needed updates developed and incorporated to the plan at that time.

As discussed in previous sections of this plan, the water quality benchmarks selected for TN, TP, and TSS are based on Bluegrass bioregion reference reach data and hence represent fairly aggressive objectives for the heavily impacted Hinkston Creek watershed. The BMP implementation strategies described in this watershed plan acknowledge the “high bar” that has been set through the adoption of these benchmarks, and recognize that adjustments might be necessary as plan implementation rolls out via the adaptive management approach described in this section.

The plan will be reviewed by project staff with input from the county soil and water conservation districts, resource professionals, and other stakeholders (Table 7-1). BMP and activity implementation will be reviewed annually, to determine effectiveness and determine whether or not adjustments in the approach are required. A summary report on watershed plan implementation will be provided annually to the county soil and water conservation boards along with a solicitation for their input in amending the plan every three years. The report will focus on BMP implementation, progress toward the project short-term and long-term milestones, and water quality trends as determined from the monitoring program.

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Appendix A. Riparian Buffer Status

Table A-1. Riparian Buffer Status and Percent Deficiency

Assessment Subwatershed	Riparian Buffer Area (acres)			Riparian Buffer Deficiency (%)
	Impacted	Intact	Total	
101	814	281	1,095	74%
102	144	51	195	74%
103	7.6	4.7	12	62%
104	381	93	474	80%
105	211	42	253	83%
106	154	77	230	67%
107	460	167	626	73%
108	486	89	575	85%
109	21	16	37	58%
110	24	27	52	47%
111	506	209	715	71%
112	329	315	645	51%
113	9.5	6.3	16	60%
114	39	31	70	56%
115	11	4.6	16	71%
116	50	14	65	78%
117	4.9	0	4.9	100%
118	59	17	76	78%
119	17	21	37	45%
120	11	4.3	15	72%
121	40	30	70	57%
122	37	10	47	78%
123	183	44	227	81%
124	23	4.0	27	85%
125	27	7.2	34	79%
126	69	13	82	84%
127	101	8	109	93%
128	79	15	94	84%
129	21	11	32	64%
130	52	32	84	62%
131	381	135	515	74%
132	411	125	536	77%
133	436	68	504	86%
134	218	14	232	94%
Entire Watershed	5,816	1,988	7,804	75%

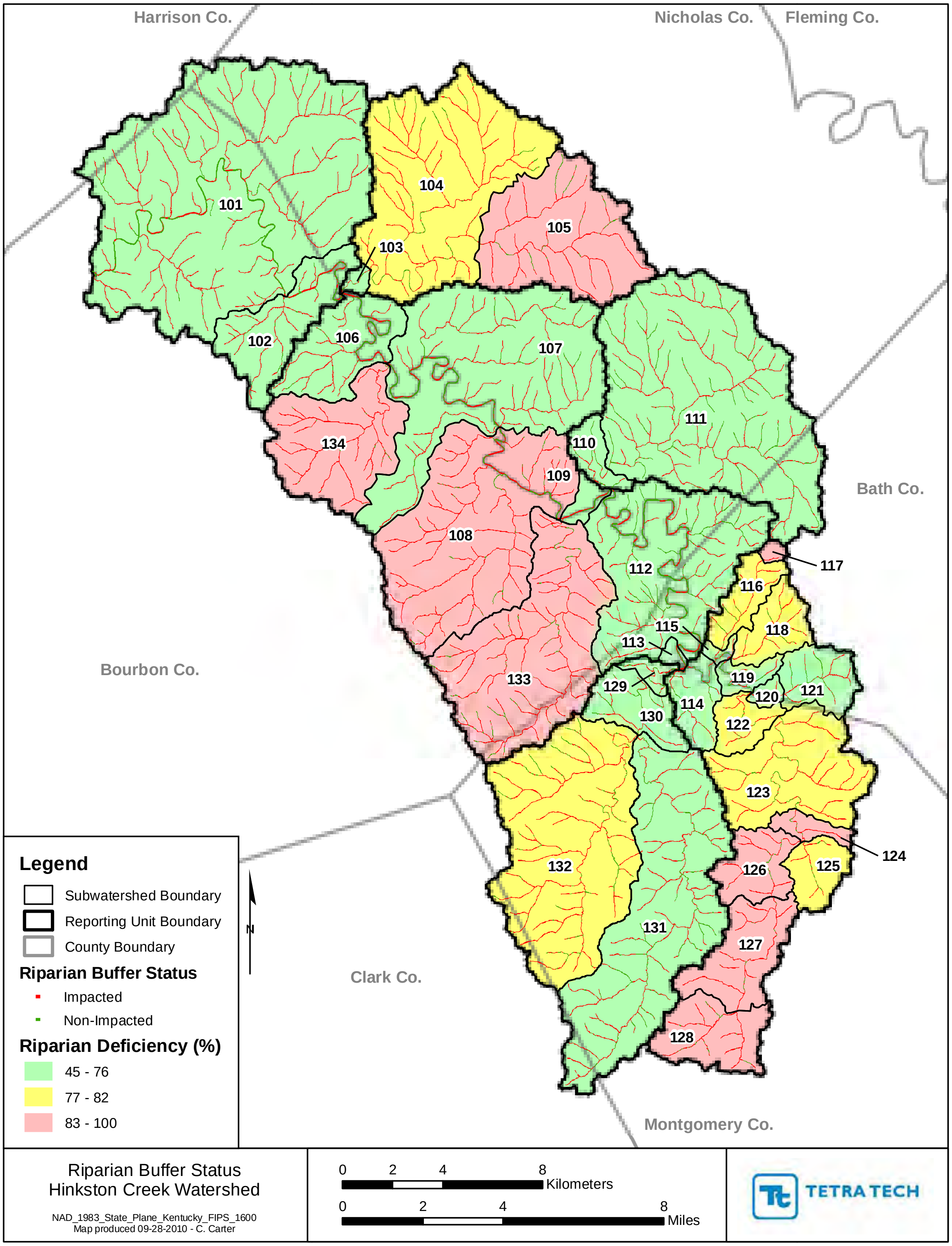

Figure A-1. Riparian Buffer Deficiency and ID for Each Assessment Subwatershed

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Appendix B. Land Use and Land Cover

Table B-1. Proportion of Land Use and Land Cover within Each Reporting Unit

Reporting Unit	Water/ Wetland	Low Intensity Dev.	Med./High Intensity Dev.	Forest/ Shrub	Pasture/Hay/ Fallow Field	Cropland	Total Area (acres)
Lower Hinkston	0.17%	7.20%	0.11%	12.11%	76.22%	4.19%	27,143
Big Brushy Creek	0.74%	8.87%	0.58%	22.25%	65.53%	2.04%	18,742
Hinkston Midreach	0.11%	4.88%	0.00%	20.52%	72.59%	1.90%	53,140
Somerset Creek	0.06%	5.88%	0.00%	28.58%	62.48%	3.01%	17,061
Hinkston Headwaters	0.17%	14.22%	2.87%	15.32%	65.88%	1.53%	23,963
Grassy Lick Creek	0.09%	6.72%	0.22%	26.47%	64.66%	1.85%	26,413
Entire Watershed	0.19%	7.44%	0.53%	20.36%	69.13%	2.34%	166,462

Table B-2. Percent Impervious Land Cover for Each Reporting Unit

Reporting Unit	Acres of Imperviousness	Acres per Reporting Unit	% Impervious
Lower Hinkston	160	27,143	0.59%
Big Brushy Creek	250	18,742	1.33%
Hinkston Midreach	156	53,140	0.29%
Somerset Creek	62	17,061	0.36%
Hinkston Headwaters	1,013	23,963	4.23%
Grassy Lick Creek	193	26,413	0.73%
Entire Watershed	1,835	166,462	1.10%

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Appendix C. Point Source Dischargers

Table C-1. Hinkston Creek Watershed KPDES Permitted Facilities (HUC11 = 05100102010)

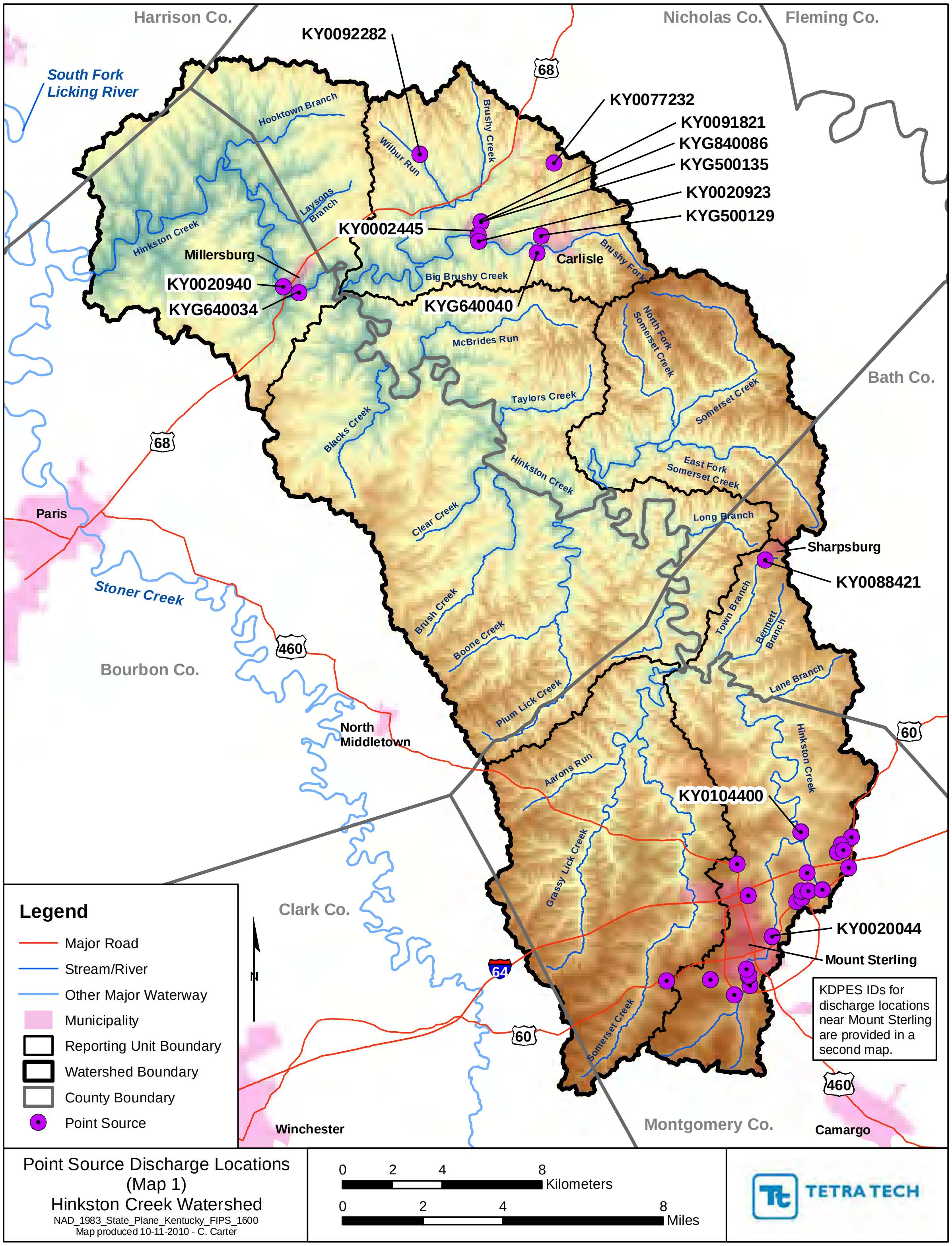
KPDES ID	Name	Design Flow (MGD)	Description	Permit Expiration
KY0091821	Nicholas Co. Landfill	0	Refuse Systems	9/1/2005
KY0088421	Sharpsburg STP	0.07	Municipal WWTP	12/31/2014
KYR000237	Greif Plastic Drum Inc.	0	Manufacturer of Plastic Drums / Discharge of storm water runoff	9/30/2007
KYR001235	City Cartage Company	0	Trucking Company / Discharge of storm water runoff	9/30/2007
KYR002074**	Joy Global	0	Mining Machinery Company / Discharge of storm water runoff	9/30/2007
KYR001612**	Cooper Tire and Rubber Company	0	Discharge of storm water runoff	9/30/2007
KYR001906**	The Walker Company of KY	0	Petroleum and Coal Products Manufacturing Facility / Discharge of storm water runoff	9/30/2007
KYR001907**	Atlas Concrete	0	Discharge of storm water runoff	9/30/2007
KYR002060	Transcraft Eagle Plant	0	Truck Trailer Manufacturer / Discharge of storm water runoff	9/30/2007
KYR002168	Lexington Metals Systems	0	Manufacturer of Automotive Stampings / Discharge of storm water runoff	9/30/2007
KYR000824	Mt. Sterling Industries	0	Special Dies/Tools/Jigs & Fixt	6/5/2010
KYR001105	Atlas Concrete Products	0	Ready-mixed Concrete (permit inactivated 10/10/2006)	9/30/2007
KYR001358	Mt. Sterling Depot	0	Local Trucking Without Storage	9/30/2007
KYR001374	Benny's Used Cars & Auto Parts	0	Motor Vehicle Parts, Used	9/30/2007
KYR001779	Summit Polymers Inc.	0	Plastics Products, NEC (permit inactivated 1/28/2003)	9/30/2007
KYR101283	Pentair Technical Products	0	Management Services	7/11/2008
KY0002445	Jockey International Inc.	0	Finish of BRD WOV FAB of COTTN (permit inactivated 3/15/2007)	1/31/2008
KY0020044	Mt. Sterling STP	3	Sewerage Systems (permit inactivated 8/24/2006)	1/31/2008
KY0096032	Bonfield Brothers Inc.	0	Petroleum Bulk Stations & Term (permit inactivated 10/15/2004)	1/31/2008
KYG500036	KTC Montgomery County Maintenance Garage	0	Discharge of storm water runoff	3/31/2008
KYG500129	KTC Nicholas County Maintenance Garage	0	Discharge of storm water runoff	3/31/2008
KYG500135	Nicholas County Road Department	0	Discharge of storm water runoff	3/31/2008
KYR104112	Valhalla Subdivision Unit 1	0	Subdivision / Discharge of storm water runoff from construction activities	10/19/2010

KPDES ID	Name	Design Flow (MGD)	Description	Permit Expiration
KYG640034	Millersburg WTP	0	Water Supply	3/31/2016
KYG640040	Carlisle Water Treatment Plant (WTP)	0	Discharge of filter backwash water	3/31/2016
KYG840086	Nicholas County Fiscal Court	0	Rock Quarry / Discharge of storm water runoff	6/30/2012
KY0106909	Pilot Travel Center #041	0	Auto/Truck Fueling Station and Convenience Store / Discharge of storm water runoff from fueling areas	11/30/2012
KYG400198	Lane Residence	0	Residential Wastewater Treatment Plant (WWTP)	12/31/2012
KY0077232	North Central 4H Camp	0.02	Discharge of treated sanitary wastewater	12/31/2012
KY0092282	Green Acres Mobile Home Park	0.0075	Discharge of treated sanitary wastewater	3/31/2013
KY0002771	A O Smith Electrical Products Company	0.105	Manufacturer of Electrical Motors and Generators / Discharge of roof drainage and storm water runoff	7/31/2013
KY0020940	Millersburg STP	0.20	Municipal WWTP	4/30/2014
KYR10E303	St. Joseph Hospital Mt. Sterling	0	Discharge of storm water runoff from construction activities	7/31/2014
KYR104945**	Peck/Burdine Property Phase II	0	Discharge of storm water runoff from construction activities (permit inactivated 10/19/2010)	7/31/2014
KYR106092	Kyosan Denso Manufacturing KY LLC	0	Discharge of storm water runoff from construction activities (permit inactivated 10/19/2010)	7/31/2014
KYR108830**	Mt. Sterling Elementary School	0	Discharge of storm water runoff from construction activities (permit inactivated 10/19/2010)	7/31/2014
KY0020923	Carlisle STP	0.35	Municipal WWTP	10/31/2014
KY0104400	Mt. Sterling Hinkston Creek Sewage Treatment Plant (STP)	3	Municipal WWTP	11/30/2014
KYR104144*	The Walker Company of KY - Hot-Mix Plant 2	0	Petroleum and Coal Products Manufacturing Facility / Discharge of storm water runoff from construction activities	10/10/2006
KYR10E638	Montgomery County High School Turf and Track	0	Discharge of storm water runoff from construction activities	7/31/2014

* KYR104144: Also found KPDES IDs of KYR001107 and KYR104803 for the asphalt plant #2 and The Walker Co. of KY Inc., respectively. Both permits expired on 9/30/2007.

** Latitude and longitude position was not reported.

Notes: KYR1xxxxx - General Storm Water Permit Coverage / Construction Activities
KYR0xxxxx - General Storm Water Permit Coverage / Other Facilities
KYG4xxxxx - Individual Family Residence General Permit Coverage
KYG5xxxxx - Kentucky Transportation Cabinet Facilities with Storm Water Runoff
KYG64xxxx - General Permit Coverage / Drinking Water Plant Filter Backwash Water
KYG840000 - General Permit Coverage / Non-Coal Mineral Mining
KY0xxxxxx - KPDES Individual Permit



Point Source Discharge Locations
(Map 1)
Hinkston Creek Watershed
NAD_1983_State_Plane_Kentucky_FIPS_1600
Map produced 10-11-2010 - C. Carter

Figure C-1. Point Source Discharge Locations (Map 1)

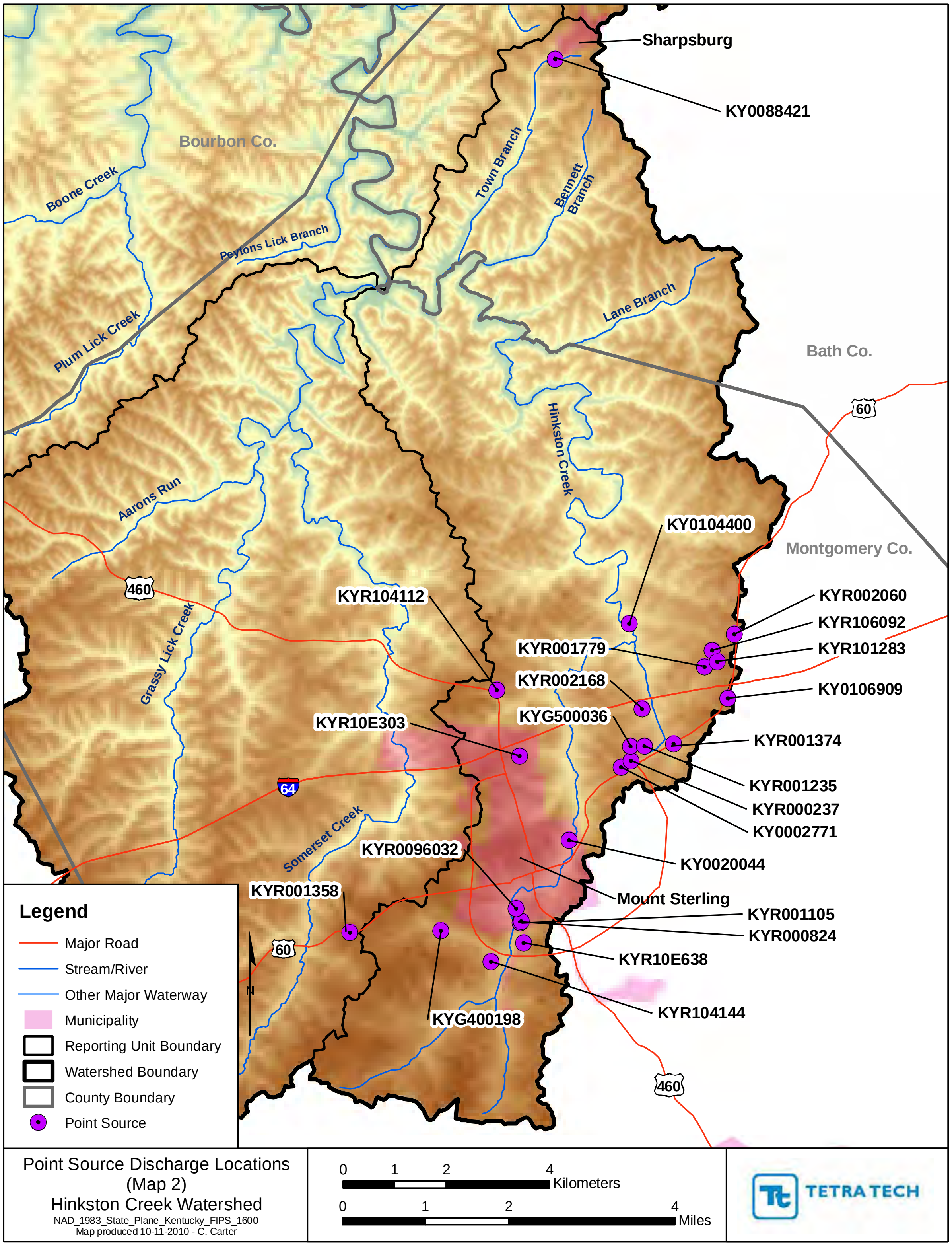


Figure C-2. Point Source Discharge Locations (Map 2)

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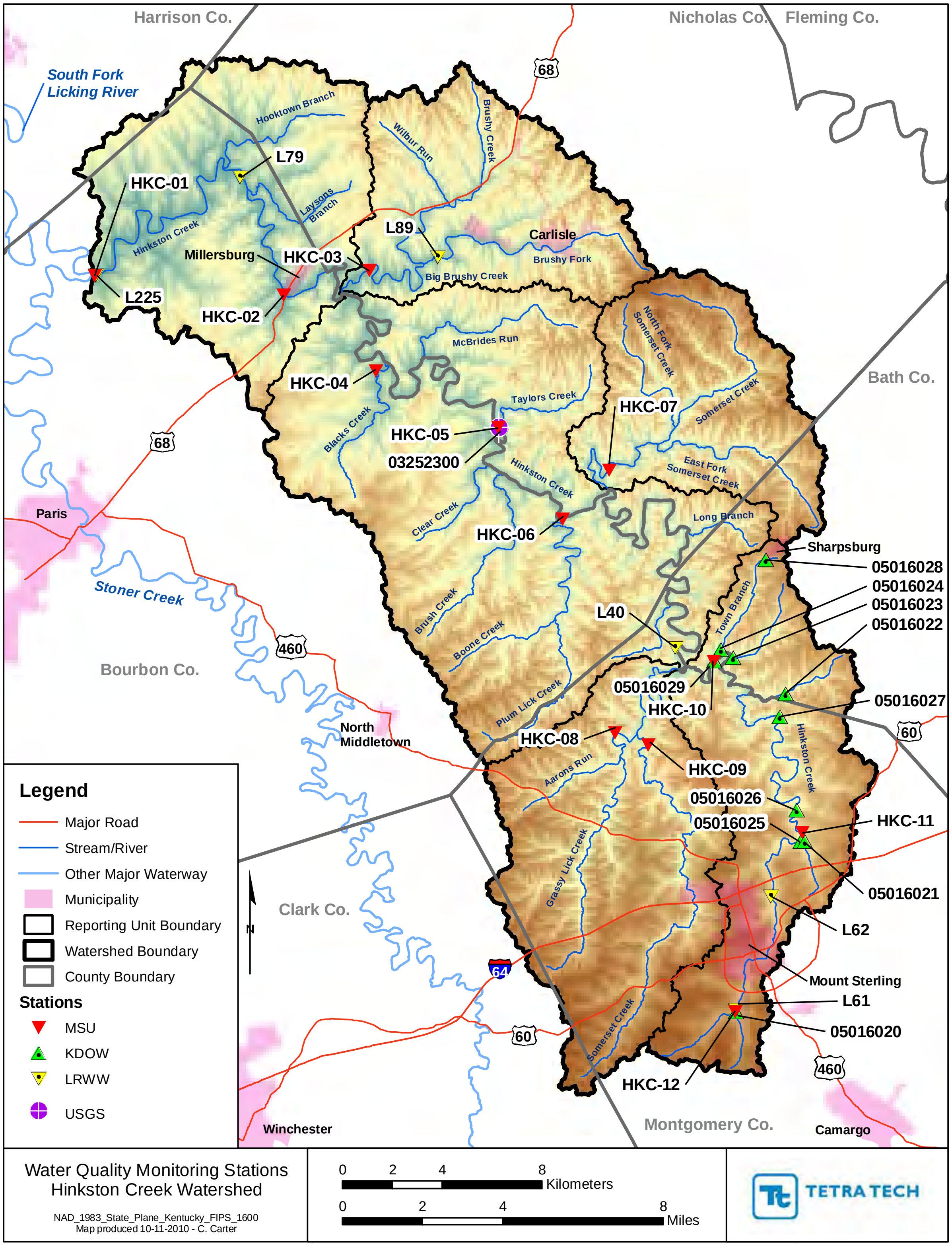


Figure D-1. Monitoring Station Locations within the Hinkston Creek Watershed

D.1 Total Nitrogen (TN)

D.1.1 Concentration Comparisons

Mainstem

KDOW

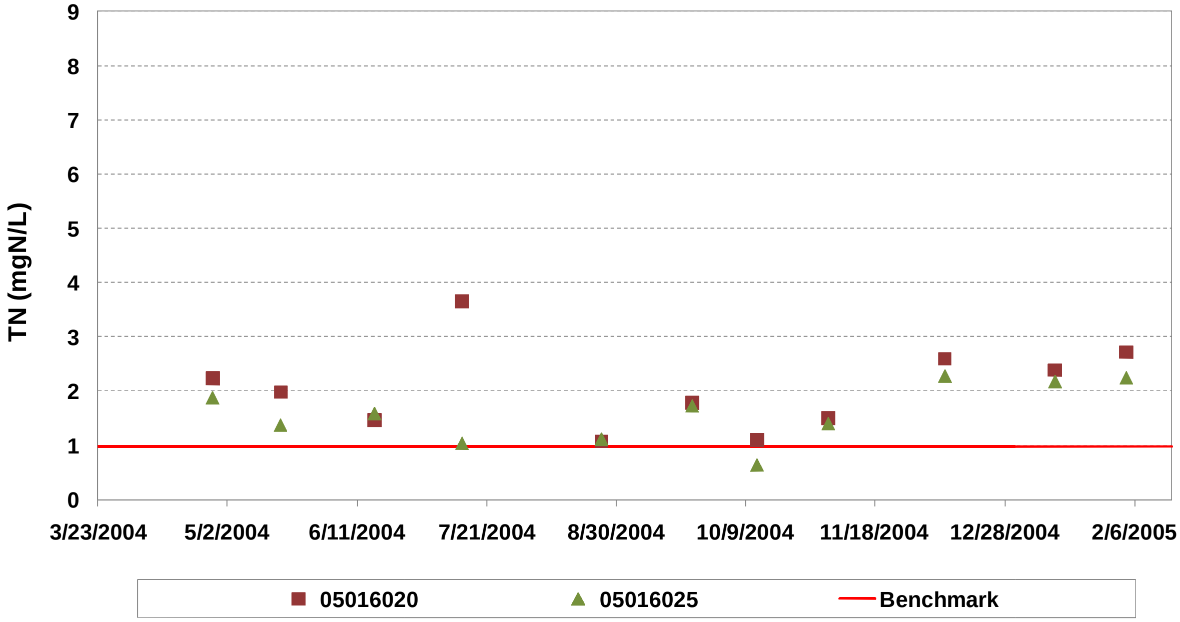


Figure D-2. Total Nitrogen Concentrations Measured for Mainstem KDOW Stations

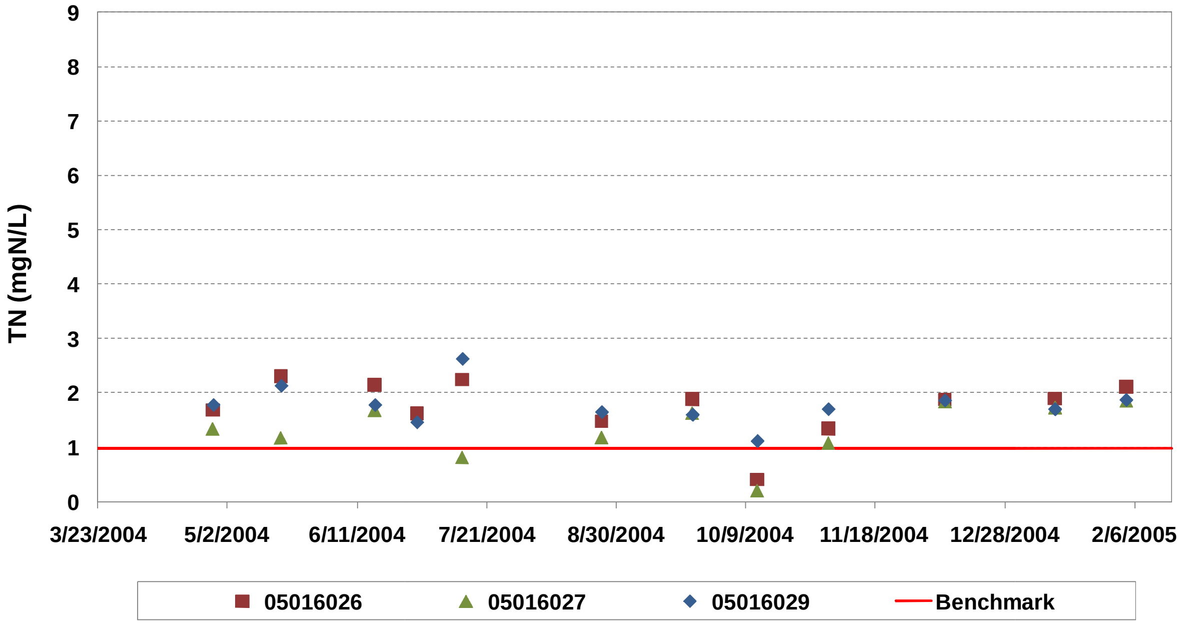


Figure D-3. Total Nitrogen Concentrations Measured for Mainstem KDOW Stations

MSU

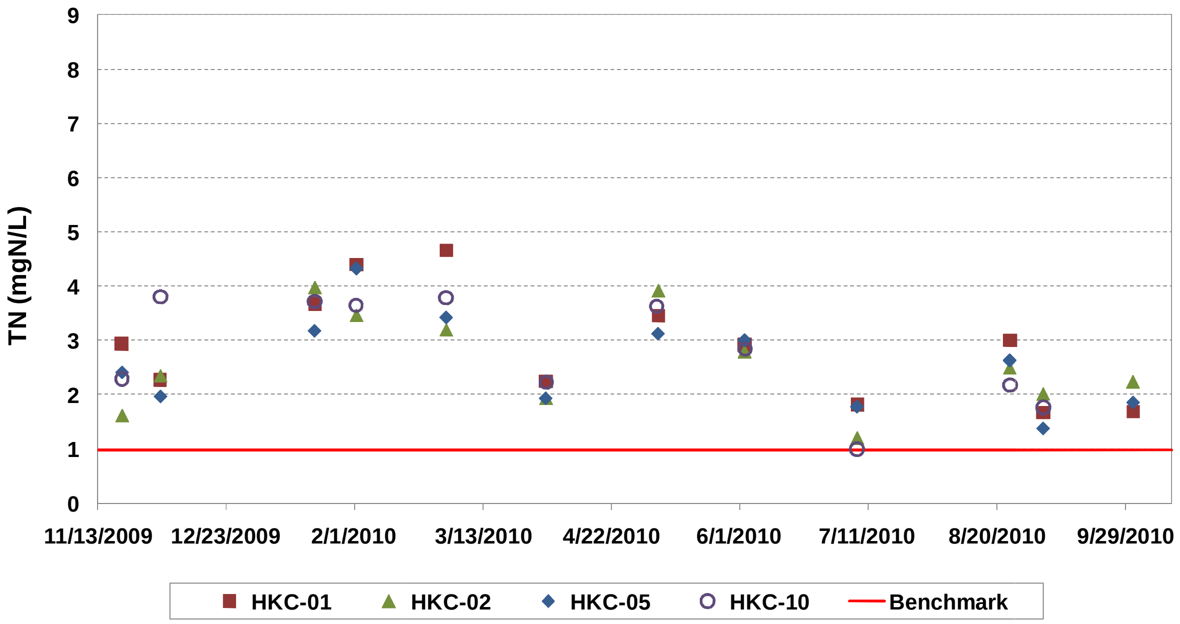


Figure D-4. Total Nitrogen Concentrations Measured for Mainstem MSU Stations

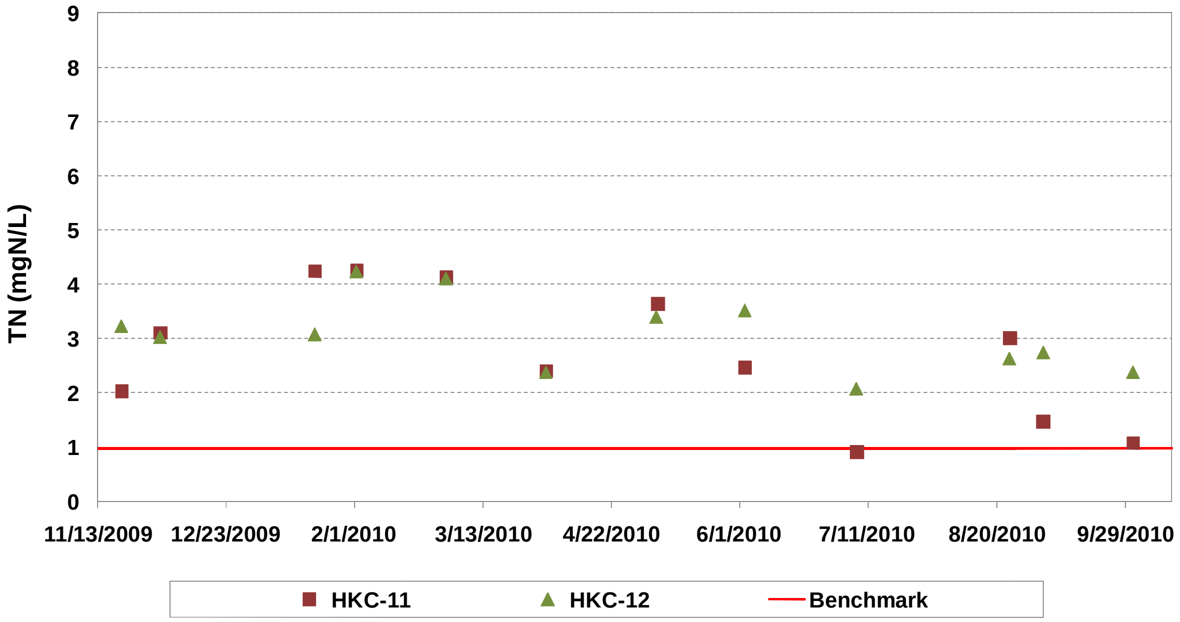


Figure D-5. Total Nitrogen Concentrations Measured for Mainstem MSU Stations

Tributaries

KDOW

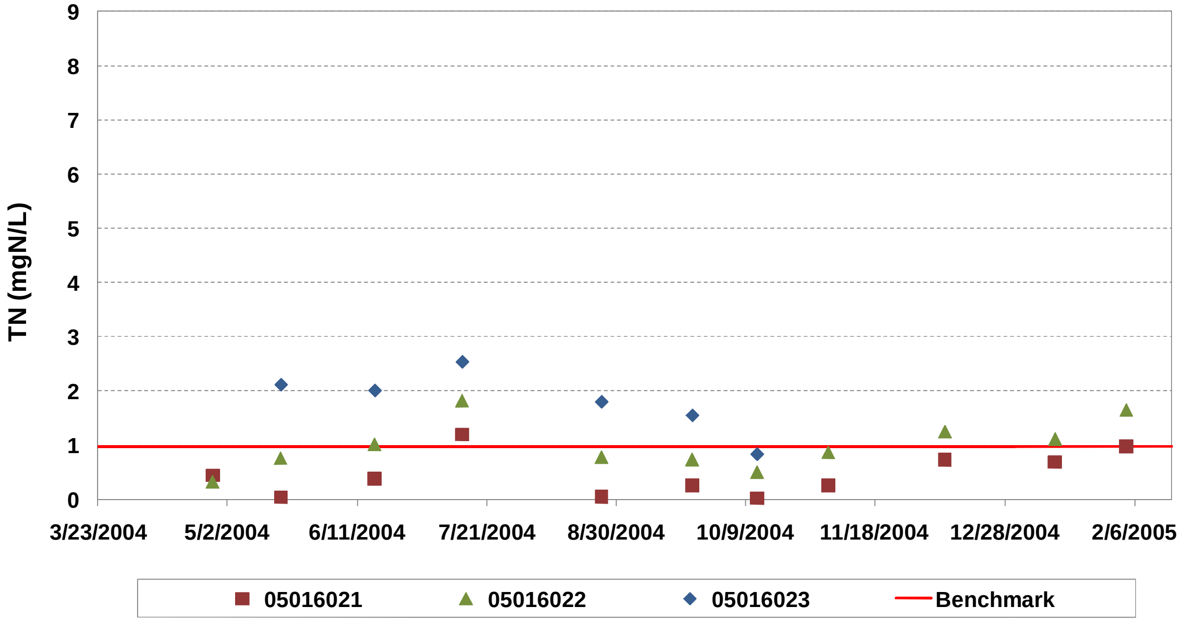


Figure D-6. Total Nitrogen Concentrations Measured for Tributary KDOW Stations

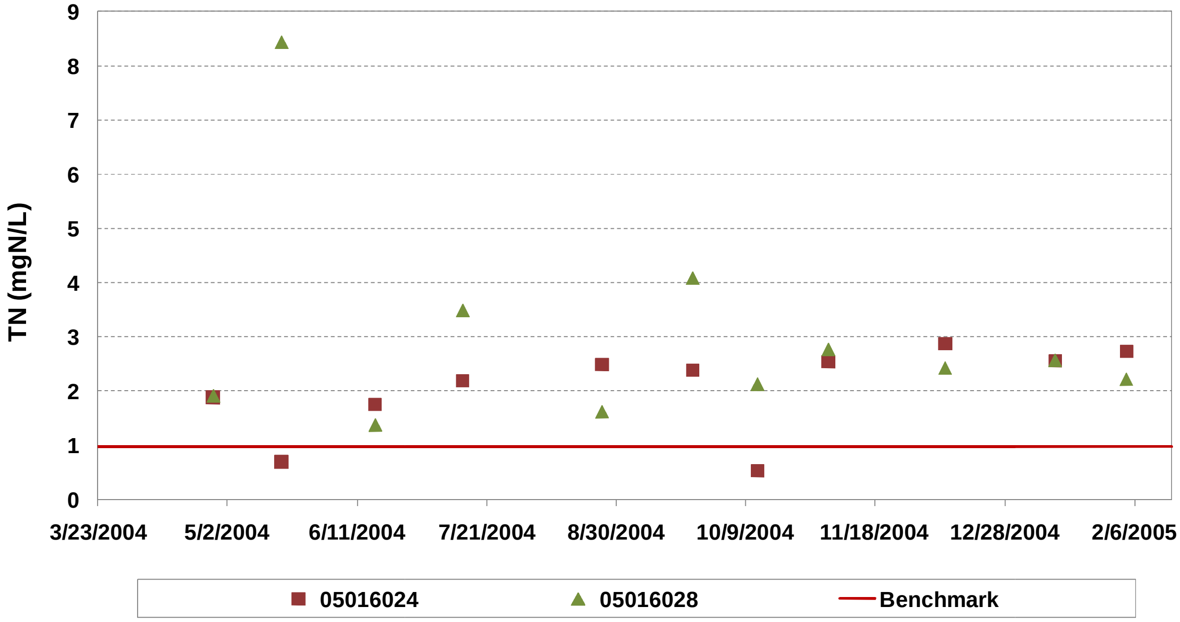


Figure D-7. Total Nitrogen Concentrations Measured for Tributary KDOW Stations

MSU

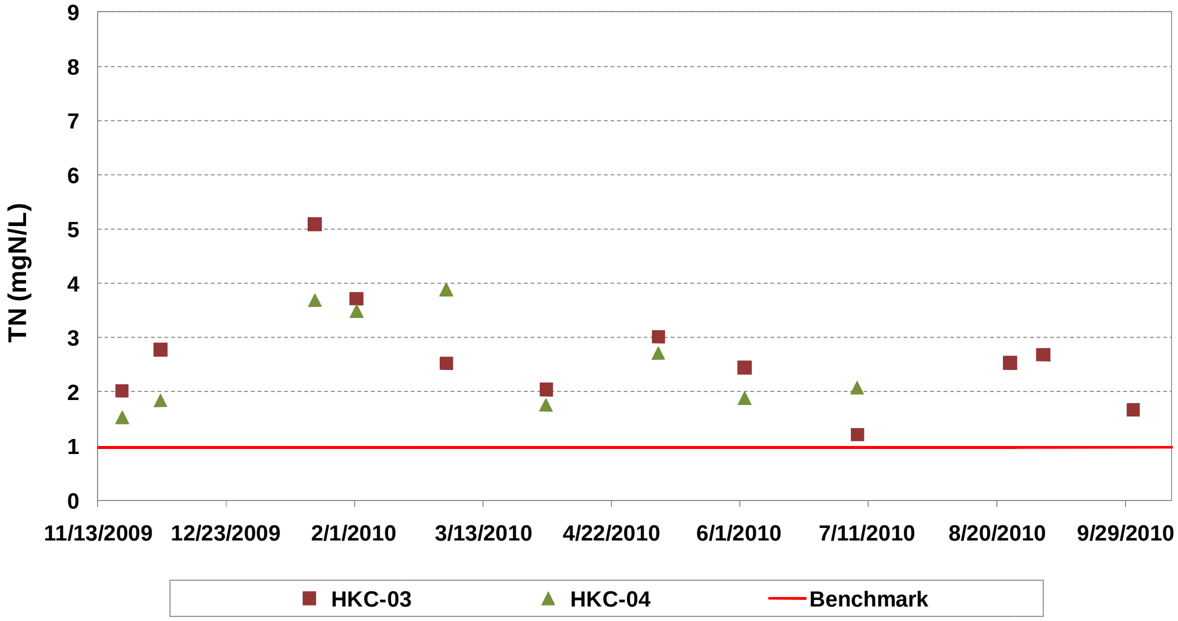


Figure D-8. Total Nitrogen Concentrations Measured for Tributary MSU Stations

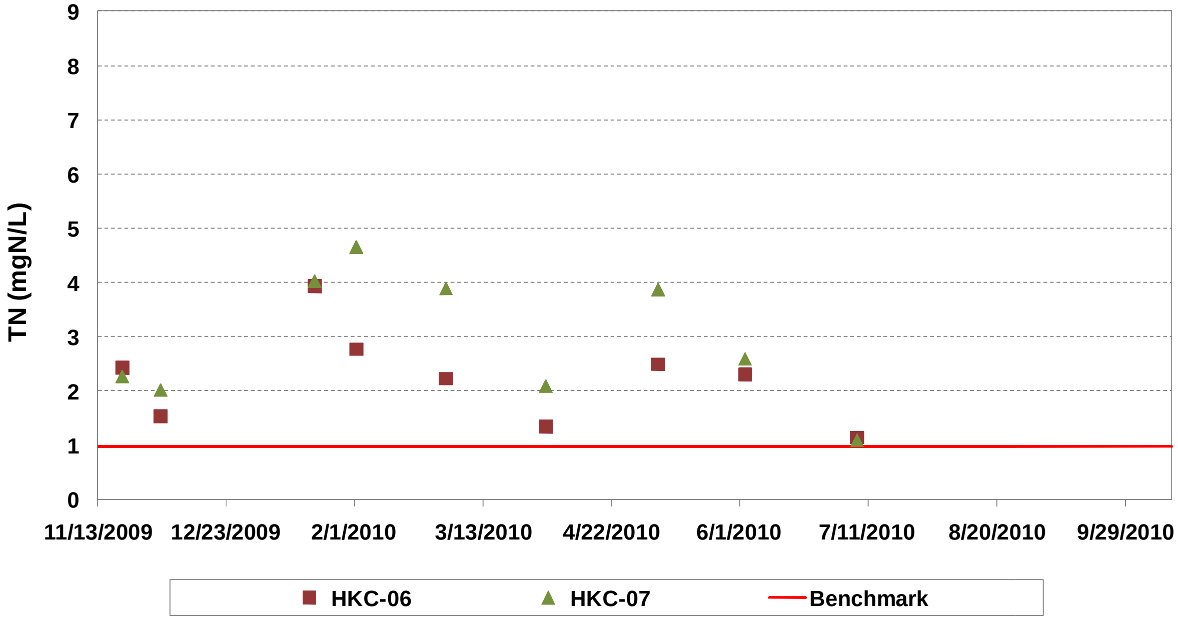


Figure D-9. Total Nitrogen Concentrations Measured for Tributary MSU Stations

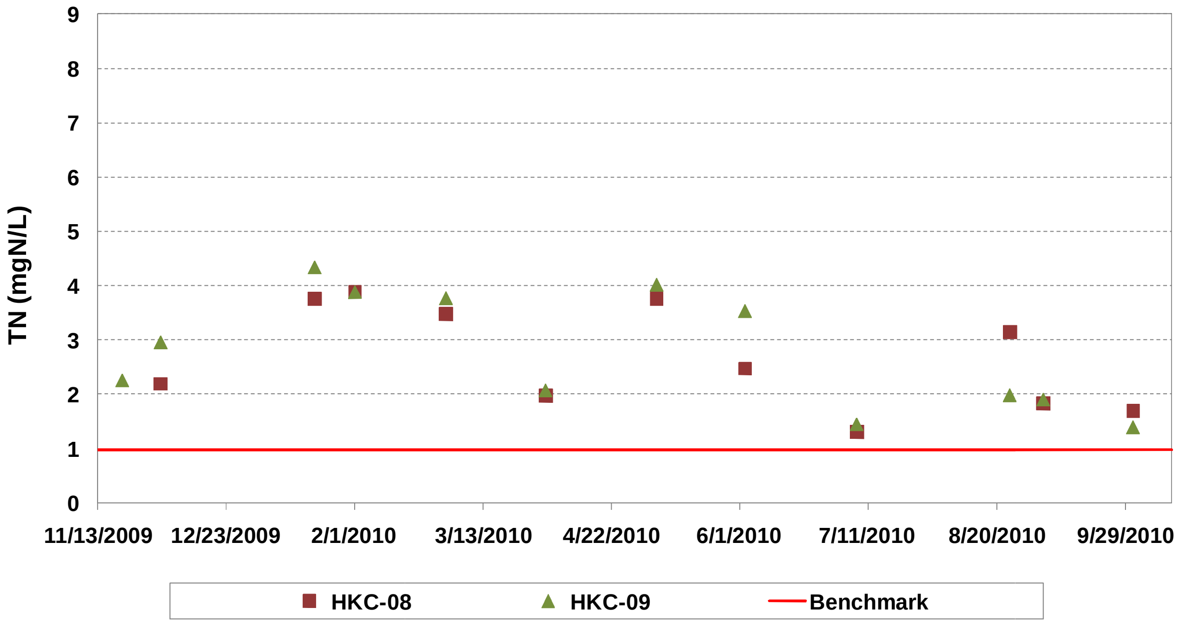


Figure D-10. Total Nitrogen Concentrations Measured for Tributary MSU Stations

Table D-2. Summary Statistics for Total Nitrogen Concentrations (mgN/L) for KDOW, MSU, and Coincident KDOW/MSU Stations

Parameter	Stations	05016020	05016021	05016022	05016023	05016024	05016025	05016026	05016027	05016028	05016029
TN	Max	3.65	1.19	1.82	2.66	2.95	2.28	2.31	1.86	8.44	2.62
	75th	2.49	0.73	1.18	2.53	2.65	2.18	2.14	1.71	3.79	1.91
	Median	1.98	0.38	0.87	2.01	2.49	1.59	1.88	1.19	2.57	1.78
	25th	1.48	0.04	0.65	1.55	1.82	1.11	1.51	1.09	2.02	1.62
	Min	1.07	0.02	0.32	0.84	0.53	0.63	0.40	0.20	1.38	1.12
	Average	2.08	0.46	0.95	1.93	2.16	1.59	1.75	1.30	3.07	1.79
	# Obs.	12	11	13	7	13	11	12	13	13	13
	# Exceed	12	2	6	6	11	10	11	11	13	13
	% Exceed	100	18.2	46.2	85.7	84.6	90.9	91.7	84.6	100	100

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
TN	Max	4.66	3.97	5.09	3.89	4.32	3.93	4.65	3.89	4.34	3.80	4.26	4.24
	75th	3.62	3.40	2.96	3.59	3.16	2.63	3.95	3.76	3.85	3.72	4.01	3.49
	Median	2.93	2.42	2.53	2.08	2.52	2.31	2.59	2.47	2.60	2.84	2.73	3.05
	25th	1.93	1.96	2.02	1.80	1.87	1.44	2.05	1.83	1.92	2.18	1.60	2.44
	Min	1.67	1.20	1.21	1.53	1.37	1.14	1.09	1.31	1.39	0.99	0.91	2.08
	Average	2.89	2.60	2.64	2.54	2.58	2.24	2.94	2.68	2.79	2.80	2.72	3.07
	# Obs.	12	12	12	9	12	9	9	11	12	11	12	12
	# Exceed	12	12	12	9	12	9	9	11	12	11	11	12
	% Exceed	100	100	100	100	100	100	100	100	100	100	91.7	100

Parameter	Stations	05016029 and HKC-10	05016020 and HKC-12
TN	Max	3.80	4.24
	75th	2.78	3.19
	Median	1.91	2.54
	25th	1.70	2.01
	Min	0.99	1.07
	Average	2.25	2.57
	# Obs.	24	24
	# Exceed	24	24
	% Exceed	100	100

D.1.2 Load Comparisons

Table D-3. Total Nitrogen Loads Based on KDOW Monitoring (2004 – 2005)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
05016020	Hinkston Creek	11	71.2	4.2	9.6
05016021	Twin Oaks Subdivision/Industrial Park Tributary	11	6.3	2.2	1.6
05016022	Lane Branch	13	12.2	2.7	2.6
05016023	Bennett Branch	7	13.7	2.6	3.0
05016024	Town Branch	12	44.6	2.5	10.2
05016025	Hinkston Creek	11	122.6	12.0	5.8
05016026	Hinkston Creek	12	155.7	15.2	5.8
05016027	Hinkston Creek	11	197.8	23.7	4.8
05016028	Town Branch	12	5.9	0.3	11.2
05016029	Hinkston Creek	13	372.8	35.2	6.0

Table D-4. Total Nitrogen Loads Based on MSU Monitoring (2009 – 2010)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
HKC-01	Hinkston Creek	12	3234.4	260.4	7.1
HKC-02	Hinkston Creek	12	2745.4	223.7	7.0
HKC-03	Big Brushy Creek	12	214.5	28.9	4.2
HKC-04	Blacks Creek	9	250.6	8.5	16.8
HKC-05	Hinkston Creek	12	1625.2	154.7	6.0
HKC-06	Boone Creek	9	105.3	15.6	3.9
HKC-07	Somerset Creek	9	409.1	25.2	9.3
HKC-08	Grassy Lick Creek	11	191.6	18.8	5.8
HKC-09	Somerset Creek (Grassy)	12	235.8	18.8	7.2
HKC-10	Hinkston Creek	11	529.7	35.2	8.6
HKC-11	Hinkston Creek	12	294.2	15.2	11.0
HKC-12	Hinkston Creek	12	85.0	4.24	11.4

D.2 Total Phosphorus (TP)

D.2.1 Concentration Comparisons

Mainstem

KDOW

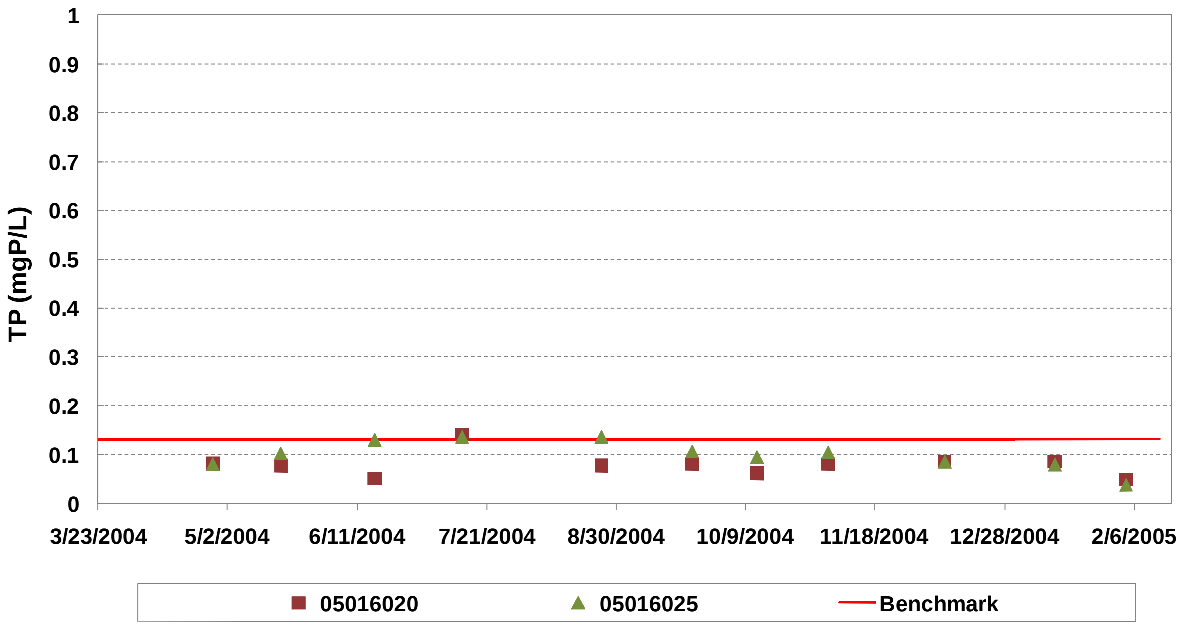
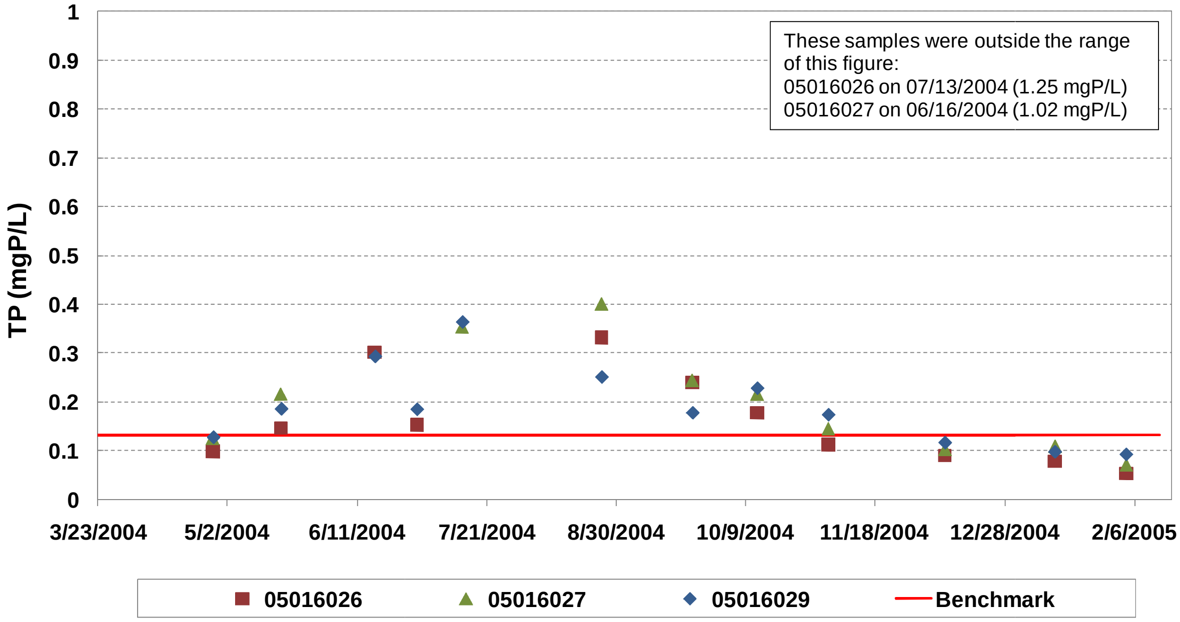


Figure D-11. Total Phosphorus Concentrations Measured for Mainstem KDOW Stations



These samples were outside the range of this figure:
05016026 on 07/13/2004 (1.25 mgP/L)
05016027 on 06/16/2004 (1.02 mgP/L)

Figure D-12. Total Phosphorus Concentrations Measured for Mainstem KDOW Stations

MSU

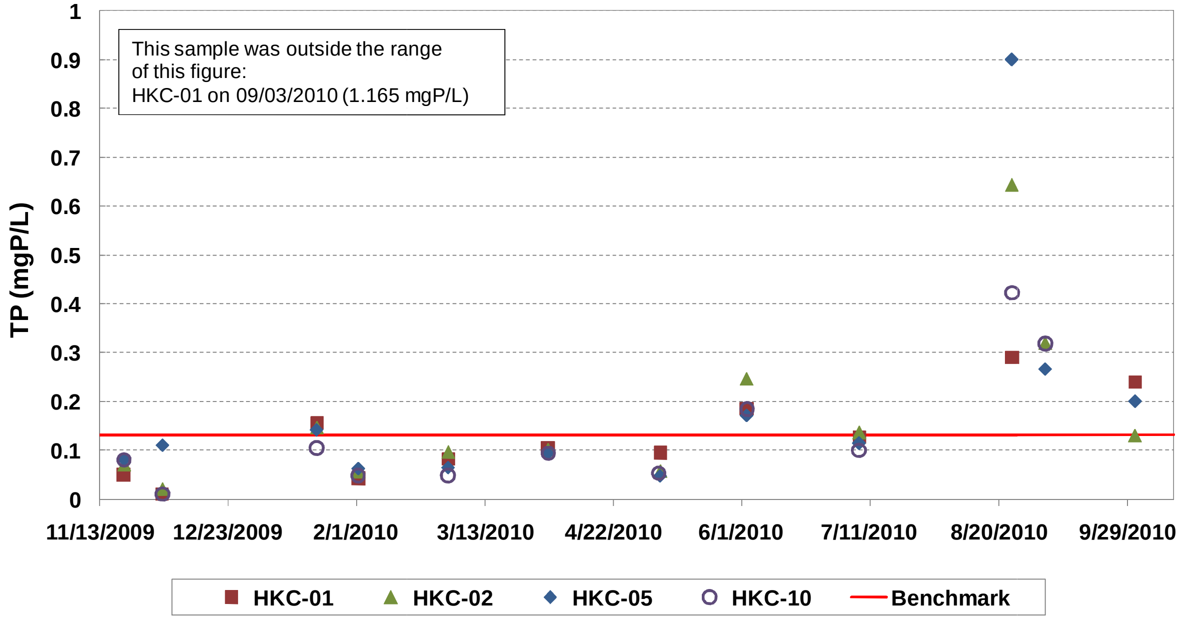


Figure D-13. Total Phosphorus Concentrations Measured for Mainstem MSU Stations

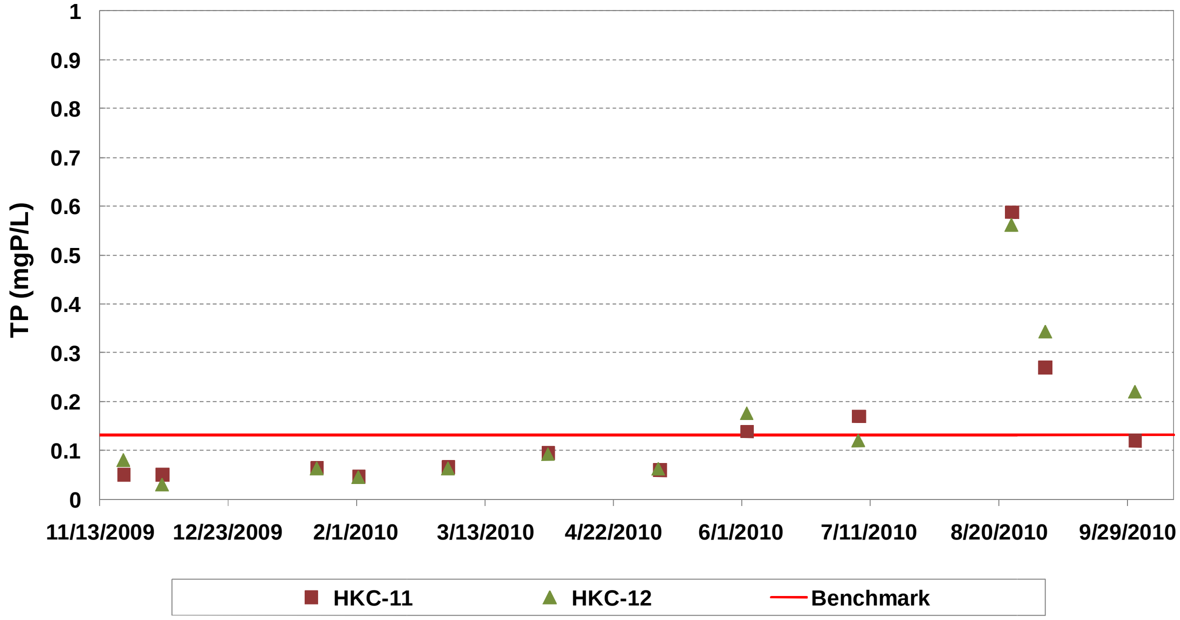


Figure D-14. Total Phosphorus Concentrations Measured for Mainstem MSU Stations

Tributaries

KDOW

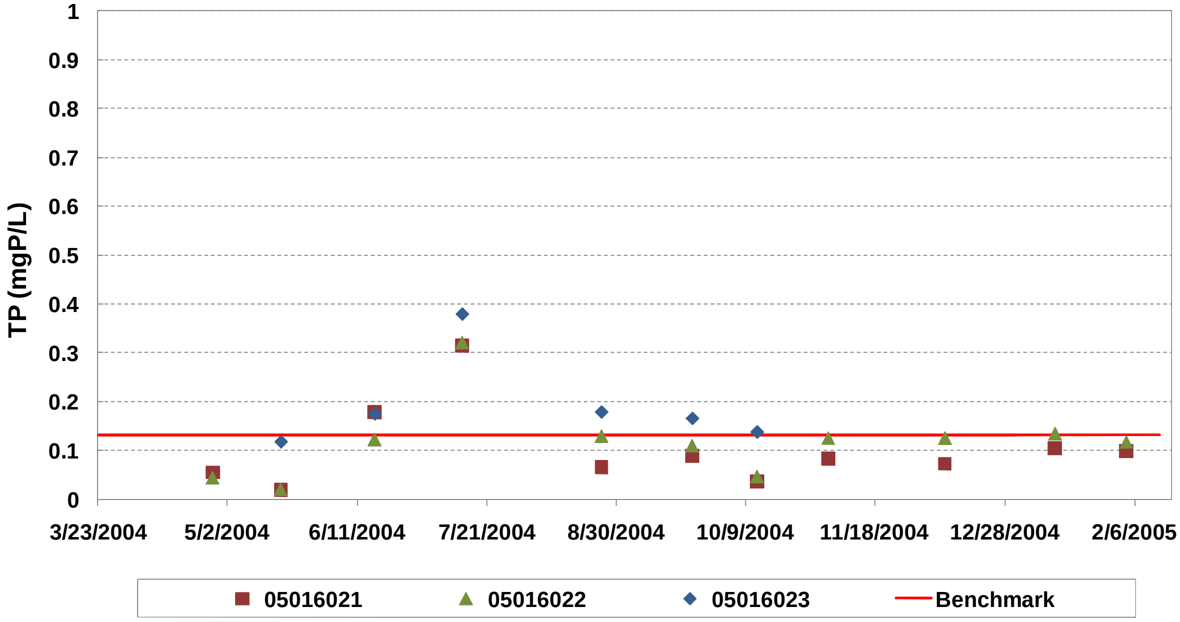
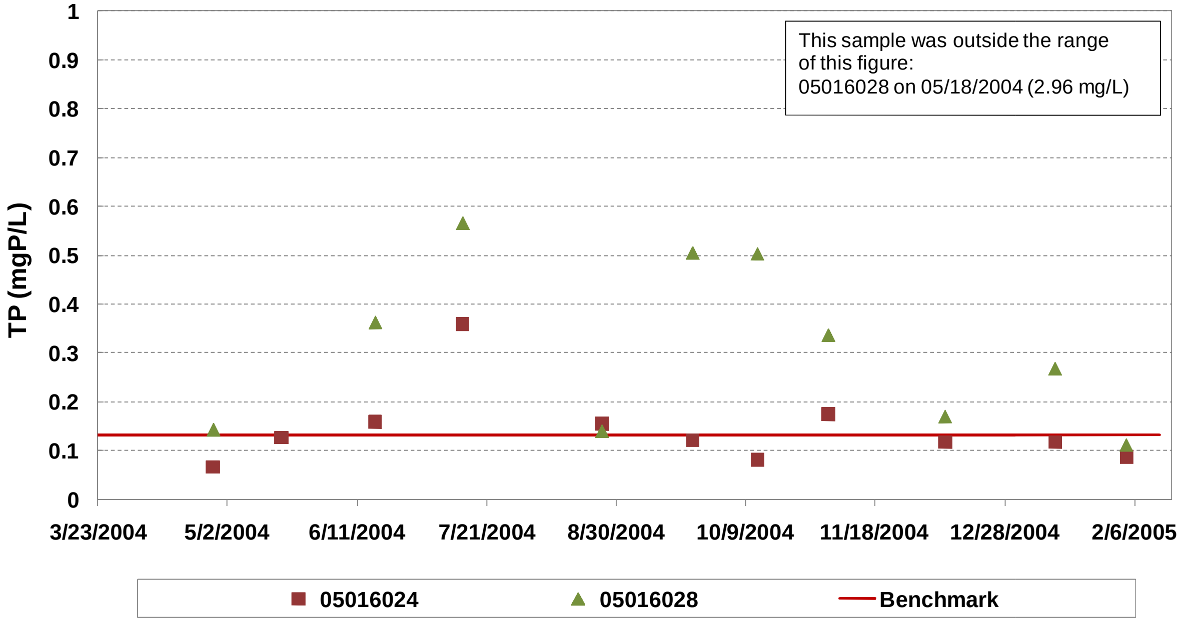


Figure D-15. Total Phosphorus Concentrations Measured for Tributary KDOW Stations



This sample was outside the range of this figure:
05016028 on 05/18/2004 (2.96 mg/L)

Figure D-16. Total Phosphorus Concentrations Measured for Tributary KDOW Stations

MSU

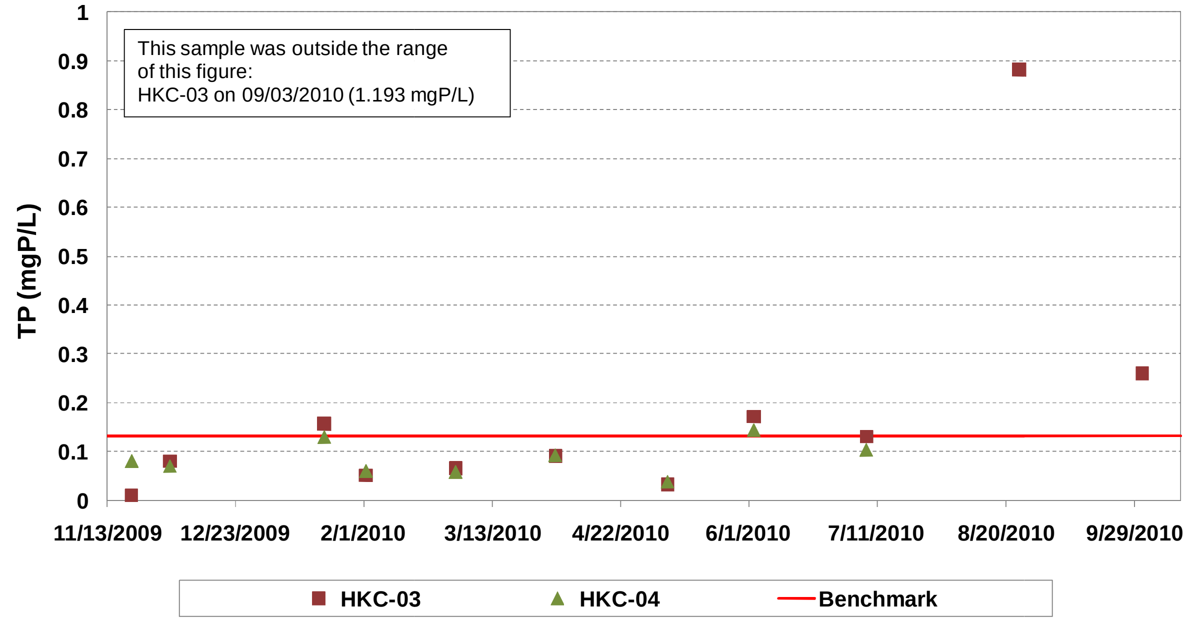


Figure D-17. Total Phosphorus Concentrations Measured for Tributary MSU Stations

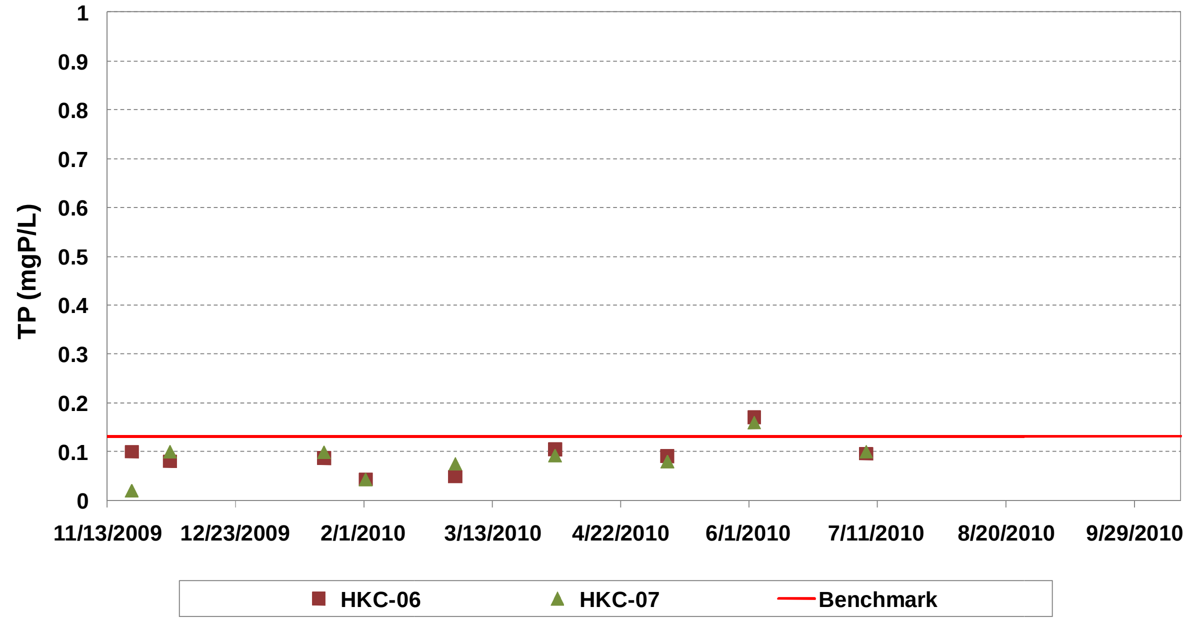


Figure D-18. Total Phosphorus Concentrations Measured for Tributary MSU Stations

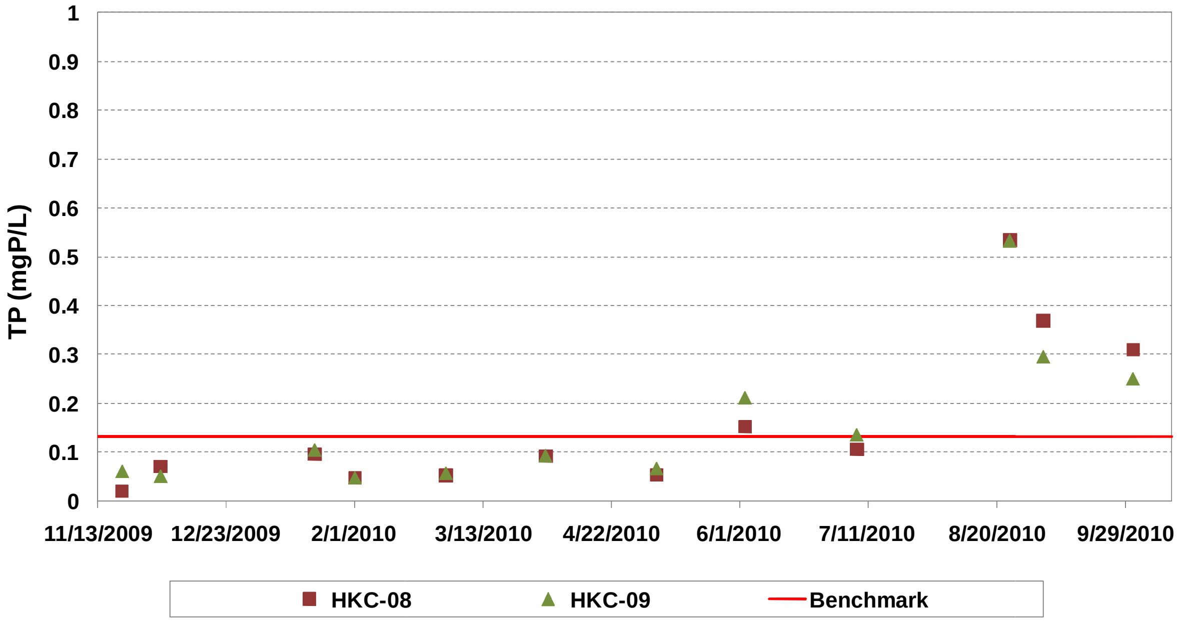


Figure D-19. Total Phosphorus Concentrations Measured for Tributary MSU Stations

Table D-5. Summary Statistics for Total Phosphorus Concentrations (mgP/L) for KDOW, MSU, and Coincident KDOW/MSU Stations

Parameter	Stations	05016020	05016021	05016022	05016023	05016024	05016025	05016026	05016027	05016028	05016029
TP	Max	0.140	0.314	0.321	0.387	0.359	0.136	1.250	1.020	2.960	0.363
	75th	0.084	0.104	0.127	0.379	0.158	0.130	0.287	0.299	0.509	0.240
	Median	0.080	0.083	0.122	0.175	0.121	0.103	0.150	0.216	0.336	0.178
	25th	0.070	0.055	0.046	0.138	0.102	0.080	0.092	0.117	0.156	0.108
	Min	0.049	0.019	0.020	0.118	0.066	0.038	0.053	0.071	0.111	0.093
	Average	0.080	0.101	0.112	0.220	0.141	0.100	0.253	0.259	0.526	0.184
	# Obs.	12	11	13	7	13	11	12	13	13	13
	# Exceed	1	2	2	6	5	2	7	9	12	8
	% Exceed	8.3	18.2	15.4	85.7	38.5	18.2	58.3	69.2	92.3	61.5

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
TP	Max	1.165	0.643	1.193	0.143	0.901	0.171	0.160	0.534	0.533	0.422	0.588	0.561
	75th	0.226	0.221	0.238	0.116	0.193	0.102	0.100	0.271	0.240	0.184	0.162	0.209
	Median	0.116	0.116	0.111	0.080	0.112	0.091	0.092	0.094	0.098	0.094	0.081	0.086
	25th	0.058	0.060	0.055	0.059	0.068	0.065	0.059	0.052	0.057	0.048	0.053	0.062
	Min	0.010	0.020	0.010	0.038	0.047	0.043	0.020	0.020	0.047	0.010	0.046	0.030
	Average	0.212	0.168	0.260	0.086	0.187	0.091	0.085	0.158	0.158	0.133	0.143	0.155
	# Obs.	12	12	12	9	12	9	9	12	12	11	12	12
	# Exceed	5	5	5	1	5	1	1	4	5	3	4	4
	% Exceed	41.7	41.7	41.7	11.1	41.7	11.1	11.1	33.3	41.7	27.3	33.3	33.3

Parameter	Stations	05016029 and HKC-10	05016020 and HKC-12
TP	Max	0.422	0.561
	75th	0.218	0.113
	Median	0.123	0.08
	25th	0.093	0.062
	Min	0.01	0.03
	Average	0.16	0.117
	# Obs.	24	24
	# Exceed	11	5
	% Exceed	45.8	20.8

D.2.2 Load Comparisons

Table D-6. Total Phosphorus Loads Based on KDOW Monitoring (2004 – 2005)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
05016020	Hinkston Creek	11	2.5	4.2	0.34
05016021	Twin Oaks Subdivision/Industrial Park Tributary	11	1.0	2.2	0.26
05016022	Lane Branch	13	1.3	2.7	0.27
05016023	Bennett Branch	7	1.6	2.6	0.36
05016024	Town Branch	12	2.5	2.5	0.57
05016025	Hinkston Creek	11	5.4	12.0	0.26
05016026	Hinkston Creek	12	12.4	15.2	0.47
05016027	Hinkston Creek	11	23.8	23.7	0.57
05016028	Town Branch	12	0.7	0.3	1.40
05016029	Hinkston Creek	13	29.0	35.2	0.47

Table D-7. Total Phosphorus Loads Based on MSU Monitoring (2009 – 2010)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
HKC-01	Hinkston Creek	12	99.7	260.4	0.22
HKC-02	Hinkston Creek	12	81.3	223.7	0.21
HKC-03	Big Brushy Creek	12	5.3	28.9	0.10
HKC-04	Blacks Creek	9	8.3	8.5	0.56
HKC-05	Hinkston Creek	12	50.4	154.7	0.19
HKC-06	Boone Creek	9	3.4	15.6	0.12
HKC-07	Somerset Creek	9	10.4	25.2	0.24
HKC-08	Grassy Lick Creek	12	4.2	18.8	0.13
HKC-09	Somerset Creek (Grassy)	12	6.3	18.8	0.19
HKC-10	Hinkston Creek	11	11.5	35.2	0.19
HKC-11	Hinkston Creek	12	5.0	15.2	0.19
HKC-12	Hinkston Creek	12	1.8	4.2	0.24

D.3 Total Suspended Solids (TSS)

D.3.1 Concentration Comparisons

Mainstem

KDOW

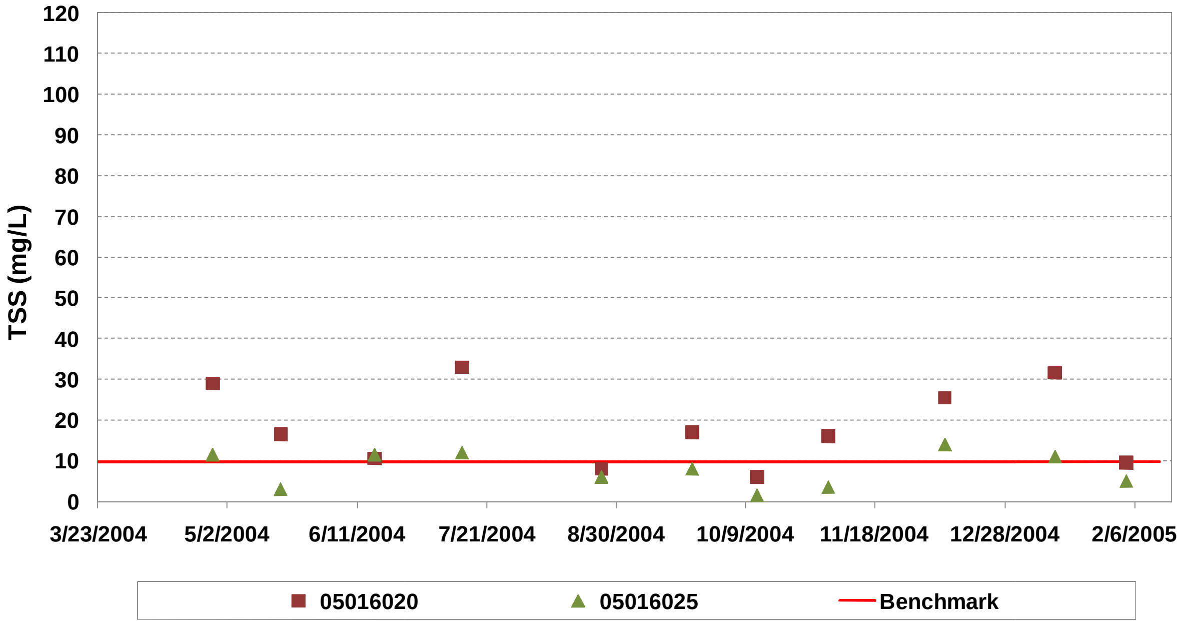


Figure D-20. Total Suspended Solids Concentrations Measured for Mainstem KDOW Stations

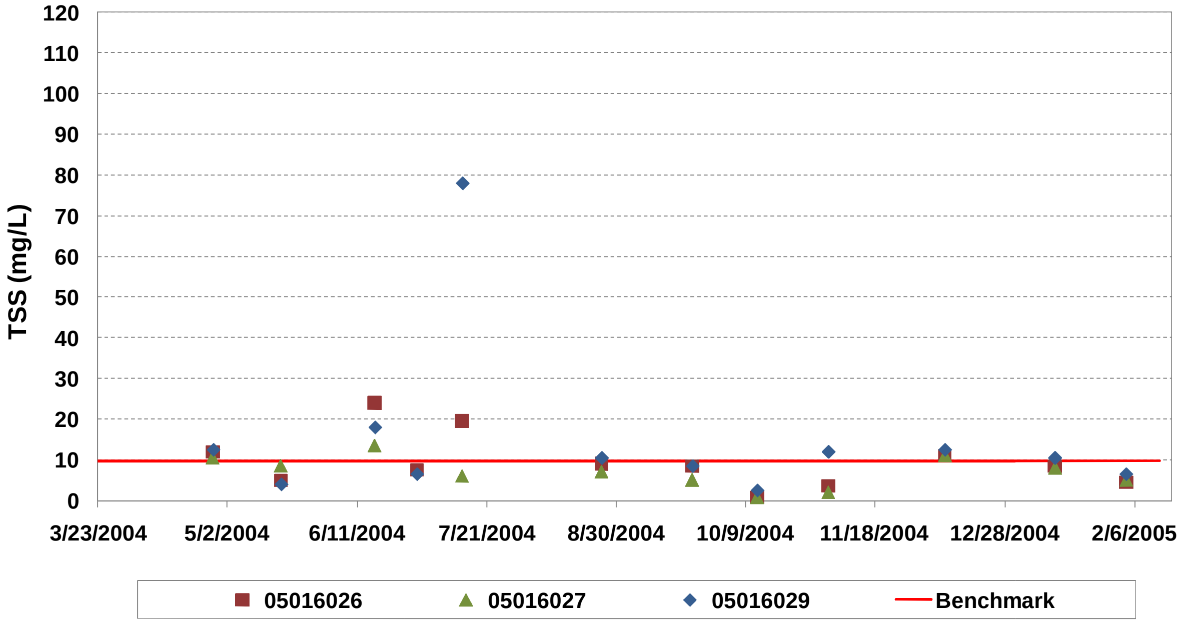


Figure D-21. Total Suspended Solids Concentrations Measured for Mainstem KDOW Stations

MSU

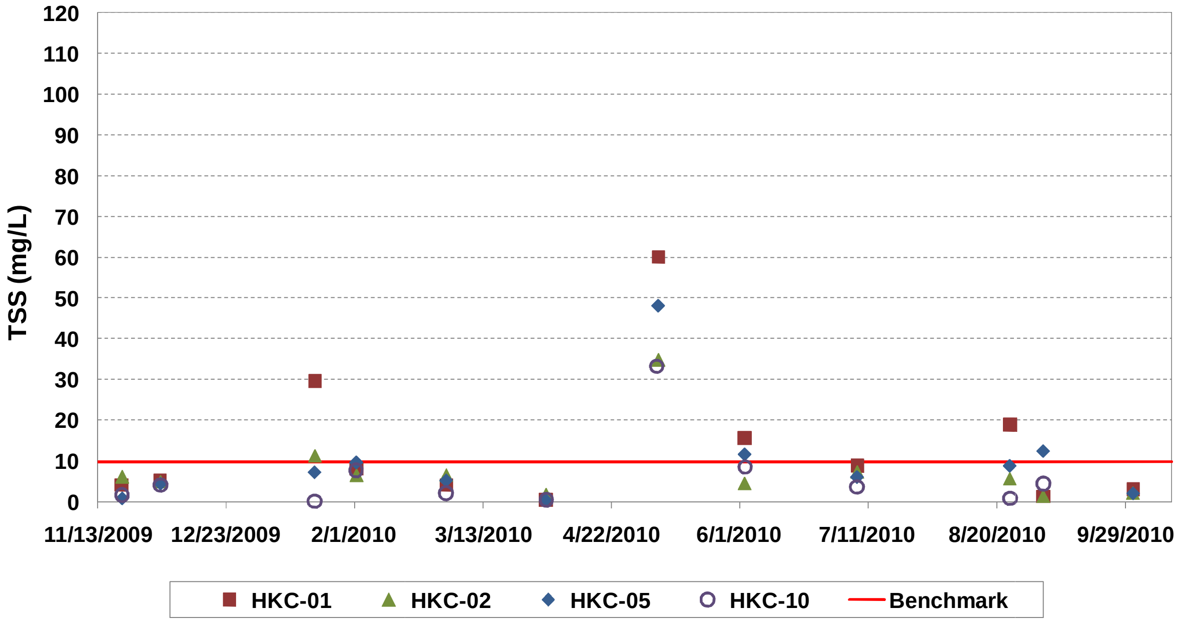


Figure D-22. Total Suspended Solids Concentrations Measured for Mainstem MSU Stations

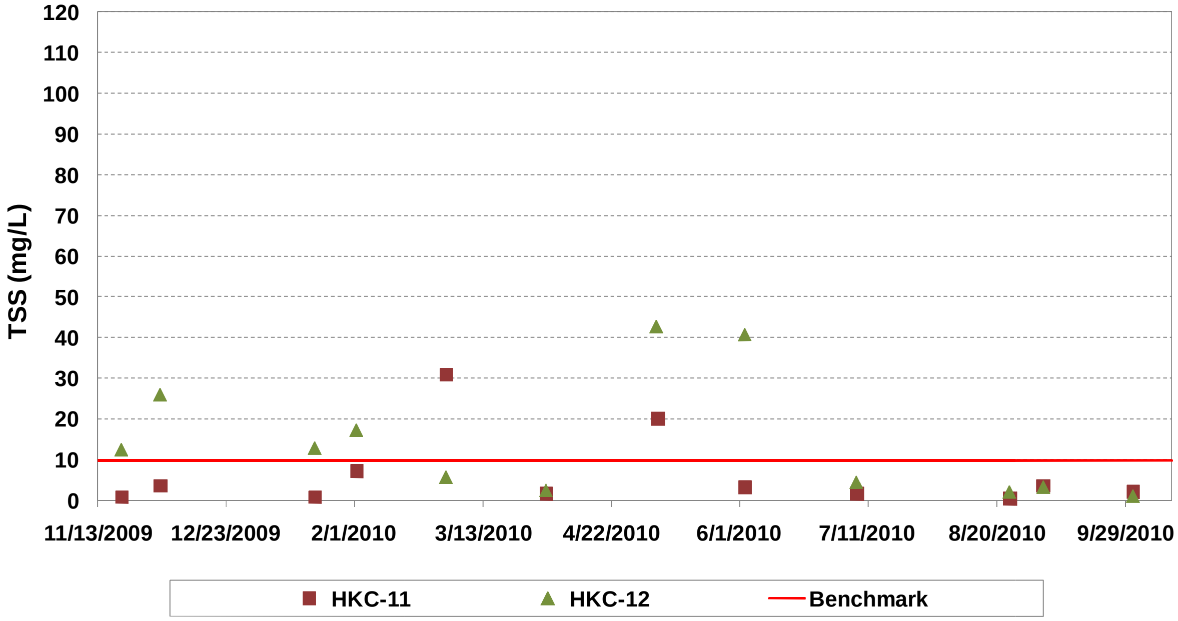


Figure D-23. Total Suspended Solids Concentrations Measured for Mainstem MSU Stations

Tributaries

KDOW

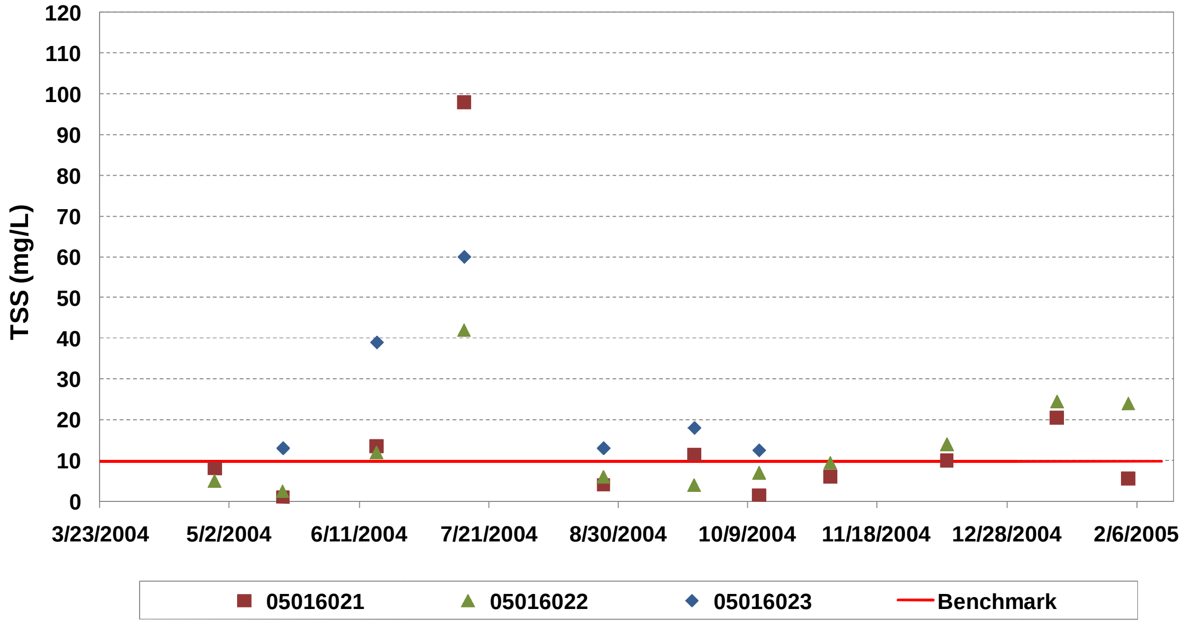


Figure D-24. Total Suspended Solids Concentrations Measured for Tributary KDOW Stations

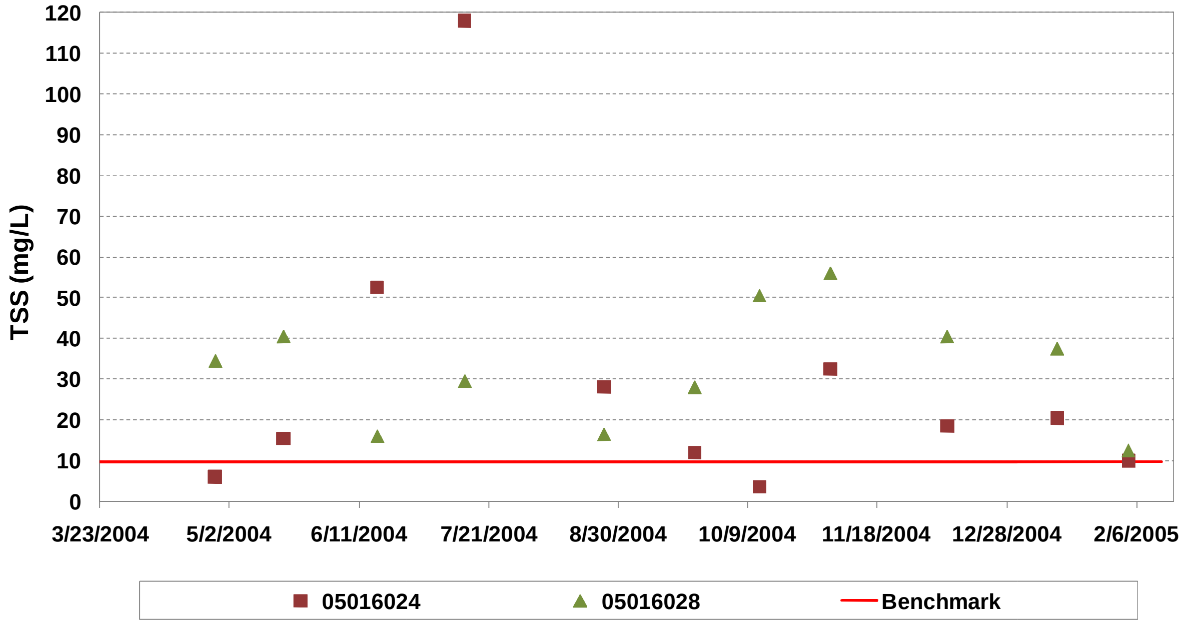


Figure D-25. Total Suspended Solids Concentrations Measured for Tributary KDOW Stations

MSU

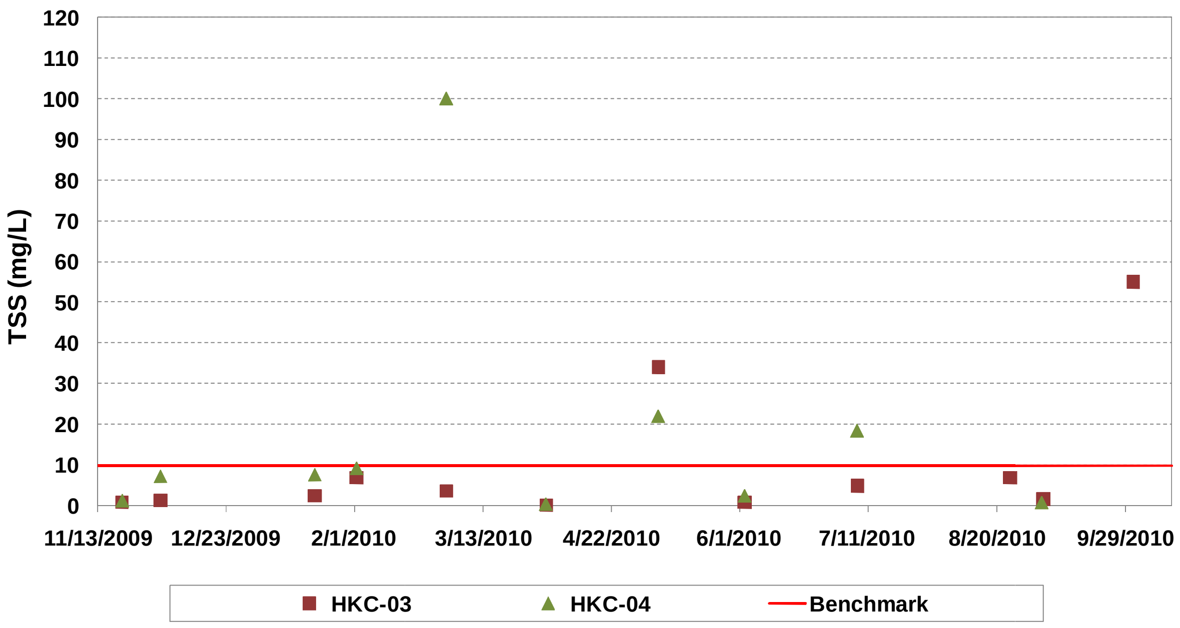


Figure D-26. Total Suspended Solids Concentrations Measured for Tributary MSU Stations

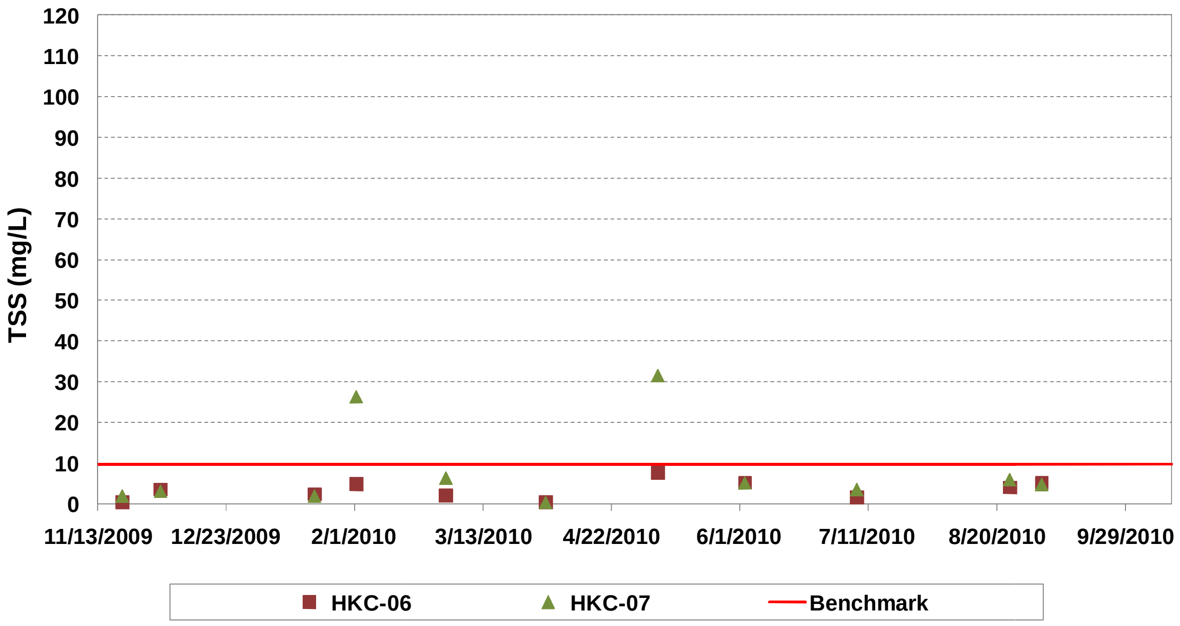


Figure D-27. Total Suspended Solids Concentrations Measured for Tributary MSU Stations

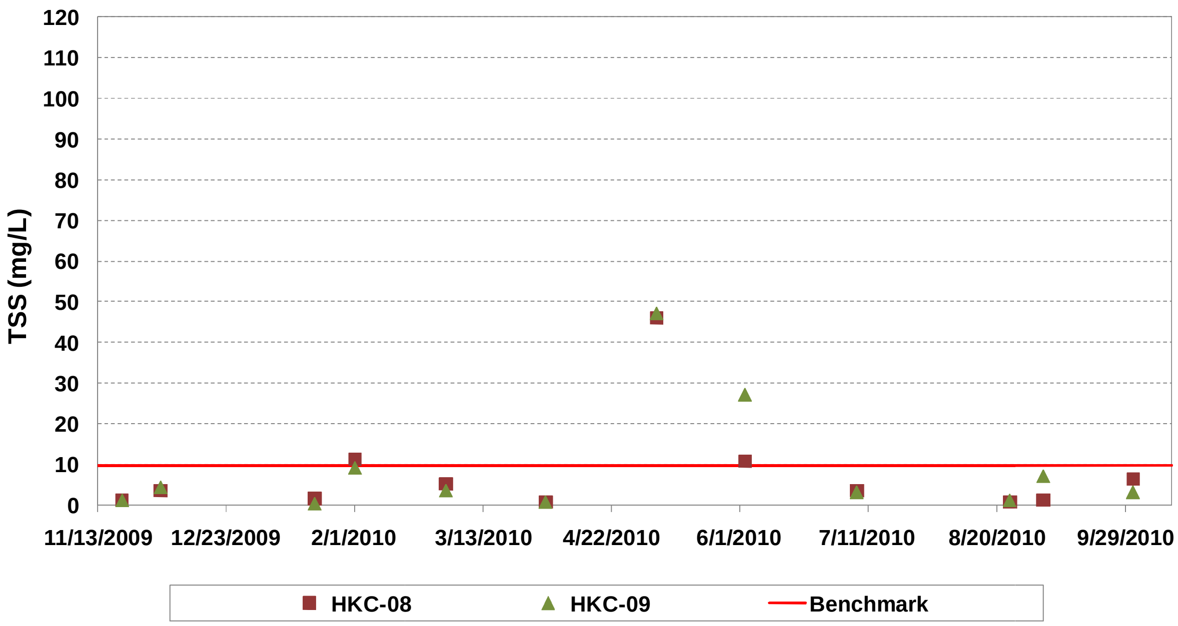


Figure D-28. Total Suspended Solids Concentrations Measured for Tributary MSU Stations

Table D-8. Summary Statistics for Total Suspended Solids (mg/L) for KDOW, MSU, and Coincident KDOW/MSU Stations

Parameter	Stations	05016020	05016021	05016022	05016023	05016024	05016025	05016026	05016027	05016028	05016029
TSS	Max	33.0	98.0	42.0	74.0	118.0	14.0	24.0	13.5	56.0	78.0
	75th	27.5	13.5	19.0	60.0	30.5	11.5	11.8	10.0	40.5	12.5
	Median	16.5	8.0	9.5	18.0	20.0	8.0	8.5	7.0	34.5	10.5
	25th	10.0	4.0	5.5	13.0	11.0	3.5	4.6	3.8	22.3	6.5
	Min	6.0	1.0	2.5	12.5	3.5	1.5	1.5	1.5	12.5	2.5
	Average	19.4	16.3	13.2	32.8	28.1	7.9	9.5	6.9	33.4	14.5
	# Obs.	12	11	13	7	13	11	12	13	13	13
	# Exceed	9	5	6	7	11	5	4	3	13	7
	% Exceed	75	45.5	46.2	100	84.6	45.5	33.3	23.1	100	53.8

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
TSS	Max	60.0	34.8	55.0	100.0	48.0	7.6	31.6	46.0	47.2	33.2	30.8	42.8
	75th	18.0	7.0	6.8	19.3	11.1	5.2	6.4	9.7	8.7	7.6	6.3	23.8
	Median	6.6	5.8	3.0	7.4	6.6	3.6	4.8	3.6	3.4	3.6	2.6	9.0
	25th	3.3	2.6	0.9	1.1	2.6	1.6	2.0	1.2	1.2	0.8	1.0	2.6
	Min	0.4	1.2	0.0	0.4	0.4	0.4	0.4	0.8	0.4	0.0	0.4	1.0
	Average	13.2	7.6	9.8	16.9	9.7	3.4	8.3	7.7	9.1	6.0	6.3	14.2
	# Obs.	12	12	12	10	12	11	11	12	12	11	12	12
	# Exceed	4	2	2	3	3	0	2	3	2	1	2	6
	% Exceed	33.3	16.7	16.7	30	25	0	18.2	25	16.7	9.1	16.7	50

Parameter	Stations	05016029 and HKC-10	05016020 and HKC-12
TSS	Max	78	42.8
	75th	11.6	28.3
	Median	6.75	14.4
	25th	2.8	5.7
	Min	0	1
	Average	10.6	16.8
	# Obs.	24	24
	# Exceed	8	15
	% Exceed	33.3	62.5

D.3.2 Load Comparisons

Table D-9. Total Suspended Solid Loads Based on KDOW Monitoring (2004 – 2005)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
05016020	Hinkston Creek	11	777.0	4.2	104.5
05016021	Twin Oaks Subdivision/Industrial Park Tributary	11	164.2	2.2	42.6
05016022	Lane Branch	13	175.3	2.7	37.0
05016023	Bennett Branch	7	328.5	2.6	72.1
05016024	Town Branch	12	505.5	2.5	115.3
05016025	Hinkston Creek	11	607.0	12.0	28.8
05016026	Hinkston Creek	12	808.5	15.2	30.3
05016027	Hinkston Creek	11	1014.0	23.7	24.4
05016028	Town Branch	12	76.3	0.3	145.0
05016029	Hinkston Creek	13	2408.1	35.2	39.0

Table D-10. Total Suspended Solid Loads Based on MSU Monitoring (2009 – 2010)

Station ID	Reach	No. Obs.	Average Observed Load (lb/d)	DA (sq mi)	Avg. Unit Area Load (lb/ac/y)
HKC-01	Hinkston Creek	12	25875.2	260.4	56.7
HKC-02	Hinkston Creek	12	12093.3	223.7	30.8
HKC-03	Big Brushy Creek	12	608.2	28.9	12.0
HKC-04	Blacks Creek	9	717.0	8.5	48.1
HKC-05	Hinkston Creek	12	8840.6	154.7	32.6
HKC-06	Boone Creek	9	122.9	15.6	4.5
HKC-07	Somerset Creek	9	1094.0	25.2	24.8
HKC-08	Grassy Lick Creek	12	715.7	18.8	21.7
HKC-09	Somerset Creek (Grassy)	12	949.7	18.8	28.8
HKC-10	Hinkston Creek	11	1570.7	35.2	25.4
HKC-11	Hinkston Creek	12	739.3	15.2	27.7
HKC-12	Hinkston Creek	12	478.2	4.2	64.3

D.4 Dissolved Oxygen (DO)

Mainstem

KDOW

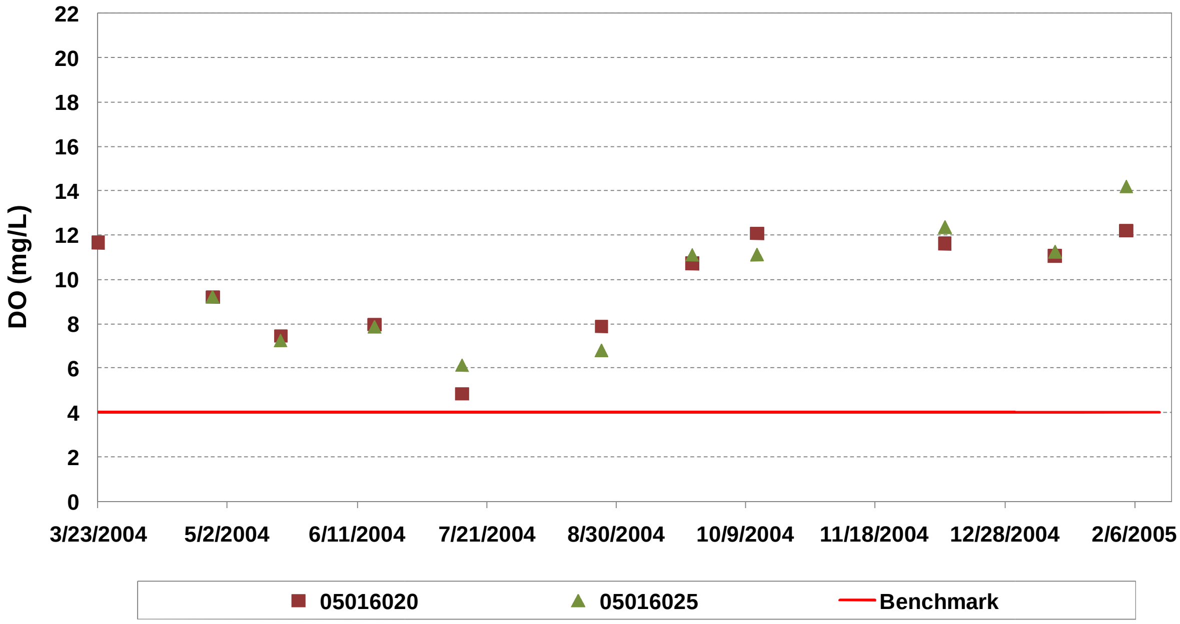


Figure D-29. Dissolved Oxygen Concentrations Measured for Mainstem KDOW Stations

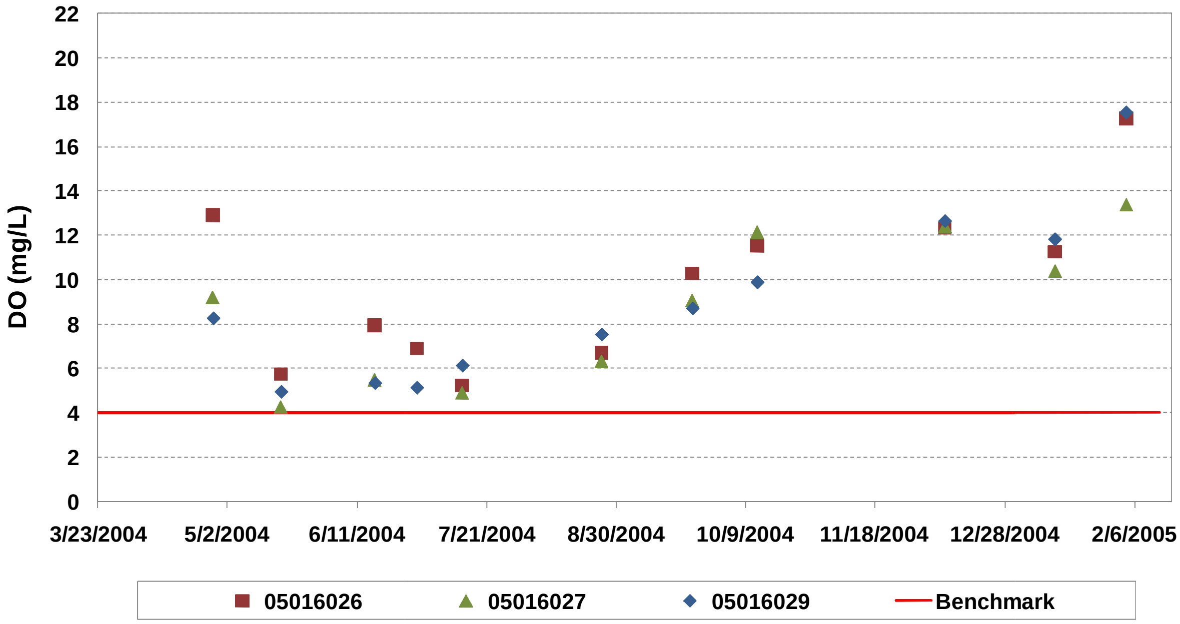


Figure D-30. Dissolved Oxygen Concentrations Measured for Mainstem KDOW Stations

MSU

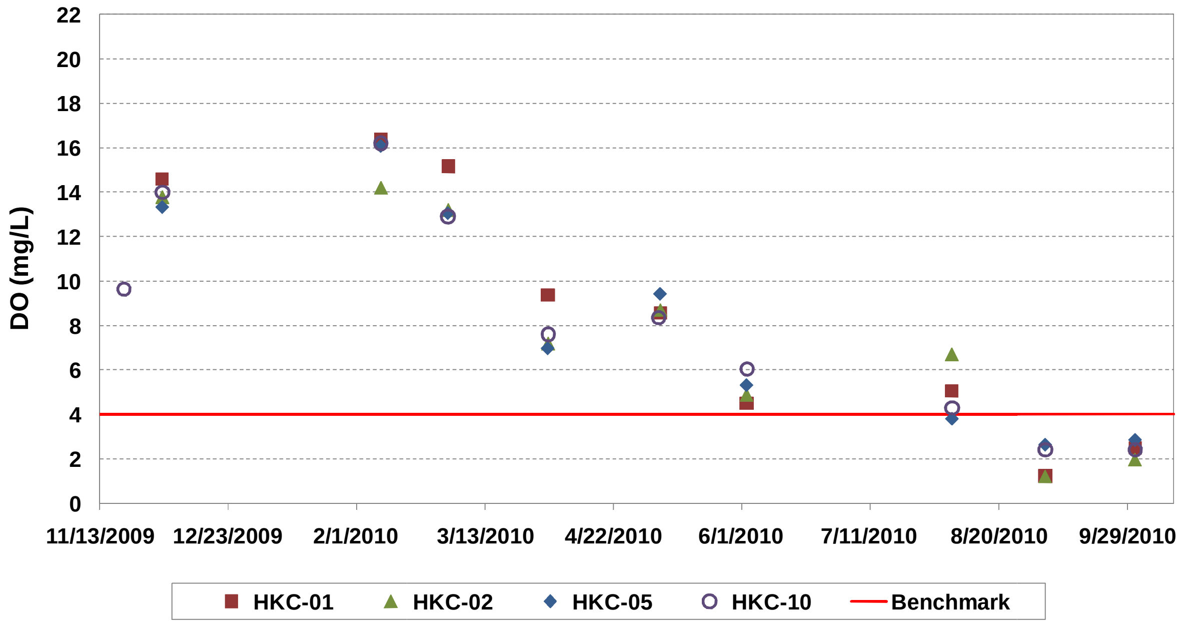


Figure D-31. Dissolved Oxygen Concentrations Measured for Mainstem MSU Stations

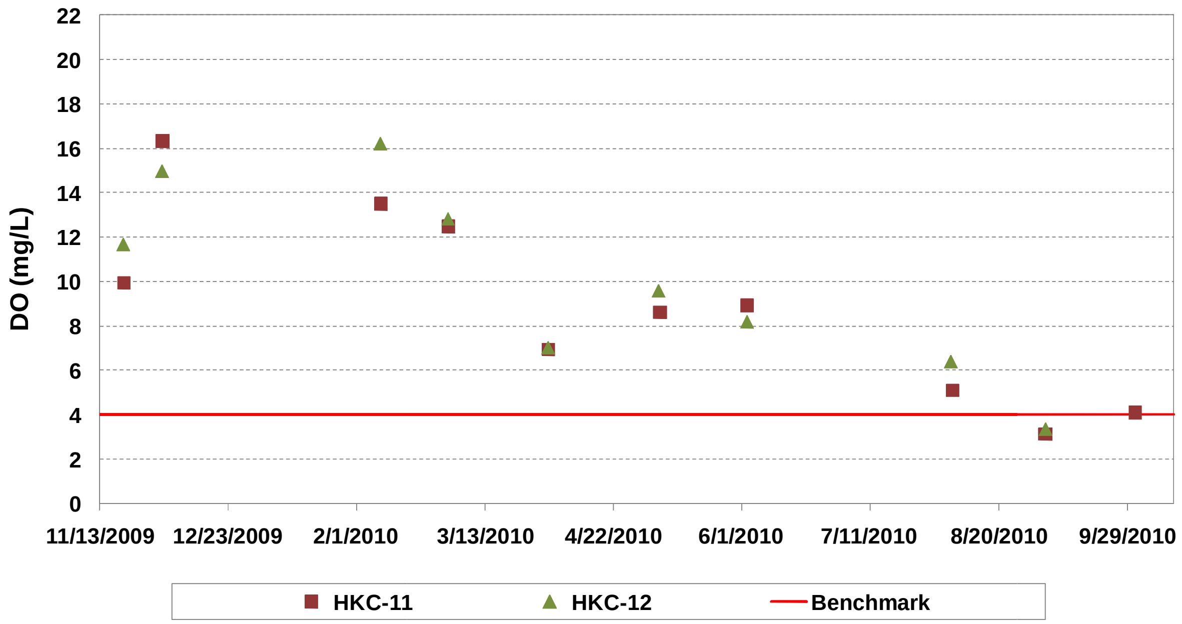


Figure D-32. Dissolved Oxygen Concentrations Measured for Mainstem MSU Stations

Tributaries

KDOW

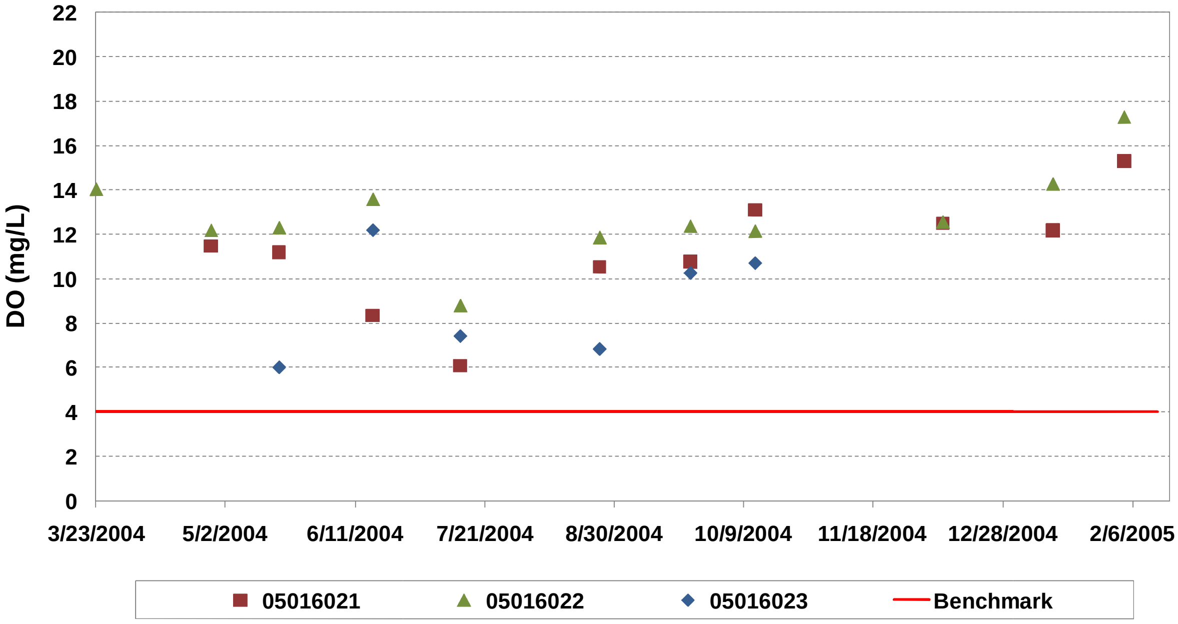


Figure D-33. Dissolved Oxygen Concentrations Measured for Tributary KDOW Stations

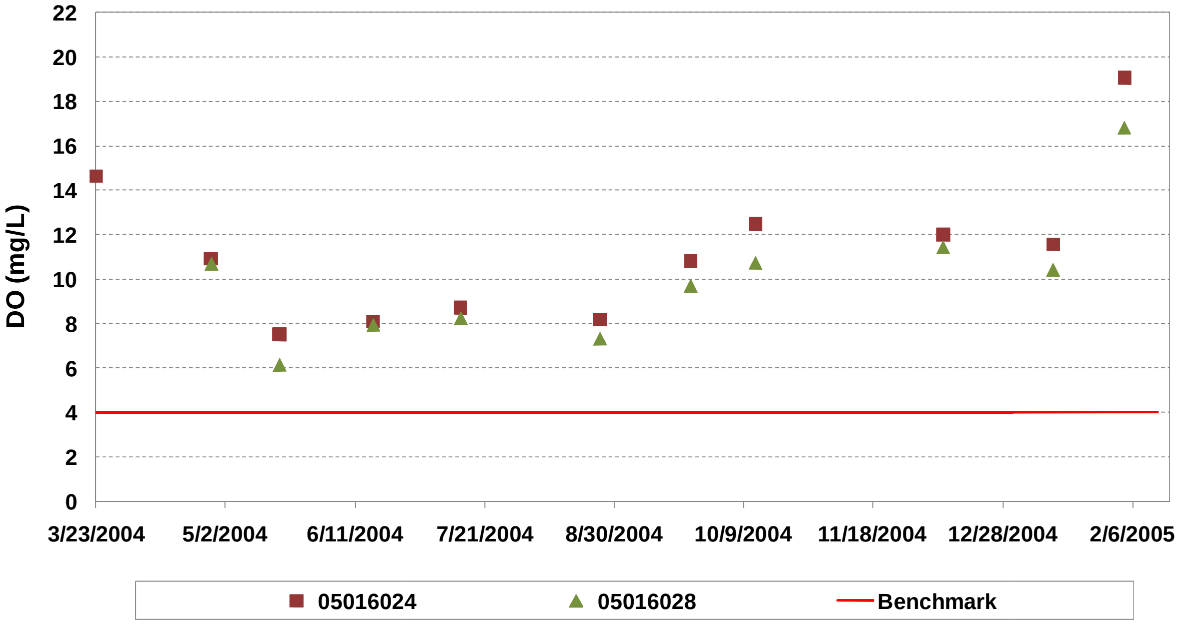


Figure D-34. Dissolved Oxygen Concentrations Measured for Tributary KDOW Stations

MSU

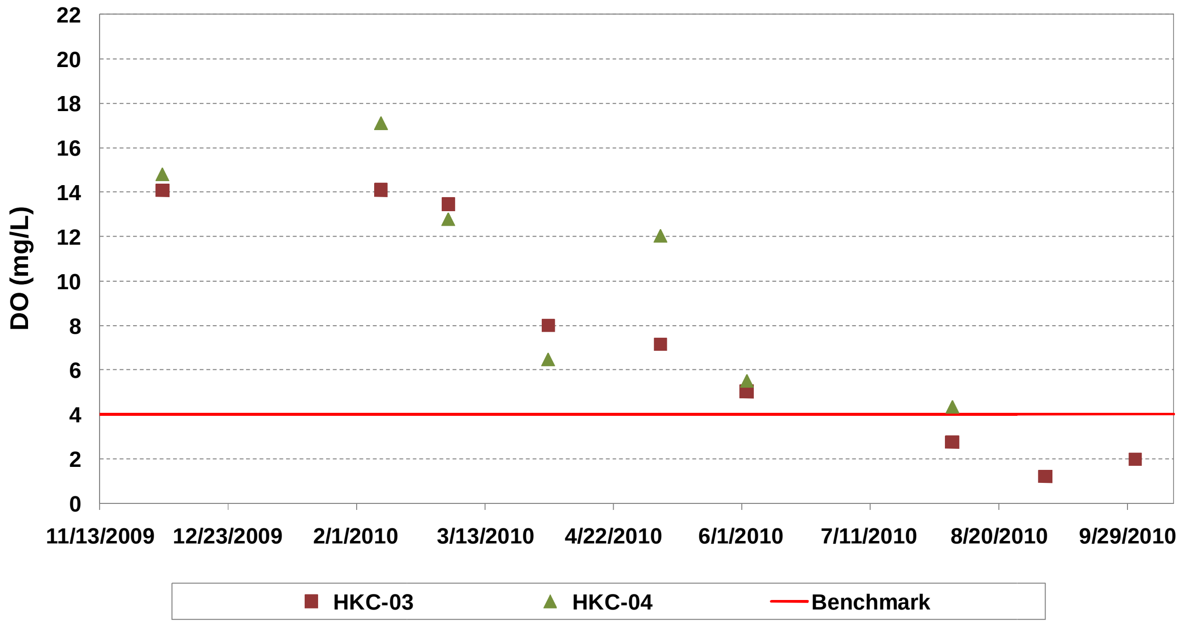


Figure D-35. Dissolved Oxygen Concentrations Measured for Tributary MSU Stations

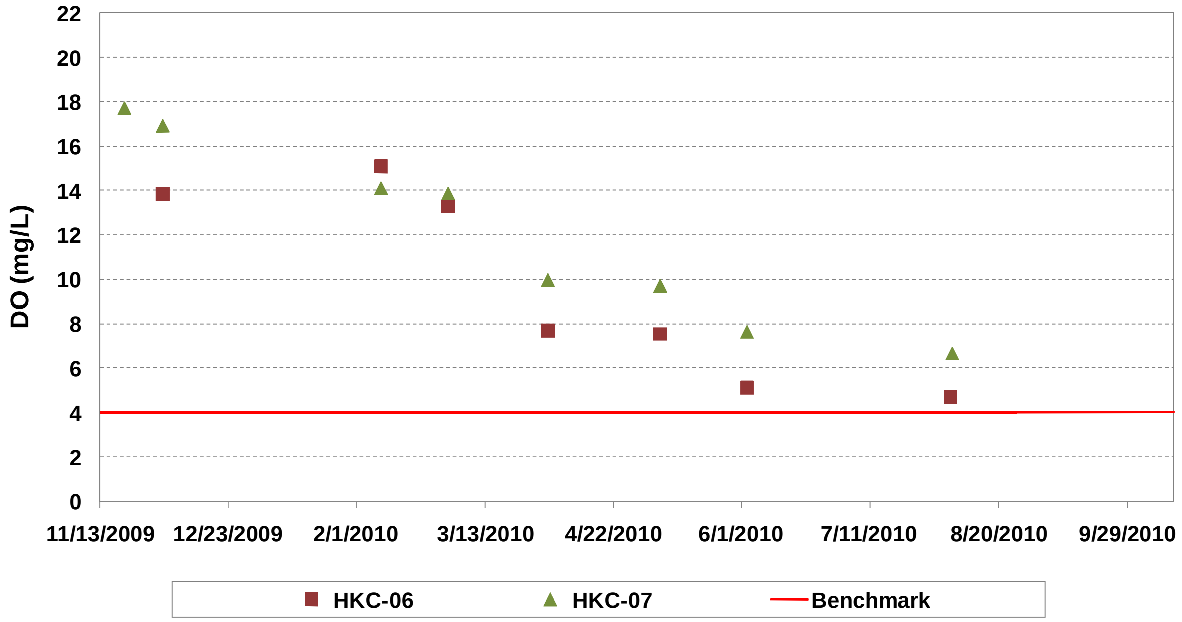


Figure D-36. Dissolved Oxygen Concentrations Measured for Tributary MSU Stations

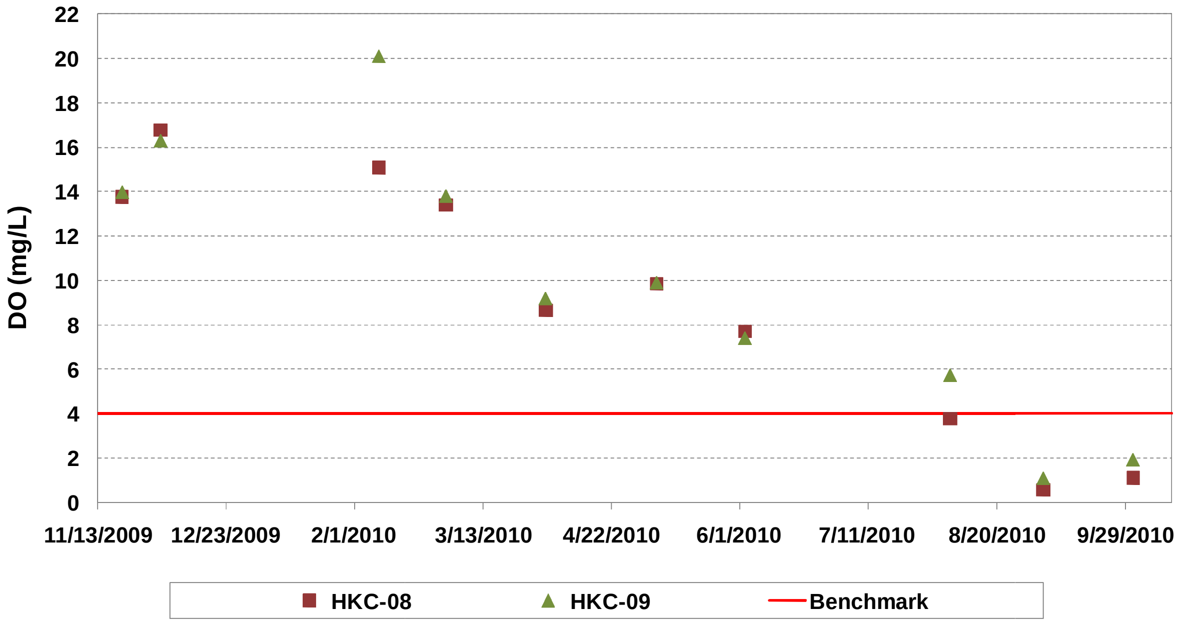


Figure D-37. Dissolved Oxygen Concentrations Measured for Tributary MSU Stations

Table D-11. Summary Statistics for Dissolved Oxygen (mg/L) for KDOW, MSU, and Coincident KDOW/MSU Stations

Parameter	Stations	05016020	05016021	05016022	05016023	05016024	05016025	05016026	05016027	05016028	05016029
DO	Max	12.2	15.3	17.3	12.2	19.1	14.2	17.3	13.4	16.8	17.6
	75th	11.6	12.7	14.0	11.1	12.5	11.5	12.3	12.2	10.9	11.8
	Median	10.7	11.3	12.4	8.8	10.9	10.2	10.3	9.1	10.1	8.3
	25th	7.9	10.0	12.2	6.6	8.2	7.1	6.7	5.4	7.8	5.3
	Min	4.9	6.1	8.8	6.0	7.5	6.1	5.2	4.3	6.1	4.9
	Average	9.7	11.2	12.9	8.9	11.3	9.7	9.8	8.8	9.9	8.9
	# Obs.	11	10	11	6	11	10	11	10	10	11
	# Below	0	0	0	0	0	0	0	0	0	0
	% Below	0	0	0	0	0	0	0	0	0	0

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
DO	Max	16.4	14.2	14.1	17.1	16.1	15.1	17.7	16.8	20.1	16.2	16.3	16.2
	75th	14.9	13.5	13.8	14.8	13.2	13.9	16.2	14.1	14.6	13.2	12.7	13.9
	Median	8.6	7.2	7.2	12.0	7.0	7.7	11.9	9.3	9.6	8.0	8.8	9.6
	25th	3.5	3.4	2.4	5.5	3.3	5.1	8.2	3.1	4.8	3.8	4.8	6.7
	Min	1.2	1.2	1.2	4.3	2.6	4.7	6.7	0.6	1.1	2.4	3.1	3.4
	Average	8.6	8.0	7.5	10.4	8.2	9.6	12.1	9.1	10.0	8.4	8.9	10.0
	# Obs.	9	9	9	7	9	7	8	10	10	10	10	9
	# Below	2	2	3	0	3	0	0	3	2	2	1	1
	% Below	22.2	22.2	33.3	0	33.3	0	0	30	20	20	10	11.1

Parameter	Stations	05016029 and HKC-10	05016020 and HKC-12
DO	Max	17.6	16.2
	75th	12.2	12.0
	Median	8.3	10.2
	25th	5.2	7.6
	Min	2.4	3.4
	Average	8.7	9.8
	# Obs.	21	20
	# Below	2	1
	% Below	9.5	5

D.5 E. coli

D.5.1 Concentration Comparisons

Mainstem

MSU and LRWW

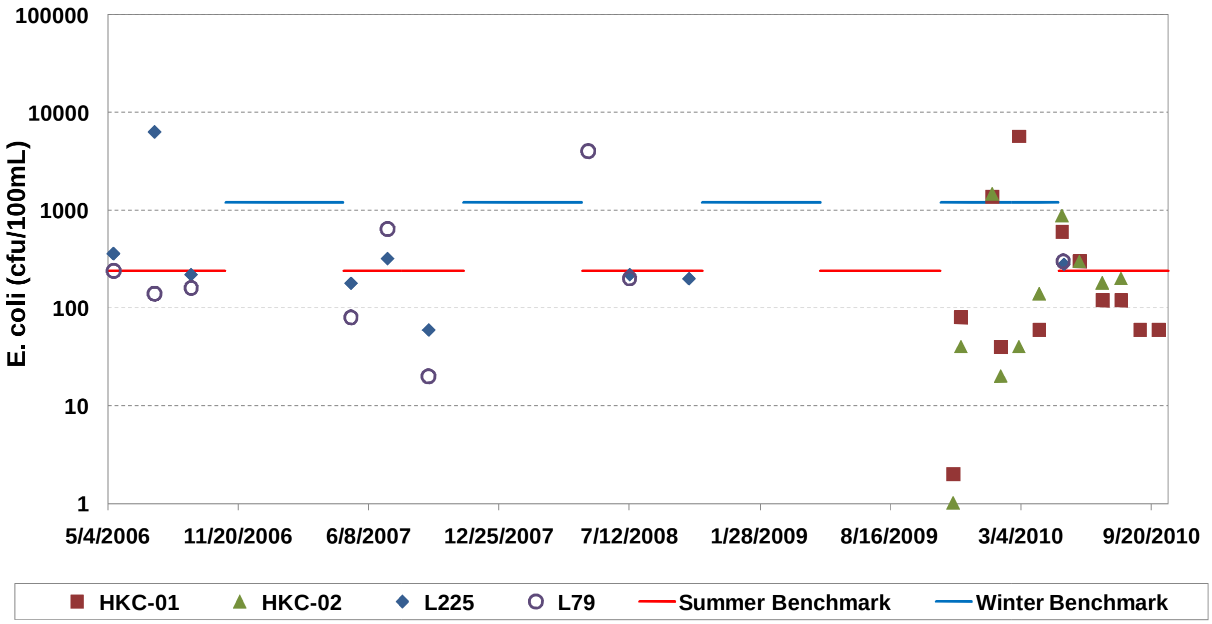


Figure D-38. E. coli Measured for Mainstem MSU and LRWW Stations

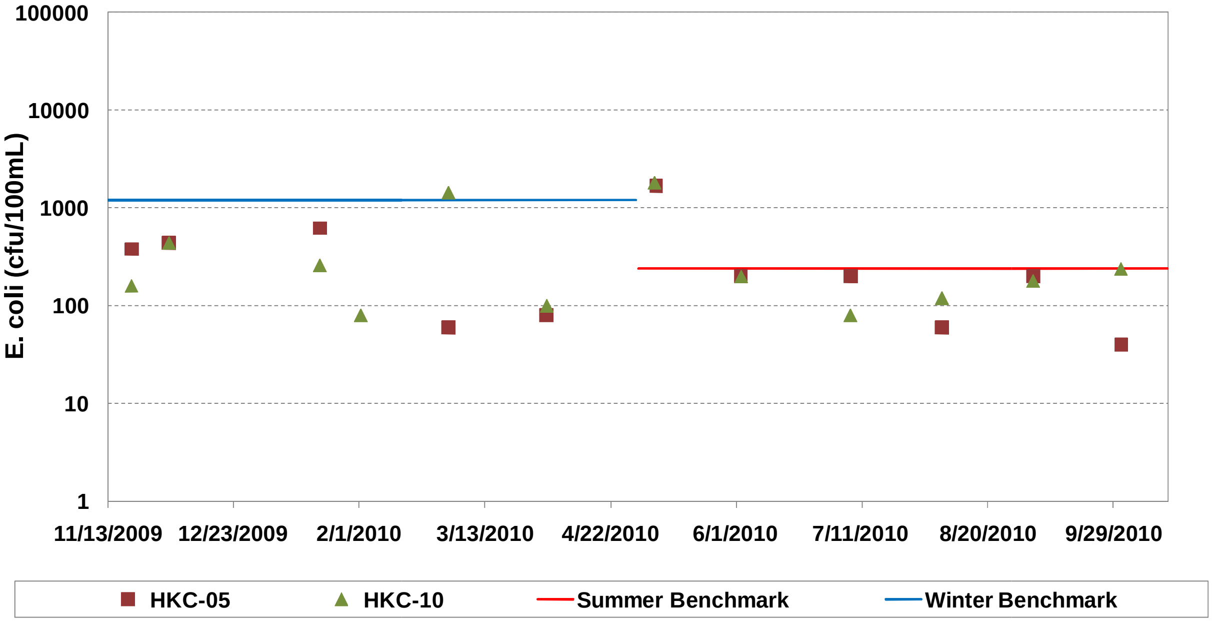


Figure D-39. E. coli Measured for Mainstem MSU Stations

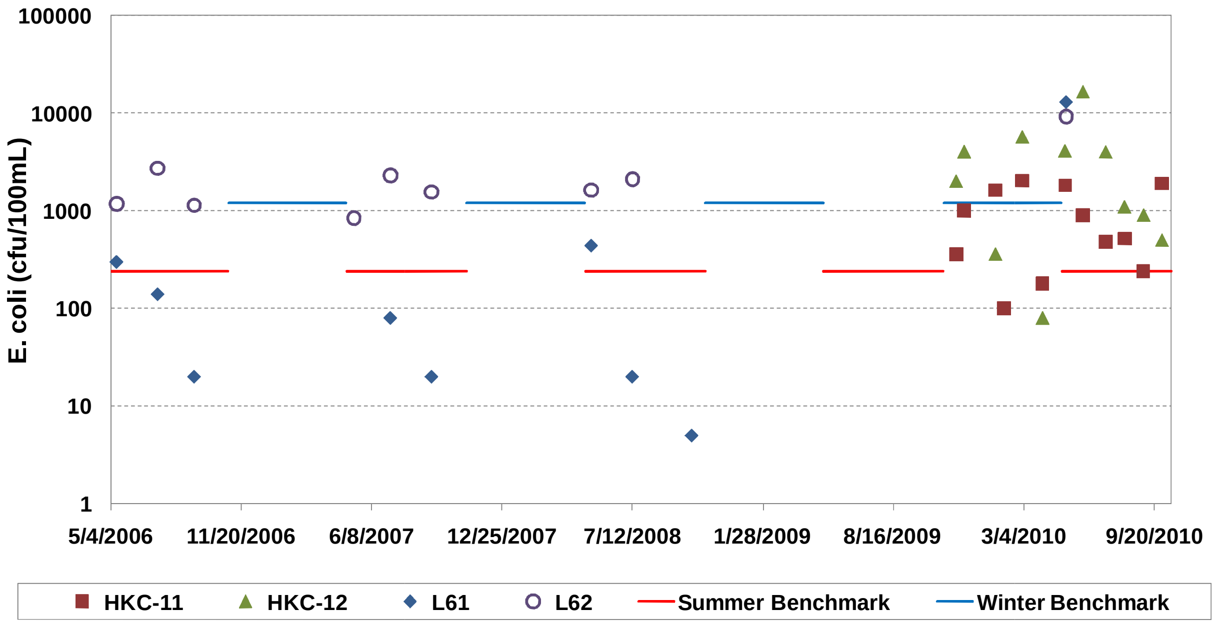


Figure D-40. E. coli Measured for Mainstem MSU and LRWW Stations

Tributaries

MSU and LRWW

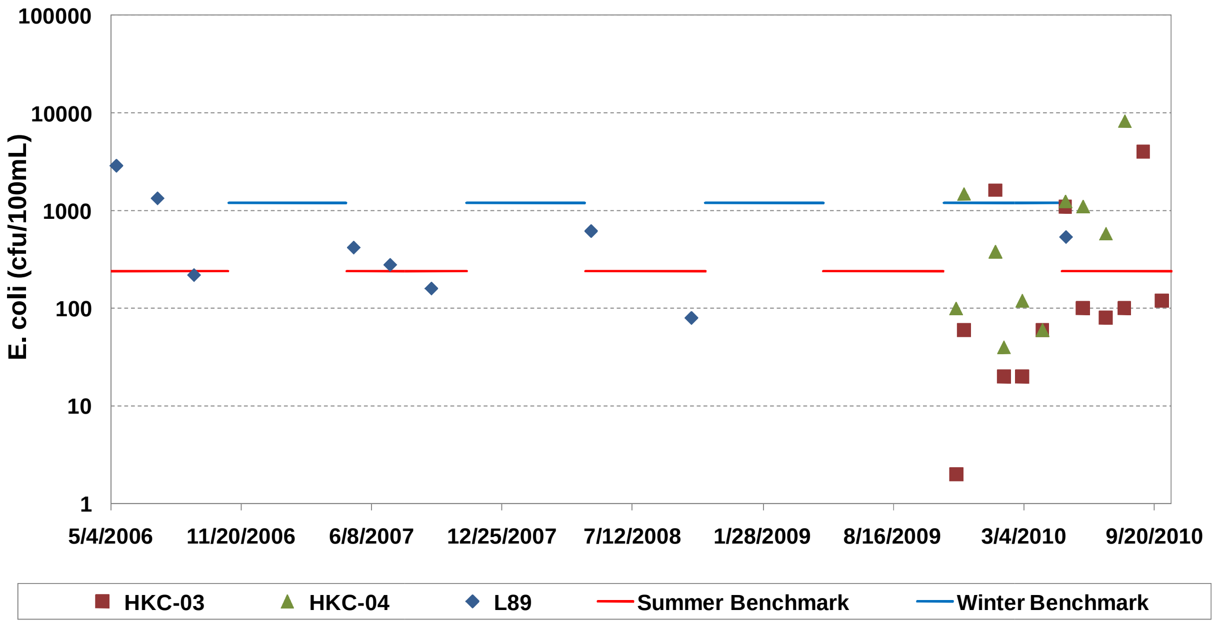


Figure D-41. E. coli Measured for Tributary MSU and LRWW Stations

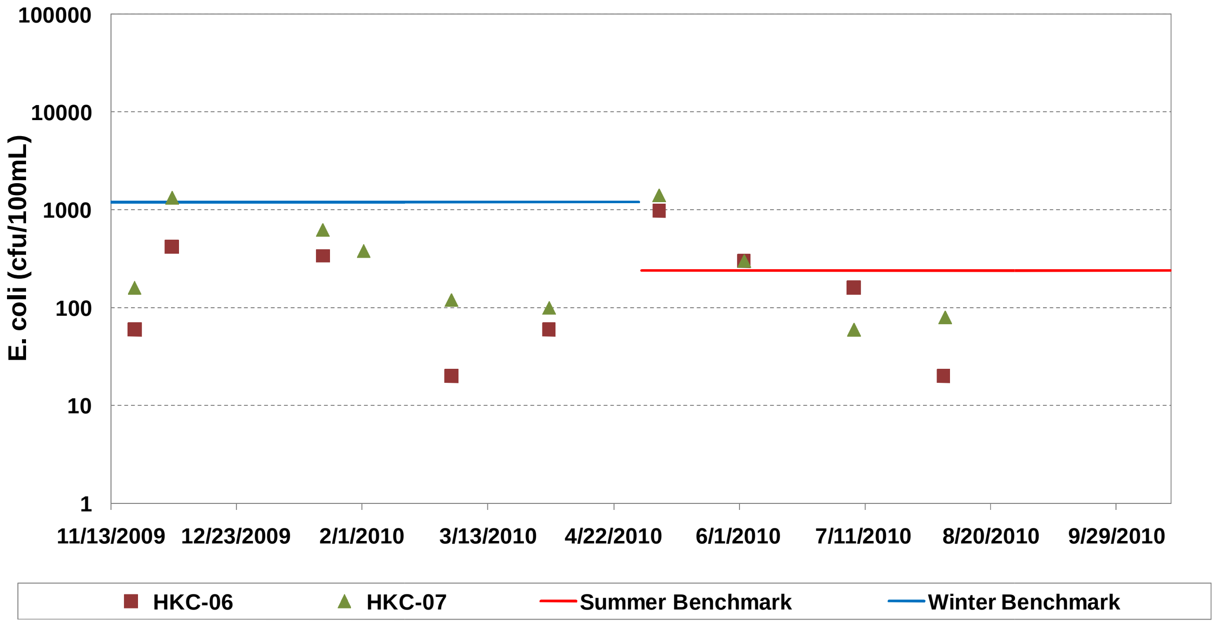


Figure D-42. E. coli Measured for Tributary MSU Stations

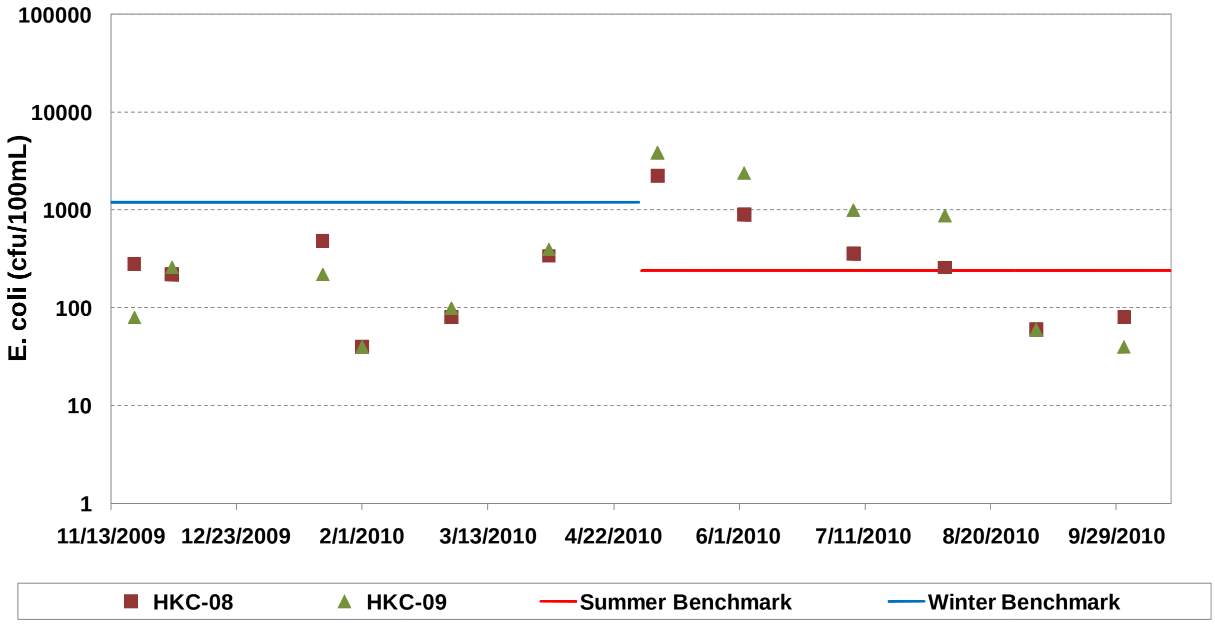


Figure D-43. E. coli Measured for Tributary MSU Stations

Table D-12. Summary Statistics for E. coli (cfu/100mL) for MSU, LRWW, and Coincident MSU/LRWW Stations

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
E. coli (Summer)	Max	600	880	4000	8220	1680	980	1400	2240	3880	1820	1900	16500
	75th	375	445	1825	6475	570	810	1125	1235	2770	635	1840	7200
	Median	120	190	110	1170	200	230	190	310	940	190	710	2550
	25th	60	0	95	710	55	55	65	75	55	110	420	800
	Min	60	0	80	580	40	20	60	60	40	80	240	500
	Average	210	260	917	2785	397	365	460	650	1377	440	977	4517
	# Obs.	6	6	6	4	6	4	4	6	6	6	6	6
	# Exceed	2	2	2	4	1	2	2	4	4	1	5	6
	% Exceed	33.3	33.3	33.3	100	16.7	50	50	66.7	66.7	16.7	83.3	100

Parameter	Stations	HKC-01	HKC-02	HKC-03	HKC-04	HKC-05	HKC-06	HKC-07	HKC-08	HKC-09	HKC-10	HKC-11	HKC-12
E. coli (Winter)	Max	5700	1480	1620	1480	620	420	1320	480	400	1440	2040	5700
	75th	2460	475	450	655	485	340	795	375	295	690	1725	4860
	Median	70	40	40	110	230	60	270	250	160	210	680	2000
	25th	31	15	16	55	45	20	115	70	70	95	160	220
	Min	2	1	2	40	0	0	100	40	40	80	100	80
	Average	1210	287	297	363	263	143	450	240	183	413	883	2432
	# Obs.	6	6	6	6	6	7	6	6	6	6	6	5
	# Exceed	2	1	1	1	0	0	1	0	0	1	2	3
	% Exceed	33.3	16.7	16.7	16.7	0	0	16.7	0	0	16.7	33.3	60

Parameter	Stations	L225	L61	L62	L79	L89
E. coli (Summer)	Max	6260	12980	9220	4020	2900
	75th	340	370	2510	470	980
	Median	220	80	1620	200	420
	25th	190	20	1160	110	190
	Min	60	10	840	20	80
	Average	900	1557	2520	644	729
	# Obs.	9	9	9	9	9
	# Exceed	4	3	9	3	6
	% Exceed	44.4	33.3	100	33.3	66.7

Parameter	Stations	HKC-12 and L61	HKC-01 and L225
E. coli (Summer)	Max	16500	6260
	75th	4000	320
	Median	440	220
	25th	20	120
	Min	10	60
	Average	2741	624
	# Obs.	15	15
	# Exceed	9	6
	% Exceed	60	40

D.5.2 Load Comparisons

Table D-13. E. coli Loads Based on MSU Monitoring (2009 – 2010)

Station	Reach	No. Obs.	Avg. Observed Winter Load (cfu/d)	Avg. Observed Summer Load (cfu/d)	DA (sq mi)	Avg. Annual Unit Area Load (cfu/ac/y)
HKC-01	Hinkston Creek	12	7.9E+12	1.5E+12	260.4	1.0E+10
HKC-02	Hinkston Creek	12	3.6E+12	1.9E+12	223.7	6.9E+09
HKC-03	Big Brushy Creek	12	2.2E+11	1.3E+11	28.9	3.5E+09
HKC-04	Blacks Creek	10	1.6E+11	5.8E+10	8.5	7.4E+09
HKC-05	Hinkston Creek	12	1.0E+12	2.1E+12	154.7	5.8E+09
HKC-06	Boone Creek	10	4.2E+10	7.6E+10	15.6	2.1E+09
HKC-07	Somerset Creek	10	2.2E+11	2.3E+11	25.2	5.1E+09
HKC-08	Grassy Lick Creek	12	1.2E+11	2.6E+11	18.8	5.8E+09
HKC-09	Somerset Creek (Grassy)	12	1.4E+11	6.5E+11	18.8	1.2E+10
HKC-10	Hinkston Creek	12	2.3E+11	5.6E+11	35.2	6.4E+09
HKC-11	Hinkston Creek	12	5.0E+11	4.2E+11	15.2	1.7E+10
HKC-12	Hinkston Creek	11	2.6E+11	3.0E+11	4.2	3.8E+10

D.6 Fecal Coliform

Mainstem

LRWW

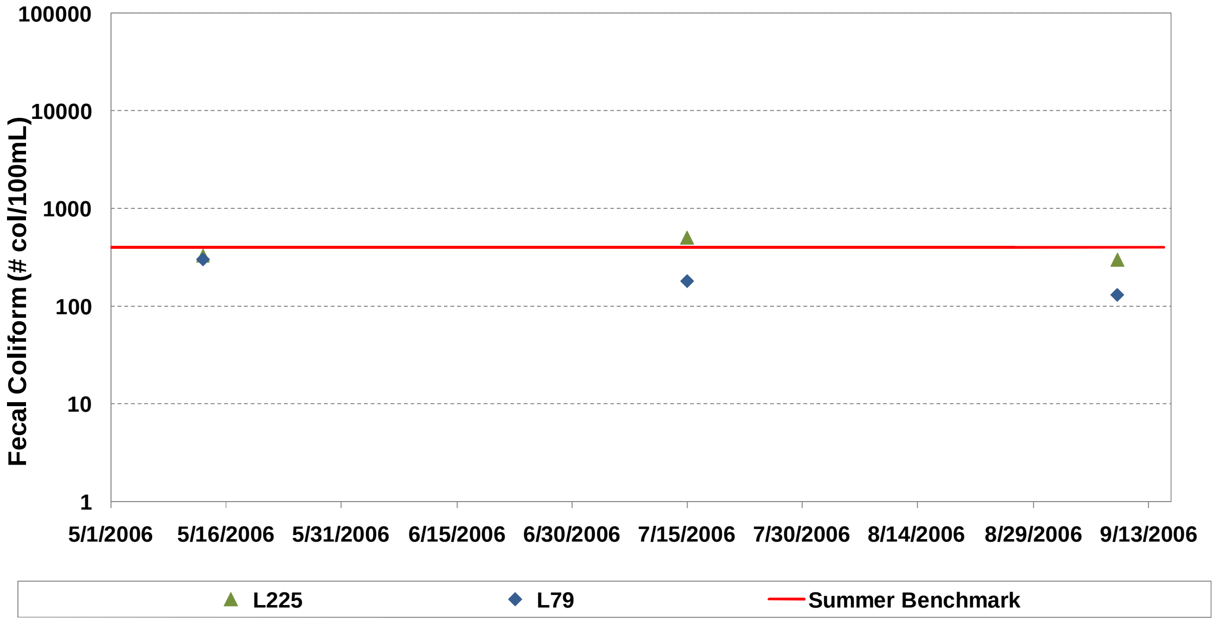


Figure D-44. Fecal Coliform Measured for Mainstem LRWW Stations

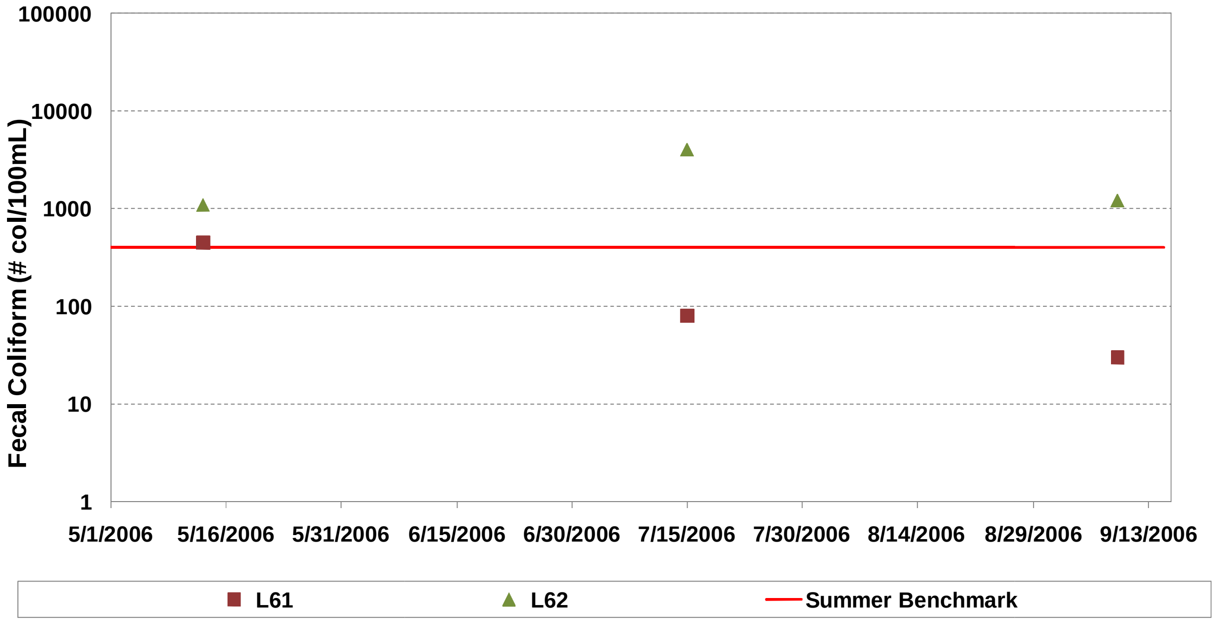


Figure D-45. Fecal Coliform Measured for Mainstem LRWW Stations

Tributaries

LRWW

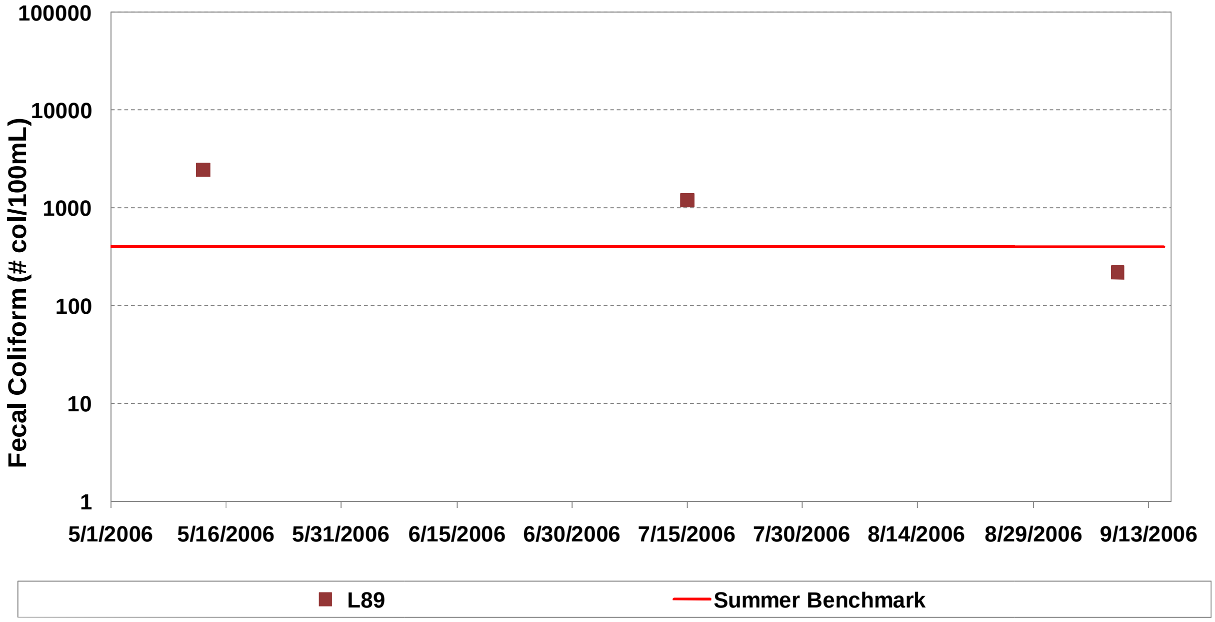


Figure D-46. Fecal Coliform Measured for Tributary LRWW Stations

Table D-14. Summary Statistics for Fecal Coliform (# col/100mL) for LRWW Stations

Parameter	Stations	L225	L61	L62	L79	L89
Fecal	Max	500	450	4000	300	2460
	75th	415	265	2610	240	1830
	Median	330	80	1220	180	1200
	25th	300	30	1100	130	220
	Min	300	30	1100	130	220
	Average	377	187	2107	203	1293
	# Obs.	3	3	3	3	3
	# Exceed	1	1	3	0	2
	% Exceed	33.3	33.3	100	0	66.7

Appendix E. SWAT Model Letter Report

E.1 Soil and Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) is a basin scale semi-distributed model which is capable of predicting long term water quality impacts of watershed management practices. SWAT is a semi-distributed model in which the watershed is divided into many subwatersheds. A subwatershed is further divided into hydrologic response units (HRUs) which are unique combinations of land use, slope and soil type. An HRU is the smallest unit in SWAT. An HRU is an individual unit acting independently. For each HRU, different processes are simulated by SWAT. The water and chemical load generated at each HRU is routed to the subwatershed outlet through the stream system. The loadings from the subwatersheds are routed through the mainstem to the watershed outlet. The major processes in SWAT consist of climate, hydrology, nutrient cycling, plant growth/land cover, sediment and nutrient transport, and routing.

E.2 Hinkston Creek Watershed SWAT Model Setup

E.2.1 Soil Characteristics

Soils in the watershed, as described in SSURGO soil surveys, fall primarily into hydrologic soil groups (HSGs) B (moderately high infiltration capacity) and C (low infiltration capacity). SWAT uses soil name drawn directly from the soils data layer to populate the model.

E.2.2 Land-Use Representation

Land use/cover in the watershed is based on the 2001 National Land Cover Database (NLCD) coverage. NLCD land cover classes were aggregated according to the scheme shown in Table E-1 for representation in the model. SWAT uses the built-in hydrologic response unit (HRU) overlay mechanism in the ArcSWAT interface. SWAT HRUs are formed from an intersection of land use and SSURGO major soils.

The Pasture/Hay class in NLCD 2001 was reclassified into Tall Fescue and Alfalfa in comparison with 2009 Cropland Data Layer (CDL) for Kentucky (USDA-NASS, 2010).

Table E-1. Aggregation of NLCD Land Cover Classes

NLCD Class	Comments	Model Input
11	Water surface area usually accounted for as reach area	WATR
12	Perennial ice/snow	WATR
21	Developed open space	URLD
22	Developed Low Intensity	URMD
23	Dev. Med. Intensity	URHD
24	Dev. High Intensity	UIDU
31	Barren Land	SWRN
41	Forest Deciduous	FRSD
42	Forest Evergreen	FRSE
43	Forest Mixed	FRST
51-52	Shrubland	RNGB

NLCD Class	Comments	Model Input
71-74	Herbaceous Upland	RNGE
81	Pasture/Hay	HAY
82	Cultivated	AGRR
91-97	Emergent & woody wetlands	WETF, WETL, WETN
98-99	Aquatic bed wetlands (not emergent)	WATR

E.2.3 Point Sources

There are four point source dischargers within the Hinkston Creek watershed. Monthly time series for flow and pollutant loads were used in the SWAT model for three of the point sources (KY0020940, KY0020923, and KY0088421). Daily time series was used for the Mount Sterling WWTP (KY0104400).

Table E-2. Major Point Source discharges in the Hinkston Creek Watershed

NPDES ID	Name	Monthly Avg. Permitted Flow (MGD)	Latitude	Longitude
KY0020940	Millersburg WWTP	0.20	38.299444	-84.152778
KY0020923	Carlisle WWTP	0.35	38.314722	-84.062778
KY0088421	Sharpsburg WWTP	0.07	38.197778	-83.934444
KY0104400	Mt Sterling WWTP	3.00	38.099444	-83.920556
KY0020044	Mt Sterling WWTP (discontinued in 2003)	-	38.061944	-83.934722

E.2.4 Meteorological Data

The required meteorological time series for the Hinkston Creek SWAT simulations are precipitation and air temperature. The simulations do not include water temperature and uses a degree-day method for snowmelt. SWAT estimates Priestley-Taylor potential evapotranspiration using a statistical weather generator for inputs other than temperature and precipitation. These meteorological time series are drawn from the Summary of the Day (SOD) stations from NOAA (Table E-3). Precipitation and temperature data required patching to fill data gaps using an MS excel based VBA MetADAPT developed by Tetra Tech. QAPP was performed on the patched precipitation and temperature time series before using them in model simulations.

Table E-3. Precipitation and Temperature Stations for the Hinkston Creek Watershed Model

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (m)
156170	Paris	38.204722	-84.239167		247
155640	Mt Sterling	38.058333	-83.933333	x	293
150804	Blue Lick Springs	38.416667	-84.000000		186

E.2.5 Watershed Segmentation

The Hinkston Creek watershed was divided into 34 assessment subwatersheds for the purposes of modeling (see Figure A-1). The model encompasses the complete watershed and does not require specification of any upstream boundary conditions for application.

E.2.6 Calibration Data and Locations

Hydrology calibration was performed at the USGS gage located on the Hinkston Creek at Carlisle (03252300). Water quality calibration for sediment and nutrients were performed at 20 different locations within the Hinkston Creek watershed, where water quality sampling was carried out by the Kentucky Division of Water (KDOW) and Morehead State University (MSU) – two of these locations had coincident KDOW and MSU stations (05016029/HKC-10 and 05016020/HKC-12). The calibration time frame was from 10/1/2000 to 9/30/2010.

E.3 SWAT Modeling

E.3.1 Hydrology Calibration

A 0/0/0 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. Because this threshold was set to zero percent, no categories within land use, soil, or slope were considered insignificant based on percent coverage and all land use, soil, and slope categories were retained for the model.

The hydrology calibration focus area is generally representative of the general land use characteristics of the overall watershed. The parameters were adjusted within the practical range to obtain reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows.

The water balance of the Hinkston Creek watershed predicted by the SWAT model over the 10-year simulation period is as follows:

Table E-4. SWAT Model Water Balance for Hinkston Creek Watershed

Water Balance	(mm/yr)
PRECIP	1247.0
SNOW FALL	130.34
SNOW MELT	130.32
SUBLIMATION	0.01
SURFACE RUNOFF Q	508.32
LATERAL SOIL Q	9.52
TILE Q	0.00
GROUNDWATER (SHAL AQ) Q	21.90
REVAP (SHAL AQ > SOIL/PLANTS)	23.50
DEEP AQ RECHARGE	29.15
TOTAL AQ RECHARGE	72.88
TOTAL WATER YLD	539.74
PERCOLATION OUT OF SOIL	72.87
ET	663.8
PET	973.2
TRANSMISSION LOSSES	0.00

Hydrologic calibration adjustments focused on the following parameters:

- CN2 (initial SCS runoff curve number for moisture condition II)
- ESCO (soil evaporation compensation factor)
- SURLAG (surface runoff lag coefficient)
- SOL_AWC (available water capacity of the soil layer, mm water/mm of soil)
- ALPHA_BF (baseflow alpha factor, days)
- GW_DELAY (groundwater delay time, days)
- GWQMIN (threshold depth of water in the shallow aquifer required for return flow to occur, mm)
- GW_REVAP (groundwater “revap” coefficient)
- CH_N2 (Manning’s “n” value for main channels)
- CH_N1 (Manning’s “n” value for tributary channels)

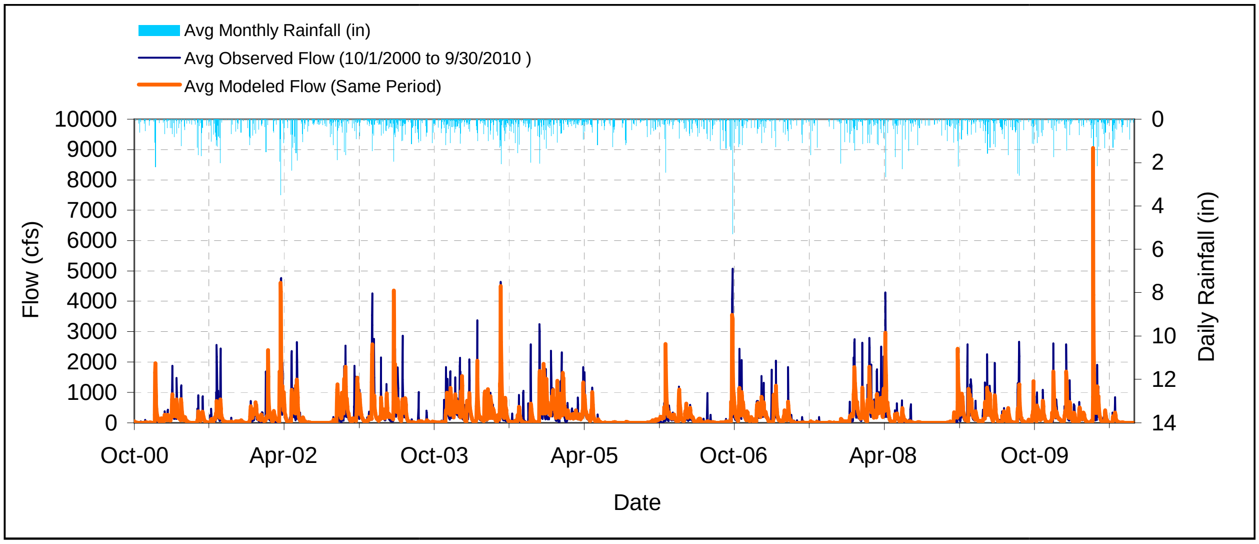


Figure E-1. Mean daily flow: USGS 03252300 Hinkston Creek near Carlisle, KY

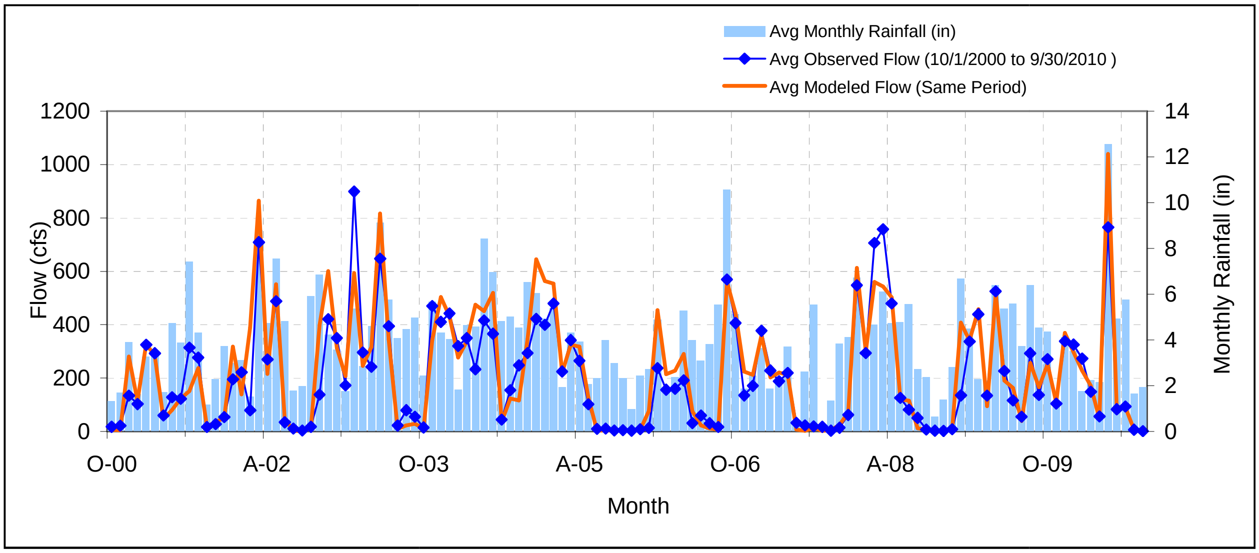


Figure E-2. Mean monthly flow: USGS 03252300 Hinkston Creek near Carlisle, KY

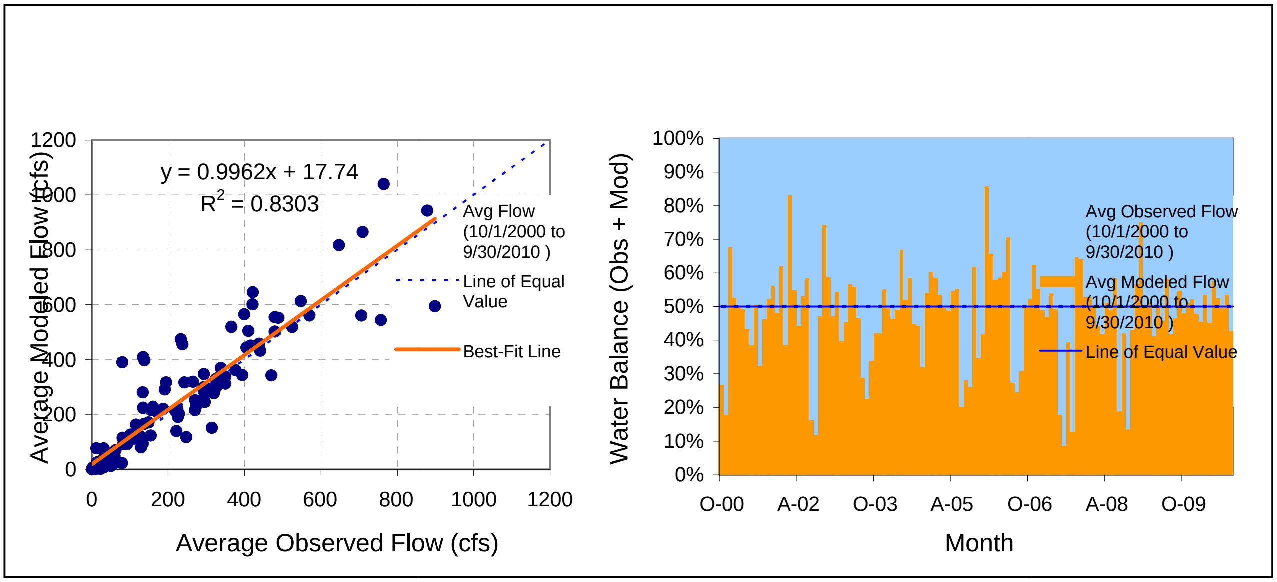


Figure E-3. Monthly flow regression and temporal variation: USGS 03252300 Hinkston Creek near Carlisle, KY

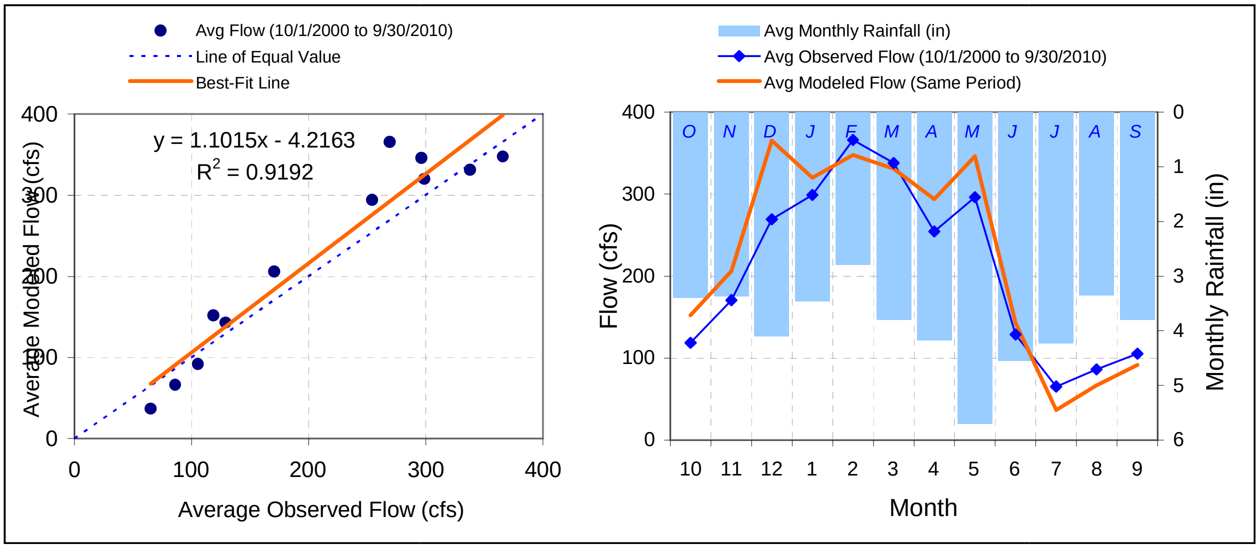


Figure E-4. Seasonal regression and temporal aggregate: USGS 03252300 Hinkston Creek near Carlisle, KY

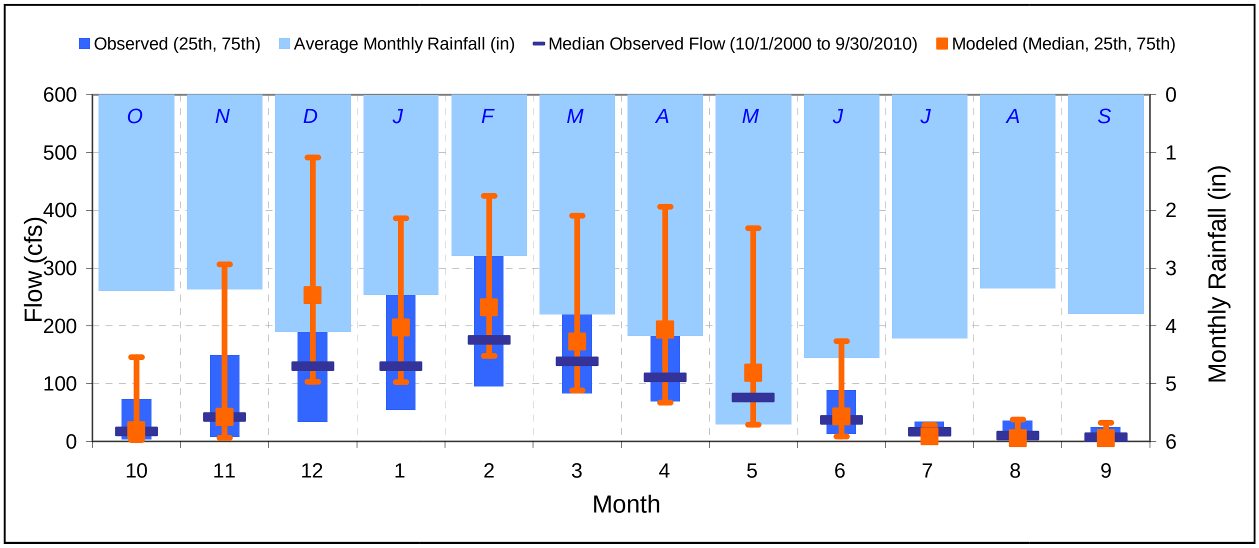


Figure E-5. Seasonal medians and ranges: USGS 03252300 Hinkston Creek near Carlisle, KY

Table E-5. Seasonal summary: USGS 03252300 Hinkston Creek near Carlisle, KY

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	118.64	17.00	3.40	73.50	151.87	19.41	2.04	146.21
Nov	170.51	42.00	7.58	149.25	205.90	42.10	5.86	306.73
Dec	269.23	130.00	34.00	310.00	365.53	253.17	102.78	491.40
Jan	298.78	130.00	55.25	320.75	319.87	197.21	102.59	385.90
Feb	365.93	175.50	95.25	369.50	347.64	231.84	148.34	424.84
Mar	337.86	138.50	83.00	312.25	331.21	172.62	88.00	390.85
Apr	254.34	110.50	68.75	227.75	294.05	193.54	67.22	405.94
May	296.31	75.50	38.00	214.75	346.00	118.55	28.97	369.13
Jun	128.94	37.00	13.00	89.00	143.04	43.31	8.44	173.21
Jul	65.23	16.50	9.70	34.00	36.80	8.68	2.26	28.49
Aug	85.95	10.00	3.33	36.00	66.38	5.44	0.49	37.46
Sep	105.44	7.35	1.48	25.25	91.76	5.43	0.71	32.13

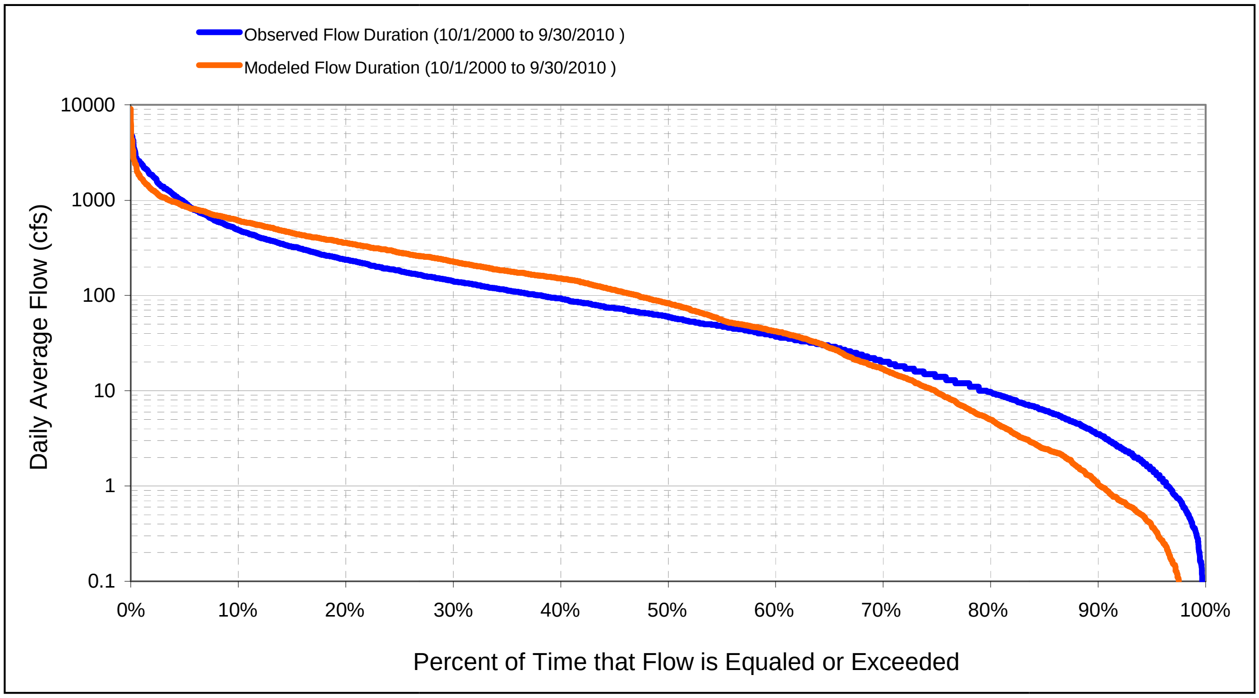


Figure E-6. Flow exceedence: USGS 03252300 Hinkston Creek near Carlisle, KY

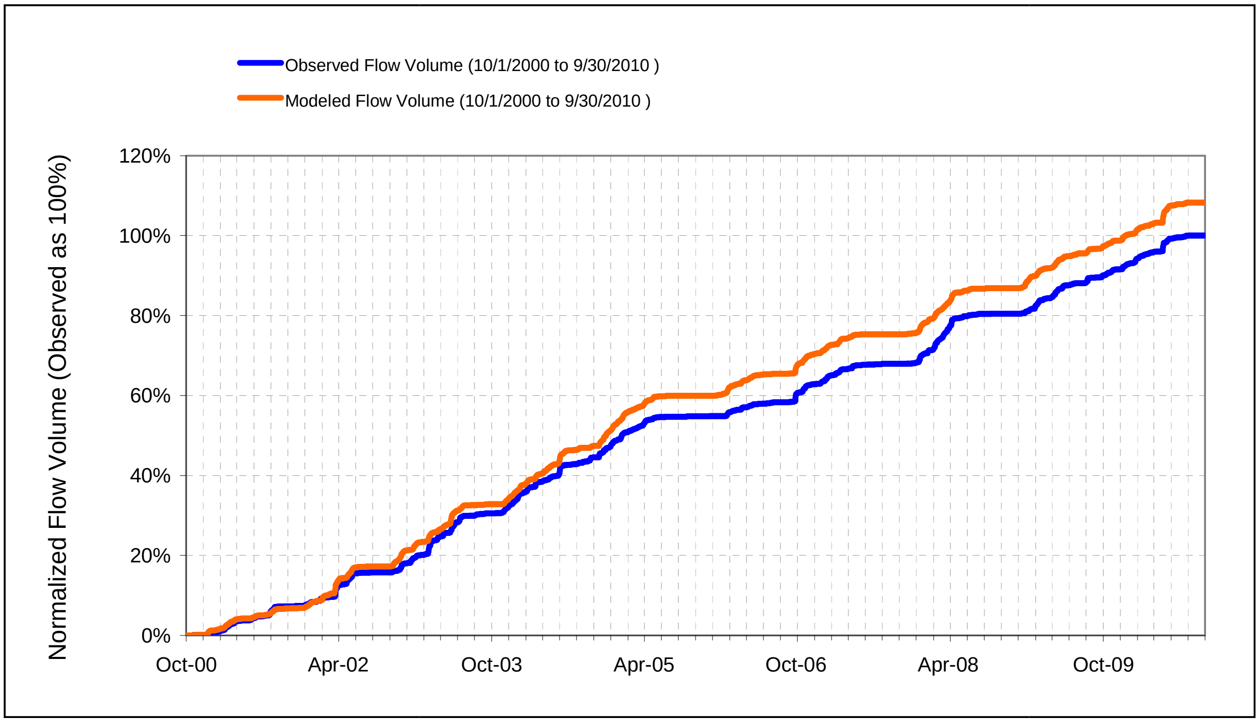


Figure E-7. Flow accumulation: USGS 03252300 Hinkston Creek near Carlisle, KY

Table E-6. Summary statistics: USGS 03252300 Hinkston Creek near Carlisle, KY

SWAT Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM OUTLET 8 10-Year Analysis Period: 10/1/2000 - 9/30/2010 Flow volumes are (inches/year) for upstream drainage area		**USGS 03252300 HINKSTON CREEK NEAR CARLISLE, KY** Hydrologic Unit Code: 5100102 Latitude: 38.2474368 Longitude: -84.05514979 Drainage Area (sq-mi): 154	
Total Simulated In-stream Flow:	**19.80**	Total Observed In-stream Flow:	**18.29**
Total of simulated highest 10% flows:	**9.66**	Total of Observed highest 10% flows:	**11.16**
Total of Simulated lowest 50% flows:	**0.89**	Total of Observed Lowest 50% flows:	**0.88**
Simulated Summer Flow Volume (months 7-9):	**1.44**	Observed Summer Flow Volume (7-9):	**1.90**
Simulated Fall Flow Volume (months 10-12):	**5.37**	Observed Fall Flow Volume (10-12):	**4.14**
Simulated Winter Flow Volume (months 1-3):	**7.24**	Observed Winter Flow Volume (1-3):	**7.26**
Simulated Spring Flow Volume (months 4-6):	**5.76**	Observed Spring Flow Volume (4-6):	**5.00**
Total Simulated Storm Volume:	**7.69**	Total Observed Storm Volume:	**10.71**
Simulated Summer Storm Volume (7-9):	**0.65**	Observed Summer Storm Volume (7-9):	**1.41**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	8.27	10		
Error in 50% lowest flows:	1.25	10		
Error in 10% highest flows:	-13.44	15		
Seasonal volume error - Summer:	-24.18	30		
Seasonal volume error - Fall:	29.62	30		
Seasonal volume error - Winter:	-0.23	30		
Seasonal volume error - Spring:	15.25	30		
Error in storm volumes:	**-28.16**	**20**		
Error in summer storm volumes:	**-53.91**	**50**		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.581	Model accuracy increases as E or E' approaches 1.0		
Baseline adjusted coefficient (Garrick), E':	0.443			
Monthly NSE	0.900			

Water Quality Calibration

Water quality calibration was performed for 20 different locations (2 locations had coincident KDOW and MSU stations) within the watershed for sediment, total phosphorus and total nitrogen. The calibration results are presented in the graphs below.

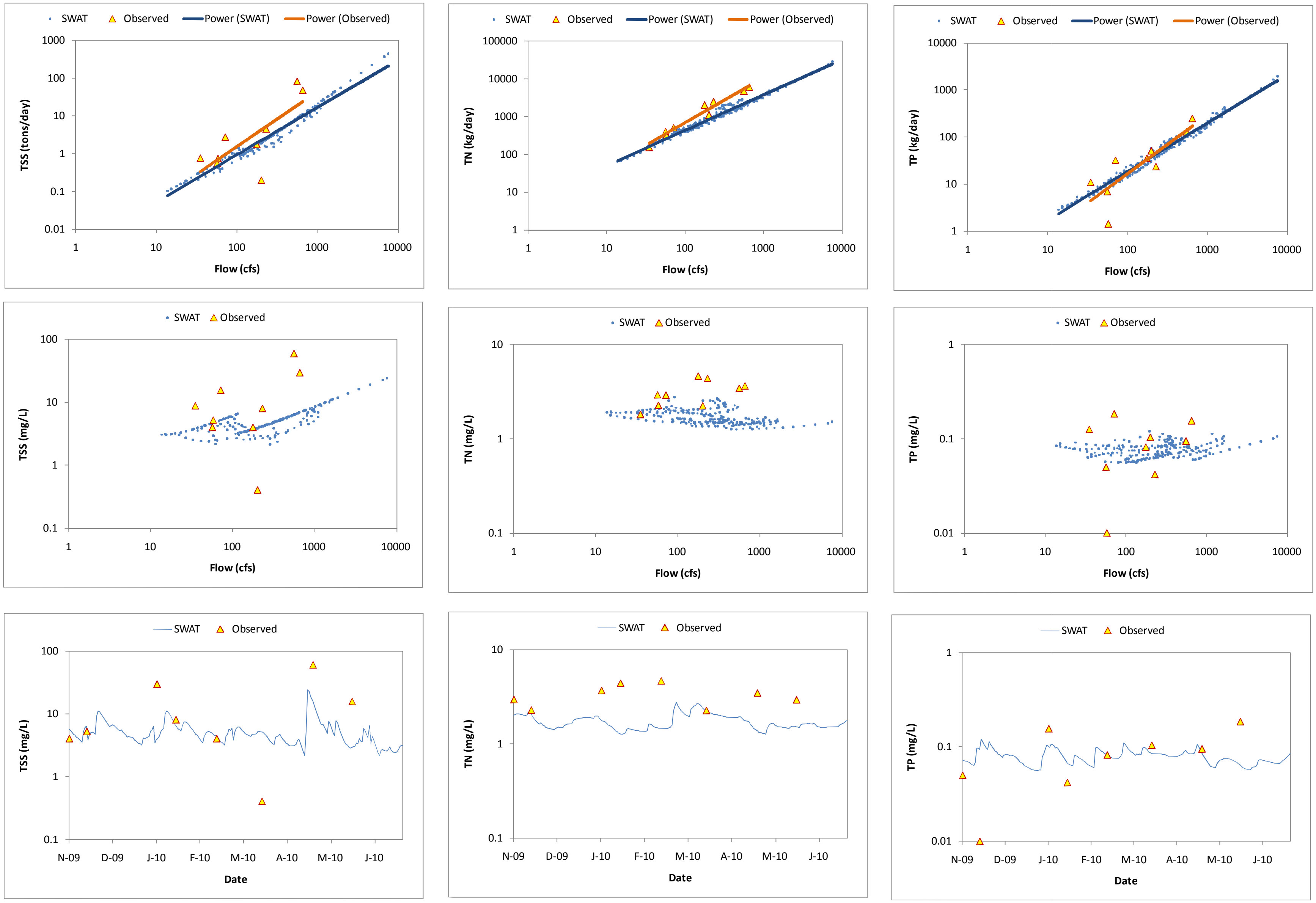


Figure E-8. SWAT Water Quality Calibration at HKC-01

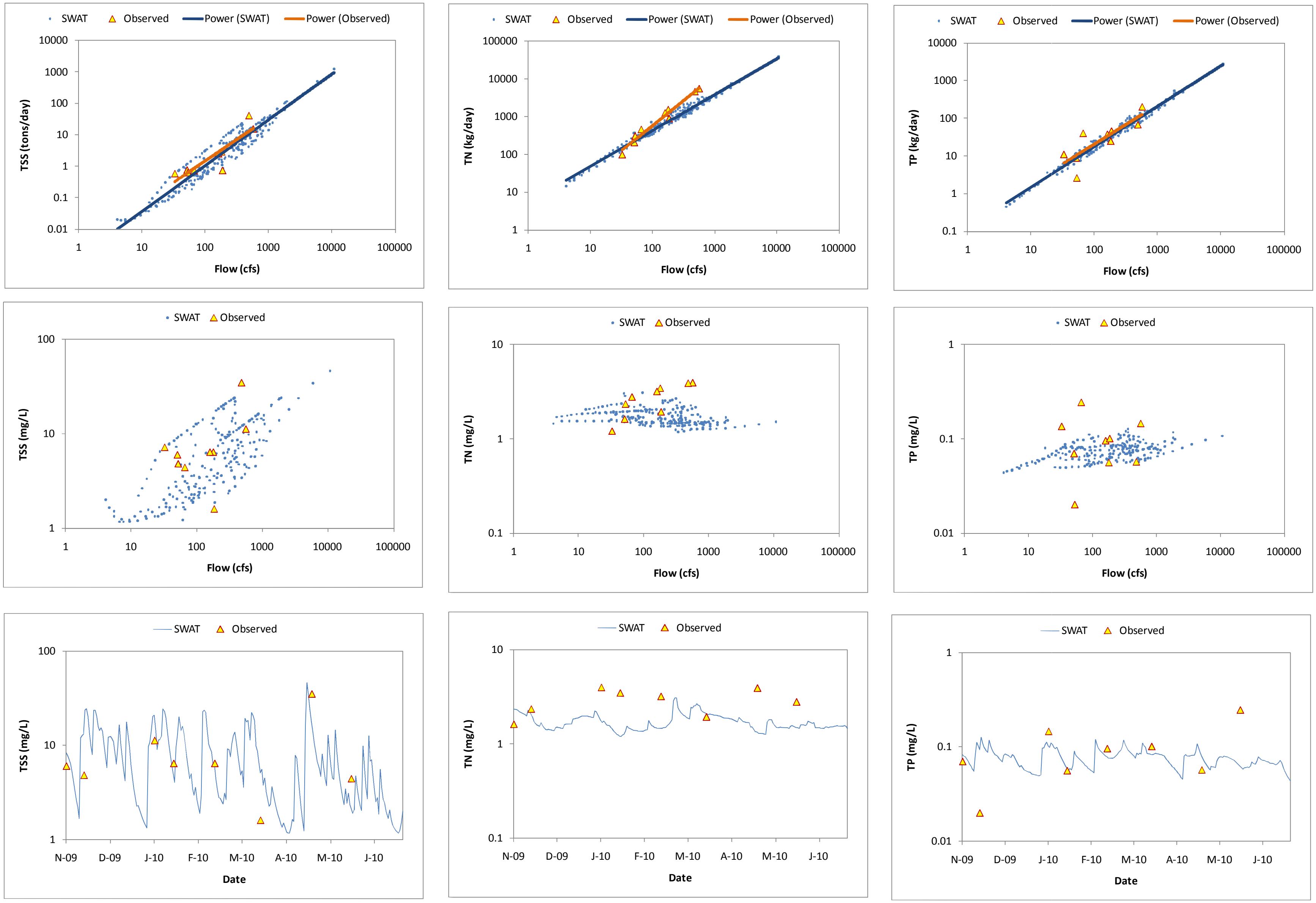


Figure E-9. SWAT Water Quality Calibration at HKC-02

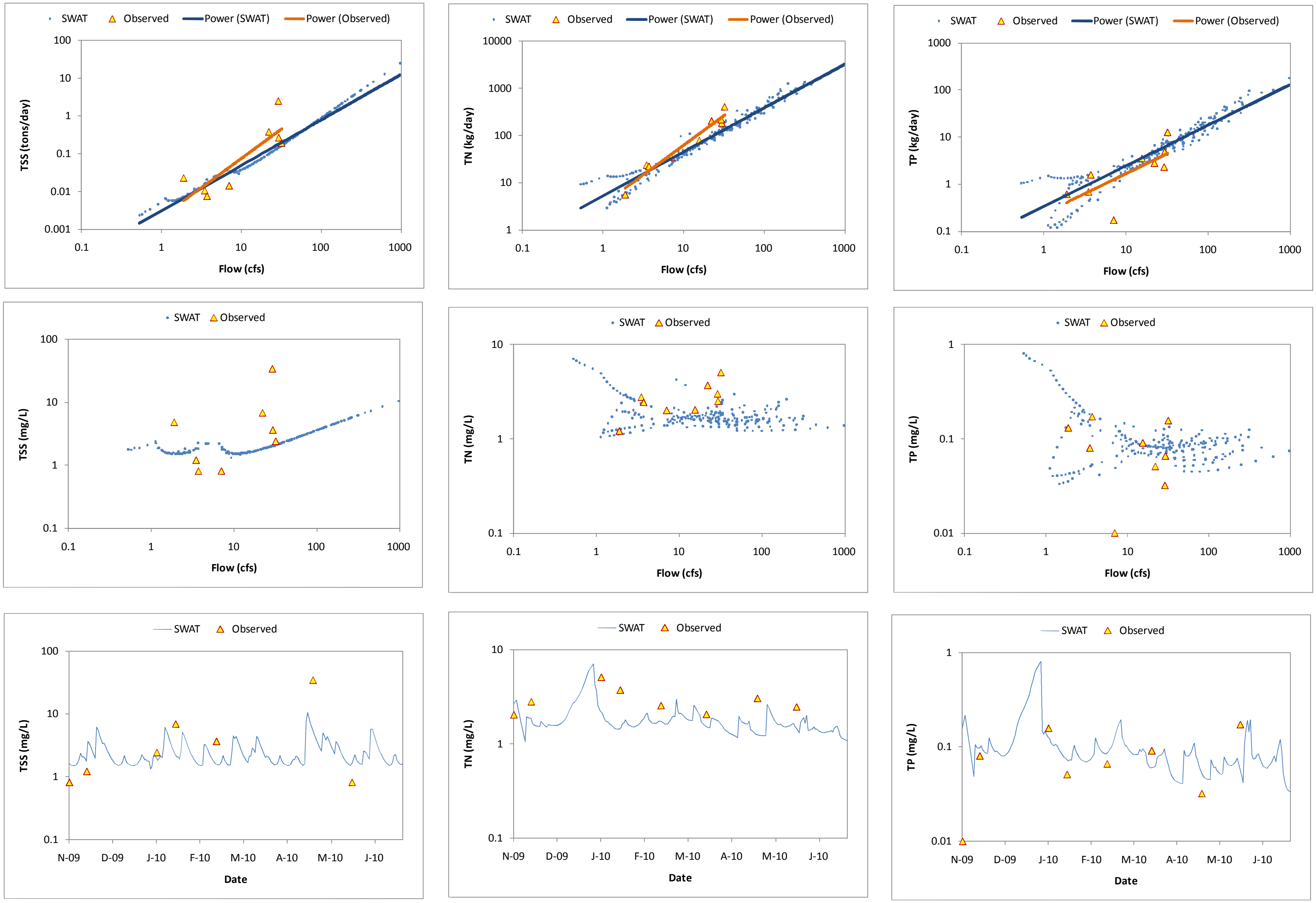


Figure E-10. SWAT Water Quality Calibration at HKC-03

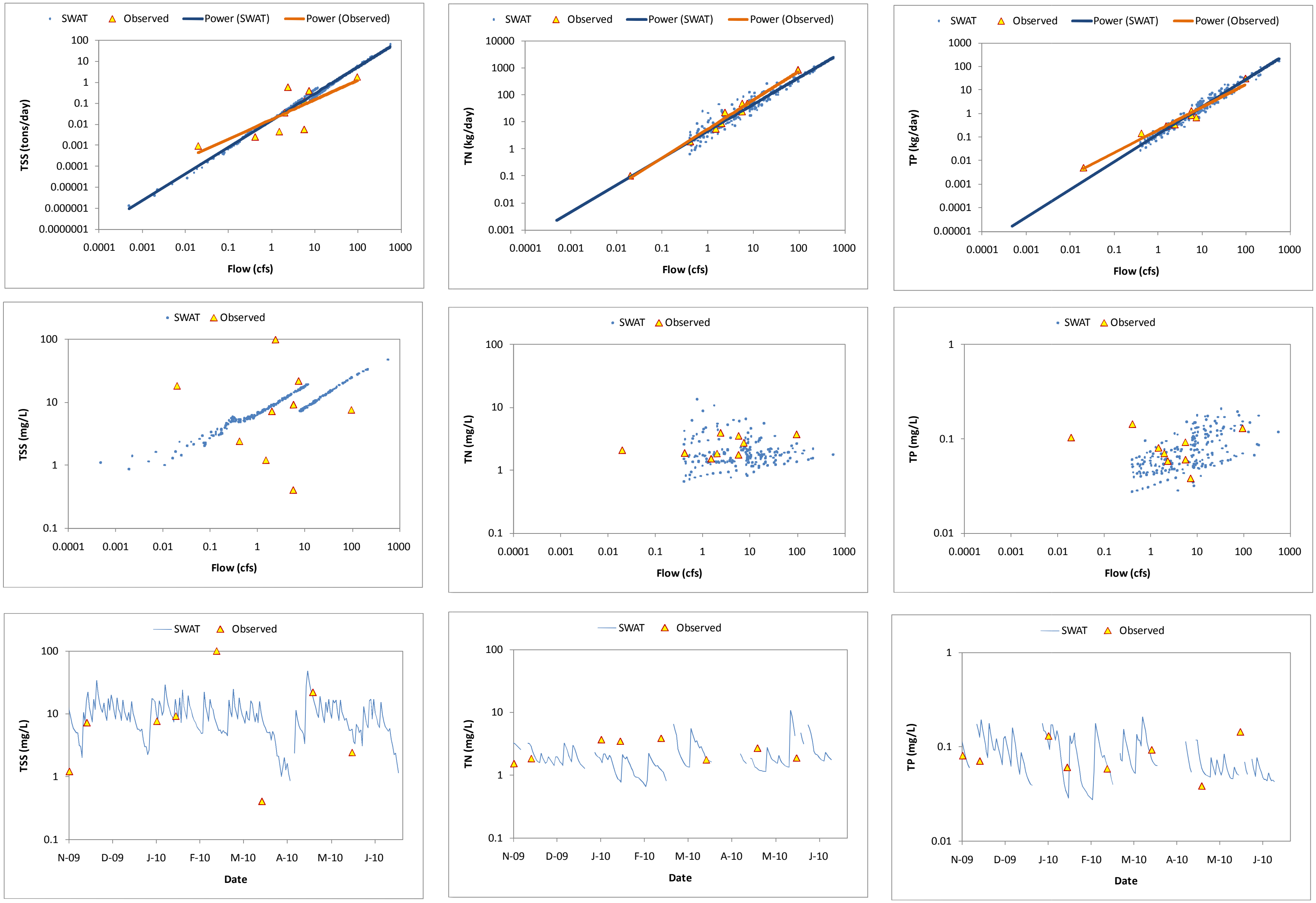


Figure E-11. SWAT Water Quality Calibration at HKC-04

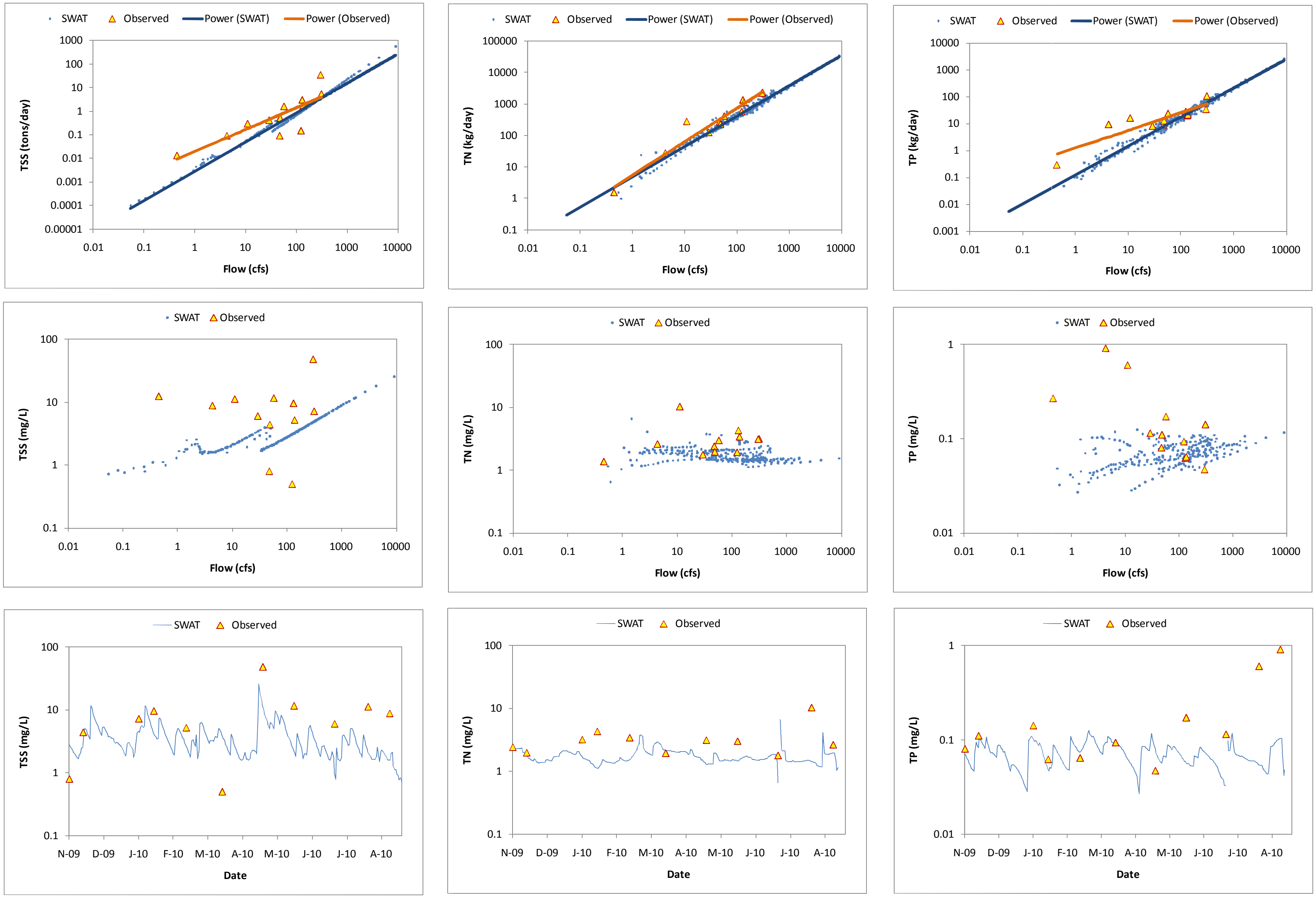


Figure E-12. SWAT Water Quality Calibration at HKC-05

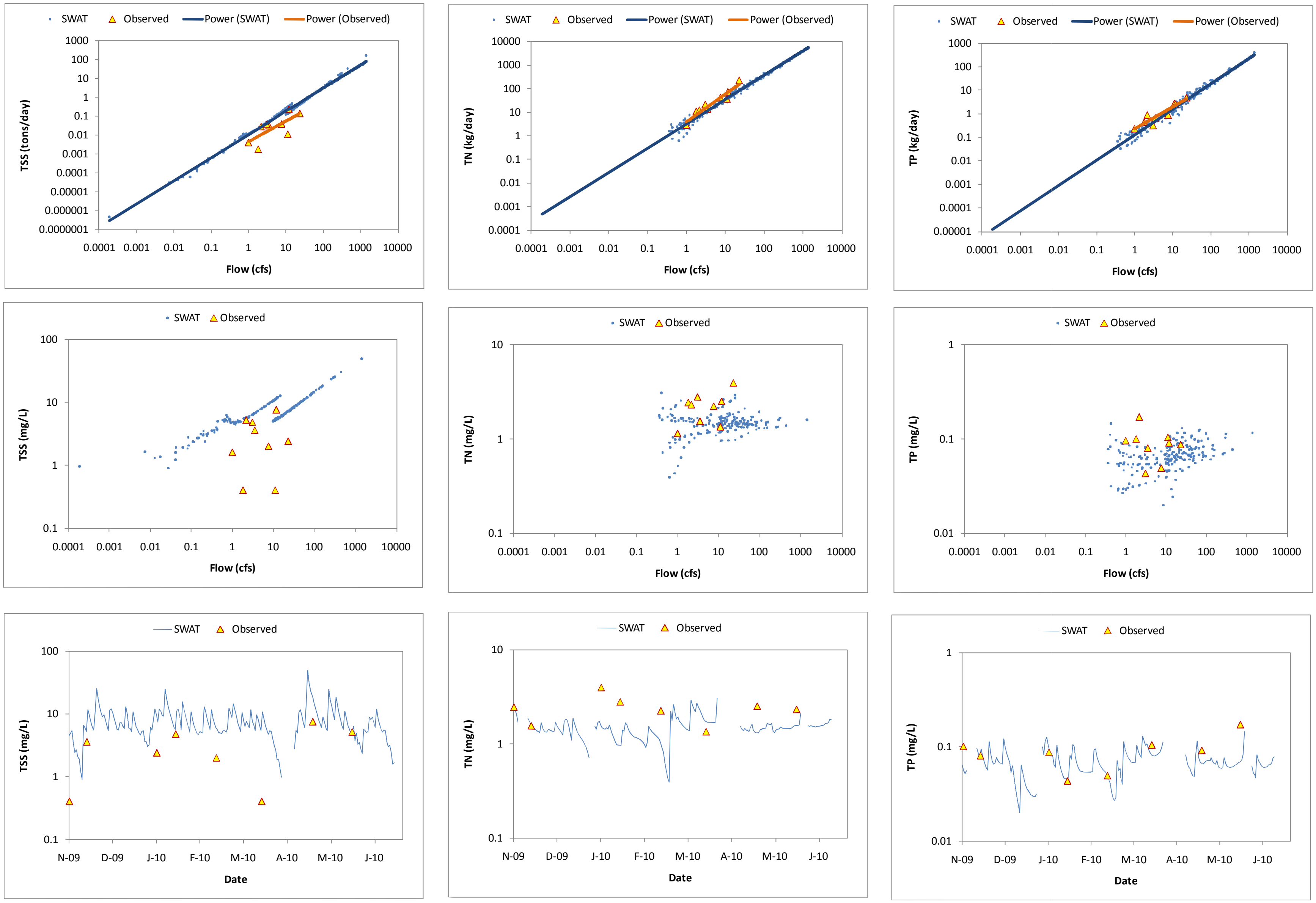


Figure E-13. SWAT Water Quality Calibration at HKC-06

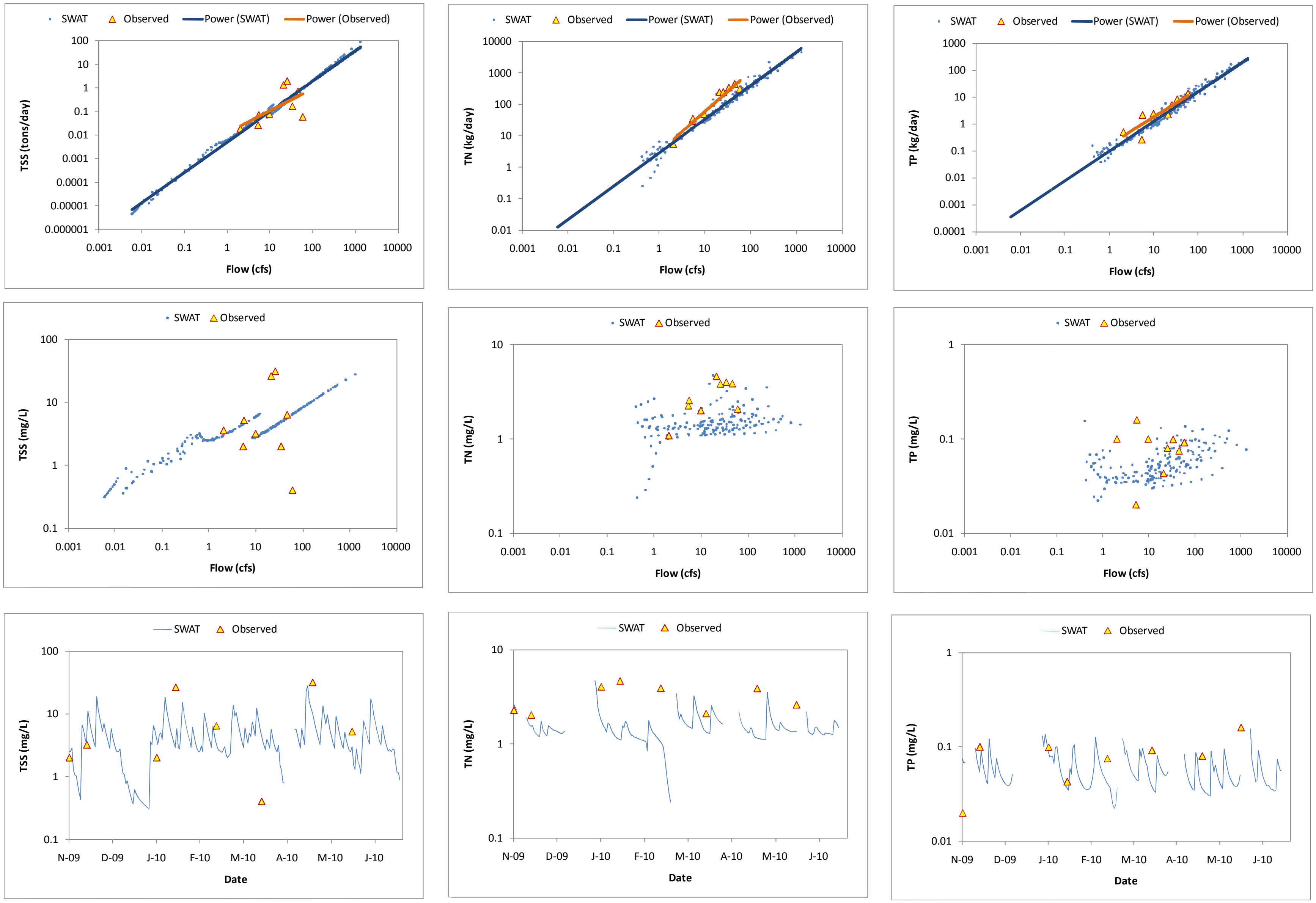


Figure E-14. SWAT Water Quality Calibration at HKC-07

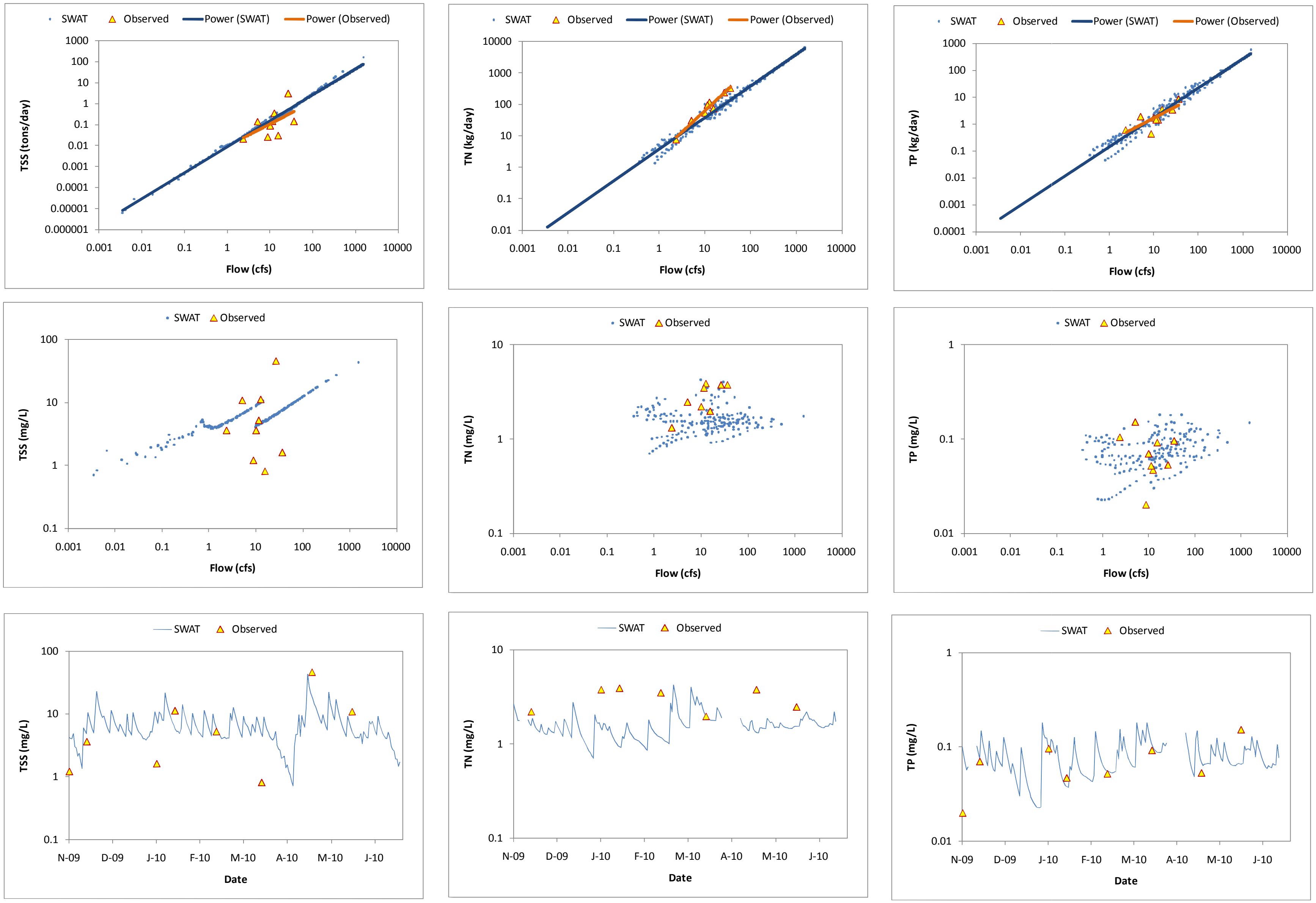


Figure E-15. SWAT Water Quality Calibration at HKC-08

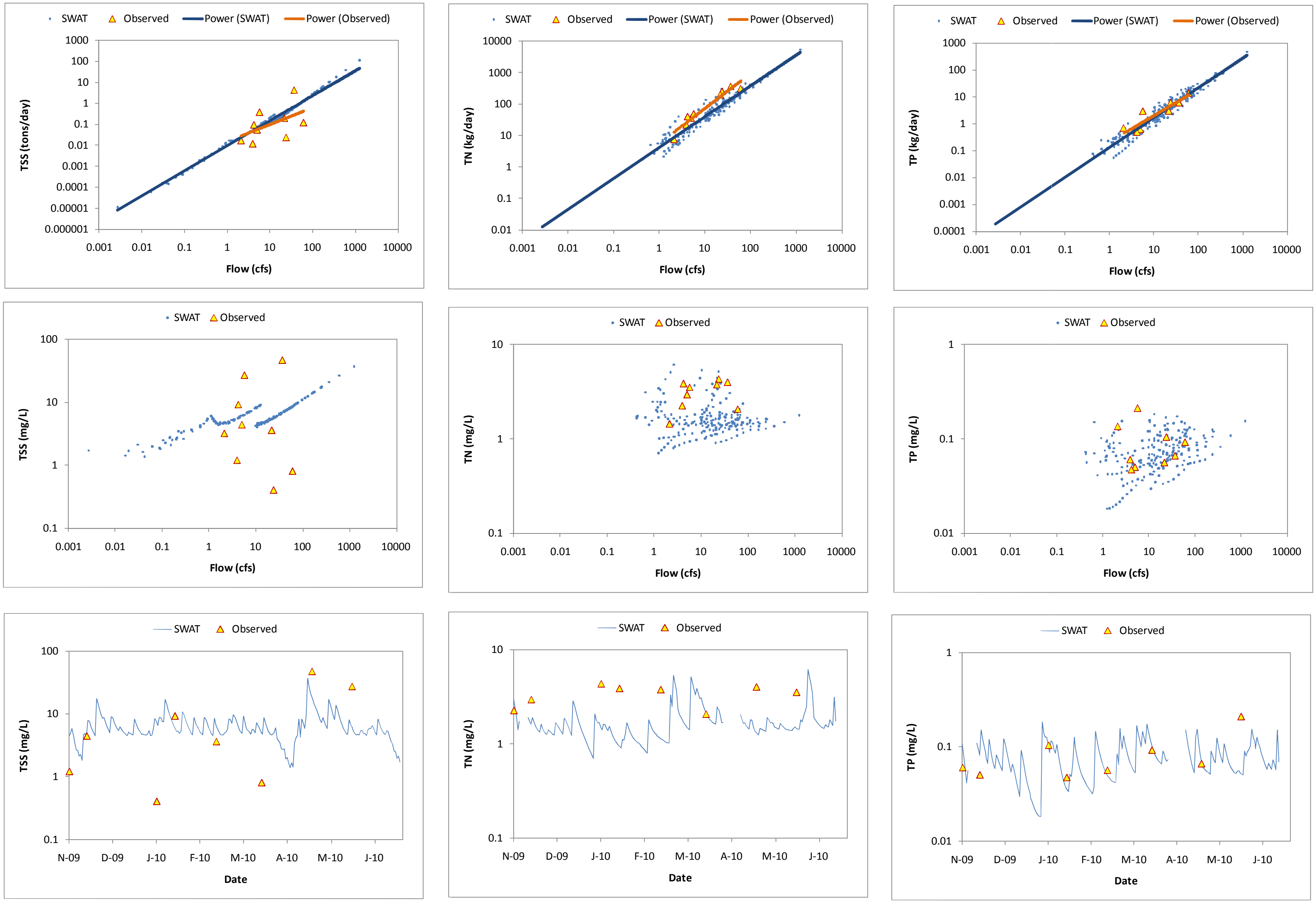


Figure E-16. SWAT Water Quality Calibration at HKC-09

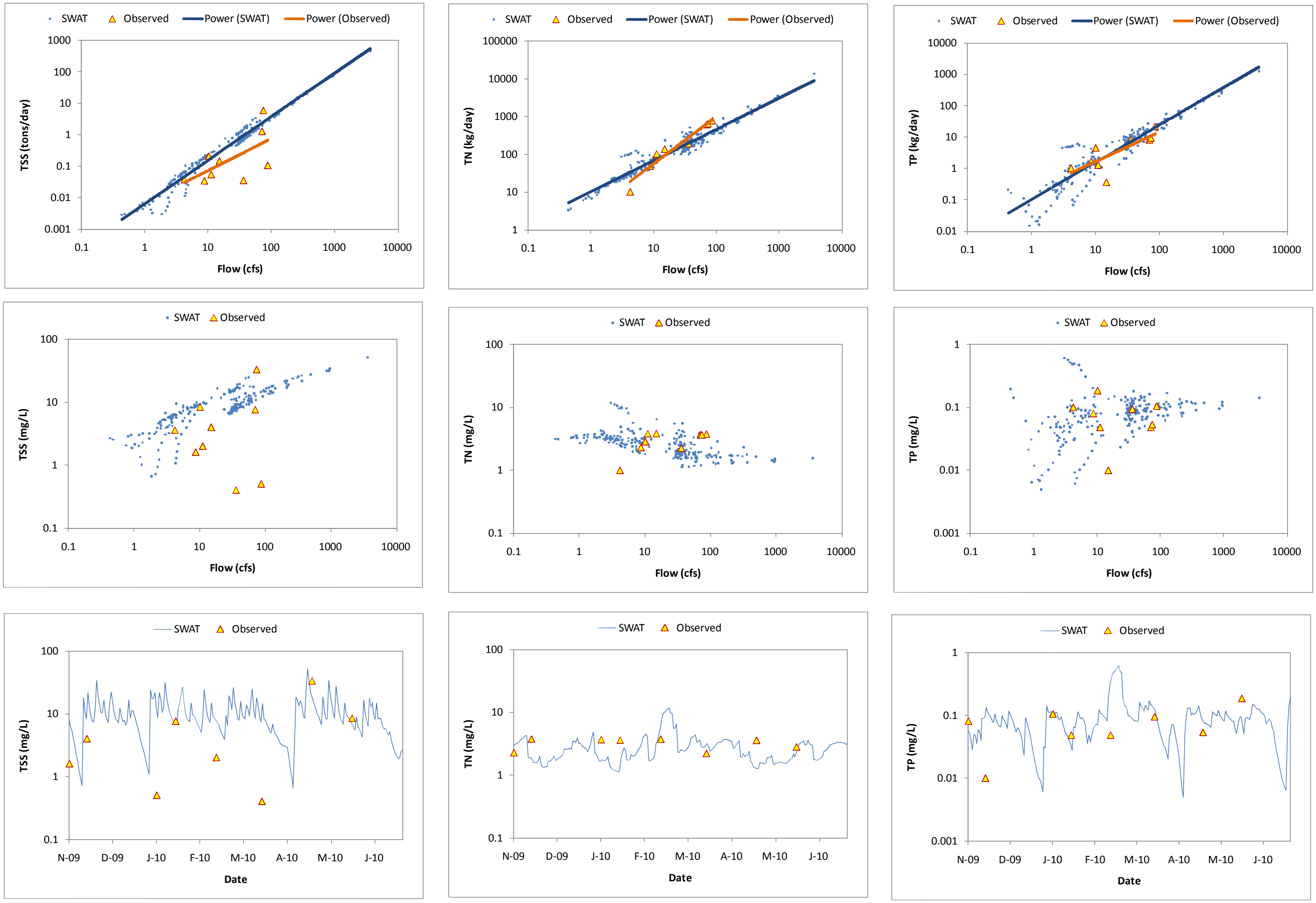


Figure E-17. SWAT Water Quality Calibration at HKC-10

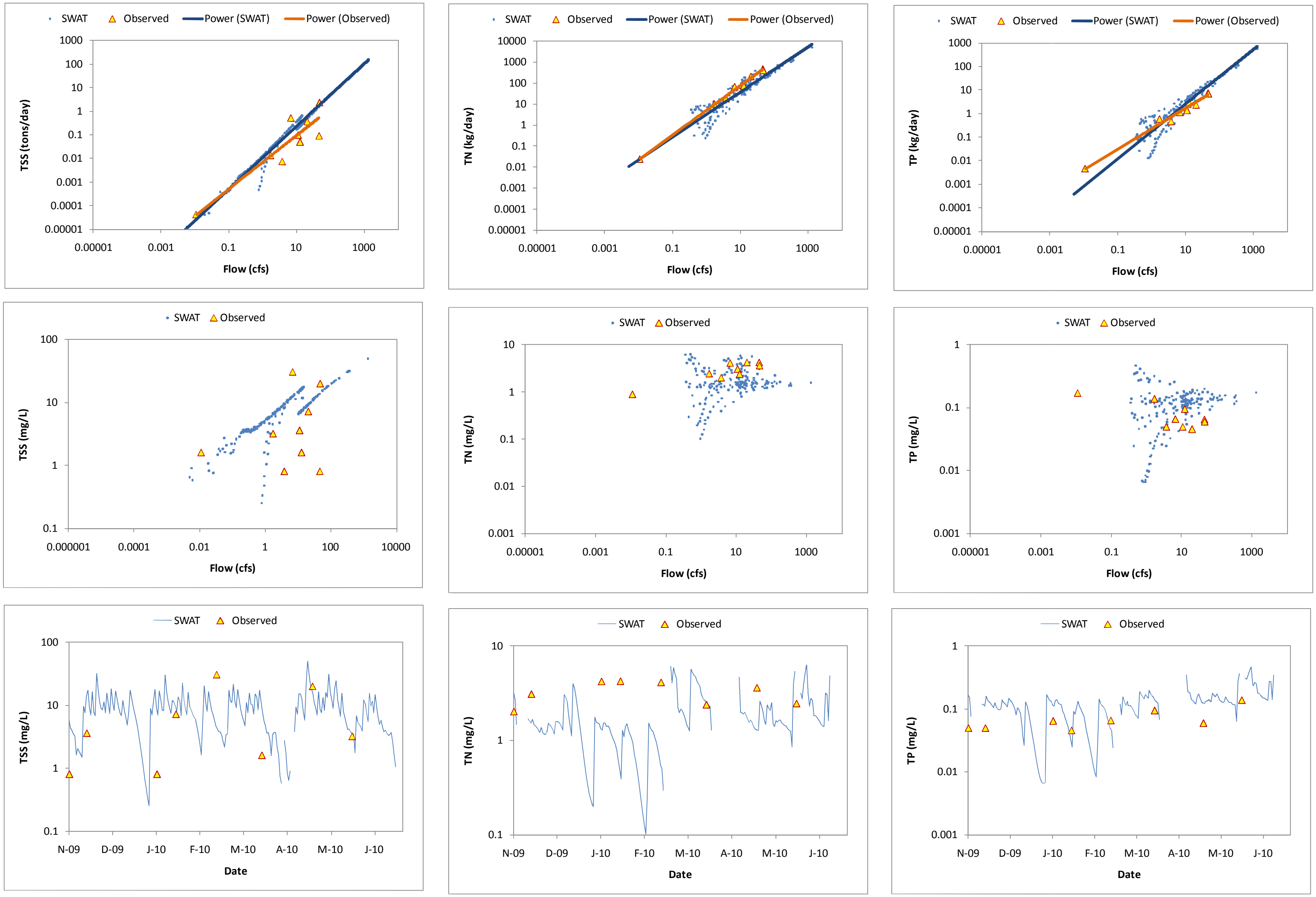


Figure E-18. SWAT Water Quality Calibration at HKC-11

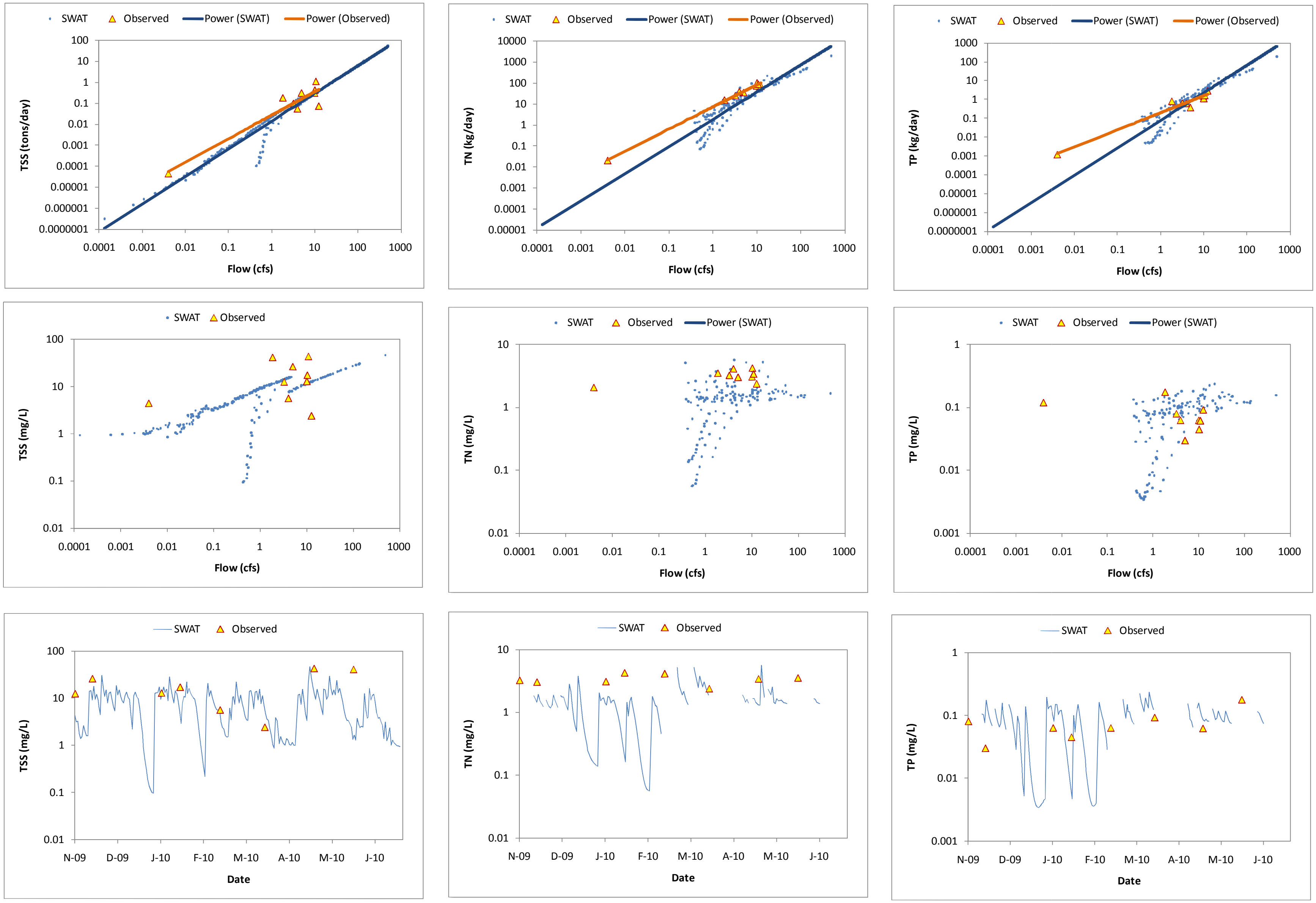


Figure E-19. SWAT Water Quality Calibration at HKC-12

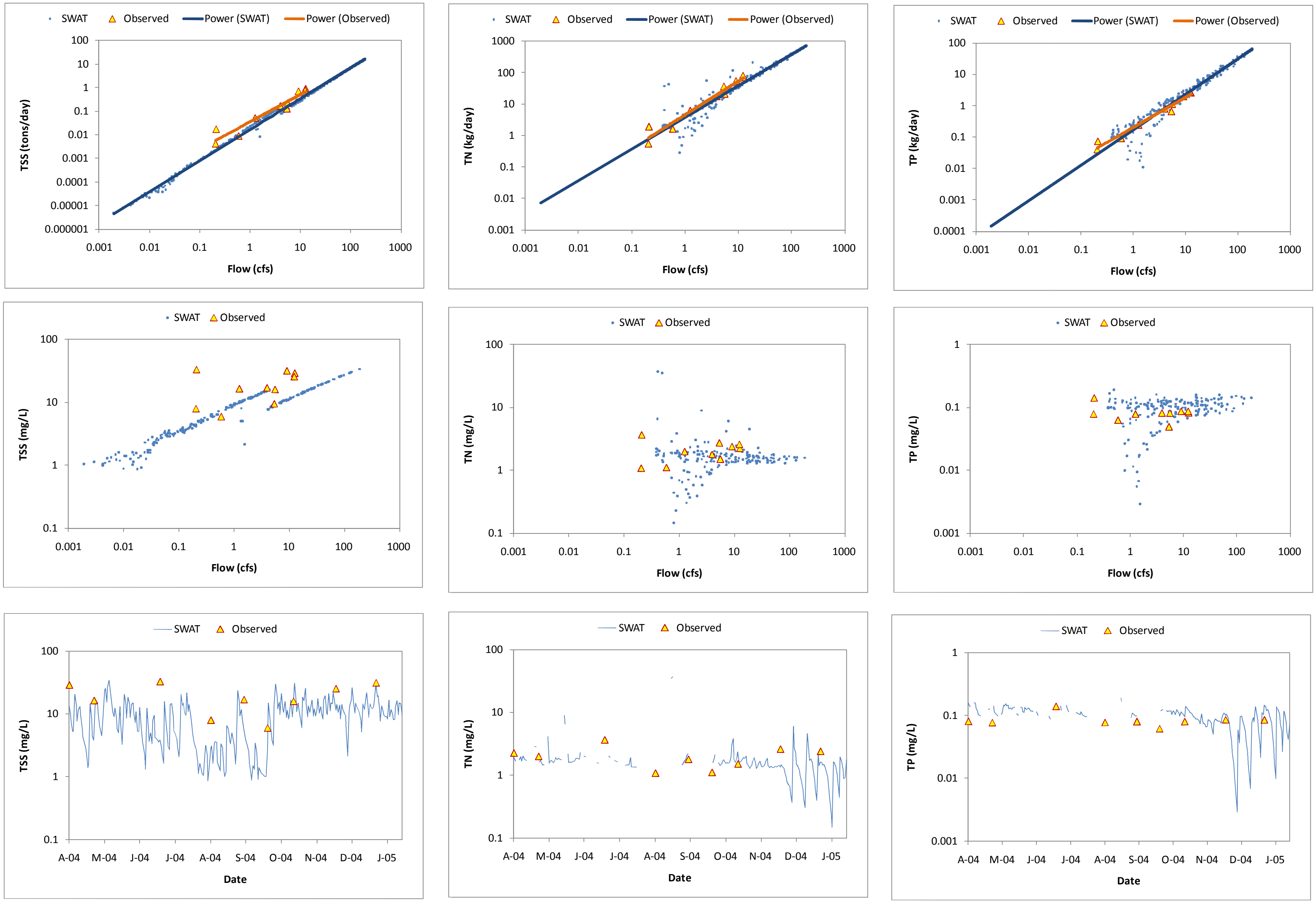


Figure E-20. SWAT Water Quality Calibration at KDOW 05016020

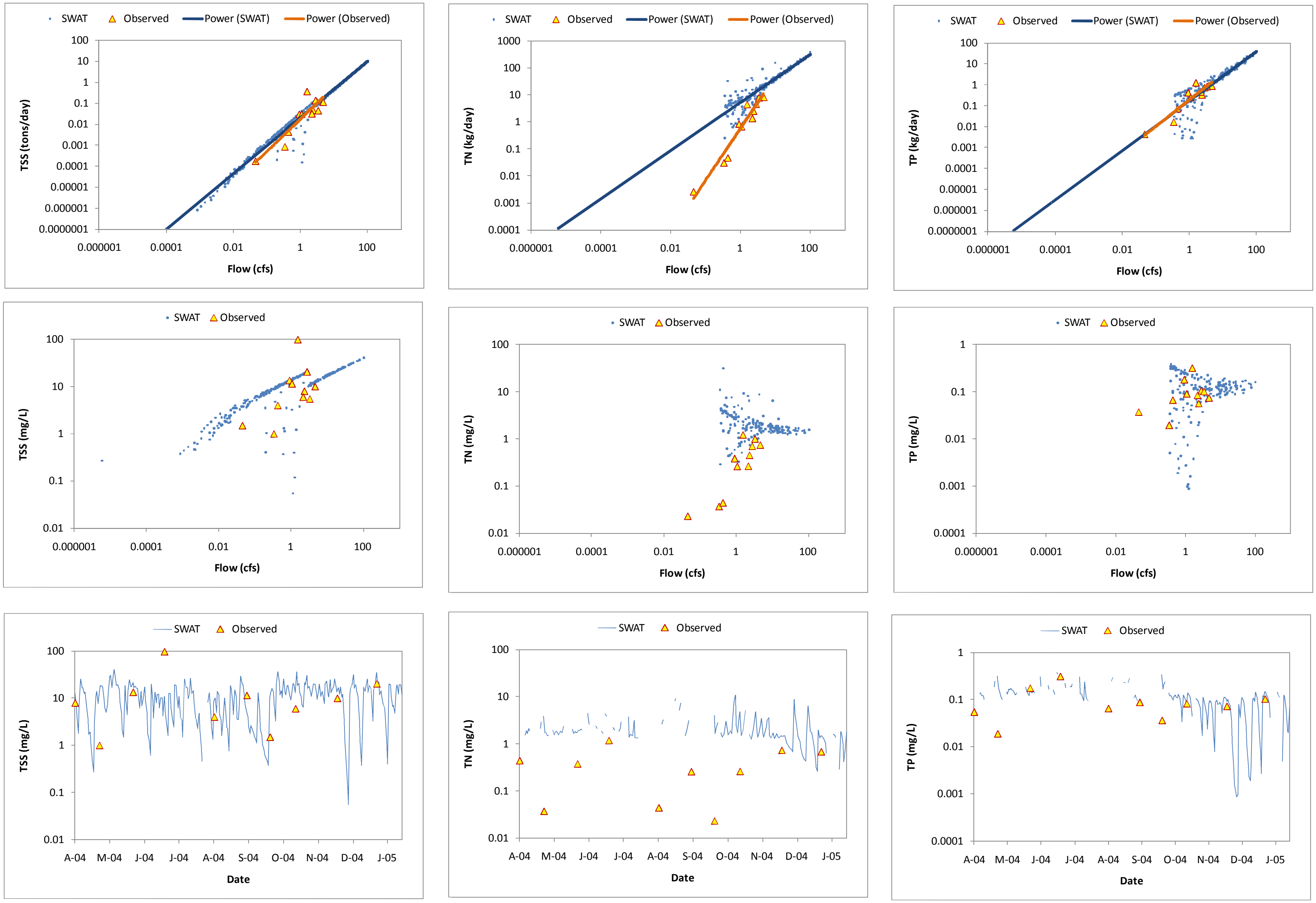


Figure E-21. SWAT Water Quality Calibration at KDOW 05016021

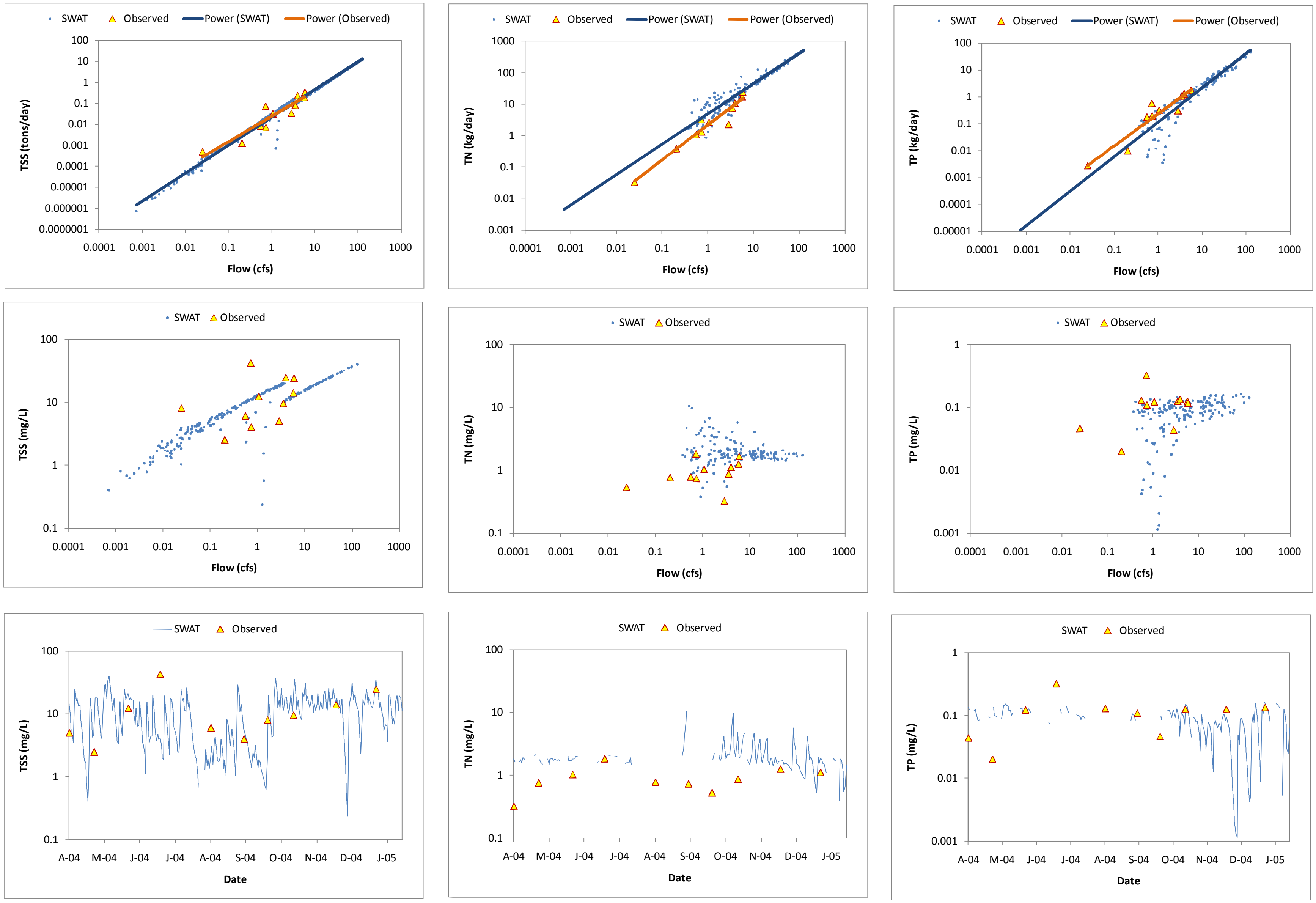


Figure E-22. SWAT Water Quality Calibration at KDOW 05016022

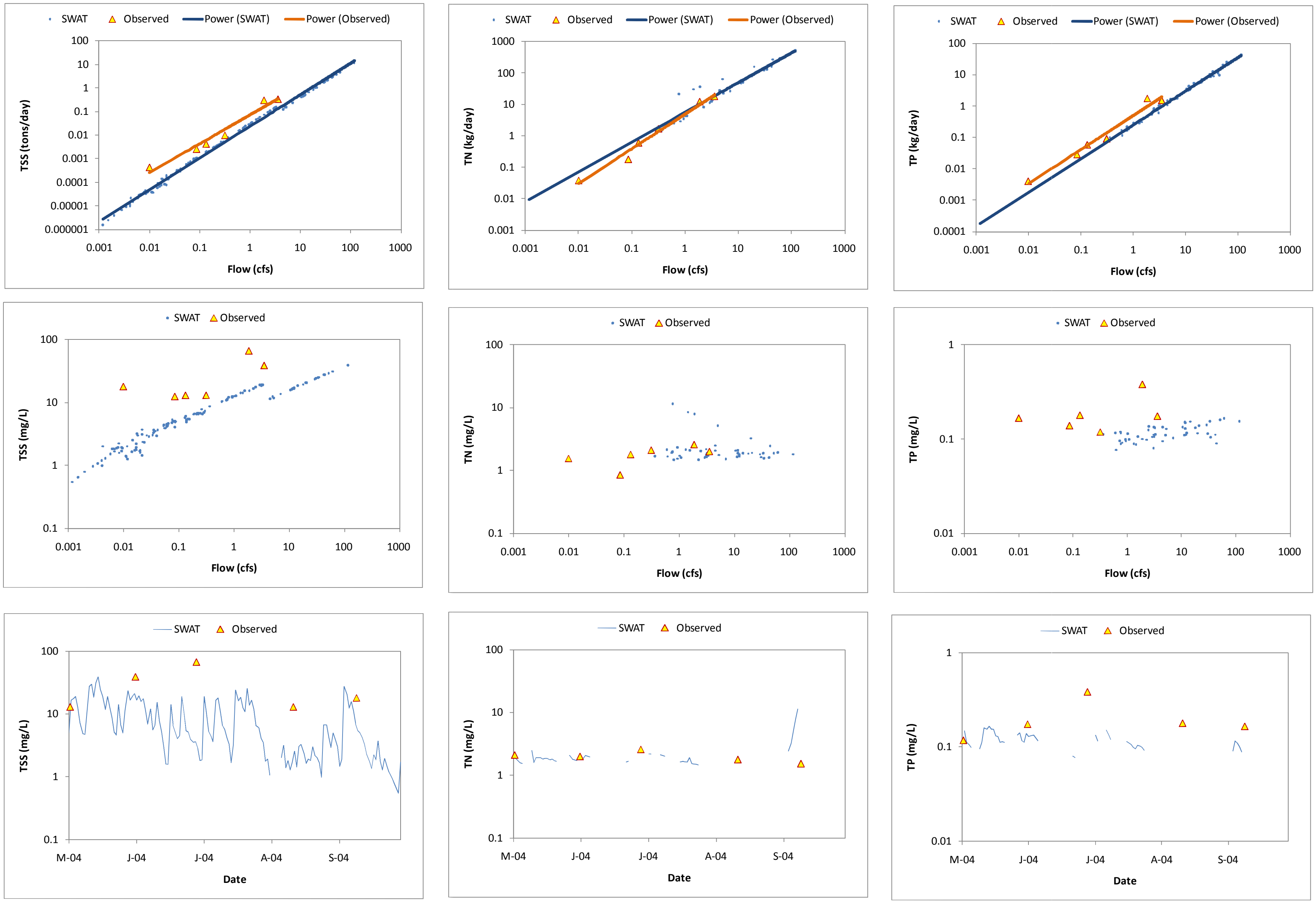


Figure E-23. SWAT Water Quality Calibration at KDOW 05016023

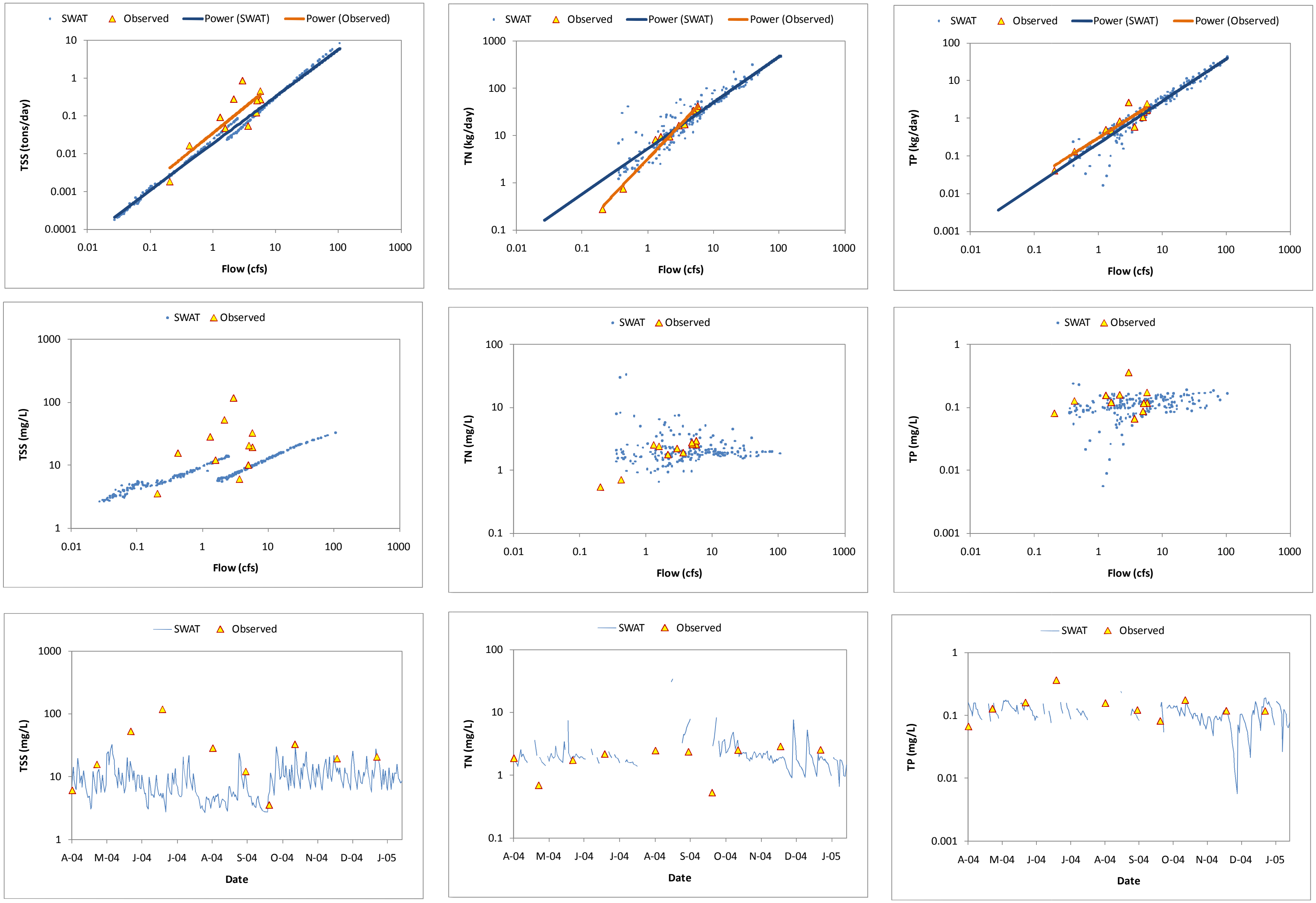


Figure E-24. SWAT Water Quality Calibration at KDOW 05016024

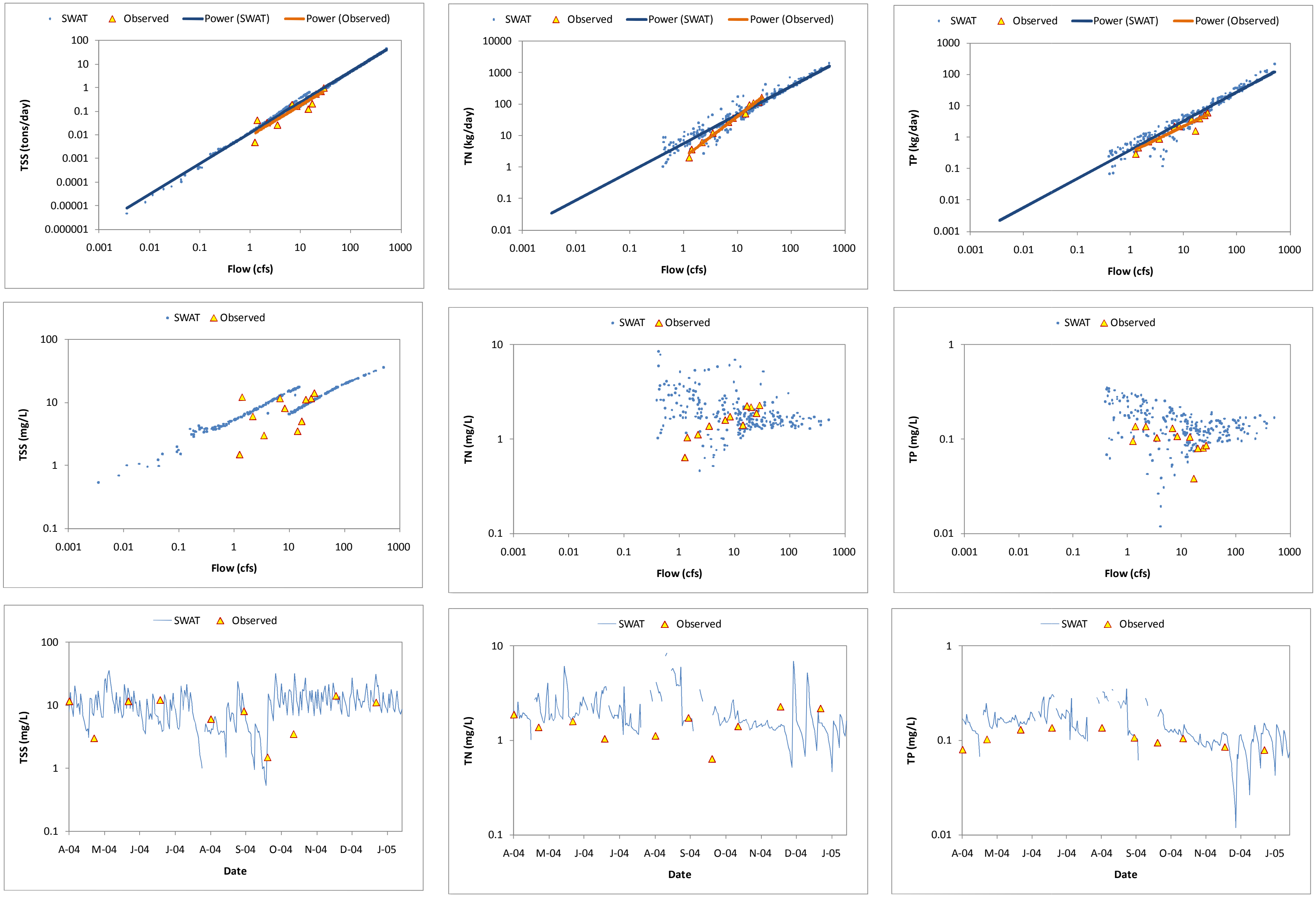


Figure E-25. SWAT Water Quality Calibration at KDOW 05016025

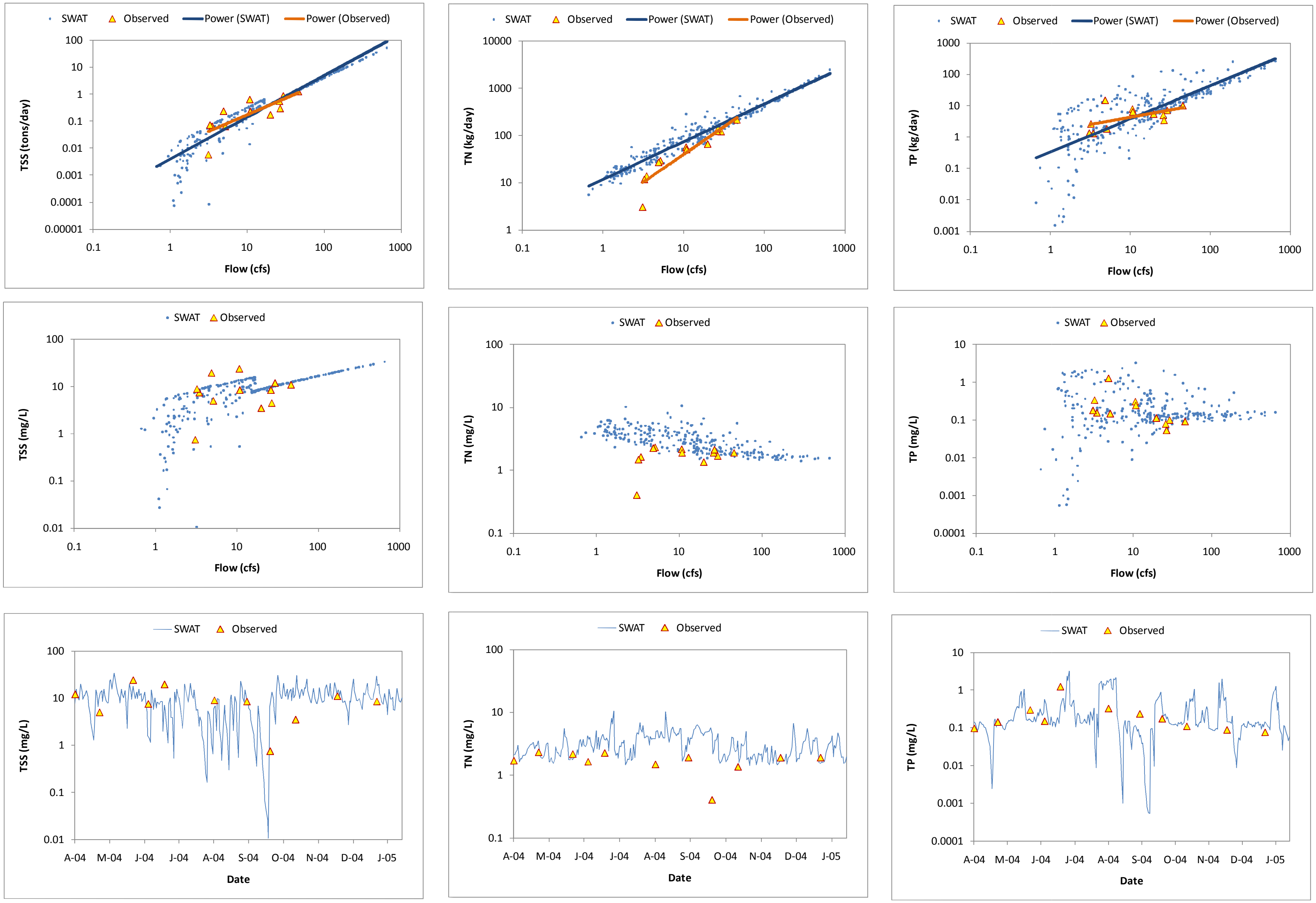


Figure E-26. SWAT Water Quality Calibration at KDOW 05016026

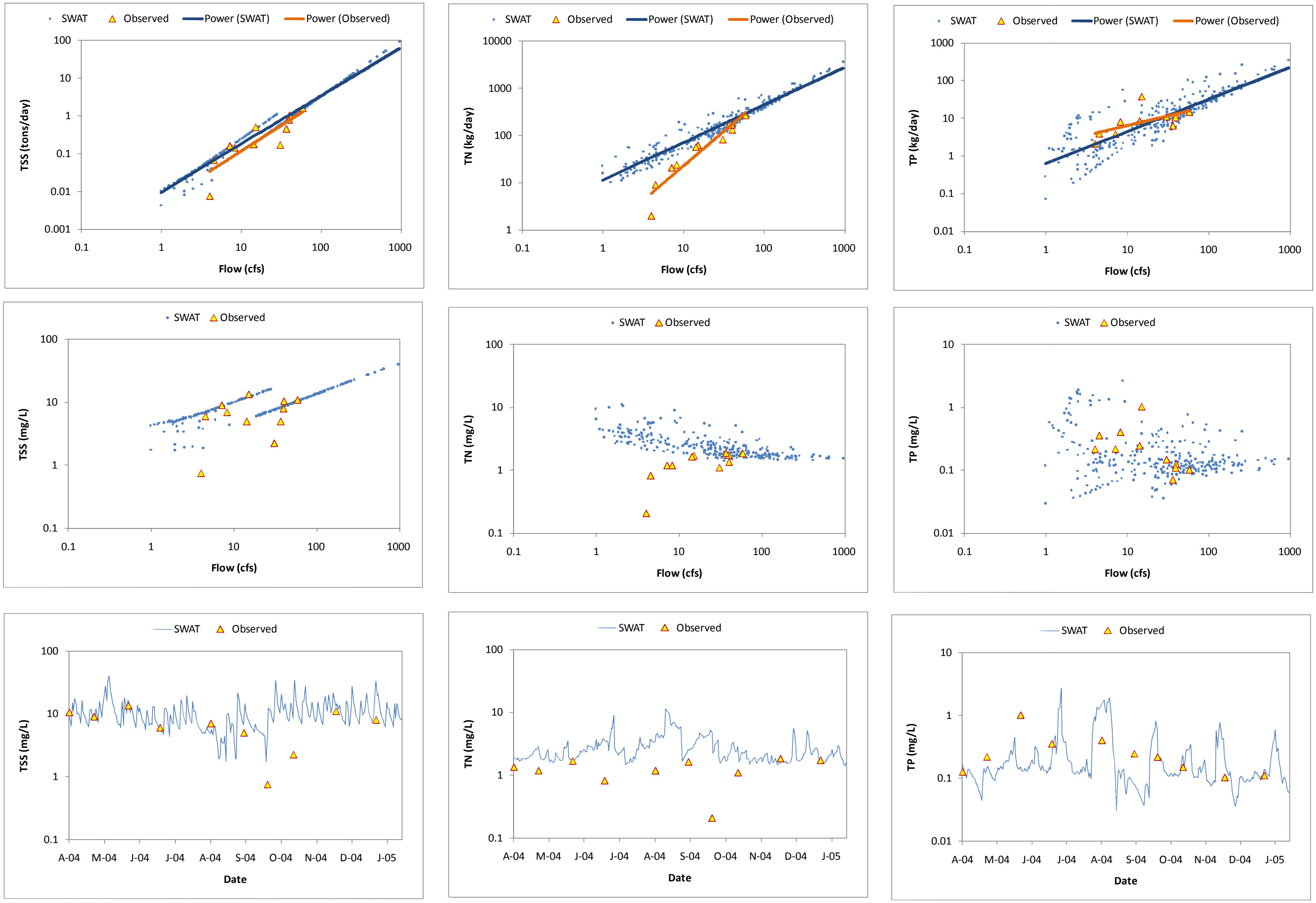


Figure E-27. SWAT Water Quality Calibration at KDOW 05016027

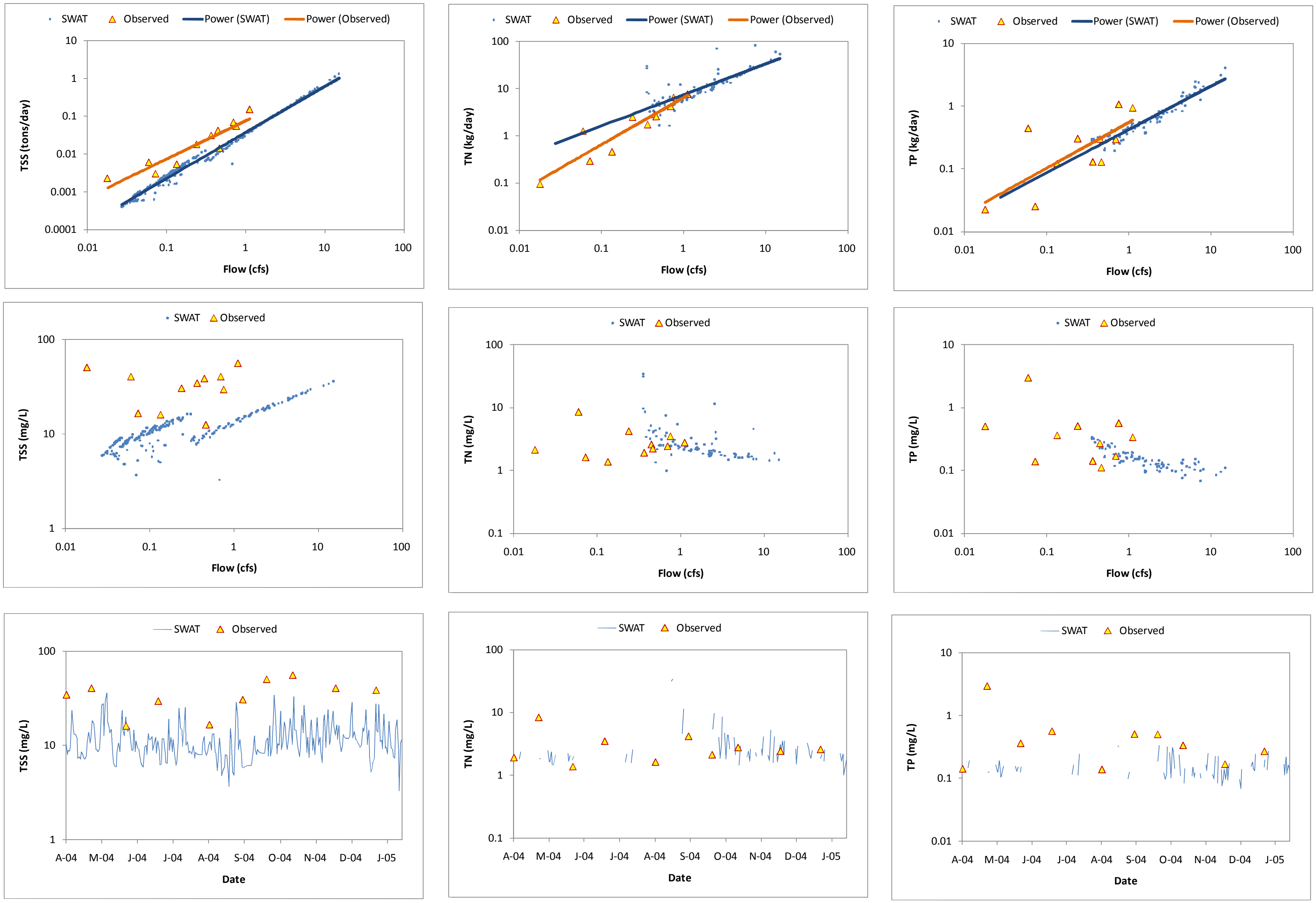


Figure E-28. SWAT Water Quality Calibration at KDOW 05016028

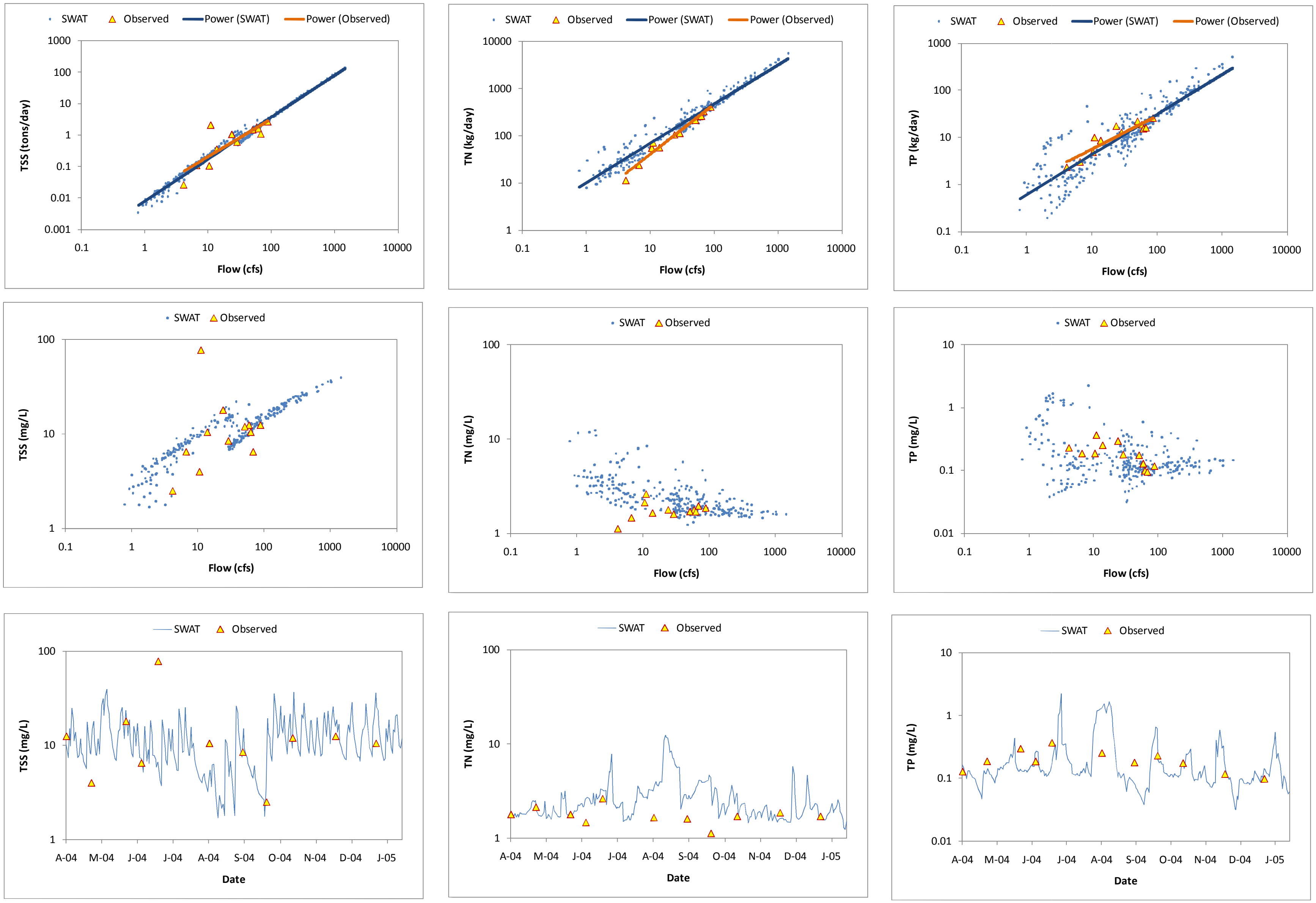
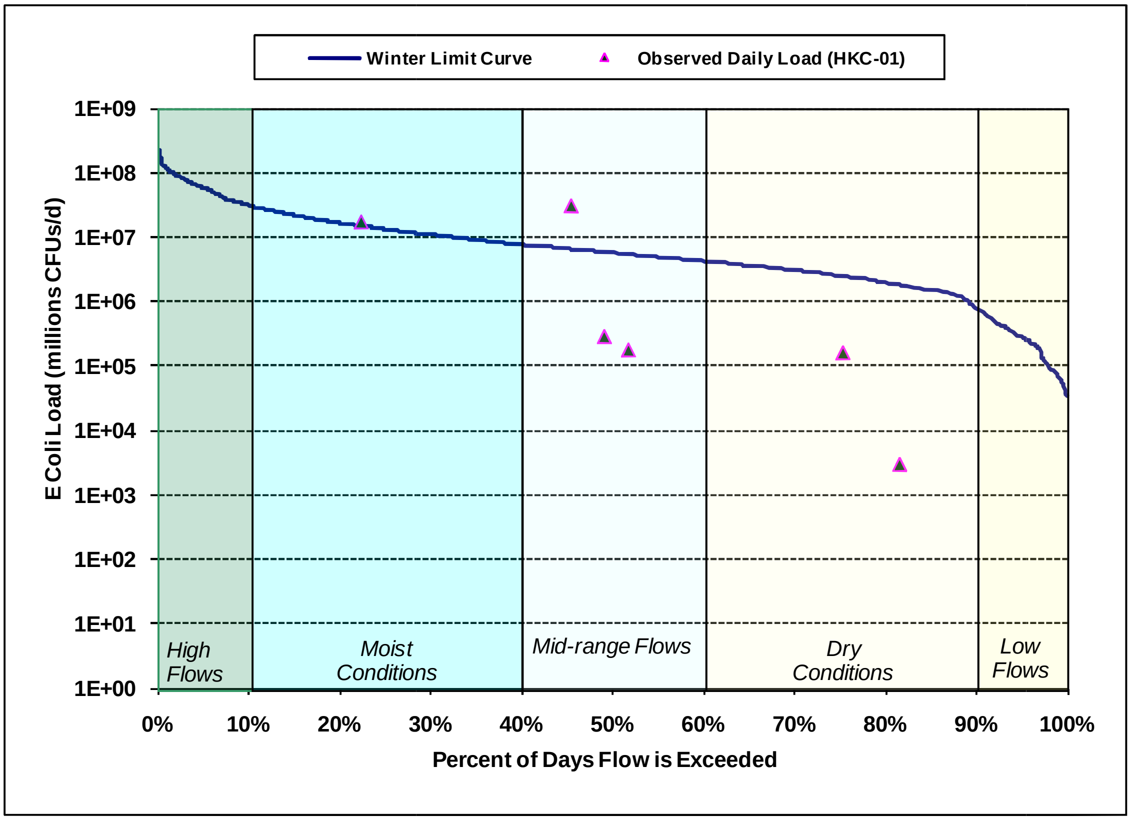


Figure E-29. SWAT Water Quality Calibration at KDOW 05016029

Appendix F. *E. coli* Load Duration Curves



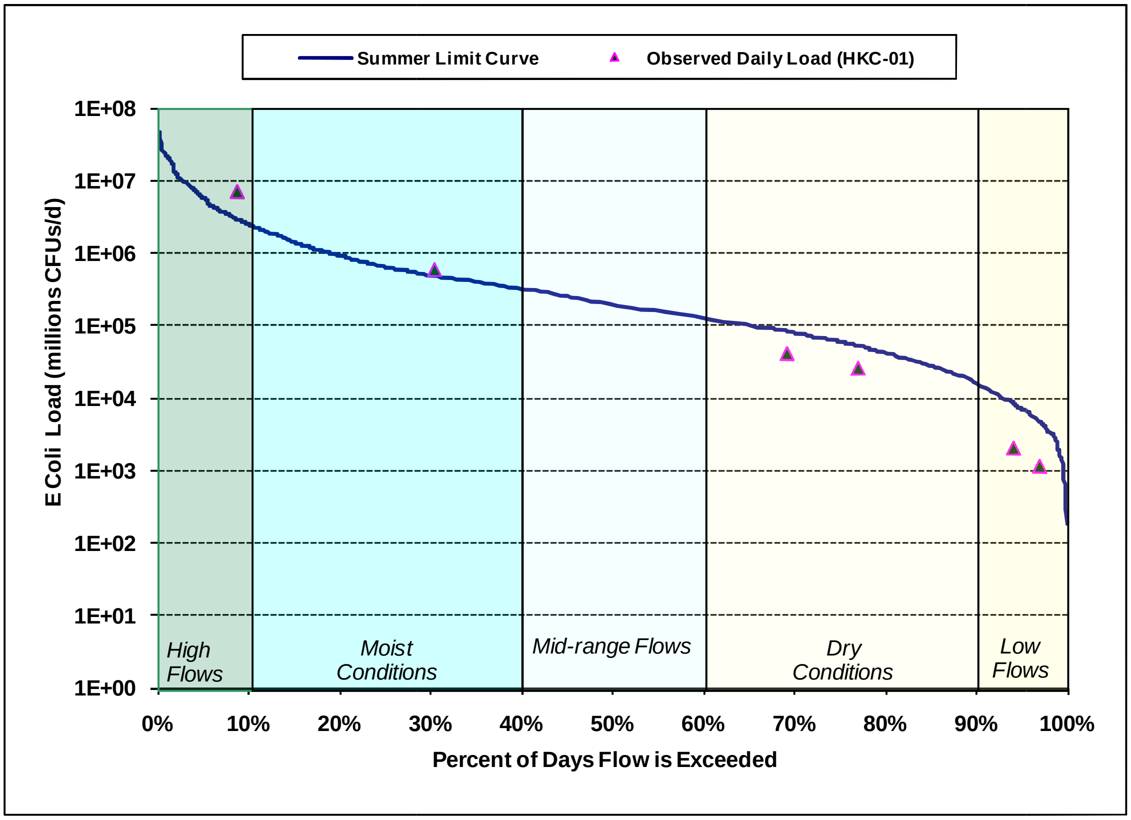
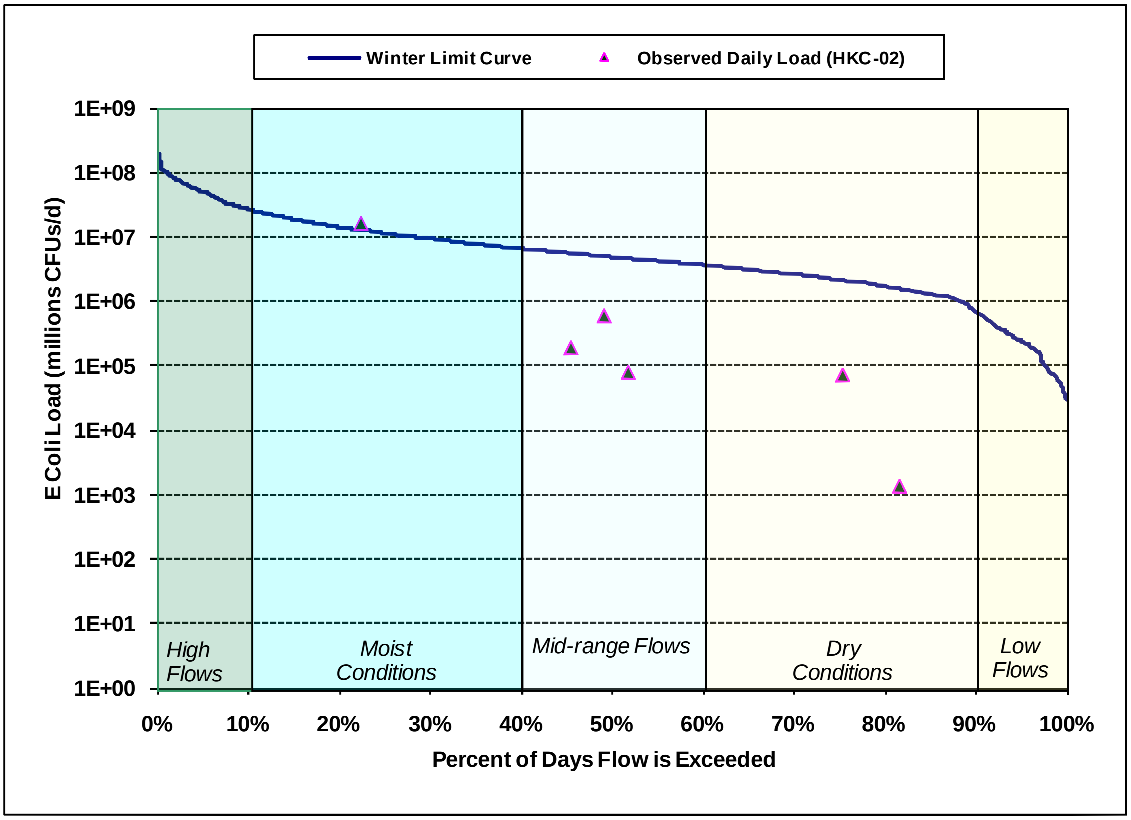


Figure F-1. Load Duration Curve for Mouth of Hinkston Creek Watershed (HKC-01)



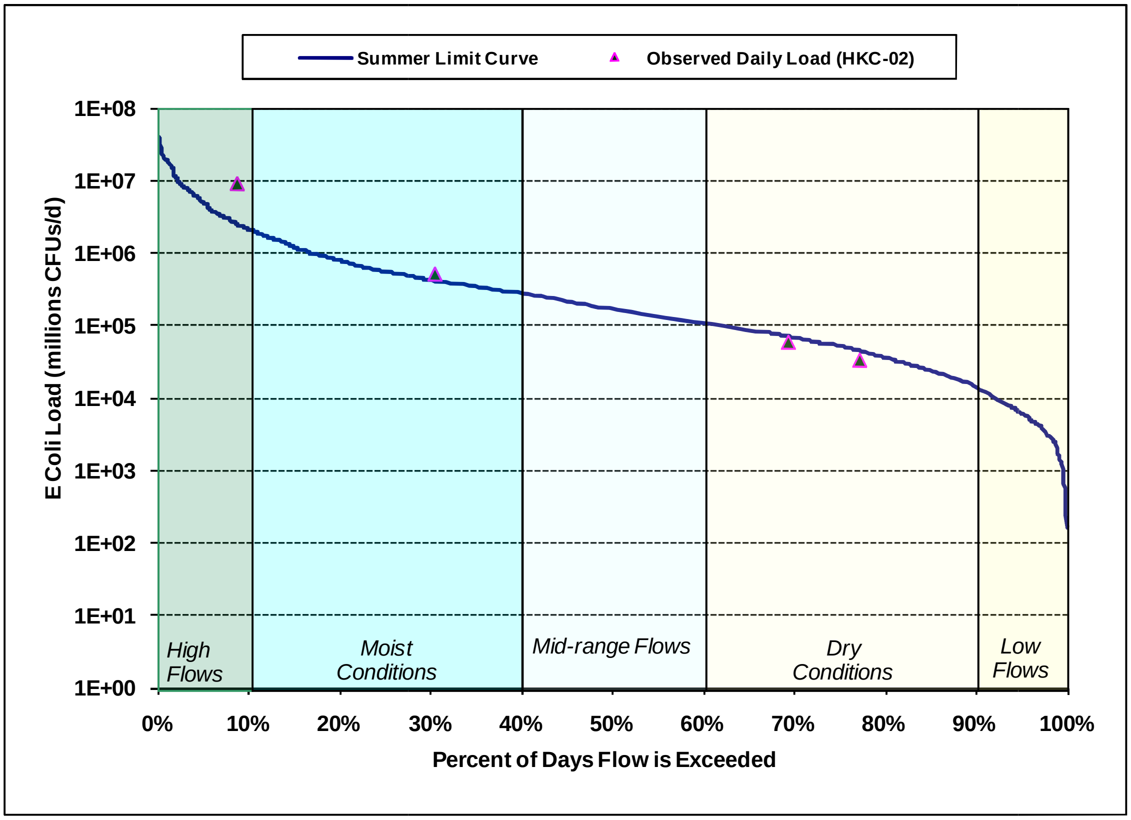
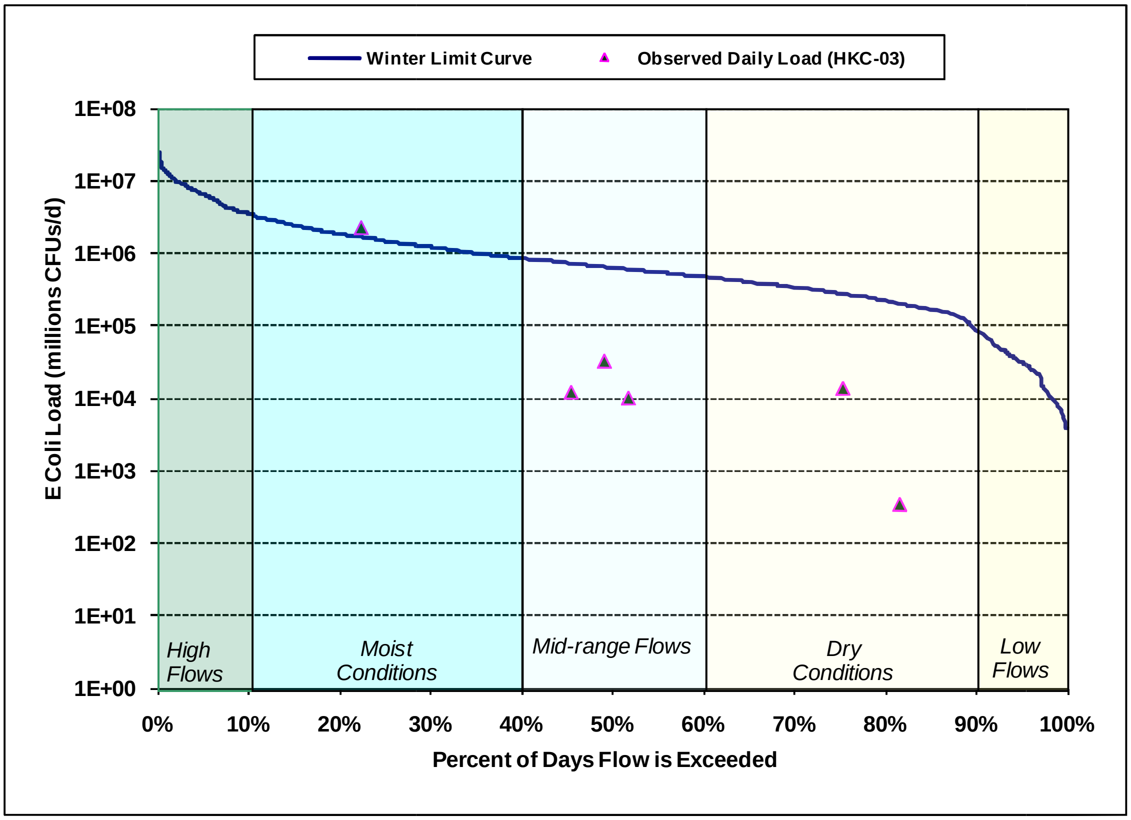


Figure F-2. Load Duration Curve for Station HKC-02



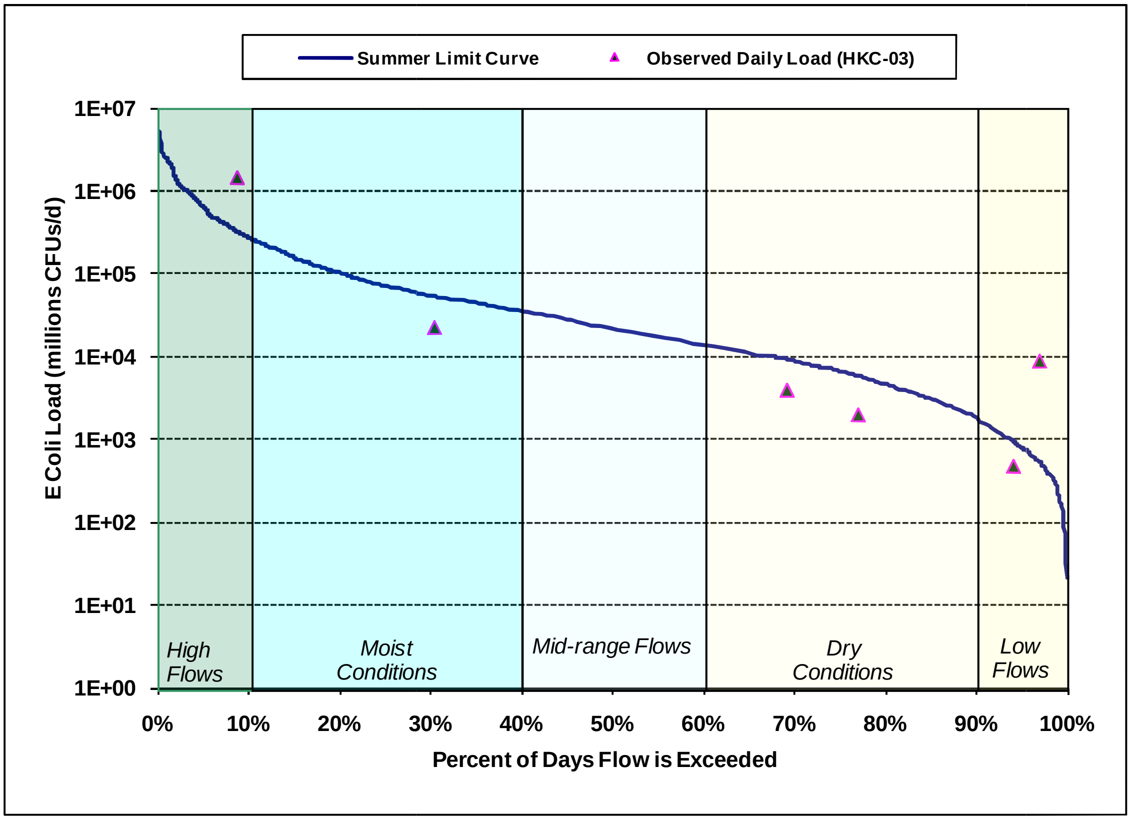
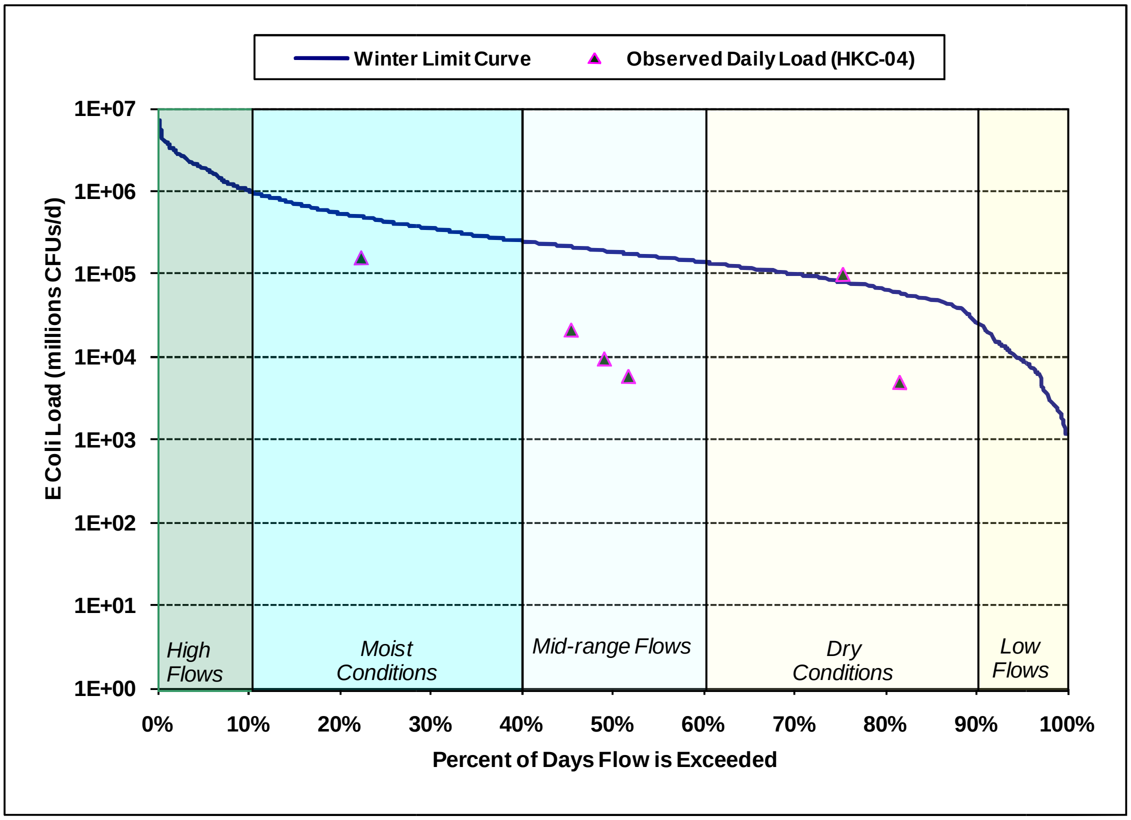


Figure F-3. Load Duration Curve for Station HKC-03



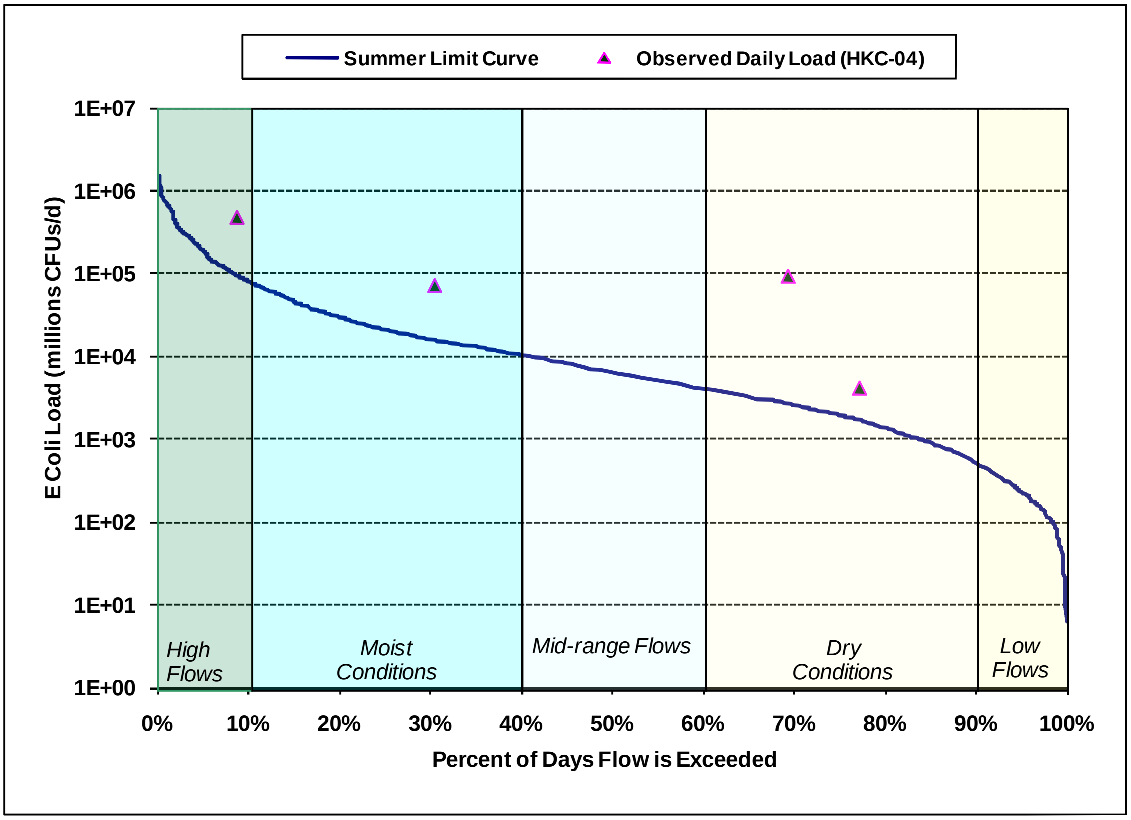
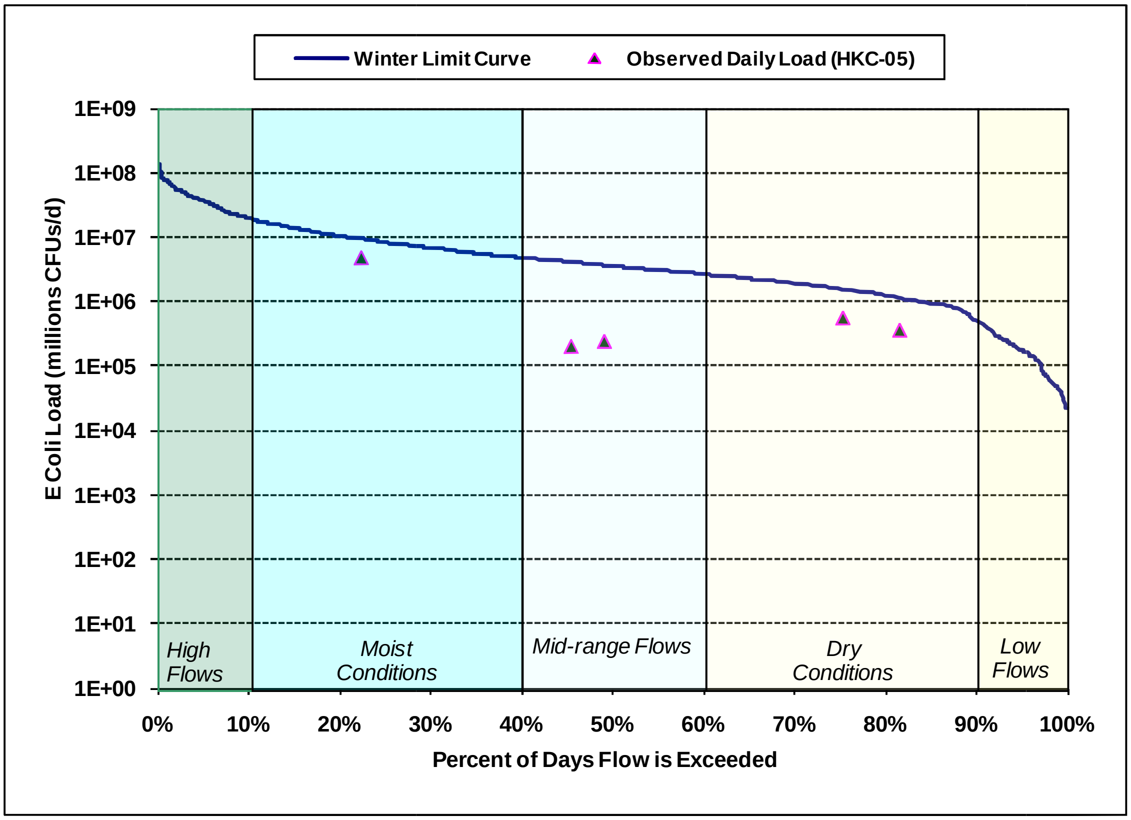


Figure F-4. Load Duration Curve for Station HKC-04



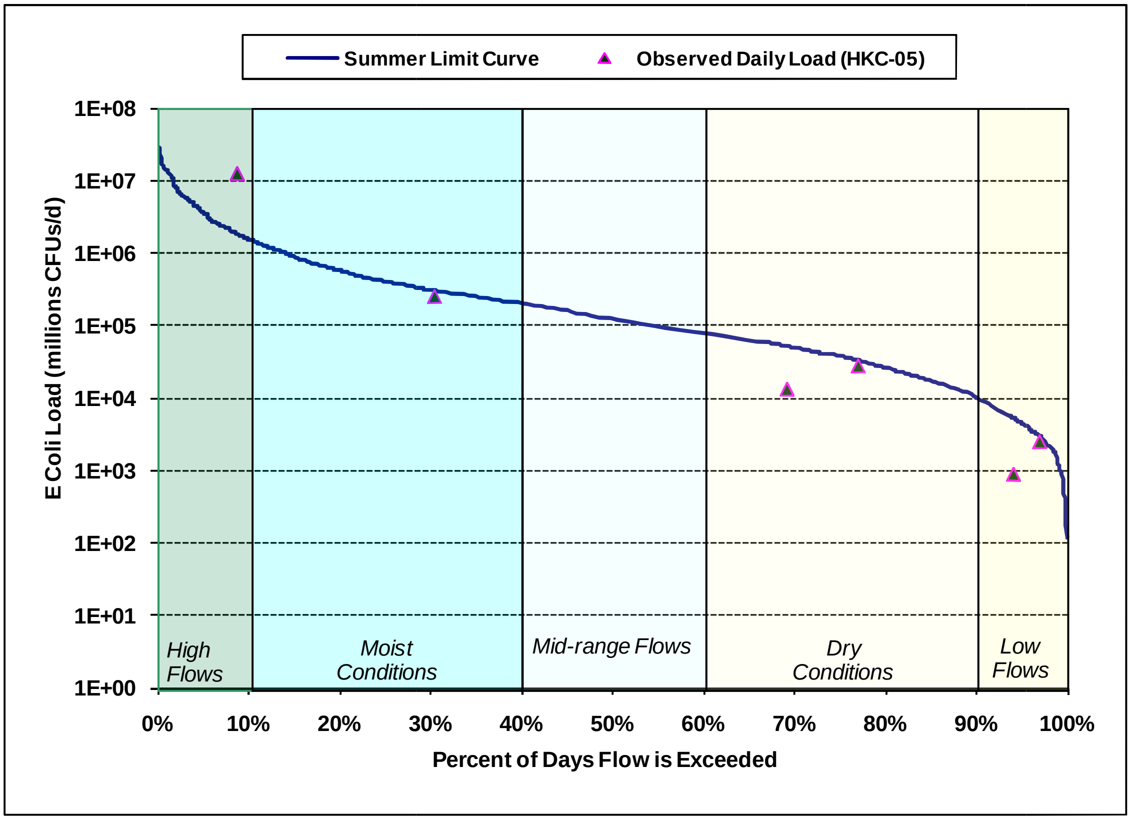
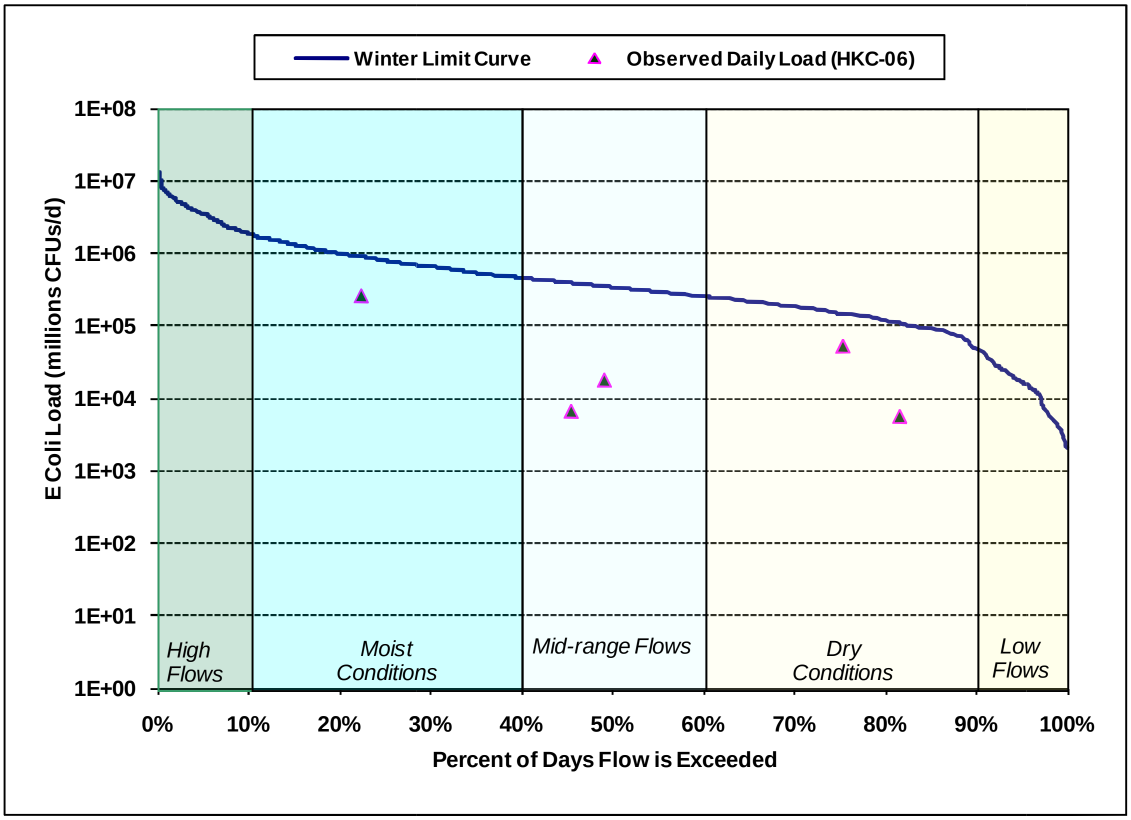


Figure F-5. Load Duration Curve for Station HKC-05



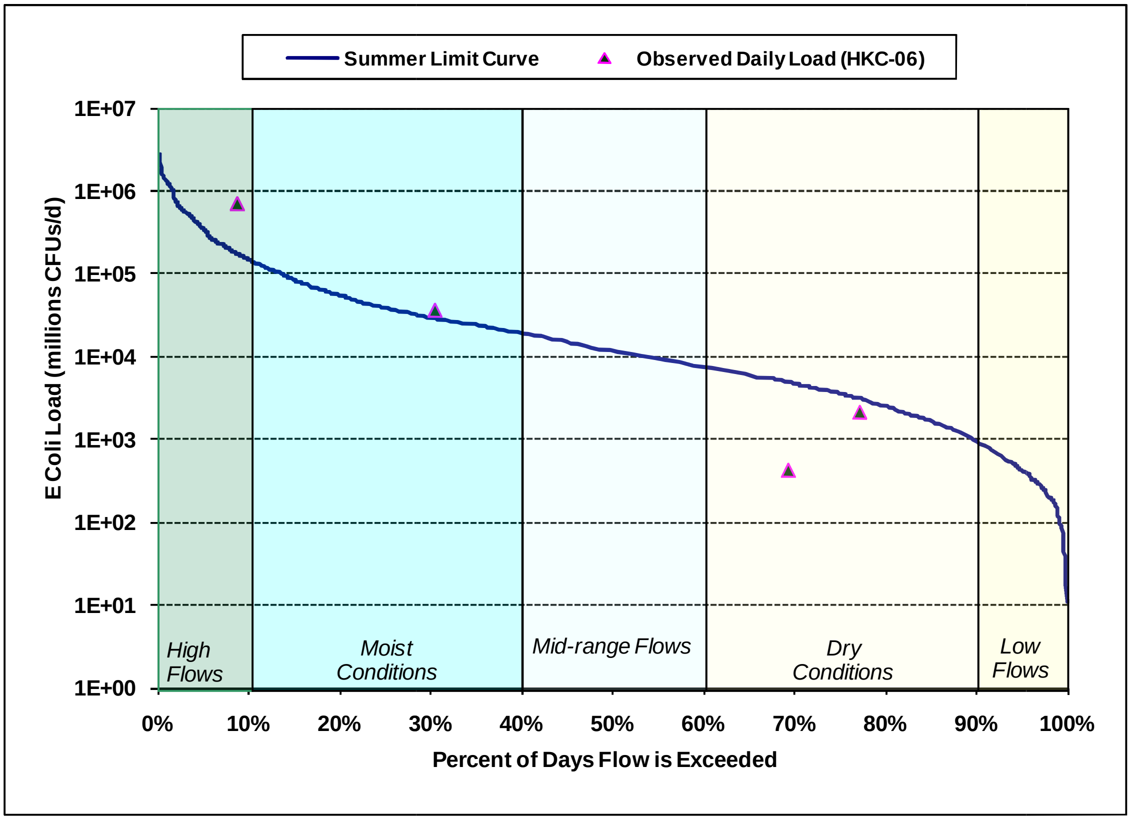
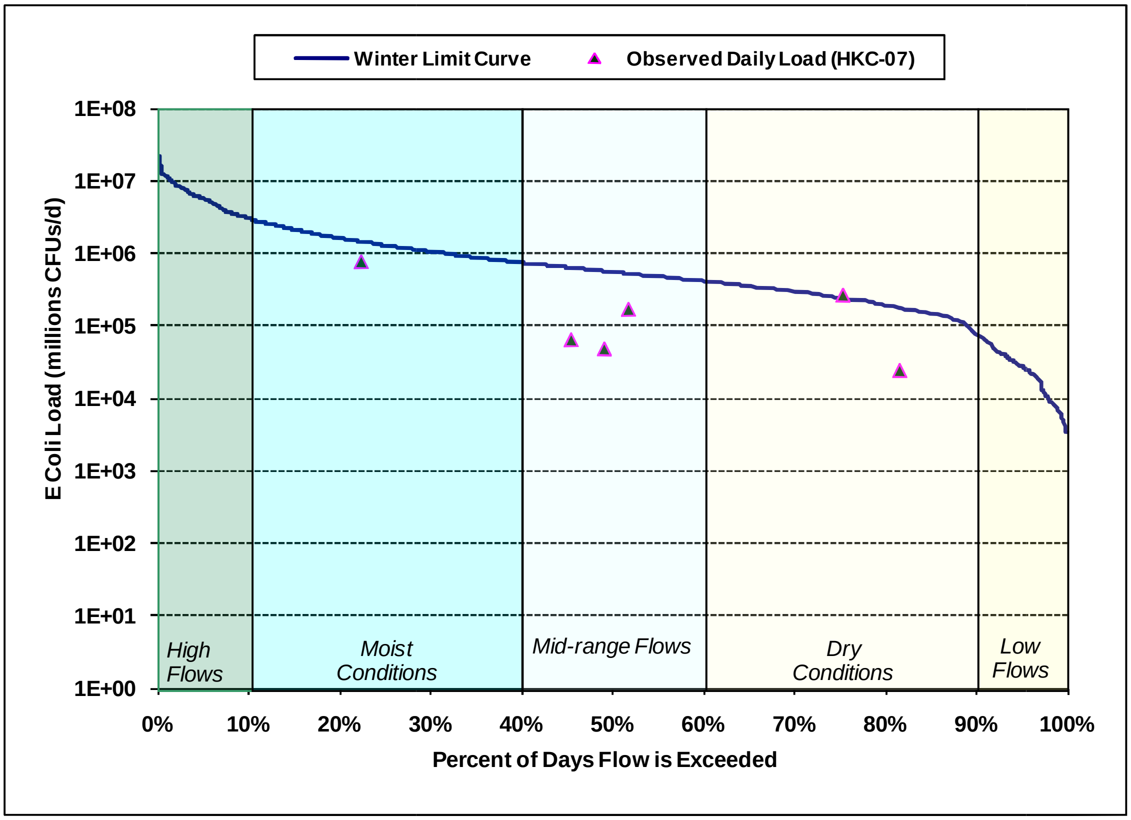


Figure F-6. Load Duration Curve for Station HKC-06



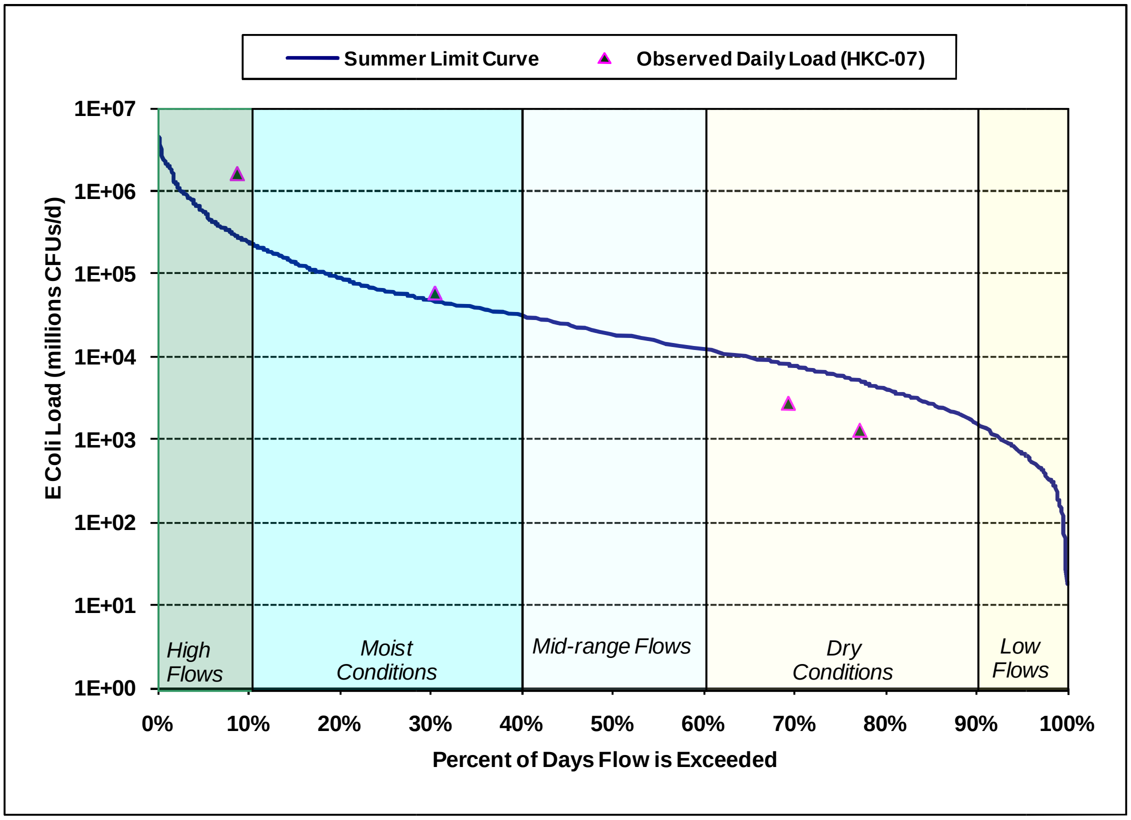
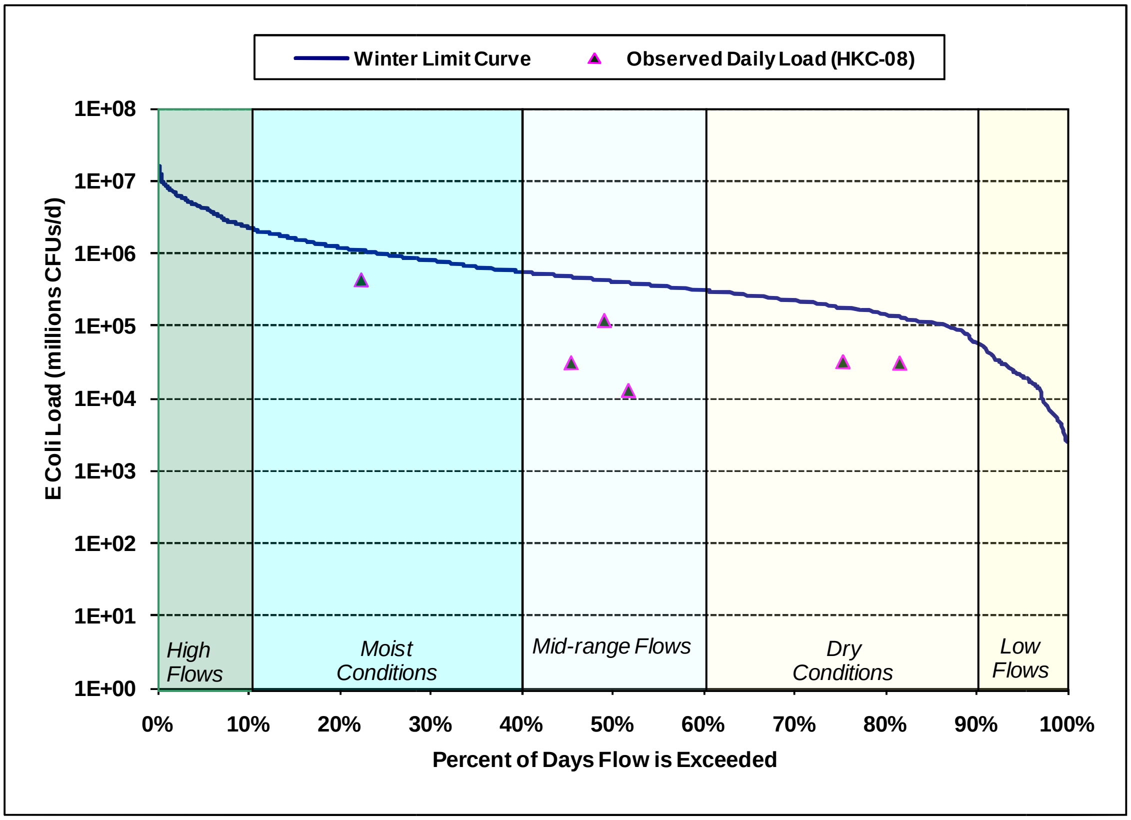


Figure F-7. Load Duration Curve for Station HKC-07



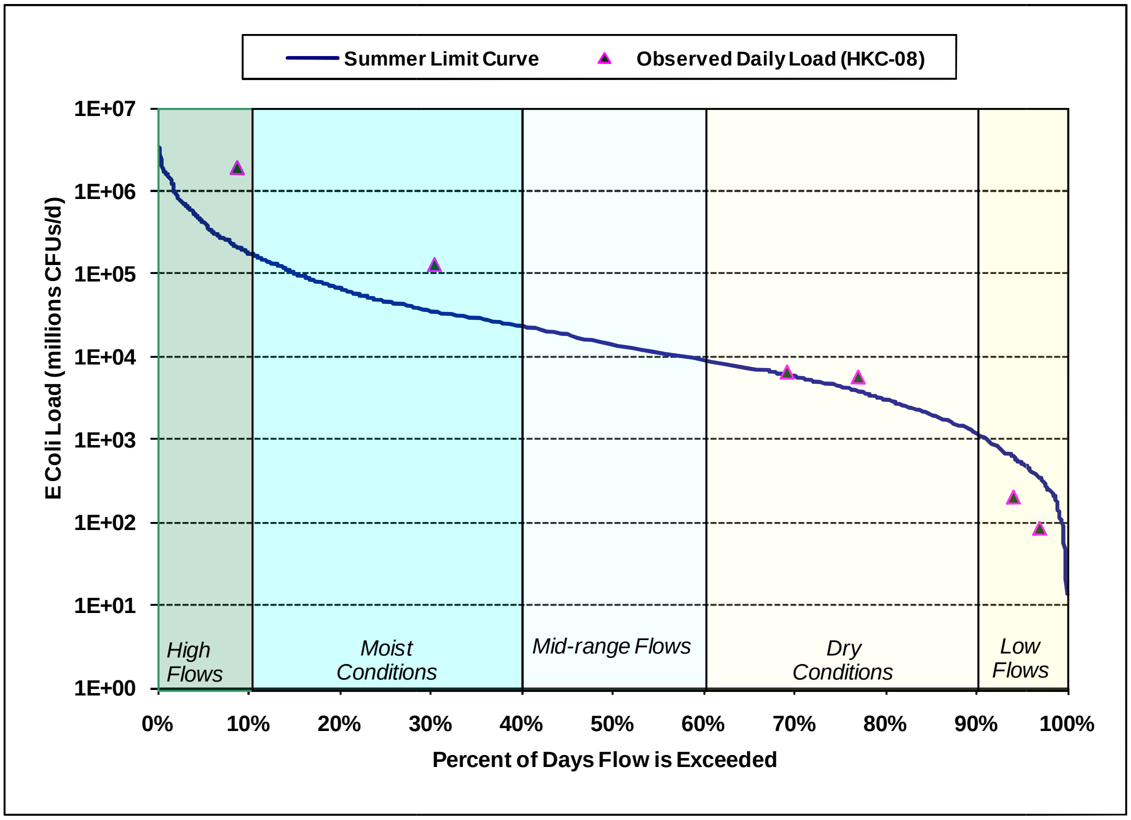
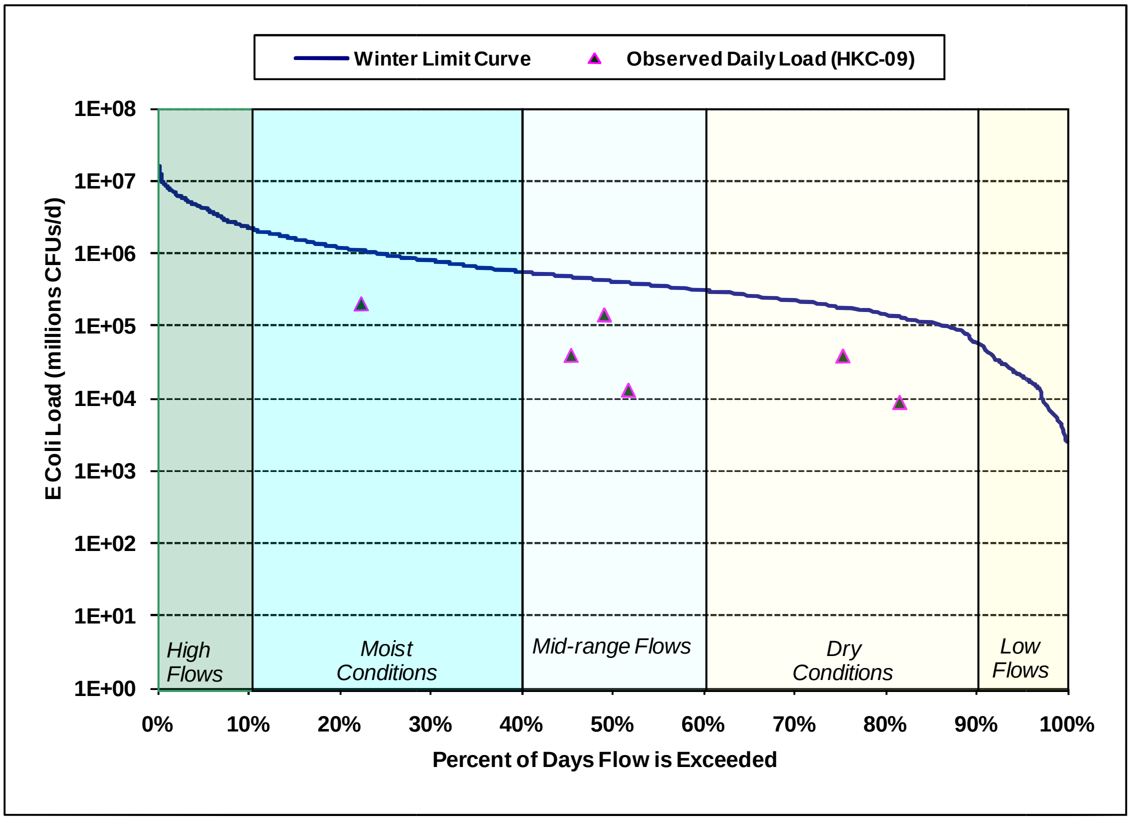


Figure F-8. Load Duration Curve for Station HKC-08



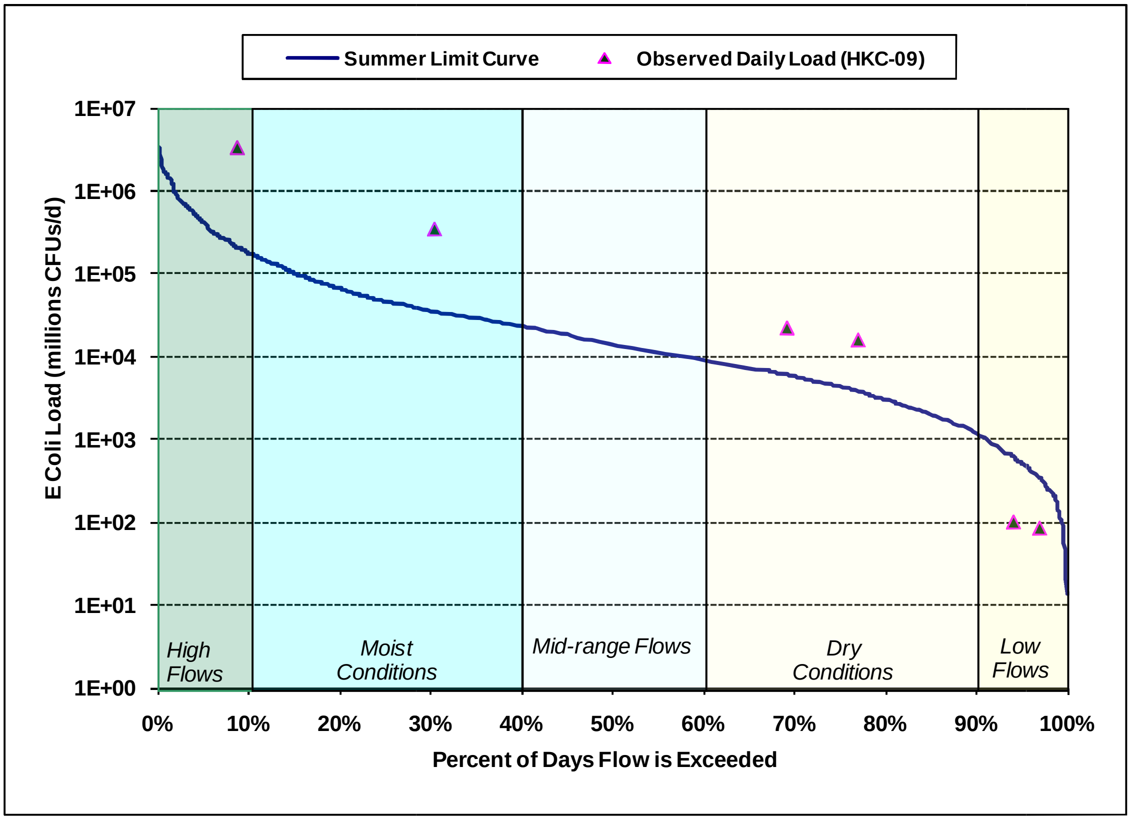
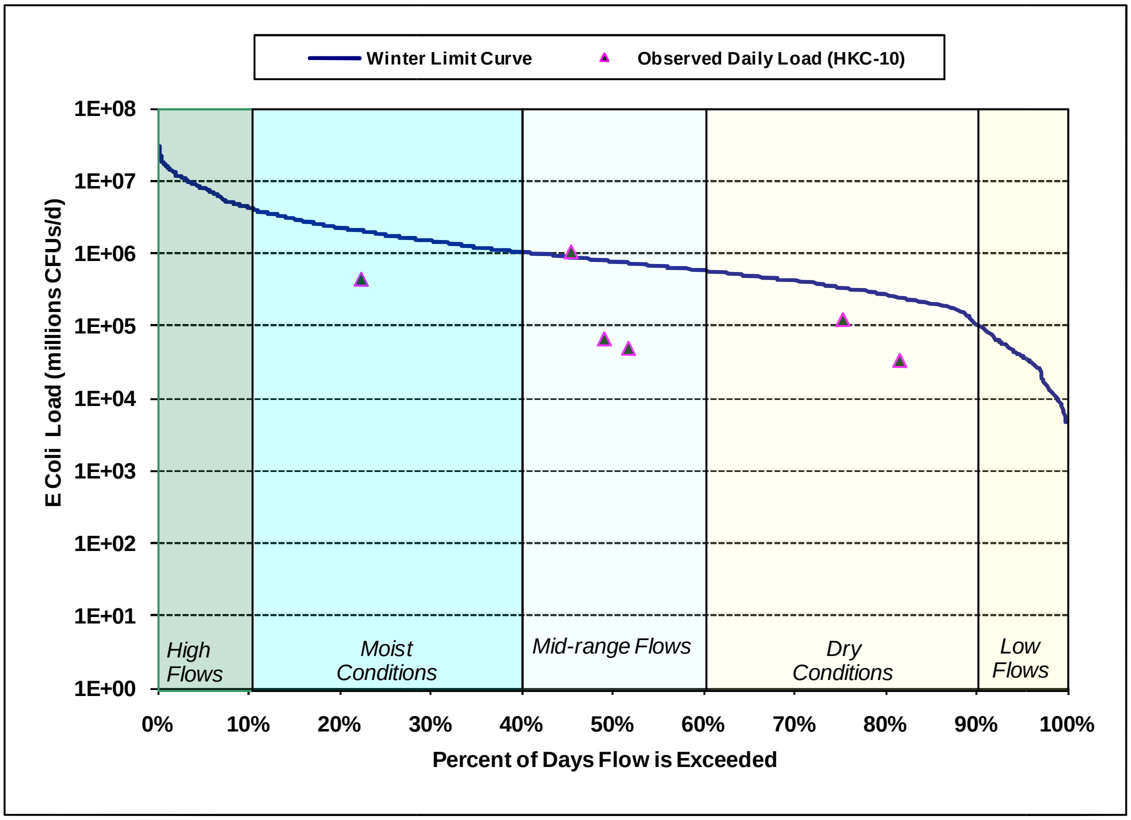


Figure F-9. Load Duration Curve for Station HKC-09



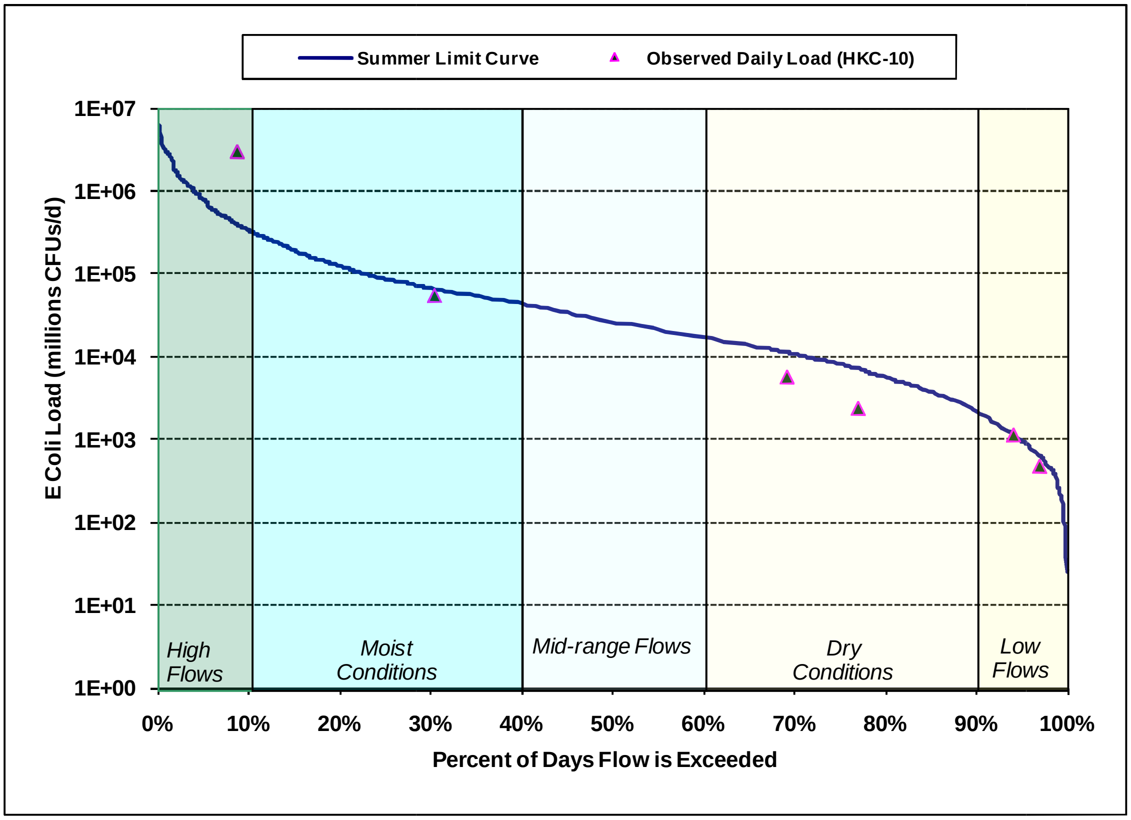
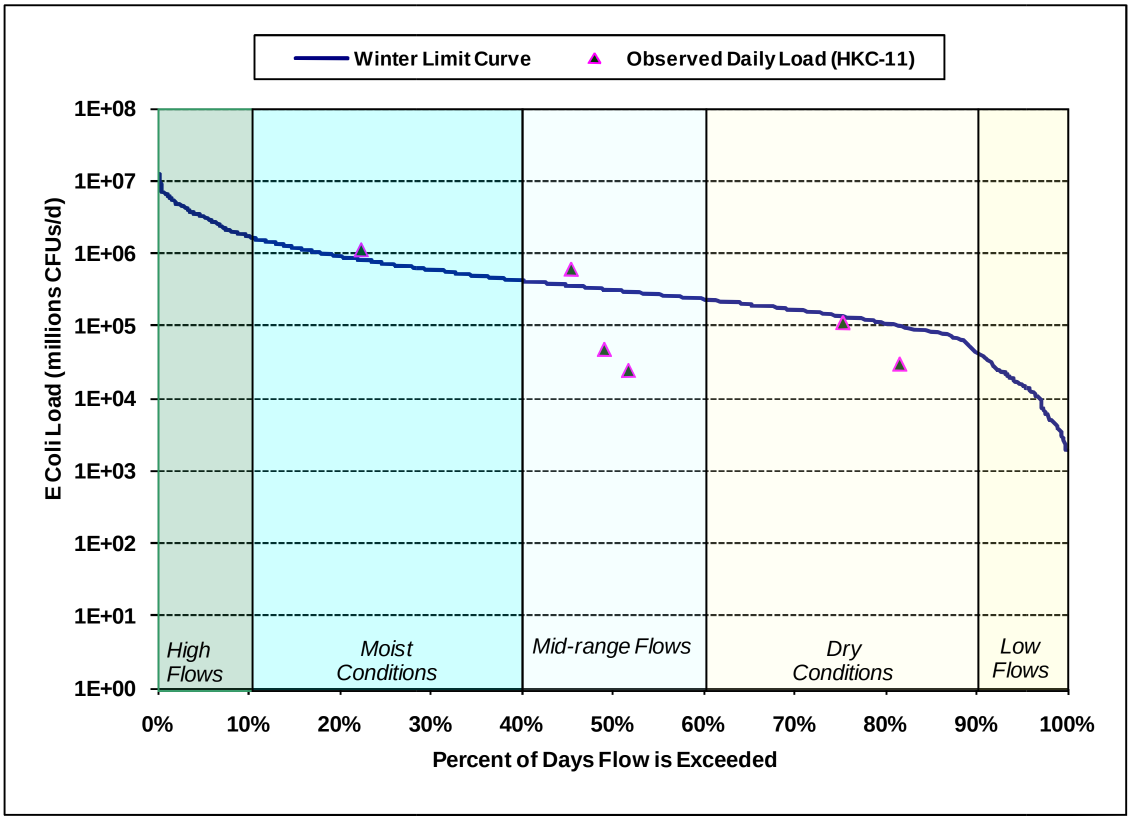


Figure F-10. Load Duration Curve for Station HKC-10



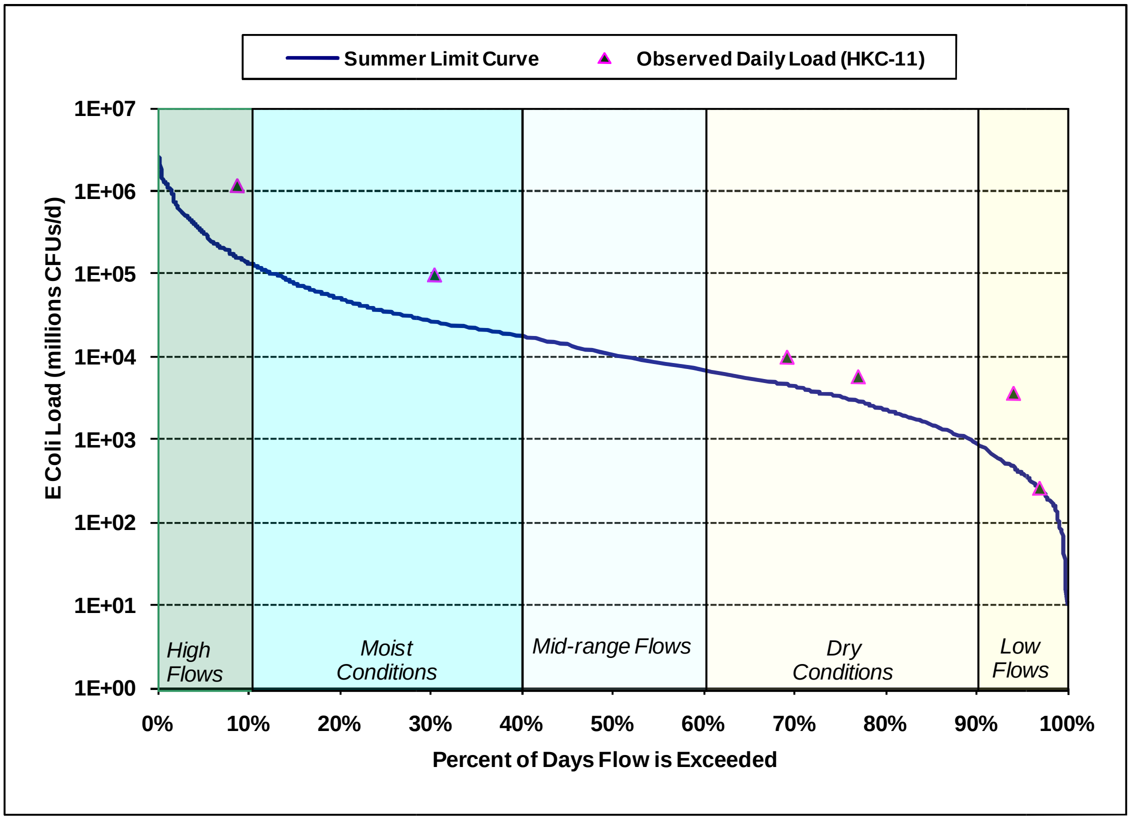
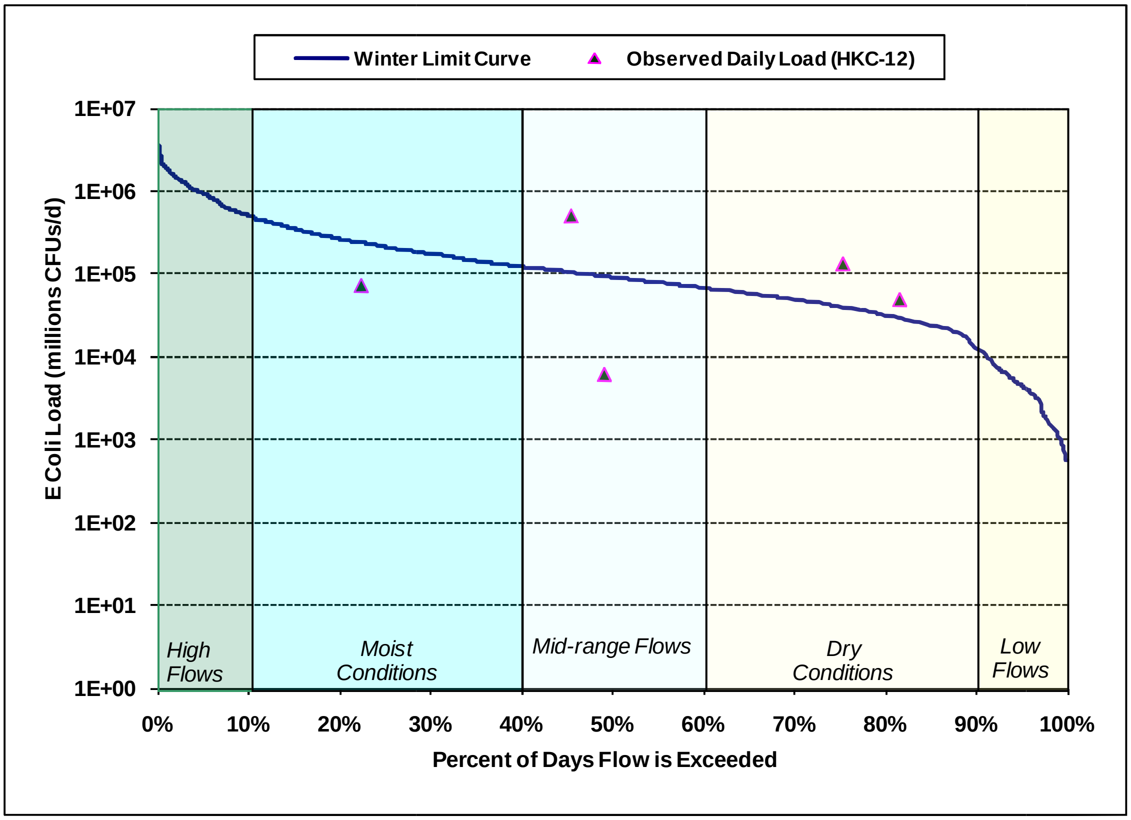


Figure F-11. Load Duration Curve for Station HKC-11



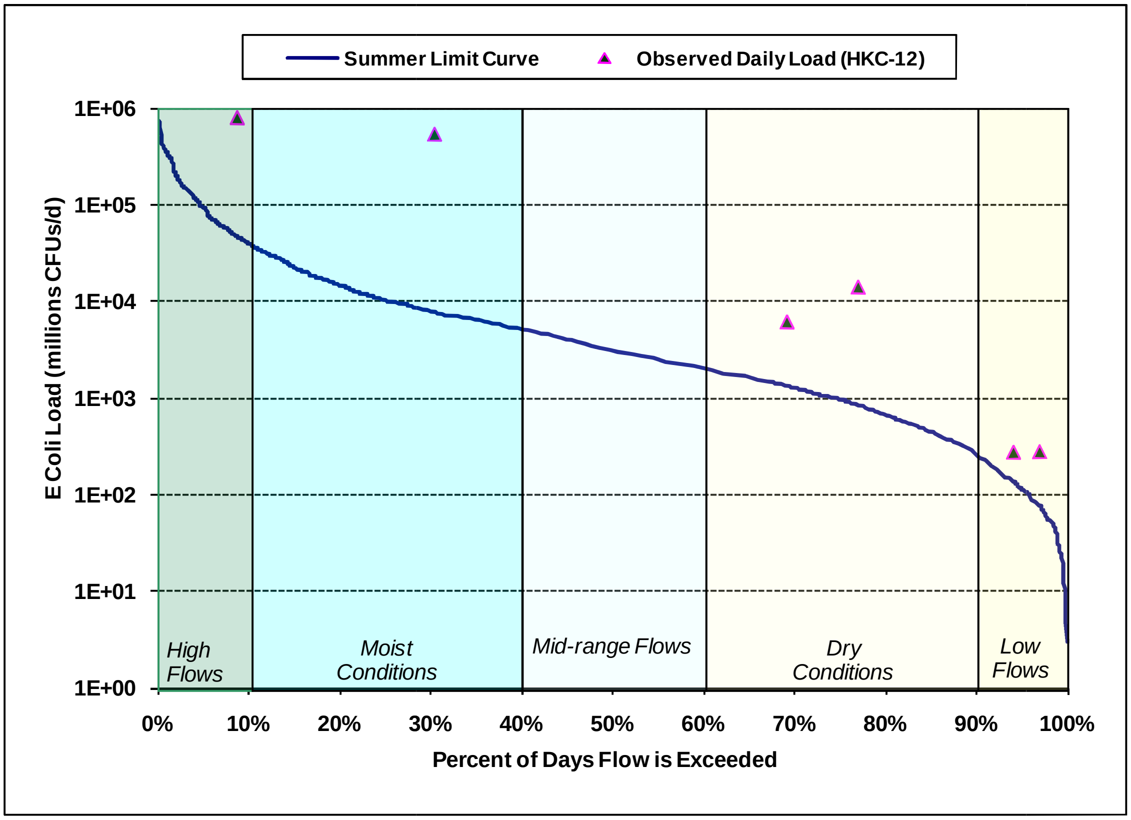


Figure F-12. Load Duration Curve for Station HKC-12

Appendix G. Bank Erosion

Measured bank erosion rate studies were not available for the Hinkston Creek watershed. To estimate a range of load reduction due to stream bank stabilization/restoration, erosion rates attributed to streams with differing degrees of erosion hazards were used. Van Eps et al. (2011) estimated relationships between measured lateral erosion rates, bank erosion hazard index (BEHI), and near bank shear stress (NBSS) for the West Fork White River watershed in northwest Arkansas and compared the results with two similar studies in Colorado and North Carolina. BEHI and NBSS are measures of streambank erosion potential outlined in Rosgen (2001).

To inform bank erosion estimates for the Hinkston Headwaters and Grassy Lick reporting units, the lateral erosion rates reported in Van Eps et al. (2011) were applied to an estimated average bank height to calculate the potential range of sediment loading from streambank erosion. The following equation for average bankfull height for channels in the Bluegrass Region, estimated by Parola et al. (2007), was used:

$$D_{bkf}=0.70DA^{0.51}$$

Where D_{bkf} = average bankfull depth in feet and DA = upstream drainage area in square miles. The estimated average bank heights are 4 and 5 feet for Hinkston Headwaters and Grassy Lick reporting units, respectively. A conversation factor of 101 lbs per cubic foot was used to convert the rates from volume to weight per year; this factor reflects bank material similar in texture and composition to bank material found along streams in the Hinkston Creek watershed (S. K. Reid, PhD, Department of Earth and Space Sciences, Morehead State University, personal communication to B. Tonning, March 21, 2011).

The resulting estimated loading rates using the three studies are shown in Table G-1 by corresponding BEHI and NBSS ratings. The results show that bank erosion may vary widely depending on the condition of the streambanks as well as location-specific conditions. Factors that affect variability include watershed area, soils, precipitation, and other characteristics.

Table G-1. Approximate Bank Erosion Rate Estimates for Hinkston Headwaters and Grassy Lick Reporting Units using Relationships between Measured Rates, BEHI, and NPSS (Van eps et al., 2011) applied to Average Bank Height (Parola et al., 2007)

Bank Erosion Hazard Index	Near-Bank Shear Stress	Tons per Mile per Year		
		Arkansas	Colorado	North Carolina
Hinkston Headwaters				
Moderate	High	74	466	194
Moderate	Extreme	883	1,747	3,107
High	Extreme	2,059	2,951	4,272
Extreme	Extreme	10,296	16,581	11,650
Grassy Lick				
Moderate	High	204	490	204
Moderate	Extreme	2,449	1,836	3,265
High	Extreme	5,713	3,101	4,489
Extreme	Extreme	28,566	17,425	12,243

Of the three studies, the Arkansas methods likely provide the most applicable erosion estimates for the Hinkston Creek watershed considering that this study took place in a similar part of the U.S. and included mostly rural land with some pasture uses. Of the Arkansas drainage areas studied in Van Eps et al. (2011), Winn Creek is most similar in size to Hinkston Headwaters (37 square miles) and Grassy Lick (41 square miles) with a drainage area of 14.4 square miles. The BEHI scores measured along Winn Creek ranged from low to high, and the NBSS scores ranged from high to very high. The average annual erosion rate for Winn Creek was estimated as 126 tons/mile. This may be a conservative estimate of the erosion occurring in Hinkston Headwaters and Grassy Lick considering the range of the available data and the fact that the reporting units are larger than the Winn Creek watershed. However, the Winn Creek rate may reflect an approximate lower limit for potential erosion rates along impacted reaches.

Preliminary data on erosion rates for BEHI rated streams were also available from Morehead State University for the Triplett Creek watershed, which is within the vicinity of the Hinkston Creek watershed. Using the average bank height assumptions for Hinkston Headwaters and Grassy Lick, the preliminary Triplet Creek survey results suggest that measured stream erosions rates could range from about 1,100 tons/mile/year for a low to moderate BEHI reach to 6,600 tons/mile/year for an extreme BEHI reach (S. K. Reid, PhD, Department of Earth and Space Sciences, Morehead State University, personal communication to B. Tonning, March 21, 2011).

An approximate range of 200 to 2000 tons per mile annual loading was estimated to represent the likely range of annual sediment loading from bank erosion in the Grassy Lick and Hinkston Headwaters reporting units. The midpoint of 1,100 tons per mile per year was used for the purposes of the cost-benefit analysis. The lower limit was selected to represent the approximate lower limit of loading indicated by the Winn Creek loading rates in Arkansas. The upper limit was based on a consideration of Table G-1 and the preliminary Triplett Creek estimates. This range is likely conservative for some reaches since the available data show that erosion rates can be much greater where very high and extreme erosion hazards and shear stress exist.

As noted above, stream erosion rates and load reductions due to stream restoration can vary widely. These loading estimates are provided for reference purposes and should not be considered absolute estimates of bank and channel erosion in the Hinkston Creek watershed or substitutes for watershed-specific field measurements.