3.0 WATERSHED INVENTORY II-A: WATER QUALITY AND WATERSHED ASSESSMENT

In order to better understand the watershed, an inventory and assessment of the watershed and existing water quality studies conducted within the watershed is necessary. Examining previous efforts allowed the project participants to determine if sufficient data were available or if additional data needed to be collected in order to characterize water quality problems. The following sections detail the water quality and watershed assessment efforts on both the broad, watershed-wide scale and in a focused manner looking at each subwatershed within the Deer Creek-Sugar Creek watershed

3.1 Water Quality Targets

Many of the historic water quality assessments occurred using different techniques or goals. Several sites were sampled only one time and for a limited number of parameters. Steering committee members were reluctant to draw too many conclusions based on a single sampling event. Nonetheless, the available data are detailed below and compared in general with water quality targets. In order to compare the results of these assessments, the monitoring committee identified a standard suite of parameters and parameter benchmarks. Table 16 details the selected parameters and the benchmark utilized to evaluate collected water quality data.

Table 16. Water quality benchmarks used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Benchmark	Source
Dissolved Oxygen	Min: 4.0 mg/L Max: 12.0 mg/L	Indiana Administrative Code (327 IAC 2-1-6)
E. coli	Max: 235 CFU/ 100mL in a single sample Max Geometric Mean of 125 CFU/100 mL from 5 equally spaced samples over a 30-day period	Indiana Administrative Code (327 IAC 2-1.5-8)
Nitrate –Nitrogen	Max: 1.0 mg/L	Ohio EPA recommended criteria for Warm Water Habitat
pH	6 to 9	
Temperature	Dependent on time of year and whether stream is designated as a cold water fisheries	Indiana Administrative Code (327 IAC 2-1-6)
Total Phosphorus	Long Term Target Max: 0.08 mg/L	Dodds et al. 1998
	Short Term Target Max: 0.3 mg/L	IDEM TMDL target
Turbidity	Max: 9.89 NTU	U.S. EPA recommendation
Total Suspended Solids (TSS)	Max: 15.0 mg/L	Michigan DEQ
Qualitative Habitat Evaluation Index	> 51	IDEM
Macroinvertebrate Index of Biotic Integrity	> 2.2 (1990-2003 using rapid assessment single habitat method); >36 (2005-present scored using multi-habitat method)	IDEM
Index of Biotic Integrity	> 36 points	IDEM

3.2 Historic Water Quality Sampling Efforts

A variety of water quality assessment projects have been completed within the Deer Creek-Sugar Creek watershed (Figure 43). Statewide assessments and listings include the integrated water monitoring assessment, the impaired waterbodies assessment, and fish consumption advisories. Additionally, the Indiana Department of Natural Resources (IDNR) completed assessments within the watershed. Corridor-wide assessments of the fish community along the length of the Wabash River were completed by DePauw University and Ball State University. Regional water quality assessments were completed by the Tippecanoe County Soil and Water Conservation District (SWCD) and the Tippecanoe County Health Department (TCHD). Purdue University professors completed mussel and fish assessments throughout Tippecanoe County; additionally water quality data were collected. Prior to the construction of the Hoosier Heartland, a biological assessment was completed for the areas that will be impacted by the new highway. A summary of each assessment methodology and general results are discussed below. These are detailed within subwatershed discussions in subsequent section.

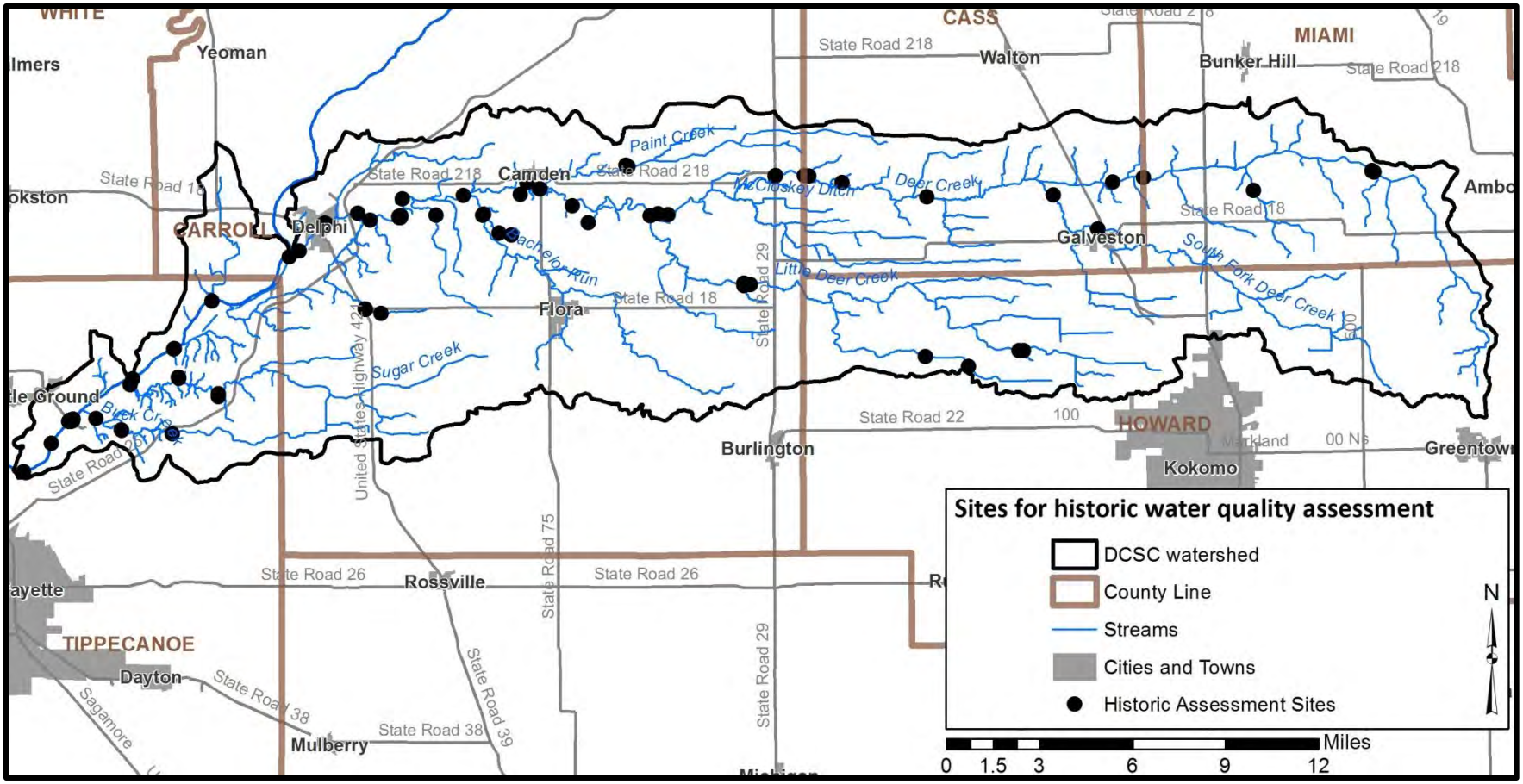

Figure 43. Historic water quality assessment locations.
Data used to create this map are detailed in Appendix A.

3.2.1 Integrated Water Monitoring Assessment (305(b) Report)

The Indiana Department of Environmental Management (IDEM) is the primary agency tasked with monitoring surface water quality within the state of Indiana. Chapter 305(b) of the Clean Water Act requires that the state report on the quality of waterbodies throughout the state on a biannual basis. These assessments are known as the Integrated Water Monitoring Assessment (IWMA) or the 305(b) Report (IDEM, 2012). To complete this report, the 305(b) coordinator reviews all data collected by IDEM and selected high-quality data collected by other organizations on a waterbody basis. Each assessed waterbody is then assigned a water quality rating based on its ability to meet Indiana's water quality

standards (WQS). WQS are set at a level to protect Indiana waters' and their designated uses of swimmable, fishable, and drinkable. Waterbodies that do not meet their designated uses are proposed for listing on the Impaired Waterbodies List.

3.2.2 Impaired Waterbodies (303(d) List)

Waterbodies in the Deer Creek-Sugar Creek watershed which are included on the Impaired Waterbodies List are detailed in section 2.7.3 above.

3.2.3 Fish Consumption Advisory (FCA)

Three state agencies collaborate annually to compile the Indiana Fish Consumption Advisory (FCA). The Indiana Department of Natural Resources, Indiana Department of Environmental Management, and Indiana State Department of Health have worked together since 1972 on this effort. Samples are collected through IDEM's rotating basin assessment for bottom feeding, mid-water column feeding, and top feeding fish. Fish tissue samples are then analyzed for heavy metals, PCBs, and pesticides.

Table 17 details the advisories for the Deer Creek-Sugar Creek watershed from the 2011 report (IDEM, 2011). Advisory listings are as follows:

- Level 3 – limit consumption to one meal per month for adult males and females; women who are pregnant or breastfeeding; women who plan to have children; and children less than15 years of age should consume zero volume of these fish.
- Level 4 – limit consumption to one meal every two months for adult males and females; women and children detailed above having zero consumption.
- Level 5 – zero consumption or do not eat.

Based on these listings, the following conclusions can be drawn:

- No carp should be consumed from any waterbody within the watershed.
- Smallmouth bass longer than ten inches should only be consumed once a month.
- The Wabash River is under a fish consumption advisory for selected fish of select size within the length of the river in Carroll, Cass, Miami, and Tippecanoe counties up stream of Lafayette, IN.

Table 17. Fish Consumption Advisory listing for the Deer Creek-Sugar Creek watershed.

Waterbody	Fish Species	Fish Size	Advisory
All	Carp	15-20 inches	3
		20-25 inches	4
		25+ inches	5
Deer Creek	Smallmouth Bass	10+ inches	3
Wabash River	Black Redhorse	19+ inches	3
	Blue Sucker	21-26 inches	3
		26+ inches	4
	Carpsuckers	ALL	3
	Channel Catfish	15+ inches	3
	Freshwater Drum	16+ inches	3
	Sauger	13+ inches	3
	Shorthead Redhorse	15+ inches	3
	Smallmouth Buffalo	Up to 20 inches	3
		20+ inches	4

3.2.4 Wabash River Total Maximum Daily Load (TMDL) Study

Water quality data collected from the Wabash River indicated that the Wabash River did not consistently comply with the state's water quality standards. Based on these determinations, segments of the Wabash River have been included on the state's 303(d) list since its inception. The 2002 listing included segments of the Wabash River in non-compliance for pathogens (*E. coli* and fecal coliform), nutrients, pH, dissolved oxygen, and impaired biotic communities. Subsequent lists prepared in 2004, 2006, and 2008 replicate these listings. In order to cohesively address impairments, one TMDL was written for the entire length of the Wabash River including the 30 miles in Ohio and the 475 miles in Indiana and Illinois (Tetra Tech, 2006). Maps from the TMDL report showing the locations of impaired Wabash River segments, water quality sampling stations along the Wabash River, and verified nutrient impaired segments are included in Appendix G. Within the Deer Creek-Sugar Creek watershed, the TMDL addresses nutrient, dissolved oxygen, and *E. coli* impairments.

Data collected by several agencies were obtained for water quality model development and TMDL calculation. The following conclusions were drawn with regards to water quality in the Wabash River:

- Nitrate+nitrite concentrations routinely exceeded the Indiana benchmark (10 mg/L); however, median concentrations measured 5 mg/L. Concentrations were generally higher in the reach of the Wabash River included in the watershed than those observed both up and downstream.

- Median dissolved oxygen concentrations generally exceeded 8 mg/L with only a few stations measuring below the minimum benchmark (4 mg/L). However, several stations, including the stations within the watershed, routinely exceeded the upper benchmark (12 mg/L).
- Phosphorus concentrations routinely exceeded the long-term target and phosphorus benchmark (0.3 mg/L) used for impaired waterbody listing by the IDEM.
- Most station impairments resulted from a combination of phosphorus and nitrate+nitrite or dissolved oxygen exceedances.

Due to the routine nature of the listings, one TMDL was developed for the entire Wabash River. The TMDL was calibrated at six locations along the river where sufficient data were available for calculation. Specific information for the Deer Creek watershed was addressed as part of the TMDL. Based on the Wabash River TMDL, the following conclusions have been drawn:

- A monthly reduction in *E. coli* from April to October of 87% is needed in Deer Creek. This percent reduction results in a reduction of 52,700,000,000,000 *E. coli* colonies per year (TetraTech, 2007).
- Monthly reductions of total phosphorus of 4% are needed in Deer Creek. This results in an overall reduction of 0.64lb of phosphorus per day or 234 lbs. of phosphorus per year (TetraTech, 2007).
- No nitrate reductions are required in Deer Creek.

3.2.5 IDEM Fixed Station and Rotational Basin Assessments

Through IDEM's fixed station water quality monitoring program, IDEM scientists collect water quality samples once per month at 160 stream and river sample sites throughout the state. Three fixed sampling stations are located within the Deer Creek-Sugar Creek watershed, two on the Wabash River and one on Deer Creek. The sites on the Wabash River are located downstream of Americus (1991-2000) at State Road 225 and at Americus (2001 to present) at Americus Road. Based on the fixed station sampling data, the following conclusions can be drawn:

- Total phosphorus concentrations exceeded the recommended criteria during a majority of months sampled at both the upstream and downstream locations. Samples routinely exceeded the watershed short-term target of 0.3 mg/L resulting in these reaches of the Wabash River being listed on Indiana's Impaired Waterbodies List.
- Total Kjeldahl nitrogen and nitrate-nitrogen concentrations routinely exceeded the recommended criteria at both the upstream and downstream locations.
- Total suspended solids concentrations were elevated in a majority of the samples collected in both the up and downstream locations.
- *E. coli* concentrations varied over time but generally exceeded the state standard at both the upstream and downstream locations.

The fixed sampling station on Deer Creek is located at Country Road 300 Northeast of Delphi (1991-2012). Based on this fixed station's sampling data, the following conclusions can be drawn:

- Total phosphorus concentrations exceeded the long-term target of Dodds et al. (1998) of 0.08 mg/L during a third of sampling occasions.
- Total Kjeldahl nitrogen and nitrate-nitrogen concentrations routinely exceeded the recommended criteria and sometimes the EPA's drinking water standard (10 mg/L).

- Total suspended solids concentrations were elevated compared to the suggested concentration of 15 mg/L by Waters (1995) in a quarter of the samples collected.
- *E. coli* concentrations varied over time but only exceeded the state standard two of the eight sampling events.

In 1998, 2003, and 2008, IDEM sampled water chemistry at several locations in the Deer Creek-Sugar Creek watershed via their rotational basin assessment program. Sampling occurred on Bridge Creek, Deer Creek, Little Deer Creek, and Paint Creek in 1998. In 2003, Deer Creek was sampled at two locations. In 2008, IDEM sampled two additional sites on Deer Creek and one site each on Harrison-Harlan Ditch, Little Deer Creek, a tributary of Sugar Creek, and the Wabash River. A majority of these assessments included a single sampling event with some sites assessed three times. Based on the rotational basin water chemistry assessments, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the state standard in Harrison-Harlan Ditch, at two of the four Deer Creek sites, in the tributary to Sugar Creek, and the Wabash River during at least one assessment.
- Nitrate-nitrite concentrations exceeded the recommended standard by Dodds et al. (1998) of 1 mg/L in Bridge Creek, in three of four Deer Creek sites, Harrison-Harlan Ditch, Little Deer Creek, Paint Creek, the tributary to Sugar Creek, and the Wabash River during at least one sampling event.
- Total phosphorus concentrations exceeded long term target of 0.08 mg/L by Dodds et al. (1998) in Bridge Creek, Deer Creek (all sites), Little Deer Creek, Paint Creek, and the Wabash River.
- Pesticide monitoring in Deer Creek occurred in 1998. Results indicate that pesticide concentrations are elevated especially acetochlor, alachlor, atrazine, clomazone, and metolachlor. Acetochlor and alachlor concentrations measured as high as 2.3 µg/L, while atrazine measured as high as 16 µg/L. Clomazone and metoachlor measured as high as 3.2 µg/L and 30 µg/L, respectively.

3.2.6 IDEM Biological and Habitat Assessments

IDEM completed biological and habitat assessments throughout the watershed. In 2004, a multi-habitat macroinvertebrate index of biotic integrity (mIBI) calibration study was completed at four sites: three on Deer Creek and one on Little Deer Creek. Fish sampling occurred at eight sites including, Bridge Creek, five sites at Deer Creek, Harrison-Harlan Ditch, and Little Deer Creek in 2003 and 2008. Macroinvertebrate communities were sampled at 17 sites Deer Creek-Sugar Creek subwatershed including sites on Bachelor Run, Bridge Creek, Buck Creek, nine sites on Deer Creek, Harrison-Harlan Ditch, Little Deer Creek, Sugar Creek, and the Wabash River. Fish and macroinvertebrate samples were collected and habitat was assessed using IDEM's standard methods. Based on these assessments, the following conclusions can be drawn:

- Habitat within Bachelor Run, Buck Creek, Bridge Creek, Deer Creek (County Road 1100 South in Miami County), Harrison-Harlan Ditch, and the Wabash River rated below the state standard indicating that the streams are not fully supporting the aquatic life use designation. Harrison-Harlan Ditch was rated the lowest with a score of 27.
- The macroinvertebrate communities rated as severely impaired in Bridge Creek, Buck Creek, Deer Creek (State Road 25, County Road 300 North in Cass County and County Road 1100 South in Miami County), Harrison-Harlan Ditch and the Wabash River at State Road 225 in Tippecanoe County.

3.2.7 IDEM Fisheries Assessment

Between July of 1998 and June of 2008, IDEM surveyed eight sites within the Deer Creek-Sugar Creek watershed. Five of the sampling locations were on located on Deer Creek, while the remaining three were on Harrison-Harlan Ditch, Bridge Creek, and Little Deer Creek. Based on these data, the following conclusions can be drawn:

- The most prevalent species at the Bridge Creek, Harrison-Harlan Ditch, and Little Deer Creek was the western blacknose dace, striped shiner, and central stoneroller, respectively.
- The most prevalent species at the five Deer Creek sites were not the same. The species that were most prevalent were the striped shiner, bluntnose minnow, black redhorse, longear sunfish, and central stoneroller.
- Of the nine sampling events, eight calculated Index of biotic integrity (IBIs) rated as fair or higher; the IBI calculated for Bridge Creek rated as poor.
- Of eight sites, habitat at six sites scored a QHEI greater than 51 indicating that the habitat was not negatively impacting the community. Habitat at one site on Deer Creek and at the Little Deer Creek site scored below 51 indicating that habitat could be negatively impacting the fish community.

3.2.8 Little Deer Creek Headwaters Watershed Management Project (2010)

As part of Little Deer Creek Headwaters 319 Program Watershed Management Project in Howard County, water quality data were collected (Howard County SWCD, 2010). The project occurred from November 2006 to May 2010. The headwaters of Little Deer Creek were sampled at County Road 800 West. Samples were collected a total of four times, three times in 2008 and once in 2009 using Hoosier Riverwatch methods. Based on the data collected, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) only once occurring in July of 2008 and was measured at 278 colonies/100 mL.
- Nitrate levels were greater than 1.0 mg/L during three of the four assessments, and exceed the EPA drinking water standard (10 mg/L) once in May of 2008 with a nitrate level of 17.6 mg/L
- The site's CQHEI was greater than 60, thus suggesting that the site is conducive of warm water fauna. The biological data indicated that the macroinvertebrate community's pollution tolerance was good to excellent at all four sampling events.

3.2.9 Wabash River Fishery Assessments: DePauw University (1973-1994)

Assessment and study of the Wabash River began in 1967. Initial studies focused on thermal effects on the fish community near Terre Haute and Cayuga. Research efforts extended to longer stretches of the river in 1973 and expanded north to include the river from Delphi (RM 330) downstream to Merom (RM 161). Extensive data collected via IDEM's fixed monitoring station network are also reported as part of Gammon's efforts (Gammon, 1995). Based on Gammon (1995), the following conclusions have been drawn:

- The average suspended sediment concentration in the Wabash River from 1977-1987 measured 64.9-157.2 mg/L.

- Mean nutrient concentrations calculated from measurements occurring from 1977-1987 indicate that nitrate-nitrogen (3.0-3.5 mg/L) and phosphate (0.170-0.300 mg/L) concentrations were elevated and need to be reduced. Higher concentrations were seen in the upper Wabash River, such as the reach from Delphi to Lafayette, which was probably due to agriculture and channelization.
- In Gammon's 1994 assessment of riparian conditions, 58 km of Wabash River bank from Delphi to Lafayette were examined. Bare banks were observed on 0.9 km, while banks with few trees occurred on 4.3 km. These data indicate that in 1994, the banks of the Wabash River had several short sections with limited bank protection.
- Carp was the fish in the community with the largest catch rate. A large population of carp can indicate degraded environmental conditions.
- Dominate species in the reach from Delphi to Lafayette include carpsucker species, hog suckers, longear sunfish, redhorse species, sauger, skipjack herring, smallmouth buffalo, and white bass.

3.2.10 Wabash River Fishery Assessment: Ball State University (2001-2008)

Ball State University continued Jim Gammon's Wabash River assessment efforts starting in 2001; samples were collected three times throughout the summer in 2001 and 2002 (Pyron and Lauer, 2004). Beginning in pre-summer of 2001, the assessment of the fish communities in 500 meter reaches from below Delphi, IN to Prairie Creek were conducted. The sampling was repeated during the summer of 2008. Sampling occurred along two reaches within the Deer Creek-Sugar Creek watershed; sites were located on the Wabash River, the first was below Delphi and the other was above Americus. During the six sampling times from 2001-2002, 68 species were collected, but in 2008 only 59 species were collected throughout the 230 km section of the Wabash River. Based on thiee data, the following conclusions can be drawn:

- The five most prevalent species in the upstream site were three redhorse and two minnow species (silver redhorse, river redhorse, short redhorse, sand shiner, and mimic shiner) while the downstream site was dominated by bluegill, spotted bass and two gar species.
- The sites below Delphi and above Americus were the most stable according to Gammon (1998) and these sites were made the reference sites to which all others were compared.
- Dissolved oxygen concentrations were lower at the two sites within the Deer Creek-Sugar Creek watershed than all of the other sites; however, none of the concentrations were low enough to cause concern.
- Conductivity was elevated at the site below Delphi (724 µmhos) but was below the highest recorded conductivity (741 µmhos).
- All sites possessed IBI scores which exceeded the score at which IDEM indicates streams are not meeting their aquatic life use designation (35); the IBI of the site below Delphi and above Americus were 59 and 51, respectively.

3.2.11 The Nature Conservancy Wabash River Study

The Nature Conservancy (TNC) compiled a database of biological stressor and threat data for the Wabash River and its tributaries (Armitage and Rankin, 2009). The data were then used to analyze water quality and fish community information on an 11-digit watershed level. Although no new data were collected as part of this study, their analysis methods allow conclusions to be drawn which can be used to compare this watershed with others along the length of the Wabash River. Based on existing data, the following conclusions can be drawn:

- An ideal habitat (QHEI) score for this portion of the Wabash River based on 1800s conditions is 93.5. At that time, habitat would have rated as excellent to near maximum scores for most metrics.
- This segment of the Wabash River was historically home to riffles and represents the most downstream reach where riffles occurred. TNC hypothesized that increased flashiness, increased peak flows, and modifications in meander patterns occur within this region of the Wabash River
- The fish community in this reach is generally lacking in sensitive species with common carp and freshwater drum dominating the population.
- Total phosphorus and nitrate-nitrogen concentrations are elevated within both the main stem and tributaries in this reach. The elevated nutrient concentrations present in the tributaries, coupled with the lack of buffers, increase the delivery of nutrients via drainage systems and tile drains, and degradation of in stream habitat due to altered hydrology.

3.2.12 Tippecanoe County SWCD Assessment (2002, 2003)

In 2002 and 2003, as part of the World Water Monitoring Day, the Soil and Water Conservation District (SWCD) and their volunteers monitored water quality at 44 sites throughout Tippecanoe County. Two of these sites were located within the Deer Creek-Sugar Creek watershed; sites were located on Buck Creek and Sugar Creek. Samples were analyzed for dissolved oxygen, pH, turbidity, and *E. coli*. Dissolved oxygen, pH, and turbidity measurements were completed using Hoosier Riverwatch methodologies, while *E. coli* was analyzed by IDEM's mobile laboratory. No flow data are available for these samples; however, it is assumed that since the samples were collected in late October that water levels and thus flow, were relatively low. Based on these data, the following conclusions can be drawn:

- Dissolved oxygen percent saturation was measured at or below 50% in both of the streams sampled within the watershed. Dissolved oxygen concentration was at the state standard (4 mg/L) in Buck Creek.
- *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) in Buck Creek in 2002, but not in 2003.

3.2.13 USGS – Concentrations of *Escherichia Coli* in Streams in the Upper Wabash River Watershed in Indiana, June-September 1998

In 1998, the USGS assessed four sites within the Deer Creek-Sugar Creek watershed five times during a 30-day period during the recreational season (April-October). The assessment included collection of field data and *E. coli* samples. Sites were located on Deer Creek and the Wabash River. The sites on Deer Creek were located at State Road 29 and County Road 300 North near Delphi. The sites on the Wabash River were located at State Road 225 near Battle Ground and County Road 200 North near Delphi. The sample collection was designed for the calculation of geometric means following IDEM's standards. Based on these data, the following conclusions can be drawn:

- All four of the sites' five sample geometric mean *E. coli* concentrations were higher than the water-quality standard for full-body contact.
- *E.* coli concentrations exceeded the state standard four of the five times at both of the Wabash River sites.
- Of the five samples collected at the Deer Creek site at State Road 29, *E. coli* concentrations were greater than the state standard four of the five times. The Deer Creek site near Delphi only had two of the five samples greater than the state standard for full-body contact.

3.2.14 Purdue University Sturgeon Sampling (2003-2004, 2007-2008)

Shovelnose sturgeon populations within the Wabash River were assessed by Kennedy et al. (2007) from April 2003 through November 2004. Sturgeons were assessed in two portions of the Wabash River: from Wabash to Lafayette and from Lafayette to Terre Haute to determine relative abundance, size, age structure, growth, mortality rate, condition, and gender ratio. Two of the six sampling areas within the upper reach are located within the Deer Creek-Sugar Creek watershed. Based on this data, the following conclusions can be drawn:

- Relative abundance of shovelnose sturgeon measured greater in the upper reach during the spring than abundances measured in the lower reach. This is likely due to upstream migration associated with spawning activities. This migration suggests that the upper reach contains suitable spawning habitat that may significantly contribute to sustaining the overall shovelnose sturgeon population.
- Population characteristics observed by Kennedy et al. (2007) indicate that the Wabash River shovelnose sturgeon population is similar to populations reported in other river systems. However, despite shovelnose sturgeon attaining larger body sizes, reaching older age classes, and experiencing lower mortality rates, growth rates and relative weights were lower than those observed in other river systems.

3.2.15 Tippecanoe County-wide Mussel Assessment (1995)

Purdue University researchers conducted mussel surveys at 52 stream sites throughout Tippecanoe County from June to August 1995 (Myers-Kinzie et al., 2001). In total, six of these sites are located within the Deer Creek-Sugar Creek watershed; sites were located on Bowen Ditch, Bridge Creek, Buck Creek, and Sugar Creek. Based on the results of these studies, the following conclusions can be drawn:

- Four mussel species were observed in watershed streams. Only weathered shells (dead mussels) were identified in Buck Creek and Sugar Creek. The existence of weathered shells suggests that mussels once existed within these streams, but that conditions no longer allow them to do so.
- Sugar Creek contained the highest mussel diversity with three species identified, while Bridge Creek had the lowest with zero species (alive or weathered).
- A new species to Tippecanoe County records was found in Bowen Ditch. The *Toxolasmaparvus* or Lilliput was only found in three other sites in Tippecanoe County.
- Mussel species diversity was highly correlated with stream drainage, indicating that the volume of water, and thus remnant pool depths, is highly indicative of mussel diversity. The six sites within the watershed had the smallest drainage area and also the least number of species of all sample sites assessed by Myers-Kinzie et al (2001).

3.2.16 IDNR Mussel Assessment

From November 2001 to September 2005, the Indiana Department of Natural Resources identified and documented mussel species at 16 sites within the Deer Creek-Sugar Creek watershed. Twelve of these sites were located on the mainstem of Deer Creek, two sites on Little Deer Creek, and the remaining two sites on the South Fork of Deer Creek. Based on the information collected the following conclusions have been drawn:

- Within the Deer Creek-Sugar Creek watershed, a total of 28 species of mussels were identified. The only species found at all 16 sites was the *Lampsilis siliquoidea* (fatmucket)

- The average number of species found across all the sites was 13. The number of species found at the sites, including live, weathered dead, fresh dead, and subfossil shell material, ranged from 3-25 species. The sites with the lowest and highest number of species were on Deer Creek at Strawtown Pike in Miami County and Deer Creek at County Road 325 East in Carroll County, respectively.
- Three state species of special concern were identified at these sites; the *Lampsilis fasciola* (wavy-rayed lampmussel), *Toxoplasma lividus* (purple lilliput), and the *Ptychobranchusfasciolaris* (kidney shell). The purple lilliput was found at ten of the sites, the wavy-rayed lampmussel at nine sites, and the kidney shell at six sites.
- The Asian clam (*Corbicula fluminea*), an invasive species, was found at ten of the 16 sites.

3.2.17 Tippecanoe County Fish Assessment (1971-1977, 1994)

Purdue University researchers conducted fish surveys at 39 steam sites throughout Tippecanoe County annually from 1971 through 1977 (Curry and Spacie, 1978). These sites and 31 additional sites were sampled between June and December 1994. A variety of sampling methods were used during both assessments with species lists generated for each site. Three of the sites included within these studies are in the Deer Creek-Sugar Creek watershed. The sites were located on the Wabash River at the mouth of Sugar Creek, Americus, and near Battle Ground. Based on the results of these studies, the following conclusions can be drawn:

- The site on the Wabash River at the mouth of Sugar Creek had the greatest diversity of fish of the three sites within the Deer Creek-Sugar Creek watershed with 49 species identified. The remaining two sites on the Wabash River near Battle Ground and Americus had 37 and 39 species, respectively.

3.2.18 Hoosier Heartland Biologic Assessment

Prior to the construction of the State Road 25 Hoosier Heartland Highway a biological impact assessment had to be completed. The biological assessment addressed issues such as water quality impacts, floodplains, wetlands, endangered/threatened species, and wildlife impacts. A series of surveys of the area from Lafayette to Logansport were completed to evaluate the impacts and/or problems the highway will have on the environment. Based on the information collected the following conclusions have been drawn:

- Due to the construction of the Hoosier Heartland Highway, 1.7 miles of stream length will be crossed, 80.8 acres of riparian/forest and 2.7 acres of wetlands will be directly impacted.
- Along Sugar Creek where the highway will be crossing, federally endangered Indiana bats (*Myotis sodalist*) were captured. Additionally, the area along Sugar Creek is suitable habitat for maternity colonies of the bats.
- Six state protected, endangered, threatened species have been documented in the two natural areas which might be impacted by the construction of the highway, Americus Fern and Delphi Swamp. These include the spotted turtle, yellow sedge, hairy-fruited sedge, eastern Massasauga rattlesnake, Kirkland's snake, and the small yellow lady's slipper.
- To assess the fish and mussel communities, 11 sampling sites were selected along Buck Creek, Sugar Creek, Bridge Creek, Deer Creek, and Rock Creek (outside of watershed). From these sites, 36 species of fish and 11 species of mussels were identified. All mussels found within the watershed were found as weathered dead or subfossil shell material.

3.2.19 Summary of Historic Water Quality Sampling Efforts

Historically, the IDEM, the IDNR, The Nature Conservancy, Purdue University, DePauw University, Ball State University, the Tippecanoe County and Howard County SWCDs, and the Indiana Department of Transportation have sampled water quality at 47 locations throughout the Deer Creek-Sugar Creek watershed. These assessments indicated that waterbodies throughout the Deer Creek-Sugar Creek watershed generally contain elevated nutrient and sediment concentrations with *E. coli* levels that exceed state standards. In total, *e. coli* exceedances were observed in more than 50% of samples collected at 14 sites, total nitrogen exceedances were observed in more than 50% of samples collected at 7 sites, total phosphorus concentration exceedances were observed in more than 50% of samples collected at 8 sites, and total suspended solids concentrations exceedances were observed in more than 50% of samples collected at 24 sites within the Deer Creek- Sugar Creek watershed (Figure 44). IDEM identified *E. coli* impairments in 12 streams assessed from 1991 through 2008 as well as elevated PCB concentrations in Deer Creek and the Wabash River, and impaired biotic communities in Deer Creek, Little Deer Creek and Buck Creek. Fixed station and random sampling events indicate that total phosphorus generally exceeds both the short (0.3 mg/L) and long-term (0.08 mg/L) total phosphorus targets, nitrate-nitrogen targets (1.0 mg/L), and total suspended solids targets (15 mg/L). The Wabash River Nutrient and Pathogen TMDL (TetraTech, 2007) indicates a need to reduce *E. coli* by 87% and total phosphorus by 4% in Deer Creek. This reduction will assist the Wabash River in meeting its target *E. coli* and total phosphorus concentrations.

Biotic community assessments suggest that both water chemistry and habitat impair macroinvertebrate and fish communities within the Deer Creek-Sugar Creek watershed. Habitat generally measured below aquatic life use standards in channelized portions of the watershed, while habitat assessments in the more natural reaches indicated sufficient habitat quality to support high quality biotic communities. In general, macroinvertebrate population assessments reflect the elevated nutrient and sediment levels and poor habitat present within most assessment reaches with most communities rating as moderately to severely impaired. The fish communities rated fair to good suggesting that water chemistry rather than habitat limits their community. Mussel assessments completed by the DNR and Purdue University indicated relatively high diversity with 28 species collected at 16 sites. These collections include three species of special concern as well as the invasive Asian clam. These assessments collected throughout the Deer Creek-Sugar Creek watershed reflect fish community assessments completed within the mainstem of the Wabash River. Historic assessments (1970s to 1990s) indicate that the Wabash River contained elevated sediment and nutrient concentrations with the carp possessing the highest catch rate. More recent assessments (2000s) indicate an improvement in sediment and nutrient concentrations and a switch to a more balanced community which still lacks sensitive species.

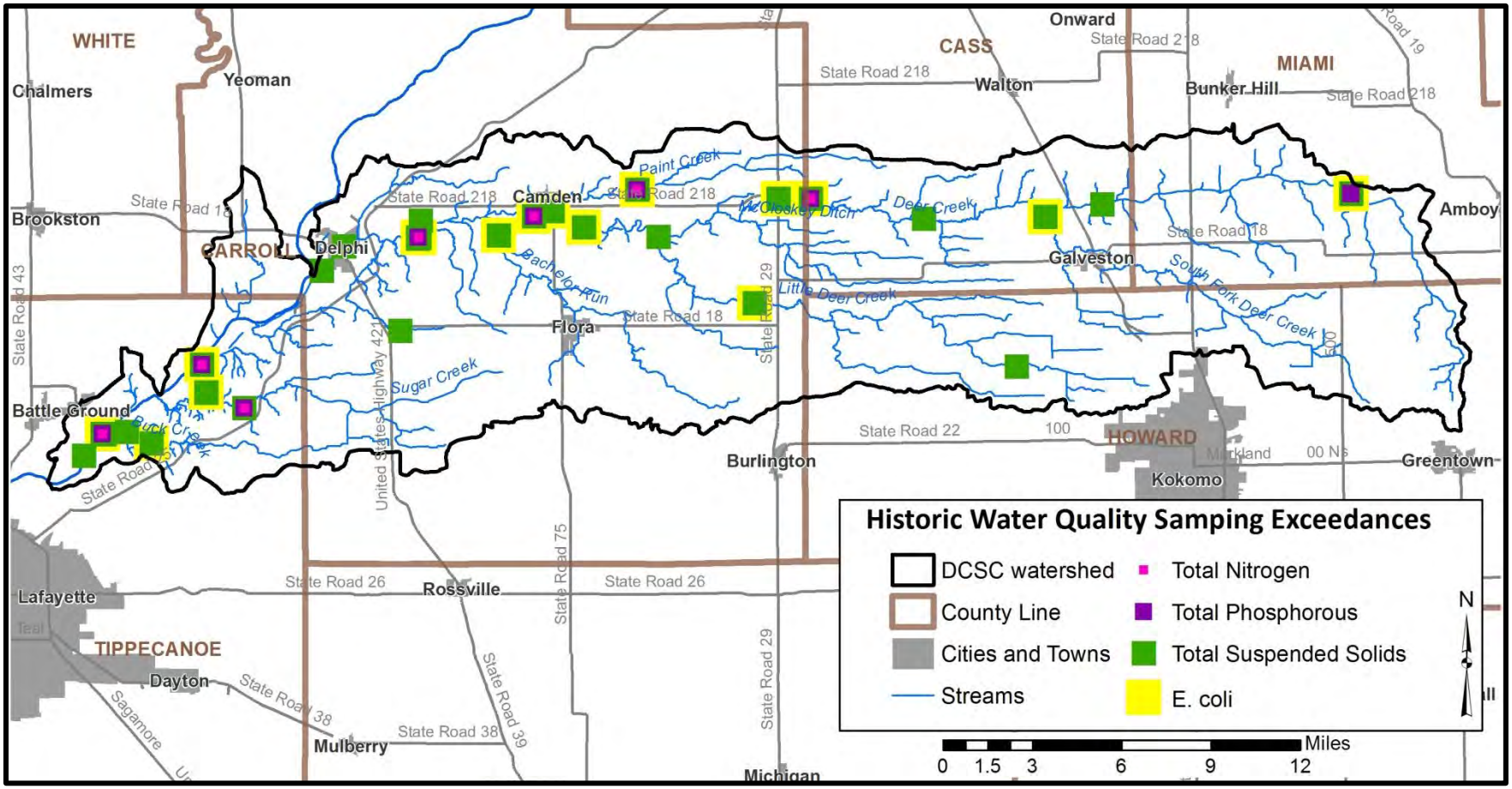

Figure 44. Historic Water Quality Sampling - Exceedances in Nitrogen, Phosphorus, Total Suspended Solids, and *E. coli.*
Data used to create this map are detailed in Appendix A.

3.3 Current Water Quality Assessment

3.3.1 Water Quality Sampling Methodologies

As part of the current project, Purdue University implemented a one year professional water quality monitoring program. The program included water chemistry, fish and macroinvertebrate community, and habitat assessments. Additionally, WREC and Carroll County SWCD implemented a volunteer monitoring program. The program is detailed below and in the Quality Assurance Project Plan for Deer Creek-Sugar Creek Watershed Management Plan approved on July 18, 2012 (WREC, 2012). Sites sampled through this program are displayed in Figure 45. Sample sites were

selected based on land use and watershed drainage. The twelve sites represent each major tributary to Deer Creek or the Wabash River as well as important subwatershed areas. The biweekly sampling regimen was enacted to create a baseline of water quality data.

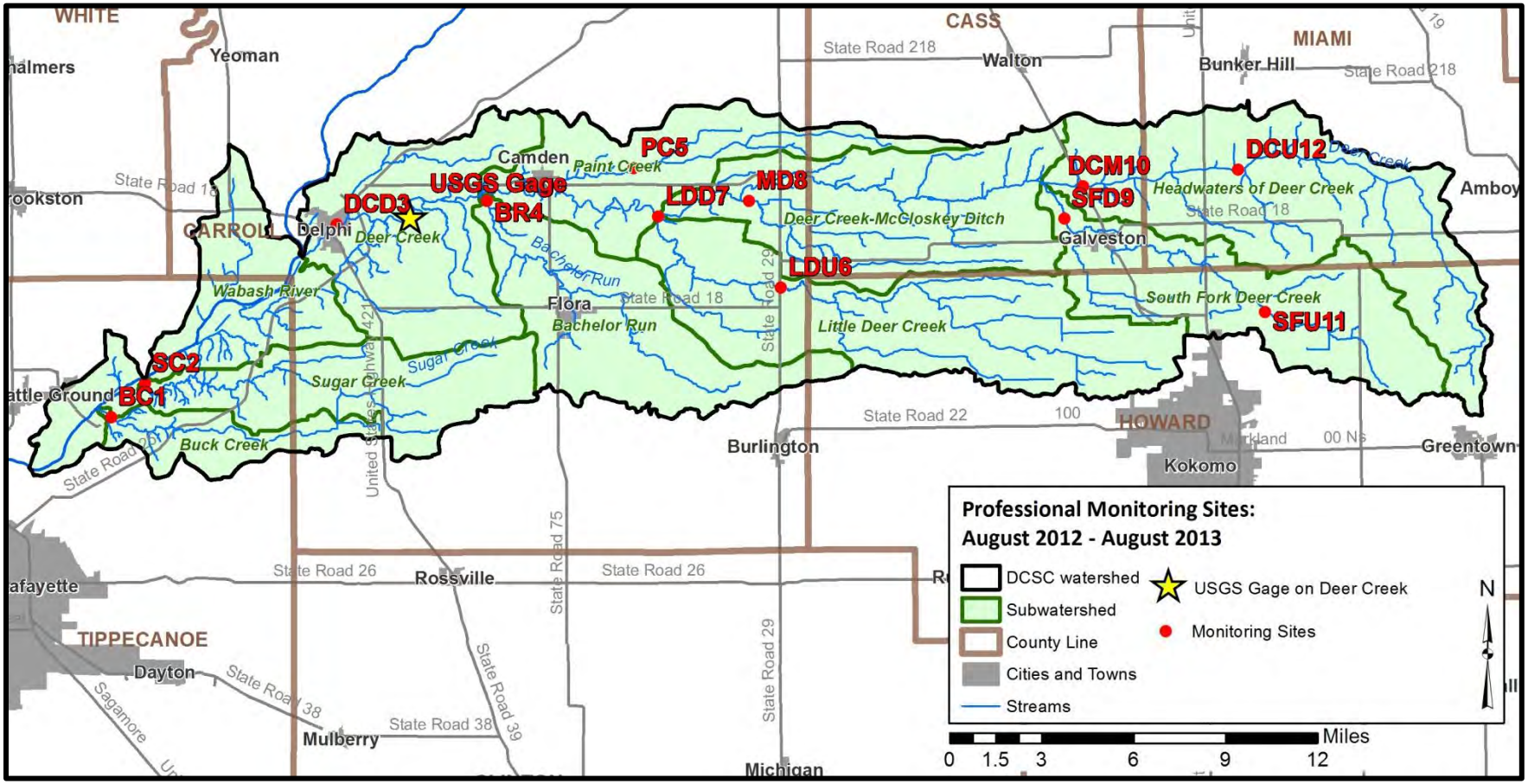

Figure 45. Sites sampled as part of the Deer Creek-Sugar Creek River Watershed Management Plan.
Data used to create this map are detailed in Appendix A.

Stream Flow

Stream flow was measured *in situ* when grab samples were collected. Stream flow was also calculated by scaling stream flow measured at the U.S. Geological Survey (USGS) stream gages to subwatershed drainage area. Based on a similar drainage area, the gage on Pine Creek near Montmorenci (USGS Gage #LPCI3) was used as a proxy for stream flow for the monitoring sites on Buck Creek (site BC1) and Sugar Creek (SC1). The gage on Deer Creek near Delphi (USGS Gage #DCDI3, mapped in Figure 45) was used to as a proxy for stream flow for the remaining monitoring sites.

Field Chemistry Parameters

Purdue University established twelve chemistry monitoring stations as part of the monitoring program. Stations are located on Buck Creek, Sugar Creek, Deer Creek, Paint Creek, Little Deer Creek, Bachelor Run and McCloskey Ditch. Dissolved oxygen, temperature, pH, turbidity, and conductivity were measured biweekly at the sampling stations from August 2012 to August 2013. Appendix E details the parameters measured and potential impacts to particular parameters.

Laboratory Chemistry Parameters

Like the field parameters, biweekly laboratory sample collection and analysis occurred throughout the one year sampling program. Samples were analyzed for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli*. Appendix E details the parameters measured and potential impacts to particular parameters.

Habitat

The physical habitat at each of the biological sample sites was evaluated using the Qualitative Habitat Evaluation Index (QHEI). The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin, 1989, 1995) and the IDEM adapted the QHEI for use in Indiana. Purdue University assessed habitat at all twelve sites in the summer of 2012. Appendix E details the QHEI and its individual metrics.

Fish Community

The fish community within the Deer Creek-Sugar Creek watershed was assessed at twelve sites once in 2012 Sampling. Methods followed Simon (1991). Index of Biotic Integrity (IBI) scores were calculated for each sampling event. Appendix E details the IBI metrics used to calculated Index of Biotic Integrity values for these samples.

Macroinvertebrate Community

The macroinvertebrate community within the Deer Creek-Sugar Creek watershed was assessed at twelve sites once in 2012. Samples were collected concurrent with fish community sampling. The 2012 samples consisted of six Surbers collected on each sample date. Surber samplers are used to collect aquatic invertebrate samples in moving water habitats with larger sediment particles (i.e., gravels and cobbles). The sampler is composed of a 0.0625 square meter quadrat that lays flat against the bottom and a wedge-shaped net suspended in the water column behind the quadrat. Samples are collected by disturbing the sediments within the quadrat and allowing the dislodged organisms to be carried by the

current into the net. Surber samples were then 100% sorted for aquatic macroinvertebrates and one Surber sample for each sample date was randomly selected for 100% family level identification.

The 2010 samples consisted of D-frame kicknet samples as described in Barbour et al. (1999). While D-frame nets can be used in the same fashion as Surber samplers, they are more commonly used in slow-moving habitats with fine sediments to collect aquatic invertebrates. Many of the invertebrates in such habitats are clinging to overhanging vegetation and root wads, and the dip net is "jabbed" into these habitats to loosen and collect the invertebrates. Data in this case are more qualitative and are collected by making the same number of jabs from these habitats at each sample site. D-net samples were 100% sorted and aquatic macroinvertebrates were identified to family level. The macroinvertebrate Index of Biotic Integrity (mIBI) scores were calculated for each sampling event. The mIBI averages a series of ten metric scores resulting in an overall score rating the macroinvertebrate community in terms of impairment. The HBI which ranks species tolerance on a scale of 0-10 with 0 being intolerant and 10 being tolerant of pollution. Appendix E details the mIBI and its scoring methodologies.

3.3.2 Field Chemistry Results

Figure 46 through Figure 50 display results for field chemistry data collected every week at the twelve sample sites. At each of the stream sites, a multi parameter probe is deployed. The probe collects data for temperature, dissolved oxygen, specific conductivity, pH and turbidity.

Temperature

Figure 46 illustrates the biweekly temperature measurements in Deer Creek-Sugar Creek watershed stream. As shown, temperatures measure approximately the same at each of the stream sites with seasonal changes in temperature creating major differences in temperature throughout the sampling period. Temperatures measured near 0 ^{o}C in all streams from December 2012 through February 2013. The highest temperatures occurred during the August 2013 assessments.

Dissolved Oxygen

Dissolved oxygen concentrations also display seasonal changes like those observed for temperature. However, as shown in Figure 47, dissolved oxygen concentrations are opposite those measured for temperature. This is as expected as colder water holds more dissolved oxygen than warmer water; therefore, when water temperatures are low, dissolved oxygen concentrations are high and vice-versa. As such, the dissolved oxygen graph shows a general pattern where dissolved oxygen concentrations are higher in winter and lower in summer. All streams display variation in dissolved oxygen concentration due to individual conditions present within each system. The lowest dissolved oxygen concentrations occurred in May 2013. During this sampling event, Deer Creek at Riley Park (DCD3), Paint Creek (PC4), Little Deer Creek at SR 29 (LDCU7), McCloskey Ditch (MD8), South Fork Deer Creek at CR 1225 South (SFD9), Creek Deer Creek at SR 35 (DCM10), South Fork Deer Creek at Touby Road (SFU11) and Deer Creek at Elm Street (DCU12) contained dissolved oxygen concentrations below the state standard (5 mg/L). These low dissolved oxygen levels are likely due to elevated production within the streams.

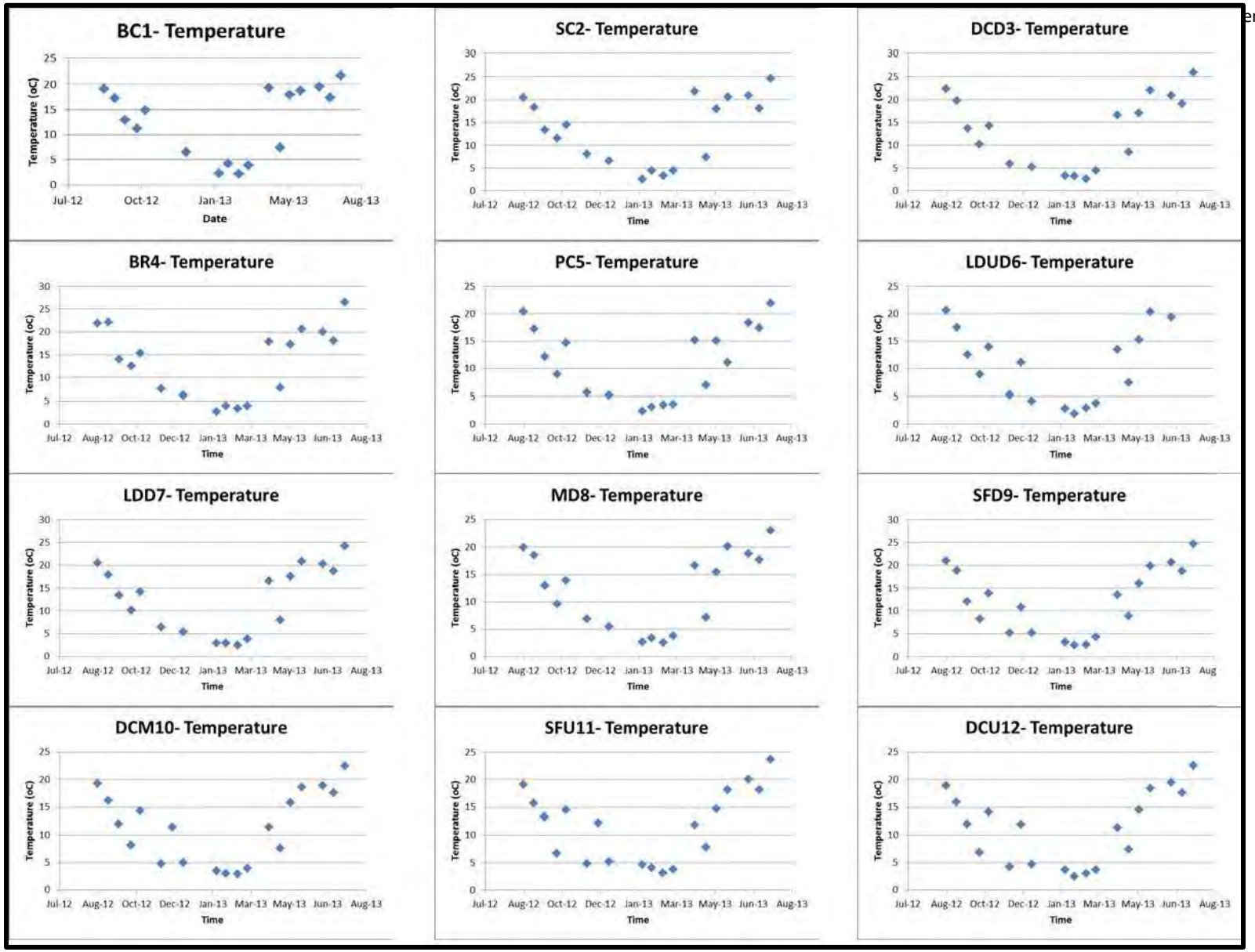

Figure 46. Temperature measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

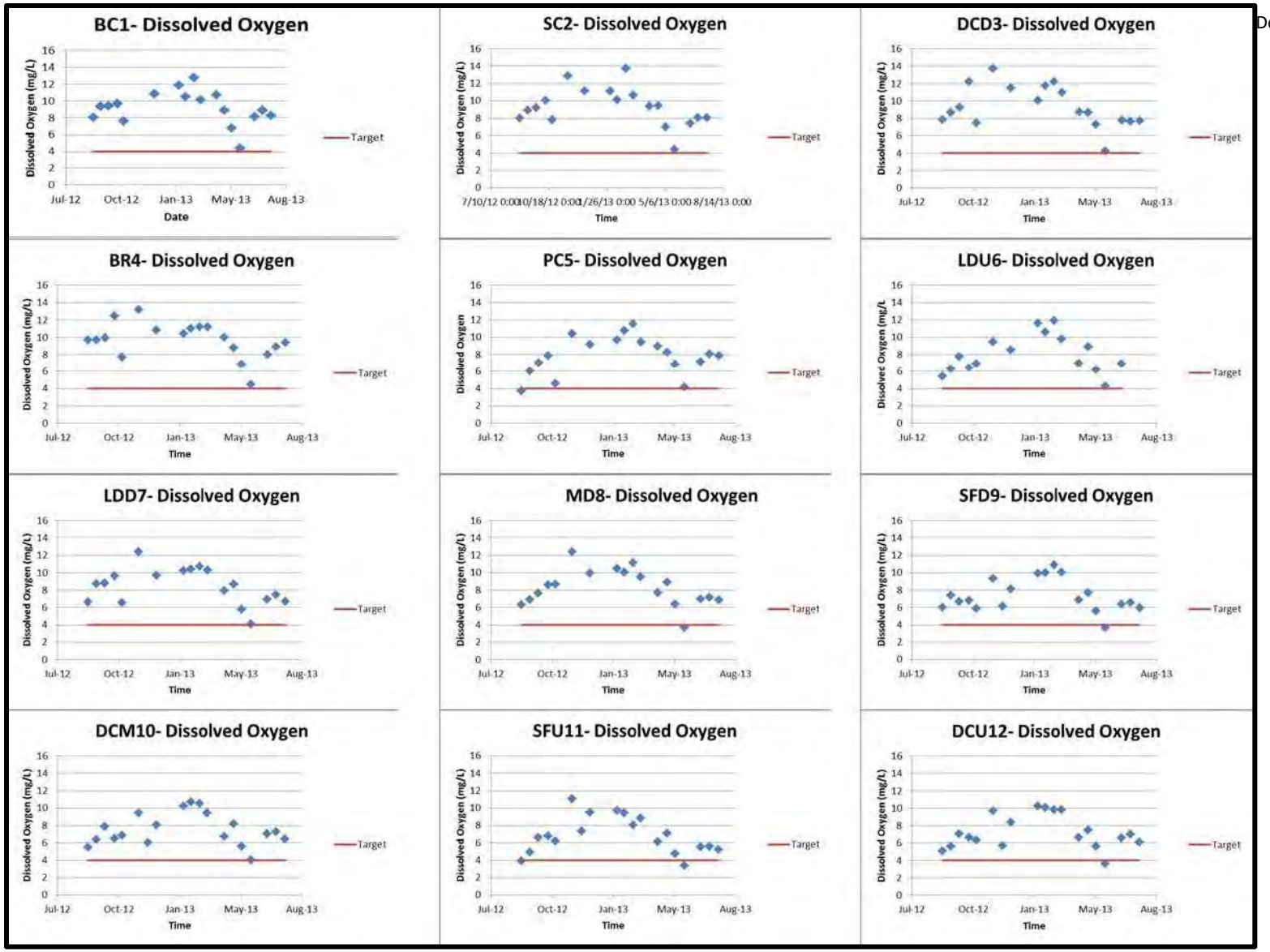

Figure 47. Dissolved oxygen measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

pH

Throughout the sampling period, pH generally remained in an acceptable range in all three streams. No discernible pattern can be found in pH levels in any of the monitored streams (Figure 48). During the December 2012 sampling, Buck Creek (BC1), Sugar Creek (SC2), Deer Creek at Riley Park (DCD3), and Bachelor Run (BR4) contained pH measurements above the upper pH target (9.0). Elevated pH levels suggest that elevated phytoplankton populations may be present at these sites. High plankton densities result in high photosynthesis levels which can elevate pH.

Specific Conductivity

Figure 49 displays conductivity measurements in Deer Creek-Sugar Creek watershed streams. Conductivity measurements varied greatly over the sampling period. Conductivity never exceeded state standards.

Turbidity

Turbidity measurements for Deer Creek-Sugar Creek watershed streams are displayed in Figure 50. Turbidity concentrations exceeded the target in 60% of collected samples. Turbidity tends to spike during high flow events and this can be observed at several sites throughout the sampling season. Most exceedances in the Deer Creek-Sugar Creek watershed measured just above the target (15 NTU). The highest turbidity levels occurred in Deer Creek at Riley Park (DCD3) and Deer Creek at SR35 (DCM10) with turbidities as high at 700 NTU observed in May 2013.

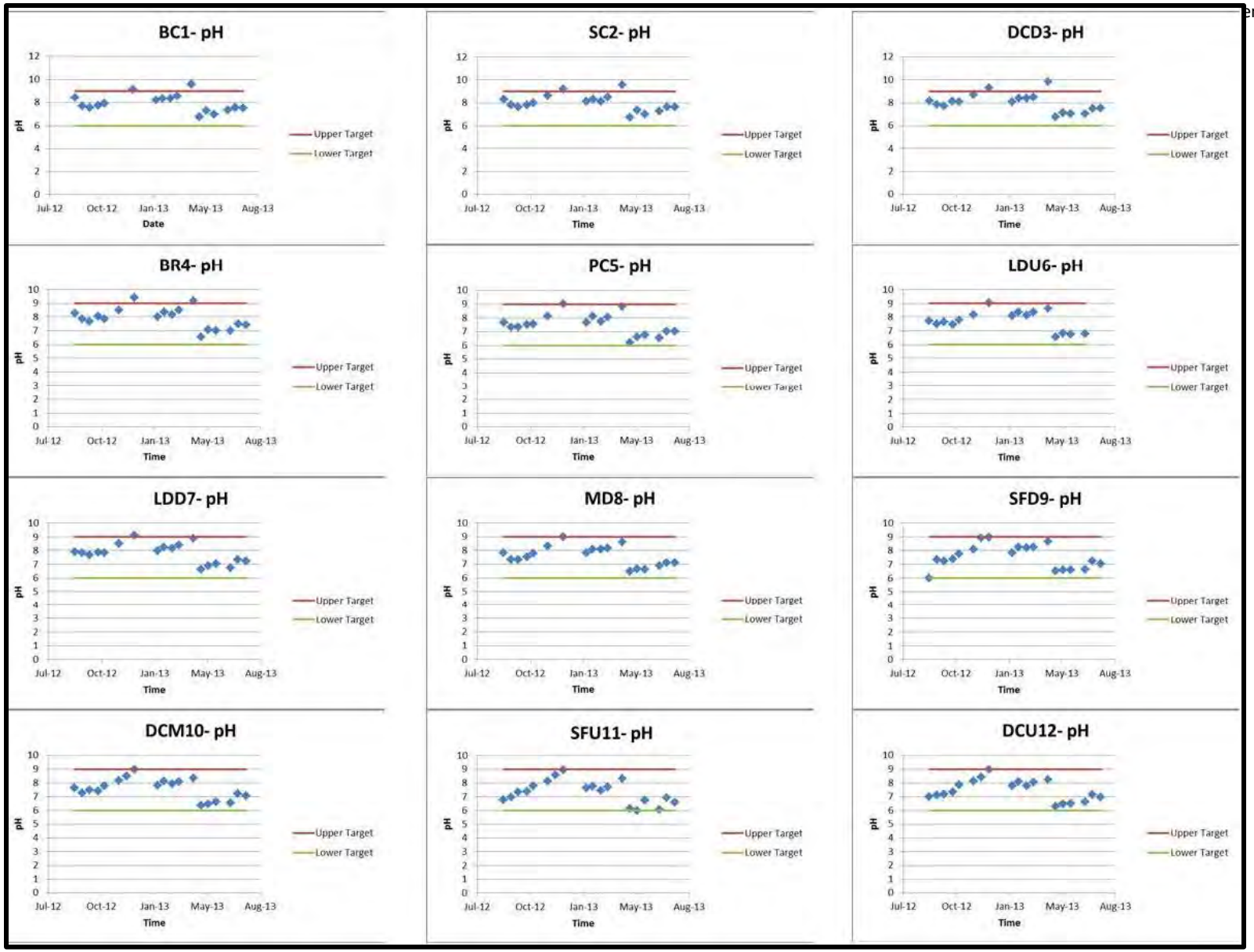

Figure 48. pH measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

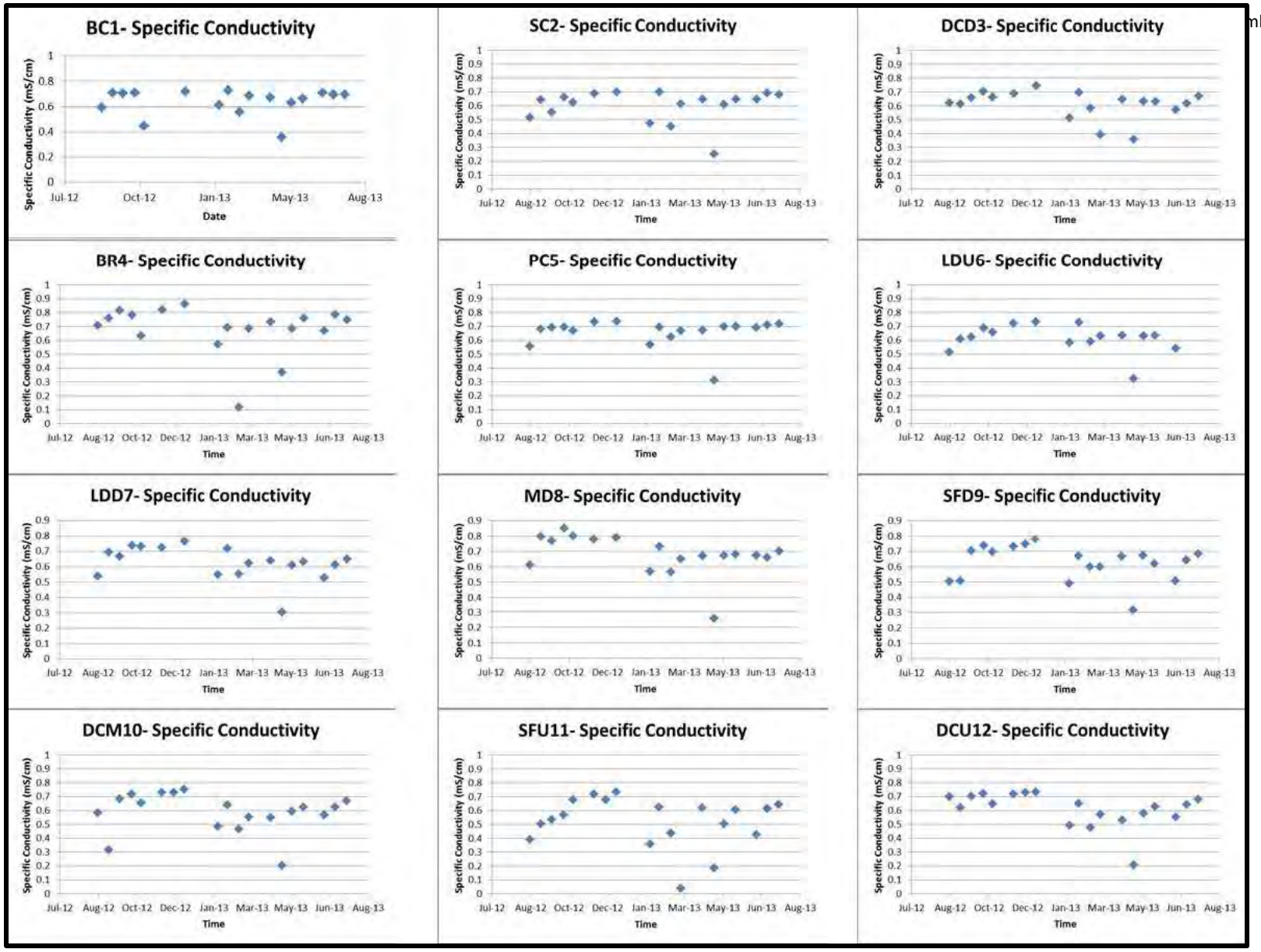

Figure 49. Conductivity measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

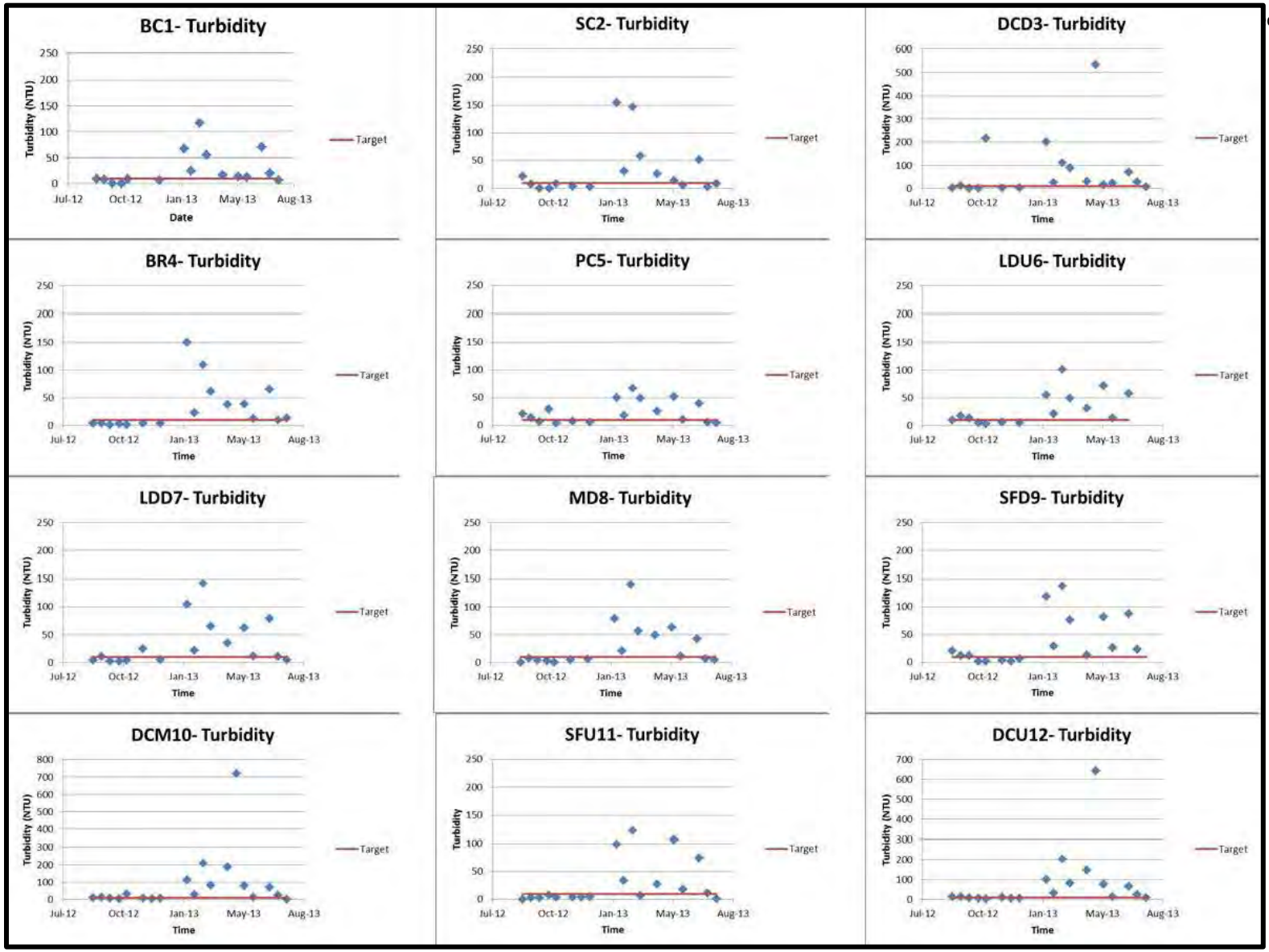

Figure 50. Turbidity measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.3 Water Chemistry Results

Figure 51 to Figure 59 display results for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli* collected biweekly from twelve locations in the Deer Creek-Sugar Creek watershed. Data are displayed in comparison to target concentration and on load duration curves during the sample period. Appendix E details individual measurements collected throughout the sampling period.

Nitrate-nitrogen

Figure 51 displays nitrate-nitrogen concentrations compared to target levels (2 mg/L). As shown below, nitrate-nitrogen concentrations measured in 2013 almost always exceeded target levels, while 2012 concentrations are below target levels. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Levels did begin to drop at the end of our study when flow conditions lessened and plants had used up nitrogen applied in the spring. In Deer Creek, nitrate-nitrogen concentrations exceed targets 57% of the time at the most upstream location (DCU12) and 57% of the time midstream (DCM10) but then increases to 83% exceedances in Deer Creek at Riley Park (DCD3). This suggests that there are limited sources of nitrate-nitrogen between the headwaters and middle Deer Creek site, but that nitrate-nitrogen sources are present between DCM10 and DCD3. In Little Deer Creek, nitrate-nitrogen exceeds targets 62% of the time at the headwaters site (LDU7) and 70% of the time at the mouth (LDD6). These data suggest that sources of nitrate-nitrogen may increase slightly between sites. Buck Creek (BC1) and Bachelor Run (BR4) exceeded targets in more than 90% of collected samples suggesting that flow condition does not impact sources of nitrate-nitrogen in Buck Creek and Bachelor Run. Buck Creek (BC1) and Paint Creek (PC5) contained the highest average nitrate-nitrogen concentrations.

Total Phosphorus

Total phosphorus concentrations rarely exceed target concentrations (Figure 52). However, when exceedances do occur, they measure up to three times that target concentration (0.3 mg/L). Concentrations measured in both Little Deer Creek (LDU6 and LDD7) and both Headwaters Deer Creek (DCM10 and DCU12) sites exceeded 1 mg/L during December 2012 sampling events. Buck Creek contained the highest percentage of exceedances with more than 25% of samples measuring higher than target concentrations and the third highest average total phosphorus concentration. Deer Creek Headwaters (DCU12) and Paint Creek (PC5) contained the highest average total phosphorus concentrations respectively. Neither average concentration exceeded the target concentration.

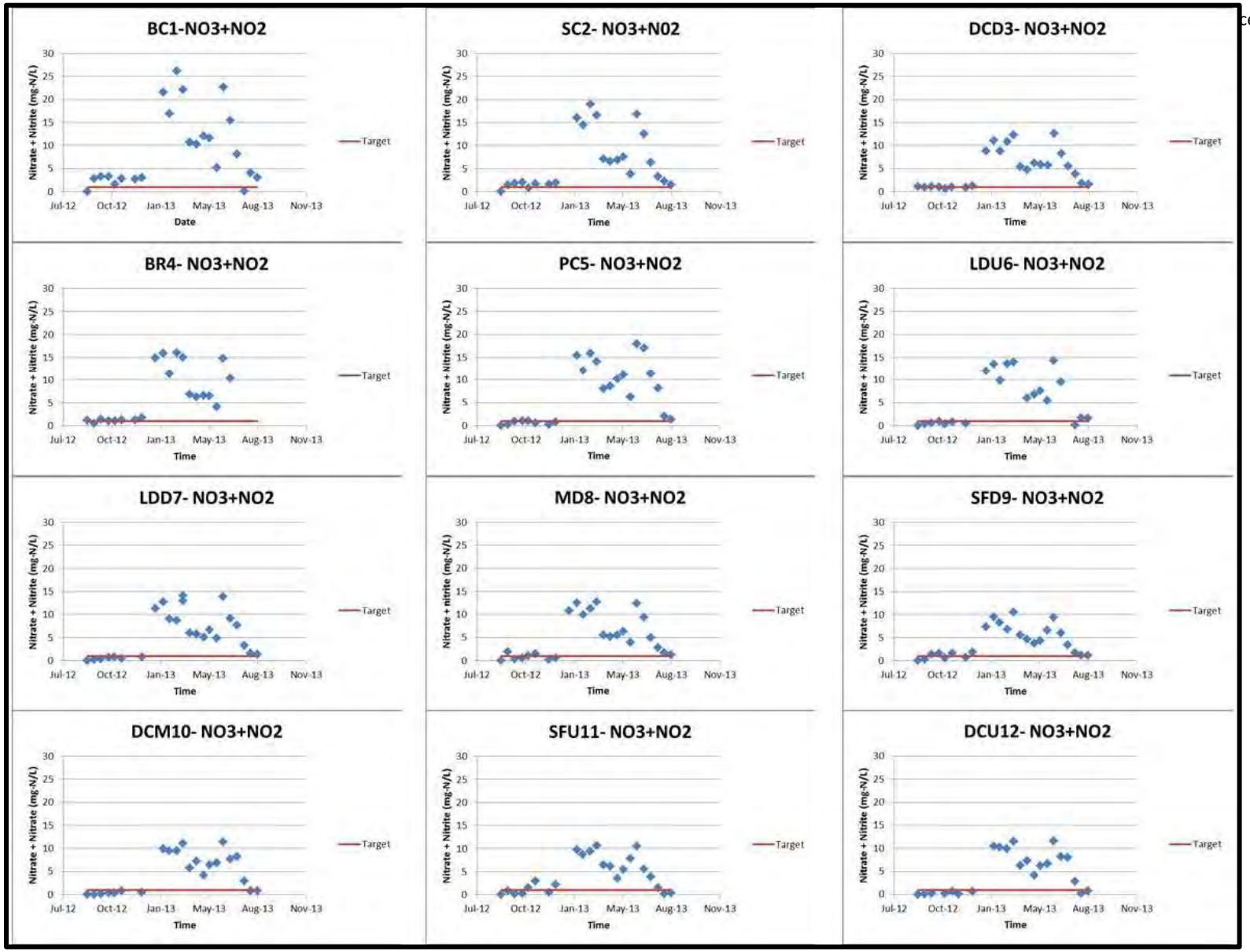

Figure 51. Nitrate-nitrogen concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

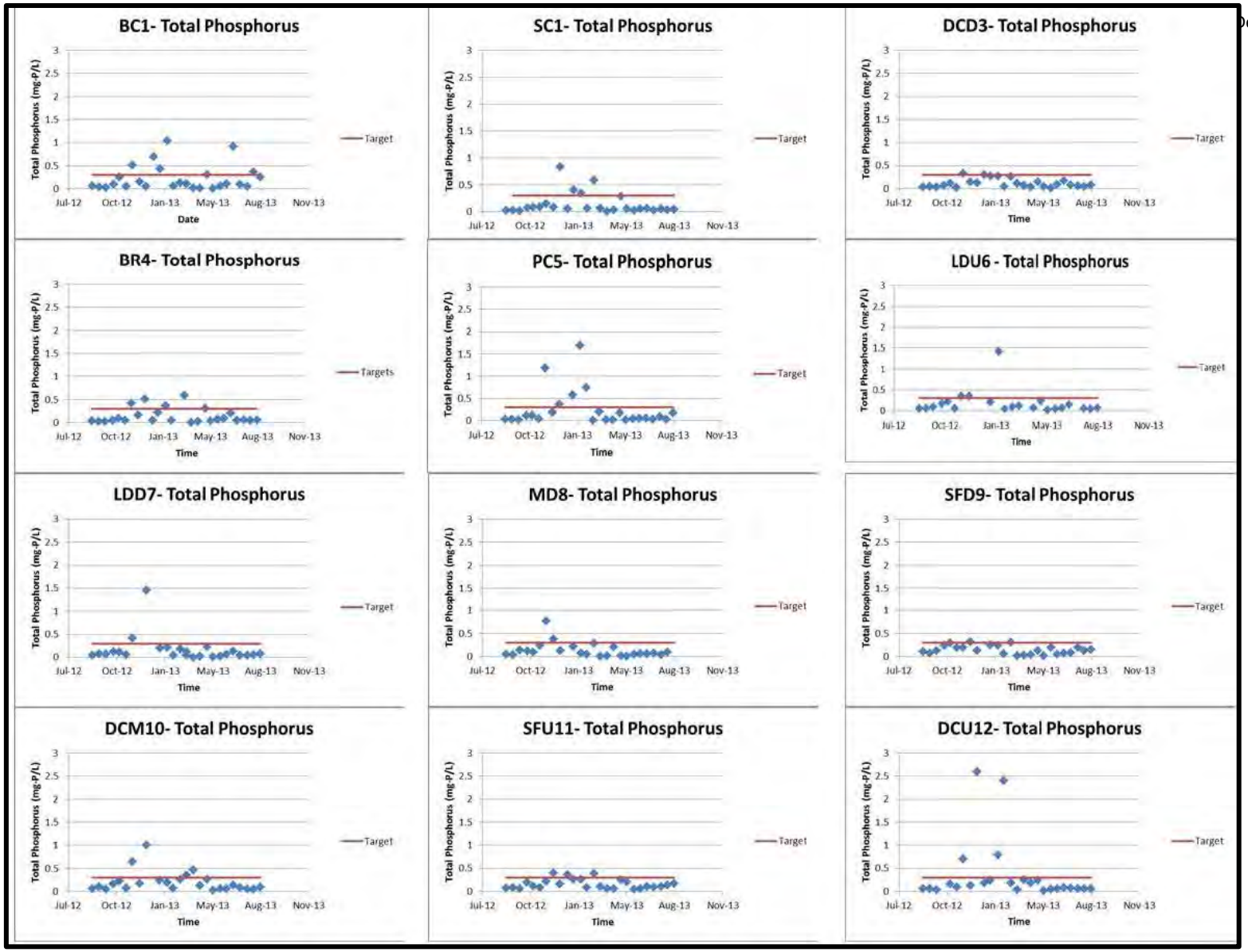

Figure 52. Total phosphorus concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

Total Suspended Solids

Total suspended solids (TSS) levels generally measured above target levels during high flow events (Figure 53). Little Deer Creek at CR 300 N (LDD7) and Deer Creek at Riley Park (DCD3) contained the highest average TSS concentrations. These sites also contained the highest percentage of exceedances with each exceeding targets in more than nine collected samples. TSS concentrations exceeded 300 mg/L in Deer Creek (DCD3, DCM10, DCU12), Little Deer Creek (LDU7), Bachelor Run (BR4) and Sugar Creek (SC2).

E. coli

E. coli concentrations observed at Deer Creek-Sugar Creek sites are shown in Figure 54. *E. coli* concentrations exceed state standards during a majority of samples. In Buck Creek, *E. coli* concentrations are elevated during various flow conditions. Deer Creek (DCU12) and Buck Creek (BC1) contained the highest average *E. coli* concentrations, respectively. All Deer Creek-Sugar Creek watershed sites possessed average *E. coli* concentrations in excess of state standards (235 col/100 mL). Deer Creek at Riley Park (DCD3) and Bachelor Run (BR4) contained the lowest average *E. coli* concentrations with concentrations greater than 300 col/100 mL. *E. coli* exceedances appear to coincide with flow conditions with many sites containing elevated *E. coli* concentrations under elevated flow conditions.

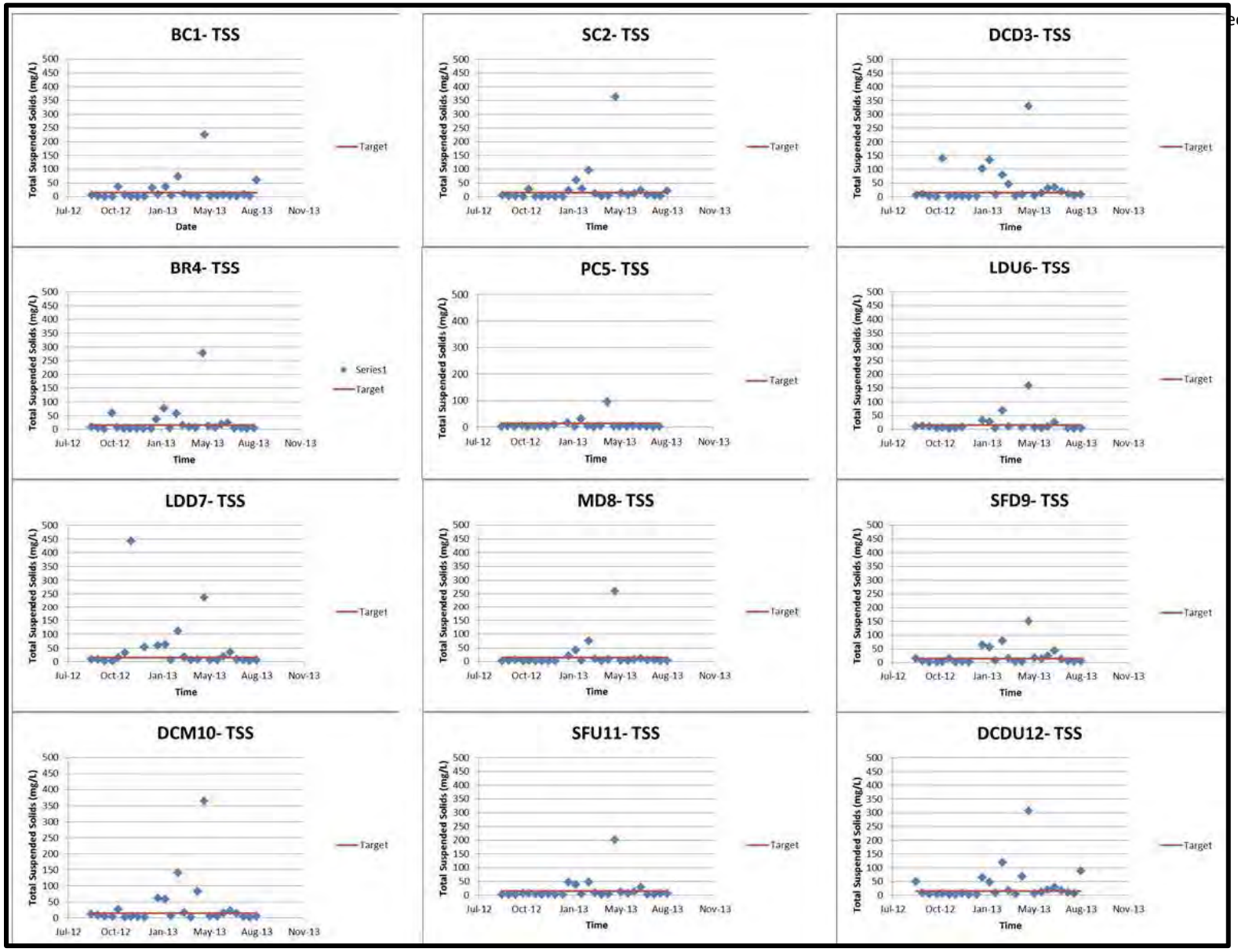

Figure 53. Total suspended solids concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

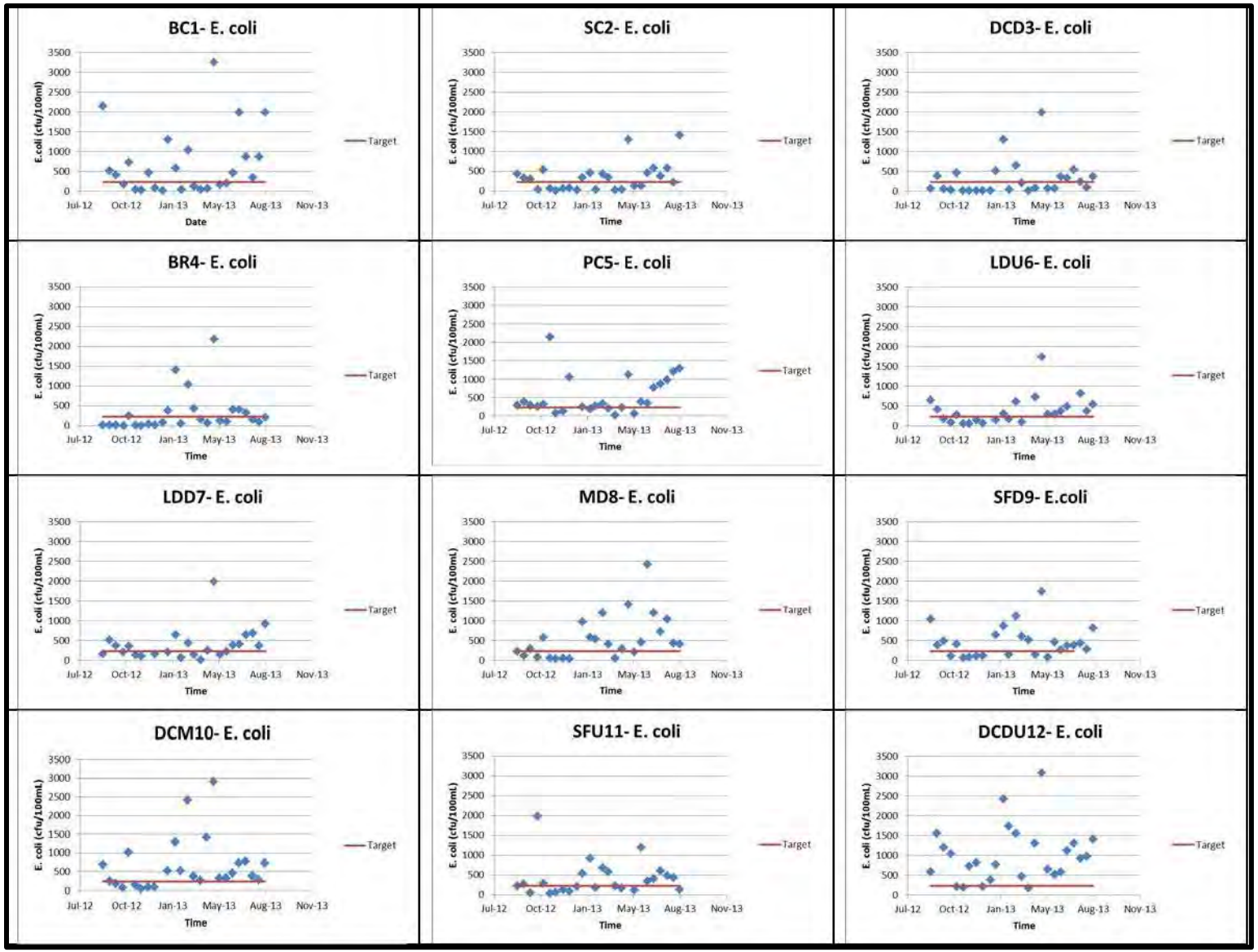

Figure 54. *E. coli* concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.4 Flow Duration Curves

Flow duration curves allow characterization of flow conditions within a particular stream. Instead of plotting individual flows as a time series, they are plotted as a percent of time that a given flow occurs within the stream. The resultant curve indicates the percent of time that a given flow is equaled or exceeded within the system. For instance, the median flow (Q50) is the flow observed in the stream 50% of the time. Flows below Q50 indicate base flow conditions within the stream. If this portion of the curve contains a steep slope, a relatively small contribution from natural storage sources like groundwater is suggested. Other indices can be used to characterize low flow conditions within the stream. The ratio of discharge observed 90% of the time compared to that observed 50% of the time (Q90/ Q50) is commonly used to determine the portion of flow which is contributed from groundwater storage. Of additional importance is calculation of the percentage of time that zero-flow conditions occur.

The flow duration curves present the flow characteristics for the twelve systems during the time of study from August 28, 2012 to August 27, 2013 (Figure 55). Data used for the curves were calculated by scaling flow measured at two gauges; one on Deer Creek and the other on Little Pine Creek. Headwater stream flows were scaled using watershed size to the sample point in comparison with Little Pine Creek's watershed size. For downstream locations, Deer Creek stream flow measured at the U.S. Geological Survey gage was scaled to watershed size.

Drainage ratio = (sample site drainage area) / (gauge site drainage area)
*Estimated flow = (drainage ratio) * (flow at gauge)*

Buck Creek (BC1), Paint Creek (PC4), McCloskey Ditch (MD8) and the headwaters of South Fork Deer Creek (SFU11) contain the lowest maximum flows (<200 cfs). Deer Creek at Riley Park (DCD3) contains the highest maximum flow measuring greater than 10,000 cfs. Flow intensities increase from the headwaters to the mouth of Deer Creek as is typical for streams (Figure 55).

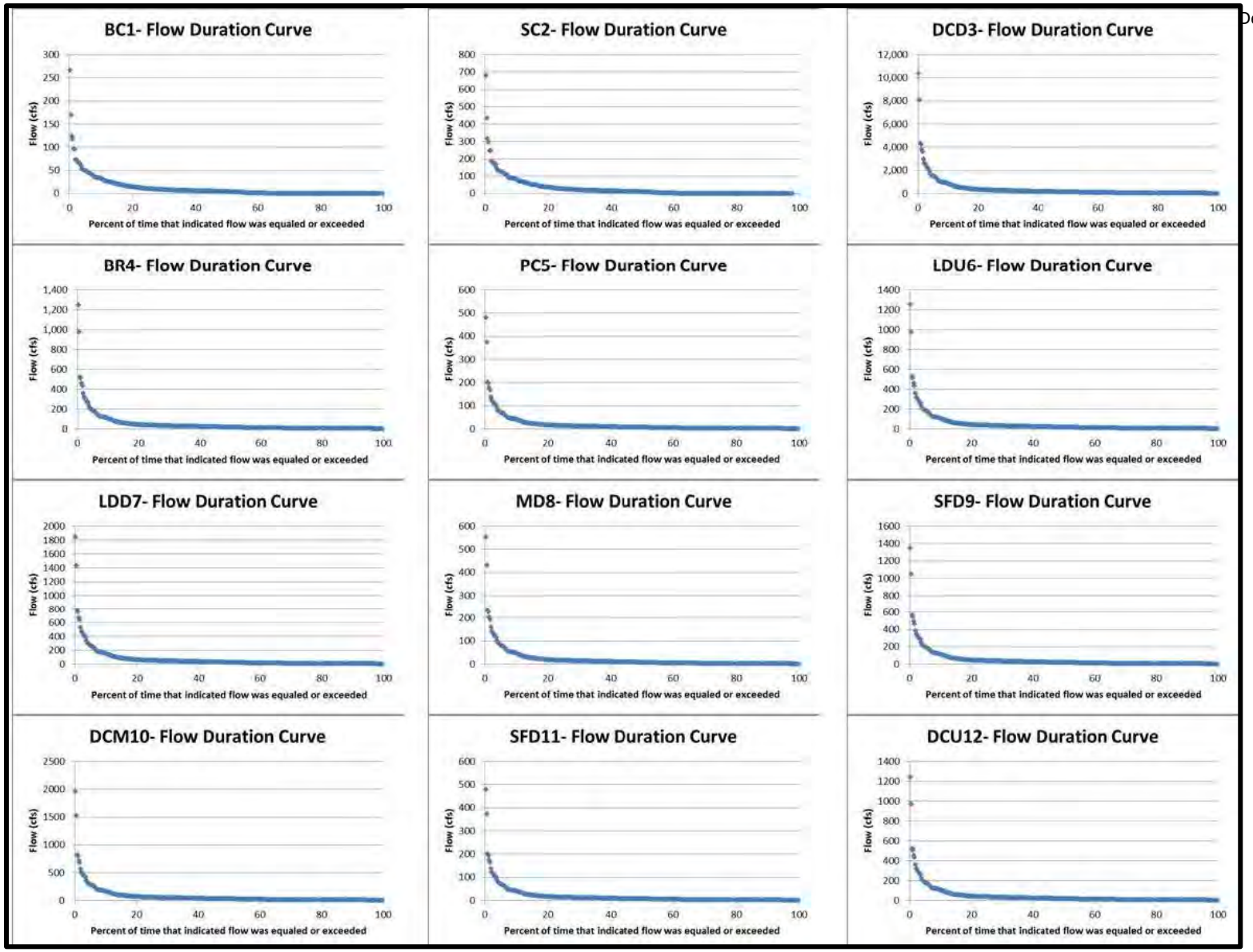

Figure 55. Flow duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.5 Load Duration Curves

Load duration curves allows for comparison of instream loading with stream flow so that conditions of concern can be identified. The load duration curves present the flow characteristics for the twelve systems during the time of study from August 28, 2012 to August 27, 2013. Data used for the curves were calculated by scaling flow measured at two gauges; one on Little Pine Creek (for monitoring sites BC1 and SC2), and one on Deer Creek (for the other monitoring sites). The difference in measured flow from these two gages becomes apparent because the load duration curves are plotted on a logarithmic scale to enhance the visibility of the data, and the low flow data due to drought conditions are particularly apparent in the Pine Creek gage data (sites BC1 and SC2). Headwater stream flows were scaled using watershed size to the sample point in comparison with Little Pine Creek's watershed size. For downstream locations, Deer Creek stream flow measured at the U.S. Geological Survey gauge was scaled to watershed size.

observed flow (cfs)) x (conversion factor) x (target concentration or state criteria) = total load /day

The individual load duration curves, also known as the allowable load curves, are displayed below (Figure 56 to Figure 59). In the graphs, the total daily load of each contaminant sample result (points) is plotted against the "percent time exceeded" for the day of sampling (curve). Those points above the curve exceed the state criterion or target concentration. Values on a load duration curve can be grouped by hydrologic condition to help identify possible sources and conditions that result in the material being present in the system under those flow conditions. Most often, the flow ranges fall in High (0 to 10), Moist (10-40), Mid-Range (40-60), Wet (60-90), and Low (90-100). Exceedances falling in the moist range (10-40) are typically associated surface runoff or stormwater loads, while exceedances associated with the dry zone are most often associated with dry conditions. These exceedances are suggested to result from point sources that are the most likely source.

Nitrate + Nitrite-nitrogen Load Duration Curves

Nitrate + Nitrite loads tend to measure higher than target concentrations at most sites during all conditions (Figure 56). Buck Creek (BC1), Sugar Creek (SC2), Bachelor Run (BR4) and South Fork Deer Creek (SFD9, SFU11) nitrate-nitrogen concentrations measured above target levels more than 70% of the time. This suggests that a steady stream of nitrate-nitrogen is available within these subwatersheds. Deer Creek (DCD3, DCM10 and DCU12), McCloskey Ditch, Little Deer Creek (LDD6 and LDU7) and McCloskey Ditch (MD8) typically contain elevated nitrate-nitrogen during high flow conditions only. This suggests that under normal flow conditions, nitrogen is washed into the stream and that it may enter when sediment enters. During high flow conditions, nitrate-nitrogen concentrations in Buck Creek (BC1) measure below the target suggesting that higher volumes of nitrate-nitrogen being present in the watershed at all times like those from livestock or fertilizers.

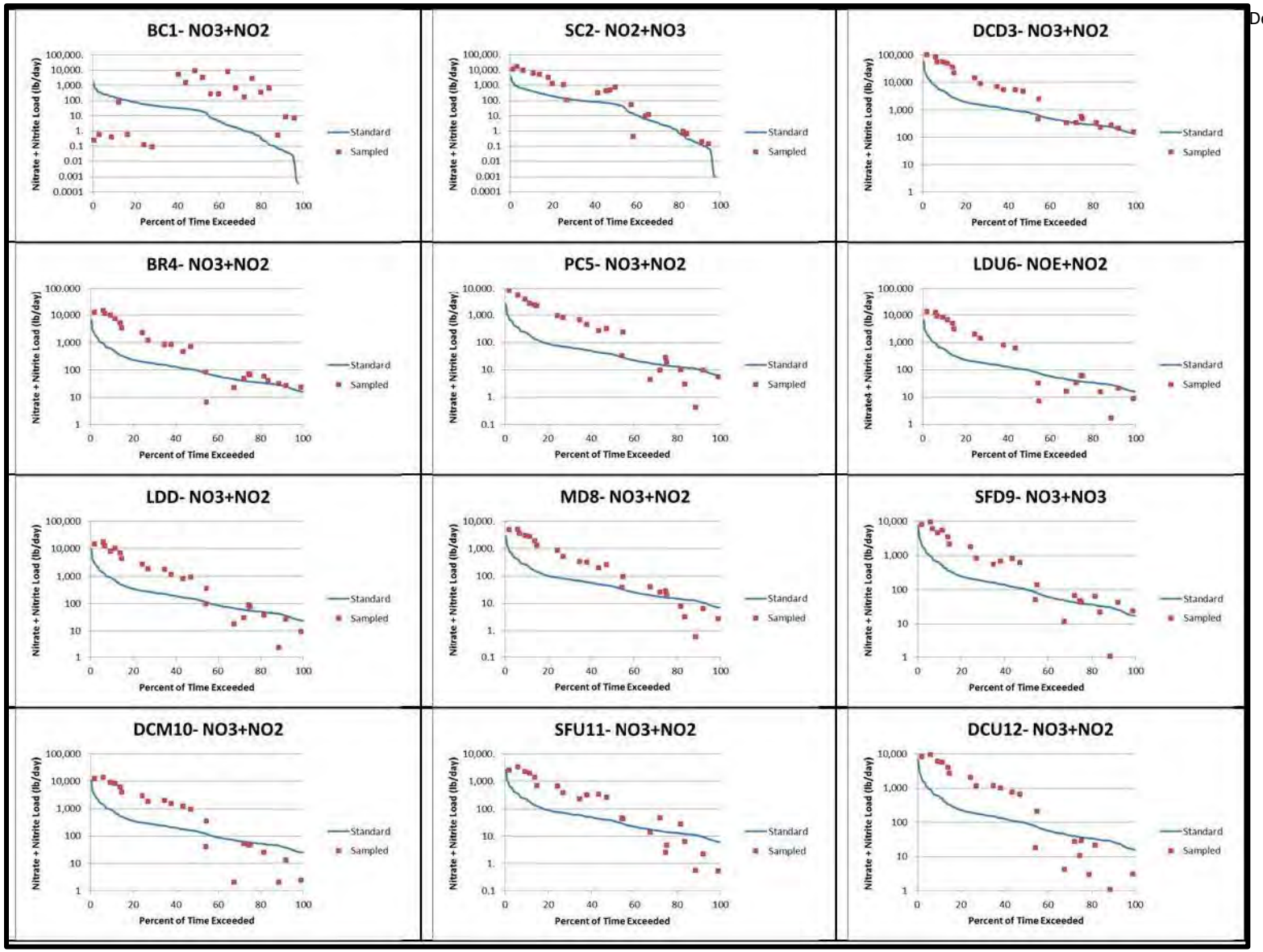

Figure 56. Nitrate-nitrogen load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

Total Phosphorus Load Duration Curves

Total phosphorus (TP) levels generally measured below target levels under all flow conditions (Figure 57). This is somewhat surprising considering that most total phosphorus enters streams attached to suspended solids. Exceedances of the target concentrations occurred only a few times in Sugar Creek (SC2), Deer Creek (DCD3, DCM10 and DCU12), Little Deer Creek (LDU6 and LDD7), Bachelor Run (BR4) and McCloskey Ditch (MD8). Most exceedances occurred in Sugar Creek (SC1), Bachelor Run (BR4) and Paint Creek (PC5) during storm flow events suggesting erosion or runoff is the cause of these values. Buck Creek (BC1) exceeded target levels under low flow conditions more than under high flow conditions. This suggests that a steady stream of total phosphorus is present in Buck Creek under all conditions.

Total Suspended Solids Load Duration Curves

Total suspended solids (TSS) levels generally measured above target levels during high flow events, which typically occurred under the wet conditions (Figure 58). Most exceedances occurred in Sugar Creek (SC2), Deer Creek (DCD3, DCM10 and DCU12), Little Deer Creek (LDD6 and LDU7), Bachelor Run (BR4), Paint Creek (PC5), McCloskey Ditch (MD8) and South Fork Deer Creek (SFU9 and SFD11) during storm flow events suggesting erosion or runoff is the cause of these values. Buck Creek exhibited a converse pattern for high flow event and several exceedances occurred during lower flow conditions as well. Possible sources of total suspended solids include the livestock access or stream bank erosion, both of which can provide a continuous source of total suspended solids to Buck Creek.

***E. coli* Load Duration Curves**

E. coli load duration curves display completely different conditions than those presented by nitrate-nitrogen, total phosphorus and total suspended solids curves (Figure 59). E. coli curves indicate that *E. coli* concentrations exceed targets in Buck Creek (BC1), Paint Creek (PC4), Little Deer Creek (LDU6 and LDD7), McCloskey Ditch (MD8), Headwaters of Deer Creek (DCM10 and DCU12), and South Fork Deer Creek (SFD9 and SFU11) during all flow conditions. These data suggest a nearly continuous source of *E. coli* within these streams. When flows are at their lowest, most of these sites contain *E. coli* concentrations below target levels suggesting that during wet or low exceedance conditions (60-100), there are limited sources of *E. coli* within these streams. Deer Creek at Riley Park (DCD3) and Bachelor Run (BR4) load duration curves indicate that *E. coli* concentrations exceed targets only during high flow conditions.

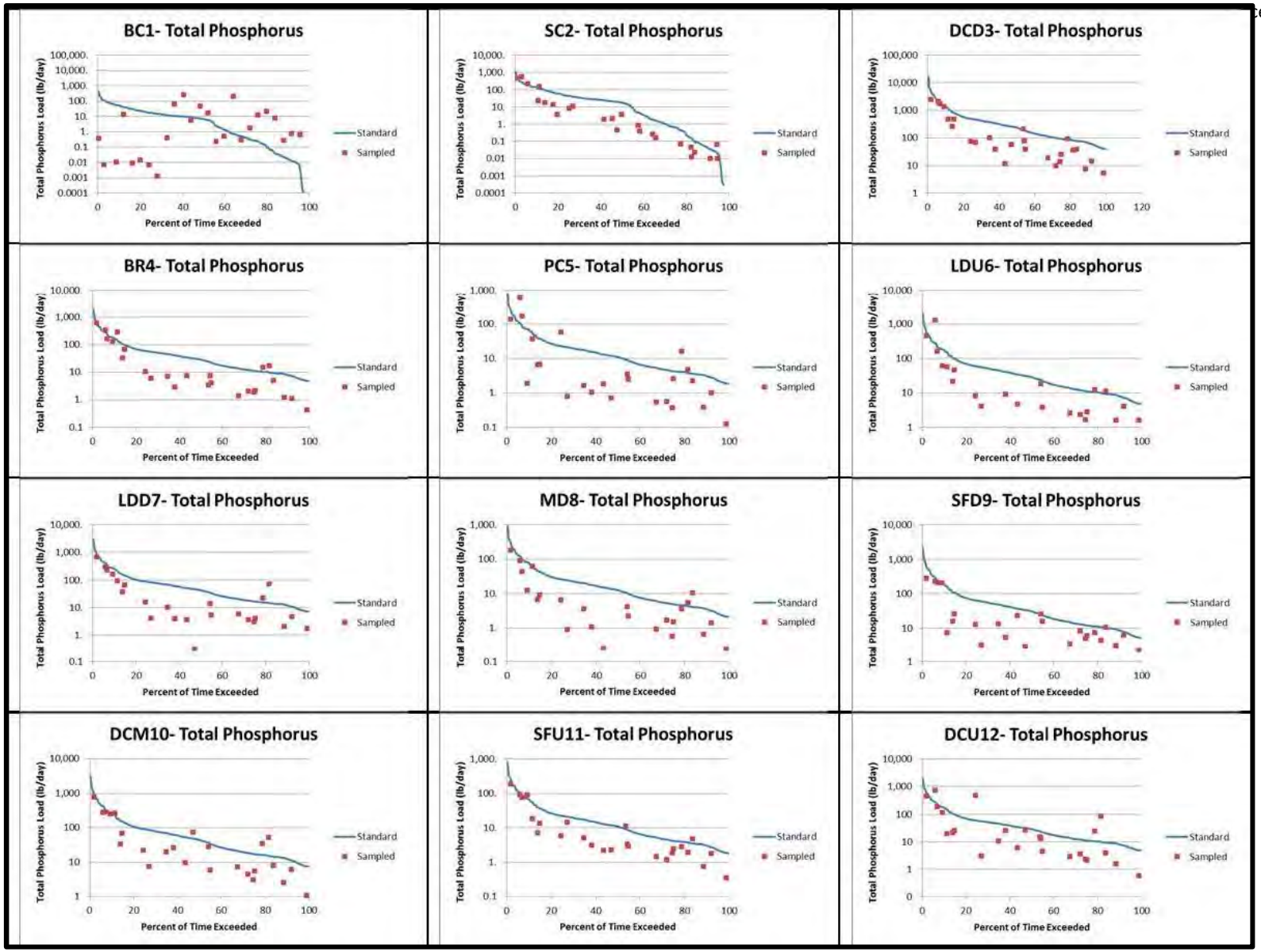

Figure 57. Total phosphorus load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

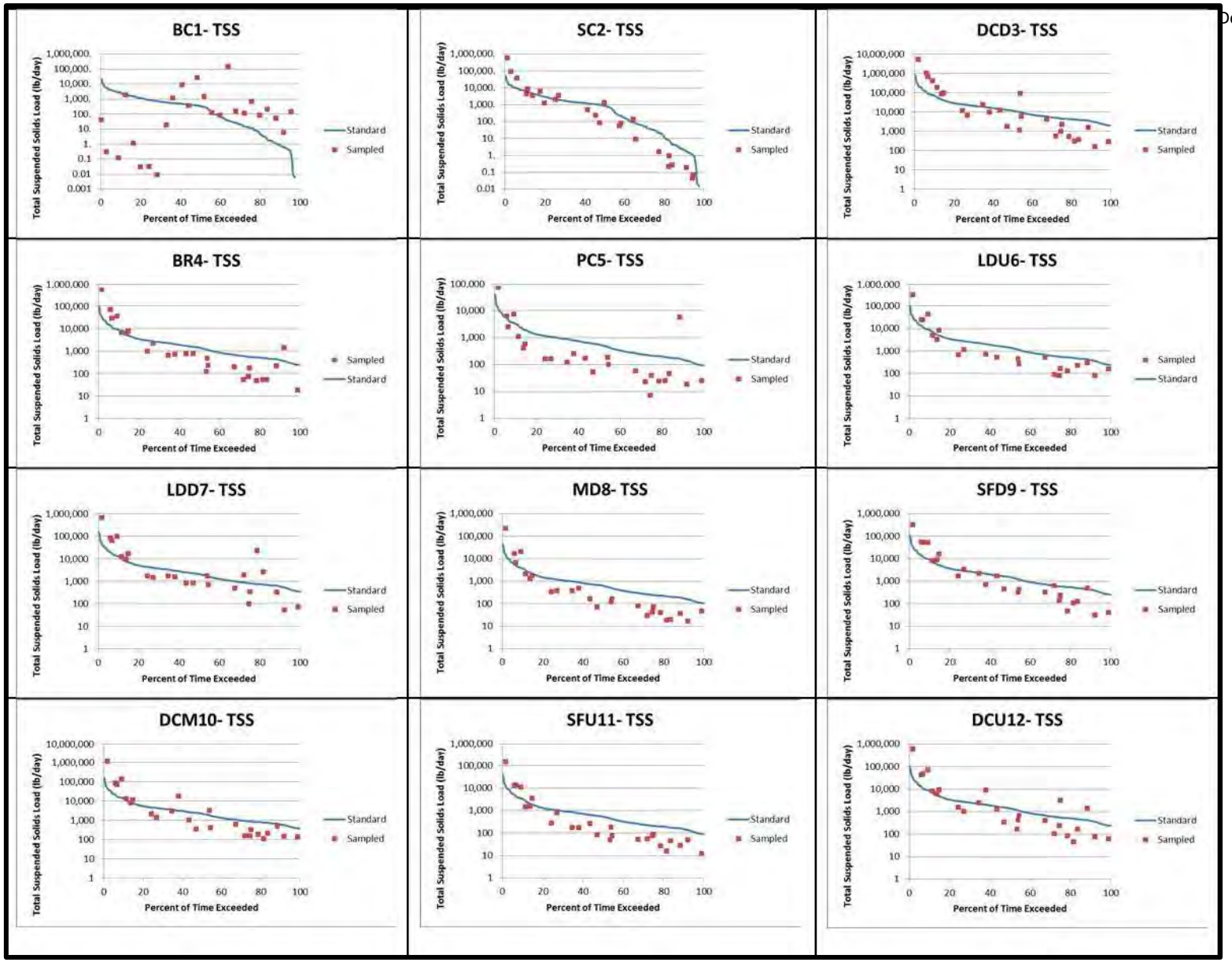

Figure 58. Total suspended solids load curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

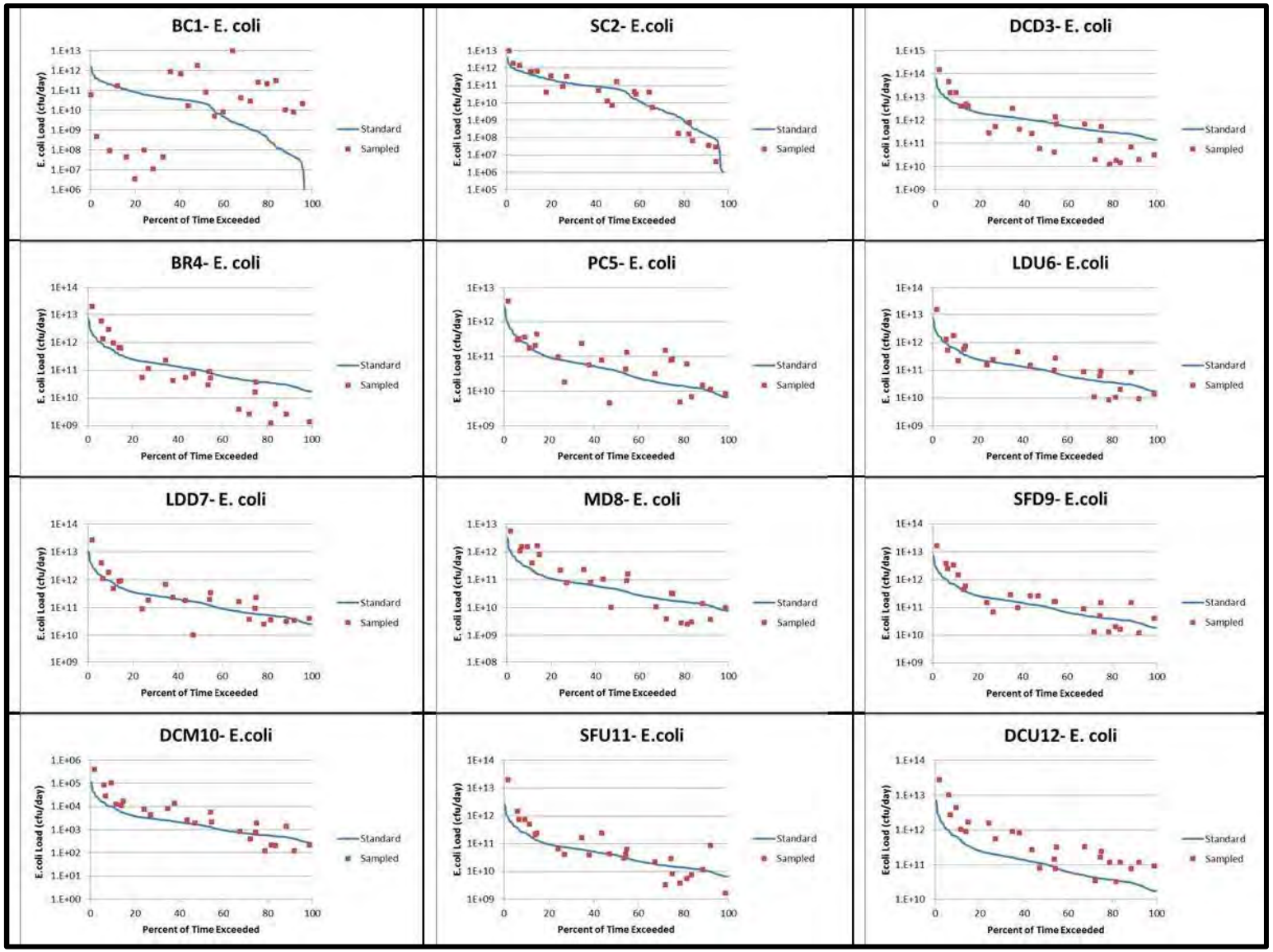

Figure 59. *E. coli* concentrations load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.6 Habitat Results

Stream water quality and available habitat influence the quality of a biological community in a stream, and it is necessary to assess both factors when reviewing biological data. Table 18 presents the results of QHEI assessments at each of the 12 stream sites sampled in the Deer Creek-Sugar Creek watershed during the summer of 2012. Figure 60 details metric and total scores for all sites. Among all the sites, riparian scores were relatively low and many sites had low pool/riffle development scores, contributing to overall lower QHEI scores. The lowest scores occurred at the South Fork Deer Creek upstream (SFU11) and Deer Creek upstream (DCU12) sites. These sites were representative of ditched streams present throughout Indiana. With high banks, narrow riparian zones, and limited pool and riffle development, it is not surprising that these sites scored poorly relative to other stream sites. The highest scores occurred at Little Deer Creek downstream (LDD7) and McCloskey Ditch (MD8) where comparatively high amounts of instream cover and larger substrates contributed strongly to the higher scores at these sites.

Table 18. Qualitative Habitat Evaluation Index (QHEI) scores measured in the Deer Creek-Sugar Creek watershed.

Study Site	Substrate	Cover	Channel	Riparian	Pool/Riffle	Gradient	Total
Buck Creek (BC1)	16.5	15	9	3.5	13.25	8	65.25
Sugar Creek (SC2)	15	13.5	10.75	6.5	8.5	10	64.25
Deer Creek Downstream (DCD3)	16	12.5	12.5	4.25	11.5	10	66.75
Bachelor Run (BC4)	17	10	6.5	5.25	12	8	58.75
Paint Creek (PC5)	17	13	8.5	3	4	10	55.5
Little Deer Creek Upstream (LDU6)	6	15	11	11	10	10	64
Little Deer Creek Downstream (LDD7)	18	16.5	14.25	6.5	10.5	8	73.75
McCloskey Ditch (MD8)	17	18.5	12	7.75	5	10	70.25
South Fork Deer Creek (SFD9)	10.5	15.5	12.5	7.75	9	10	65.25
Deer Creek Middle (DCM10)	14	15	9.5	4.75	7	6	56.25
South Fork Deer Creek (SFU11)	14	9.5	6	5.25	4	6	44.75
Deer Creek Upstream (DCU12)	6	11.5	7.5	4.25	12.5	6	47.75

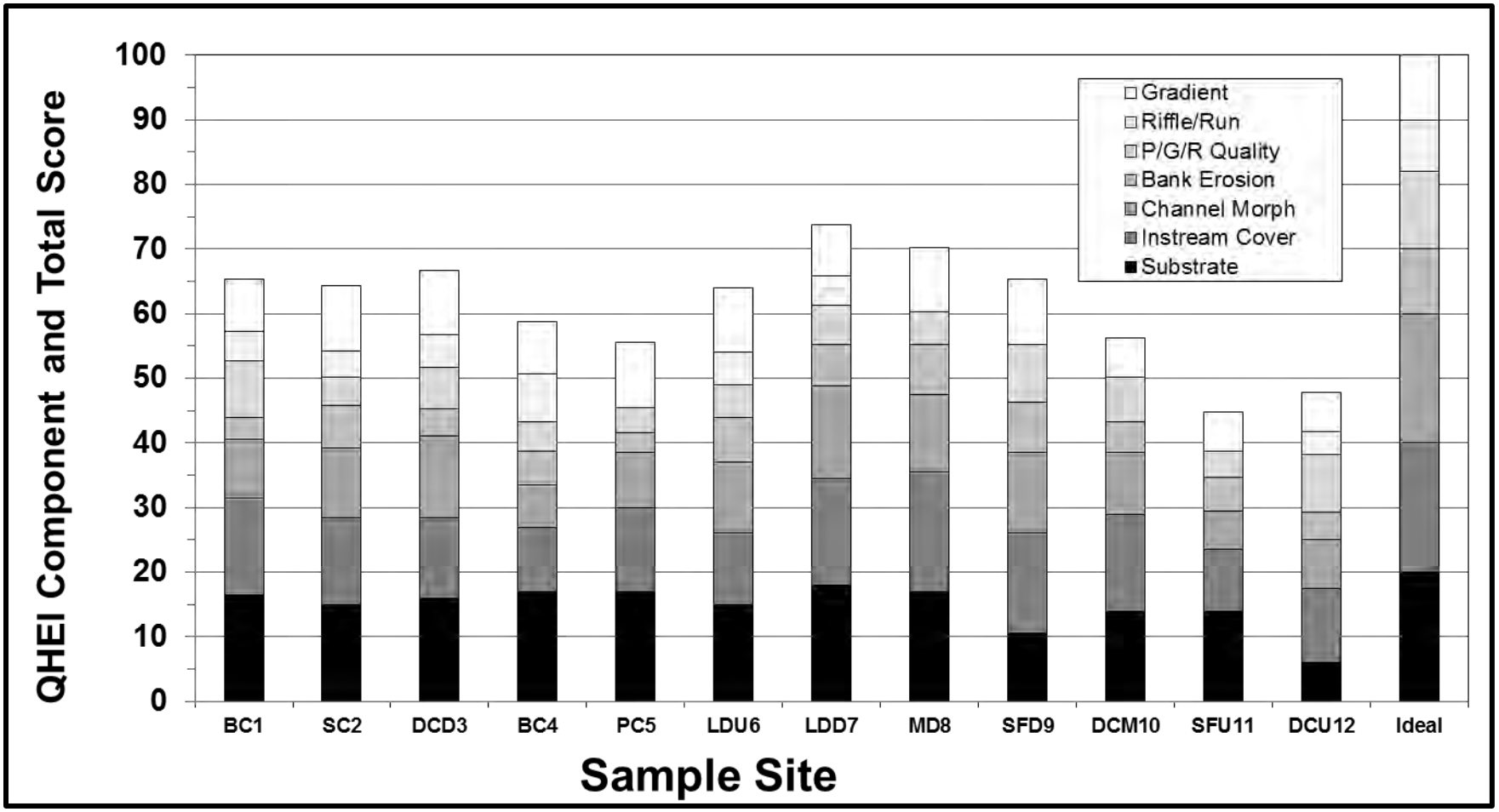

Figure 60. Qualitative Habitat Evaluation Index (QHEI) total and component scores measured for stream sites in the Deer Creek-Sugar Creek watershed.

3.3.7 Fish Community Results

A total of 50 fish species was collected over the sampling period from the Deer Creek-Sugar Creek watershed sample sites. Fish community data collected during sampling indicate that fish communities present in the Deer and Sugar Creek watersheds generally rate as poor to fair (scores of 30-40; Figure 61, Table 19). Only two sites along Deer Creek rated good condition, Deer Creek downstream (DCD3) and Deer Creek middle (DCM10). The lowest fish IBI scores (34 or less) occurred in Buck Creek (BC1), Paint Creek (PC5), Little Deer Creek upstream (LDU6), McCloskey Ditch (MD8), and South Fork Deer Creek downstream (SFD9). These sites represent streams impacted by changing water conditions and poor instream habitat. The highest fish IBI scores at Deer Creek downstream (DCD3) and Deer Creek middle (DCM10) reflect the presence of copious instream cover at the sites.

Table 19. Fish Index of Biotic Integrity (IBI) raw data used to score metrics and IBI scores for Deer Creek-Sugar Creek streams.

Fish IBI Metric	BC1	SC2	DCD3	BC4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Species Richness	18	26	28	20	18	20	31	28	13	31	24	27
#DMS species*	4	N/A	N/A	N/A	5	N/A	N/A	5	N/A	N/A	6	N/A
#Darter species	2	1	3	3	3	5	6	4	1	4	5	6
%Headwater species	27	2	0	17	17	5	0	0	0	0	0	2
#Sunfish species	4	4	7	3	3	3	7	5	6	6	5	5
#Minnow species	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12	1	11	9	10
#Sucker species	1	2	2	1	2	1	3	4	3	4	1	2
#Sensitive species	3	8	12	11	2	7	11	9	3	12	7	9
%Tolerant species	45	19	6	17	31	25	23	42	18	21	27	38
%Omnivorous species	17	11	17	17	7	2	31	31	1	23	21	39
%Insectivorous species	41	75	72	50	48	55	46	39	84	54	49	39
%Pioneer species	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55	19	15	57	21
%Carnivorous species	1	0	7	2	0	3	3	3	3	16	0	4
CPUE (#individuals/hour)	146	613	249	108	129	76	138	204	49	109	344	103
% Simple Lithophilic species	17	4	40	19	15	7	25	28	5	37	11	47
Total Fish IBI Score	**34**	**40**	**48**	**36**	**34**	**34**	**40**	**34**	**30**	**50**	**36**	**38**

*Darter, Madtom and Sculpin species

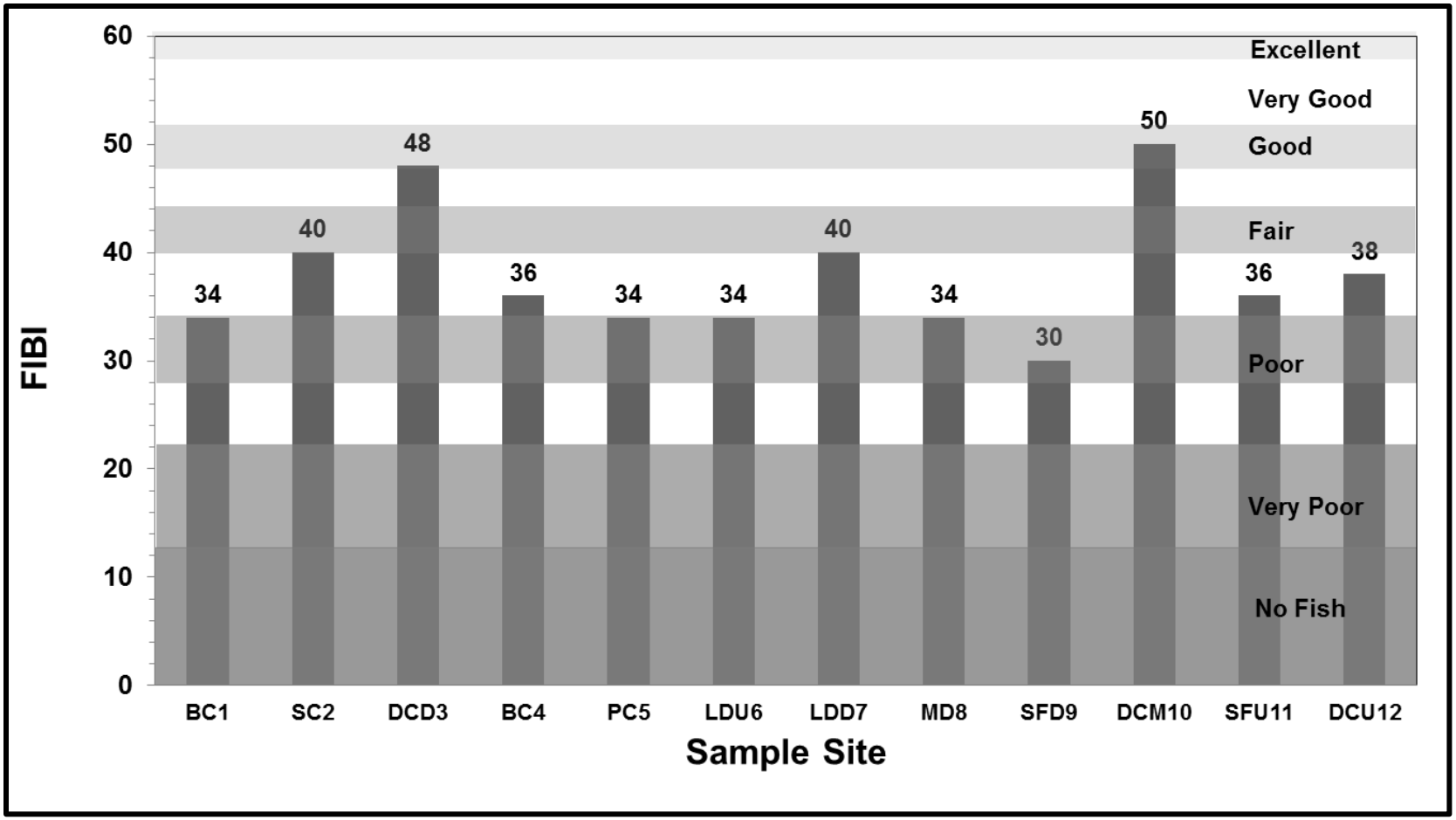

Figure 61. Fish Index of Biotic Integrity (IBI) scores calculated based on stream samples collected in the Deer Creek-Sugar Creek watershed streams during summer 2012. Condition classifications are indicated by shaded areas and associated descriptions provided on the right side of the graph.

3.3.8 Macroinvertebrate Results

Macroinvertebrate community data collected from sample sites in the Deer Creek-Sugar Creek watershed streams indicated a wide range of benthic macroinvertebrate Index of Biotic Integrity (mIBI) scores (Table 20 and Figure 62). The lowest mIBI scores occurred at McCloskey Ditch (MD8) and Deer Creek (DCM10) where the benthic macroinvertebrate communities rated as being severely impaired. The remainder of the sites contained mIBI scores that were higher than the threshold value (36) that separates impaired and unimpaired sites. However, four sites were just above this threshold, including Buck Creek (BC1), South Fork Deer Creek downstream (SFD9), South Fork Deer Creek upstream (SFU11), and Deer Creek upstream (DCU12). The highest mIBI scores occurred at Sugar Creek (SC2), Little Deer Creek upstream (LDU6), and Little Deer Creek downstream (LDD7).

Table 20. Benthic macroinvertebrate Index of Biotic Integrity (mIBI) raw data and mIBI scores for Deer Creek-Sugar Creek watershed streams.

mIBI Metric	BC1	SC2	DCD3	BC4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Total #Taxa	33	59	25	24	17	82	28	10	25	11	12	27
Total #Indiv	292	408	370	266	239	2019	233	314	222	147	251	307
Total EPT	12	35	11	13	3	50	15	2	4	3	3	10
Total #Diptera Taxa	14	12	3	2	5	15	4	1	10	4	1	8
%Chironomidae	0.64	0.18	0.25	0.15	0.21	0.15	0.22	0.49	0.46	0.52	0.18	0.57
%Non-insect Indiv. Excl. Crayfish	0.02	0.05	0.11	0.11	0.12	0.02	0.08	0.38	0.05	0.34	0.18	0.18
%Intolerant Individuals	0.15	0.58	0.61	0.62	0.15	0.52	0.56	0.08	0.09	0.10	0.40	0.12
%Tolerant Individuals	0.03	0.05	0.10	0.10	0.08	0.01	0.07	0.41	0.14	0.31	0.23	0.17
%Predators	0.10	0.09	0.01	0.01	0.41	0.06	0.01	0.03	0.16	0.03	0.12	0.02
%Shredders and/or Scrapers	0.04	0.49	0.10	0.20	0.07	0.44	0.32	0.01	0.03	0.03	0.02	0.06
%Collectors-Filterers	0.23	0.12	0.01	0.06	0.02	0.14	0.06	0.00	0.01	0.04	0.00	0.03
%Sprawlers	0.24	0.50	0.59	0.52	0.15	0.34	0.47	0.09	0.09	0.10	0.37	0.10
Total Benthic IBI Score	**38**	**52**	**44**	**48**	**40**	**54**	**50**	**24**	**38**	**24**	**38**	**38**

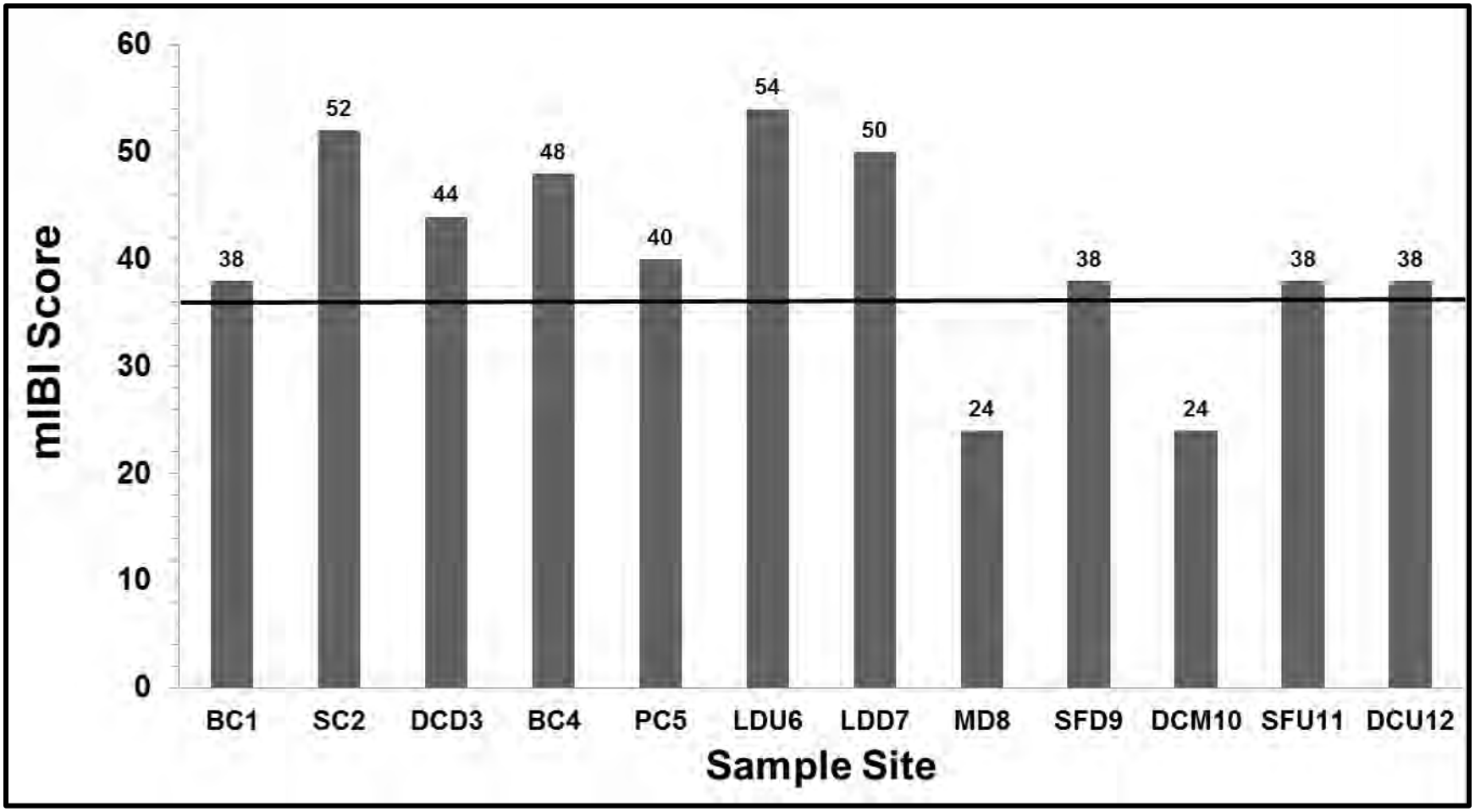

Figure 62. Total benthic macroinvertebrate (mIBI) scores for stream sites sampled in the Deer Creek-Sugar Creek watershed in summer 2012. Scores below the solid line were considered impaired.

3.3.9 Summary and Conclusions

The fish, macroinvertebrate, and QHEI data all indicated some degree of stream degradation for the stream sites assessed in the Deer and Sugar Creek watersheds, although there was a great amount of variation among sites. There were few cases where all assessment techniques yielded completely consistent results with regard to characterizations of site quality. This is not uncommon because each assessed group (i.e., fish, benthic macroinvertebrates, and habitat) does respond differently to environmental stressors.

QHEI and mIBI scores for South Fork Deer Creek Headwaters (SFU12) and Deer Creek Headwaters (DCU11) indicate that stream conditions were impaired. This is likely due to the low gradient of the channel and high amounts of sedimentation associated with these waterways. There was little to no discernible riffle habitat in the streams, and large sections of the stream bottom were covered in loose sand, which likely contributed to the low mIBI and QHEI scores. Buck Creek (BC1) biotic integrity and QHEI scores were lower than most of the other streams despite the fact the sample sites contained high quality habitat. Poor water quality in Buck Creek and substrates covered by silt during sampling events likely impair biological communities. The QHEI score for McCloskey Ditch (MD8) was among the highest observed in our assessments. However, the biological components of McCloskey Ditch did not score as high in those assessments. This suggested that physical habitat was not a limiting factor for reduced stream health in this stream. The sites with lower mean IBI scores (SFU12 and DCU11) also typically had lower mean QHEI scores.

The biological data for the ten sites that were consistently sampled suggested that many of these streams are impacted by either poor instream conditions (reduced QHEI); elevated nitrate-nitrogen, total suspended solids, and *E. coli* concentrations; or some other unknown impairment leading to compromised biological integrity. McCloskey Ditch and Buck Creek would be expected to exhibit high environmental quality based solely on the QHEI scores, although the biota at these sites suggested that there were likely other issues not related to physical habitat that influenced the biological communities and overall environmental quality. Conversely, Sugar Creek (SC2) and Deer Creek (DCD3) would be considered to be of relatively high environmental quality based on its mIBI and IBI scores, but their moderate QHEI scores suggested that the physical habitat of these sites may be degraded and of moderate environmental quality. It is obvious that incorporating biology, chemistry and habitat in site assessments is critical for making truly informed environmental evaluations of sites, and it is likely that a range of restoration actions will be necessary to address the impairments reported herein.

3.4 Watershed Inventory Assessment

3.4.1 Watershed Inventory Methodologies

Volunteers and Wabash River Enhancement Corporation staff completed windshield surveys throughout the Deer Creek-Sugar Creek watershed in spring 2013. Individuals conducted surveys by driving all accessible roads throughout the watershed. Large maps with aerial photographs, road and stream names, and public property labels were provided to each volunteer group. Volunteers recorded observations on the provided maps and data sheets, documented field conditions with photographs, and provided all notes to the Urban and/or Rural Committees for review. The windshield surveys were also used to confirm GIS map layer data throughout the watershed. Items targeted during the surveys included, but were not limited to the following:

- Aerial land use category
- Field or gully erosion
- Pasture locations and condition
- Livestock access and impact to streams
- Buffer condition and width
- Bank erosion or head-cutting
- Environmental site confirmation (NPDES, CFO, open dump, Superfund, etc.)

3.4.2 Watershed Inventory Results

The Deer Creek- Sugar Creek watershed was inventoried by watershed inventory volunteers and staff in the spring of 2013. A majority of the issues identified fall into two categories: stream buffers limited in width or lacking altogether and streambank erosion. Figure 63 details locations throughout the Deer Creek-Sugar Creek watershed where problems were identified. Additional assessments will be on-going; therefore, those areas identified in Figure 63 should not be considered exhaustive. Nearly 104 miles of tributary streambanks possessed limited buffers, nearly 70 miles of stream bank were eroded, and livestock had access to over 26 miles of streambanks. Additionally, nearly 40 of 42 miles of the Wabash River require stabilization and nearly 6.25 acres of land require buffering within 30 feet of the Wabash River.

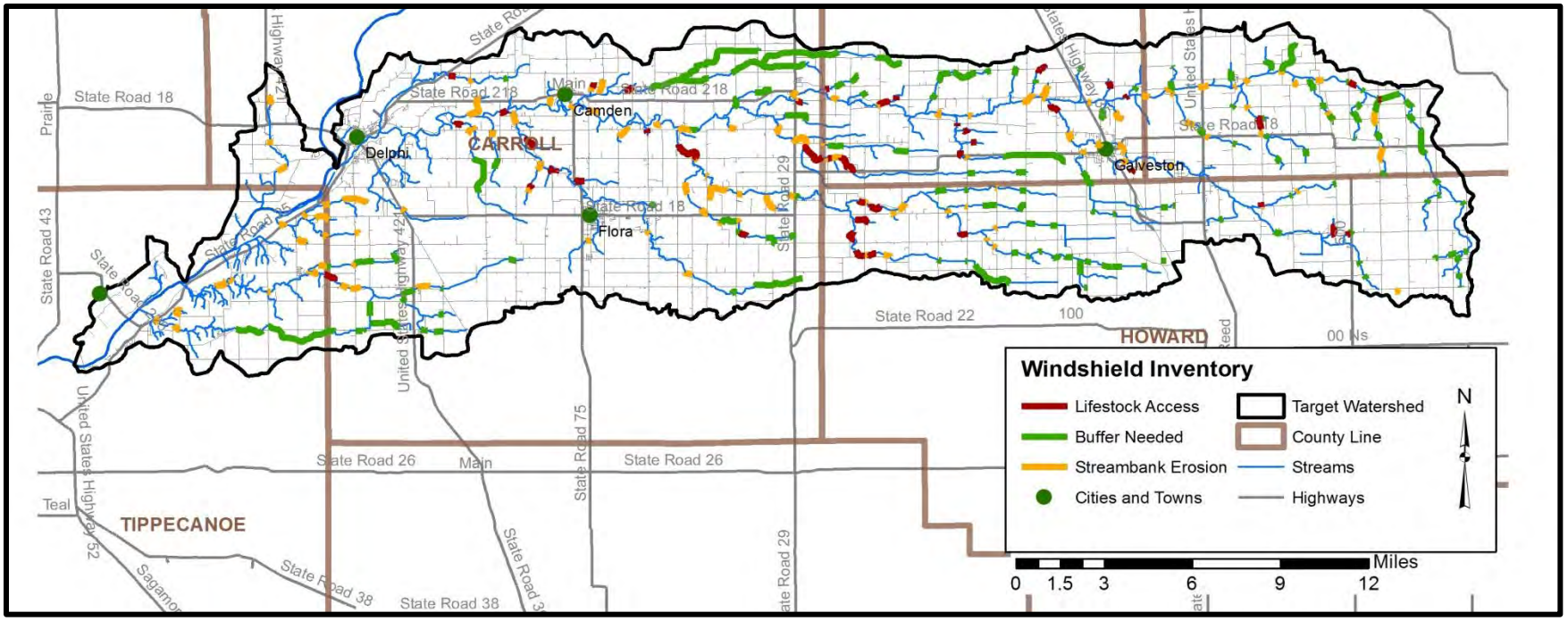

Figure 63. Stream-related watershed concerns identified during watershed inventory efforts, spring 2013.
Data used to create this map are detailed in Appendix A.

4.0 WATERSHED INVENTORY II-B SUBWATERSHED DISCUSSIONS

To gather more specific, localized data, the Deer Creek-Sugar Creek watershed was divided into ten subwatersheds (Figure 64). These subwatersheds reflect specific tributary drainages, similar land uses, and hydrology. Land uses, soil types, point and non-point watershed concern areas, and historic and current water quality sampling locations are detailed below for each watershed.

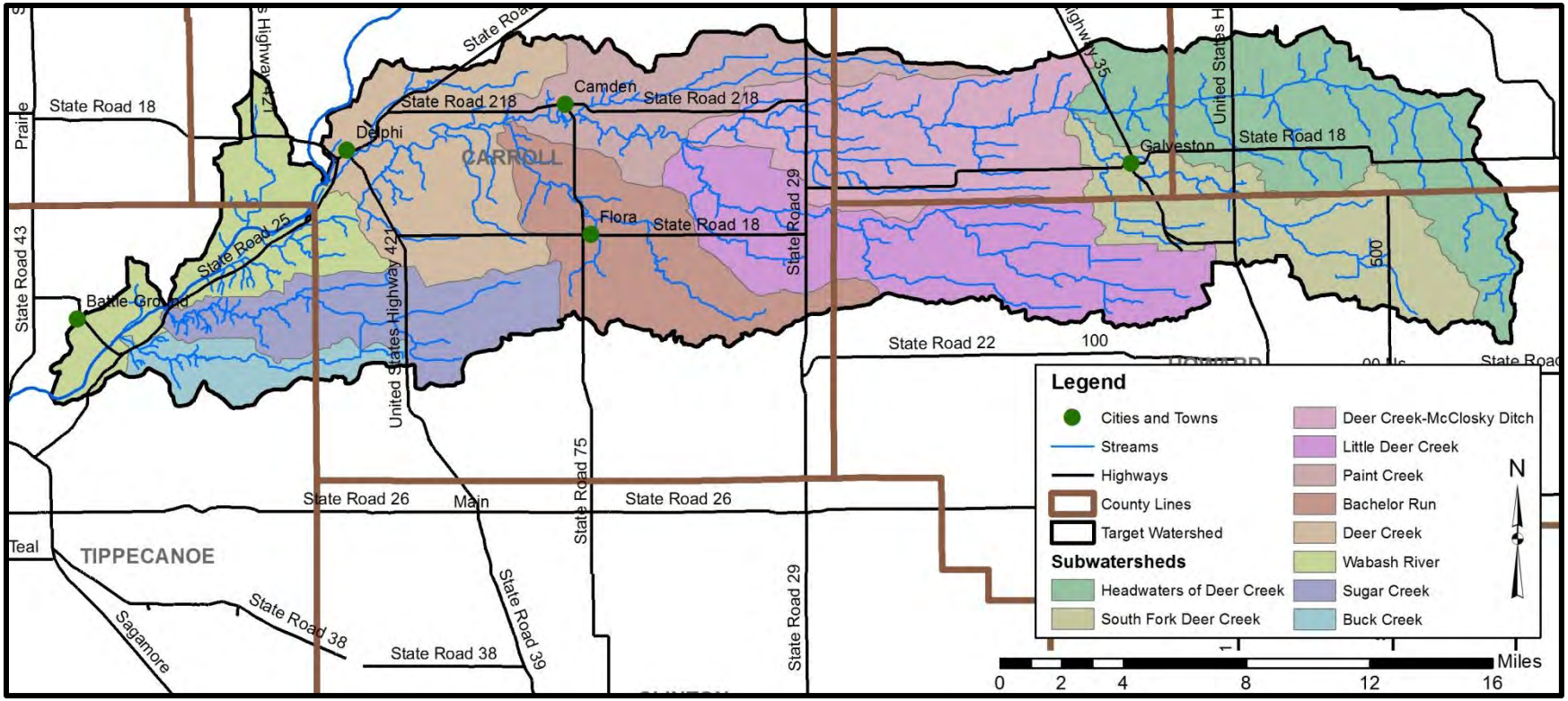

Figure 64. Ten subwatersheds in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

4.1 Headwaters of Deer Creek

The Headwaters of Deer Creek subwatershed is located in the eastern part of the Deer Creek-Sugar Creek watershed forming the northeastern boundary. The Headwaters of Deer Creek subwatershed spans three counties including, Cass, Howard, and Miami, with the majority the subwatershed located in Miami County. The watershed includes three 12-digit watersheds, Copper Creek-Deer Creek (051201050401), Wise Grinslade Ditch-Deer Creek (051201050402), and Russell Ditch-Deer Creek (051201050405) and drains 37,499 acres or 58.6 square miles. In

total, 54.7 miles of stream are present within the Headwaters of Deer Creek subwatershed. Of those, 13.4 miles are considered impaired for *E. coli*, biotic communities, and nutrients according to IDEM's draft 2012 303(d) list (Figure 65, IDEM, 2012).

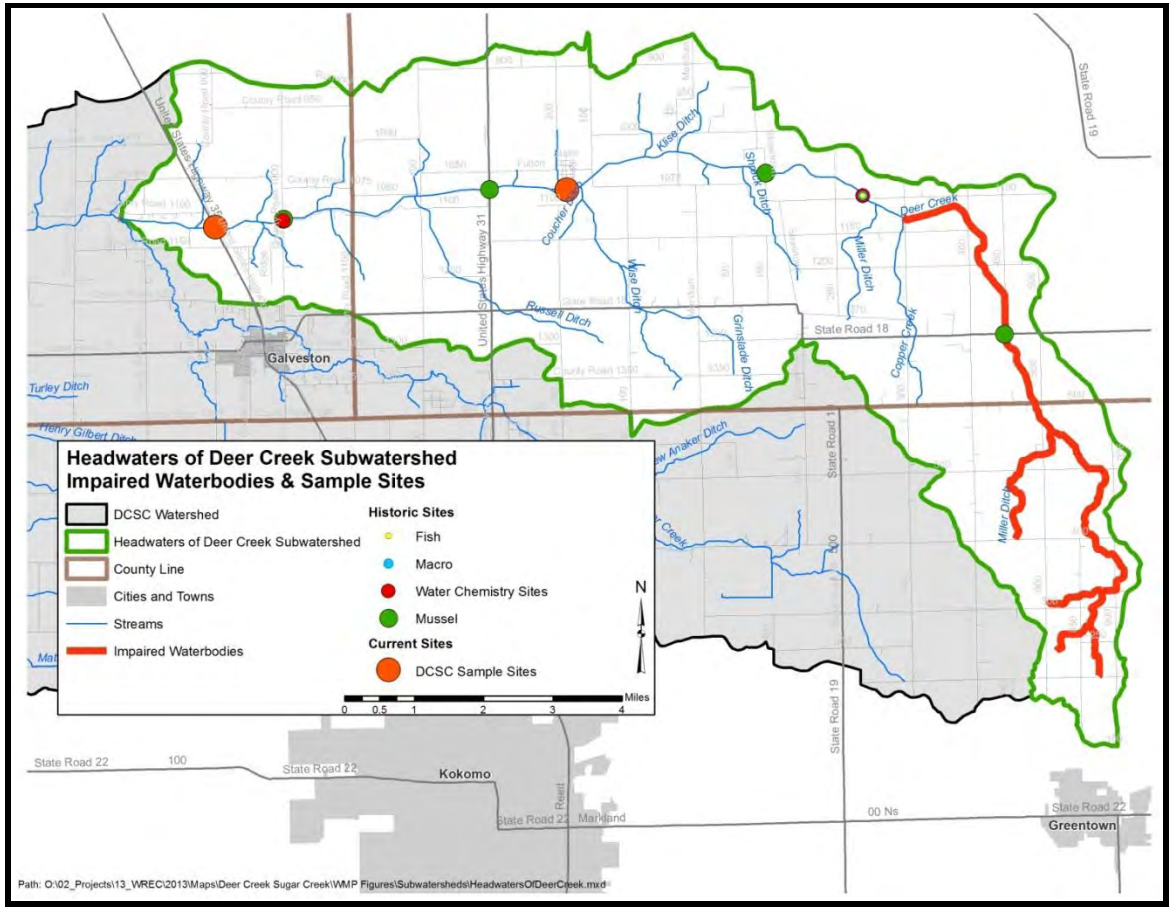

Figure 65. Impaired waterbodies and sample sites in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.1 Soils

Hydric soils dominate the Headwaters of Deer Creek subwatershed (Figure 66). Hydric soils cover 14,977 acres, or approximately 40%, of the subwatershed. The hydric soils are equally dispersed throughout the watershed. Highly and potentially highly erodible soils cover 1,844 and 790

acres (4.9% and 2.1%), respectively. Highly erodible soils are isolated in the Miami County (eastern) portion of the watershed bordering Deer Creek and a few of its smaller tributaries. Potentially highly erodible soils are located predominantly along Deer Creek and its minor tributaries within the Cass County portion of the subwatershed. The Headwaters of Deer Creek subwatershed has the lowest percentage of potentially highly erodible soils of the ten subwatersheds.

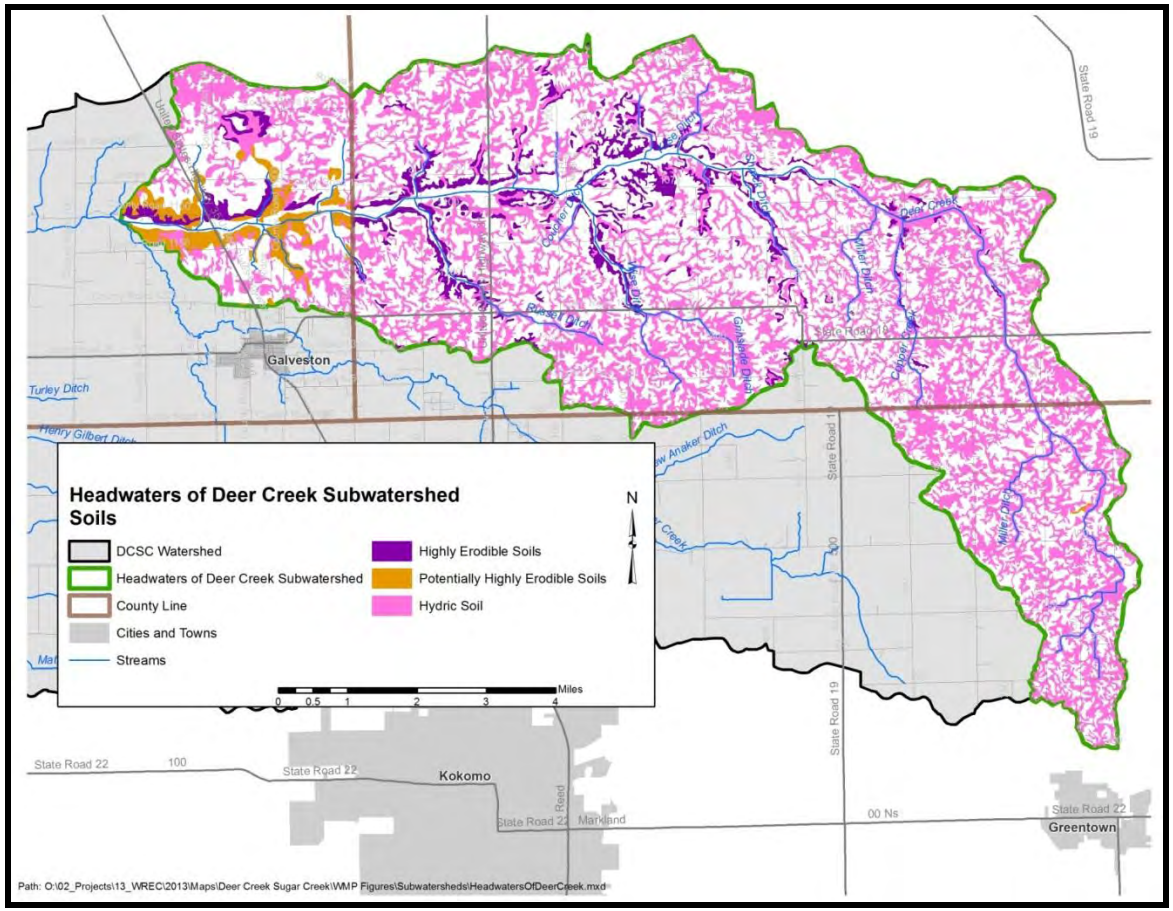

Figure 66. Properties of soils located in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.2 Land Use

Agricultural land uses dominate the Headwaters of Deer Creek subwatershed. Agricultural land uses covers approximately 90% of the subwatershed. This subwatershed and the Little Deer Creek subwatershed are tied for the highest percentage of agriculture land use in the watershed. Developed open spaces and deciduous forests are the only other land uses making up greater than 1% of the watershed, comprising 5.7% and 1.6% of the watershed, respectively. The Headwaters of Deer Creek subwatershed has the lowest percentage of open water and forest in the watershed.

4.1.3 Point Source Water Quality Issues

As detailed above, the majority of the Headwaters of Deer Creek subwatershed is in agricultural land uses. There is one NPDES permitted facility within the subwatershed: the Maple Lawn Village mobile home park located on US Highway 31 North (Figure 67). The facility discharges into Deer Creek. There is one open dump within the subwatershed; it is located approximately two miles north of Galveston. There are no brownfields, industrial waste, or LUST sites within the Headwaters of Deer Creek subwatershed.

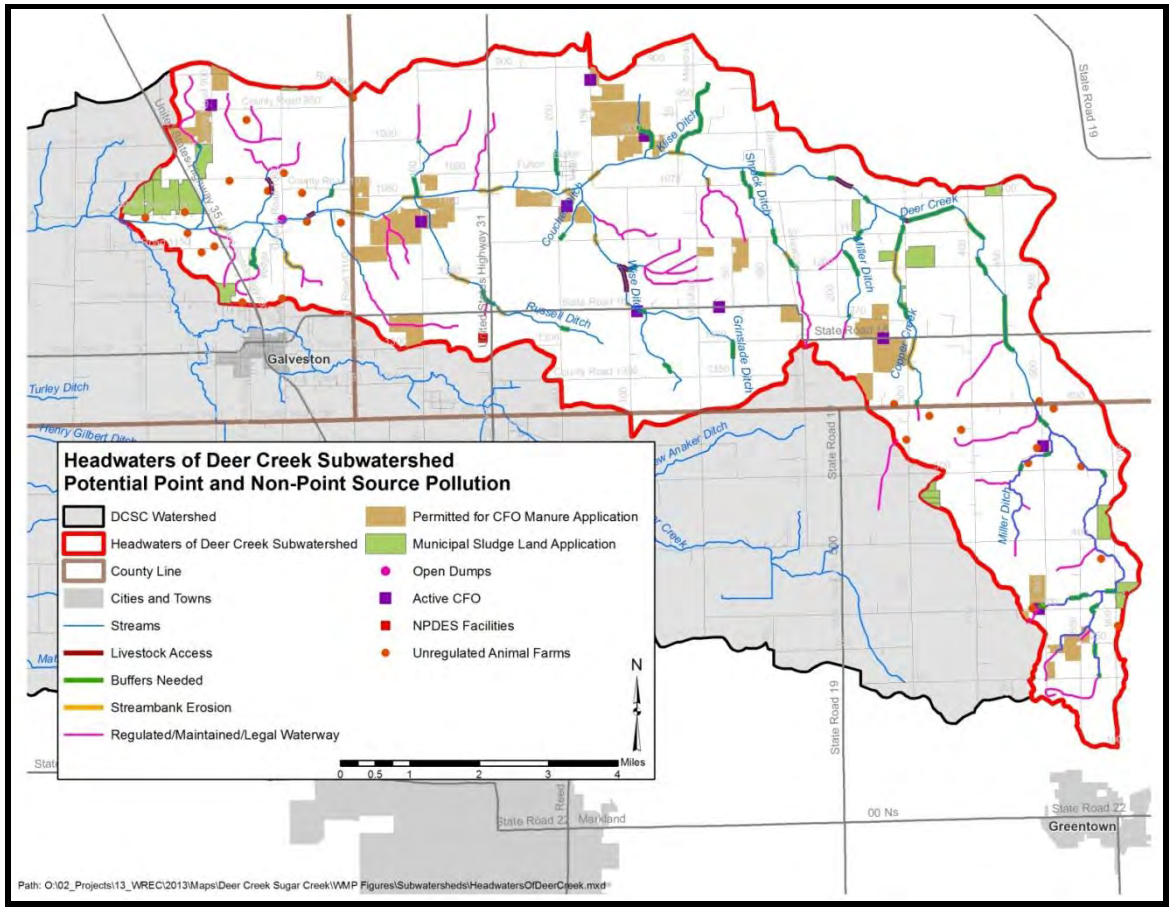

Figure 67. Point and non-point sources of pollution in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Headwaters of Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Nearly 30 unregulated animal farms are located within the Headwaters of Deer Creek subwatershed. Approximately, 208 cattle, 2 hogs, 20 sheep, 11 goats, and 40 horses are located on 27 farms. There are ten active CFOs in the Headwaters of Deer Creek subwatershed. CFOs in the Headwaters of Deer Creek subwatershed contain approximately 5,950 nursery pigs, 5,048 finishing pigs, and 1,565 sows. The CFO permits allow for distribution of manure on approximately 1,956 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 13

thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,956 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 708 acres within the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 2.5 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Headwaters of Deer Creek subwatershed. In total, 19 miles of stream buffers and 16.4 miles of streambank stabilization are needed within the subwatershed.

4.1.5 Water Quality Assessment

IDEM and the IDNR sampled waterbodies within the Headwaters of Deer Creek subwatershed at five locations (Figure 65). The first sample site is on Deer Creek at its intersection with Miami County Road 1100 South. This site has been sampled by IDEM for fish, macroinvertebrates, and water chemistry. The second site is also on Deer Creek in Cass County at the intersection of County Road 1000 East and County Road 1100 South. IDEM sampled *E. coli* and the IDNR sampled the mussel community at this site. The remaining three sites are also on Deer Creek in Miami County at Strawtown Pike, US Highway 31, and State Road 18. The IDNR also surveyed the mussel communities are these sites. As part of the current planning project, Purdue University sampled Deer Creek at State Road 35 (site DCM10) and Deer Creek at Elm Street (site DCU12) (Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli was sampled five times over a 30 day period on Deer Creek located at the intersection of County Road 1100 South and 1000 East during September and October of 2003. *E. coli* levels exceed the state standard during three of the five sampling times. Of the samples that exceeded the state standard concentrations ranged from 435 to 1,300 colonies/100 mL. In the summer and fall of 2008, nutrient and field parameters collection occurred at Deer Creek's intersection with County Road 1100 South. *E. coli* was analyzed five times over a 30 day period and exceeded the state standard during four of the times measuring365 to920 colonies/100mL. Dissolved oxygen measured below the state standard (4.0 mg/L) with 0.42 mg/L measured during one of the sampling events. During all other times dissolved oxygen was measured, it measured above the state standard. Inorganic nitrogen (nitrate+nitrite) measured unusually high during a June sampling event with a concentration of 9.57 mg/L recorded. This is nearly four times the suggested benchmark of Dodds et al (1998) of 2 mg/L. Total phosphorus exceeded the benchmark of Dodds (1998) of 0.08 mg/L during two of the four samples measuring 0.178 and 0.474 mg/L.

In total, 19 field measurements and 25 samples were collected at Deer Creek at State Road 35 (site DCM10). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 12 of 19 assessments measuring from 12.1 to 209 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen

concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 13 of 19 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during two events measuring as high at 11.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 16 of 25 sampling events with concentrations measuring as high as 1.01 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 8 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.3 to 365 mg/L. *E. coli* concentrations measured above the state standard during 19 of 25 sampling events. Concentrations in exceedance ranged from 249 cfu/100 mL to 2909 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations never measured below the detection level.

Deer Creek at Elm Street (site DCU12) exhibited similar conditions to Deer Creek at State Road 35 during the sampling period. Temperature, conductivity and pH measured within standards or recommendations throughout the sampling period. Dissolved oxygen typically measured above the state standard (4 mg/L); however in May 2013 dissolved oxygen was low measuring 3.6 mg/L. Turbidities exceeded targets during 13 of 19 sampling events ranging from 11.1 to 202 NTU while in exceedance. Like Deer Creek at SR 35, nitrate-nitrogen concentrations in Deer Creek at Elm Street exceeded targets during 13 of 23 sampling events with all exceedances occurring in 2013 under more typical flow conditions. Total phosphorus concentrations exceeded the 0.08 mg/L target during 13 of 25 sampling events with concentrations in excess ranging from 0.089 to 2.59 mg/L. Concentrations measured greater than 2.0 mg/L during two events occurring in December 2012 and again in February 2013. Total suspended solids concentrations measured in excess of targets during 11 of 26 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 17 to 306 mg/L. *E. coli* concentrations measured above the state standard during 22 of 26 sampling events with concentrations in excess ranging from 387 cfu/100 mL to 3075 cfu/100 mL. Furthermore, total phosphorus and *E. coli* concentrations measured the highest on average of all streams monitored during the planning process.

Habitat

IDEM used the Qualitative Habitat Evaluation Index (QHEI) to evaluate habitat at one site (Country Road 1100 South in Miami County) during two assessments, while Purdue University assessed habitat once at two locations. The QHEI scores the habitat in a stream reach based on the presence or absence of specific characteristics. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in June and July of 2008, while Purdue University assessments occurred in 2012. Scores showed mixed results, in June 2008 the stream was fully in support of the aquatic life scoring 56, but in July 2008 it was no longer considered to support the aquatic life use designation scoring 41. In 2012, habitat rated fair with the two Headwaters of Deer Creek streams scoring two of the poorest habitat scores within the watershed (DCM10 scored 56; DCU12 scored 48). Poor instream cover, limited pool and riffle development and low stream gradients limit habitat in the Headwaters of Deer Creek streams.

Fish

In June of 2008, IDEM assessed the fish community in Deer Creek at its intersection with Miami County County Road 1100 South. The three most prevalent species by count were the striped shiner, longear sunfish, and the bluntnose minnow (19, 13, and 10, respectively). The IBI score was 38, rating this section of stream as poor to fair. Purdue University assessed Deer Creek at State Road 35 (DCM10) and Elm Street (DCU12) in 2012. Despite the relatively poor habitat present in the Headwaters of Deer Creek watershed streams, fish communities present at these two sites contained relatively high quality fish communities. Both sites contained high species diversity, low number of tolerant species and high percentages of intolerant species. Deer Creek at State Road 35 (DCM10) scored the highest IBI of all sites (tie).

Macroinvertebrates

The macroinvertebrate community was sampled once by IDEM in the summer of 2008 and at two sites by Purdue University in the Headwaters of Deer Creek subwatershed. The IDEM sampling event occurred at County Road 1100 South in Miami County. The mIBI score indicated that this segment was not supporting for aquatic life use rating as very poor scoring 20 using the new IDEM mIBI scoring method. The most prevalent species was Sphaerium, a moderately pollution tolerant clam species. The Purdue University events occurred at State Road 35 (DCM10) and Elm Street (DCU12). The macroinvertebrate community at State Road 35 (DCM10) contained high taxa richness but was dominated by tolerant taxa. The benthic taxa richness was very, very low (at least 11 taxa) and the sample was dominated by taxa considered tolerant of poor conditions. The mIBI (24) was tied for the lowest valued observed among sites. Deer Creek at Elm Street (DCU12) contained low benthic taxa richness and contained high densities of relatively tolerant species. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. Benthic taxa richness was moderate (at least 27 taxa), and comprised of primarily tolerant taxa.

Mussels

The INDR surveyed the mussel communities of Deer Creek at County Road 1000 East, Strawtown Pike, US Highway 31, and State Road 18. At the County Road 1000 East site, a total of nine species were identified; eight as weathered dead shell material and the other as live. Three species of mussels, two live and one weathered dead were identified at the Strawtown Pike site. The site located on US Highway 31 contained eight species of mussels; five were weathered dead shell material, one was fresh dead shell material and two live species were identified. Of the weathered dead mussel species, a state species of special concern was identified, the purple lilliput (*Toxolasmalividus*). At State Road 18, the IDNR identified 20 live mussels, the most live mussels within this subwatershed. Of those live mussels, four species were identified. Additionally, two more species were found as fresh dead shell material.

4.1.6 Headwaters of Deer Creek Subwatershed Summary

The Headwaters of Deer Creek subwatershed is comprised of 90% agricultural land, and, along with the Little Deer Creek subwatershed, has the highest percentage of agriculture land use in the watershed. Although agricultural land use is high, Headwaters of Deer Creek has the lowest percentage of potentially highly erodible soils of the ten subwatersheds. Stream bank stabilization and stream buffers are still a concern for this subwatershed, as turbidity levels were in exceedance in all sampled locations. Though fish communities consisted of low tolerance species,

macroinvertebrate communities were comprised of high tolerance species, coinciding with poor to fair habitat evaluation scores. Overall water quality is poor to fair in this subwatershed due to elevated measurements of pathogens, sediment, and nutrient levels.

4.2 South Fork of Deer Creek

The South Fork of Deer Creek subwatershed is located immediately south of the Headwaters of Deer Creek subwatershed forming the southeast border of the Deer Creek-Sugar Creek watershed. The South Fork of Deer Creek subwatershed is located in Cass, Howard, and Miami counties with the majority within Howard County. The South Fork of Deer Creek subwatershed includes the Town of Galveston. The subwatershed includes two 12-digit watersheds, Matthew Anaker Ditch-South Fork of Deer Creek (051201050403) and Manson Kingery Ditch-South Fork of Deer Creek (051201050404) and drains 25,440 acres or 40 square miles. In total, 36.1 miles of stream are present within the South Fork of Deer Creek subwatershed. None of the stream lengths within this subwatershed are listed as impaired according to IDEM's 2012 draft 303(d) list (Figure 68).

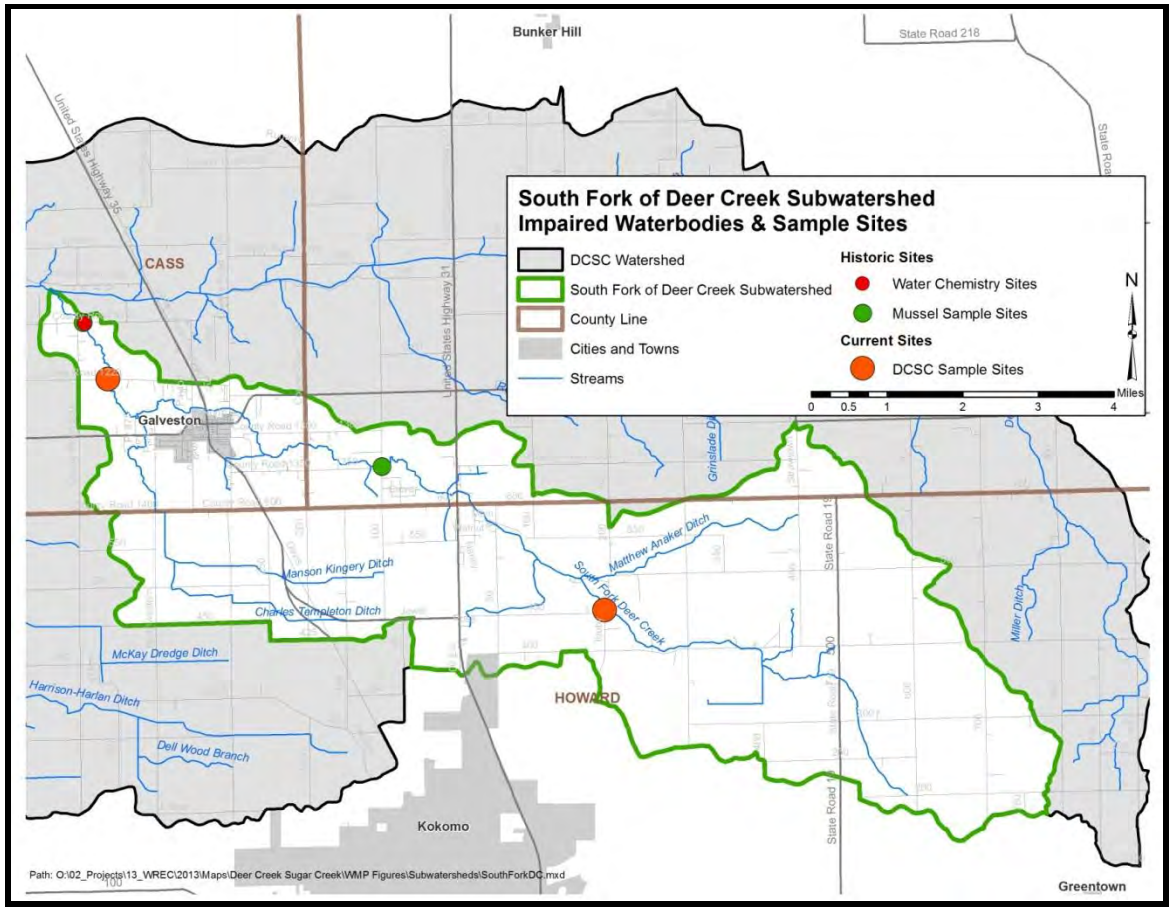

Figure 68. Impaired waterbodies and sample sites in the South Fork Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.1 Soils

Highly erodible soils cover 1,697 acres or 6.7% of the South Fork of Deer Creek subwatershed (Figure 69). Most of these soils are located adjacent to the Deer Creek stream channel within Cass County. An additional 10,458 acres, or 41% of the subwatershed, are covered by hydric soils. This indicates that the soils in the South Fork of Deer Creek subwatershed were historically in wetland uses with nearly 41% of the subwatershed soils developing under wetland conditions. Currently, less than 1% of South Fork of Deer Creek subwatershed is covered by

wetlands; this suggests that less than 8% of historic wetlands are still present. The South Fork of Deer Creek has the highest percentage of hydric soils of the ten subwatersheds.

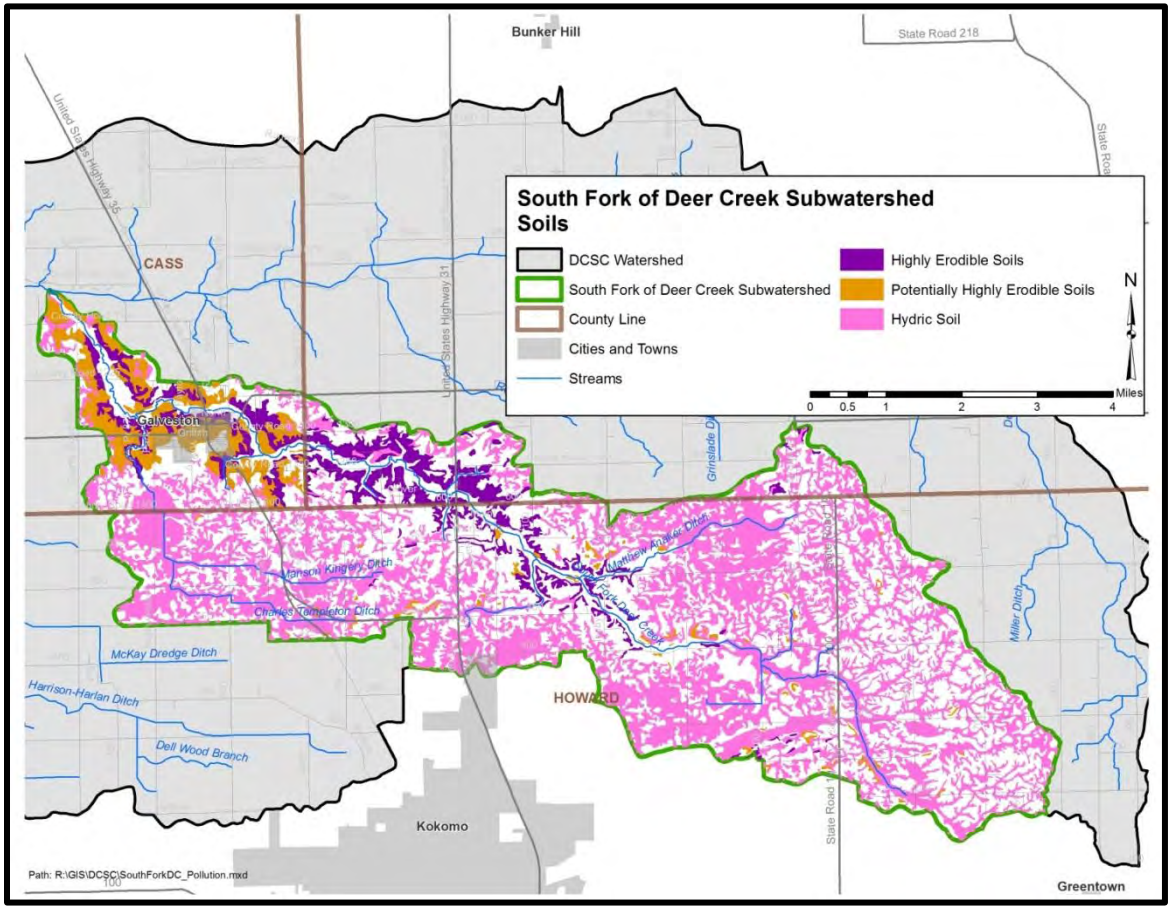

Figure 69. Properties of soils located in the South Fork of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.2 Land Use

Agriculture land uses dominates the South Fork of Deer Creek subwatershed accounting for 84% of land use. Urban land uses, including the city of Galveston, accounts for 10% of the subwatershed land use. Forest and wetland land uses account for approximately 7% of the subwatershed (3.6% and 3.1%, respectively), while open water covers less than 1% of the South Fork of Deer Creek subwatershed.

4.2.3 Point Source Water Quality Issues

As detailed above, the South Fork of Deer Creek subwatershed is predominately in agricultural land uses. There is one NPDES-permitted facility located within the subwatershed, the Galveston Municipal STP (Figure 70). Galveston operates a sewage treatment plant which serves 1,884 residents. In total, the plant treats 0.28MGD, which is treated at an advanced level, and is then discharged into the South Fork of Deer Creek (USEPA, 2008). Six leaking underground storage tanks (LUST) are located throughout the subwatershed. There is also an open dump on County Road 600 North near the Miami County-Howard County line.

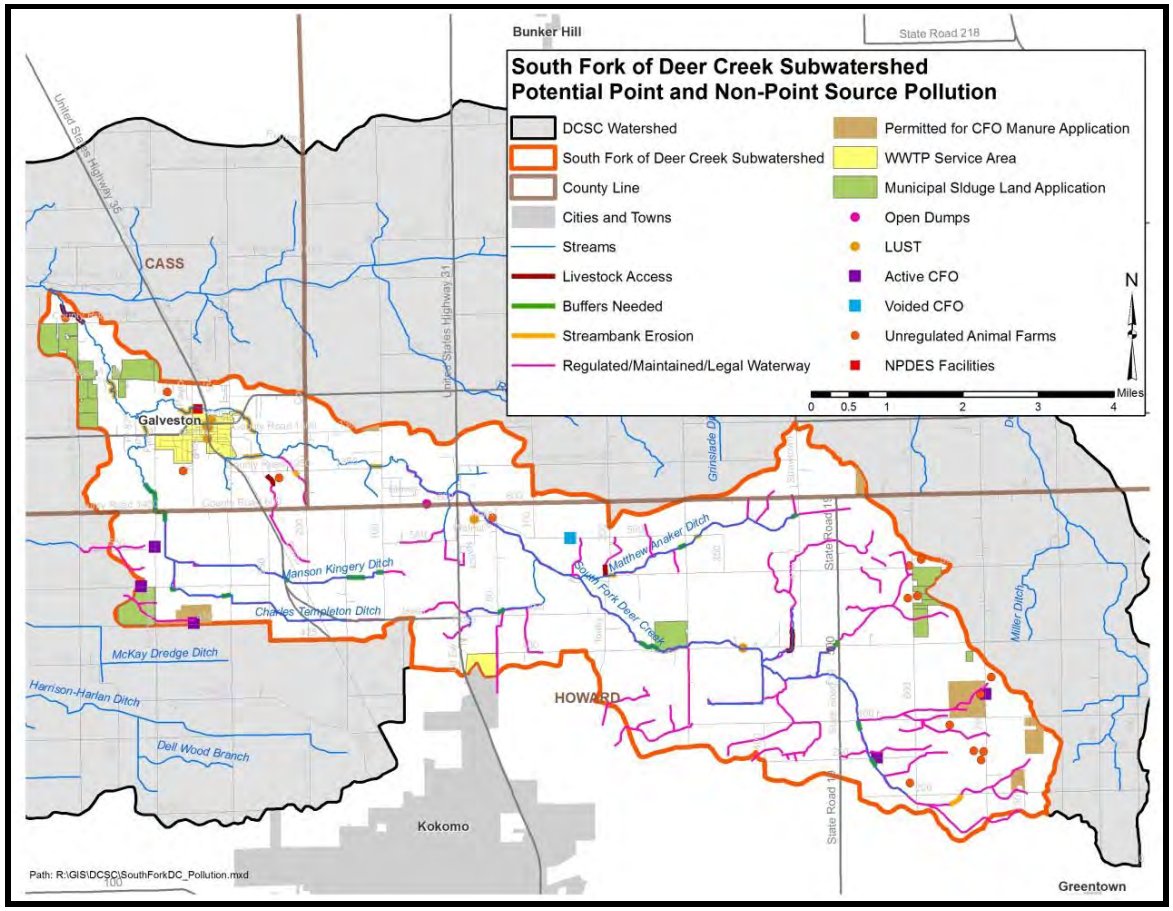

Figure 70. Point and non-point sources of pollution in the South Fork of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the South Fork of Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the South Fork of Deer Creek subwatershed. A number of unregulated animal farms are located within the Wabash River subwatershed. Approximately, 195 cattle, 20 sheep, and 23 horses are located on 17 farms. In the South Fork of Deer Creek subwatershed, there are five active CFOs. The South Fork of Deer Creek contains the lowest number of animals on CFOs. There are approximately 5,635 animals housed within this subwatershed. The South Fork of Deer Creek is also the only subwatershed to have veal calves;

there are 1,492 calves in the subwatershed. The remaining animals in the subwatershed are nursery pigs (830), finishing pigs (2,883), and sows (430). CFO permits allow for distribution of manure on approximately 348 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 9 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 348 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 716 acres within the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 2.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the South Fork of Deer Creek subwatershed. In total, nearly 4.5 miles of stream buffers and 4 miles of streambank stabilization are needed within the subwatershed.

4.2.5 Water Quality Assessment

Waterbodies within the South Fork of Deer Creek subwatershed were sampled at two locations (Figure 68). IDEM and the IDNR sampled the South Fork of Deer Creek in Cass County at County Road 1150 South for *E. coli* and mussel communities, respectively. The IDNR sampled the mussel community at a second site at County Road 400 West in Miami County. As part of the current planning project, Purdue University sampled the South Fork of Deer Creek at County Road 1125 South (site SFD9) and at Touby Road (site SFU11) (Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In the fall of 2003, IDEM sampled the South Fork of Deer Creek in Cass County on County Road 1150 South for *E. coli.* Five samples were collected over a 30 day period. *E. coli* was higher than the Indiana state standard during three of the five sampling events. *E. coli* ranged from 191.8 to 1,986.3 colonies/100 mL of sample.

In total, 19 field measurements and 25 samples were collected at South Fork Deer Creek at County Road 1125 South (SFD9). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 13 of 19 assessments measuring from 12 to 354 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 20 of 24 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during one event in March 2013 measuring as high as 10.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 16 of 25 sampling events with concentrations measuring as high as 0.312 mg/L in December 2012. Total suspended solids concentrations measured

above target levels during 8 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 15.2 to 63.6 mg/L. *E. coli* concentrations measured above the state standard during 17 of 25 sampling events. Concentrations in exceedance ranged from 261 cfu/100 mL to 1732 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations measured below the detection level only once.

South Fork Deer Creek at Touby Road (SFU11) exhibited similar conditions to South Fork Deer Creek at County Road 1125 South during the sampling period. Temperature, conductivity and pH measured within standards or recommendations throughout the sampling period. Dissolved oxygen typically measured above the state standard (4 mg/L); however in August 2012 and again in May 2013 dissolved oxygen was low measuring less than 4 mg/L. Turbidities exceeded targets during 9 of 19 sampling events ranging from 11.2 to 502 NTU while in exceedance. Like South Fork Deer Creek at County Road 1125 South, nitrate-nitrogen concentrations in South Fork Deer Creek at Touby Road exceeded targets during 16 of 23 sampling events. Nitrate-nitrogen concentrations were generally elevated throughout the sampling period with the two sampling events exceeding the state standard for drinking water (10 mg/L). Total phosphorus concentrations exceeded the 0.08 mg/L target during 18 of 26 sampling events with concentrations in excess ranging from 0.083 to 0.389 mg/L. Total suspended solids concentrations measured in excess of targets during 5 of 26 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 28.7 to 202 mg/L. *E. coli* concentrations measured above the state standard during 14 of26 sampling events with concentrations in excess ranging from 272 cfu/100 mL to 5794 cfu/100 mL.

Habitat

Purdue University assessed habitat in the South Fork Deer Creek at County Road 1125 (SFD9) and Touby Road (SFU11) in 2012. Habitat rated fully supporting in South Fork Deer Creek at Touby Road (SFU11); however, South Fork Deer Creek at County Road 1125 (SFD9) contained the poorest rated habitat of any of the Deer Creek-Sugar Creek watershed sites. South Fork Deer Creek at County Road 1125 (SFD9) score 44.75 indicating this site was not fully supporting for aquatic life. Generally, both sites contained poorly developed riffles, limited instream habitat and poor cover.

Macroinvertebrates and Fish

Purdue University assessed the macroinvertebrate and fish communities in South Fork Deer Creek at County Road 1125 (SFD9) and at Touby Road (SFU11). Macroinvertebrate community was moderate at SFU11 with low taxa richness with highly tolerant species present. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. Benthic taxa richness was very low (at least 12 taxa), and comprised of primarily tolerant taxa. Benthic taxa richness was moderate (at least 25 taxa) at SFD9, and the community was dominated by taxa considered tolerant of degraded stream conditions. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. South Fork Deer Creek at County Road 1125 (SFD9) scored the poorest IBI of all sites (30) containing low species diversity; low number of darters, minnows and sensitive species; and high percentages of tolerant species. South Fork Deer Creek at Touby Road (SFU11) also rated relatively low (36) containing poor headwater species diversity, low number of suckers, and high densities of tolerant species.

Mussels

The IDNR surveyed the mussel communities at two locations within the South Fork of Deer Creek subwatershed, County Road 1150 South (Cass) and County Road 400 West (Miami). At County Road 1150 South, a total of 17 mussel species were identified, including 13 as live samples, three as fresh dead shell materials and one as weathered dead shell material. The site located on County Road 400 West contained eight mussel species, including five alive and one of each of fresh dead, weathered dead, and subfossil shell material. Of the weathered dead mussel species, the purple Lilliput, a state species of special concern, was identified at both sites as weathered dead. Additionally, IDNR identified a second species of special concern, the wavyayed lampmussel (*Lampsilis fasciola*), as a fresh dead shell material at the County Road 1150 South site.

4.2.6 South Fork of Deer Creek Subwatershed Summary

The South Fork of Deer Creek subwatershed is dominated by 84% agricultural land use. Urban land use represents 10% of the subwatershed, mainly in the City of Galveston. This subwatershed has the highest amount of hydric soils of the ten subwatersheds; 41% of the soil is anaerobic in the upper sediment layers. South Fork of Deer Creek has the lowest number of regulated animals present and a relatively smallest amount of acreage permitted for manure distribution. Streambank erosion and stream buffering remain a concern for both the Headwaters of Deer Creek and South Fork Deer Creek subwatersheds. South Fork of Deer Creek had the lowest scoring habitat assessment of all sites sampled during water monitoring, indicating that water quality is impaired. Overall water quality is relatively poor as suspended solids, pathogen levels, and nitrogen levels all exceed state target concentrations, particularly during high flow storm events.

4.3 Deer Creek-McCloskey Ditch

The Deer Creek-McCloskey Ditch subwatershed is located immediately downstream of and receives water from the Headwaters of Deer Creek and South Fork of Deer Creek subwatersheds. The majority of its drainage area is located in Cass County with portions in Carroll and Howard counties. The watershed includes two 12-digit watersheds, Monson Ditch-Deer Creek (051201050507) and McCloskey Ditch (051201050502) and drains 28,764 acres or 45 square miles. In total, 61.6 miles of stream are present within the Deer Creek-McCloskey Ditch subwatershed. Of these, approximately 7.4 miles are considered impaired for *E. coli* and 6.1 miles are considered impaired for PCBs and mercury in fish tissue (Figure 71; IDEM, 2012).

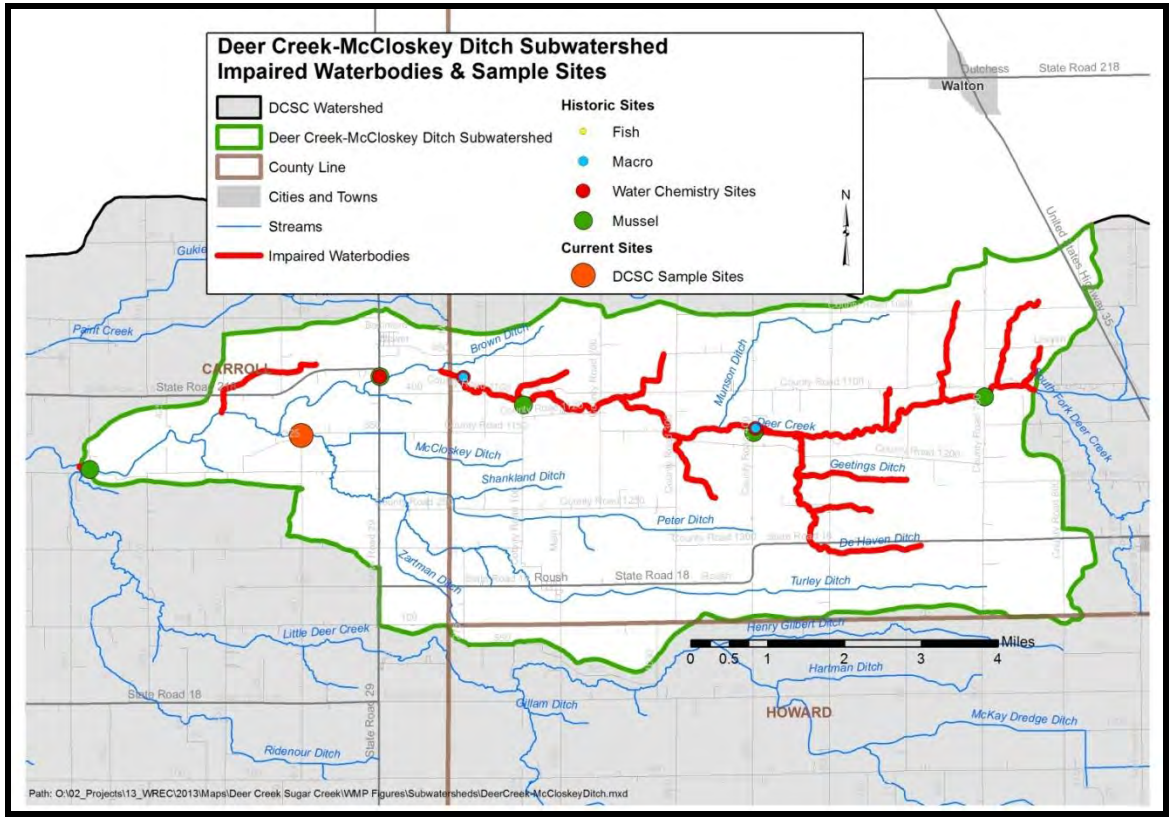

Figure 71. Impaired waterbodies and sample sites in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.1 Soils

Hydric soils cover approximately 36%, or 10,310 acres, of the Deer Creek-McCloskey Ditch subwatershed (Figure 72). Highly erodible and potentially highly erodible soils cover 3% and 15% of the watershed, respectively. These soils are located primarily along the mainstem of Deer Creek and its minor tributaries within Cass County. The Deer Creek-McCloskey Ditch subwatershed has the second highest percentage of potentially highly erodible soil in the watershed; these soils cover a total of 4,362 acres of the subwatershed. The soils in the subwatershed are rated as severely limited for septic system usage for approximately 95% of the watershed. Only about 2,060 acres or 1.5% of the watershed is actually suitable for septic tank absorption fields.

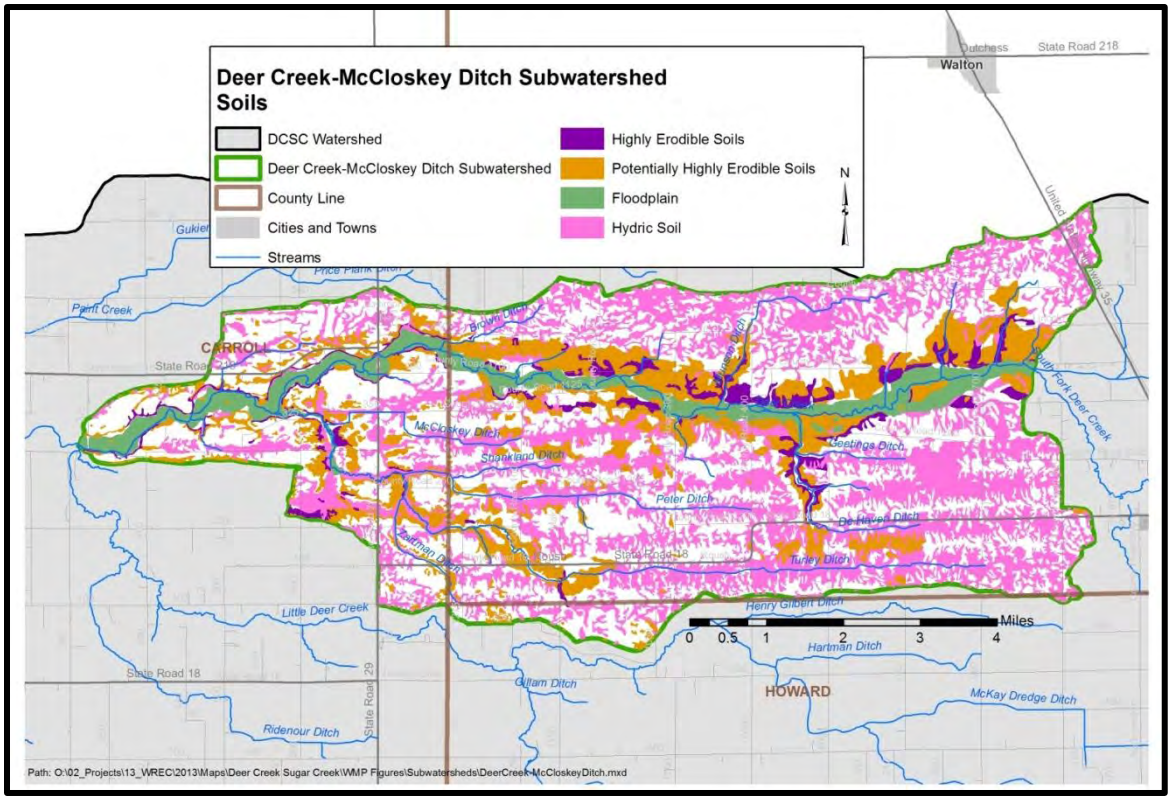

Figure 72. Properties of soils located in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.2 Land Use

Agricultural land uses dominates the Deer Creek-McCloskey Ditch subwatershed at 87%. Forests and urban land uses account for 5.6% and 5.4%, respectively. The Deer Creek-McCloskey Ditch subwatershed has approximately 3%, or 807 acres, classified as woody or emergent wetlands.

4.3.3 Point Source Water Quality Issues

There are no point source water quality issues in the Deer Creek-McCloskey Ditch subwatershed.

4.3.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Deer Creek-McCloskey subwatershed and a corn-soybean rotation dominates the agricultural land use. A number of unregulated animal farms are located within the Deer Creek-McCloskey Ditch subwatershed. Approximately, 341 cattle, 33 hogs, 65 sheep, 36 goats, and 53 horses are located on 55 farms. There are currently 12 active permitted CFOs in the subwatershed (Figure 73). The CFOs in the Deer Creek-McCloskey Ditch subwatershed contain approximately 6,130 nursery pigs, 5,534 finishing pigs, 30 sows in farrowing, 70 gestation sows, six boars, 222 sows, 3,300 swine greater than 55 pounds, and 1,200 swine less than 55 pounds. There are a total of 16,492 animals on CFOs in the Deer Creek-McCloskey Ditch subwatershed. CFO permits allow for distribution of manure on approximately 3,666 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 22 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 3,666 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is applied to approximately 6,367 acres, or 22%, of the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 7 miles of stream within the subwatershed. Streambank erosion and lack of stream buffering are also of concern within the Deer Creek-McCloskey Ditch subwatershed. In total, 17.2 miles of stream buffers and 9.5 miles of streambank stabilization are needed within the subwatershed.

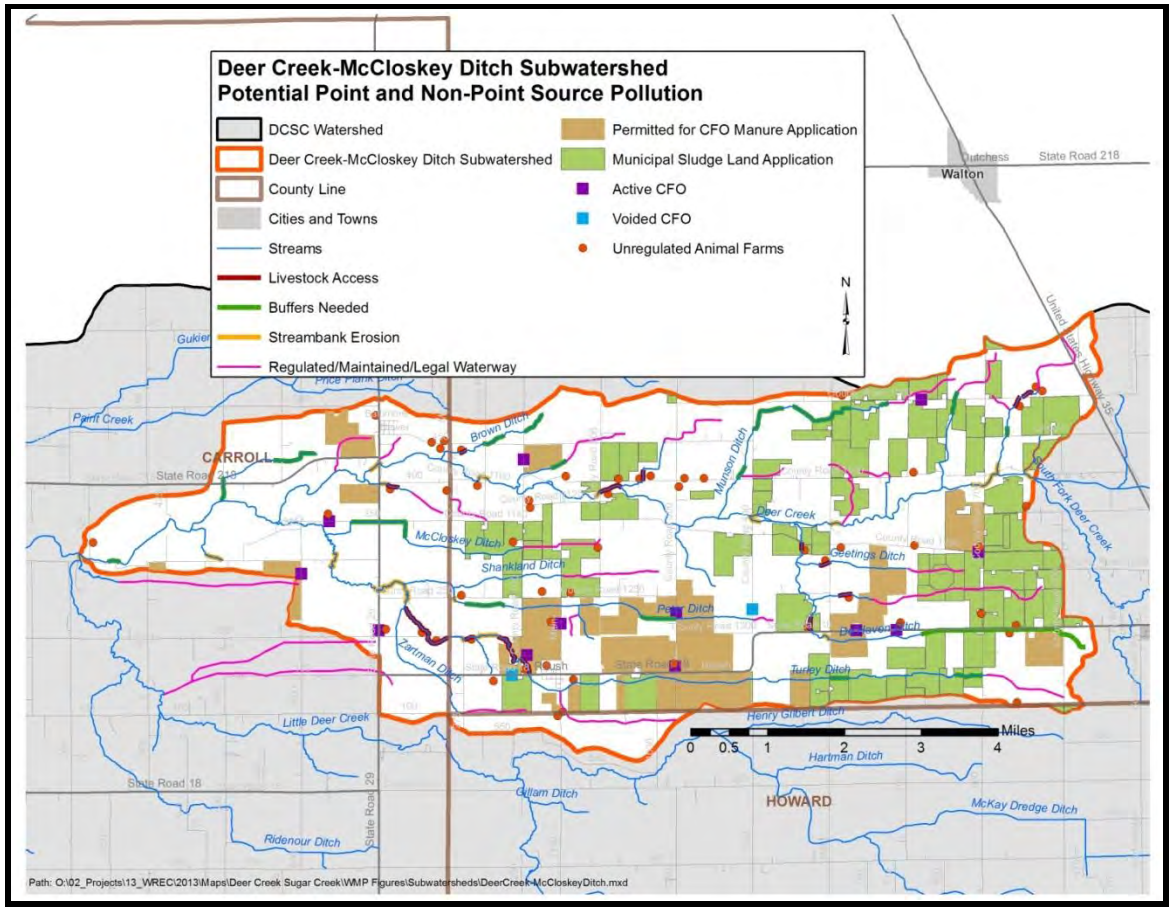

Figure 73. Non-point sources of pollution in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.5 Water Quality Assessment

Waterbodies within the Deer Creek-McCloskey Ditch subwatershed were sampled at three locations (Figure 71). Historic assessments include analysis of *E. coli* concentrations and evaluating the habitat and fish and macroinvertebrate communities in Deer Creek. The sampling sites were all located on the mainstem of Deer Creek less than six miles apart. *E. coli* samples were collected at State Road 29 in Carroll County and County Road 1100 South in Cass County. The fish and macroinvertebrate communities were also assessed at the County Road 1100 South location, while only macroinvertebrates were sampled at County Road 400 East. As part of the current planning project, Purdue University sampled McCloskey

Ditch at County Road 600 East (site MD8, Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli concentrations were measure twice at State Road 29 in Carroll County, once in 1998 and then again in 2003. In 1998, five samples were collected over a 30-day period. Four of the five samples exceeded the Indiana state standard of 235 colonies/100 mL; concentrations ranged from 220-780 colonies/100 mL. In 2003, six samples were collected with a duplicate being processed on one of the dates. Three of the six concentrations exceeded the state standard. One of the concentrations measured more than ten times the state standard measuring 2,419 colonies/100 mL. In 2008, IDEM assessed *E. coli* in Deer Creek at County Road 1100 South in Cass County. *E. coli* concentrations ranged from 192 to 2,419 colonies/100 mL; concentrations exceed state standards during three of the five times. During this assessment, IDEM collected field and nutrient water chemistry as well; parameters of concern during this sampling event included nitrogen (nitrate + nitrite) and total phosphorus. During the June sampling event, nitrogen concentrations measured almost four times the standard suggested by Dodds et al. (1998) with a concentrations of 7.4 mg/L. Total phosphorus also exceed Dodds et al (1998) suggested standard (less than 0.08 mg/L) in two of the three total phosphorus samplesmeasurering0.137 and 0.157 mg/L.

In total, 18 field measurements and 25 samples were collected at McCloskey Ditch at County Road 600 East (MD8). All temperature, conductivity, and pH measurements were within standards or recommendations. One dissolved oxygen sample in May 2013 measured below the detection level. Turbidity measured above recommended levels during 9 of 18 assessments measuring from 11.5 to 427 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 18 of 24 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during five events in January, February, March and June 2013 measuring as high as 12.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 25 sampling events with concentrations measuring as high as 0.769 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 4 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 20 to 260 mg/L. *E. coli* concentrations measured above the state standard during 16 of 25 sampling events. Concentrations in exceedance ranged from 290 cfu/100 mL to 2420 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations measured below the detection level only twice.

Habitat

Habitat assessments occurred twice at each location sampled by IDEM and once by Purdue University within the Deer Creek-McCloskey Ditch subwatershed using the Qualitative Habitat Evaluation Index (QHEI). IDEM assessed the site located on County Road 400 East in 1991 and 2003. The habitat was scored at 72 and 76, respectively. Deer Creek at SR 29 was assessed in June and July of 2008 scoring 82 in June and 72 in July. All

four of these scores suggest that Deer Creek within the Deer Creek-McCloskey Ditch subwatershed are fully supporting the designated aquatic life uses. Purdue University's assessment of McCloskey Ditch rated the second highest of all Deer Creek-Sugar Creek watershed sites scoring 70.24. This score indicates a high quality habitat; however, there was limited pool/riffle development. All five of these scores suggest that Deer Creek within the Deer Creek-McCloskey Ditch subwatershed are fully supporting the designated aquatic life uses.

Macroinvertebrates

The macroinvertebrate communities within the Deer Creek-McCloskey Ditch subwatershed were sampled three times by IDEM. The site located at County Road 400 East was sampled twice, once in 1991 and again in 2003. The macroinvertebrate community rated as slightly impaired during both assessments scoring 5.0 and 5.4, respectively. The community was dominated by *Philopotamidae*, a relatively-intolerant caddisfly family in 1991 and *Simuliidae* (fairly tolerant to pollution) in 2003. The other site sampled was IDEM assessed the macroinvertebrate community in Deer Creek County Road 1100 South in 2008. The macroinvertebrate community rated as moderately impaired on IDEM's new mIBI scoring system (score = 42) and was dominated by *Boyeriavinosa*, a moderately tolerant to pollution dragonfly. Purdue University assessed the macroinvertebrate community in McCloskey Ditch in 2012. The taxa richness of the community was one of the poorest and was dominated by taxa considered tolerant of poor conditions. The benthic taxa richness was very, very low (at least 10 taxa) and the sample was dominated by taxa considered tolerant of poor conditions. The mIBI (24) was tied for the lowest valued observed among sites. This community suggests that something other than water quality is limiting the macroinvertebrate community in McCloskey Ditch.

Fish

IDEM assessed the fish community once in the Deer Creek-McCloskey Ditch subwatershed sampling Deer Creek at County Road 1100 South in Cass County in June 2008. The IBI score rated this portion of stream as good to excellent (IBI score = 54), indicating that there was exceptional assemblage of species including some of the more intolerant species. Twenty-six species of fish were identified within this section of Deer Creek; the two most prevalent species were the central stoneroller and the northern hog sucker. Purdue University assessed the fish community in McCloskey Ditch in 2012 with the community rating as fair. The fish community contained low percentages of headwater species, high percentage of tolerant species and low percentages of carnivores and pioneer species.

4.3.6 Deer Creek-McCloskey Ditch Subwatershed Summary

Deer Creek-McCloskey Ditch is made up of 87% agricultural land use, whereas urban land use makes up a 5.4% of the total land usage. Point source pollution is not a concern in this subwatershed, as no permitted point source discharge points currently exist. Measured at 15%, this subwatershed has the second highest percentage of potentially highly erodible soil in the entire watershed, most of which is located along the mainstem of Deer Creek and its tributaries. Consequently, stream bank erosion and lack of stream buffering are issues of concern for this subwatershed. Overall water quality is fair for Deer Creek-McCloskey Ditch. In addition, habitat assessments determined this subwatershed was the second highest for fully supporting its aquatic life. However, one of the poorest taxa richness scores was measured at this location. This could indicate that something other than water quality is affecting the macroinvertebrate community at this particular sampling location.

Nutrient levels, total suspended solids, and pathogen levels all measured below detection levels for more than half of the samples and measurements taken.

4.4 Little Deer Creek

The Little Deer Creek subwatershed is located immediately south of the Deer Creek-McCloskey Ditch subwatershed forming the southern boundary of the watershed in western Howard County. The subwatershed is located in Carroll and Howard counties with a sliver in Cass County. The watershed includes two 12-digit watersheds, Henry Gilbert Ditch-Little Deer Creek (051201050501) and Little Deer Creek (051201050503) and drains 34,814 acres or 54 square miles. In total, 59.7 miles of stream are present within the Little Deer Creek subwatershed. Of these, approximately 6.4 miles are considered impaired for *E. coli* (Figure 74; IDEM, 2012).

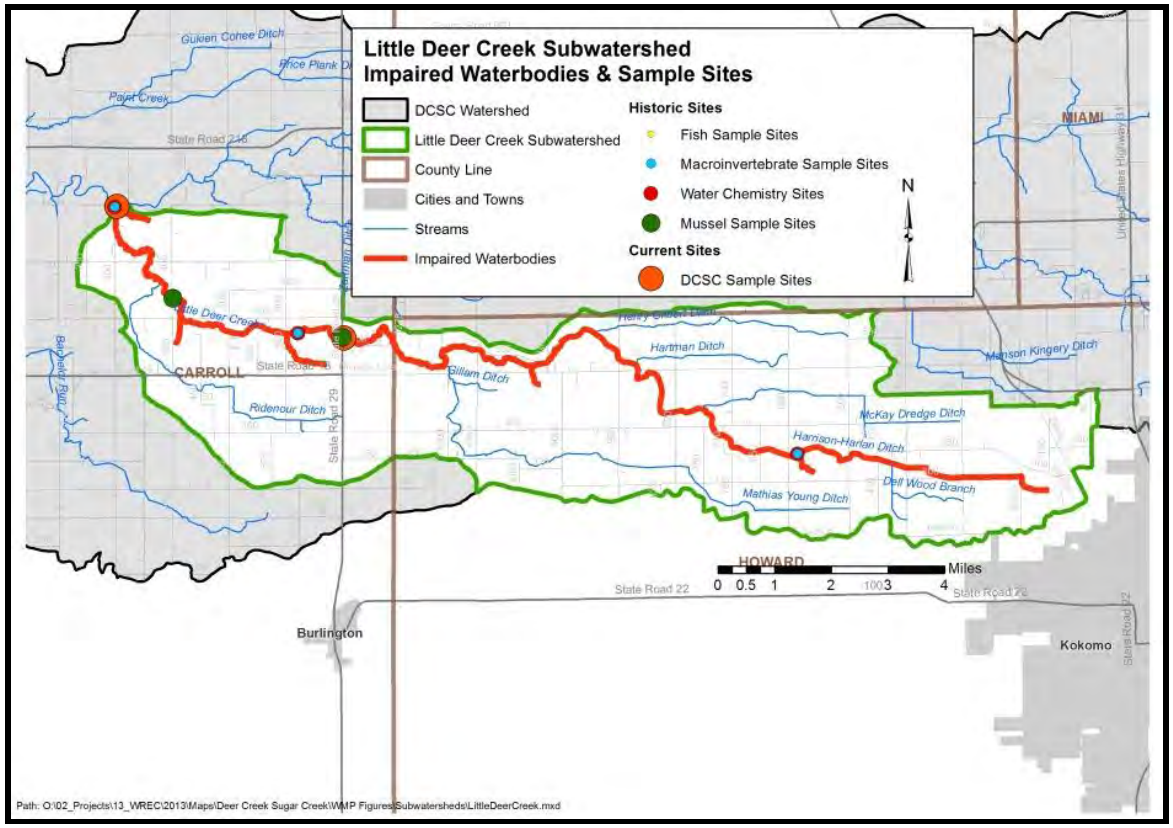

Figure 74. Impaired waterbodies and sample sites in the Little Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.4.1 Soils

Soils in the Little Deer Creek subwatershed are dominated by those that are unsuitable for use in septic treatment. Nearly 92% of the soils in the subwatershed are rated as severely limited for use in septic tank absorption fields. Highly erodible soils cover only 2.7% or 943 acres of the Little Deer Creek subwatershed, while potentially highly erodible soils cover 2,358 acres or 6.7% of the subwatershed (Figure 75). A majority of the erodible soils are located adjacent to the mainstem of Little Deer Creek. Hydric soils cover nearly 40% of this subwatershed.

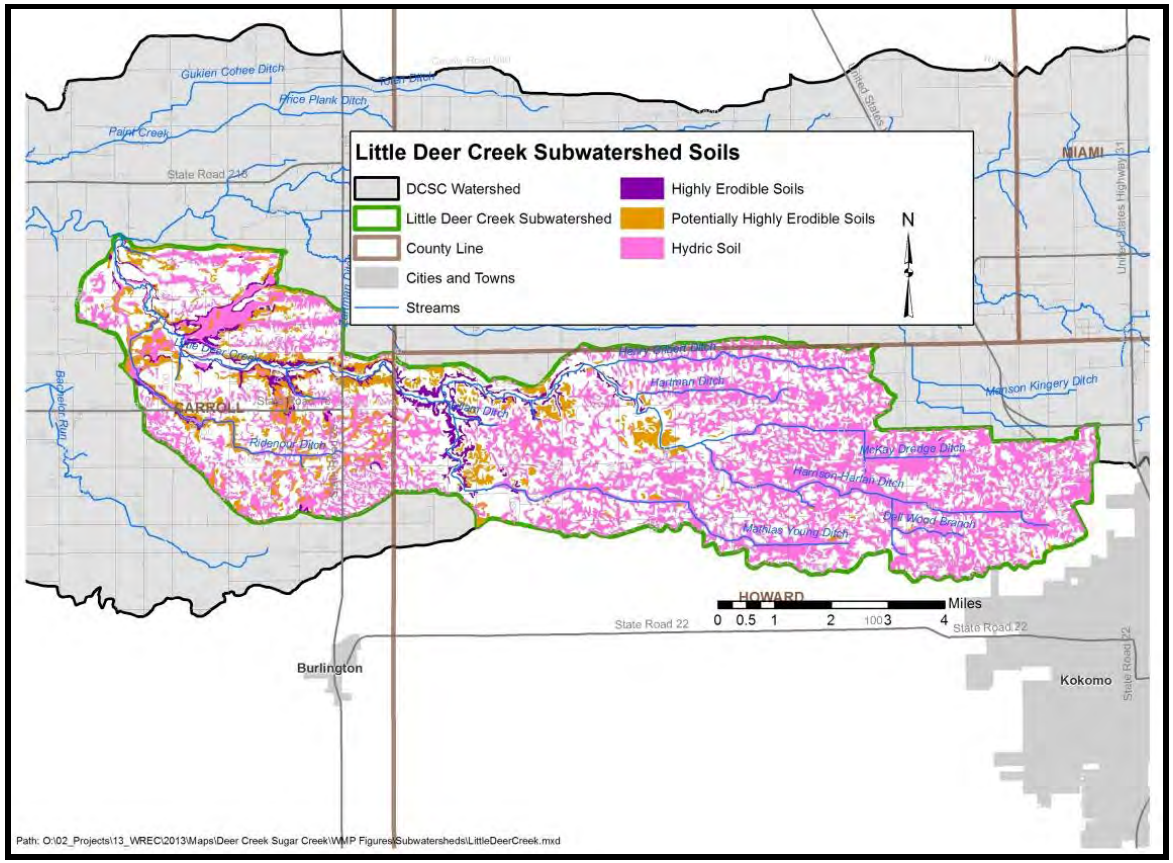

Figure 75. Properties of soils located in the Little Deer Creek subwatershed.

Data used to create this map is detailed in Appendix A

4.4.2 Land Use

Agricultural land uses account for approximately 90%, or 31,489 acres, of the subwatershed. Agricultural land uses in the Little Deer Creek subwatershed are tied for dominance with the Headwaters of Deer Creek subwatershed for the highest percent agriculture for all subwatersheds. The Little Deer Creek subwatershed also has the lowest percentage of urban land in the watershed; only 5.2% of the subwatershed is classified as developed. Natural land accounts for approximately 5% of the subwatershed.

4.4.3 Point Source Water Quality Issues

As detailed above, almost 90% of the Little Deer Creek subwatershed is classified as row crops according to land use data. There is one NPDES-permitted facility located within the subwatershed (Figure 76). The NPDES facility is Northwestern Elementary and High School located northwest of Kokomo. This facility discharges into Harrison-Harlan Ditch. There is one LUST within the subwatershed; it is located on County Road 350 North in Howard County at Northwestern Jr. Sr. High School.

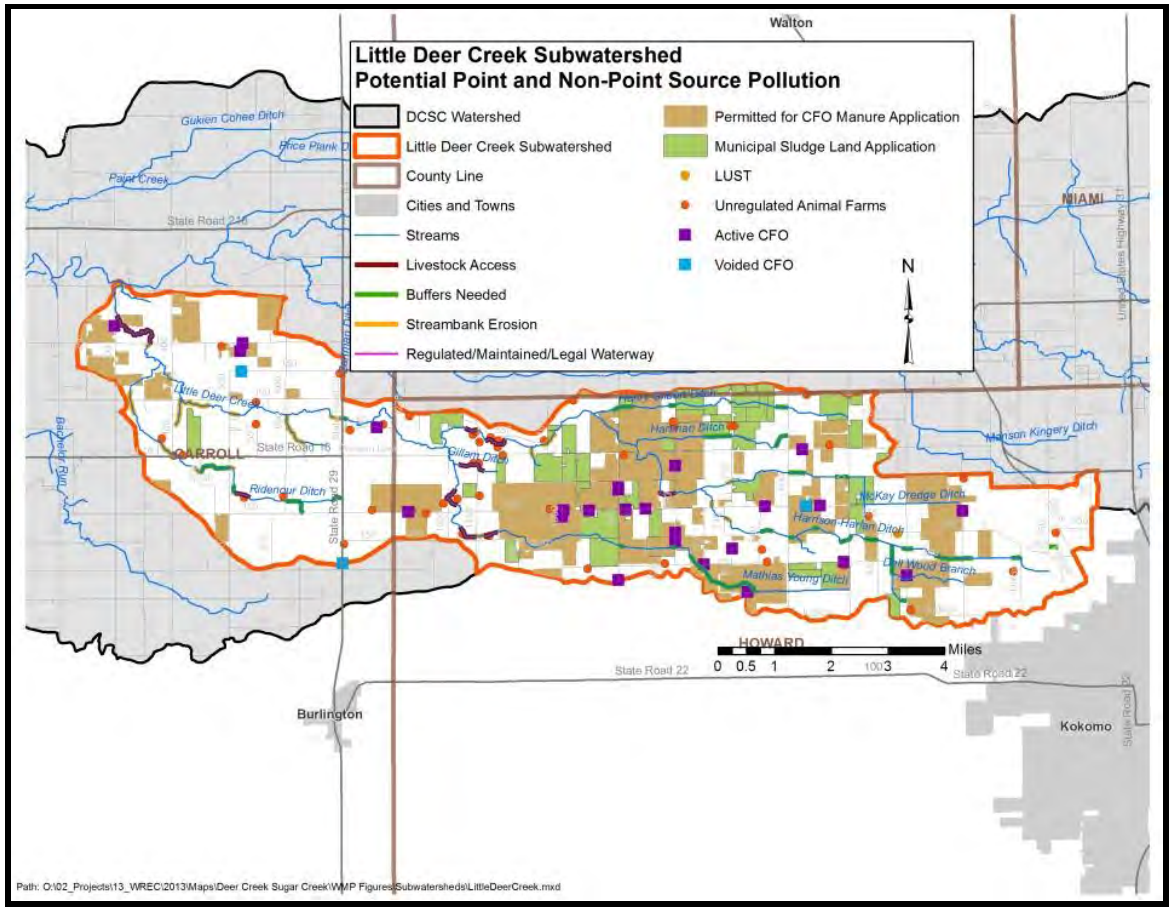

Figure 76. Point and non-point sources of pollution in the Little Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.4.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Little Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Approximately 50 unregulated animal farms are located within the Little Deer Creek subwatershed. Approximately, 193 cattle, 41 hogs, 18 sheep, 60 goats, and 70 horses are located on 51 farms in the Little Deer Creek subwatershed. There are 27 active confined feeding operations (CFO) located within the Little Deer Creek subwatershed. The Little Deer Creek subwatershed contains the third highest number of animals on confined feeding operations with approximately 39,080 animals housed in CFOs. This subwatershed is also the only one where beef cattle are housed and

contains the highest number of sows in farrowing. The Little Deer Creek subwatershed also contains nursery pigs (6,880), finishing pigs (14,378), sows (978), swine greater than 55 lbs (8,900), and swine less than 55 lbs (1,200). CFO permits allow for distribution of manure on approximately 9,553 acres or 27% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 44 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 9,553 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 4,840 acres or 14% of the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed including the Grissom Redevelopment Authority, Merrell Bros Regional Bio-solids Center, and Walton Municipal STP and from two facilities within the watershed: the A. E. Staley Manufacturing Company and the Flora Municipal STP. Livestock have access to approximately 8.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Little Deer Creek subwatershed. In total, 14.6 miles of stream buffers and 12 miles of streambank stabilization are needed within the subwatershed.

4.4.5 Water Quality Assessment

Waterbodies within the Little Deer Creek subwatershed were sampled at three locations by IDEM (Figure 74). Harrison-Harlan Ditch in Howard County on County Road 600 West was sampled for fish and macroinvertebrate communities and nutrients and field chemistry. IDEM sampled two sites on Little Deer Creek in Carroll County. Little Deer Creek at County Road 600 East was sampled as part of the rotational basin assessment and the macroinvertebrate community was evaluated. IDEM also evaluated the fish and macroinvertebrate communities, as well *E. coli* at Little Deer Creek at County Road 300 North. As part of the current planning project, Purdue University sampled water chemistry at Little Deer Creek at State Road 29 (site LDU6) and at County Road 300 North (site LDD7) Figure 45. Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli was sampled five times over a 30 day period at Harrison-Harlan Ditch at County Road 600 West during September and October of 2008. *E. coli* levels exceed the state standard during all five assessments with concentrations ranging from 307.6 to 1,414 colonies/100 mL. In 2003, *E. coli* was measured by IDEM in Little Deer Creek at County Road 300 North. *E. coli* concentrations exceeded the state standard during five of the six sampling events; however, one of the duplicates collected on September 16th (209.8 colonies/100 mL) measured below the state standard. The remaining samples ranged from 365.4 to 1,414 colonies/100 mL. As part of IDEM's watershed assessment, Little Deer Creek at County Road 600 East was sampled in July 1998. Atrazine and metolachlor both were measured at 0.4 µg/L. Nitrogen, as nitrate and nitrite, measured 6.7 mg/L which is more than three times the standard (2 mg/L) suggested by Dodds et al. (1998).

In total, 17 field measurements and 23 samples were collected at Little Deer Creek at State Road 29 (LDU6). All temperature, conductivity, dissolved oxygen, and dissolved oxygen measurements were within standards or recommendations. One pH measured at the high end of the state standard range (9) suggesting high photosynthesis rate within the stream during the December 2012 sampling event. Turbidity measured above recommended levels during 11 of 17 assessments measuring from 12.9 to 309 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 13 of 21 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during five events measuring as high at 14.3 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 22 sampling events with concentrations measuring as high as 1.42 mg/L in January 2013. Total suspended solids concentrations measured above target levels during 5 of 22 sampling events measuring as high as 159 mg/L. *E. coli* concentrations measured above the state standard during 14 of 23 sampling events. Concentrations in exceedance ranged from 281 cfu/100 mL to 1733 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations never measured below the standard.

Little Deer Creek at County Road 300 North (LDD7) exhibited similar conditions to Little Deer Creek at State Road 29 during the sampling period. Temperature, conductivity and dissolved oxygen measured within standards or recommendations throughout the sampling period. pH measured above the state standard (9.0) during the December 2012 sampling event. This suggests that high levels of photosynthesis occurred in the stream during this sampling event. Turbidities exceeded targets during 11 of 17 sampling events ranging from 10.9 to 104 NTU while in exceedance. Like Little Deer Creek at SR 29, nitrate-nitrogen concentrations in Little Deer Creek at CR 300 North exceeded targets during 16 of 23 sampling events with all exceedances occurring in 2013 under more typical flow conditions. Nitrate-nitrogen concentrations exceeded the state drinking water standard (10 mg/L) during four sampling events with concentrations as high as 13.8 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 24 sampling events with concentrations in excess ranging from 0.083 to 1.45 mg/L. Total suspended solids concentrations measured in excess of targets during 10 of 24 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 17 to 442 mg/L. *E. coli* concentrations measured above the state standard during 13 of 24 sampling events with concentrations in excess ranging from 248 cfu/100 mL to 1986 cfu/100 mL.

Habitat

IDEM used the QHEI to evaluate habitat at the same three sites detailed above during five assessments. Little Deer Creek's habitat was assessed at two sites in Carroll County, Country Road 300 North and Country Road 600 East, while Harrison-Harlan Ditch was assessed at County Road 600 West in Howard County. Little Deer Creek at County Road 300 North was evaluated twice, once in 1991 and again in 2004. The QHEI at this site scored 79 and 77 in 1991 and 2004, respectively. Little Deer Creek at County Road 600 East was assessed once in 1998 scoring 87. These are the highest QHEI scores recorded within the watershed. The scores from the two Little Deer Creek sites suggest that the stream was fully in support

of the aquatic life. The site located on Harrison-Harlan Ditch was evaluated twice, once in June2008 and again in July of 2008. The QHEI scores for this site suggest that the stream is not supporting of the aquatic life use designation scoring 43 and 27, respectively.

Little Deer Creek at State Road 29 (LDU6) and at County Road 300 North (LDD7) contained some of the highest quality habitat observed by Purdue University in 2012 scoring 65 and 74, respectively. Diverse instream habitat and well developed pool and riffle habitat characterized both sites. The most notable negative aspect of the QHEI was that the stream habitats were not as well developed and stable in the downstream site (LDD7). At the upstream site, the lower instream cover and channel morphology scores indicate unstable habitats.

Macroinvertebrates

The macroinvertebrate communities within the Little Deer Creek subwatershed were sampled three times by IDEM at the same sites detailed above. In 1991 and 2004, IDEM assessed the macroinvertebrate community in Little Deer Creek at County Road 300 North. In 1991, the macroinvertebrate community rated as slightly impaired scoring 4.2 using the old scoring method. However, in 2004 the macroinvertebrate community rated as moderately impaired with a score of 38 using the new scoring method. The community was dominated by *Elmidae* and *Hetaerinaamericana* in 1991 and 2004, respectively. *Elmidae* is a riffle beetle that is intolerant to pollution while *Hetaerinaamericana* is a dragonfly that is moderately tolerant to pollution. In 1998, IDEM assessed the macroinvertebrate community of Little Deer Creek at County Road 600 East. During this assessment, the community rated as slightly impaired scoring 5.6 using the old scoring method. The dominant specie was *Elmidae*. The macroinvertebrate community at Harrison-Harlan Ditch was sampled in 2008. The site rated as very poor and scoring 30 using the new mIBI scoring method. The dominate species collected was *Physella*, a freshwater snail which is very tolerant of pollution.

Purdue University assessed the macroinvertebrate community in Little Deer Creek at State Road 29 (LDU6) and County Road 300 North (LDD7) in 2012. The community near Little Deer Creek's mouth (LDD7) contained a high quality macroinvertebrate community with very high taxa richness. Most of the taxa observed at this site are considered intolerant to degraded conditions. The macroinvertebrate community present in Little Deer Creek at State Road 29 contained a species with modest species richness including taxa that are typically indicative of higher quality instream conditions. At the upstream site (LDU6), the mIBI score was the highest observed (54), in part reflecting the especially high benthic taxa richness (at least 82) compared to most sites. Most taxa present are considered to be intolerant of degraded conditions.

Fish

IDEM assessed the fish communities in the Little Deer Creek subwatershed twice. The first assessment occurred in 1998 at County Road 600 East in Carroll County and IDEM assessed a second site in 2008 at County Road 600 West in Howard County. During the 1998 assessment, the dominant species was the central stoneroller. The IBI score measured 40 during this assessment, which is rated as fair. In 2008, the fish community of Harrison-Harlan Ditch, a tributary of Little Deer Creek was assessed. The striped shiner was the dominant species and the IBI score was 46, which is rated as fair to good.

Purdue University assessed the macroinvertebrate community in Little Deer Creek at State Road 29 (LDU6) and County Road 300 North (LDD7) in 2012. In general, fish IBIs rated relatively moderately scoring 40 and 34, respectively. Little Deer Creek at State Road 29 contained a more modest number of species and lower numbers of sunfish and sucker species. The fish community in Little Deer Creek at State Road 29 rated as fair, while the fish community in Little Deer Creek at County Road 300 North rated as fair.

Mussels

The INDR surveyed the mussel communities at five locations within the Little Deer Creek subwatershed. Two sites were located in Carroll County at State Road 29 and County Road 325 East, while three were in Cass County at County Road 100 East, County Road 400 East, and County Road 700 East. At the State Road 29 site, a total of 17 species were identified; 13 species were found alive, two as fresh dead, and one of each weathered dead and subfossil shell material. At the Carroll County County Road 325 East site, 25 species of mussels were identified. Sixteen species were found alive, five as fresh dead and four as weathered dead shell material. Twenty species of mussels, twelve live, six fresh dead, and two weathered dead were identified at the County Road 100 East in Cass County. The site located on County Road 400 East contained 18 species of mussels; 14 live, three weathered dead, and one fresh dead shell material. The County Road 700 East site contained15 species of mussels and seven were found alive. The remaining mussels were found as weathered dead (5), subfossil (2), and fresh dead (1) shell material. All five of the sites contained at least two state species of special concern, the wavy-rayed lampmussel and purple lilliput. A third species of special concern, the kidneyshell, was found at all sites except at Deer Creek at County Road 700 East.

4.4.6 Little Deer Creek Subwatershed Summary

Little Deer Creek subwatershed is the largest subwatershed comprised of 90% agricultural land use and has the lowest urban land use percentage at 5.2% of the subwatershed. Highly erodible soils and potentially highly erodible soils make up roughly 9% of the soil portrait in the subwatershed. These soils are typically found alongside Little Deer Creek. Though temperature, conductivity and dissolved oxygen were all within standards for the sampling period, pH was elevated in two of the three sampling locations. This could suggest that increased levels of photosynthesis were occurring at the time of sampling. This subwatershed had varied results in terms of overall water quality. Two of the sites had the highest habitat assessment scores in the watershed, while Harrison-Harlan Ditch sampling site had one of the lowest. In addition, high taxa richness and species diversity were observed at the two locations other than Harrison-Harlan Ditch. Measurements suggested Harrison-Harlan Ditch also had a majority of high-tolerance macroinvertebrate communities, reinforcing the assumption that the water quality is relatively impaired at this location. Despite major discrepancies among the habitat assessments and macrointertebrate populations, the fish communities were more or less similar and all three were given a fair score. Turbidity, nutrient levels and pathogens were in exceedance in close to 50% of the samples and measurements.

4.5 Paint Creek

The Paint Creek subwatershed is located immediately north of the Deer Creek-McCloskey Ditch subwatershed forming the northern boundary of the watershed in eastern Carroll County. The majority of its drainage area is located in Carroll County with a small section in Cass County. The Paint Creek subwatershed includes the Town of Camden. The watershed includes two 12-digit watersheds, Paint Creek (051201050504) and

Monson Ditch-Deer Creek (051201050507) and drains 18,866 acres or 29 square miles. In total, 34.7 miles of stream are present within the Paint Creek subwatershed. Of these, approximately 19.4 miles are considered impaired for *E. coli* and 5.9 miles are considered impaired due to PCBs and mercury in fish tissue (Figure 77; IDEM, 2012).

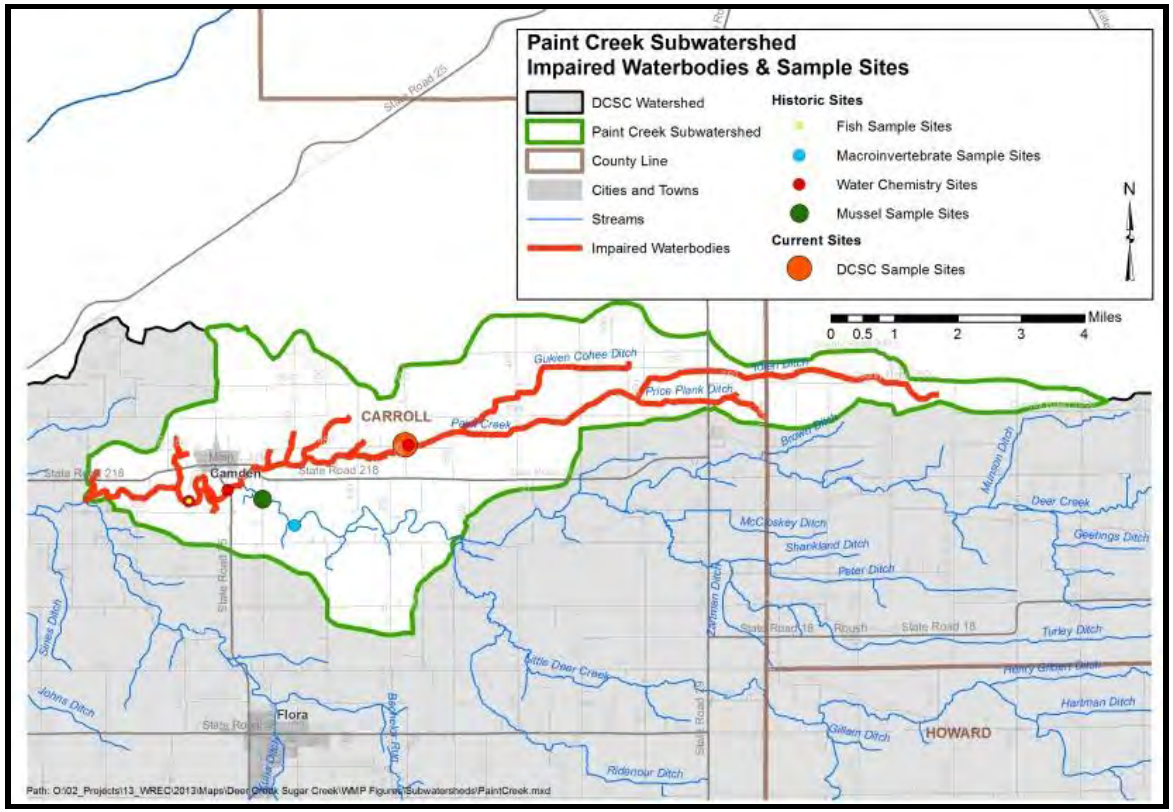

Figure 77. Impaired waterbodies and sample sites in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.1 Soils

The Paint Creek subwatershed has the second highest percentage of soil that is suitable for septic treatment, approximately 17% or 3,175 acres. However, the remaining 82% of the subwatershed is classified as severely limited and is unsuitable for septic treatment. Approximately 34% of the Paint Creek subwatershed is hydric soil. Potentially highly erodible soils cover 12% of the subwatershed and are primarily located around the mainstem of Deer Creek and where Paint Creek enters Deer Creek (Figure 78).

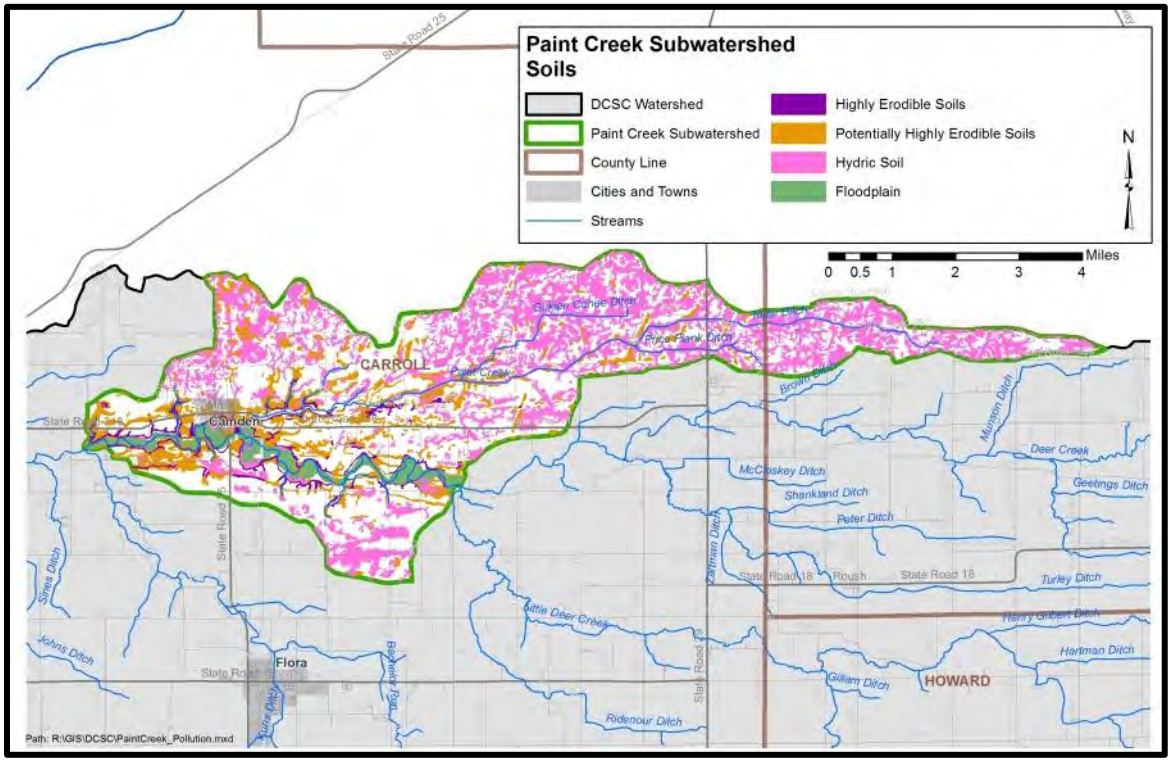

Figure 78. Properties of soils located in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.2 Land Use

Agriculture is the dominate land use in the Paint Creek subwatershed accounting for 89% of the land use. Urban land uses, including the Town of Camden, accounts for 6.3% of the subwatershed land use. Forest and wetland land uses account for 7% of the subwatershed, while open water comprises less than 1% of the subwatershed's land use.

4.5.3 Point Source Water Quality Issues

Approximately 85% of the Paint Creek subwatershed is in agricultural land uses. There is one NPDES-permitted facility located within the subwatershed, the Camden Municipal STP (Figure 79). The Town of Camden operates a sewage treatment plant which serves the town's 615 residents. In total, the plant treats 0.06 million gallons per day (MGD), which is treated at the secondary level, and is then discharged into Deer

Creek (USEPA, 2008). Two LUSTs are located throughout the subwatershed. There are no brownfields, industrial waste, or open dumps within the Paint Creek subwatershed.

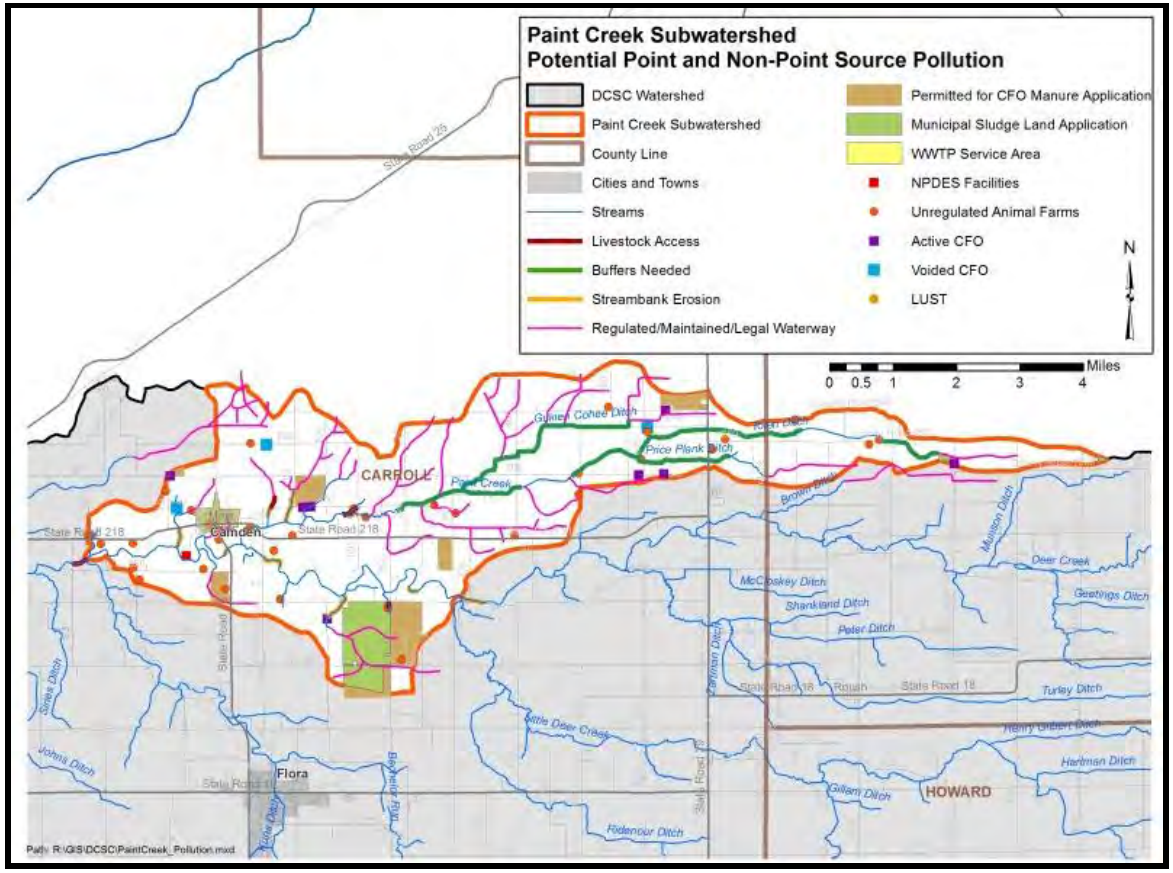

Figure 79. Point and non-point sources of pollution in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Paint Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Paint Creek subwatershed. Approximately, 141 cattle, 28 hogs, 50 sheep, 60 goats, and 32 horses are located on 33 farms. There are eight active CFOs within the subwatershed. The Paint Creek subwatershed contains approximately

11,082 animals housed in the CFOs. There are 6,050 nursery pigs, 4,650 finishing pigs, and 382 sows. The CFO manure is being distributed on approximately 488 acres. CFO permits allow for distribution of manure on approximately 488 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 9 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 488 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

In the Paint Creek subwatershed, municipal sludge is applied to 627 acres; the majority of the sludge is applied southwest of Camden. The only industry that is permitted to apply municipal sludge within the Paint Creek subwatershed is the Grissom Redevelopment Authority. Livestock have access to approximately 1.2 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Paint Creek subwatershed. In total, 24.2 miles of stream buffers and 5.7 miles of streambank stabilization are needed within the subwatershed.

4.5.5 Water Quality Assessment

Within the Paint Creek subwatershed, samples have been collected at five locations within Carroll County (Figure 77). Three of the sites were located on the mainstem of Deer Creek, while two were located on Paint Creek. Historic assessments included the collection of *E. coli*, fish, and macroinvertebrates by IDEM and mussel communities by the IDNR. *E. coli* samples were collected in Paint Creek at County Road 225 East and in Deer Creek at County Road 300 North, Cemetery Road, and State Road 75. The fish and macroinvertebrate communities were also assessed in Deer Creek at County Road 300 North, while only fish were sampled in Deer Creek at Cemetery Road. The mussel community of Deer Creek was surveyed at County Road 00 in Carroll County. As part of the current planning project, Purdue University sampled water chemistry in Paint Creek at County Road 450 North (site PC5, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

As part of the basin assessment program performed by IDEM, three sites within the Paint Creek subwatershed were sampled and only additional site was sampled for *E. coli.* In 1998, a variety of water chemistry parameters were assessed in Paint Creek located on County Road 225 East; concerning parameters include pesticides, nitrogen, and total phosphorus. A variety of pesticides measured above the detection limit including atrazine, clomazone, and metolachlor. Atrazine levels were at or exceed the maximum contaminant level (MCL) for finished drinking water (0.3 µg/L).The MCL for finished drinking water is used as a guide since there is not a standard for surface water. Nitrogen and total phosphorus measured higher than suggested standard concentration. Nitrogen measured more than three times the suggested standard at 6.2 mg/L and total phosphorus was measure approximately 0.04 mg/L greater than the standard at0.12 mg/L. In 2003, Deer Creek at County Road 300 North and at Cemetery Road were sampled as part of the basin assessment for various water chemistry parameters. The only parameter of concern for both sites was nitrogen. In Deer Creek at County Road 300 North in Carroll County, nitrogen concentrations exceed the suggested standard during every sampling event with concentrations ranging from 2.4 to 3.5 mg/L. In Deer Creek at Cemetery Road, nitrogen concentrations also exceeded the standard during every sampling event. Concentrations ranged from 2.5 to3.7 mg/L. In 2003, *E. coli* concentrations were measure

five times over a 30-day period in Deer Creek at State Road 75.*E. coli* concentrations exceed the state of Indiana's standard during three of the five times with concentrations ranging from 308 to 1,203 colonies/100mL.

In total, 18 field measurements and 25 samples were collected in Paint Creek at County Road 450 North (PC5). All temperature, conductivity, and pH measurements were within standards or recommendations. One dissolved oxygen sample in August 2012 measured below the detection level. Turbidity measured above recommended levels during 12 of 18 assessments measuring from 10.9 to 67.1 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 15 of 23 sampling events. All of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during six events in January, February, March, April, and June 2013 measuring as high as 17.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 25 sampling events with concentrations measuring as high as 1.69 mg/L in January 2013. Total suspended solids concentrations measured above target levels during 4 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.2 to 504 mg/L. *E. coli* concentrations measured above the state standard during 19 of 25 sampling events. Concentrations in exceedance ranged from 275 cfu/100 mL to 2196 cfu/100 mL. Nitrate-nitrogen and total suspended solids concentrations in Paint Creek were the second highest average concentrations at all sites within the Deer Creek-Sugar Creek watershed.

Habitat

In 2003, habitat was assessed three times by IDEM and once by Purdue University within the Paint Creek subwatershed using the QHEI. Deer Creek at County Road 300 rated as excellent with a score of 95. Deer Creek at Cemetery Road was sampled twice on back-to-back days in August 2003. The QHEI scored 95 on the first day and dropped to 87 on the second day. Paint Creek at County Road 450 North (PC5) rated 55.5. All four scores suggest that the waterbodies within the Paint Creek subwatershed are fully supporting the designated aquatic life uses. During the most recent assessment, the overall QHEI score (56) was on the low side of good, and bank erosion and riparian development at the site are both poor. Further, there was little to no development of riffle and run habitat.

Macroinvertebrates

The macroinvertebrate community within the Paint Creek subwatershed was sampled once by IDEM and once by Purdue University. Sampling occurred once in at Deer Creek at County Road 300 North by IDEM and once by Purdue University in Paint Creek at County Road 450 North (PC5). The Deer Creek macroinvertebrate community rated as moderately impaired rating a mIBI score of 2.4. The community was dominated by other *Chironomidae* whose tolerance for pollution ranges from fairly tolerant to very tolerant. The Paint Creek macroinvertebrate community was dominated by very tolerant taxa and contained low taxa richness. The community rated very poor. The mIBI score (40) was moderate compared to all other sites, although the benthic community was very taxa poor (at least 17) and dominated by taxa that are more typical of low quality sites.

Fish

IDEM assessed the fish communities of Deer Creek within the Paint Creek subwatershed three times at two locations during 2003. Sampling occurred once at County Road 300 North and twice at Cemetery Road. IBI scores ranged from 48 to 50 during all three events indicating a good fish community that is diverse, contains many trophic levels, and possesses pollution intolerant species. The most prevalent species at the Cemetery Road site was the longear sunfish, while the black redhorse was most prevalent at the County Road 300 North site.

Purdue University assessed the fish community in Paint Creek at County Road 450 North in 2012. The community contained low numbers of suckers, high percentages of tolerant species and low percent pioneer species. This site tied for the second lowest IBI score (34) and overall contained one of the poorest communities. The percent tolerance was elevated with tolerant species comprising 31% of the community in this reach of Paint Creek.

Mussels

The IDNR surveyed the mussel community at one site within the Paint Creek subwatershed. The site was located on Deer Creek at County Road 00. A total of 18 species were identified at this site; 16 were found dead as weathered dead (8), fresh dead (4), or subfossil (4) shell material and two species were found alive. Three state species of special concern were identified at this location. Weathered dead shell material of the wavy-rayed lampmussel and the purple lilliput and subfossil shell material of the kidney shell were collected.

4.5.6 Paint Creek Subwatershed Summary

Paint Creek subwatershed is comprised of 89% agricultural lands. Urban land usage is the second most prevalent practice, as it forms 6.3% of the remaining land and includes the Town of Camden. Highly erodible soils cover 12% of the subwatershed and are typically located alongside the mainstem of Deer Creek in addition to where Paint Creek enters Deer Creek. All temperature, conductivity, pH, and dissolved oxygen measurements were within standards or recommendations. Problem areas for Paint Creek subwatershed include turbidity and *E. coli*, which exceeded targets in close to 50% of the samples and measurements. Additional concerns include nitrogen and pesticides. Nitrogen levels were measured at three times the suggested standard in one event, and were measured above the suggested standard in all sampling events. Three pesticides also tested above the maximum containment level for drinking water in this subwatershed. Habitat assessments suggest that the waterbodies of Paint Creek are fully supporting aquatic life, though macroinvertebrate samples were dominated by very tolerant taxa and low taxa richness. Further fish samples reinforced the macroinvertebrate sample findings. This site tied for second for lowest mIBI score and contained one of the poorest macroinvertebrate communities in the watershed. Contrary to the macroinvertebrate data, the fish community scored high IBI numbers and contained high species richness and very intolerant fish species.

4.6 Bachelor Run

The Bachelor Run subwatershed is the most western subwatershed that drains into Deer Creek. It drains portions of Carroll and Howard counties. The Bachelor Run subwatershed forms part of the southern border of the Deer Creek-Sugar Creek watershed and includes the Town of Flora. The subwatershed includes two 12-digit watersheds, Headwaters Bachelor Run (051201050505) and Kuns Ditch-Bachelor Run (051201050506) and drains 23,032 acres or 36 square miles. In total, 25.4 miles of stream are present within the Bachelor Run subwatershed. Of these, approximately 16 miles have been listed on the 2012 draft 303(d) Impaired Waterbodies List for E. coli (Figure 80).

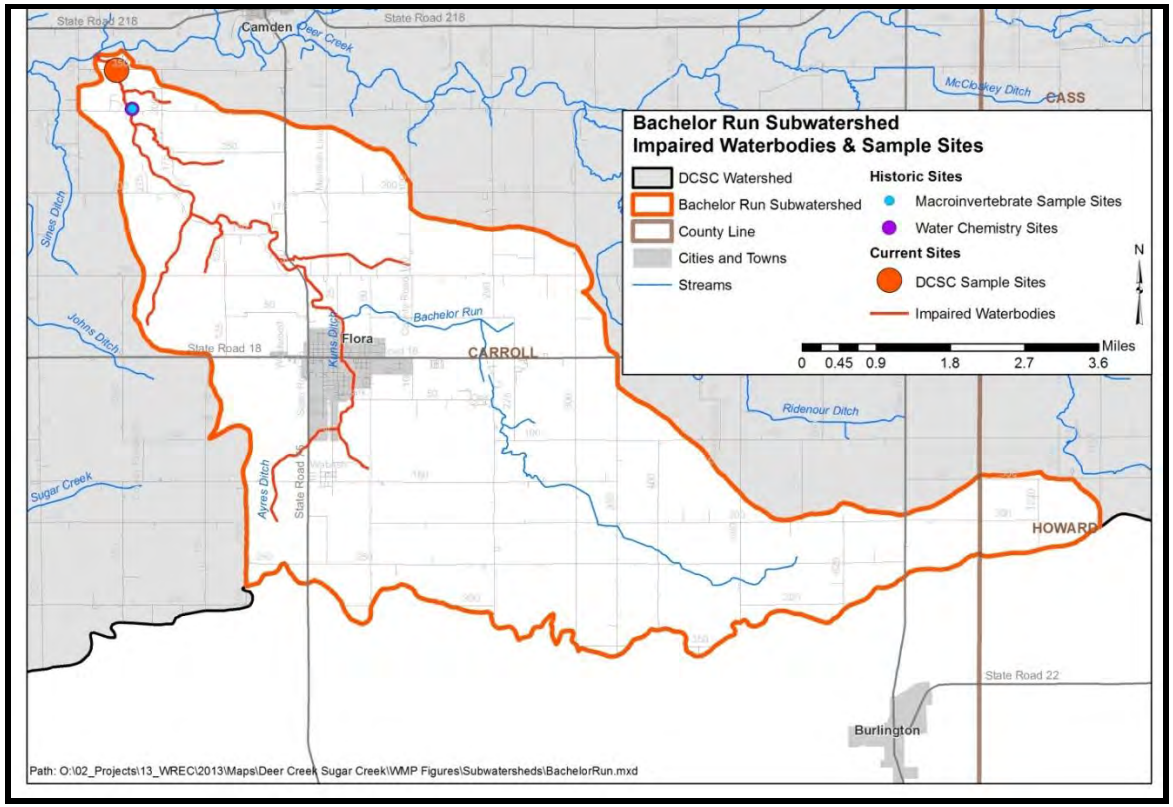

Figure 80. Impaired waterbodies and sample sites in the Bachelor Run subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.1 Soils

Soils in the Bachelor Run subwatershed are dominated by areas formed under wetland conditions. In total, 8,263 acres or 35.8% of the subwatershed are covered by hydric soils. This indicates that the soils in the Bachelor Run subwatershed were historically in wetland uses. Currently, only 1% of the subwatershed is covered by wetlands; this suggests that less than 3% of historic wetlands are still present in the Bachelor Run subwatershed. Highly erodible soils cover 320 acres or 1.4% of the Bachelor Run subwatershed; this is the lowest percentage of highly erodible soils in the ten subwatersheds (Figure 81). The highly erodible soils are primarily located along Bachelor Run and Kuns Ditch.

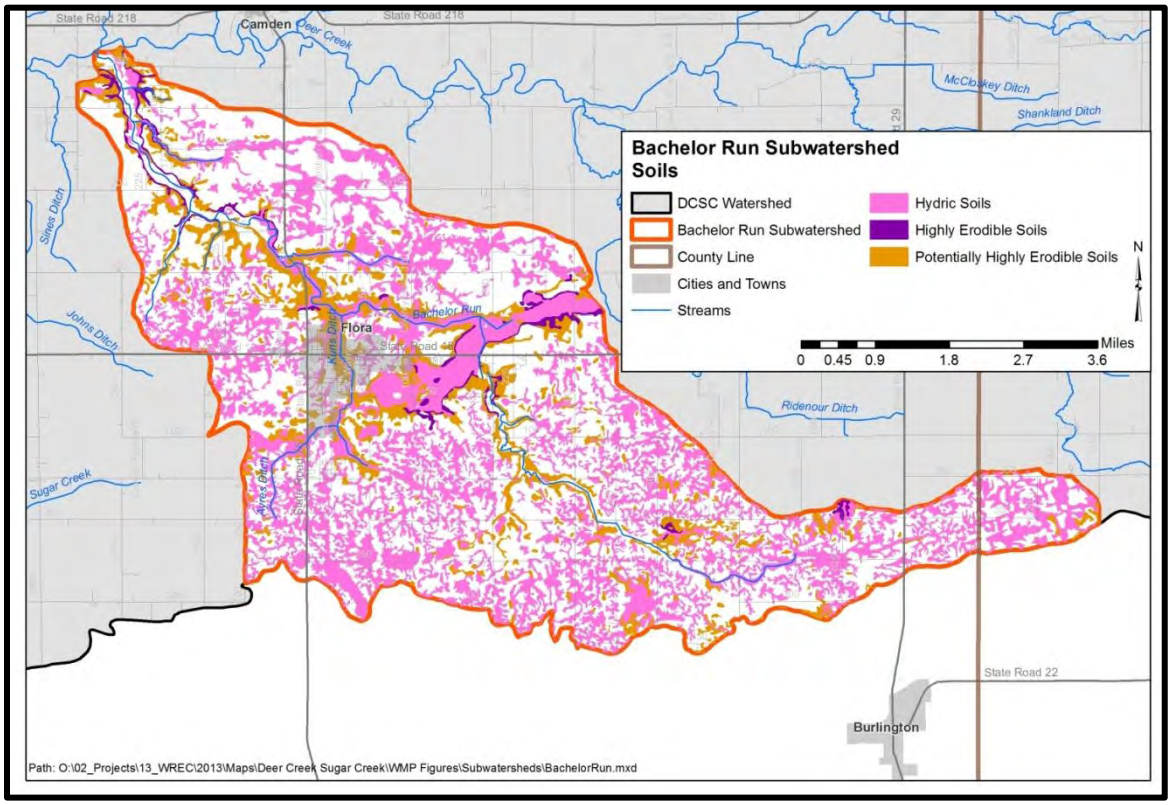

Figure 81. Properties of soils located in the Bachelor Run subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.2 Land Use

Agriculture land uses dominate the Bachelor Run subwatershed. Cultivated crops and pasture/hay account for 87% of land use. Urban land uses including the Town of Flora account for 7.8% of the subwatershed land use. Forest and wetland land uses account for only 3% of the subwatershed, while open water covers less than 0.1% of the Bachelor Run subwatershed.

4.6.3 Point Source Water Quality Issues

As detailed above, much of the Bachelor Run subwatershed is in agricultural land uses. Three NPDES-permitted facilities are located within the subwatershed (Figure 82). Two of the sites service the Town of Flora, Flora Municipal STP and the Flora Water Works. The Flora Municipal STP serves the town's approximately 2,227 residents. In total, the plant treats 0.428 MGD, which is treated at the secondary level, and is then discharged into Bachelor Run, while the Flora Water Works discharges into Kuns Ditch (USEPA 2008). The third NPDES-permitted facility is the Briggs Industries, INC (SAYCO); this facility discharges to the Flora Municipal STP. Seven leaking underground storage tanks (LUST) are located within the Town of Flora. There are also two brownfields are located on or adjacent to State Road 18 in Flora. Additionally, there is also an industrial waste site located on State Road 75 within the limits of the Town of Flora.

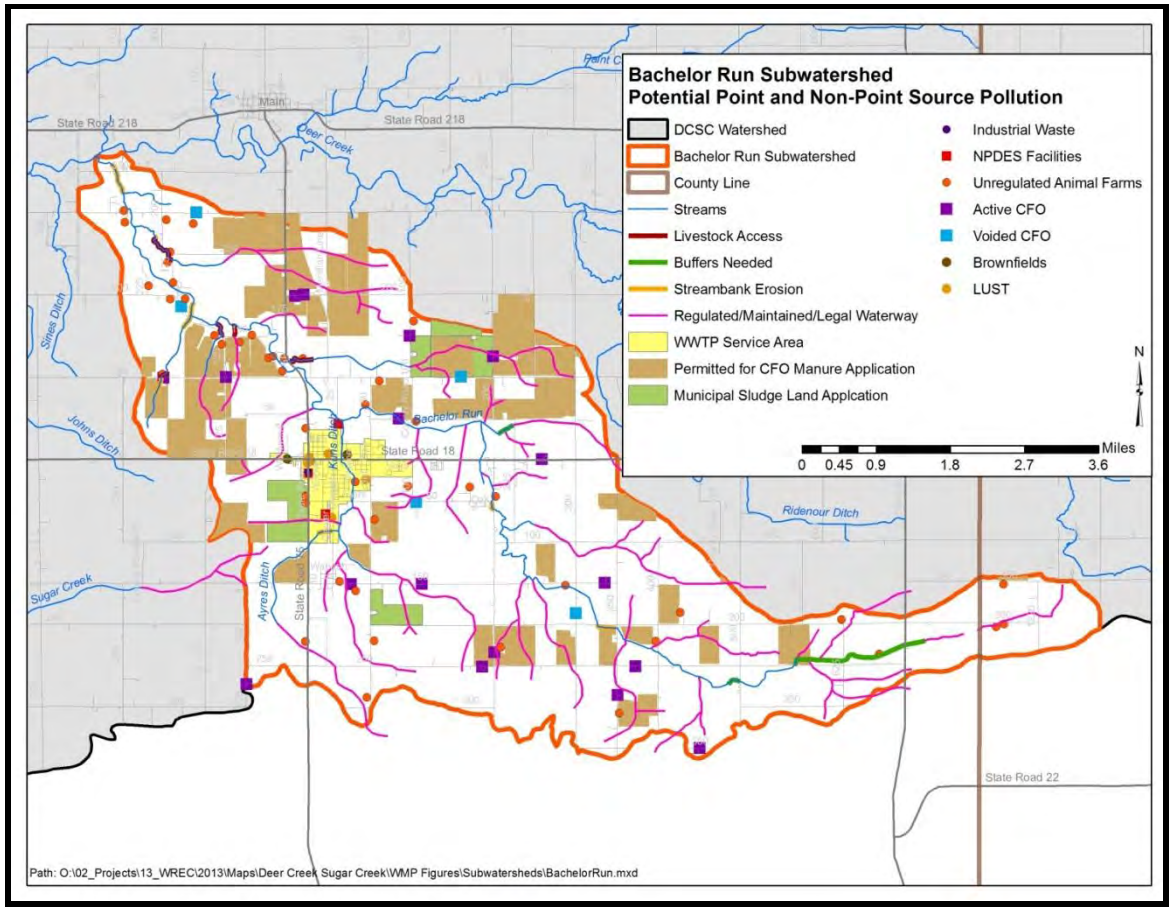

Figure 82. Point and non-point sources of pollution in the Bachelor Run subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Bachelor Run subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Bachelor Run subwatershed. Approximately, 184 cattle, 30 hogs, 51 sheep, 31 goats, and 55 horses are located on 47 farms. Agricultural land uses dominates the Bachelor Run subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, 17 CFOs are scattered throughout the subwatershed. The CFOs in the Bachelor Run subwatershed contain approximately 28,025 animals. The remaining animals are nursery pigs (2,820), sows (744), and swine greater than 55 pounds (21,800). The CFO

manure is being distributed on approximately 1,938 acres. CFO permits allow for distribution of manure on approximately 1,938 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 55 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,938 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Livestock have access to approximately 2.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Bachelor Run subwatershed. In total, 4.2 miles of stream buffers and 3 miles of streambank stabilization are needed within the subwatershed.

4.6.5 Water Quality Assessment

Within the Bachelor Run subwatershed, IDEM assessed water quality at one location, County Road 300 North. Historic assessments included the collection of *E. coli* and macroinvertebrates. *E. coli* was sampled five times from September to October in 2003. Macroinvertebrates were sampled twice, once in 1991 and again in 1998. As part of the current planning project, Purdue University sampled water chemistry in Bachelor Run at County Road 350 North (site BR4, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli concentrations measured in excess of the state standard for more than 50% of samples collected at Bachelor Run. Dissolved oxygen, total coliform, pH, specific conductivity, temperature, and turbidity were also measured when samples were collected for *E. coli* analysis. Turbidity was the only parameter that exceeded the target level during one of the four sampling events.

In total, 18 field measurements and 26 samples were collected at Bachelor Run at County Road 350 North (BR4). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH samples measured outside the state standard range (9.0 mg/L) suggesting that high levels of photosynthesis occurred during the December 2012 and April 2013 sampling events. Turbidity measured above recommended levels during 11 of 18 assessments measuring from 12.8 to 150 NTU. The highest turbidity measurements occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 22 of 24 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during seven events in January, February, March and June 2013 measuring as high as 15.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 10 of 25 sampling events with concentrations measuring as high as 0.589 mg/L in March 2013. Total suspended solids concentrations measured above target levels during 7 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.4 to 59.3 mg/L. *E. coli* concentrations measured above the state standard during 9 of 26 sampling events. Concentrations in exceedance ranged from 248 cfu/100 mL to 2187 cfu/100 mL.

Habitat

Habitat was assessed twice by the IDEM and once by Purdue University within the Bachelor Run subwatershed using the Qualitative Habitat Evaluation Index (QHEI). The QHEI scores habitat within a reach based on the presence or absence of specific characteristic. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in 1991 and 1998 with both conducted in Bachelor Run at County Road 300 North, while Purdue University assessed habitat at County Road 350 North (BR4). Scores of 48 and 57, respectively, indicate that the habitat in 1991 was not fully supporting the stream's designated aquatic life use; however, scores recorded in 1998 and 2012 indicate that the quality of habitat was good and the stream was supporting the designated aquatic life use. During the most recent assessment, the QHEI score (59) was good, although the channel morphology portion of the index was scored low, suggesting low microhabitat stability. There was also little instream cover at the site based on this portion of the QHEI.

Macroinvertebrates and Fish

The macroinvertebrate community within Bachelor Run was sampled twice by IDEM and once by Purdue University. IDEM sampling occurred once in 1991 and again in 1998 with both sampling events occurring at County Road 300 North; Purdue University sampling occurred in 2012 at County Road 350 North (BR4). The macroinvertebrate community rated as slightly impaired during both IDEM assessments scoring 4.6 and 4.2, respectively. The community was dominated by *Hydroptilidae*, a relatively-tolerant caddisfly family in 1991 and *Baetidae* (intolerant to pollution) and other *Chironomidae* (fairly-very tolerant to pollution) in 1998. The 2012 assessment utilized IDEM's new scoring method. The macroinvertebrate community was low in taxa richness, possessing 30 species of macroinvertebrates. Most identified taxa represented ubiquitous taxa that are common to sites of moderate water quality. The mIBI score was moderately high (48), although the benthic invertebrate community exhibited low taxa richness (at least 24) and there were only a few taxa considered to be typical of higher quality sites.

Purdue University assessed the fish community in 2012. The fish community rated fair scoring 36 points. Low numbers of suckers, high percentage of tolerant individuals and moderate species diversity suggest that the fish community in Bachelor Run is fair.

4.6.6 Bachelor Run Subwatershed Summary

Bachelor Run subwatershed is comprised of 87% agricultural land. Urban land use makes up 7.8% of the remaining land. The Town of Flora is situated in the middle of the subwatershed and contains 3 NPDES facilities and numerous other potential point source pollution sources. This subwatershed also has the greatest number of CFOs and regulated animals. Overall, temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two measurements of pH were elevated during two separate sampling events. This could suggest that photosynthesis was increased at the time of sampling. Additionally, turbidity was measured above state standards more than 50% of the sampling events. Nitrogen could be a cause of particular concern in this subwatershed. Of 24 sampling events, 22 samples measured nitrogen levels to exceed target levels. During seven sampling events, the nitrogen levels were found to exceed state drinking levels. Phosphorus, on the other hand, is not of particular concern in this subwatershed. Though Bachelor Run contains numerous points of pollution concern, it remains comparable, if not less impaired, than surrounding subwatersheds. The habitat was scored as slightly impaired due to a mix

of not tolerant and high tolerance macroinvertebrates. The fish community reflects the macroinvertebrate community, as it also has a mix of moderate and tolerant species.

4.7 Deer Creek

The Deer Creek subwatershed represents the mainstem of Deer Creek, Robinson Branch, and these converge into the Wabash River. The Deer Creek subwatershed is located in the western portion of the watershed. The entire subwatershed's drainage area is located in Carroll County. The Deer Creek subwatershed includes the Town of Delphi. The subwatershed drains one 12-digit watershed, Robinson Branch-Deer Creek (051201050508) and covers 25,530 acres or 39 square miles. In total, 42.3 miles of stream are present within the Deer Creek subwatershed. Of these, approximately nine miles are considered impaired for *E. coli and* PCBs in fish tissue (Figure 83).

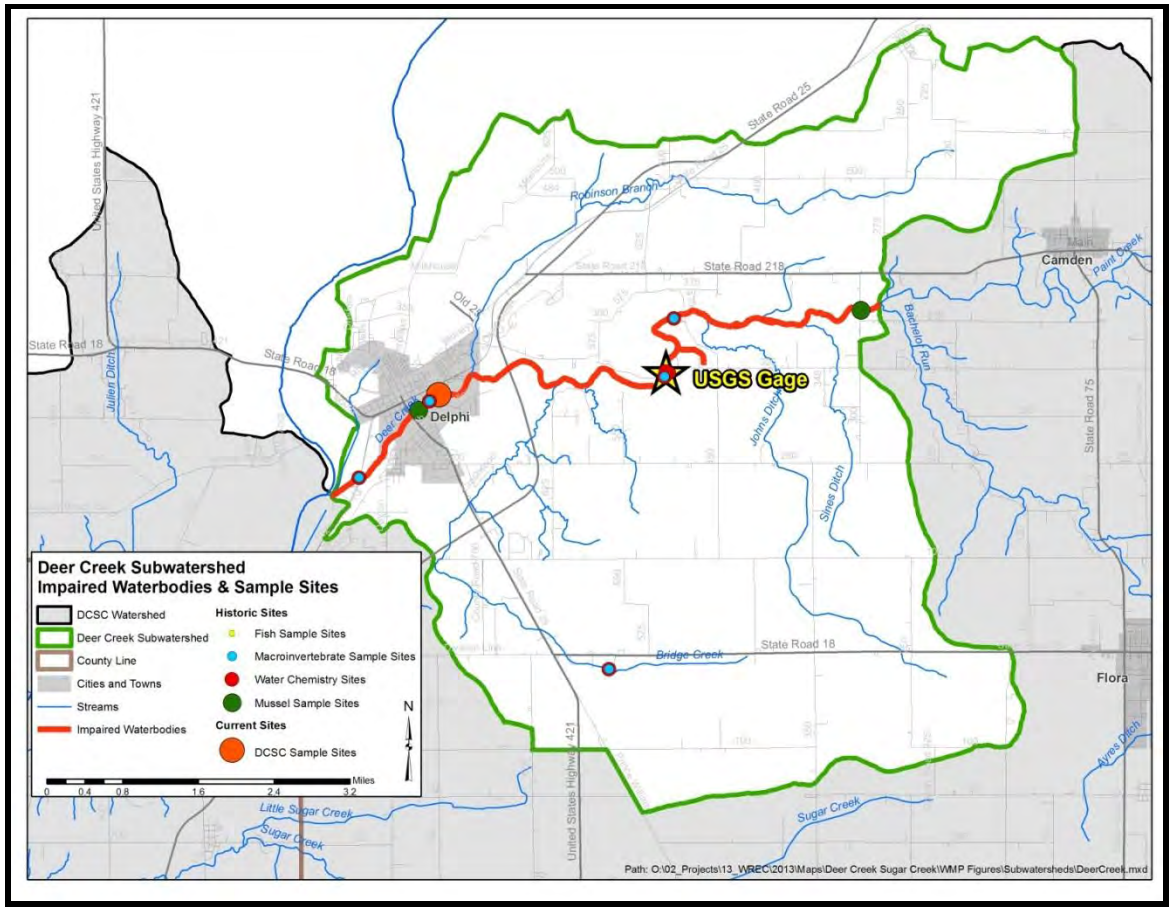

Figure 83. Impaired waterbodies and sample sites in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.1 Soils

Hydric soils comprise approximately 23%, or 5,929 acres, of the Deer Creek subwatershed (Figure 84). The Deer Creek subwatershed has the lowest percentage of soils that are rated as severely limited for septic treatment, and has the highest percentage of soils that are only slightly impaired for septic treatment of the ten watersheds. Severely and slightly impaired soils for septic treatment cover 77% and 20% of the subwatershed, respectively. Highly and potentially highly erodible soils cover 1,845 and 5,394 acres (4.6% and 21.3%), respectively. The Deer

Creek subwatershed contains the highest percentage of potentially highly erodible soils in the watershed. These soils are primary located adjacent to Deer Creek and its tributaries.

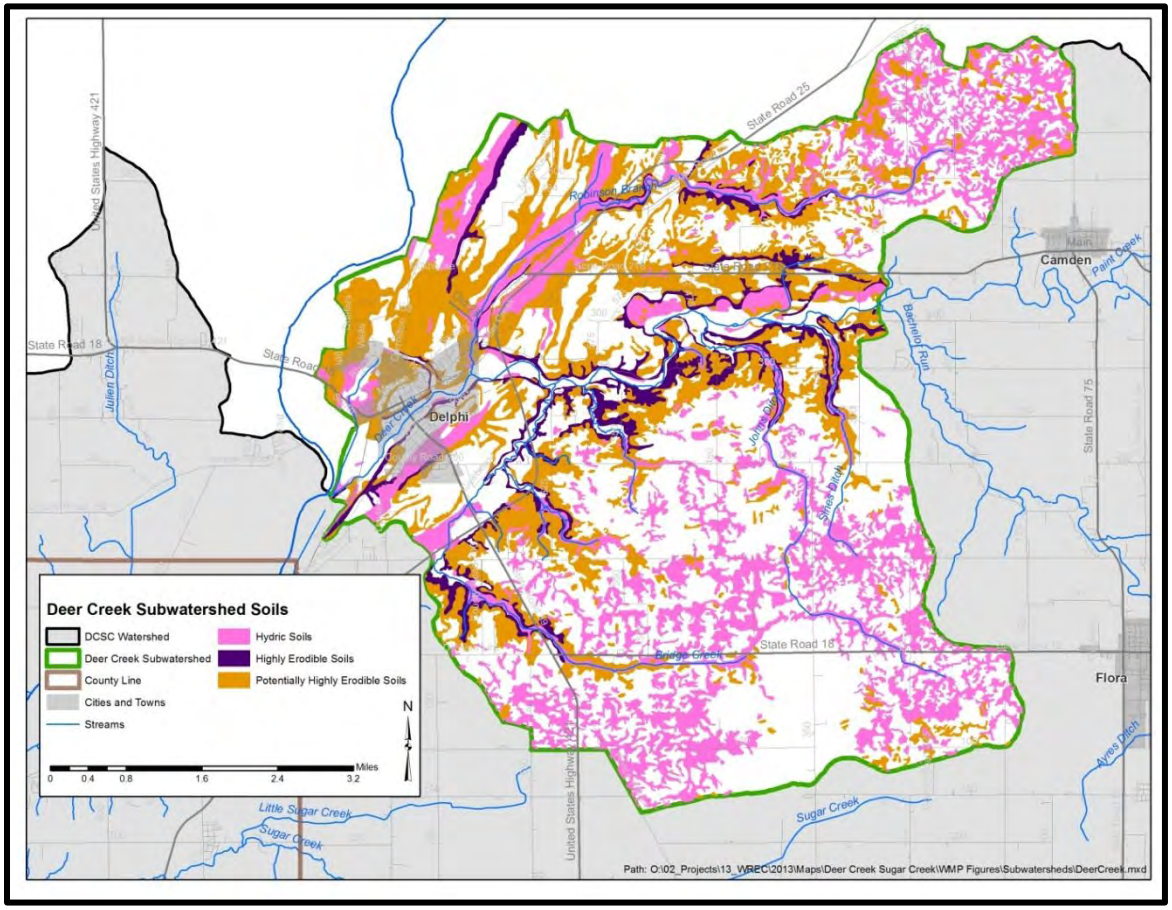

Figure 84. Properties of soils located in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.2 Land Use

Agricultural land uses dominate the Deer Creek subwatershed. Agricultural land uses covers approximately 77% of the subwatershed. Developed or urban land uses, including the Town of Delphi, accounts for 10.3% or 2,625 acres of the subwatershed. Urban land uses within the

subwatershed accounts for the highest percentage of any subwatershed. Natural areas comprise approximately 14% of the subwatershed, with forest accounting for 10.4% of the natural areas.

4.7.3 Point Source Water Quality Issues

As detailed above, the Deer Creek subwatershed is dominated by agricultural land uses. Two NPDES-permitted facilities are located within the subwatershed (Figure 85). The Town of Delphi operates the Delphi Municipal STP that serves the town's 3,015 residents. In total, the plant treats 0.4 MGD, which is treated at an advanced level, and is then discharged, into Deer Creek (USEPA, 2008). The second facility is the Indiana Packers Corporation located off Highway 421 South. This facility discharges into a tributary of Bridge Creek. Fifteen of the 34 LUST within the Deer Creek-Sugar Creek watershed are located within this subwatershed. There are also two industrial waste sites located on Washington Street southwest of Delphi. Additionally, there is one open dump and a brownfield located on County Road 625 West and State Road 18, respectively.

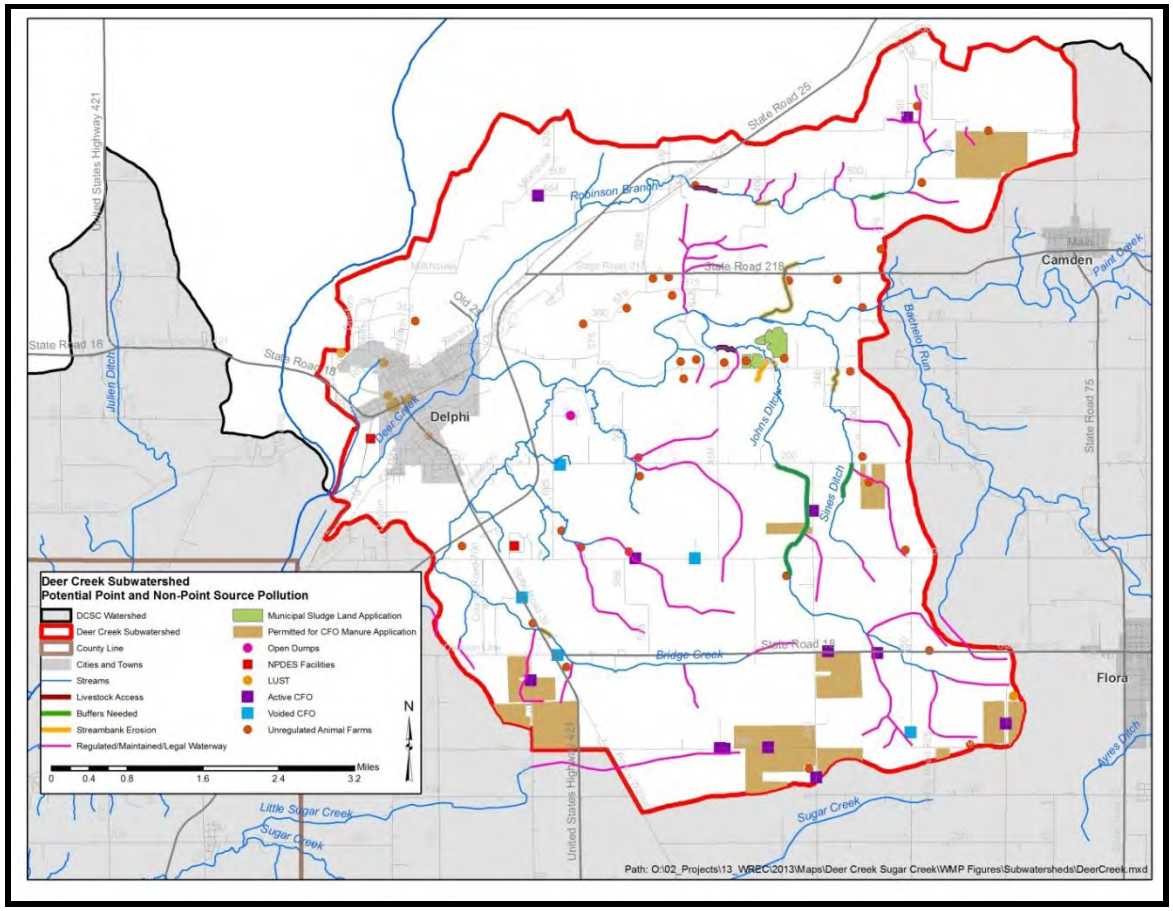

Figure 85. Point and non-point sources of pollution in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Nearly 40 unregulated animal farms are located within the Deer Creek subwatershed. Approximately, 152 cattle, 30 hogs, 51 sheep, 31 goats, and 55 horses are located on 36 farms. There are 12 active CFOs in the Deer Creek subwatershed. CFOs in the Deer Creek subwatershed contain approximately 2,820 nursery pigs, 35,035 finishing pigs, 744 sows, 21,800 swine greater than 55 pounds, and 6,600 swine less than 55 pounds. The Deer Creek subwatershed contains the highest number of nursery pigs of any of the Deer Creek-Sugar Creek subwatersheds. There are a total of 66,999

animals. CFO permits allow for distribution of manure on approximately 1,220 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 93 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,220 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 64.3 acres within the subwatershed, which comprises 5% of the watershed when combined with CFO manure coverage. The municipal sludge is coming from the A.E. Staley Manufacturing Company. Livestock have access to approximately 1.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Deer Creek subwatershed. In total, 4 miles of stream buffers and 4.2 miles of streambank stabilization are needed within the subwatershed.

4.7.5 Water Quality Assessment

Waterbodies within the Deer Creek subwatershed were sampled at six locations (Figure 83). The mainstem of Deer Creek was sampled at five locations; County Road 300 North, US Highway 421 (Riley Park), State Road 18, State Road 25, and approximately 0.3 miles South of County Road 375 North. The sixth site was located on Bridge Creek on State Road 18. The sites were assessed for one or multiple parameters by IDEM, including fish and macroinvertebrate communities, *E. coli*, pesticides, and water chemistry. As part of the current planning project, Purdue University sampled water chemistry in Deer Creek at Riley Park (site DCD3, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In 1998, the USGS assessed *E. coli* levels in Deer Creek at County Road 300 North. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels exceeded the state standard two times in this period measuring 650 and 1,500 colonies/100 mL. As part of the 2003 sampling events, Deer Creek sites located on State Road 25 and US Highway 421 were assessed. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels at the State Road 25 site exceeded the state standard four times in this period measuring 309 to 980 colonies/100 mL. *E. coli* levels at Deer Creek on US Highway 421 exceeded the state standard three times in the 30-day period measuring 361 to 866 colonies/100 mL.

As part of the 1998 basin assessment, IDEM assess Deer Creek approximately 0.3 miles from County Road 375 North and Bridge Creek at State Road 18. Nitrogen concentrations exceed Dodds et al. (1998) suggest standard at both sites; Deer Creek measured 3.7 mg/L and Bridge Creek measured 6.2 mg/L. Total phosphorus at the Deer Creek site measured approximately twice the suggested standard of 0.08 mg/L by Dodds et al. (1998)at 0.14 mg/L.

IDEM assessed the pesticide levels in Deer Creek in the summer of 1998 at County Road 300 North. Three pesticides had levels that raise concern, including acetorchlor, atrazine, and metolachlor. The MCL for acetochloris 0.2 µg/L. Levels in Deer Creek measured nearly 12 times the MCL ranging from 0.1 to 2.3 µg/L. The highest atrazine level measured over 50 times the atrazine MCL of 0.3 µg/L with concentrations ranging from 0.3 to 16 µg/L. Metolachlor does not have a MCL, but its detection level is 0.1 µg/L. Concentrations ranged from detection to 30 µg/L.

Turbidity was also measured during the pesticide sampling events and exceeded the USEPA's recommended standard of 9.89 NTU all 15 times it was measured. Turbidity ranged from 11-410 NTU in Deer Creek (2001).

In total, 18 field measurements and 26 samples were collected at Deer Creek at Trail Head Park (DCD3). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH measurements were above state standards (9.0) during two sampling events in December 2012 and April 2013. pH measured as high as 9.9 suggesting elevated levels of photosynthesis during these two sampling events. Turbidity measured above recommended levels during 12 of 18 assessments measuring from 11.1 to 217 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 20 of 24 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during three events in February, March and June 2013 measuring as high as 12.6 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 12 of 26 sampling events with concentrations measuring as high as 0.324 mg/L in November 2012. Total suspended solids concentrations measured above target levels during 9 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 30.8 to 329 mg/L. *E. coli* concentrations measured above the state standard during 11 of 26 sampling events. Concentrations in exceedance ranged from 235.9 cfu/100 mL to 1988 cfu/100 mL.

Habitat

Habitat was assessed nine times by IDEM within the Deer Creek subwatershed using the QHEI, while Purdue University assessed habitat once in 2012; all sites previously listed were evaluated. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in 1991, 1998, 2003, and 2004. Deer Creek's habitat was evaluated nine times, including the most recent assessment by Purdue University, with scores ranging from 62 to 82, suggesting that the habitat is fully supporting the aquatic life. Bridge Creek was only evaluated once in 1998. It was scored at 49, indicating that it is not fully supporting its aquatic life use designation.

Macroinvertebrates

The macroinvertebrate communities within the Deer Creek subwatershed were sampled at fives site along Deer Creek by IDEM including intersections with US Highway 421 (Riley Park), State Road 18, South of County Road 375 North, State Road 25, and Country Road 300 North. The macroinvertebrate communities in Deer Creek were assessed by IDEM at Riley Park on US Highway 421 in 1991 and 2004 and by Purdue University in 2012. In 1991, the community rated as not impaired and was dominated by *Philopotamidae*. *Philopotamidae* is a family of caddisflies that is intolerant to pollution. In 2004, the community was reassessed and rated as moderately impaired with a score of 44 using the new mIBI scoring system. The community was still dominated by a caddisfly specie, *Ceratopsyche cheilonis*, which is not particularly intolerant of degraded environmental conditions. During the 2012 assessment, the macroinvertebrate community was fairly simple being dominated by two taxa. The macroinvertebrate community suggests poorer quality than the fish community and habitat.

In 1998, Deer Creek at State Road 18 was sampled by IDEM. The mIBI score indicated that this segment is not supporting the aquatic life use rating as moderately to severely impaired, scoring 2.0. The most prevalent family of macroinvertebrates was *Chironomidae*, which are fairly tolerant to tolerant to pollution.

In 1998, IDEM assessed Deer Creek approximately 0.3 miles South of County Road 375 North. The mIBI score indicated that this segment was supporting for aquatic life use rating as moderately impaired scoring 4.4. The most prevalent family of macroinvertebrates was *Heptageniidae*, an intolerant to pollution mayfly species.

In 1991 and 2004, IDEM assessed the macroinvertebrate community in Deer Creek at Trail Head Park on State Road 25. Purdue University assessed the macroinvertebrate community at the same site in 2012. In 1991, the macroinvertebrate community rated as severely impaired scoring 1.8 using the old mIBI scoring method and in 2004 it improved to moderately impaired with a score of 40 using the new mIBI scoring system. During both sampling events, the macroinvertebrate community was dominated by *Chironomidae*, a family of flies that are fairly tolerant to tolerant to pollution. In 2004, IDEM identified the *Chironomidae* family to the species level, *Orthocladiusobumbratus.* During the 2013 assessment, Purdue University identified a highly diverse benthic macroinvertebrate community which was dominated by stoneflies. Stoneflies typically indicate high quality communities suggesting that the macroinvertebrate community in Deer Creek at Trail Head Park (DCD3) is of higher quality than other macroinvertebrate communities throughout the watershed.

IDEM assessed macroinvertebrate communities in Deer Creek at the County Road 300 North three times. In 1991 and 2003, the macroinvertebrate community was dominated by *Chironomidae*, a family of flies that are fairly tolerant to tolerant to pollution. The site was rated as moderately impaired in 1991 and then improved to slightly impaired in 2003. The third assessment was completed in 2004 after a new mIBI scoring system was introduced. The site rated as moderately impaired scoring a 38. The community was dominated by *Ceratopsychachielonis*, a net spinning, caddisfly species.

During Purdue University's assessment, the benthic community was fairly simple, not very taxa rich, and was dominated by two taxa. The mIBI (44) was moderate compared to the other sampled sites. Overall, the site should be considered in good to very good condition based on the biological community and QHEI data.

Fish

In 1998, IDEM assessed fish communities on the mainstem of Deer Creek and Bridge Creek at County Road 300 North and State Road 18, respectively. The Deer Creek site was rated as fair suggesting that species that are intolerant to pollution were absent and the trophic levels are skewed. The IBI score was 42. The dominate species were the bluntnose minnow and spotfin shiner. Bridge Creek was rated as poor scoring 32 suggesting that many species that should have been present were absent and omnivores and tolerant species dominated the fish community. All of the fish collected at this site were the western blacknose dace.

In 2012, Purdue University assessed the fish community along the mainstem of Deer Creek at Riley Park (DCD3). The fish IBI in Deer Creek at Riley Park tied for the highest IBI among all sites rating "very good." High species diversity, high diversity of sunfish, and high diversity of insectivores and omnivores are characteristic of this community. The IBI was the second highest among all sites (48) and the fish species richness was among the highest of all sites.

Mussels

Mussel communities were assessed by Myers-Kinzie and the IDNR at four sites in the Deer Creek subwatershed. Myers-Kinzie assessed the mussel community at two locations, Bowen Creek at County Road 950 North and Bridge Creek at State Road 25. During the surveys, one mussel species, the purple lilliput, was found in Bowen Creek as weathered dead shells. This was the first discovery of this species in Tippecanoe County. The lilliput is typically found in mud, sand, or fine gravel in small creeks. In Bridge Creek, there was no evidence of mussels.

The INDR surveyed the mussel community at two locations along Deer Creek at County Road 300 West and US Highway 421. At the County Road 300 West site, a total of 16 species were identified; however, only two were found alive. The remaining were found as weathered dead (8), fresh dead (5), or subfossil (1) shell material. Weathered dead shell material of two state species of special concern were identified, including the wavy-rayed lampmussel and the kidneyshell. The Riley Park (US Highway 421) site contained 12 mussel species; four species were found alive, while the remaining eight species were found as weathered dead (3), subfossil (3), or fresh dead (2) shell material.

4.7.6 Deer Creek Subwatershed Summary

Deer Creek subwatershed is comprised of 77% agricultural land. Urban land use in this subwatershed accounts for 10.3%, in part due to the presence of the Town of Delphi. This subwatershed has the highest amount of urban land use among all of the subwatersheds. Deer Creek subwatershed houses two NPDES permitted facilities and numerous other potential point source pollution sources. Pesticides, pathogens, turbidity, and nitrogen levels all exceeded recommended levels or state drinking water standards. Phosphorus and pH were elevated in nearly 50% of the samples taken. Additionally, potential manure application could be problematic in this watershed. However, temperature, conductivity and dissolved oxygen were all within recommended levels. QHEI habitat assessments suggested the waterbody was fully supporting aquatic life. However historically, Deer Creek scored relatively low on the mIBI and IBI assessments. Macroinvertebrate data suggested that Deer Creek was moderately impaired and fish data rated the creek at fair-poor, in part due to only one fish species being found present. Presently, Deer Creek has the highest mIBI score in the watershed, and also is tied for the highest IBI score, rating “very good”.

4.8 Sugar Creek

The Sugar Creek subwatershed is located in the southwest portion of the watershed and drains directly to the Wabash River. The drainage area is located in Carroll and Tippecanoe Counties. The Sugar Creek subwatershed includes the Town of Colburn. The watershed is within the 12-HUC watershed Little Sugar Creek-Sugar Creek (051201050601) and drains 18,360 acres or 29 square miles. In total, 34.2 miles of stream are present within the Sugar Creek subwatershed. Of these, approximately 24.6 miles are considered impaired for *E. coli* and less than a quarter of a mile is considered impaired due to *E. coli,* nutrients, and PCBs and mercury in fish tissue (Figure 86).

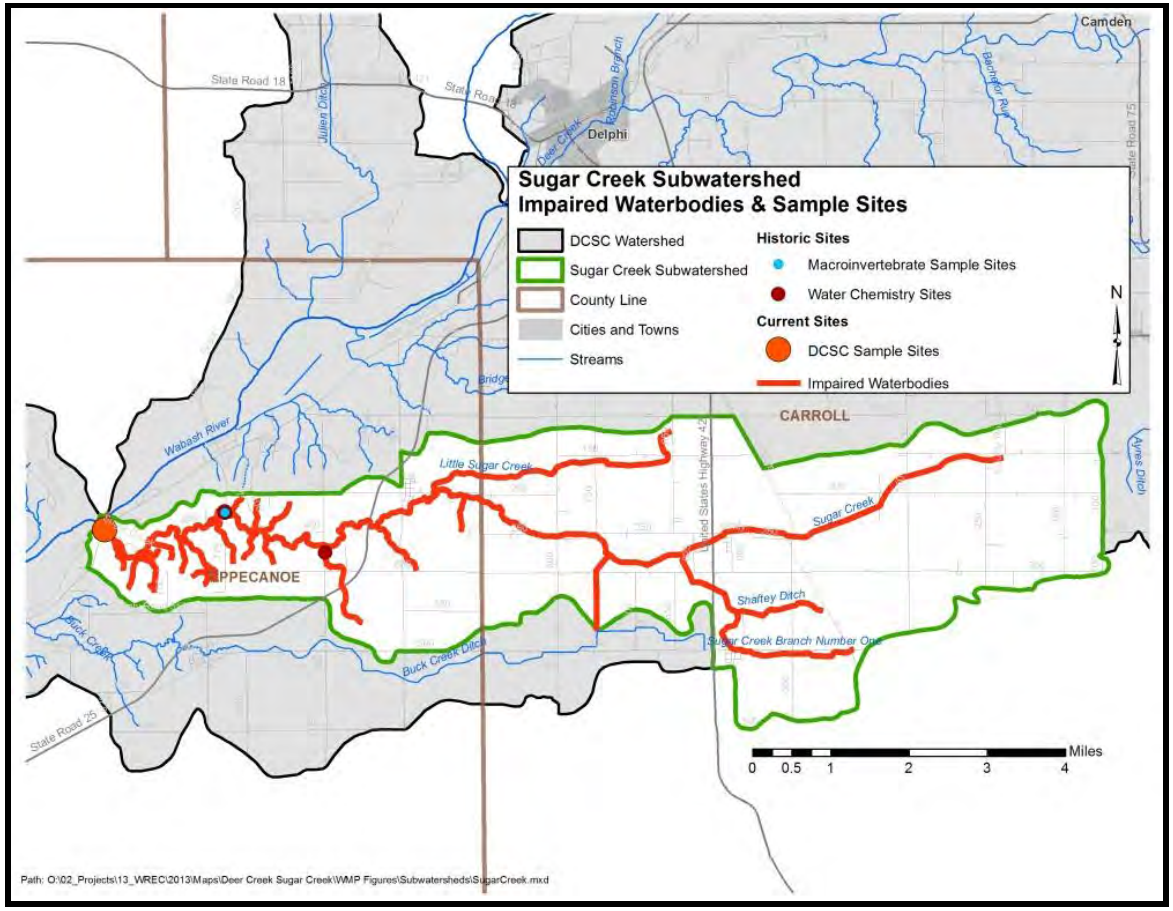

Figure 86. Impaired waterbodies and sample sites in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.1 Soils

Soils in the Sugar Creek subwatershed are dominated by those that are not suitable for use in septic treatment. Over 98% of the soils in the subwatershed are rated as severely limited for use in septic treatment. Easily erodible soils are located adjacent to the Sugar Creek from the Town of Colburn to the mouth of Sugar Creek (Figure 87). Potentially highly erodible soils cover 9.5% of 1,748 acres of the subwatershed. Highly erodible soils account for 939 acres of 5.1% of the subwatershed.

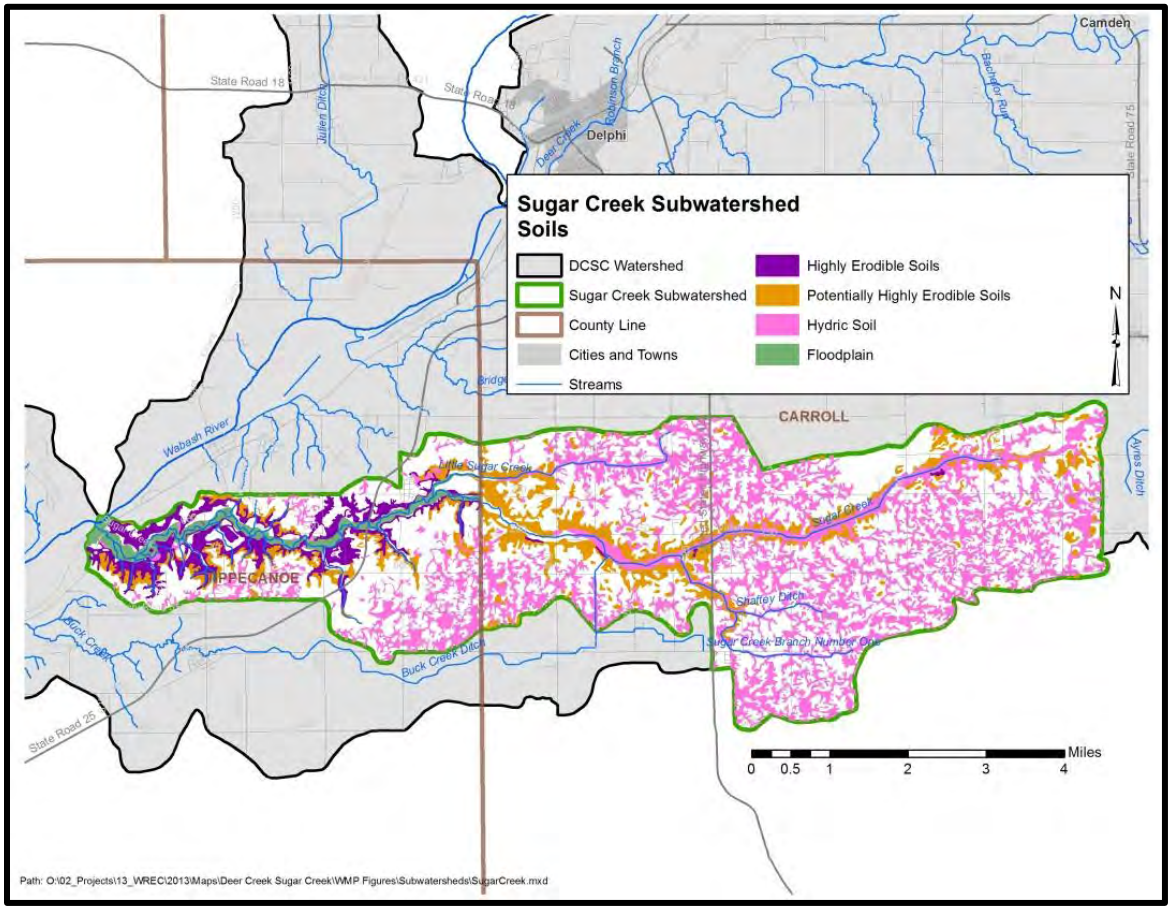

Figure 87. Properties of soils located in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.2 Land Use

Similar to the other subwatersheds in the Deer Creek-Sugar Creek watershed, the Sugar Creek subwatershed is dominated by agricultural land use which accounts for 85% of the land use. Urban land uses, including the Town of Colburn, account for 6% of the subwatershed land use. Deciduous forests accounts for approximately 8% of the subwatershed. These forests are located predominantly in the same areas as the potentially highly erodible soils. These forested areas should be protected as they provide stability on the erodible soils. The Sugar Creek subwatershed has the lowest percentage of grassland/herbaceous land use in the watershed, only 0.7% of the subwatershed is classified as grassland/herbaceous.

4.8.3 Point Source Water Quality Issues

As detailed above, the majority of the Sugar Creek subwatershed is in agricultural land uses, more specifically row crops. There is one LUST within the subwatershed; it is located on East County Line Road at Southeastway Park (Figure 88). There are no brownfields, industrial waste, NPDES facilities, or open dump sites within the Wabash River subwatershed.

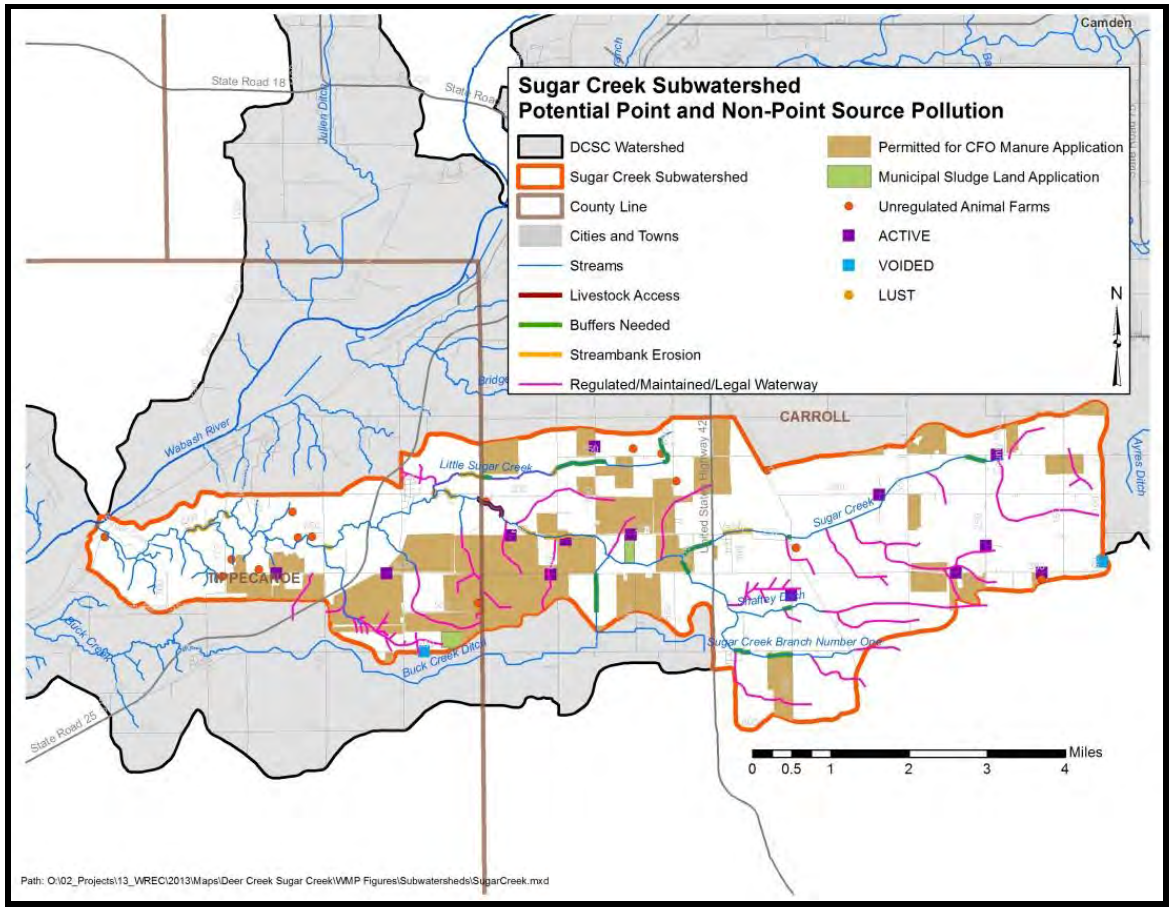

Figure 88. Point and non-point sources of pollution in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Sugar Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Sugar Creek subwatershed. Approximately, 57 cattle and 24 horses are located on 14 farms. In, total, there are 13 active CFOs in the Sugar Creek subwatershed. The CFOs in the Sugar Creek subwatershed contain approximately 5,920 nursery pigs, 11,320 finishing pigs, 36 sows in farrowing, 221 gestation sows, five boars, 930 sows, 1,300 swine greater than 55 pounds, and 4,200 swine less than 55 pounds. There are a total of 23,932 animals in the Sugar Creek subwatershed. CFO permits allow for distribution of

manure on approximately 4,698 acres or 26% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 25 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 4,698 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 62 acres within the subwatershed. The sludge originates from two facilities that are located outside of the watershed including Frito-Lay, Inc. and the Lafayette Municipal STP. Livestock have access to approximately 1 mile of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Sugar Creek subwatershed. In total, 6.2 miles of stream buffers and 5.5 miles of streambank stabilization are needed within the subwatershed.

4.8.5 Water Quality Assessment

Waterbodies within the Sugar Creek subwatershed were sampled at two locations. Sugar Creek at County Road 900 East in Tippecanoe County was assessed in 2008 (Figure 86). *E.* coli and nutrient levels were measured at this site in the summer and fall. IDEM assessed macroinvertebrate communities at Sugar Creek at County Road 775 East (Tippecanoe County) in 1991 and *E. coli* levels were measured at this site in 2003. As part of the current planning project, Purdue University sampled water chemistry in Sugar Creek at State Road 25's intersection with Stair Road (site SC2, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013

Water Chemistry

In the summer and fall of 2008, a tributary of Sugar Creek at County Road 900 East was sampled for *E. coli* and nutrients. *E. coli* was analyzed five times over a 30-day period and exceeded the state standard two of the five times. Overall, *E. coli* concentrations ranged from 54.6 to 488 colonies/100 mL. Other parameters of concern measured included nitrogen, as nitrate and nitrite, which measured 8.84 during a June sampling event. This is over four times the suggested benchmark of Dodds et al, 1998. In 2003, *E. coli* was measured by IDEM at Sugar Creek at County Road 775 East. *E. coli* levels exceeded the state standard during five of the six events; one of the duplicates collected on September 15th (98.5 colonies/100 mL) measured below the standard but its pair was above state standard (410.6 colonies/100 mL). The remaining samples ranged from 365.4 to 1,986 colonies/100 mL.

In total, 18 field measurements and 26 samples were collected at Sugar Creek at State Road 25's intersection with Stair Road (SC2). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH measurements exceeded the state standard measuring as high as 9.6. Turbidity measured above recommended levels during 9 of 18 assessments measuring from 13.9 to 154 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 21 of 23 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during five events in January, February, March, May and June 2013 measuring as high as 18.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 9 of 26 sampling events with concentrations measuring as high as 0.830 mg/L in December 2012. Total suspended solids concentrations measured

above target levels during 8 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 21.6 to 364 mg/L. *E. coli* concentrations measured above the state standard during 14 of 26 sampling events. Concentrations in exceedance ranged from 298 cfu/100 mL to 1413 cfu/100 mL.

Habitat

Habitat was assessed once by IDEM and once by Purdue University within the Sugar Creek subwatershed using the QHEI. IDEM assessment occurred in 1991 in Sugar Creek at County Road 775 East and in 2012 by Purdue University at Stair Road during the current Deer Creek-Sugar Creek planning project. IDEM scored Sugar Creek as 64, indicating the habitat was fully supporting the stream's designated aquatic life use. Purdue University scored Sugar Creek as fair (64) as well. The riffle/run score for the site was notably low, suggesting limited habitat diversity.

Macroinvertebrates and Fish

The macroinvertebrate community within Sugar Creek was sampled once by IDEM and macroinvertebrates and fish were sampled twice by Purdue University. IDEM sampling occurred in 1991 in Sugar Creek at County Road 775 East, while Purdue University sampled Sugar Creek at Stair Road (SC2). During the 1991 assessment, the macroinvertebrate community rated as slightly impaired during the assessment scoring 5.8. The community was dominated by *Hydropsychidae*, a caddisfly family which is relatively intolerant to pollution. During the current assessment, benthic macroinvertebrates were highly diverse and included a dominance by stoneflies, which both suggest higher quality benthic community. Benthic invertebrates were highly diverse at this site with at least 59 total taxa. The overall mIBI score (52) was the second highest of all sites. Of particular note is the dominance by stoneflies and other EPT taxa in the samples, which both suggest higher quality benthic community. The number of EPT taxa was at least 35 and was the second highest of all sites.

The fish community rated as fair during the Purdue University assessments. High numbers of species as well as high numbers of minnow species and sensitive species created the fair rating with the site scoring 40. The fish IBI score of 40 rated the site as fair, although the fish species richness was relatively high at 26 total species. However, there was only a single individual of one species of darter present, and this is unusual for this size stream. Overall, the Sugar Creek (SC2) site should be considered in good condition based on the biological community and physical habitat characteristics as scored using the QHEI.

Mussels

Myers-Kinzie assessed the mussel community at two locations within the Sugar Creek subwatershed. During the surveys, the creek heelsplitter (*Lasmigona compressa*), slippershell mussel (*Alasmidonta viridis),* and the cylindrical papershell (*Anodontoides ferussacianus)* were identified as weathered dead shells. The creek heelslitter and the cylindrical papershell are a headwater species typical of small streams and rivers, while the slippershell mussel was found by digging in the stream bed with hands.

4.8.6 Sugar Creek Subwatershed Summary

The land use of Sugar Creek subwatershed 85% agricultural, 6% urban, and 8% deciduous forest, which sits atop or adjacent to the majority of the subwatershed's potentially highly erodible soils. Conservation of these forests is critical, as the trees' root structures play a vital role in maintaining the stability of these PHES. Septic treatment is very limited in this subwatershed, as 98% of the soil is deemed severely limited for septic treatment. The Town of Colburn is situated in this subwatershed and houses only one leaky underground storage tank. Contrary to several of the other subwatersheds with higher urban land use, Sugar Creek subwatershed has no brownfields, industrial waste sites, NPDES facilities, or open dump sites. Temperature, conductivity, and dissolved oxygen were all within state standards or recommendations. Turbidity and E. coli were both elevated in almost 50% of the samples taken. Nitrogen is a cause of concern, as samples were in exceedance of state drinking standards in 21 out of 23 samples taken. Habitat assessments returned positive results for Sugar Creek subwatershed. Overall, the habitat was suggested to fully support aquatic life. Scores for mIBI and IBI were indicative of the same results as the habitat assessment. Intolerant and sensitive species were found in both assessments and both populations were highly diverse.

4.9 Buck Creek

The Buck Creek subwatershed is located in the southwest corner of the watershed and drains into the Wabash River. Buck Creek drains portions of Carroll and Tippecanoe Counties and includes the Town of Buck Creek. The subwatershed includes a portion of a 12-digit watershed, Harrison Creek-Wabash River (051201050603) and drains 7,480 acres or 17.7 square miles. In total, 11.7 miles of stream are present within the Buck Creek subwatershed. Nearly all of the 11.7 miles of stream are listed on the 2012 draft 303(d) Impaired Waterbodies List for *E. coli* and impaired biotic communities (Figure 89; IDEM, 2012).

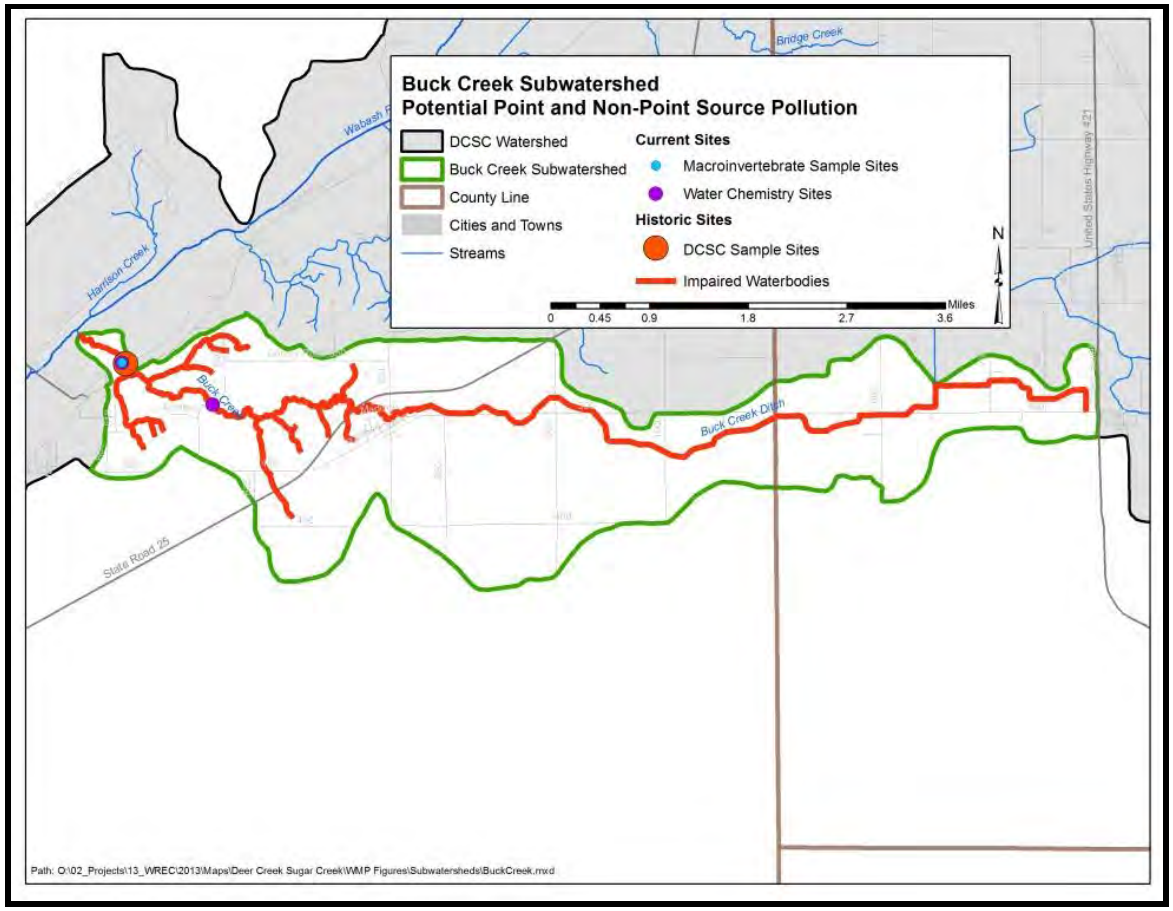

Figure 89. Impaired waterbodies and sample sites in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.1 Soils

Hydric soils cover 2,583 acres or 34.5% of the subwatershed (Figure 90). Highly erodible soils and potentially highly erodible soils cover 414 acres or 5.5% and 494 acres or 6.6% of the Buck Creek subwatershed, respectively. HES and PHES are primarily localized adjacent to the floodplain and occur along nearly a third of the stream and its tributaries from the Town of Buck Creek to the mouth of Buck Creek. The Buck Creek subwatershed has the highest percentage of severely limited soils for septic treatment. Severely limited soils cover 99%, or 7,430 acres, of the

subwatershed. Within the Buck Creek subwatershed, none of the soils are suitable for the use of septic treatment and only 0.5% of 40 acres that are considered as moderately limited for septic treatment.

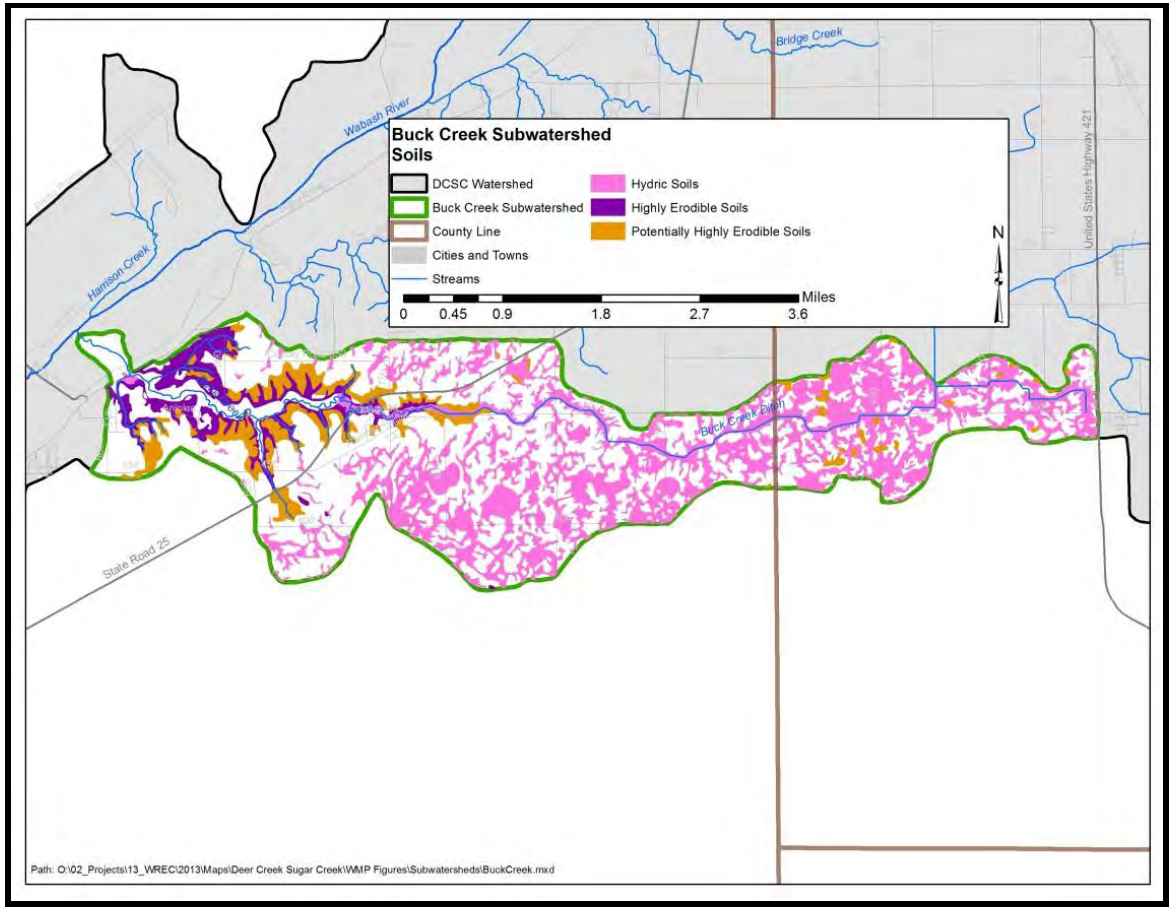

Figure 90. Properties of soils located in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.2 Land Use

Agricultural land use dominates the Buck Creek subwatershed accounting for 84% of the land use. Urban land uses, including the Town of Buck Creek, accounts for 5% of the subwatershed. The Buck Creek subwatershed has the highest percentage of grassland/herbaceous land use of the

ten subwatersheds with approximate 1.5% classified as grassland/herbaceous. Additionally, this subwatershed has the lowest percentage of wetlands (0.06%). Deciduous and mixed forests account for 9% of the land use in the subwatershed.

4.9.3 Point Source Water Quality Issues

There are no point source water quality issues in the Buck Creek subwatershed.

4.9.4 Non-Point Source Water Quality Issues

In the Buck Creek subwatershed, there are ten active CFOs. Seven unregulated animal farms are located within the Buck Creek subwatershed. Approximately, 57 cattle and 24 horses are located in the Buck Creek subwatershed. The Buck Creek subwatershed contains the second highest number of animals in confined feeding operations with are approximately 44,914 animals housed in CFOs. The subwatershed also contains the largest number of swine greater than 55 pounds, 24,575. The remaining animals in the subwatershed are nursery pigs (5,630), finishing pigs (9,144), sows (780), and swine less than 55 pounds (4,785). CFO permits allow for distribution of manure on approximately 2,929 acres or 39% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 45 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 2,929 acres of permitted receiving land, total Nitrogen would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops). However in this subwatershed, Phosphorus Pentoxide loads would exceed recommended fertilizer rates (Sutton et al., 2001).

Municipal sludge is being applied to 221 acres or 3% of the subwatershed (Figure 91). The sludge originates from the Lafayette Municipal STP which is located outside the watershed. Streambank erosion and lack of stream buffering are also of concern within the Buck Creek subwatershed. In total, 9.8 miles of stream buffers and 1.7 miles of streambank stabilization are needed within the Buck Creek subwatershed.

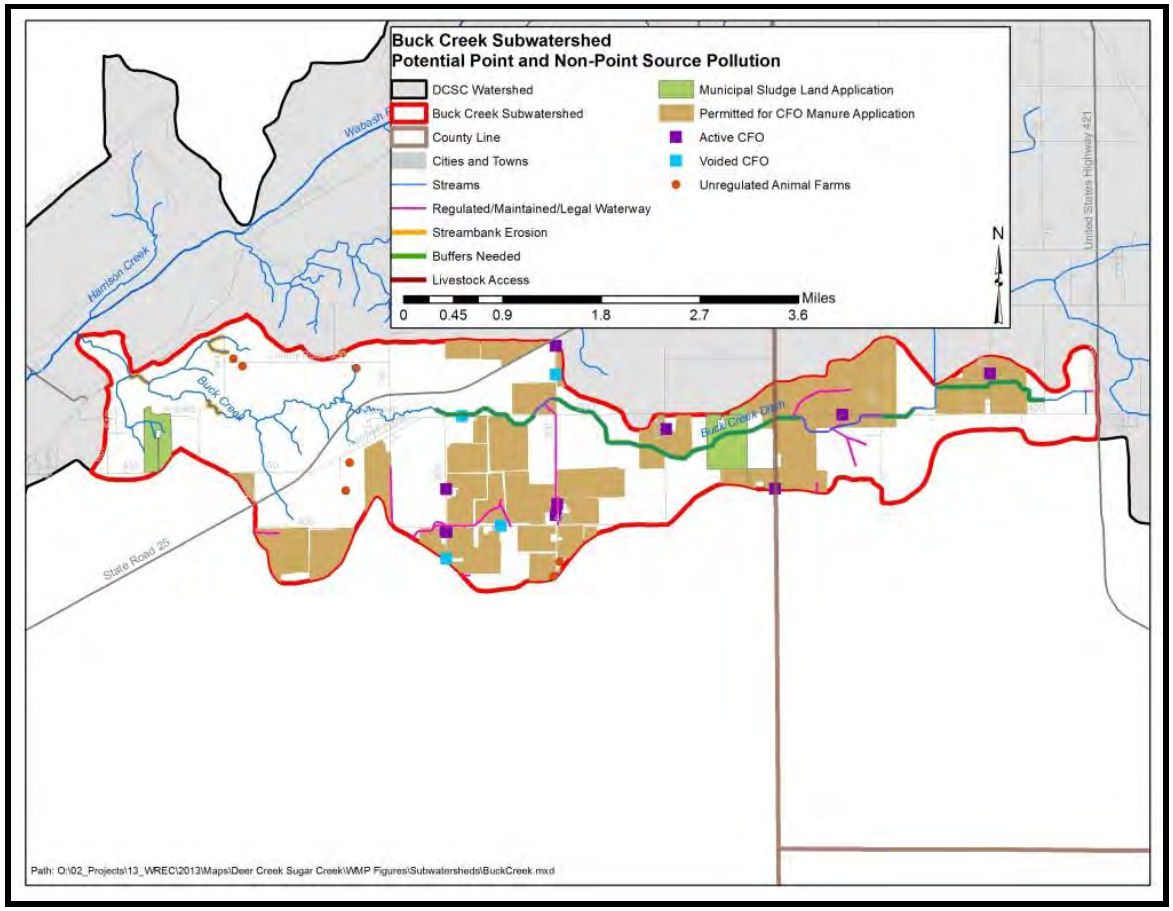

Figure 91. Non-point sources of pollution in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.5 Water Quality Assessment

Waterbodies within the Buck Creek subwatershed were sampled at two locations. Historic assessments include analysis of *E. coli* concentrations and evaluation of habitat and macroinvertebrate communities in Buck Creek. The sampling sites were located less than two miles from the mouth of Buck Creek. *E. coli* samples were collected at County Road 600 East in Tippecanoe County and the habitat and macroinvertebrates were evaluated at 5 Northwest Road (also called Stair Road). As part of the current planning project, Purdue University sampled water chemistry

in Buck Creek at Stair Road (site BC1, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In the fall of 2003, IDEM sampled Buck Creek in Tippecanoe County on County Road 600 East for *E. coli.* Five samples were collected over a 30 day period. *E. coli* measured higher than the Indiana state standard during four of the five sampling events. *E. coli* ranged from below detection to 1,203 colonies/100 mL of sample.

In total, 17 field measurements and 26 samples were collected at Buck Creek at Stair Road (BC1). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 10 of 17 assessments measuring from 16.8 to 361 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 21 of 23 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during ten events in January, February, March and June 2013 measuring as high as 22.7 mg/L. Buck Creek contained the highest average nitrate-nitrogen concentration of all Deer Creek-Sugar Creek watershed sampling sites. Total phosphorus concentrations exceeded the 0.08 mg/L target during 15 of 26 sampling events with concentrations measuring as high as 1.044 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 6 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 23.4 to 226 mg/L. *E. coli* concentrations measured above the state standard during 15 of 26 sampling events. Concentrations in exceedance ranged from 344.8 cfu/100 mL to 3255 cfu/100 mL. On average, *E. coli* concentrations were the second highest of all sample sites in the Deer Creek-Sugar Creek watershed.

Habitat

Habitat was assessed twice by IDEM within the Buck Creek subwatershed using the QHEI and once by Purdue University during the current Deer Creek-Sugar Creek planning project. IDEM assessments occurred in 1991 and 2003 with both assessments conducted at Buck Creek at 5 Northwest Road in Tippecanoe County. Scores (56 and 48, respectively) indicate the habitat in 1991 was fully supporting the stream's designated aquatic life use, but in 2003 it was not supporting the designated aquatic life use in the stream. This change in QHEI is due to the decrease in the riparian/bank score (8 to 4) and the pool score (5 to 0). In 2003, there was no longer a pool present at the site. Purdue University scored Buck Creek at Stair Road (BC1) as good (65); habitat at this site within Buck Creek rated higher than habitat present at IDEM monitored sites. . Of particular note is the low score for bank erosion in Buck Creek indicating that bank erosion is a problem in this reach of Buck Creek.

Macroinvertebrates and Fish

The macroinvertebrate community within Buck Creek was sampled twice by IDEM and fish were sampled twice by Purdue University during the current Deer Creek-Sugar Creek planning project. Sampling occurred in 1991 and 2003 with both assessments at 5 Northeast Road. The macroinvertebrate community rated as slightly impaired in 1991 with a mIBI score of 4.8; however, during the 2003 assessment, the mIBI score rated as severely impaired with a score of 1.0. The community was dominated by *Elmidae*, an intolerant to pollution riffle beetle species in 1991

and all other *Chironomidae* families (fairly to very tolerant to pollution) in 2003. Benthic invertebrate assessments completed by Purdue University used the new IDEM monitoring method. Macroinvertebrates were fairly diverse with 41 taxa present during both assessments. Benthic invertebrates were dominated by midge larva (about a third of the total count) suggesting that the quality of the site is lower than desirable. The mIBI score was 38, which is just above the threshold value that designates sites as either impaired or unimpaired (36). Overall, the Buck Creek (BC1) site should be considered in fair condition.

Purdue University monitored the fish community in Buck Creek at Stair Road (BC1) during 2012 and 2013 with the community rating as fair scoring 34. Low percentages of carnivores, low number of suckers and moderate sensitive species populations generated the fair score.

Mussels

Myers-Kinzie assessed the mussel community at two locations within the Buck Creek subwatershed. Sites were located on County Road 600 East and Stair Road in Tippecanoe County. During the surveys, one species was identified as weathered dead shells. The mucket (*Actinonaias ligamentina*) is typically found in gravel, sand or a mixture of the two in medium to large rivers.

4.9.6 Buck Creek Subwatershed Summary

Buck Creek is the smallest subwatershed. Its agricultural land comprises 84% of the total land use, as urban land use accounts for 5%, in part due to the Town of Buck Creek. This subwatershed has no point source water quality issues. Temperature, conductivity, dissolved oxygen, and pH measurements were all within standards or recommendations. Turbidity and phosphorus were cause for some concern, as they were elevated in 10 out of 17 and 15 out of 26 water samples, respectively. Nitrogen was a recurring issue for Buck Creek, as levels exceeded recommendations in 21 out of 23 samples. *E. coli* concentrations in this subwatershed were the second highest of all sample sites in the watershed, as concentrations exceeded the state standard in 15 out of 26 samples. Habitat assessment scores indicated that Buck Creek is no longer fully supporting aquatic life. Scores from the mIBI and IBI suggested that the macroinvertebrate populations and fish populations were both “fair,” as a mix of sensitive to moderate species existed and the populations were fairly diverse as well.

4.10 Wabash River

The Wabash River subwatershed is located in the west edge of watershed. This subwatershed receives water from all upstream subwatersheds. The drainage for this subwatershed is located in Carroll and Tippecanoe Counties. The Wabash River subwatershed borders the Town of Battle Ground and includes portions of Prophetstown State Park. The subwatershed includes two 12-digit watersheds, Bowen Ditch-Wabash River (051201050602) and a portion of the Harrison Creek-Wabash River (051201050603), and drains 20,177 acres, or 31.5 square miles. In total, 10.7 miles of stream are present within the Wabash River subwatershed with the entire length considered impaired for *E. coli,* impaired biotic communities, PCBs in fish tissue, or a combination of the three impairments (Figure 92; IDEM, 2012).

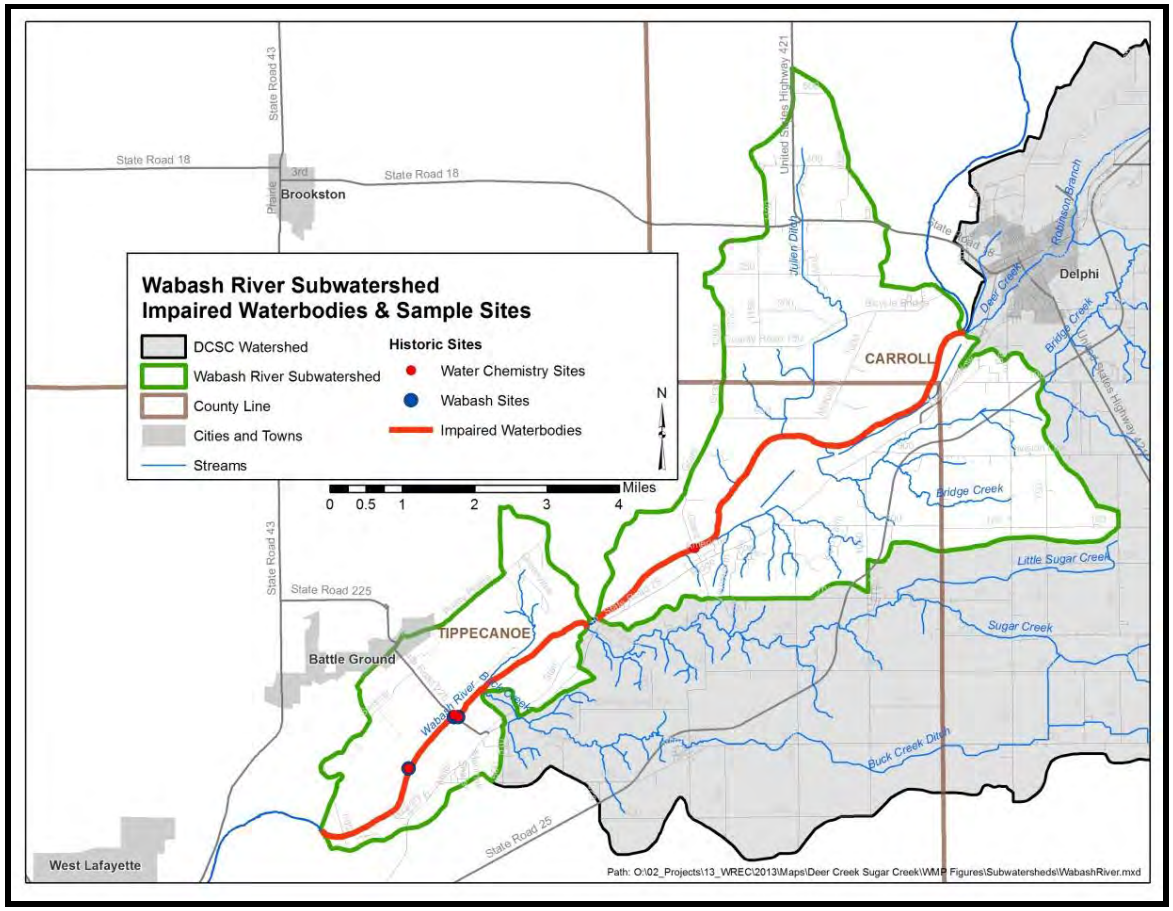

Figure 92. Impaired waterbodies and sample sites in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.1 Soils

The Wabash River subwatershed has the lowest percentage of hydric soil with approximately 8.9% or 1,789 acres in the watershed (Figure 93). However, the Wabash River subwatershed has the highest percentage of highly erodible soils out of the ten subwatersheds. Highly erodible soils cover 12.7%, or 2,564 acres, of the subwatershed and are primarily located adjacent to Julien Ditch, the Wabash River, and the Wabash River's smaller tributaries. Potentially highly erodible soils cover 10.8% of the subwatershed and are located in similar places as the highly erodible soils.

Approximately 84%, or 17,002 acres, of the Wabash River subwatershed are classified as severely limited in septic treatment and only 2%, or 429 acres, rate only slightly limited for septic treatment

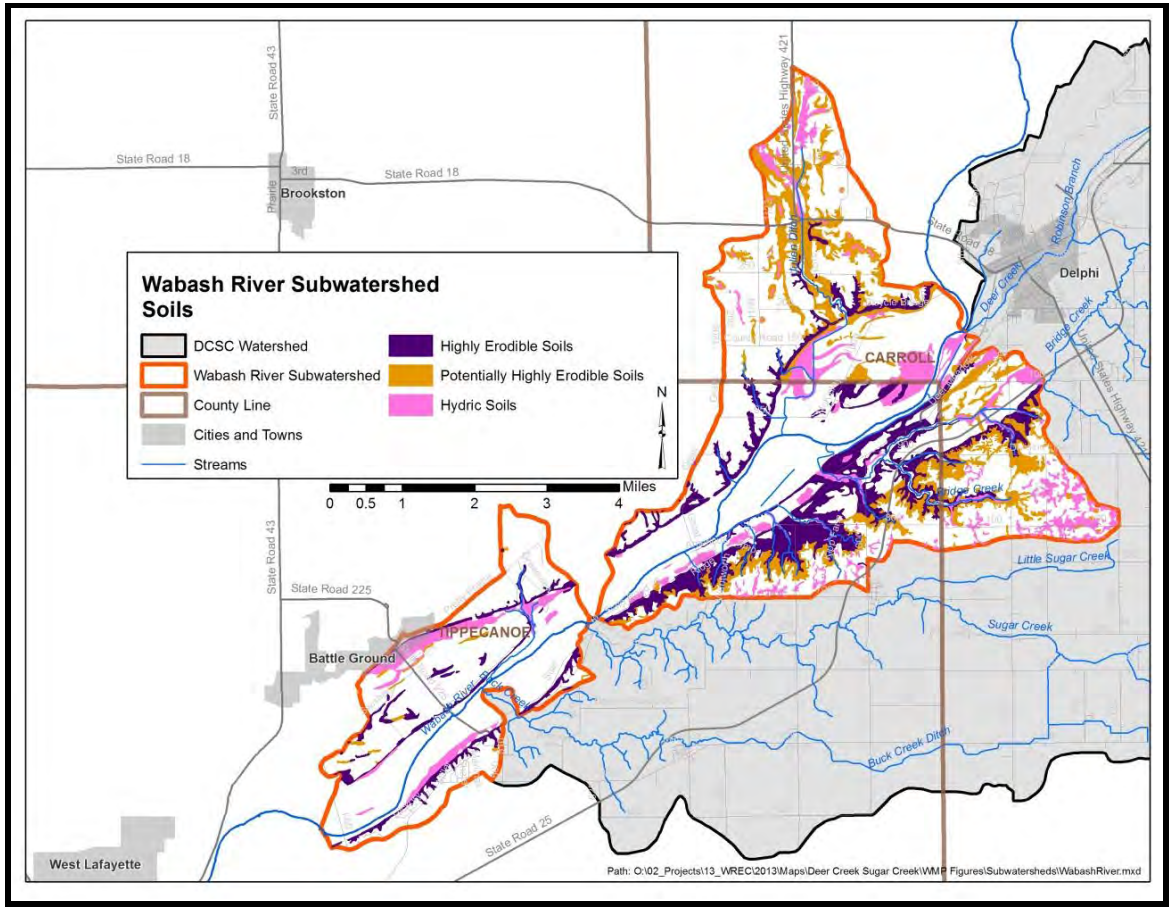

Figure 93. Properties of soils located in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.2 Land Use

Agricultural land use accounts for 71% of the Wabash River subwatershed; this is the lowest percentage of the ten subwatersheds. The Wabash River is different from the other subwatersheds in that while agriculture is the dominant land use, it covers a much smaller area of the watershed. This subwatershed has the highest percentage of open water, forest and wetlands in the watershed. Open water accounts for 2.8% of the subwatershed; that is greater than 12 times the next highest subwatershed. Deciduous forest accounts for 16.5% of 3,331 acres of the subwatershed, while wetlands account for another 6.8% or 1,380 acres.

4.10.3 Point Source Water Quality Issues

As detailed above, much of the Wabash River subwatershed is in agricultural land uses. The only point source water quality issue within this subwatershed is two leaking underground storage tanks (LUST) located on Pretty Prairie Road (Lafayette County Club) and State Road 25 (Lox Equipment Company, Figure 94). There are no brownfields, industrial waste, NPDES facilities, or open dump sites within the Wabash River subwatershed.

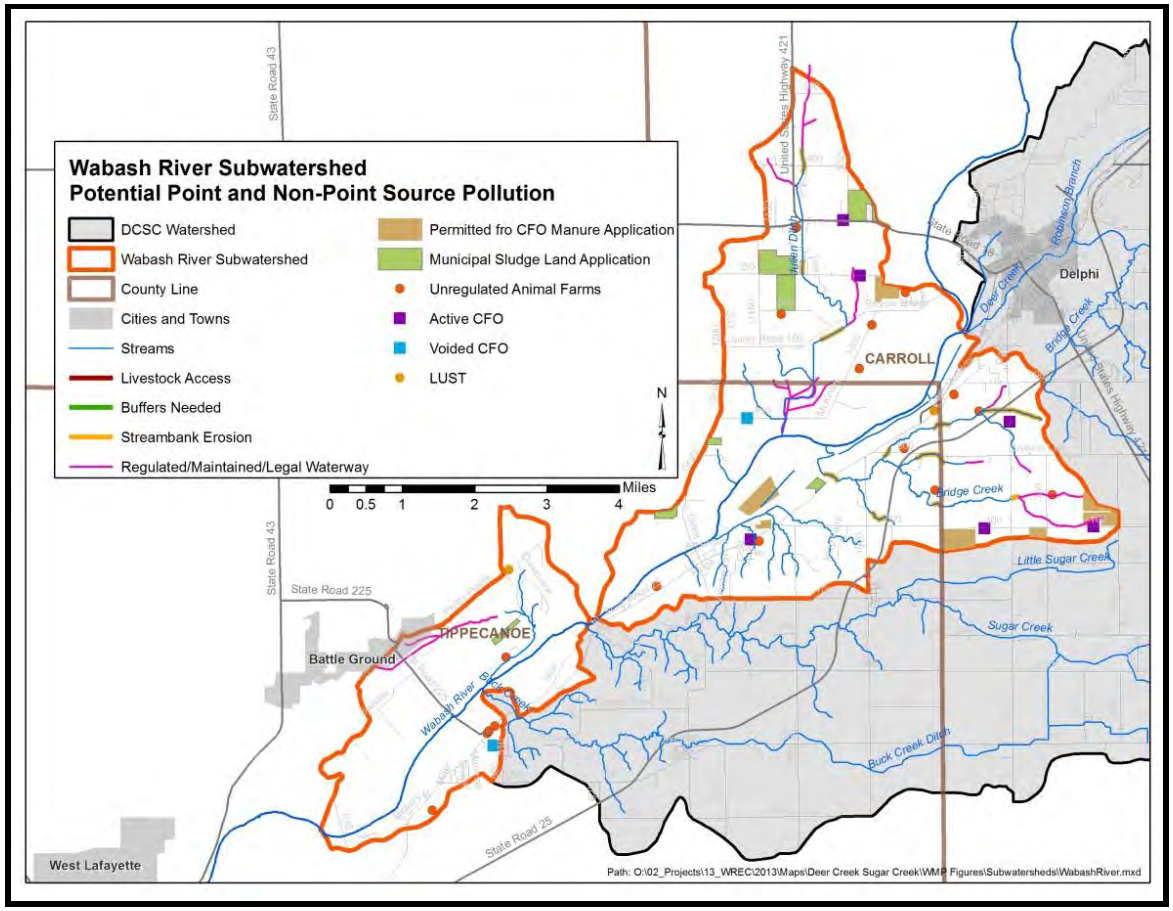

Figure 94.Point and non-point sources of pollution in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.4 Non-Point Source Water Quality Issues

Agricultural land uses account for the highest percentage of land uses in the Wabash River subwatershed. A number of unregulated animal farms are located within the Wabash River subwatershed. Approximately, 29 cattle, five goats, five sheep, and 36 horses are located on 17 farms. There are currently six active CFO scattered throughout the subwatershed. The Wabash River subwatershed contains the lowest number of animals in CFOs with only 7,640 animals. There are approximately 4,440 nursery pigs and 3,240 finishing pigs in the Wabash River subwatershed. CFO permits allow for distribution of manure on approximately 353 acres. Estimated conservatively, the livestock in this

subwatershed produce upwards of 5 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 353 acres of permitted receiving land, total Nitrogen would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops). However in this subwatershed, Phosphorus Pentoxide loads would exceed recommended fertilizer rates (Sutton et al., 2001).

Streambank erosion is also of concern within the Wabash River subwatershed. In total, 7 miles of streambank stabilization are needed along the tributaries which feed into the Wabash River. Additionally, nearly 40 miles of the Wabash River require stabilization and nearly 6.25 acres of land requires buffering within 30 feet of the Wabash River (along approximately 1.7 miles of riverbank).

4.10.5 Water Quality Assessment

Within the Wabash River subwatershed, IDEM assessed water quality and macroinvertebrate communities at four sites (Figure 92). Two of these sites are fixed monitoring stations on the Wabash River located on Grant Road and State Road 225. *E. coli* was measured at the two fixed stations. Macroinvertebrates in the Wabash River were sampled at State Road 225 and County Road 100 Northeast. Water chemistry samplers were also collected on the Wabash River downstream of the State Road 225 fixed station on the Wabash River.

Water Chemistry

IDEM assessed water chemistry in the Wabash River at SR 225 in 2008. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels exceeded the state standard once in this period measuring 272.3 colonies/100 mL; the remaining four samples measured below 70 colonies/100 mL. Nitrogen and total phosphorus measured during this sampling event were also elevated. Nitrogen concentrations exceeded Dodds et al. (1998) suggested standard during one out of three sample events measuring 5.34 mg/L. Total phosphorus exceeded the suggested standard during two of the three events with concentrations of 0.125 and 0.202 mg/L. At both of the fixed stations, *E. coli*, nitrogen, and total phosphorus were parameters of concern. Nitrogen concentrations routinely exceeded the recommended criteria at both sites. Concentrations ranged from 0.2 to 12.0 mg/L. Total phosphorus concentrations also routinely exceeded the suggested standard (0.3 mg/L) at both sites. Concentrations ranged from 0.05 to 0.81 mg/L. *E. coli* concentrations varied over time, but generally exceeded the state standard at both sites. The maximum *E. coli* concentration measured 23,000 colonies/100 mL, nearly 100 times the state standard.

Habitat

IDEM assessed habitat twice within the Wabash River subwatershed using the QHEI. IDEM assessments occurred in 1995 and 2008; sites were located at State Road 225 and County Road 100 Northeast on the Wabash River in Tippecanoe County. In 1995, the State Road 225 site's habitat was evaluated receiving a score of 52. This is barely better than the cut off for whether a stream is fully supporting their aquatic life use designation. The Wabash River on County Road 100 Northeast was sampled in 2008 and rated as not being fully supportive of the aquatic life use designation scoring 49.

Macroinvertebrates

The macroinvertebrate communities within Wabash River subwatershed were sampled at two locations by IDEM. IDEM sampled the Wabash River at SR 225 in 1995 and 1999. Communities rated as severely impaired during both assessments scoring 0.2 and 1.8, respectively. The Wabash River at County Road 100 Northeast was evaluated in 2008. The macroinvertebrate community was dominated by *Pleurocera canaliculata*, a right-handed snail that is intolerant of pollution. The mIBI score for was a 34, which rates this site severely impaired according to IDEM's new mIBI scale.

4.10.6 Wabash River Subwatershed Summary

Wabash River subwatershed has the lowest percentage of agricultural land use in the Deer Creek-Sugar Creek watershed, as it accounts for 71% of total land. This watershed has no urban land use, instead the rest of the land is comprised of 2.8% open water, 16.5% deciduous forest, and 6.8% wetlands; some of these lands are within Prophetstown State Park. The only point source water quality issue in this subwatershed is two leaky underground storage tanks. Similar to Sugar Creek subwatershed, there are no brownfields, industrial waste sites, or NPDES permitted facilities. Nitrogen concentrations were in exceedance of suggested standards in close to 30% of the samples taken, while phosphorus exceeded standards in close to 65% of the samples taken. *E. coli* was cause for concern, as samples revealed concentrations of nearly 100 times the state standard. Overall, E. coli concentrations fluctuated from sample to sample, but regularly exceeded the state standard. The habitat assessment for the Wabash River subwatershed revealed a need for improvement. The QHEI score indicated the habitat is on the verge of not fully supporting the aquatic life in the river, and the mIBI score indicated that the macroinvertebrate population was severely impaired.

5.0 WATERSHED INVENTORY III: WATERSHED INVENTORY SUMMARY

Several important factors and relationships become apparent when the Deer Creek-Sugar Creek watershed is observed both as a whole and in part. Many of these were discussed in the individual subwatershed discussions above; therefore, those discussions are not repeated here. Rather, an overall summary of water quality impairments and a review of stakeholder concerns and any data which support these concerns are included herein.

5.1 Water Quality Summary

Based on historic data collected from IDEM, IDNR, previous water quality sampling and watershed projects, and current water quality assessment, water quality impairments were identified during the watershed inventory process. These include elevated nitrate-nitrogen, total phosphorus, total suspended solids or turbidity, and E. coli concentrations; high densities of small, unregulated animal farms and confined feeding operations; and large portions of the watershed where manure or wastewater treatment plant materials are applied.

Figure 95 highlights those locations within the Deer Creek-Sugar Creek watershed where current water quality assessment detected concentrations of these parameters measured higher than the target concentrations during high flow events, Figure 43 shows the locations of historic sampling locations, and Figure 44 shows which historic sampling sites exceeded state standards. Current water quality assessment sample sites in Figure 95 are mapped only if a majority of samples collected at those sites during 20% or higher flow events exceeded the target concentration based on a load duration curve analysis. These higher flow events produced elevated concentrations in the subwatersheds and creeks as described in Table 21.

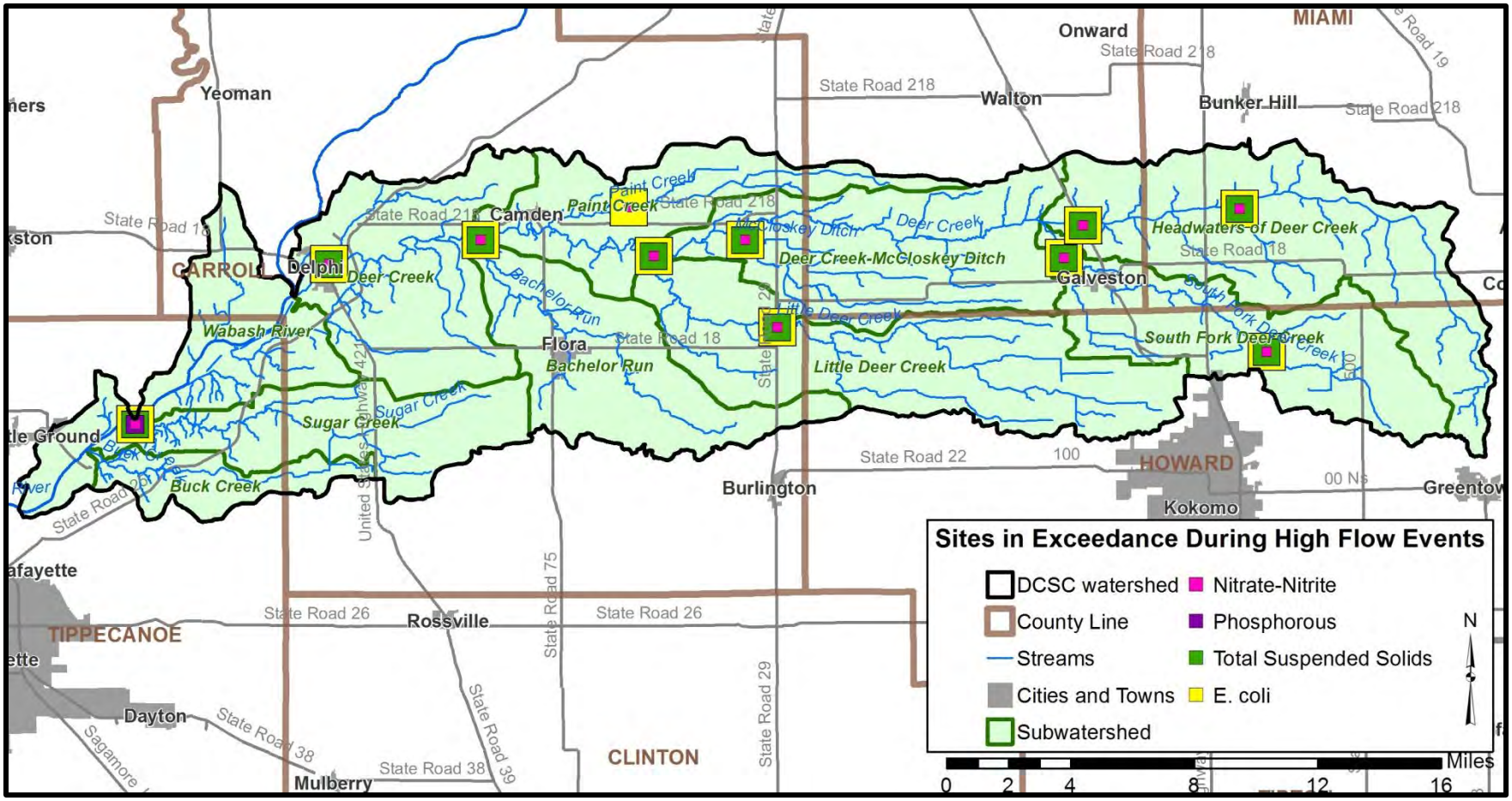

Figure 95. Locations where water chemistry concentrations exceed target concentrations during high flow events

Data used to create this map are detailed in Appendix A.

Table 21. Monitoring samples exceeding targets during high flow events

Subwatershed	E. coli	TSS	N	P
Headwaters of Deer Creek	●	●	●	
South Fork Deer Creek	●	●	●	
Deer Creek-McClosky Ditch	●	●	●	
Little Deer Creek	●	●	●	
Paint Creek	●		●	
Bachelor Run	●	●	●	
Deer Creek	●	●	●	
Sugar Creek	●	●	●	●
Buck Creek				
Wabash River	NA	NA	NA	NA
Stream	**E. coli**	**TSS**	**N**	**P**
South Fork Deer Creek	●	●	●	
Little Deer Creek	●	●	●	
McCloskey Ditch	●	●	●	
Paint Creek	●		●	
Bachelor Run	●	●	●	
Deer Creek	●	●	●	●
Sugar Creek	●	●	●	
Buck Creek				
Wabash River	NA	NA	NA	NA

5.2 Stakeholder Concern Analysis

All of the identified concerns generated both from stakeholder input and through water quality and watershed inventory efforts are detailed in Table 22. The steering committee rated each concern as to whether it is supported by watershed-based data, what evidence does or does not support the concerned, whether the concern is quantifiable, whether it is in the scope of the watershed management plan, and if it is something on which the committee wants to focus. Nearly all concerns were quantifiable and many were rated as being within the scope and items on which the committee wants to focus. If, in evaluating this table, the committee elected not to focus on a concern, the concern has been grayed out.

Table 22. Analysis of stakeholder concerns.

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed.	Yes	• Cultivated crops accounts for 83.3% of the watershed's land use. Also, tile drained soils cover approximately 65% of the watershed. • Based on historic data, turbidity exceeded the USEPA's recommended standard of 9.89 NTU at 20 sites within the watershed (Bachelor Run, Deer Creek, Little Deer Creek, Paint Creek, South Fork of Deer Creek, Sugar Creek and the Wabash River). • Based on historic data, concentrations of nitrate-nitrite exceeded the recommended standard of 2 mg/L (Dodds et al., 1998) at 14 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, Sugar Creek and the Wabash River). During the current assessment, nitrate exceeded targets in 209 of 264 measurements. • Using historic data, concentrations of total phosphorus exceeded the recommended standard of 0.3 mg/l (Dodds et al., 1998) at 8 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, and the Wabash River). During the current assessment, total phosphorus concentrations exceeded targets in 43 of 264 measurements.	Yes	No	Yes
Pesticide concentrations in Deer Creek.	Yes	Based on historic IDEM data, there was evidence of pesticides in Deer Creek at CR 300 North in Carroll County. Pesticides detected include: Acetochlor – 0.1-2.3 µg/L; Alachlor – 0.1-2.3 µg/L; Atrazine – 0.3-16 µg/L; Benz[a]anthracene – 0.1 µg/L; Benzo[a]pyrene – 0.16 µg/L; Benzo(b)fluoranthene – 0.2 µg/L; Benzo[k]fluoranthene – 0.2 µg/L; Clomazone 0.1-3.2 µg/L; Cyanazine – 0.3 µg/L; Di(2-ethylhexyl) phthalate – 0.6-0.9 µg/L; Fluoranthene – 0.2-0.4 µg/L; Metolachlor – 0.1-30 µg/L. There is no data for the other waterbodies in the watershed.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed.	Yes	Approximately 58% of the floodplain is classified as cultivated crops or hay/pasture (NLCD, 2006).	Yes	No	Yes
Too few agricultural best management practices are located in the Deer Creek-Sugar Creek watershed.	No data available at this time	Agricultural BMPs were identified during the watershed inventory; however, determination of whether "too few" are present did not occur. The committee agrees that increased usage of BMPs will improve water quality.	Yes	No	Yes
There are dead animals (hogs) in Deer Creek.	No	No data are available to support or refute this concern. The steering committee would like to address this issue if future evidence is found.	Yes	No	Yes
Waste from livestock is increasing the *E. coli* concentrations in watershed waterbodies.	No	The only way to definitively determine the actual source of *E. coli* is to perform DNA analysis of water quality samples. However, DNA analysis will not be done as part of this project. However, the steering committee would like to address the issue of livestock access in streams	Yes	No	Yes
Hog sewage (waste) is sitting/stagnate in Little Deer Creek.	No	No data are available to support or refute this concern. However the committee is interested in limiting the potential for sewage or waste to enter and stagnate in Little Deer Creek.	Yes	No	Yes
Livestock is negatively impacting water quality.	Yes	Livestock with stream access have the tendency to increase turbidity from entering and exiting the stream. Livestock have access to nearly 25 miles of watershed streams.	Yes	No	Yes
There are unregulated animal farms within the watershed.	Yes	There are 306 unregulated animal farms housing 259,000 animals.	Yes	No	Yes
Livestock access to the stream	Yes	Livestock have access to nearly 24 miles of watershed streams as observed during the watershed inventory.	Yes	No	Yes
Fish populations have been negatively affected by the water quality.	Yes	11 sites within the watershed were sampled for fish communities by IDEM; 7 sites were classified as below excellent using the IBI scale and 3 were not classified. Only one of the sites assessed during this planning process rated as excellent.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Macroinvertebrate populations have been negatively affected by the water quality.	Yes	Three sites assessed by IDEM using the current macroinvertebrate assessment method and five sites assessed by IDEM using the old assessment method rated below the IDEM standard. During this planning process, only the Headwaters of Deer Creek and McCloskey Ditch rated below the IDEM standard.	Yes	No	Yes
Wildlife areas should be encouraged and protected within the watershed.	Yes	IDNR manages 2,696 acres; Niches manages 64 acres within the watershed.	Yes	No	Yes
There has been a decline in crawfish populations.	No	Crawfish population surveys have not and will not be completed as part of this project.	Yes	No	No
Lack/decrease of wetlands within the watershed.	Yes	Based on the extent of hydric soils, nearly 92% of wetlands have been modified or lost. Approximately 3.4% of the watershed is classified as wetlands according to the National Wetland Inventory that updated in 2012 (NLCD, 2006 and NWI, 2012).	Yes	No	Yes
There are invasive species issues within the watershed.	No	Invasive species coverage will not be quantified as part of this project.	Yes	No	Yes
Fish caught within the watershed are not safe for consumption.	Yes	Fish consumption advisory exists for Deer Creek and the Wabash River (FCA, 2012):All waterbodies: Carp 15+ inches; Deer Creek – Smallmouth Bass 10+ inches; Wabash River – Black Redhorse 19+ inches; Blue Sucker 21+ inches; Carpsuckers ALL; Channel Catfish 15+ inches; Freshwater Drum 16+ inches; Sauger 13+ inches; Shorthead Redhorse 15+ inches; Smallmouth Buffalo 20+ inches	Yes	Yes	No
The volume of manure produced in the Deer Creek-Sugar Creek watershed.	Yes	Just over 42 square miles in the watershed are permitted for manure application. Based on average per head ton/year approximations, regulated animals from CFOs in the watershed are producing nearly 300,000 tons of manure per year. This does not include the additional waste produced by unregulated animal farms.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
There is a lack of manure management in areas of the watershed.	No	Confined feeding operations have manure management plans on file with IDEM. Based on average per head ton/year approximations, regulated animals from CFOs in the watershed are producing nearly 300,000 tons of manure per year. This does not include the additional waste produced by unregulated animal farms. IDEM incident reports; newspaper articles indicate the following: •March 24th and April 18th of 1975: Fish kill in Little Sugar Creek and Sugar Creek due to a wastewater spill from a swine confined animal facility. • July 1981: Fish kill in Sugar Creek attributed to poor manure management on site resulting in manure inputs to the stream. •There are nine IDEM incident reports for CFO violations (IDEM virtual filing cabinet 1900-2013)	Yes	No	Yes
Some CFO facilities are storing their manure too close to creeks.	Undetermined at this time	Manure is being applied within the following distances from the creeks (determined using buffers along the streams and manure application sites):10 ft. – 64.3 acres; 50 ft. – 328.3 acres; 100 ft. – 689.3 acres; 200 ft. – 1,495 acres. CFO facility storage information will be updated upon the completion of the windshield survey	Yes	No	Yes
There have been several manure spills/fish kills within the watershed.	Yes	IDEM incident reports; newspaper articles indicate the following: •March 24th and April 18th of 1975: Fish kill in Little Sugar Creek and Sugar Creek due to a wastewater spill from a swine confined animal facility. • July 1981: Fish kill in Sugar Creek attributed to poor manure management on site resulting in manure inputs to the stream. •There are nine IDEM incident reports for CFO violations (IDEM virtual filing cabinet 1900-2013).	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Manure is being applied throughout the watershed.	Yes	Manure is spread on 42.4 square miles of the watershed; this does not include manure from small producers and farms (IDEM and WREC, 2013).	Yes	No	Yes
Bio-solid issues	No	Municipal sludge (bio-solids) is being applied to approximately 14,596 acres. Application sites are predominately located in Cass and Howard Counties, 7,270 and 6,100 acres, respectively (IDEM, 2012).	Yes	No	Yes
Nitrogen concentrations exceed suggested levels.	Yes	Using historic data, concentrations of nitrate-nitrite exceeded the recommended standard of 2 mg/L (Dodds et al., 1998) at 14 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, Sugar Creek and the Wabash River). During the current assessment, nitrate exceeded targets in 209 of 264 measurements.	Yes	No	Yes
Phosphorus concentrations exceed suggested levels.	Yes	Using historic data, concentrations of total phosphorus exceeded the recommended standard of 0.3 mg/l (Dodds et al., 1998) at 8 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, and the Wabash River). During the current assessment, total phosphorus concentrations exceeded targets in 43 of 264 measurements.	Yes	No	Yes
Turbidity/sediment exceeds recommended levels by USEPA.	Yes	Using historic data, turbidity exceeded the USEPA's recommended standard of 9.89 NTU at 20 sites within the watershed (Bachelor Run, Deer Creek, Little Deer Creek, Paint Creek, South Fork of Deer Creek, Sugar Creek and the Wabash River). During the current assessment, turbidity measurements exceeded targets in 133 of 216 measurements.	Yes	No	Yes
E. coli concentrations exceed the state of Indiana's suggested level.	Yes	19 sites sampled by IDEM had *E. coli* concentrations exceeding Indiana's recommended standard of 235 colonies/100 mL. During the current assessment, *E. coli* concentrations exceeded targets during 188 of 216 measurements.	Yes	No	Yes
Develop long term monitoring stations on Deer Creek/Wabash River.	Yes/No	There are two USGS gauges within the watershed. One on Deer Creek and the other on the Wabash River.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
There are limited buffers along Buck Creek which are contributing to poor water quality, and instable banks.	Yes	Insufficient or limited buffers are present along nearly 87 miles of watershed streams.	Yes	No	Yes
Care of soil quality and erosion.	Yes	Using historic data, turbidity concentrations were higher than the USEPA's suggested standard of 9.89 NTU at the majority of the historic sampling sites. During the current assessment, turbidity measurements exceeded targets in 133 of 216 measurements.	Yes	No	Yes
Stream bank erosion occurs along the waterbodies within the watershed.	Yes	Streambank erosion occurs along nearly 58 miles of watershed streams.	Yes	No	Yes
Educational programs addressing conservation practices, recycling, climate change, and disposing of chemicals need to be developed.	Yes/No	Educational programming and information is available throughout the watershed; however, additional programming and materials can always be useful.	Yes	No	Yes
Limited of recreation in the watershed.	Yes/No	Public access sites are available on Deer Creek and the Wabash River within the watershed. Efforts related to increasing recreation will be addressed via education and outreach efforts.	No	Yes	No
Carroll County zoning regulations are not providing sufficient protection for sensitive and high quality areas.	No	Carroll County is working to implement revised floodplain zoning which will most likely address these concerns.	No	Yes	No
Problem with land value.	No	No data could be identified to support or refute this issue with relationship to water quality.	No	Yes	No
Flooding concerns within residential areas (Flora and Delphi).	Yes/No	Documentation of historic flood events is available for both Flora and Delphi and both communities are making efforts to address these issues.	No	Yes	No
Instream flows are unpredictable	Yes/No	Flow data collected during this planning process indicate unpredictable flows; however, the committee will not address instream flows themselves but rather water retention and filtration efforts.	No	Yes	No
Wells are low and may be contaminated by nitrate.	No	No well data were collected as part of this planning effort.	No	Yes	No

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Effects of highway construction (State Road 25).	No	A biological assessment occurred as part of the planning process for Hoosier Heartland. This document includes notation of streams that will be crossed but does not detail the communities present prior to construction.	No	Yes	No
Illegal septic systems	No	None of the county health departments have data on any illegal septic systems within the watershed. However, given the rural nature and development history, it is likely that some illegal septic systems exist within the watershed.	Yes	Yes	No
Increased population of zooplankton species	No	No zooplankton data were collected as part of the current or historic database.	No	Yes	No
Waste water needs more conservation of water, don't use drinking water for other uses	No	No water conservation data were collected as part of this planning process.	No	Yes	No
Dredge river; make it deeper	No	The need to dredge the Wabash River was not investigated as part of this planning process.	No	Yes	No
Reservoirs – effect on stream flow	No	The need for a reservoir within the Deer Creek-Sugar Creek watershed or the potential impact of such a waterbody was not investigated as part of this planning process.	No	Yes	No
Engineering of tile drains in Carroll County	No	Tile drains are present within the watershed including 65% of all soils and are engineered to increase the flow of water to surface waterbodies. This increase can impact water quality.	No	Yes	No
Stone quarry being constructed outside of Americus.	Yes	A stone quarry is planned outside of Americus within the Deer Creek-Sugar Creek watershed.	Yes	Yes	No
Dumping/burying of chemical waste	No	No evidence of dumping or burying of chemical waste was identified as part of this planning project.	No	Yes	No
Hydromodification of the stream system in the watershed	Yes	It appears that there are approximately 400 miles of regulated drains, indicating that the stream system is highly modified. More data need to be digitized, and variations in county definitions of legal, regulated, and maintained waterways need to be reconciled in order to review the exact mileage and locations of hydromodifications.	Yes	No	No