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 was available or if additional data needed to be collected in order to characterize water quality problems. Once the water quality data assessment occurred, the watershed was then characterized to determine potential sources of any water quality issues identified by the data review. Subsequently, pollutant sources could then be tied to stakeholder concerns and collected data could be used to estimate pollutant loads from each identified source location. 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 Region of the Great Bend of the Wabash River 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. Monitoring 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 24 details the selected parameters and the benchmark utilized to evaluate collected water quality data.

Table 24. Water quality benchmarks used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Benchmark	Source
Dissolved oxygen	>4 mg/L	Indiana Administrative Code
pH	<6 or >9	Indiana Administrative Code
Temperature	Monthly standard	Indiana Administrative Code
E. coli	<235 colonies/100 mL	Indiana Administrative Code
Nitrate-nitrogen	<2.0 mg/L	Dodds et al. (1998)
Total phosphorus	<0.08 mg/L	Dodds et al. (1998)
Orthophosphorus	<0.05 mg/L	Dunne and Leopold (1978)
Total suspended solids	<25 mg/L	Waters (1995)
Turbidity	<9.89 NTU	USEPA (2001)
Qualitative Habitat Evaluation Index	>51 points	IDEM (2008)
Index of Biotic Integrity	>36 points	IDEM (2008)
Macroinvertebrate Index of Biotic Integrity	>2.2 points	IDEM (2008)

3.2 Historic Water Quality Sampling Efforts

A variety of water quality assessment projects have been completed within the Region of the Great Bend of the Wabash River watershed (Figure 50). Statewide assessments and listings include the integrated water monitoring assessment, the impaired waterbodies assessment, and fish consumption advisories. Additionally, the Indiana Department of Environmental Management (IDEM) and Indiana Department of Natural Resources (IDNR) have both 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 by the Tippecanoe County

Soil and Water Conservation District (SWCD), the Tippecanoe County Health Department (TCHD), and the Lafayette and West Lafayette wastewater utilities; Purdue University professor-led assessments of Little Pine and Indian Creeks and mussel and fish assessments throughout the county; and volunteer-based sampling of water quality through the Hoosier Riverwatch program and via the Wabash Sampling Blitz all provide additional water quality data with which the watershed can be characterized. A summary of each assessment methodology and general results are discussed below. Specific data results are detailed within subwatershed discussions in subsequent section.

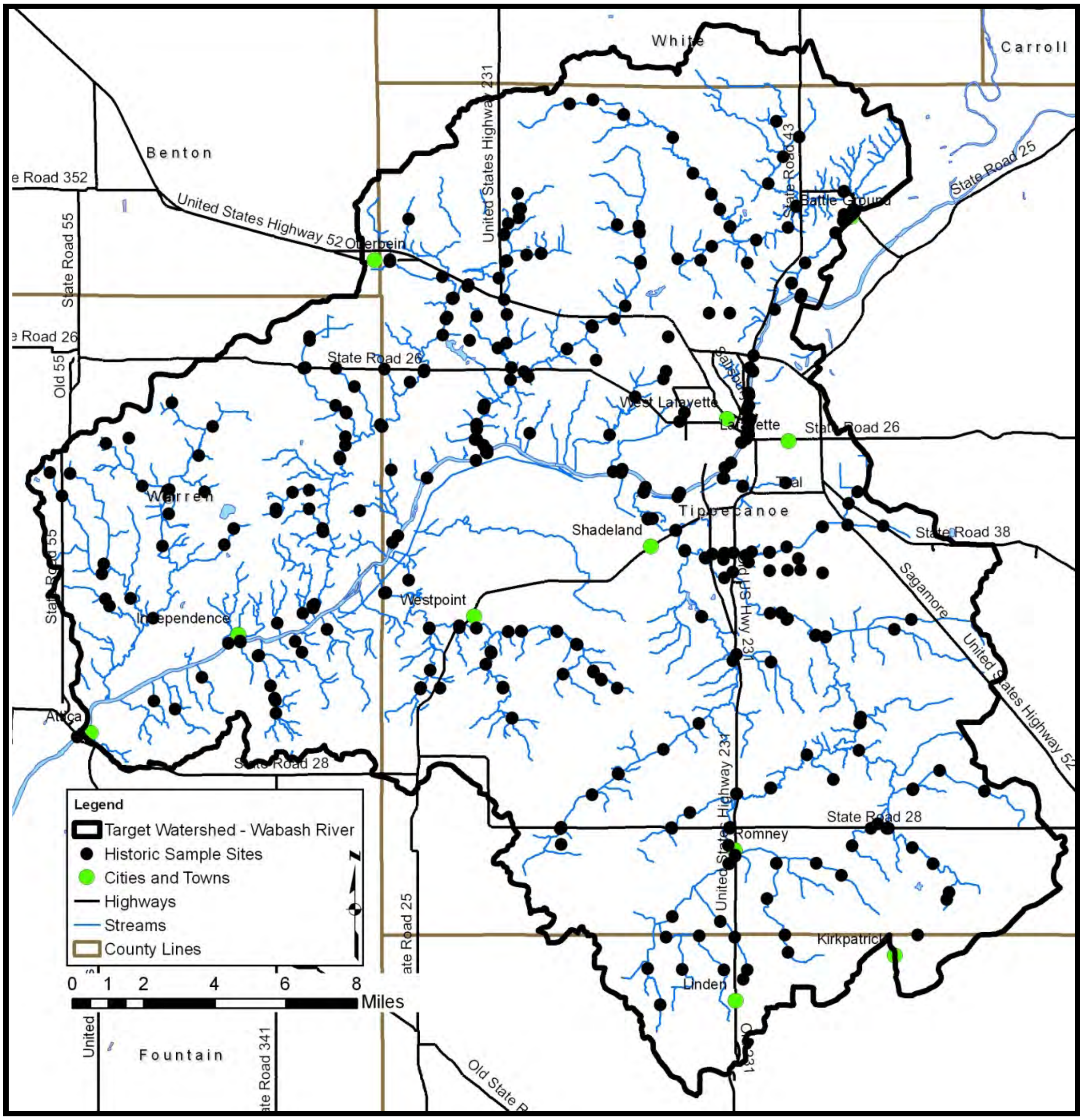

Figure 50. Historic water quality assessment locations.
Data used to create this map are detailed in Appendix A.

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. The most recently accepted report was delivered to the USEPA in 2008 (IDEM, 2008). A draft report for the 303(d) list was submitted to the USEPA; however, no changes to the listing occurred within the Region of the Great Bend of the Wabash River watershed from the 2008 to the 2010 listings. 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' designated uses of swimmable, fishable, and drinkable. Waterbodies that do not meet their designated uses are proposed for listing on the impaired waterbodies list, which is discussed in more detail below.

The 2008 IWMA indicates that many waterbodies within the watershed have been assessed in the past; however, insufficient data is available to determine if these waterbodies are or are not meeting their designated uses. These include portions of Burnett Creek, Wea Creek, Flint Creek, Elliot Ditch, Loafland Ditch, Romney-Fraley Ditch, Kellerman Lea-Ming Ditch, East Branch Wea Creek, Little Wea Creek, Flint Run, Grindstone Creek, Little Flint Creek, Little Pine creek, McFarland Ditch, Otterbein Ditch, Armstrong Creek, Peterson Ditch, Turkey Run, Opossum Hollow, Kickapoo Creek, and tributaries to the Wabash River, Flint Creek, Wea Creek, Indian Creek, and Little Pine Creek. Because of the lack of data, these waterbodies were not rated with regard to meeting or not meeting their designated uses. Sufficient data has been collected from other waterbodies within the watershed. The 2008 IWMA identifies known impairments for the Region of the Great Bend of the Wabash River watershed including portions of Burnett Creek, Elliot Ditch, Flint Creek, Wea Creek, and the Wabash River.

3.2.2 Impaired Waterbodies (303(d) List)

Waterbodies in the Region of the Great Bend of the Wabash River 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 25 details the advisories for the Region of the Great Bend of the Wabash River watershed from the 2008 report (ISDH, 2009). Advisories listings are as follows:

- Level 3 – limit consumption to one meal per month for adults with pregnant or breastfeeding women, women who plan to have children, and children under 15 consuming zero volume of these fish.
- Level 4 – limit consumption to one meal every 2 months for adults with 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:

- Elliot Ditch and Wea Creek are under a fish consumption advisory along their entire length.
- The Wabash River is under a fish consumption advisory for selected fish of select size within the length of the river in Tippecanoe, Warren, and Fountain counties.
- No carp should be consumed from any waterbody within the watershed.

Table 25. Fish Consumption Advisory listing for the Region of the Great Bend of the Wabash River watershed.

Waterbody	Fish Species	Fish Size	Advisory
All	Carp	15-20 inches	3
		20-25 inches	4
		25+ inches	5
Elliot Ditch	All	All	5
Wea Creek	All	All	5
Wabash River	Bigmouth buffalo	18+ inches	3
	Blue sucker	21-26 inches	3
		26+ inches	4
	Carpsuckers	<13 inches	3
		13-19 inches	4
		19+ inches	5
	Channel catfish	<20 inches	3
		20+ inches	4
	Flathead catfish	21+ inches	3
	Paddlefish	34+ inches	3
	Sauger	13+ inches	3
	Smallmouth buffalo	21-24 inches	3
		24+ 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). Within the Region of the Great Bend of the Wabash River watershed, the TMDL addresses nutrient, dissolved oxygen, and *E. coli* impairments.

Data collected by several agencies was 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 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 exceedences.

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 was available for calculation. The location relevant to the Region of the Great Bend watershed is the Wabash River at County Road 700 West in Tippecanoe County. Although this station does not include the entire watershed, it contains a majority and is therefore used as the base assessment regarding necessary reductions (Figure 51). Based on the Wabash River TMDL, the following conclusions have been drawn:

- A monthly reduction in *E. coli* from nonpoint sources from April to October of 87-88% is needed in the Wabash River upstream of Lafayette and thus upstream of the watershed. No reduction in point source generated *E. coli* is necessary. This percent reduction results in a reduction of 719,000,000,000,000 *E. coli* colonies per day or 19,700,000,000 colonies per 100 ml per year (TetraTech, 2007).
- Monthly reductions of total phosphorus from point sources ranging from 46 to 71% are needed in the Wabash River upstream of Lafayette; while a 4% reduction from nonpoint sources is necessary. This results in an overall reduction of 1 lb of phosphorus per day or just less than 359 lb of phosphorus per year.
- No nitrate reductions are required upstream of Lafayette from either point or nonpoint sources.

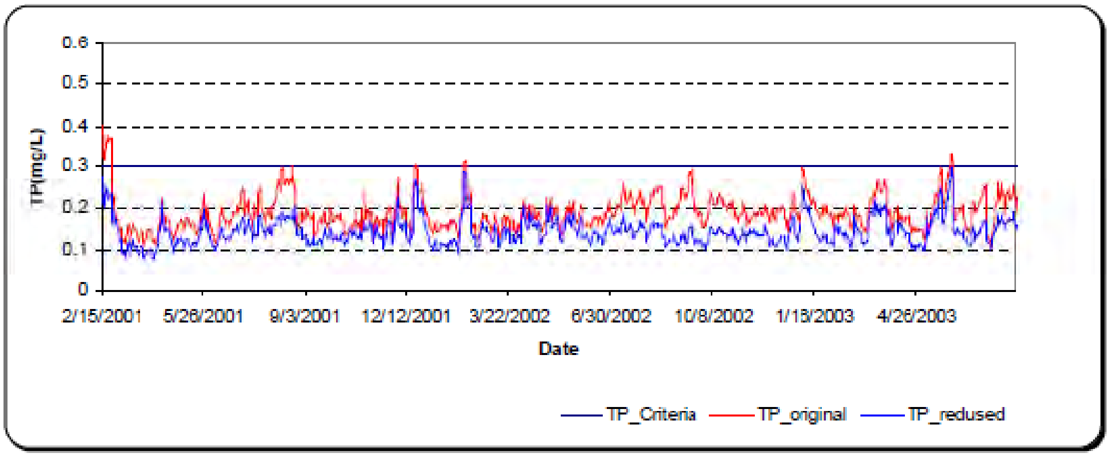

Figure H-9. TP at Upstream Lafayette

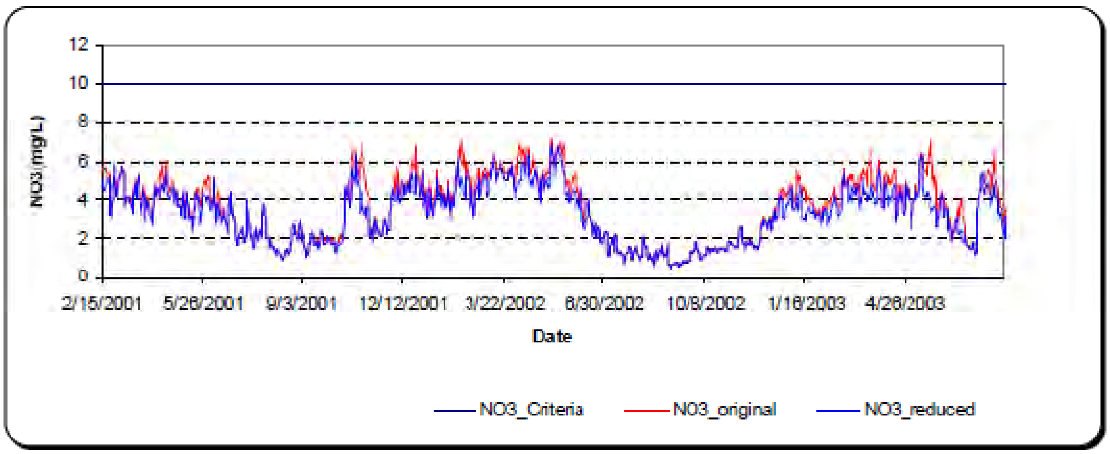

Figure H-10. NO3 at Upstream Lafayette

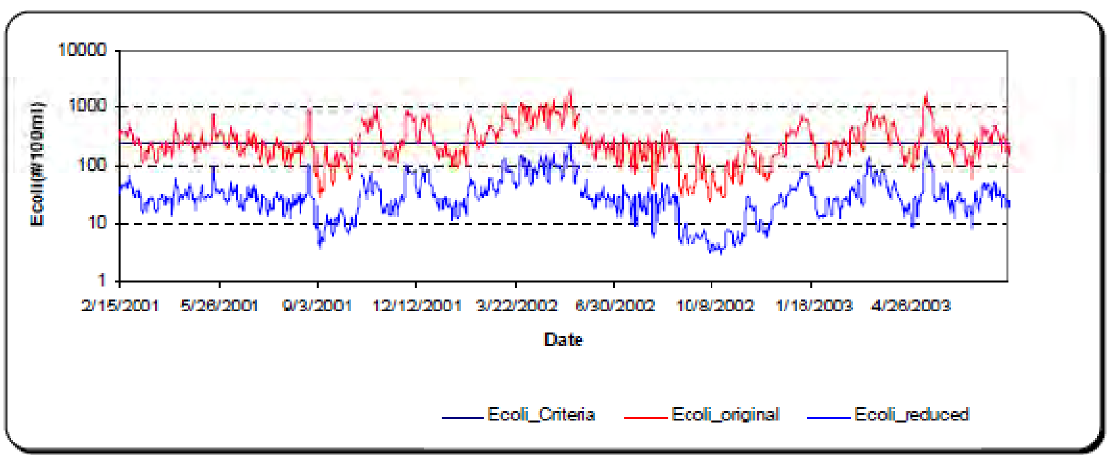

Figure H-11. *E. coli* (instantaneous) Upstream Lafayette

Figure 51. Total phosphorus (TP), nitrate (NO3), and *E. coli* load reductions identified in the Wabash River TMDL for the upstream of Lafayette portion of the Wabash River. Source: TetraTech, 2007.

3.2.5 IDEM Fixed Station (1990-2009) 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. Two sample sites are located on the Wabash River in or near the watershed. These sites include one upstream location at State Road 225 (1990 to 2000) then moving upstream to Americus (2001 to present) and one located downstream of the urban core at County Road 700 West or Granville Bridge. Although the upstream location is upstream of the upper end of the Region of the Great Bend of the Wabash River watershed, these data provide details as to the quality of water entering the watershed. 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 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.

In 1999, 2004, and 2009, IDEM sampled water chemistry at several locations in the Region of the Great Bend of the Wabash River via their rotational basin assessment program. Sampling occurred in Burnett Creek, Little Pine Creek, Opossum Hollow, Flint Creek, Wea Creek, and Wabash River in 1999. In 2004, Burnett Creek and an unnamed tributary to the Wabash River were sampled by IDEM. Additionally, IDEM completed a source identification effort in the Flint Creek watershed in 2005, which included sampling 10 sites within the Flint Creek basin. Additional sampling occurred at three sites, Wea Creek, Opossum Hollow, an unnamed Wabash River tributary in Fountain County, and the Wabash River during IDEM's 2009 rotational basin monitoring program. A majority of the assessments which occurred via the rotational basin program included a single sample event with some assessments including up to three sample events. Based on the rotational basin water chemistry assessments, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the state standard in Burnett Creek, Flint Creek, Indian Creek, Kellerman Lea-Ming Ditch, Opossum Hollow, Wea Creek, the Wabash River, and two unnamed tributary to the Wabash River during at least one assessment.
- Nitrate-nitrogen concentrations exceeded the recommended criteria and the state standard in Burnett Creek, Little Pine Creek, and Opossum Hollow during at least one sampling event. Concentrations were elevated in Burnett Creek during a majority of the assessments.
- Total phosphorus concentrations exceeded the recommended criteria in Burnett Creek, Flint Creek, Opossum Hollow, Wea Creek, an unnamed tributary to the Wabash River, and Little Pine Creek.
- Turbidity levels and total suspended solids concentrations routinely exceed the state standard at IDEM's fixed station at Granville Bridge (CR 700 W) on the Wabash River. Additional exceedances occurred in Burnett Creek, Wea Creek, and an unnamed tributary to the Wabash River.
- Pesticide monitoring in the Wabash River occurred in 1999. Results indicate that pesticide concentrations are elevated especially atrazine. Atrazine concentrations measured as high as 10 mg/L.

IDEM completed biological and habitat assessments at eight sites throughout the watershed in 1991, 1999, and 2004. Fish sampling occurred in Burnett Creek, Opossum Hollow, Little Pine Creek, Flint Creek, and an unnamed tributary to the Wabash River in 1999 and 2004. Macroinvertebrate sampling occurred in the Wabash River, Little Pine Creek, Burnett Creek, Wea Creek, Elliot Ditch, and Opossum Hollow in 1991 and 1999. Both fish and macroinvertebrate samples were collected and habitat was also assessed using the QHEI. Based on these assessments, the following conclusions can be drawn:

- Habitat within the upstream portion of Burnett Creek rated poorly while downstream portions of Burnett Creek contained high quality habitat. The fish community reflects the habitat changes along the length of the stream. Habitat in Flint Creek, Little Pine Creek, and Opossum Hollow rated well; however, the fish community within each of these streams rated as fair.
- Macroinvertebrate communities rated as severely impaired in Elliot Ditch and the Wabash River at Mascouten Park, while Opossum Hollow, Wea Creek, upper reaches of Little Pine Creek, and the Wabash River at CR 700 West rated as moderately impaired. Burnett Creek, Wea Creek, and downstream reaches of Little Pine Creek rated as moderately impaired. As with the fish community assessments, macroinvertebrate communities generally reflect the habitat available within each reach. This suggests that water quality along the length of each tributary has little influence on the biological community whereas habitat impacts the macroinvertebrate community greatly.

3.2.6 Wabash River Fishery Assessments: DePauw University (1967-1994)

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 in Lafayette from 1977-1987 measured 87 mg/L which resulted in 714 tons of suspended sediments moving through the river per day. During high flow events, clay particles accounted for 68% of suspended sediments, while silt and sand represented 27% and 6%, respectively. Based on these data, a reduction in suspended sediments is necessary.
- Mean nutrient concentrations calculated from measurements occurring from 1977-1987 indicate that nitrate-nitrogen (3.3 mg/L) and phosphate (0.170 mg/L) concentrations were elevated and need to be reduced.
- In Gammon's 1994 assessment of riparian condition, 50 km of Wabash River bank from Lafayette to Attica were examined. Bare banks were observed on 1.9 km, while banks with few trees occurred on 2.8 km. These data indicate that in 1994, the banks of the Wabash River were relatively well protected. However, areas which were denuded likely represent former riparian wetland locations, thus indicating that floodplain storage may have been lost due to these conversions.
- The fish community is affected by inputs from the cities of Lafayette and West Lafayette. Declines in the fish community occur between the Wea Creek outlet and Granville Bridge as a result of them combined industrial and municipal impacts. These effects are limited to a relatively short distance.

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

Ball State University continued Jim Gammon's Wabash River assessment efforts starting in 2001 and continuing with an annual assessment through present day (Pyron and Lauer, 2009). The most recently reported effort included assessment of the fish community and field water chemistry in 500 feet reaches throughout the Middle Wabash. Sampling occurred along nine reaches within the Region of the Great Bend of the Wabash River watershed. Data collected throughout the Middle Wabash indicate relatively similar numbers of individuals (115 in 2008; 116.2 average) and numbers of species per collection (2001 to 2008). Based on these data, the following conclusions can be drawn:

- pH and dissolved oxygen concentrations were elevated along the Wabash River; however, none of the concentrations exceeded the target value.
- The highest species diversity occurred in the below Lafayette and below Granville Bridge sampling reaches with these same reaches containing the highest density.
- The lowest diversity occurred in the Granville bridge reach while the lowest density occurred within the Attica reach. Pyron and Lauer (2004) noted that habitat is likely a contributing factor to both high and low densities and diversities.
- All sites possessed IBI scores which exceeded the score at which IDEM indicates streams are not meeting their aquatic life use designation; however, the Granville bridge reach only scored one point above the ALUS. Despite its low density and diversity, the Attica reach scored the highest IBI (61).

3.2.8 IDNR Fisheries Assessment (1999)

In July 1999, the Indiana Department of Natural Resources (IDNR) surveyed the length of the Wabash River in 48 one-half to one mile segments. Habitat and general chemistry data were collected concurrent with the fish community assessment. Four segments were located within the watershed; these occurred at Mascouten Park, Fort Ouiatenon, Independence, and Attica. During the assessment, between 17 and 36 species and 133 and 225 individuals were collected. In total, 117 species were identified during the assessment. Gizzard shad, shovelnose sturgeon, and freshwater drum were collected most often in the Fort Ouiatenon reach, while gizzard shad, emerald shiner, river carpsucker, and common carp were collected in highest numbers in the Mascouten Park reach. Based on these data, the following conclusions can be drawn:

- Habitat may be limited within the Fort Ouiatenon reach. Water clarity was also low measuring 14 in the Mascouten Park and Fort Ouiatenon reach and 18 inches at the other three reaches. Dissolved oxygen concentrations were elevated measuring greater than 11.5 mg/L in each reach.
- Stefanavage (2007) indicated that distribution of species was most explained by individual species biology and its habitat preference rather than any impact from upstream dams or water quality impacts.
- These reaches are home to the only population of shovelnose sturgeon identified within the river.

3.2.9 The Nature Conservancy Wabash River Study

The Nature Conservancy 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 data collected, 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 the Region of the Great Bend 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 mainstem and tributaries in this reach. The elevated nutrient concentrations present in the tributaries, coupled with the lack of buffers, increased delivery of nutrients via drainage systems and tile drains, and degradation of instream habitat due to altered hydrology.

3.2.10 Stream Reach Characterization and Evaluation Report (2000, 2004)

Both the City of West Lafayette and the City of Lafayette were required to complete a Stream Reach Characterization Evaluation Report (SRCER) as a component of the cities' Combined Sewer Overflow (CSO) permits. The purpose of the SRCERs was to provide the cities with water quality information which assesses the potential impacts of the CSOs on water quality and to enable technically sound evaluation and planning. The SRCERs included evaluation of historically-collected and current water quality data.

In 2000, Commonwealth Biomonitoring completed a SRCER for the City of West Lafayette (Commonwealth Biomonitoring, 2000). Based on the City of West Lafayette's SRCER, the following conclusions have been drawn:

- Although fish consumption advisories exist for the Wabash River, there is little likelihood that PCB or mercury contamination originates from the City of West Lafayette's wastewater treatment plant (WWTP).
- *E. coli* concentrations are elevated throughout the Wabash River, including locations upstream (Americus) and downstream (Granville Bridge) of West Lafayette. Reductions in *E. coli* concentrations are necessary to meet the river's designated uses.

In 2004, Greeley and Hanson completed a SRCER for the City of Lafayette. As part of this project, the City of Lafayette assessed stormwater impacts from three CSO locations and the resulting impact of these overflows on the Wabash River. Samples were collected within the first 30 minutes of a storm event and then again 60 minutes later. Samples were analyzed for *E. coli*, temperature, dissolved oxygen, pH, biochemical oxygen demand, ammonia, total Kjeldahl nitrogen, nitrate, cyanide, and lead. Based on the City of Lafayette's SRCER, the following conclusions have been drawn:

- *E. coli* concentrations are elevated in the Wabash River with higher concentration observed upstream of the urban core than downstream concentrations. *E. coli* concentrations typically measured higher during wet weather events than during dry weather events. However, data suggests that CSO impacts cannot be characterized from these data.
- *E. coli* concentrations in Durkee's Run exceeded the state standard during storm events. These *E. coli* laden waters reached the Wabash River within 12 hours of the storm's initiation.
- *E. coli* concentrations within combined sewer overflows measured between 100,000 and 200,000 cfu/100 ml.

3.2.11 City of Lafayette and West Lafayette Assessment (1992-2010)

The City of Lafayette Water Pollution Control Department and the City of West Lafayette Wastewater Department each conduct surface water quality monitoring programs. Both programs focus on monitoring water quality within the Wabash River to monitor the success of stormwater management, CSO strategies, and their overall impact on the river.

Commonwealth Biomonitoring initiated the cities' assessment efforts in 1992 with these efforts continuing through present day (Commonwealth Biomonitoring, 2010). The long-term program focuses on monitoring the biological community at 10 locations within the Wabash River. The City of Lafayette portion of the study is focused in and around the city's wastewater treatment plant outfall to the Wabash River; the City of West Lafayette's sites are focused near their outfall to the river. Based on annual biological community data, the following conclusions have been drawn:

- The macroinvertebrate community data indicates moderate impairment of the community throughout most of the Wabash River reach assessed. However, severe impairment of the macroinvertebrate community has historically been observed near the sites which carry effluent from the cities' wastewater treatment plants.
- Historical data collected at these sites since 1992 suggests that macroinvertebrate community quality is highly variable annually. These changes can be attributed to low water conditions (1999) or local influences such as wastewater treatment plant effluent or combined sewer overflow locations that directly impact a portion of sites (1992, 1997).

The City of West Lafayette also monitors water quality within the river upstream and downstream of the cities and within the urban core. Monitoring was conducted on approximately a weekly basis during the growing season from 2007 to 2009. Samples are collected from three bridges including the US 52, US 231, and the pedestrian bridges. Based on the water chemistry grab samples, the following conclusions have been drawn:

- There is little difference in temperature, dissolved oxygen, *E. coli*, total suspended solids, and biochemical oxygen demand between the three sample points.
- *E. coli* concentrations routinely exceed the Indiana state standard (235 col/100 ml) at all three sample points.
- Total suspended solids (TSS) concentrations are elevated ranging from 20 to higher than 1,200 mg/L. In 2008, mean and median TSS concentrations were below IDEM's recommended threshold. 2009 TSS mean and median concentrations exceeded the recommended threshold; these exceedances are likely due to low flows within the river during the assessment period.

From 2000 to 2002, the City of Lafayette conducted assessments to determine nutrient, dissolved oxygen, temperature, and *E. coli* concentrations in combined sewer overflow effluent and receiving streams during and following storm events. Samples were collected from three bridge crossings (US 52, US 231, and the pedestrian bridge) of the Wabash River and from Durkee's Run, the stream which receives combined sewer overflow discharge and is also the receiving waterbody for the city's wastewater effluent. Based on these water quality assessments, the following conclusions can be drawn:

- In the Wabash River, dissolved oxygen, temperature, and pH values change little during and following a storm event. pH levels increased by two points at the pedestrian bridge during two of the three storm events. This increase is likely due to the volume of stormwater entering the Wabash River immediately upstream of the sample point.
- Nitrate-nitrogen, total Kjeldahl nitrogen (TKN), lead, cyanide, and biological and biochemical oxygen demand concentrations change little during and following storm events.
- In Durkee's Run, nitrate-nitrogen concentrations doubled within the first hour of the storm initiation and tripled by hour three during each of the storm sampling events. TKN concentrations measured up to 20 times the base flow concentration, while ammonia-nitrogen concentrations were 6 to 30 times higher than the base flow concentration. Temperature increases of up to four degrees were observed during each event.

- In both systems, *E. coli* concentrations increased rapidly from at or slightly below the state standard (235 colonies/100 mL) to measure more than 20,000 colonies/100 mL in the Wabash River and over 200,000 colongies/100 mL in Durkee's Run.
- *E. coli* concentrations measured in the combined sewer overflows indicate that 52,000 to 13,000,000 colonies/100 mL are present during the first flush (start of storm to 60 minutes following storm start).

3.2.12 Tippecanoe County SWCD Assessment (2002, 2003)

In 2002 and 2003 as part of World Water Monitoring Day, the Soil and Water Conservation District (SWCD) and their volunteers monitored water quality at 44 sites throughout the county, 32 of which are located within the Region of the Great Bend of the Wabash River watershed. Samples were analyzed for dissolved oxygen, pH, turbidity, and *E. coli*. DO, pH, and turbidity measurements were completed using Hoosier Riverwatch methodologies, while *E. coli* was analyzed by IDEM's mobile laboratory. No flow data is available for these samples; however, it is assumed that since 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 concentration and percent saturation were below the Indiana state standard (4 mg/L) in several streams including: the Wabash River, Burnett Creek, Indian Creek, Little Pine, and Flint Creek. All saturation percentages measured below 75%.
- *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) at 9 sites during 2002 and at 12 sites in 2003.

3.2.13 Tippecanoe County Health Department (2005-2007)

From 2005 to 2007, the Tippecanoe County Health Department (TCHD) collected grab samples roughly every two weeks during the growing season (May to October). Samples were collected from Burnett Creek, Wea Creek, Elliot Ditch, and from three locations along the Wabash River. Based on these data, the following conclusions can be drawn:

- In Burnett Creek, Wea Creek, and the Wabash River, turbidity levels routinely exceeded recommended levels. Turbidities measured by the TCHD in the Wabash River always measured higher than 25 NTU. These data suggest that not only the Wabash River carries high sediment loads, but also that its tributaries are subject to high episodic sediment loads throughout the growing season.
- In Burnett Creek, Wea Creek, and the Wabash River *E. coli* concentrations routinely exceeded state standards. During 37 of 45 sample events, *E. coli* concentrations measured higher than the state standard. Concentrations in excess of the standard ranged from 300 to 2,800 colonies/100 ml in Burnett Creek, from 267 to 8091 colonies/100 ml in Wea Creek, and from 275 to 2,667 colonies/100 ml in Elliot Ditch. There was no pattern of increasing or decreasing *E. coli* concentrations along the downstream gradient of the Wabash River.

3.2.14 Illicit Discharge and Detection Elimination (IDDE) Assessments

As part of the MS4 requirements, MS4 entities are required to map illicit discharge locations. Once mapped, these discharge locations will be monitored for inputs into the surface water system during both storm and base flow conditions. Individual partners in TCPWQ completed their own IDDE mapping efforts. To date, partners identified more than 300 discharge locations; however, assessment of these discharges has not yet begun. Therefore, no conclusions can be drawn from this dataset at this time.

3.2.15 USGS Assessment (1999)

In 1999, the USGS assessed one site in Wea Creek five times during a 30-day period. The assessment included collection of field data and *E. coli* samples. The samples collection was designed for the calculation of geometric means following IDEM's standards. Based on these data, the following conclusions can be drawn:

- All five *E. coli* samples measured higher than the state standard for grab samples and therefore, measured higher than the state geometric mean standard.

3.2.16 USEPA Biological Assessment – Elliot Ditch / Wea Creek

In 1999, the USEPA and IDEM completed a preliminary assessment of Elliot Ditch and Wea Creek to investigate PCB and industrial contamination issues. The inspection included collection of 20 soil samples, 7 surface water/outfall samples, and 29 sediment samples (Brauner, 2001). Based on the preliminary assessment, several parameters exceeded the chosen screening level, which suggests that toxic effects were observed in a selected biotic indicator (daphnid, fathead minnow, rainbow trout, etc.). The following parameters caused some level of toxicity in one or more of the biotic indicators: 4,4-DDD, 4,4-DDE, 4,4-DDT, Aldrin, b-BHC (Lindane), Dieldrin, Endosulfan, Endrin, Heptachlor, PCB, aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, vanadium, zinc, and a variety of other organics. Based on these results, further assessment of contaminants in sediment and water samples was completed; however, IDEM determined that no further action or activity to reduce these concentrations was required (Brauner, 2008).

3.2.17 Little Pine-Indian Project (1989-2003)

Purdue University collected water quality data from 22 stream sites within the Little Pine Creek and Indian Creek watersheds as part of the Indian Pine Natural Resources Field Station. Twelve sites in the Little Pine Creek watershed were sampled between 124 and 191 times over the sampling period. Ten sites in the Indian Creek watershed were sampled 34 to 173 times throughout the sampling period. Data collection occurred from 1989 through 2003 with some sites being sampled bi-weekly or monthly and other sites sampled sporadically throughout the project. Additionally, flow gaging stations were maintained at three sites throughout the watershed during much of the sampling period. Four additional gaging stations were in operation from 1995 through 1998, while two sites were operational for 6 and 232 days, respectively. Field data meters operated in concert with several of the gaging stations throughout the sampling period. Based on these data, the following conclusions can be drawn:

- Total phosphorus concentrations were elevated at all sites throughout the sampling period. In the Little Pine Creek watershed, total phosphorus samples collected from Otterbein Ditch and from Little Pine Creek at CR 800 West routinely measured the highest with concentrations in excess of 1.4 mg/L at each location. Maximum concentrations measured in Indian Creek were lower than maximum concentrations in Little Pine Creek; however, all sites within both streams exceeded total phosphorus target concentrations during approximately 20% of sampling events.
- Nitrate-nitrogen concentrations measured in both Little Pine and Indian creeks exceeded target concentrations throughout the sampling period. Like total phosphorus, nitrate-nitrogen concentrations in Little Pine Creek generally measured higher than those in measured in Indian Creek. Concentrations nearly three times the target concentration were routinely observed within both streams throughout the sampling period.
- Conductivity measurements were elevated during the sampling period with three to five measurements at each site exceeding the state standard. Indian Creek at Jackson Highway exceeded the state standard during one-third of the sampling events with concentrations as high as 4400 mhos/cm observed. Although a minimal number of exceedances occurred in Indian Creek at State Road 26, concentrations as high at 9660 mhos/cm were observed. Concentrations this high suggest a direct input (point source) of salts within the stream system.

- Total suspended solids concentrations were also elevated throughout the sampling period. Concentrations as high as 1860 mg/L were observed at Goose Creek at State Road 26. Nearly 25% of collected samples exceeded target total suspended solids concentrations.

3.2.18 Purdue University Sturgeon Sampling (2003-2004, 2007-2009)

Shovelnose sturgeon populations within the Wabash River were assessed by Kennedy et al. (2007) from April 2003 through November 2004. Sturgeon 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. Based on these 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 shovelnose sturgeon 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.
-

3.2.19 Purdue University Agricultural Research Station Sampling (2009-2010)

Water quality within Purdue University's Animal Science Research and Education Center (ASREC) were assessed by Gall et al. (unpublished) from January 2009 to February 2010. Samples were collected from five tile locations and three surface waterbodies in the headwaters of Little Pine Creek. Chemistry samples were collected every 10 hours during base flow with samples collected more frequently during storm events; stage measurements occurred every 15 minutes. Samples were processed for a variety of phosphorus and nitrogen parameters. Based on these data, the following conclusions can be drawn:

- Nitrate-nitrogen concentrations routinely exceed the target concentration measuring as high as 25 mg/L in tile samples and 18 mg/L in surface water samples.
- Orthophosphate concentrations measured as high as 1.5 mg/L in tile samples and exceeded 1.6 mg/L in surface water samples. Although exceedances occur, orthophosphate concentrations regularly measure relatively low and typically fall below the target concentration.

3.2.20 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). The Wabash River was not surveyed as part of this assessment. In total, 32 of these sites are located within the Region of the Great Bend of the Wabash River watershed. Based on the results of these studies, the following conclusions can be drawn:

- Twelve mussel species were observed in watershed streams. Only weathered shells (dead mussels) were identified in Indian Creek, Flint Run, and Dismal Creek. The existence of weathered shells suggests that mussels once existed within these streams, but that conditions no longer allow them to do so.
- Little Pine Creek contained the highest mussel diversity with 11 species identified, including two species not observed in other streams and the purple lilliput, a state species of special concern. Wea Creek and its tributaries contained the highest density of mussels with 49 observed. 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.

- QHEI scores indicate that habitat may limit aquatic biota within these streams. Habitat ratings in Little Pine Creek (CR 800 W and CR 500 N), Montgomery Ditch (CR 950 S and SR 28), and Loafland Ditch (CR 1200 S) scored below the benchmark. Specifically, lack of instream cover, poor substrate diversity, and limited pool-riffle complex development limits habitat with these streams.

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

Purdue University researchers conducted fish surveys at 39 stream sites throughout Tippecanoe County annually from 1971 through 1977 (Curry and Spacie, 1978). These sites and 31 others were sampled again between June and December 1994. A variety of sampling methods were used during both assessments with species lists generated for each site. Based on the results of these studies, the following conclusions can be drawn:

- Headwater tributaries to Little Pine Creek including Goose Creek and Otterbein Ditch contain limited diversity.
- Headwater tributaries to Wea Creek including Loafland Ditch, Montgomery Ditch, and Kellerman Lea Ming Ditch also contain limited diversity.
- Burnett Creek and Flint Creek sample sites contain the highest diversity with species collected reflecting the quality habitat and instream cover currently observed within these streams.

3.2.22 Hoosier Riverwatch Sampling (2001-2011)

From 2000 through 2011, volunteers trained through the Hoosier Riverwatch program assessed 50 sites throughout the Region of the Great Bend of the Wabash River watershed. Assessments occurred sporadically with some sites assessed only once during the reporting period while others were monitored as many as 20 times. Volunteers monitored stream stage, flow rate, and discharge; collected water chemistry samples for analysis using HACH test kits; assessed instream habitat using the Citizen's QHEI; and surveyed the stream's macroinvertebrate community. Using the chemical data, the Water Quality Index (WQI) was calculated. Volunteers calculated a Pollution Tolerance Index (PTI) using the biological data. Based on these data, the following conclusions can be drawn:

- In Burnett Creek, nitrate-nitrogen, turbidity, and *E. coli* routinely measured higher than the benchmark. PTI scores ranged from 14 to 33 indicating fair biotic quality. CQHEI scores measured above 67 suggesting that Burnett Creek provides good habitat.
- In Flint Creek, CQHEI scores ranged from 40 to 68 suggesting that portions of Flint Creek contain limited habitat while others provide high quality habitat. Periodically, Flint Creek contains elevated turbidity, nitrate-nitrogen, and *E. coli* concentrations. Additionally, dissolved oxygen concentrations measured higher than the high benchmark (12 mg/L). During these assessments, DO saturation measured higher than 120%.
- Turbidity, *E. coli*, and pH periodically measured above the identified benchmark in the Wabash River. Elevated pH values can be attributed to high volumes of photosynthesis.
- Turbidity and *E. coli* concentrations were also elevated in Wea Creek during the assessment period. PTI scores ranged from 8 to 33 with CQHEI scores measuring between 95 and 100 suggesting that these sites are highly conducive to the existence of warm water fauna.

3.2.23 Wabash Sampling Blitz (Fall 2009-Spring 2011)

More than 180 volunteers sampled 210 stream sites on September 18, 2009, April 9, 2010, September 17, 2010, and April 15, 2011. Sample sites were located throughout the Region of the Great Bend of the Wabash River. Volunteers collected water samples for test strip and laboratory analysis, measured stream temperature, and at selected sites collected samples for *E. coli* analysis. Based on these data, the following conclusions can be drawn:

- During low flow conditions (20th percentile of historic average flows) fall conditions, nutrient and pathogen concentrations are elevated throughout the watershed. Nitrate-nitrogen concentration exceeded target concentrations in 32 of 205 sites (16%), while orthophosphate concentrations exceeded target concentrations in 16% of sites (33 of 205 sites). Pathogen concentrations exceeded the target concentration in 15 of 63 sites (24%).
- During spring collection, nitrate-nitrogen concentrations exceeded the target at 176 of 208 sites (85%), while orthophosphate concentrations exceeded the target concentration at 4% of sites (9 of 205). Pathogen concentrations in excess of the state standard occurred at 10 of the 63 sites (16%).
- Field data predicted laboratory data relatively well with some issues with the orthophosphate field measurements. Although these field data were unreliable, their ability to predict elevated concentration areas occurred throughout the watershed.
- During the fall assessment, the Wabash River contains elevated copper concentrations; however, as hardness was not concurrently measured, the state standard under these conditions cannot be calculated. Based on average hardness measurements in the Wabash River, the measured values do not exceed the state standard (approximately 40 mg/L) during sampling.

3.2.24 Pharmaceuticals in the Region of the Great Bend of the Wabash River Watershed (2010)

Historically, no pharmaceuticals and personal care product (PPCPs) concentration information has been available in the Wabash Watershed. In 2010, Purdue University conducted an Indiana Water Resources Research Center (IWRRC)-funded study to quantify a handful of PPCPs from this watershed. For this purpose, water samples were collected from Little Pine and Wea Creeks, as well from the influent and effluent of the West Lafayette sewage waste water treatment plant (SWWTP). Samples were collected every other week from January to December of 2010. Three PPCPs were quantified: triclosan (disinfectant), tylosin (animal antibiotic and growth promoter), and ethinylestradiol (EE2, synthetic estrogen used in birth control pills). PPCPs were quantified using commercial enzyme-linked immunosorbent assay (ELISA) kits. Based on these preliminary data, the following conclusions can be drawn:

- Tylosin was found ubiquitously in all sites. Mean concentration (± standard deviation) was 2.5 ± 1.5 µg/L (range of 0.05 – 6.1 µg/L). Effluent concentrations were lower than influent samples (1.3 vs. 2.8 µg/L) which suggests biodegradation of this chemical within the SWWTP.
- In constrast, triclosan and EE2 were only found in SWWTP samples. Triclosan was detected only in influent samples at a concentration of 1.5 ± 0.4 µg/L (0.9 – 2.2 µg/L). EE2 was only detected in three occasions: twice in the influent (0.06 and 0.07 µg/L) and once in the effluent (0.06 µg/L).
- With exception of EE2, all concentrations are below those reported to negatively impact aquatic life. However, very little information exists on the effects of triclosan and tylosin on aquatic organisms and more studies are needed in order to determine safe levels.
- Follow-up studies that verify these values using standard mass spectrometry techniques as well as quantify other types of PPCPs are needed.

3.3 Current Water Quality Assessment

3.3.1 Water Quality Sampling Methodologies

As part of the current project, Purdue University implemented a two year professional water quality monitoring program. The program included water chemistry, fish and macroinvertebrate community, and habitat assessments. Additionally, WREC implemented a volunteer monitoring program. The program is detailed below and in the Quality Assurance Project Plan for The Lafayette-West Lafayette Reach of the Wabash River Watershed Management Plan approved on April 20, 2009 (WREC, 2009). Sites sampled through this program are displayed in Figure 52.

Sample sites were selected based on land use and watershed drainage. The three tributary sites represent two pairs of test watersheds: one urban or urbanizing (Elliott Ditch) paired with the control watershed (Little Pine Creek) and one rural (Little Wea Creek) paired with the control watershed. The Wabash River upstream-downstream pair was used to identify any observable impacts of Greater Lafayette on the Wabash River. The weekly sampling regimen was enacted to create a baseline of water quality data so that once implementation occurs, a measurable change in water quality can potentially be observed.

Stream Flow

Stream gages were installed on Elliot Ditch, Little Wea Creek, and Little Pine Creek, shown in red in Figure 52. A gage installed on the Wabash River at Brown Street Bridge in 1924 also measures stage every 15 minutes. Gages measured stream stage every fifteen minutes and operate through the U.S. Geological Survey's stream gaging system. Rain gages were installed at the stream flow gaging stations in August 2009.

Field Chemistry Parameters

Purdue University established five chemistry monitoring stations (red and yellow sites in Figure 52) as part of the monitoring program. Stations are located on Elliott Ditch, Little Wea Creek, Little Pine Creek, and on the Wabash River up and downstream of the Lafayette-West Lafayette urban core. Dissolved oxygen, temperature, pH, turbidity, and conductivity were measured weekly at the five chemistry sampling stations from April to August 2009. In August 2009, data sondes were installed at the tributary chemistry stations. Subsequently, dissolved oxygen, temperature, pH, turbidity, and conductivity were measured every fifteen minutes at the three tributary locations with weekly measurements of the same parameters occurring at the two Wabash River locations. Weekly field chemistry parameter monitoring continued at the two Wabash River monitoring sites during the sampling period. Appendix H details the parameters measured and potential impacts to particular parameters.

Laboratory Chemistry Parameters

Like the field parameters, weekly laboratory sample collection and analysis occurred throughout the two year sampling program. Samples were analyzed for ammonia-nitrogen, nitrate-nitrogen, total phosphorus, total suspended solids, carbon, total coliform, and *E. coli*. Appendix H 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. Appendix H details the QHEI and its individual metrics.

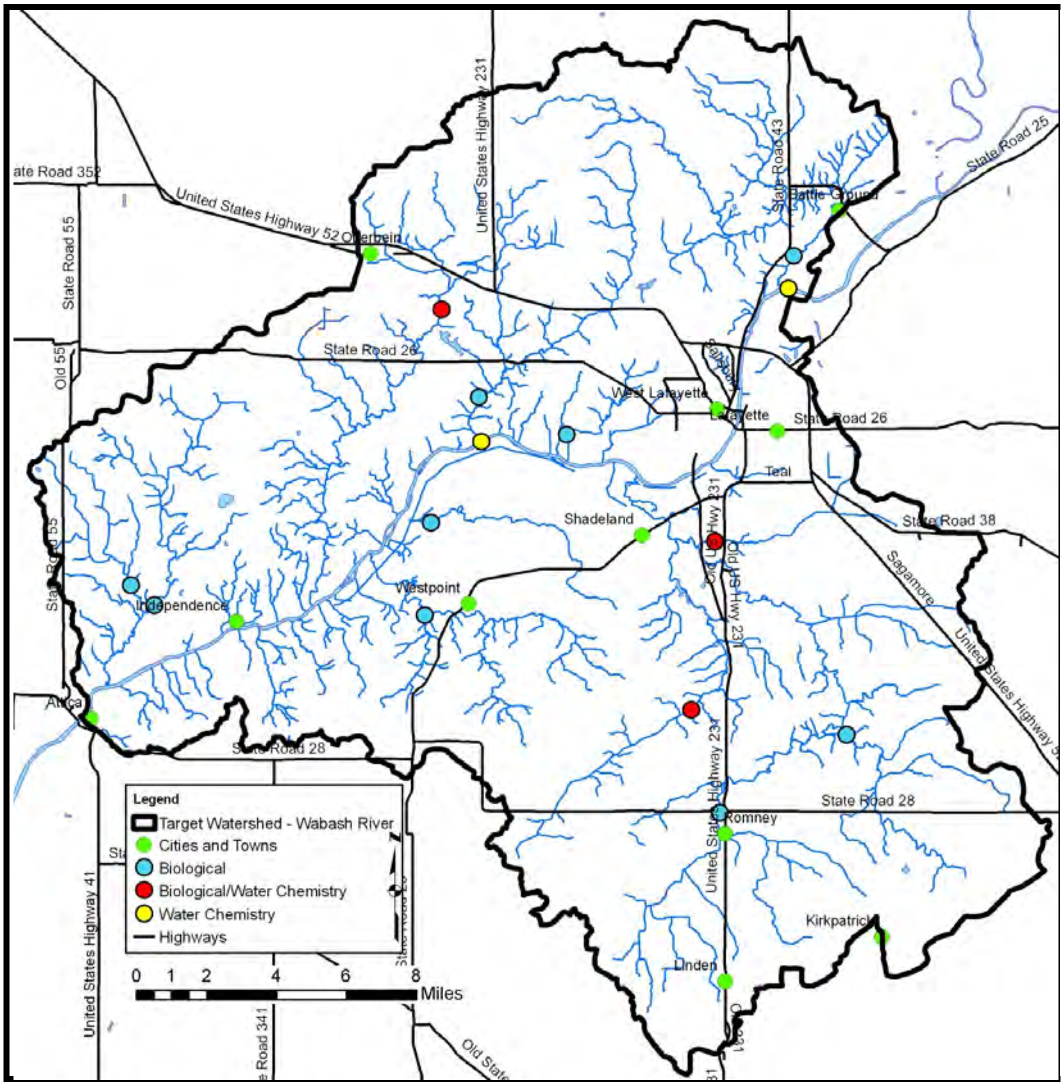

Figure 52. Sites sampled as part of the Region of the Great Bend of the Wabash River Watershed Management Plan.
Data used to create this map are detailed in Appendix A.

Fish Community

The fish community within the Region of the Great Bend of the Wabash River watershed was assessed at twelve sites (in blue and red in Figure 52) eight times over the two year sampling period (four times annually). Two sites were typically dry, resulting in collection of biological samples at 10 of 12 sites annually. Sampling methods followed Simon (1991). Index of Biotic Integrity (IBI) scores were calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 10, 11, 16, 18, 19, and 23; Sample II – July 20, 21, 22, and 23; Sample III – September 15, 16, 18, and 23; and Sample IV – November 4, 5, and 6. The 2010 samples were collected as follows: Sample V – March 19, 20, and 22; Sample VI – June 18 and 21; Sample VII – August 10, 11, 12, and 13; and Sample VIII – October 30, 30 and November 1. Appendix H details the IBI metrics used to calculated Index of Biotic Integrity values for these samples.

Macroinvertebrate Community

The macroinvertebrate community within the Region of the Great Bend of the Wabash River watershed was assessed at twelve sites (in blue and red in Figure 52) eight times over the two year sampling period (four times annually). Two sites were typically dry resulting in collection of biological samples at 10 of 12 sites annually. Samples were collected concurrent with fish community sampling as indicated above. The 2009 samples consisted of six Surbers collected on each sample date. 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). 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 H details the mIBI and its scoring methodologies.

3.3.2 Field Chemistry Results

Figure 53 through Figure 57 display results for field chemistry data collected every fifteen minutes at three tributary sites. At each of the three stream sites, a multi parameter probe is deployed. The probe collects data for temperature, dissolved oxygen, specific conductivity, pH and turbidity at 15 minute intervals. Data shown below are an average of all the values in a given day.

Temperature

Figure 53 illustrates average daily temperatures in Little Pine Creek, Elliot Ditch, and Little Wea Creek. As shown, temperature measures approximately the same at each of the three stream sites with seasonal changes in temperature creating major differences in temperature throughout the sampling period. Temperatures in Elliot Ditch ranged from 0.8 ^{o}C to 28.3 ^{o}C. In Little Pine Creek, temperatures typically measured lower with temperatures ranging from 0.04 ^{o}C to 18.9 ^{o}C. In Little Wea Creek, temperatures ranged from 0.08 ^{o}C to 23.3 ^{o}C. Differences in stream temperature can be observed between each of the three sites. For instance, higher temperatures were measured in Elliot Ditch in the spring of 2010 while temperatures in Little Pine Creek measured lower from December 2009 to April 2010 and higher during the summer 2010. Diurnal temperature changes are observable at each site as well but are not displayed in Figure 53.

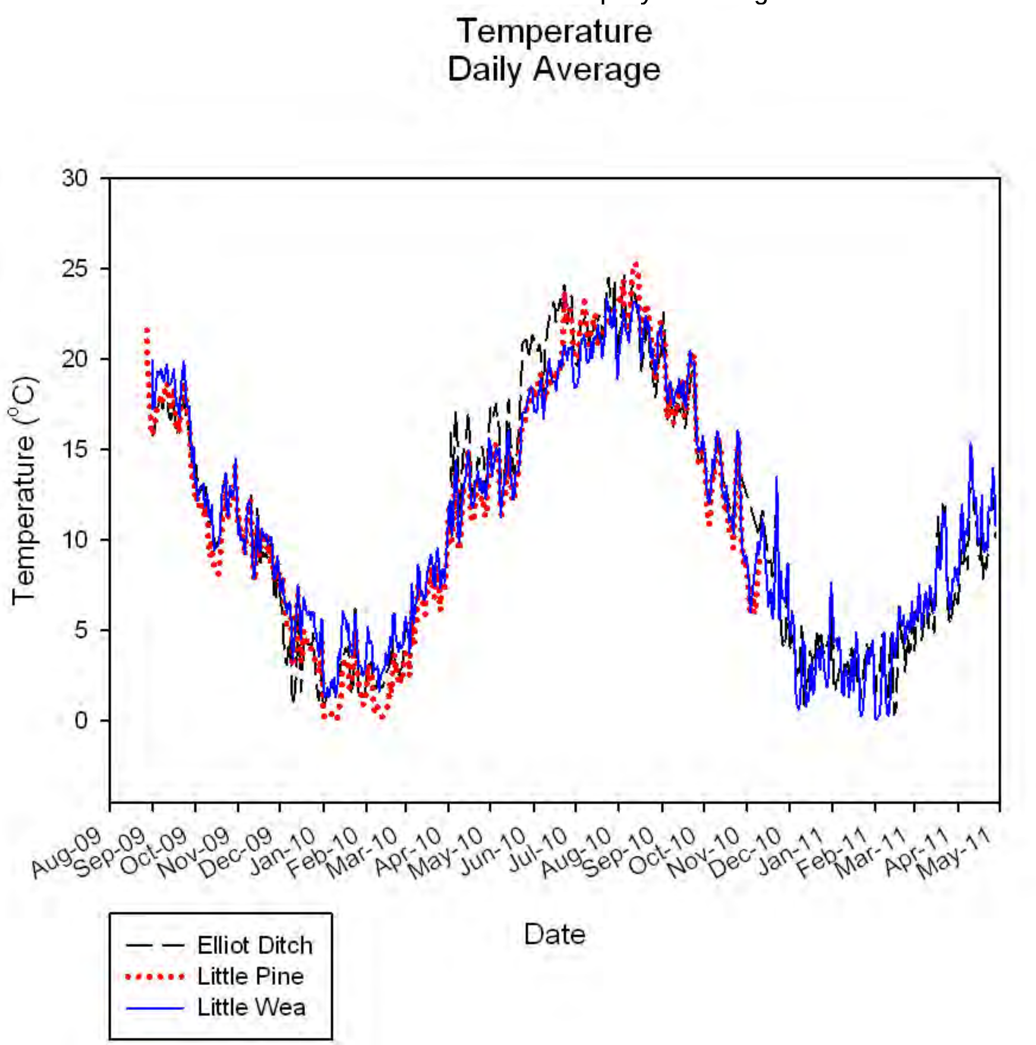

Figure 53. Temperature measured in Elliot Ditch, Little Pine Creek, and Little Wea Creek from August 2009 through March 2011.

Dissolved Oxygen

Dissolved oxygen concentrations also display seasonal changes like those observed for temperature. However, as shown in Figure 54, 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 in Little Pine Creek and Elliot Ditch concentrations are higher in winter and lower in summer. Little Pine Creek dissolved oxygen concentrations generally follow seasonal patterns; however, high productivity and large volumes of decomposition from flocculent sediments suggest that dissolved oxygen concentrations are completely utilized during spring and summer 2010 sample collection. All three streams display daily variation in dissolved oxygen concentration due to individual conditions present within each system.

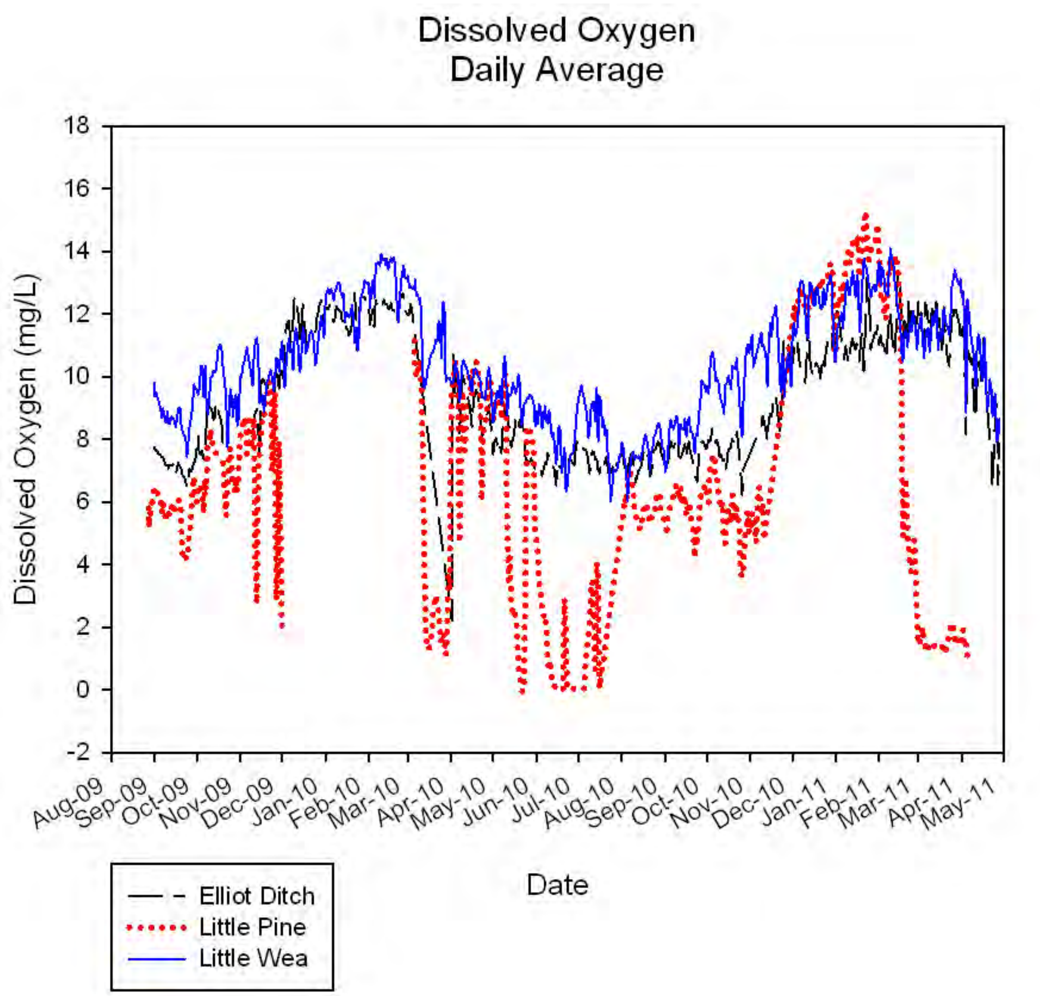

Figure 54. Dissolved oxygen measured in Elliot Ditch, Little Pine Creek, and Little Wea Creek from August 2009 through March 2011.

pH

Throughout the sampling period, pH remained in an acceptable range in all three streams. No discernable pattern can be found in pH levels in any of the three monitored streams. Although fluctuations appear to be wide, pH levels varied within 1 unit of pH (Figure 55).

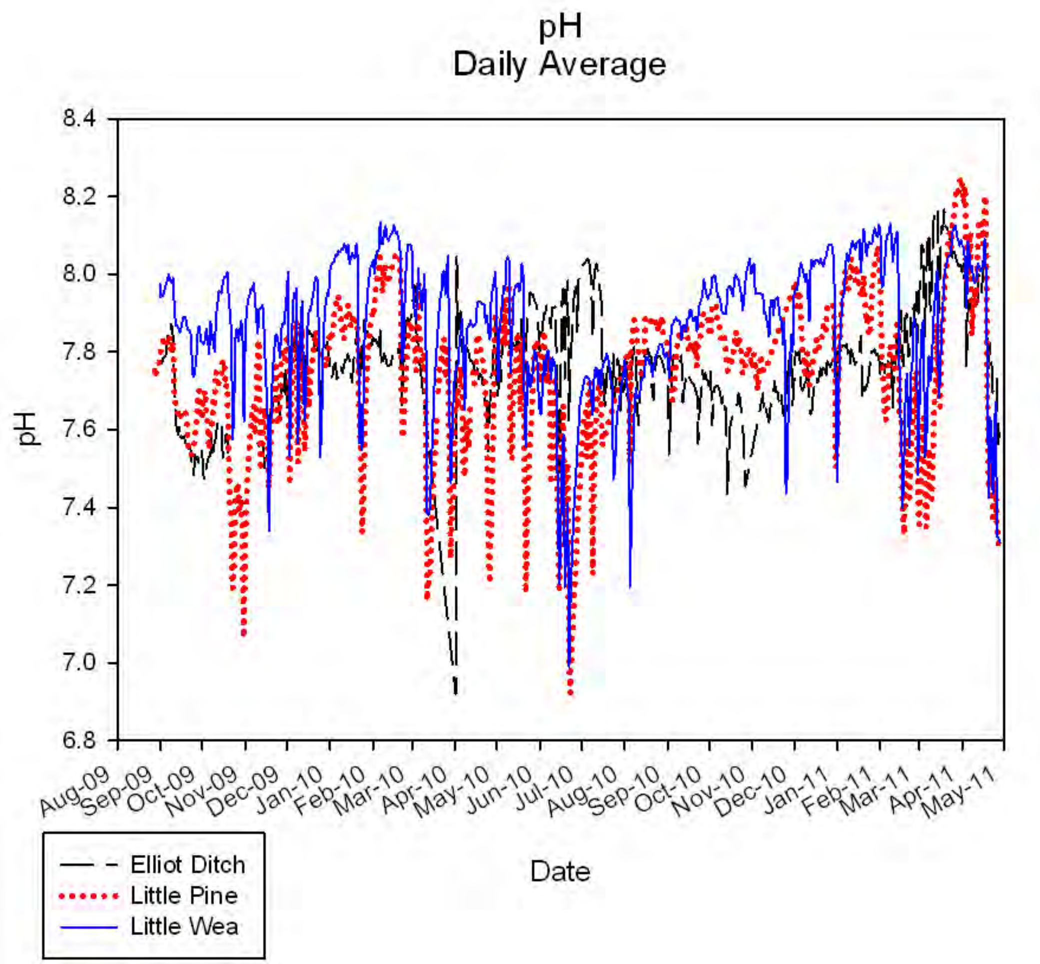

Figure 55. pH measured in Elliot Ditch, Little Pine Creek, and Little Wea Creek from August 2009 through March 2011.

Specific Conductivity

Figure 56 displays conductivity measurements in Little Pine Creek, Elliot Ditch, and Little Wea Creek. Conductivity measurements varied greatly over the sampling period. Generally, conductivity concentrations were below the state standard. However, during December 2009 to March 2010 and again during the winter months of 2010-2011, conductivity increased in Elliot Ditch. In total, conductivity daily averages in Elliot Ditch exceeded the state standard 12% of the time (59 of 467 days). The area around Elliot Ditch is urban and the increase in conductivity may be due to salts put down on the roads to melt snow and ice or result from industrial inputs during low flow stream conditions. The sustained high conductivity concentrations could be detrimental to biological communities present in Elliot Ditch.

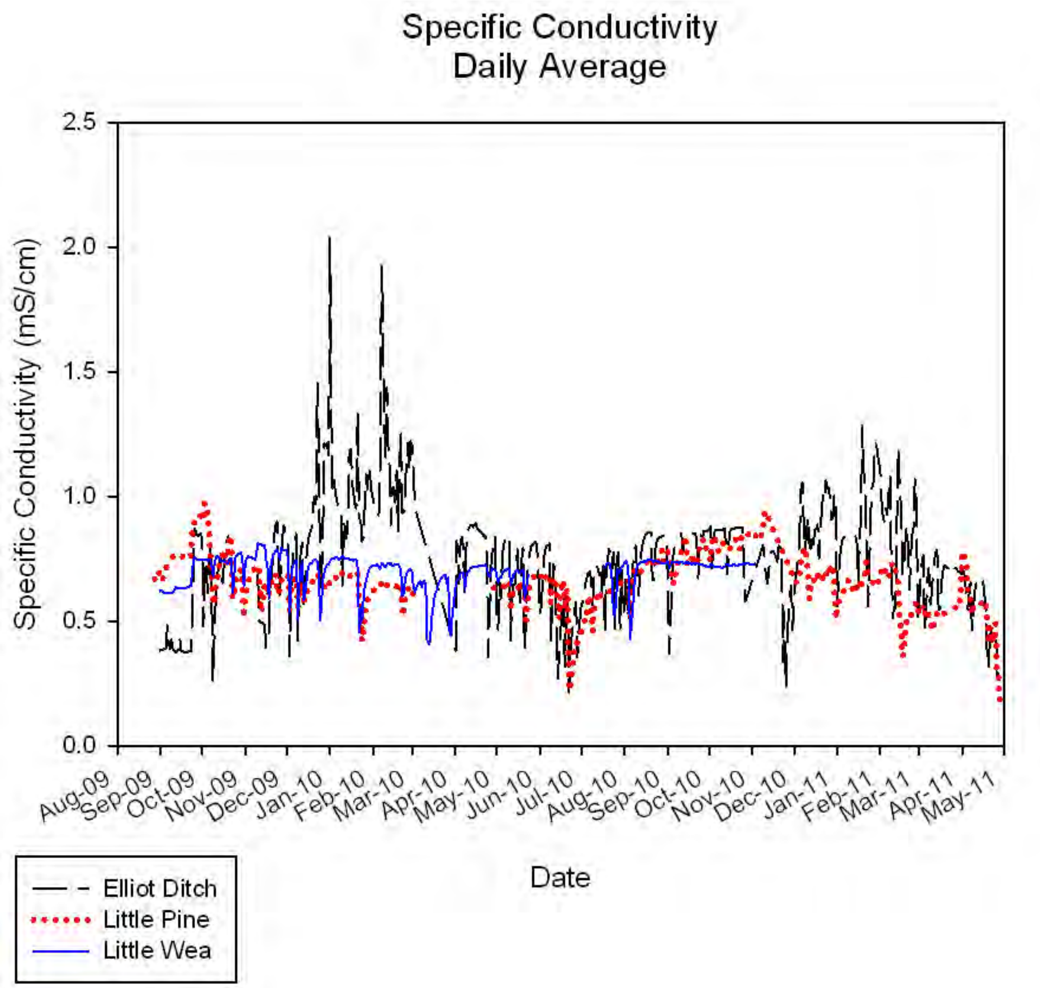

Figure 56. Conductivity measured in Elliot Ditch, Little Pine Creek, and Little Wea Creek from August 2009 through March 2011.

Turbidity
Turbidity measurements for Elliot Ditch, Little Pine Creek, and Little Wea Creek are displayed in Figure 57. Turbidity concentrations exceeded the target 35% of the time in Elliot Ditch, 23% of the time in Little Pine Creek, and 17% of the time in Little Wea Creek. In Little Wea Creek, turbidity measurements peaked at 632 NTU or more than 10 times the target turbidity concentration, while Elliot Ditch turbidity measurements peaked at 18.6 NTU. In Little Wea Creek, turbidity concentrations measured as high as 1,217 NTU or nearly 70 times the target. Turbidity tends to spike during high flow events. It is unclear neither why the values in Elliot Ditch exceed the target nor why Little Pine Creek turbidity peaks are so high. It could be due to cows or other wildlife accessing the stream, wildlife making a home in the guard surrounding the probes, or a malfunction. Herons have been observed near the probes in all three of the streams. When removing the sondes, fish, crawdads, and other macroinvertebrates have been pulled up with the instrument. All of these may cause spikes in turbidity.

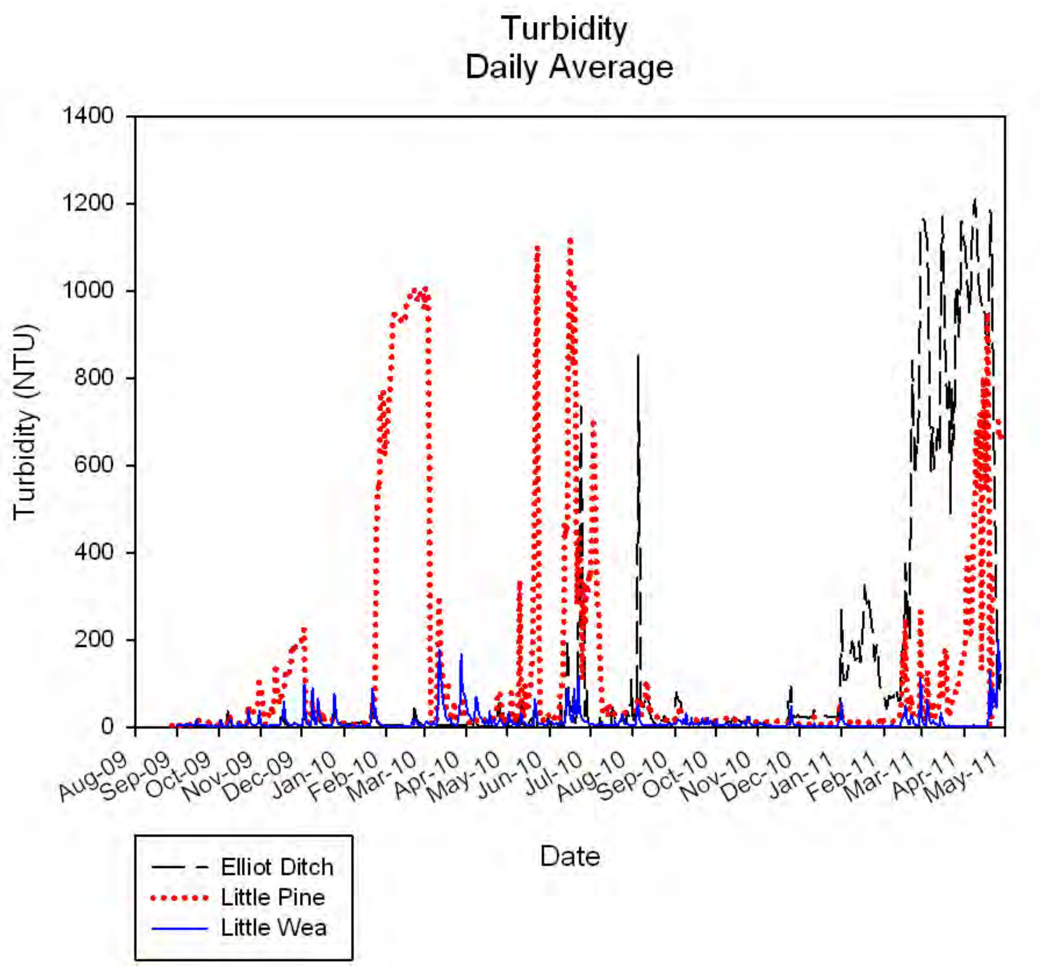

Figure 57. Turbidity measured in Elliot Ditch, Little Pine Creek, and Little Wea Creek from August 2009 through March 2011.

3.3.3 Water Chemistry Results
Figure 58 through Figure 61 display results for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli* collected weekly from five locations in the Region of the Great Bend of the Wabash River watershed. Data are displayed over stream discharge (blue)

measured at USGS-maintained gaging stations during the sample period. Appendix I details individual measurements collected throughout the sampling period.

Nitrate-Nitrogen Concentrations

Nitrate levels vary greatly throughout the year with lowest levels occurring during low flow periods during the late summer and fall months (Figure 58). Concentrations measured in Elliot Ditch generally measure below the target concentration (2 mg/L) with nitrate-nitrogen concentrations exceeding the target from May to August annually. In Elliot Ditch, nitrate-nitrogen concentrations exceed target concentrations in 8% of samples during the sampling period. Nitrate-nitrogen concentrations peaked at 3.2 mg/L which is one and one-half times the target concentration. Changes in nitrate-nitrogen concentration in Little Pine Creek appear to generally follow flow conditions with lower concentrations occurring during lower flow conditions; however, spikes in nitrate-nitrogen concentration do not always coincide with spikes in stream flow. In Little Pine Creek, nitrate-nitrogen concentrations exceed target concentrations 86% of samples during the sampling period. In Little Pine Creek, seasonal variations in nitrate-nitrogen vary widely with concentrations annually from April to September exceeding both the target and the state standard for drinking water (10 mg/L) with concentrations peaking at 14.2 mg/L. Nitrate-nitrogen concentrations measured during the sampling period mimic concentrations observed during historic water quality assessments within Little Pine Creek. This suggests that nitrate-nitrogen concentrations may be due to background conditions or that land use has changed little over time and that high volume application of manure within Little Pine Creek may inflate nitrate-nitrogen concentrations within this watershed.

Similarly, nitrate-nitrogen concentrations in Little Wea Creek mimic flow conditions with higher concentrations typically occurring during periods of higher flow. Nitrate-nitrogen concentrations in Little Wea Creek do not measure as high as those measured in Little Pine Creek (15 mg/L); however, like Little Pine Creek, concentrations in Little Wea Creek more often measure above the target concentration than below with most exceedances occurring during typical periods of manure application. In Little Wea Creek, nitrate-nitrogen concentrations exceed target concentrations 83% of samples during the sampling period. Nitrate-nitrogen concentrations in the Wabash River mimic flow conditions with lower nitrate concentrations typically occurring during low flow conditions. Nitrate-nitrogen concentrations indicate no statistical difference between upstream and downstream concentrations. This suggests that Greater Lafayette has no statistical impact on nitrate-nitrogen concentrations.

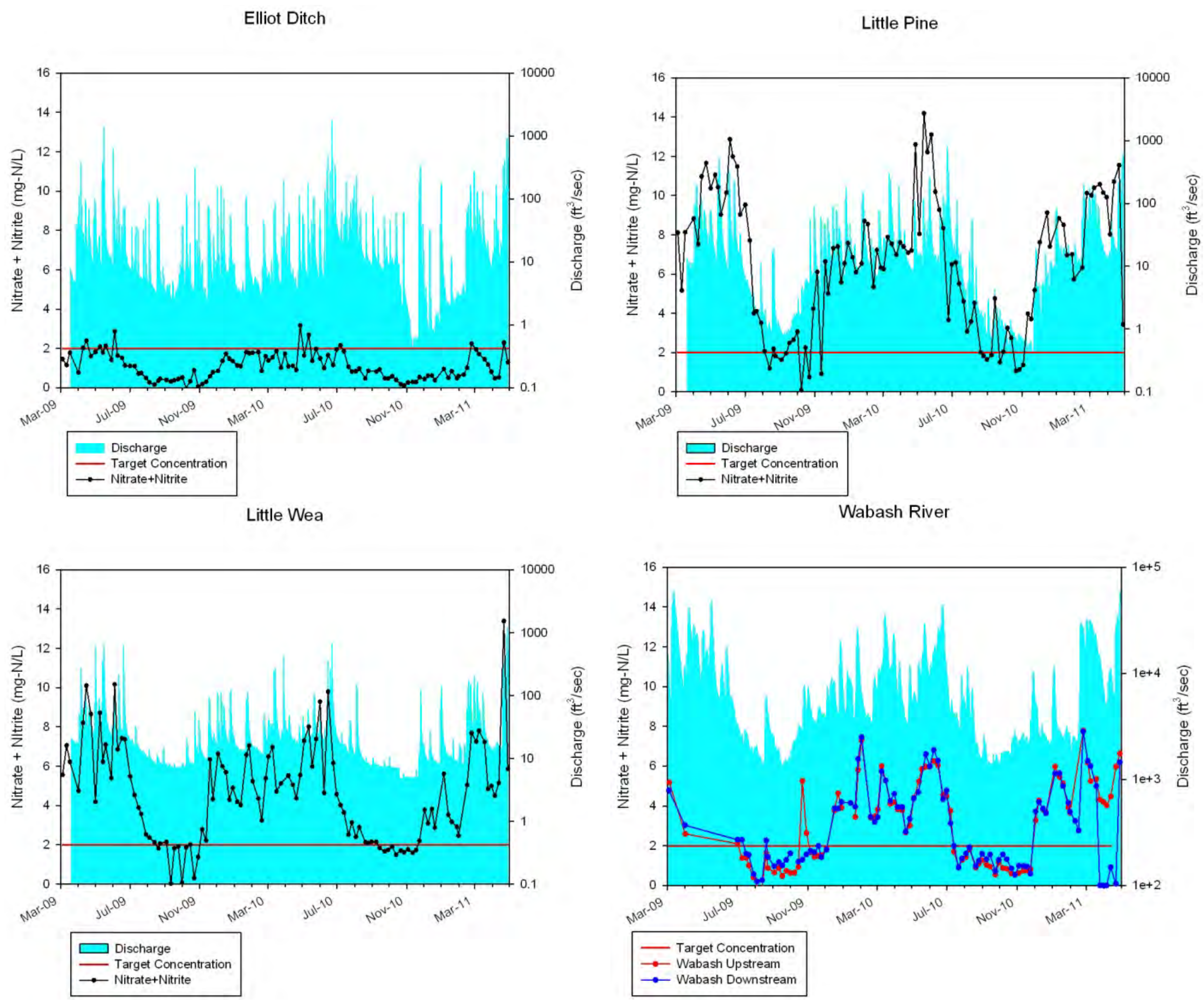

Figure 58. Nitrate-nitrogen concentrations overlain on discharge in the Wabash River (upstream and downstream), Elliot Ditch, Little Pine Creek, and Little Wea Creek. The red line indicates the target concentration (2 mg/L).

Total Phosphorus Concentrations

Total phosphorus concentrations do not follow a seasonal or flow-based pattern (Figure 59). In Elliot Ditch, total phosphorus concentrations exceed target concentrations 23% of samples during the sampling period. Concentrations spiked during high flow events which occurred in April 2010, July 2010, and December 2010. In Little Pine Creek, total phosphorus concentrations do not mimic flow patterns. During peak discharges occurring through 2010, total phosphorus concentrations were low. Conversely, when flows declined in August 2010 through December 2010, total phosphorus concentrations began to rise peaking more than an order of magnitude above the target concentration measuring a high near 0.9 mg/L. In Little Pine Creek, total phosphorus concentrations exceed target concentrations 55% of samples during the sampling period.

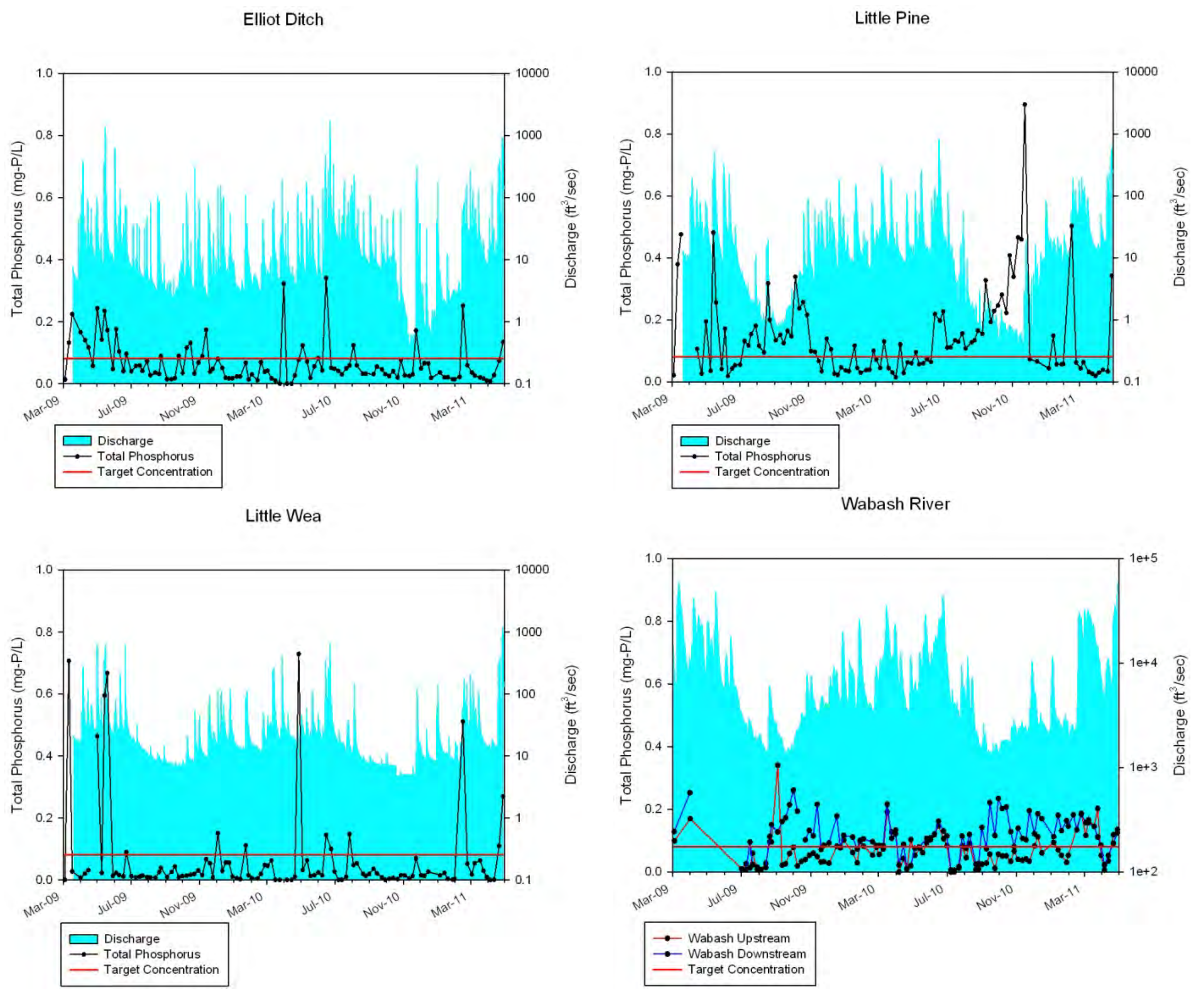

Figure 59. Total phosphorus concentrations overlain on discharge in the Wabash River (upstream and downstream), Elliot Ditch, Little Pine Creek, and Little Wea Creek. The red line indicates the target concentration (0.08 mg/L).

In general, total phosphorus concentration in Little Wea Creek and the Wabash River measure lower than those observed in Elliot Ditch and Little Pine Creek. In Little Wea Creek, total phosphorus concentrations exceed target concentrations 13% of samples during the sampling period. Peaks in total phosphorus concentration do not coincide with peak flow conditions within Little Wea Creek. Three peak concentrations were measured during the summers of 2009 and 2010 with peaks measuring near an order of magnitude higher than the target concentrations. Unlike peaks in Little Pine Creek, peak total phosphorus concentrations in Little Wea Creek typically occurred during one sampling event with concentrations quickly returning to more typical concentrations. As in Little Wea Creek, peak total phosphorus concentrations measured in the Wabash River do not coincide with peak flow conditions. In the Wabash River, total phosphorus concentrations exceed target concentrations 34% of samples upstream of Greater Lafayette and 73% of samples downstream of Greater Lafayette during the sampling period. Concentrations measured downstream of Greater Lafayette typically exceeded concentrations measured upstream of Greater Lafayette with average concentrations measuring 0.1 mg/L and 0.06 mg/L, respectively. This suggests that Greater Lafayette contributed total phosphorus to the Wabash River with larger contributions occurring under high water conditions.

Total Suspended Solids Concentrations

In general, total suspended solids increases during high flow events due to sediment runoff and soil erosion (Figure 60). In Elliot Ditch, total suspended solids concentrations typically measure below the target concentration. In Elliot Ditch, total suspended solids concentrations exceed target concentrations 15% of samples during the sampling period. Although peak total suspended solids concentrations do not coincide with peak flows, TSS concentrations typically increase during higher flow conditions and reach concentrations as high as 172 mg/L. This is to be expected as increases in TSS following storm events suggests that stormwater carries larger amounts of dissolved and suspended solids than is present during base flow conditions. Higher overland flow velocities typically result in an increase in sediment particles in runoff. Additionally, greater streambank and streambed erosion typically occurs during high flow. Therefore, higher total suspended solid concentrations are typically measured in storm flow samples. In Elliot Ditch, five peak total suspended solids concentrations were measured with two of these exceeding the target concentration by an order of magnitude. In Little Pine Creek, total suspended solids concentrations exceed target concentrations 46% of samples during the sampling period. Only three peak total suspended solids concentrations were observed in Little Pine Creek; however, the highest peak measured nearly 20 times the target TSS concentration (261 mg/L compared to 15 mg/L target). TSS concentrations generally measured higher in Little Pine Creek than those observed in Elliot Ditch and Little Wea Creek. This suggests that Little Pine Creek carries a higher bed load than the other tributary streams and that efforts to reduce total suspended solids concentrations will need to target both low and high flow stream conditions.

Total suspended solids concentrations typically measured below the target concentration within Little Wea Creek. In Little Wea Creek, total suspended solids concentrations exceed target concentrations 20% of samples during the sampling period. The few peak TSS concentrations measured in Little Wea Creek were the highest concentrations measured exceeding 350 mg/L. Like Elliot Ditch, the TSS concentration typically measured in Little Wea Creek suggest that targeting sediment moved during high flow or storm conditions will result in decreased TSS concentrations. In the Wabash River, total suspended solids concentrations typically mimic flow conditions with the highest concentrations occurring from March to September 2010. In the Wabash River, upstream and downstream total suspended solids concentrations exceed target concentrations 54% and 60% of samples, respectively during the sampling period. No obvious pattern is observable between upstream and downstream samples. This suggests that during some conditions Greater Lafayette contributes suspended sediments to the Wabash River but under different conditions, no contribution occurs.

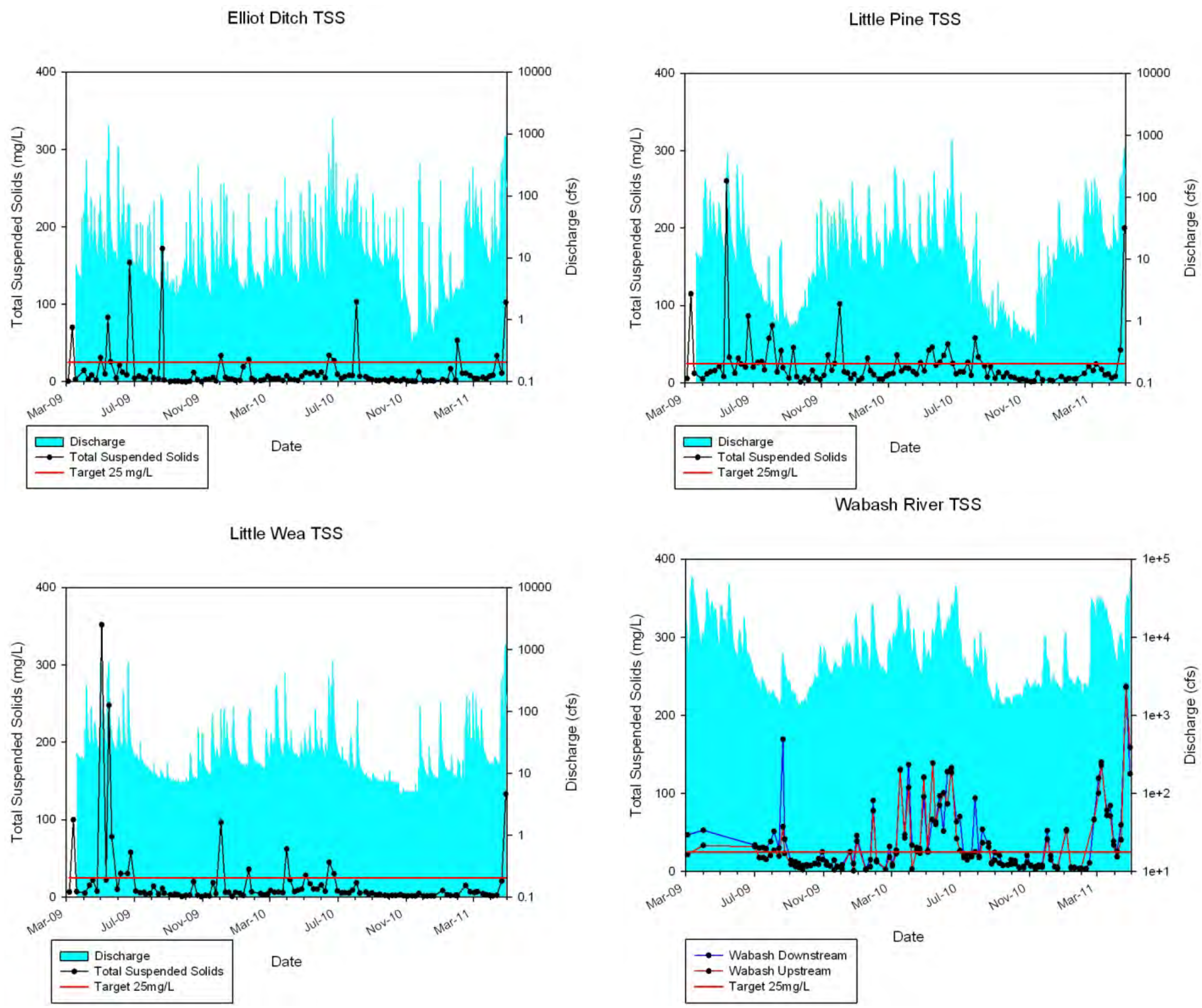

Figure 60. Total suspended solids concentrations overlain on discharge in the Wabash River (upstream and downstream), Elliot Ditch, Little Pine Creek, and Little Wea Creek. The red line indicates the target concentration (15 mg/L).

E. coli Concentrations

As shown in Figure 61, *E. coli* concentrations within Little Pine Creek, Little Wea Creek, and Elliot Ditch typically exceed the state standard (235 colonies/100 mL). In Elliot Ditch, *E. coli* concentrations exceed target concentrations 49% of samples during the sampling period. *E. coli* concentrations mimic flow conditions which suggest that *E. coli* concentrations increase when stream flows increase. This does not occur in Little Pine Creek where increases in *E. coli* concentrations do not occur when stream flows increase. Rather, *E. coli* concentrations are generally high under any condition. In Little Pine Creek, *E. coli* concentrations exceed target concentrations 92% of samples during the sampling period. *E. coli* concentrations mimic flow conditions within Little Wea Creek. When flows increase, *E. coli* concentrations typically increase. In Little Wea Creek, *E. coli* concentrations exceed target concentrations 50% of samples during the sampling period. Peak *E. coli* concentrations within all three tributaries measure approximately 10,000 colonies/100 mL, suggesting that high *E. coli* concentrations are typical within these systems. *E. coli* concentrations measured in the Wabash River are typically lower than concentrations measured in the tributary streams. Differences in *E. coli* concentrations between tributary and mainstem sites can be attributed to a number of factors including dilution, lack of direct *E. coli* sources and inputs, or more periodic direct inputs of *E. coli* rather than continuous sources as observed in the tributaries. In the Wabash River, upstream and downstream *E. coli* concentrations exceed target concentrations 33% and 49% of samples, respectively during the sampling period.

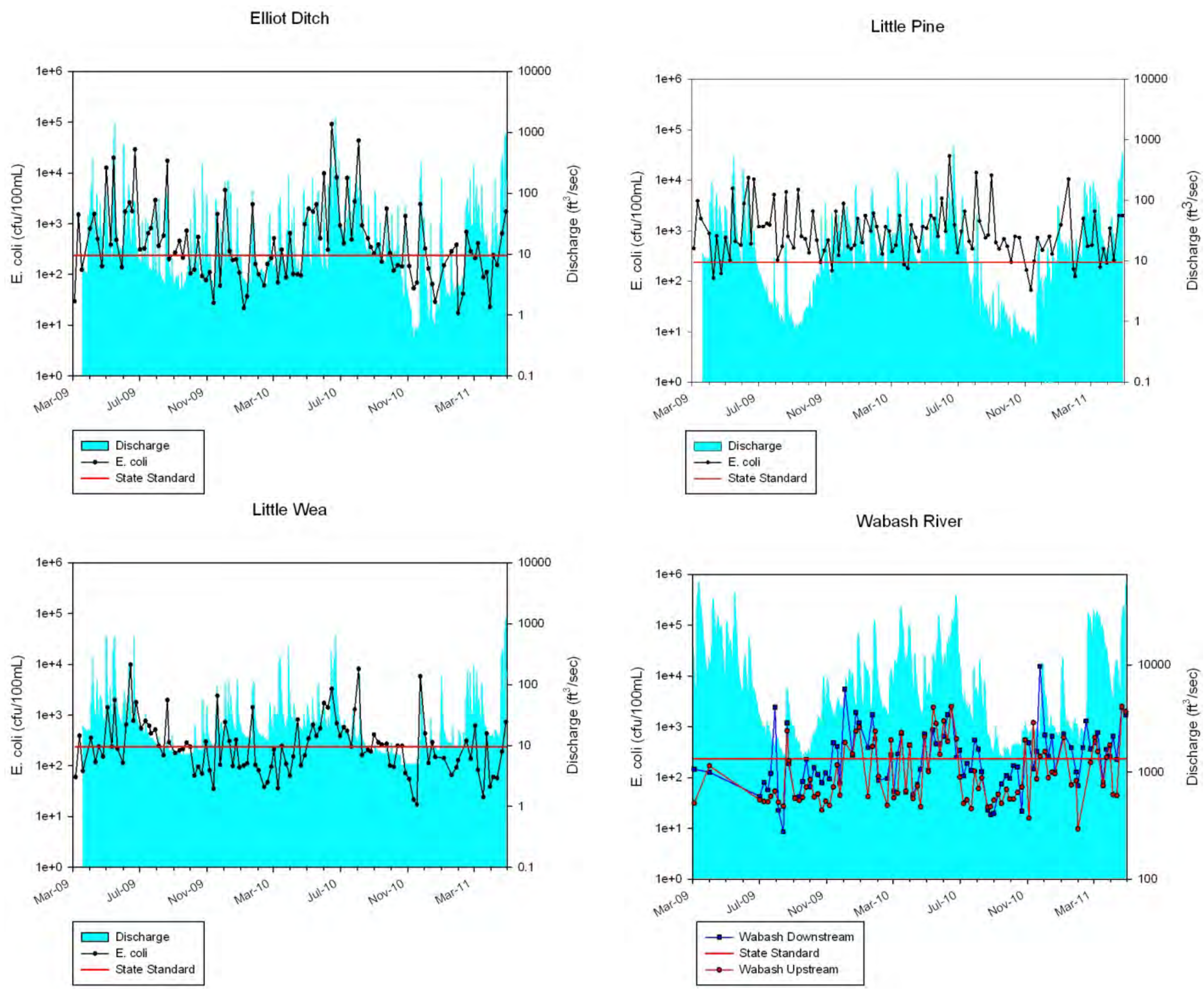

Figure 61. *E. coli* concentrations overlain on discharge in the Wabash River (upstream and downstream), Elliot Ditch, Little Pine Creek, and Little Wea Creek. The red line indicates the target concentration (235 colonies/100 ml) and state standard.

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 (Q_{50}) is the flow observed in the stream 50% of the time. Flows below Q_{50} indicate baseflow 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 (Q_{90}/ Q_{50}) 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.

Flow duration curves were developed using daily discharge values for each of the four stream gages maintained by the USGS in the Region of the Great Bend of the Wabash River watershed. The flow duration curves present the flow characteristics for the four systems (Figure 62 to Figure 65). The Wabash River has much higher flow than any of the other streams with a minimum discharge of 1,000 CFS (Figure 62). Collectively, the three smaller streams show similar patterns in their curves with a minimum discharge averaging near 1 cubic foot per second (cfs). Little Wea Creek's minimum discharge measured nearly half (0.5 cfs) minimum flows observed in Little Pine Creek and Elliot Ditch. Maximum flows tend to occur infrequently and did not exceed 1,000 cfs which is the minimum flow for the Wabash River. These data support the use of the three systems for land use comparisons.

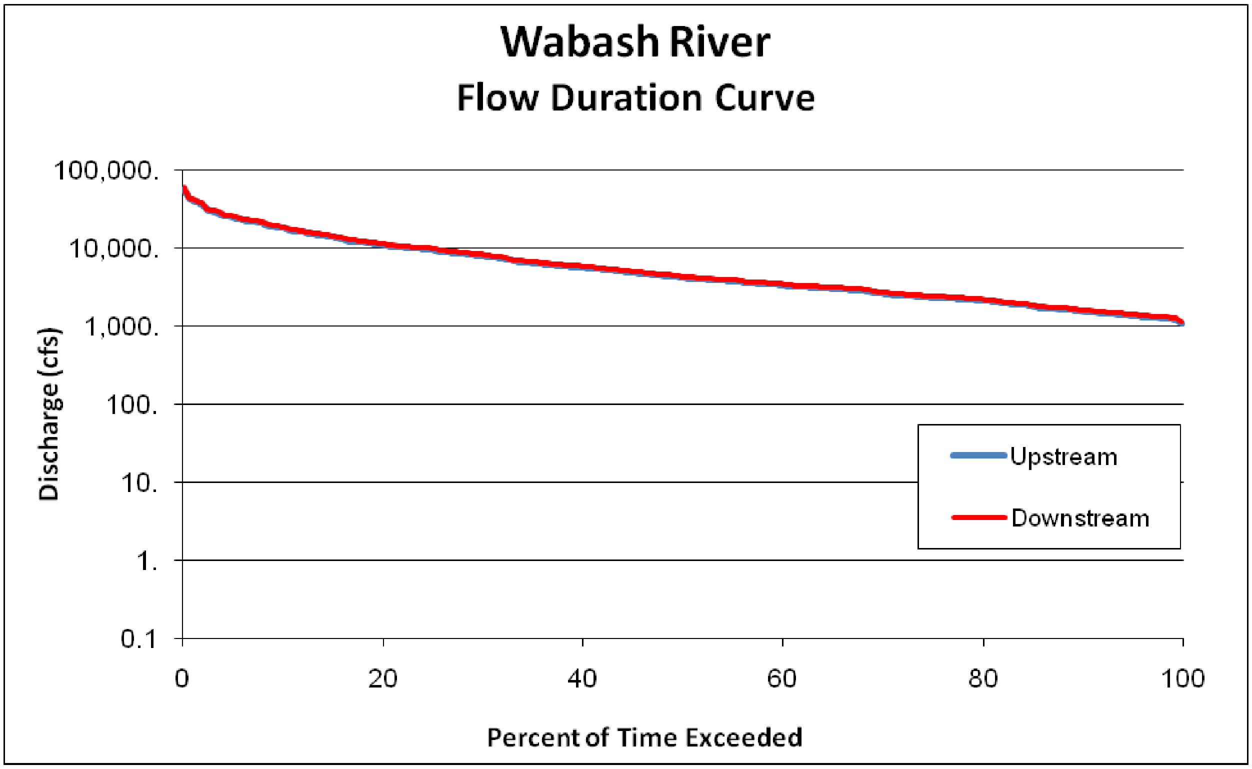

Figure 62. Wabash River flow duration curve.

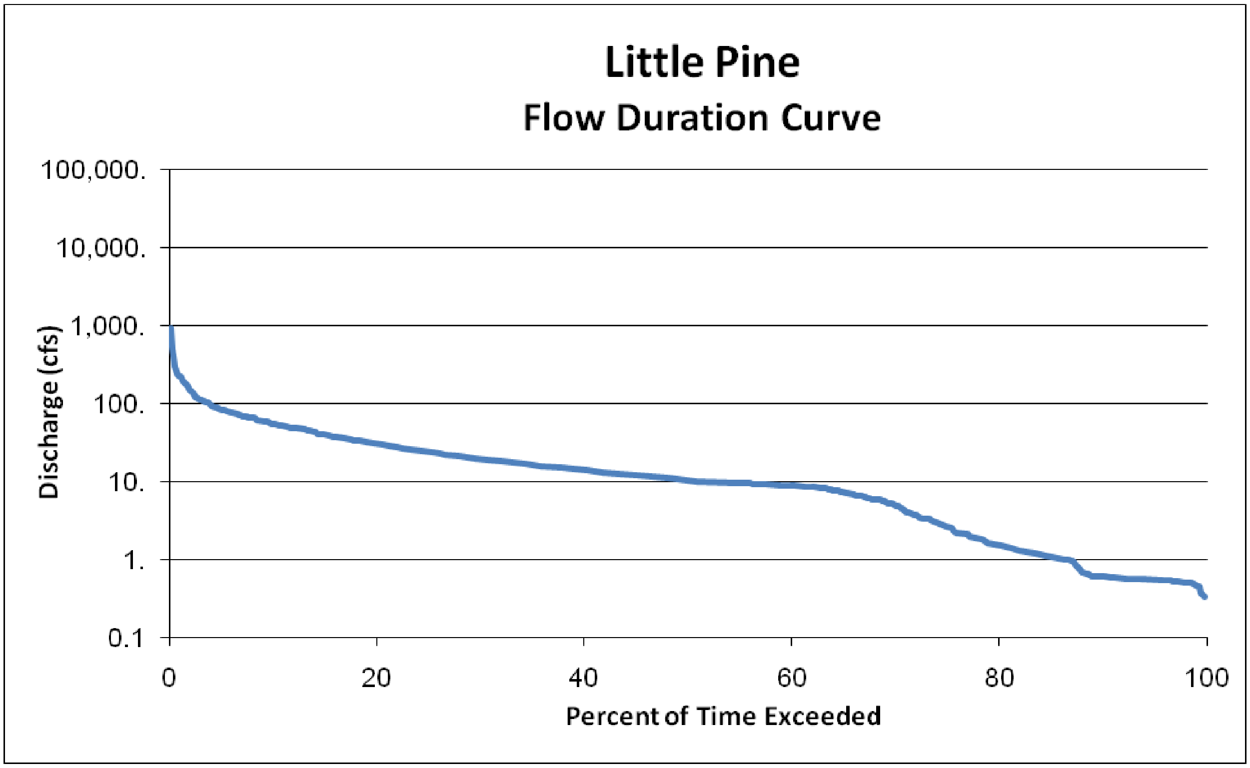

Figure 63. Little Pine Creek flow duration curve.

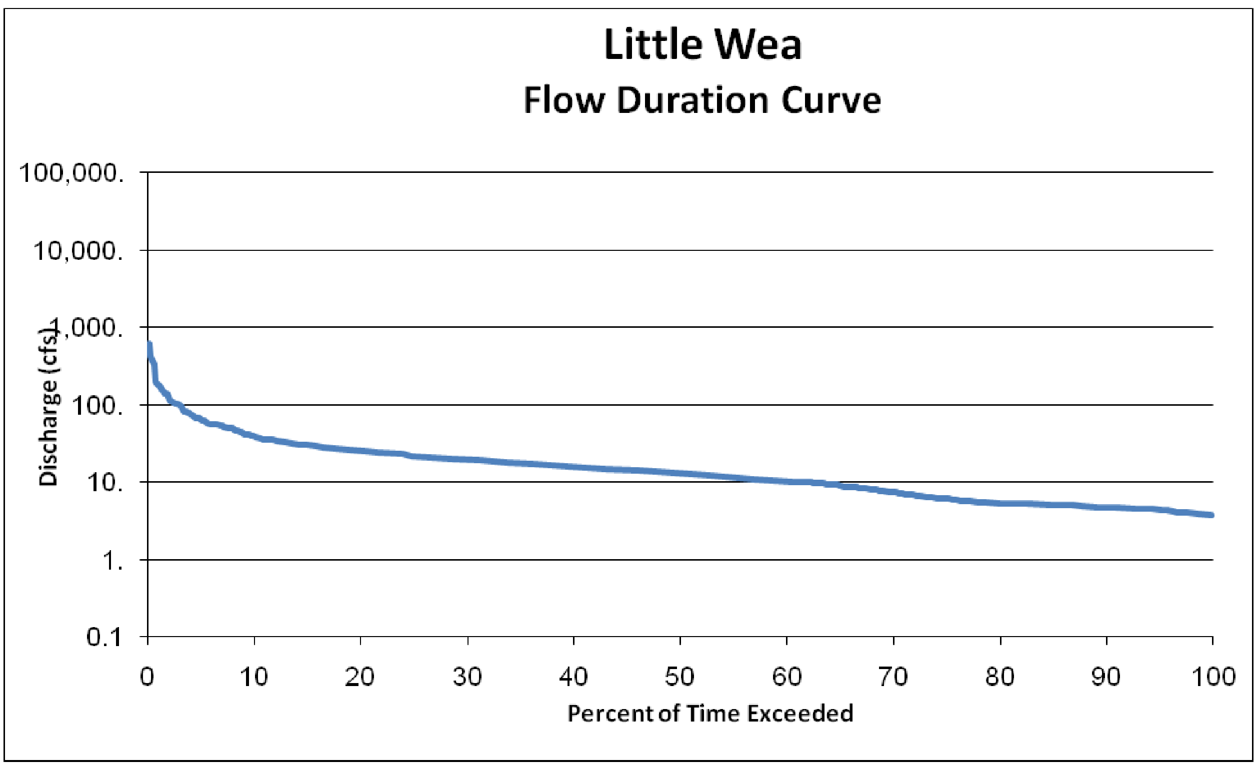

Figure 64. Little Wea flow duration curve.

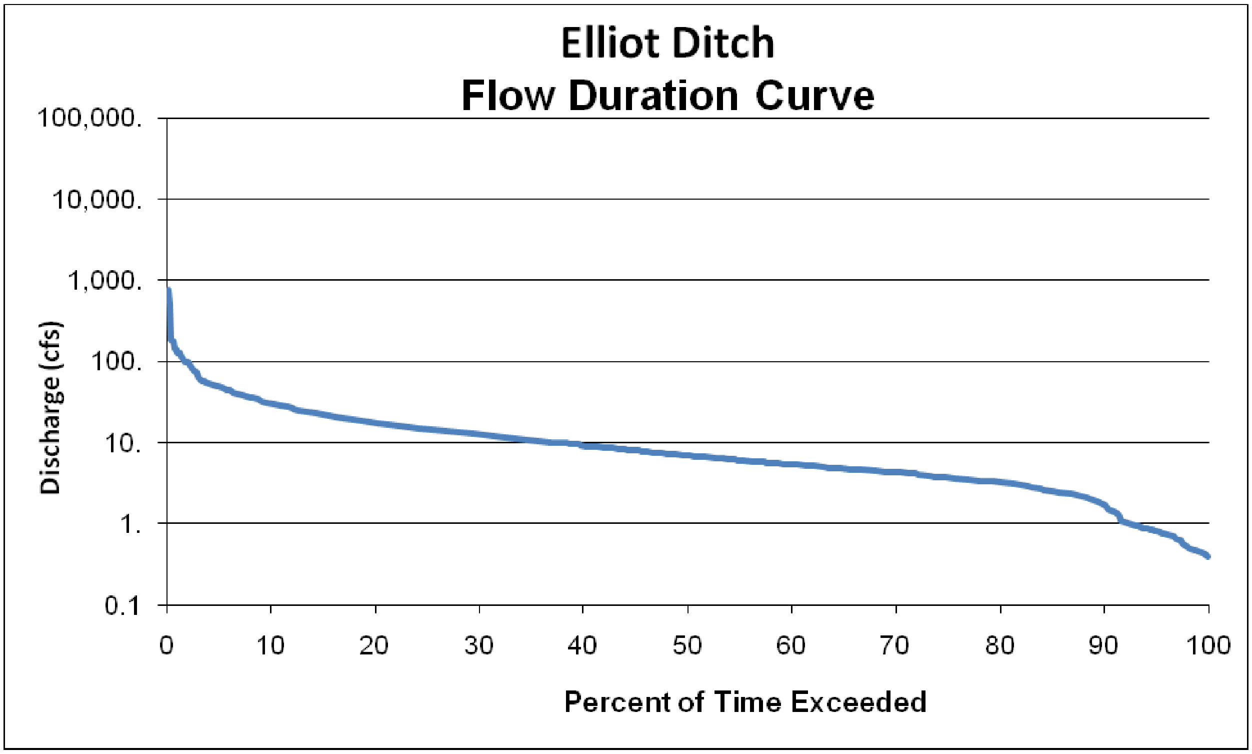

Figure 65. Elliot Ditch flow duration curve.

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. Flow duration curves were developed based on the flows records for the four stream gages located within the Region of the Great Bend of the Wabash River watershed. For the Wabash River sites USGS Gage 03335500 was used, while Little Pine used USGS Gage 033356786, Little Wea used USGS Gage 03335673, and Elliot Ditch used USGS Gage 033356725. Using the flows, a flow duration curve was generated. Then, from these curves a load duration curve for each material of concern was developed using the following equation:

(observed flow (cfs)) x (conversation 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 81 to Figure 85). In the graph, 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 during high flow events (Figure 66 to Figure 70). Interestingly, there appears to be little difference in the pattern between the upstream and downstream Wabash River sites. This suggests that Greater Lafayette is having no net effect on nitrate levels. Sampled values measured above target level 70% of the time. Nitrate-nitrogen levels measured below target levels when flows are low suggesting limited occurrences of point sources as contributors to nitrate-nitrogen. Little Pine and Little Wea creeks' nitrate + nitrite loads are similar to patterns observed in the Wabash River. Loads measured above the target level 70% of the time with most of the events occurring under high flow conditions. However, Elliot Ditch rarely contained values above targets implying nitrate is not a major contaminant in this subwatershed. This difference may be due to the dominant land use of each subwatershed. Both Little Pine and Little Wea creeks land uses are primarily agricultural while Elliot Ditch is mostly urban. Higher nitrate levels are likely caused from presence of livestock and fertilizers in the agricultural subwatersheds.

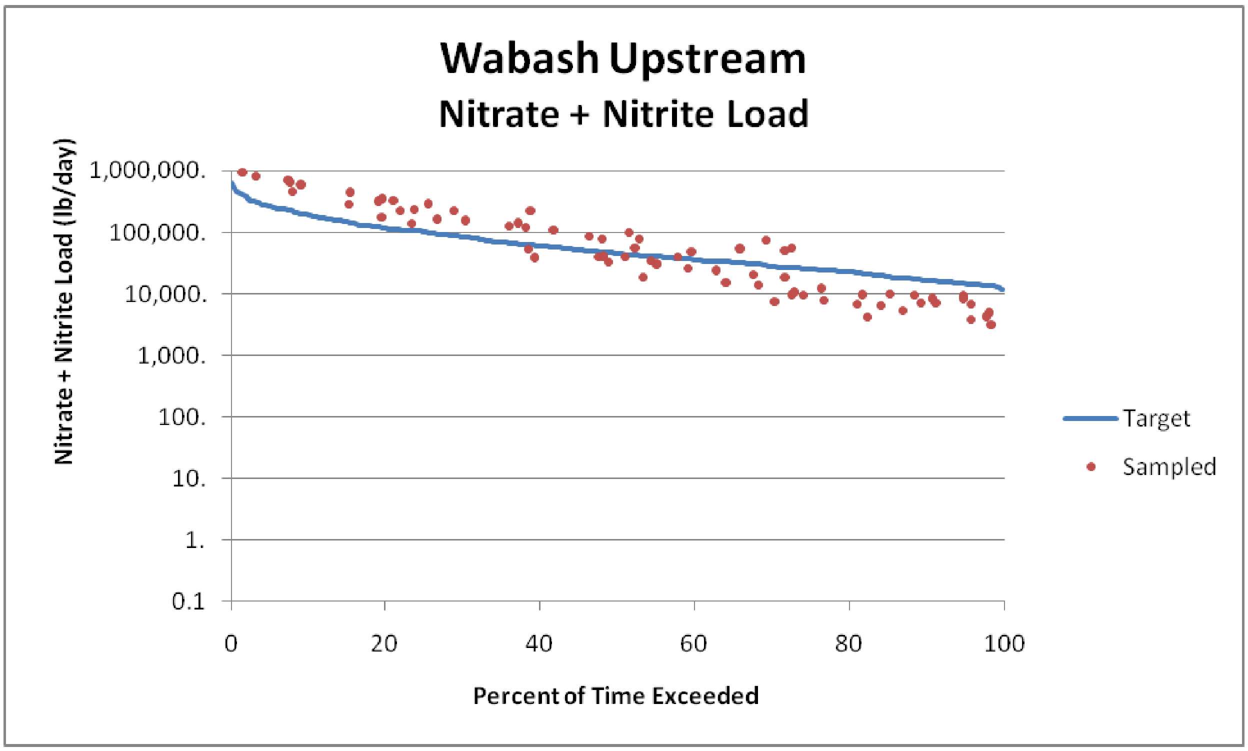

Figure 66. Wabash River nitrate-nitrogen load duration curve, upstream Greater Lafayette.

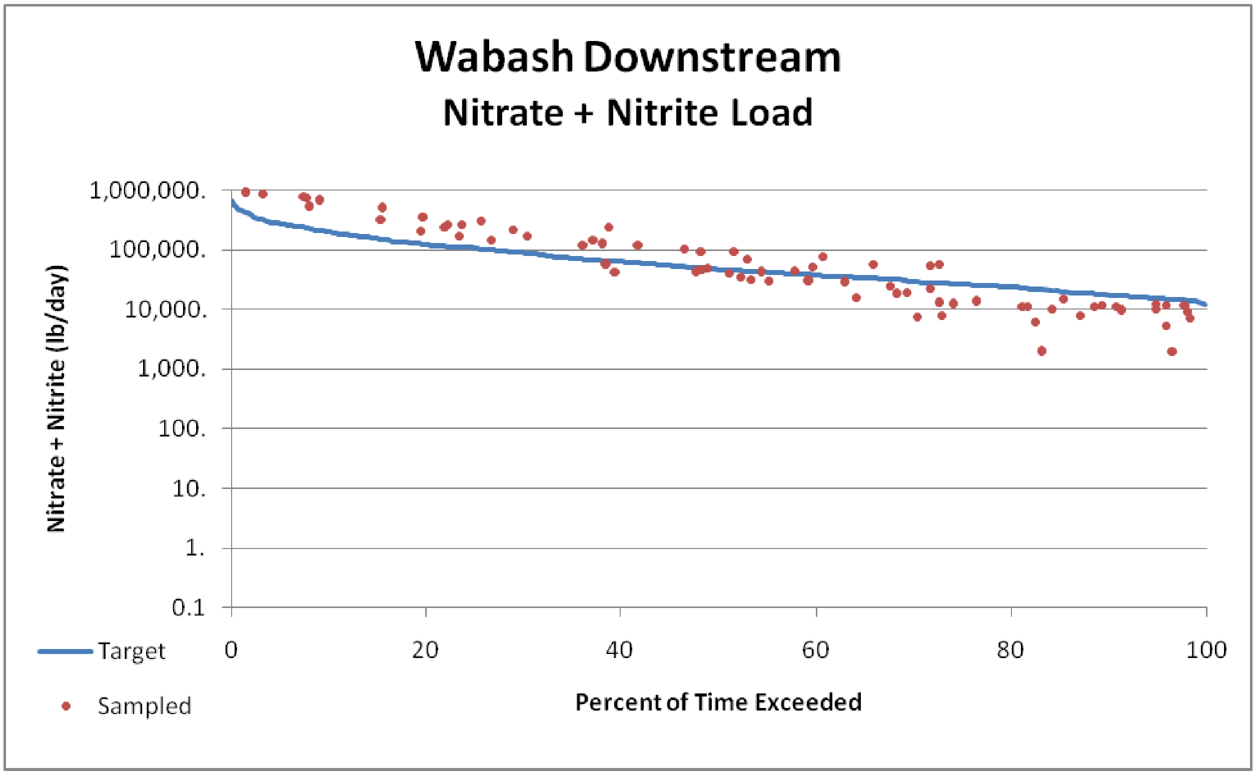

Figure 67. Wabash River nitrate-nitrogen load duration curve, downstream Greater Lafayette.

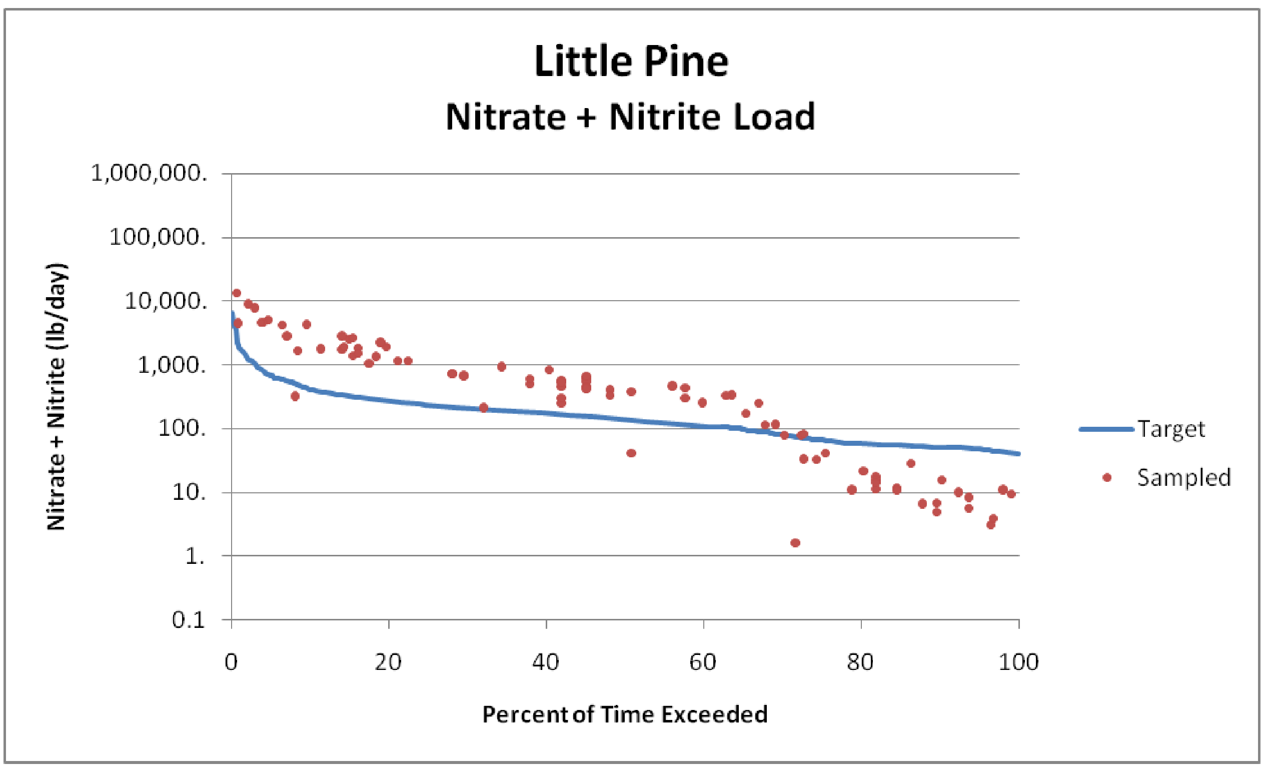

Figure 68. Little Pine Creek nitrate-nitrogen load duration curve.

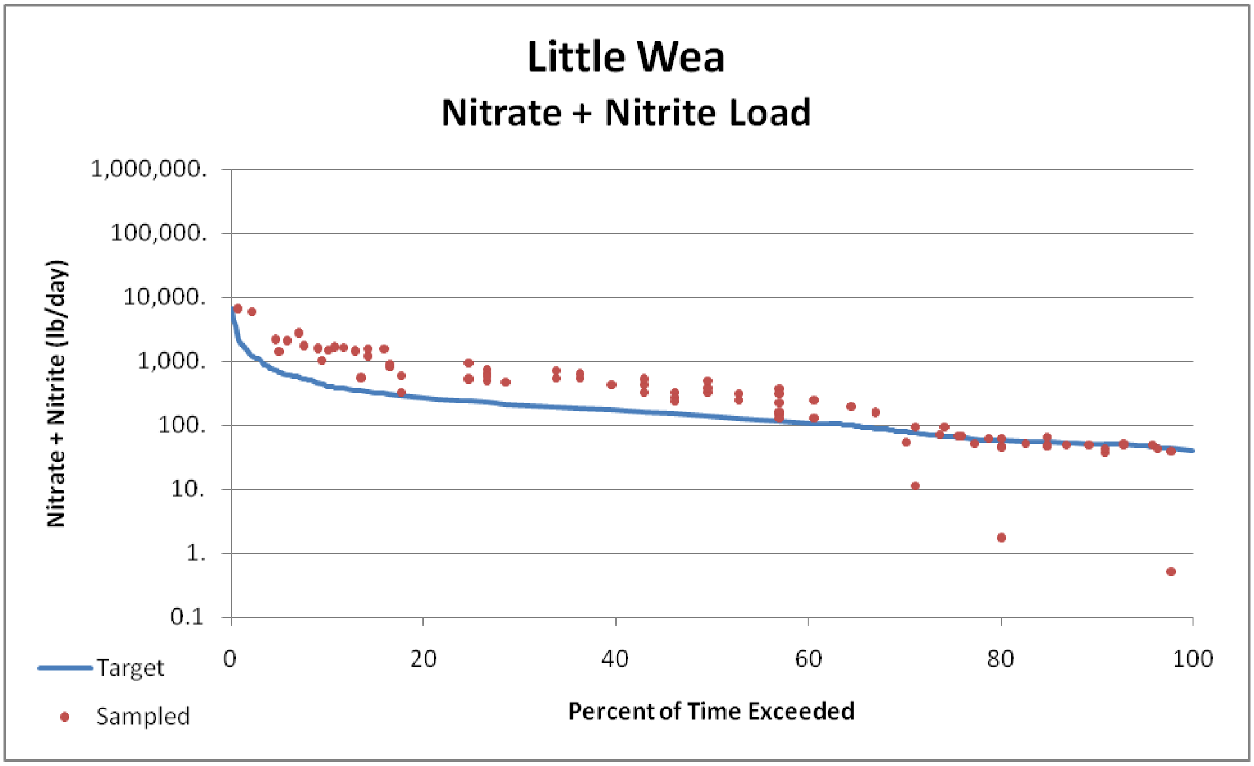

Figure 69. Little Wea Creek nitrate-nitrogen load duration curve.

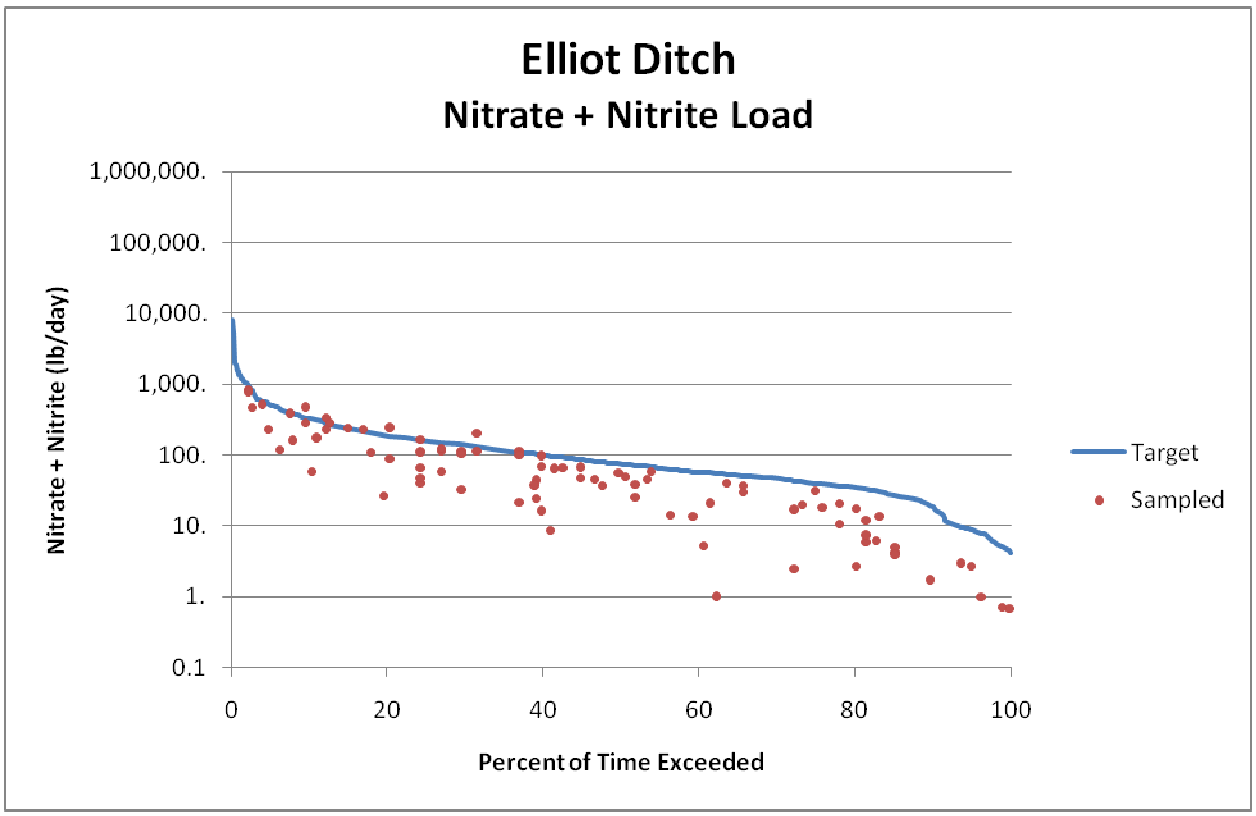

Figure 70. Elliot Ditch nitrate-nitrogen load duration curve.

Total Phosphorus

Total phosphorus (TP) levels generally measured above target levels during high flow events, which typically occurred under the wet conditions, at all sample sites (Figure 71 to Figure 75). This is not surprising as most total phosphorus is attached to suspended solids. Exceedances of the target concentrations occurred only a few times in Elliot Ditch, Little Pine Creek, and Little Wea Creek. Most exceedances occurred in Elliot Ditch and Little Wea Creek during storm flow events suggesting erosion or runoff is the cause of these values. The Wabash River site downstream of Greater Lafayette contained higher loads and exceeded the target levels more often than the upstream site. The Wabash River upstream site typically exceeded the target load only during high flow conditions. These data suggests that Greater Lafayette is contributing phosphorus to the Wabash River via surface runoff but also that phosphorus is entering the river between sites from a number of diffuse sources.

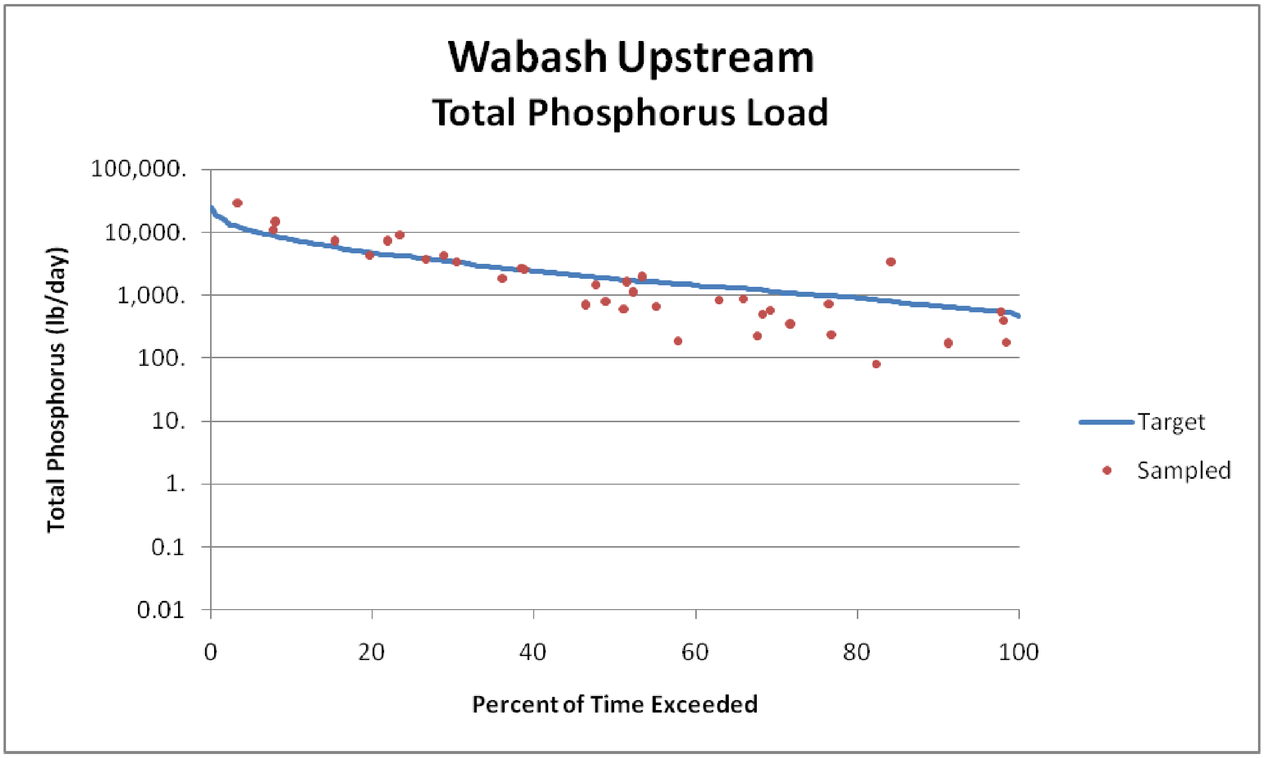

Figure 71. Wabash River Total Phosphorus load duration curve, upstream Greater Lafayette.

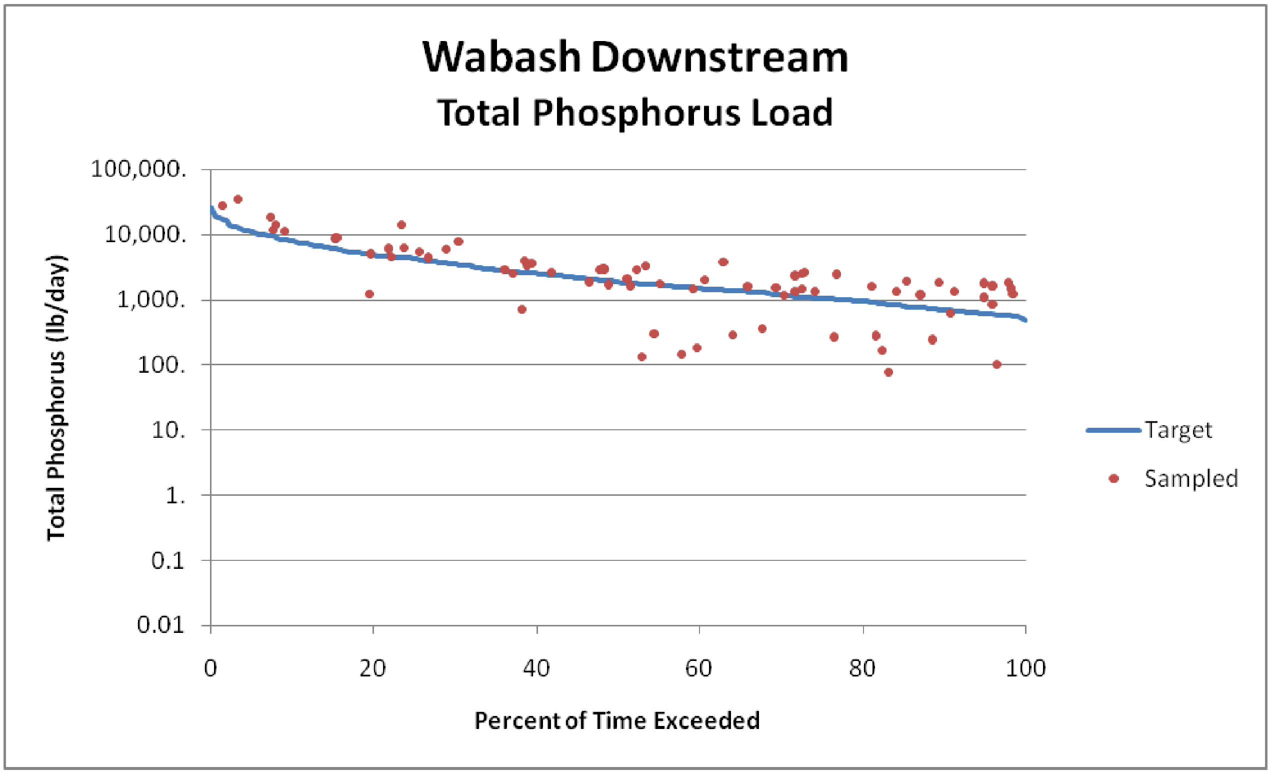

Figure 72. Wabash River Total Phosphorus load duration curve, downstream of Greater Lafayette.

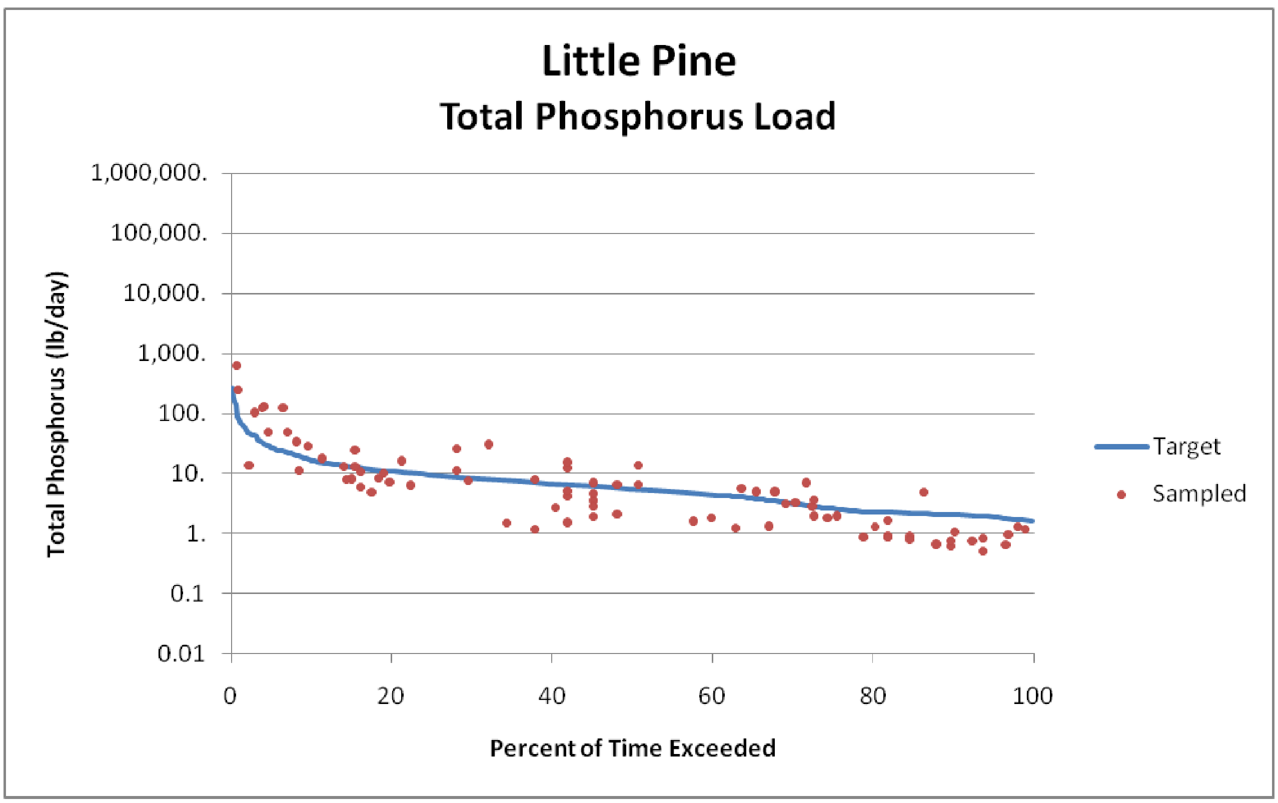

Figure 73. Little Pine Creek Total Phosphorus load duration curve.

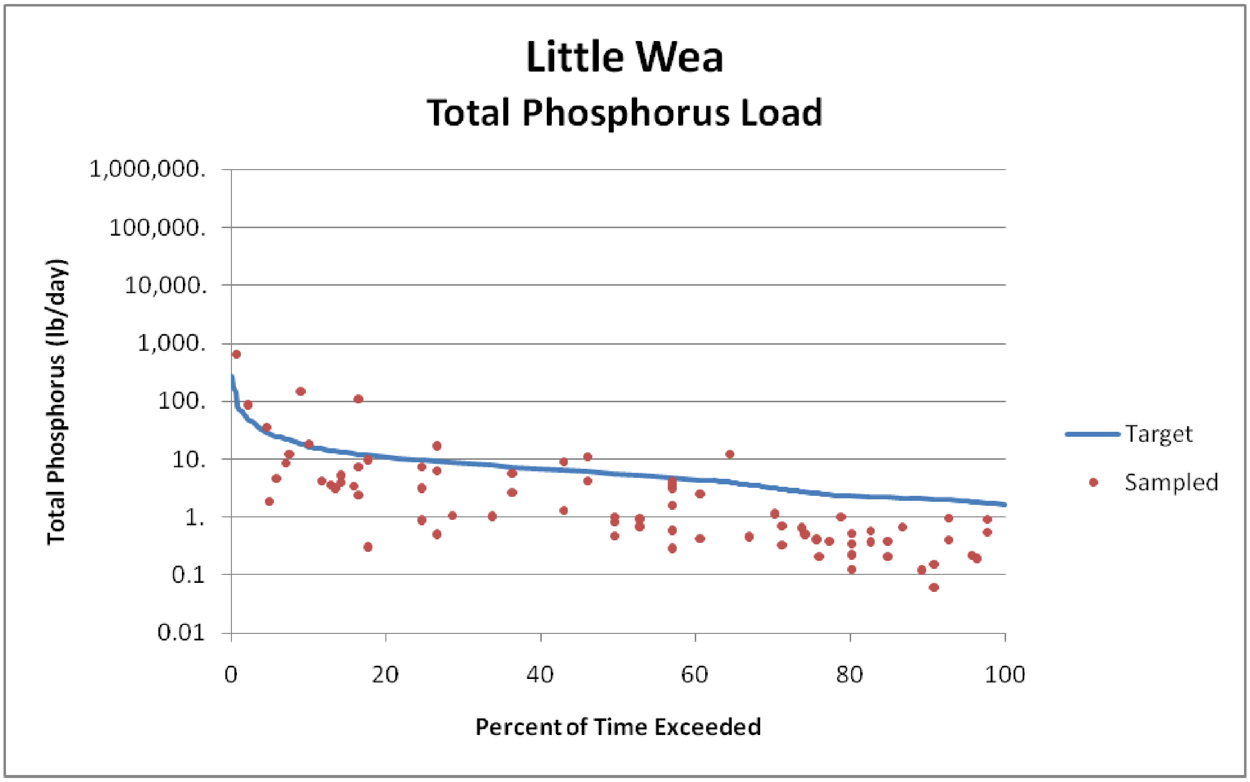

Figure 74. Little Wea Creek Total Phosphorus load duration curve.

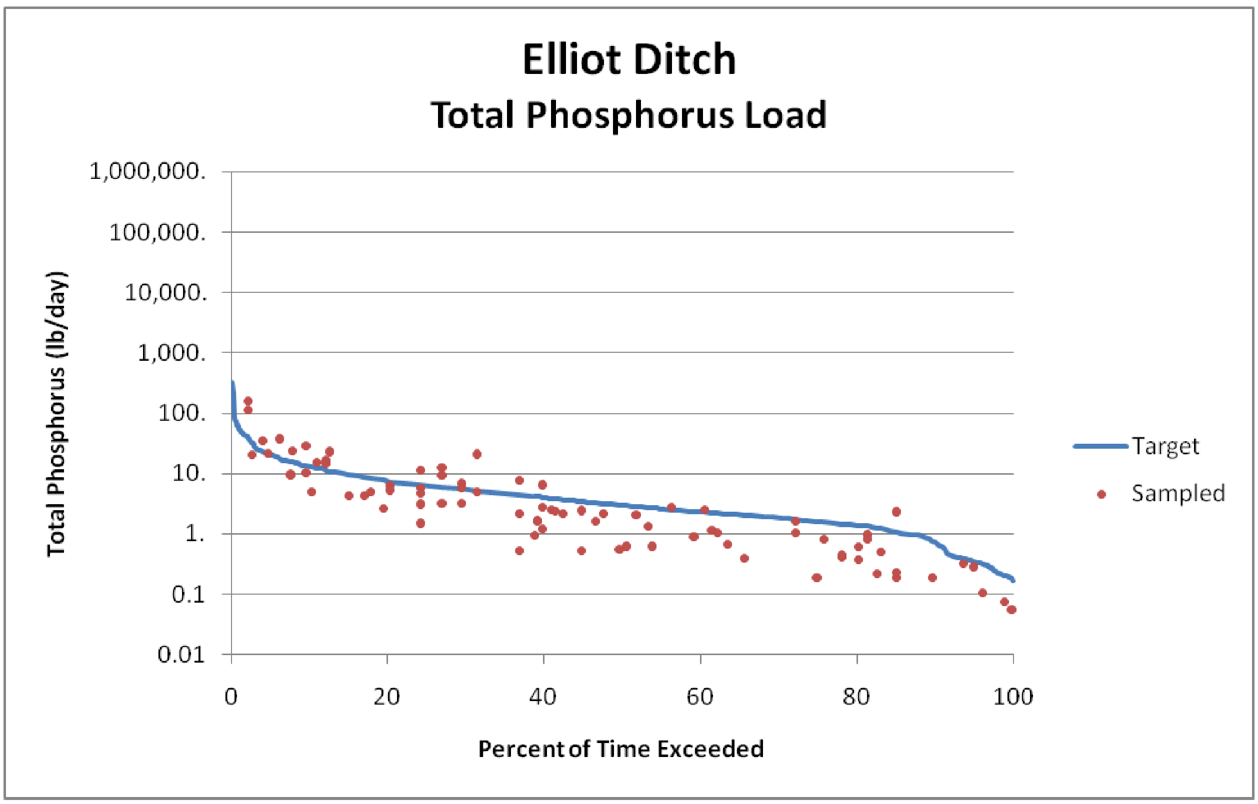

Figure 75. Elliot Ditch Total Phosphorus load duration curve.

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 76 to Figure 80). The Wabash River site downstream of Greater Lafayette contained higher loads and exceeded the target levels more often than the upstream site. These data suggests that Greater Lafayette is contributing surface sediments to the Wabash River via surface runoff. Possible sources of total suspended solids include erosion from the river banks and surface sediment runoff. Exceedances of the target concentrations occurred only a few times in Elliot Ditch and Little Wea Creek. Most exceedances occurred in Elliot Ditch and Little Wea Creek during storm flow events suggesting erosion or runoff is the cause of these values. Little Pine Creek exhibited a similar pattern for high flow events; however, several exceedances occurred during lower flow conditions as well. Possible sources of total suspended solids include the livestock access which occurs upstream of the sample site. At this location, it is common to observe livestock wading in the stream stirring up sediments and causing stream bank erosion.

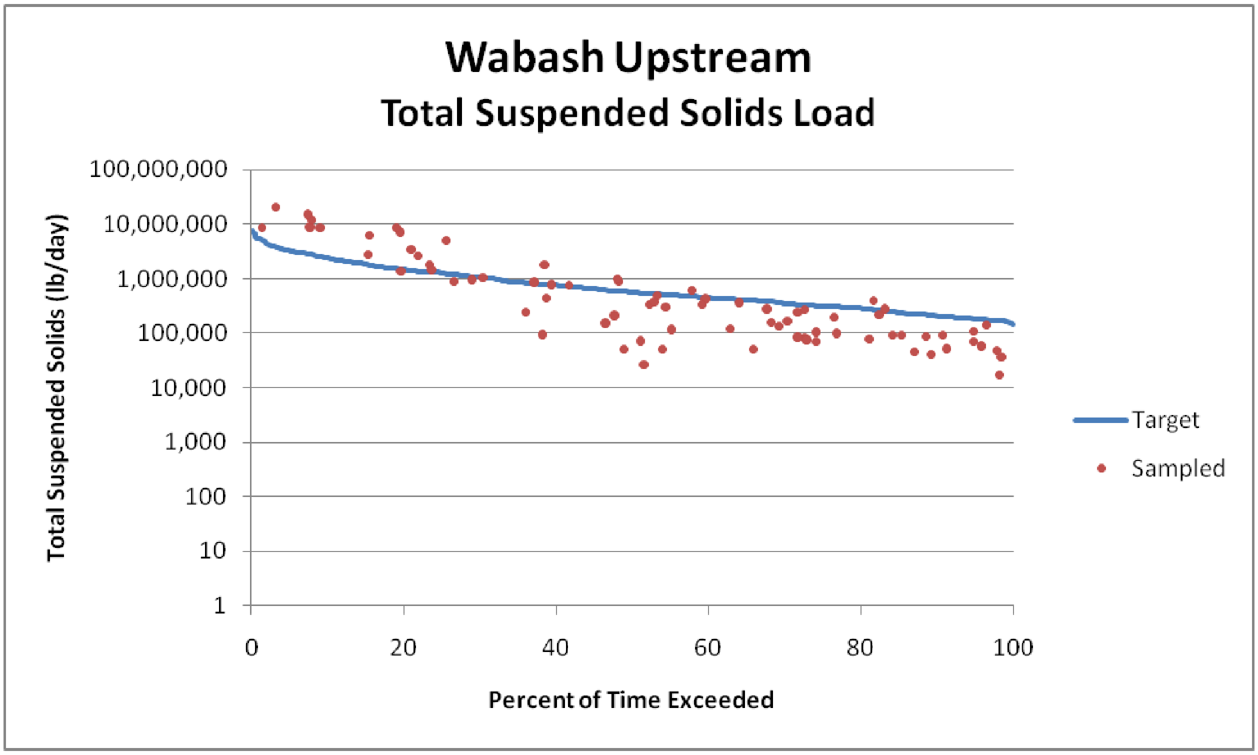

Figure 76. Wabash River Total Suspended Solids load duration curve, upstream of Greater Lafayette.

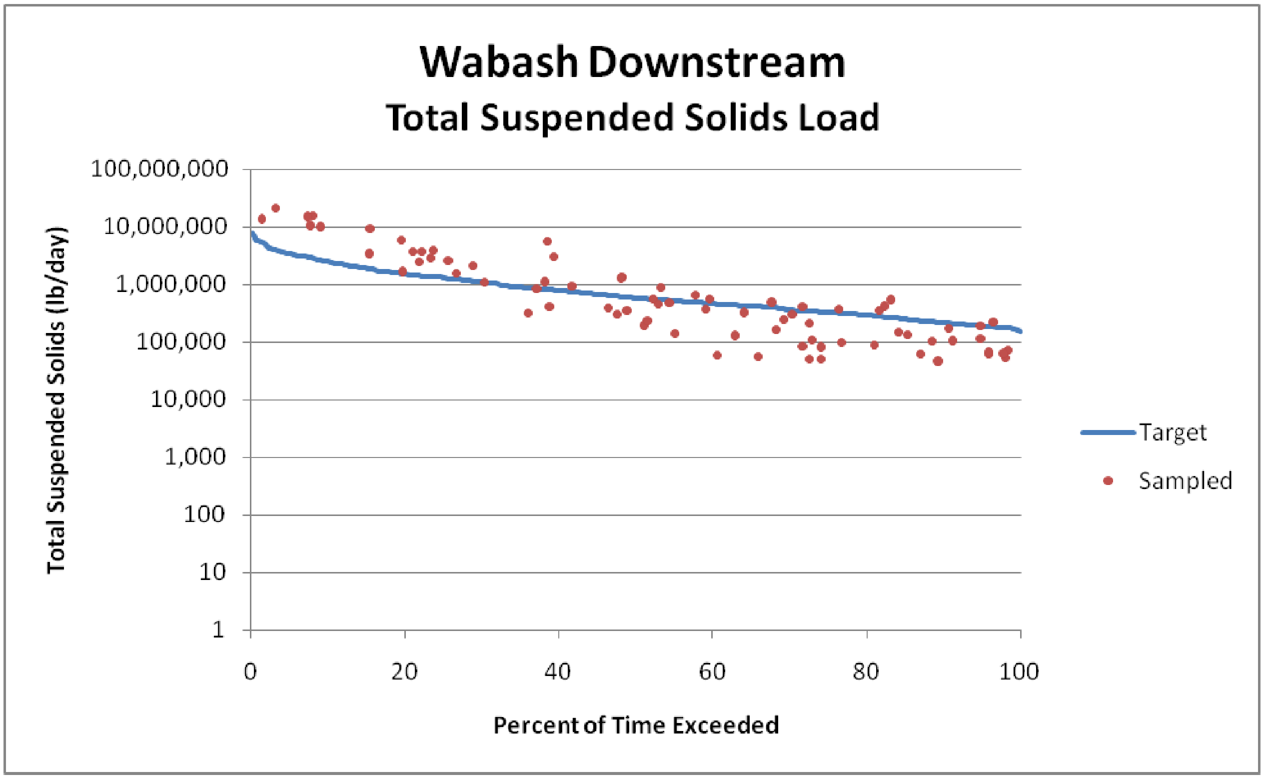

Figure 77. Wabash River Total Suspended Solids load duration curve, downstream of Greater Lafayette.

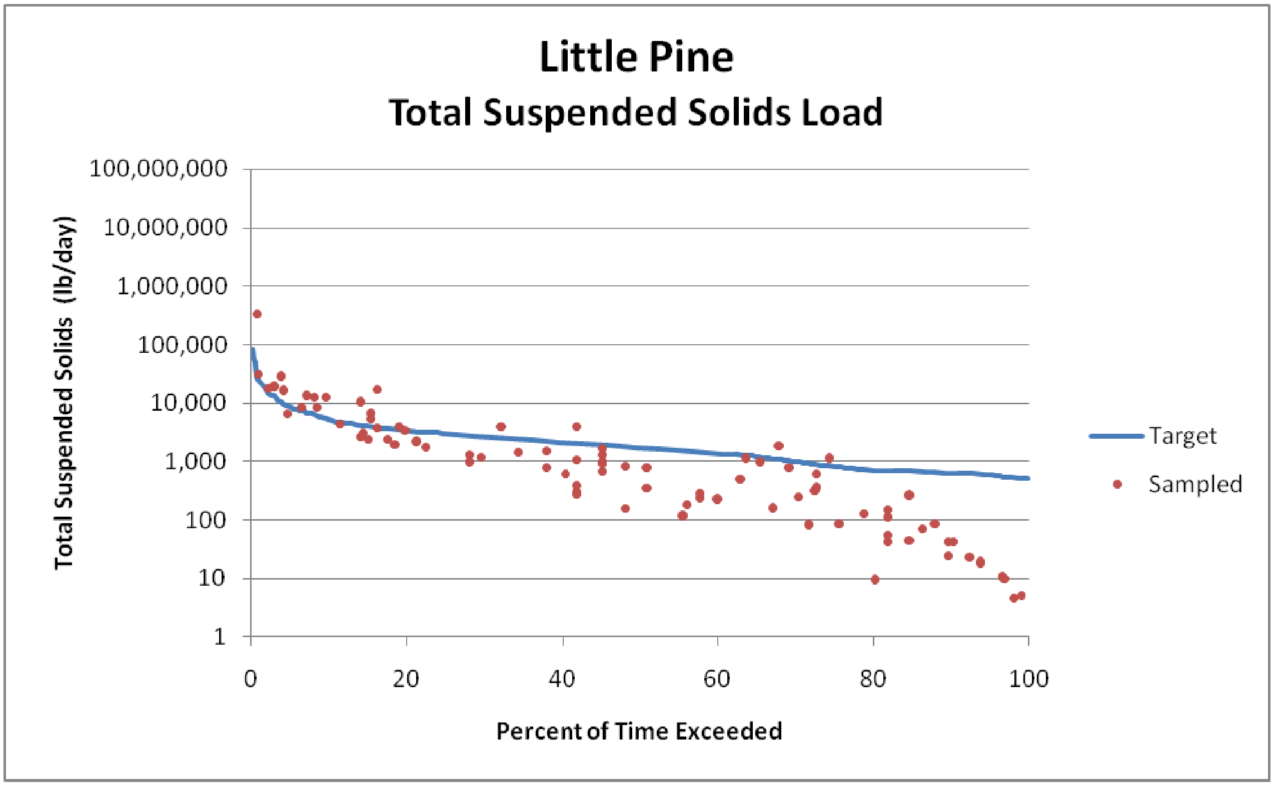

Figure 78. Little Pine Creek Total Suspended Solids load duration curve.

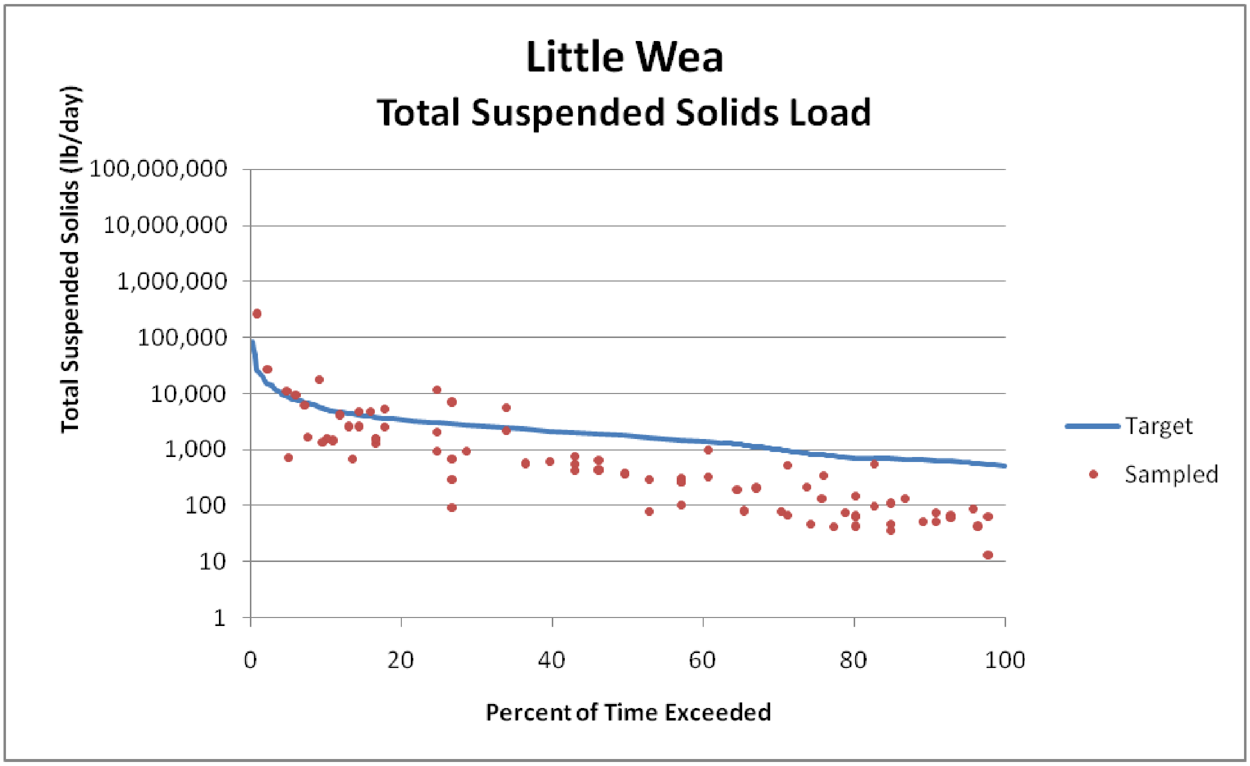

Figure 79. Little Wea Creek Total Suspended Solids load duration curve.

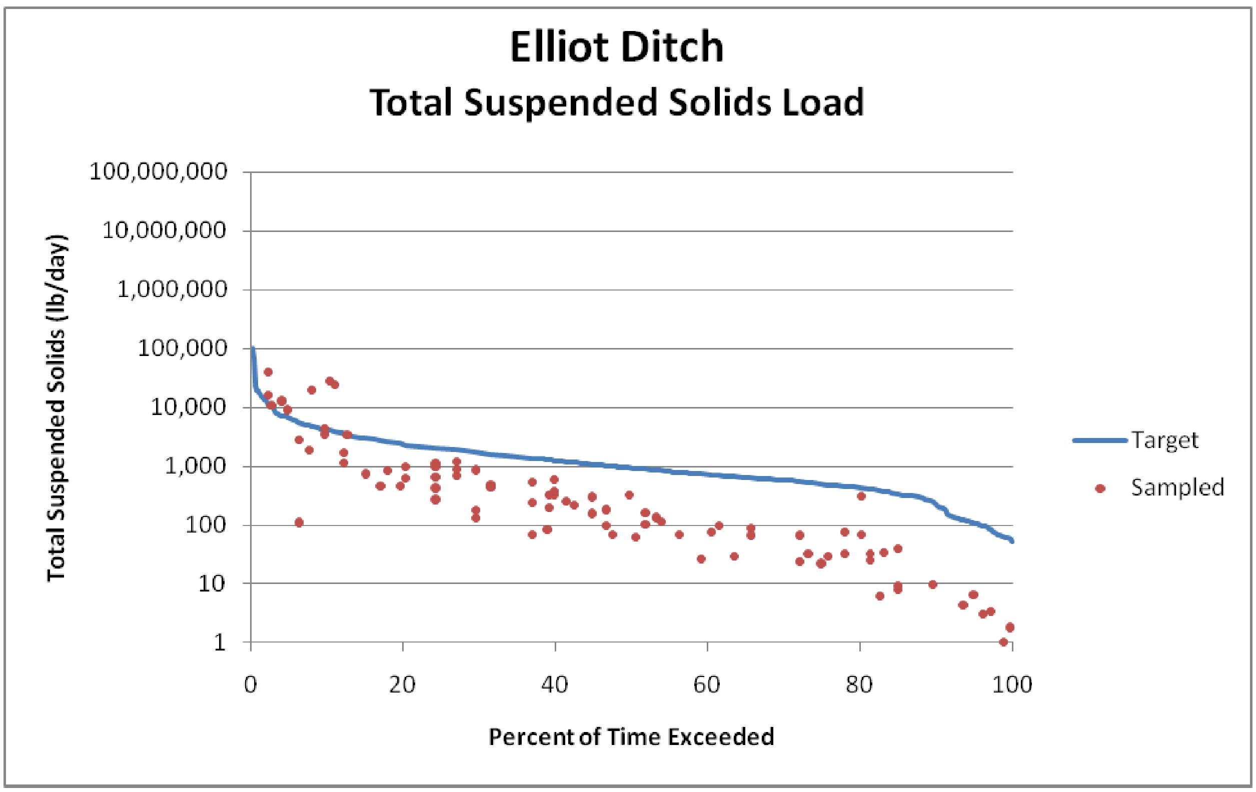

Figure 80. Elliot Ditch Total Suspended Solids load duration curve.

E. coli Load Duration Curves

In the Wabash River, *E. coli* loads tend to be above the target levels (set at 235 CFU/100 mL) during high flow events (Figure 81 and Figure 82). For the upstream Wabash River site, 23 of 81 (28%) observations exceeded the target. This means that during 28% of the time the river carried higher than desirable levels of *E. coli*. Most of these events (20%) occurred when flow was found to occur in High or Moist conditions (0 to 40). During summer months when flow is at its lowest, *E. coli* loads upstream of Greater Lafayette are also at their lowest and are typically below the target value.

At the downstream Wabash River site, approximately 44% of the samples exceeded the desired target levels of *E. coli*. These data show that downstream of Greater Lafayette, the river carried more *E. coli* compared to the upstream site. One reason for this observance is that wastewater treatment plants are allowed to legally discharge directly into the Wabash River from Nov 1 to March 31. During this time, there are rarely times when the river is at low flow conditions. It might be expected that if the treatment plants were a major source of *E. coli* exceedances would be most severe under wet or low (60-100) exceedance conditions. However, as most of the low flow occurs within the "swimming contact period" (a time requiring that *bacteria* be treatment before discharge), this response is not seen. Therefore, the winter load increases in *E. coli* on the Wabash River appear to be associated with higher flows. These observations may be caused by wastewater treatment plants located on the river legally releasing materials containing the indicator bacteria.

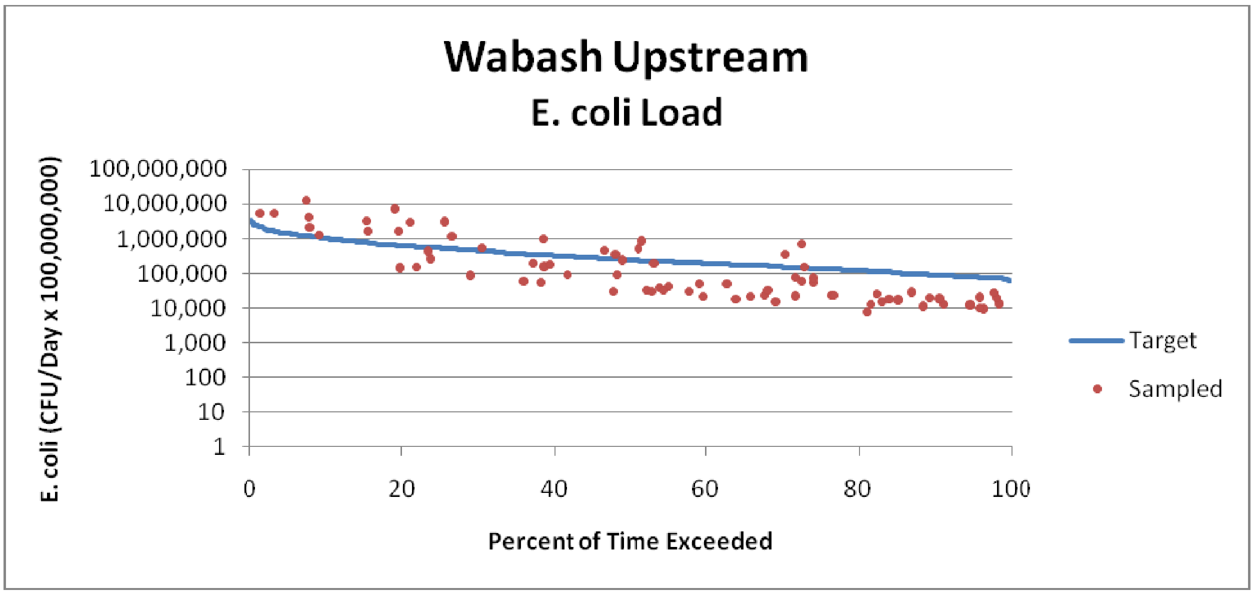

Figure 81. Wabash River *E. coli* load duration curve, upstream of Greater Lafayette.

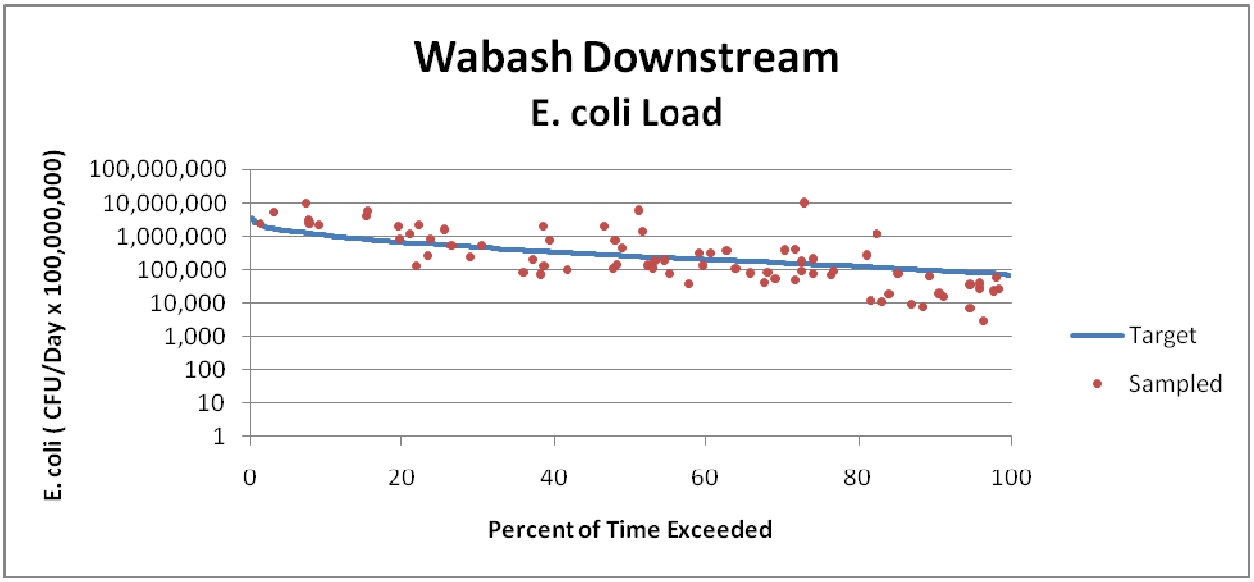

Figure 82. Wabash River *E. coli* load duration curve, downstream of Greater Lafayette.

The *E. coli* in Little Pine Creek exceeded our calculated target 91% of the time (Figure 83). *E. coli* were present under all flow regimes suggesting multiple sources of input that include runoff and point sources.

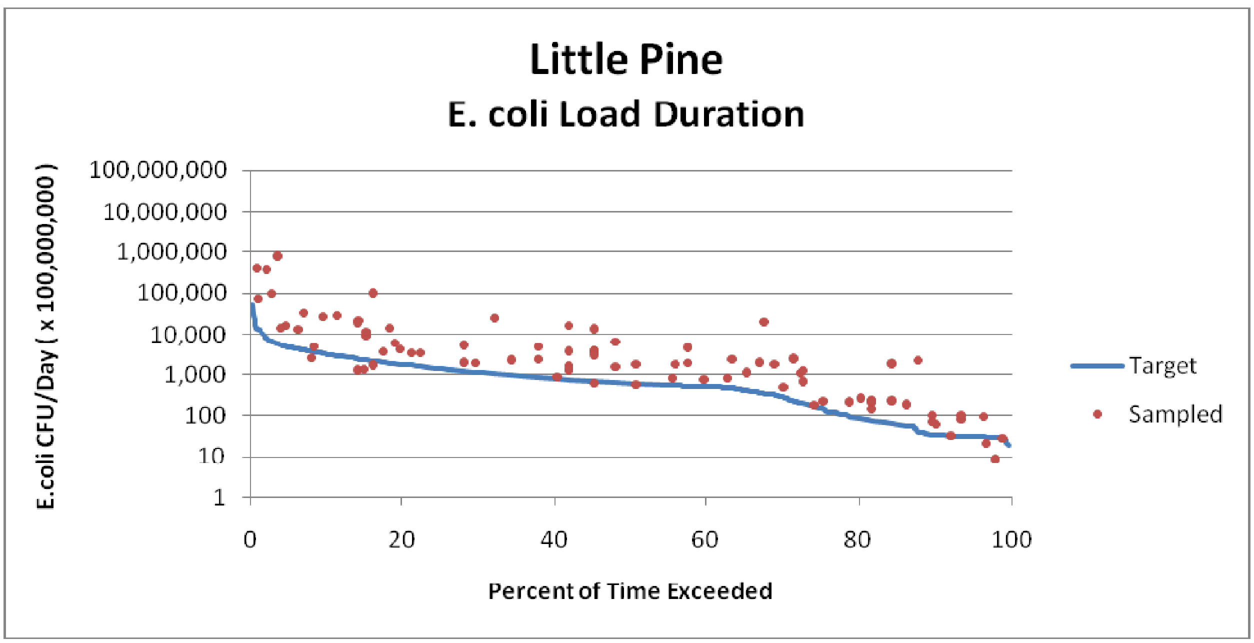

Figure 83. Little Pine Creek *E. coli* load duration curve.

E. coli in the Little Wea Creek exceeded our calculated target 51% of the time. *E. coli* were present under all flow regimes but tended to occur under the Moist and Mid-range conditions. These observations suggest surface runoff as a major source. Additionally, the lack of *E. coli* exceedances during the dry range suggest limited inputs from point sources.

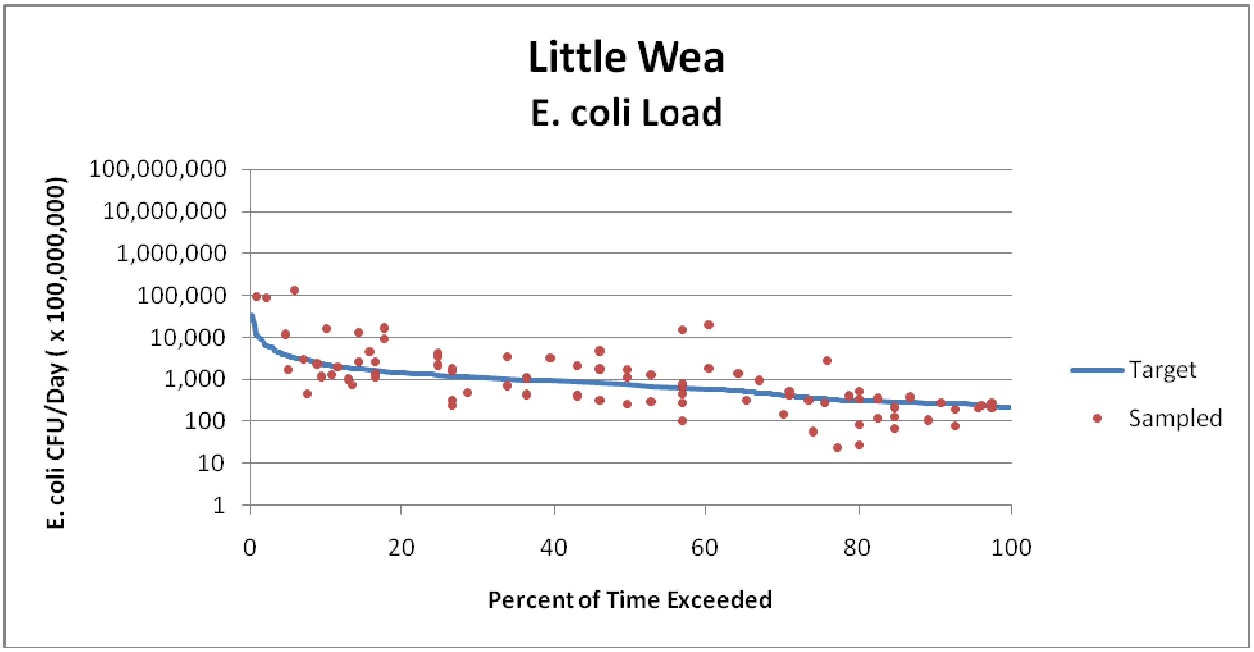

Figure 84. Little Wea *E. coli* load duration curve.

E. coli in Elliot Ditch exceeded target concentrations 59% of the time. These exceedances typically occurred during the Wet Range suggesting that the majority of *E. coli* inputs occurred as surface runoff and that little *E. coli* entered Elliot Ditch from point sources.

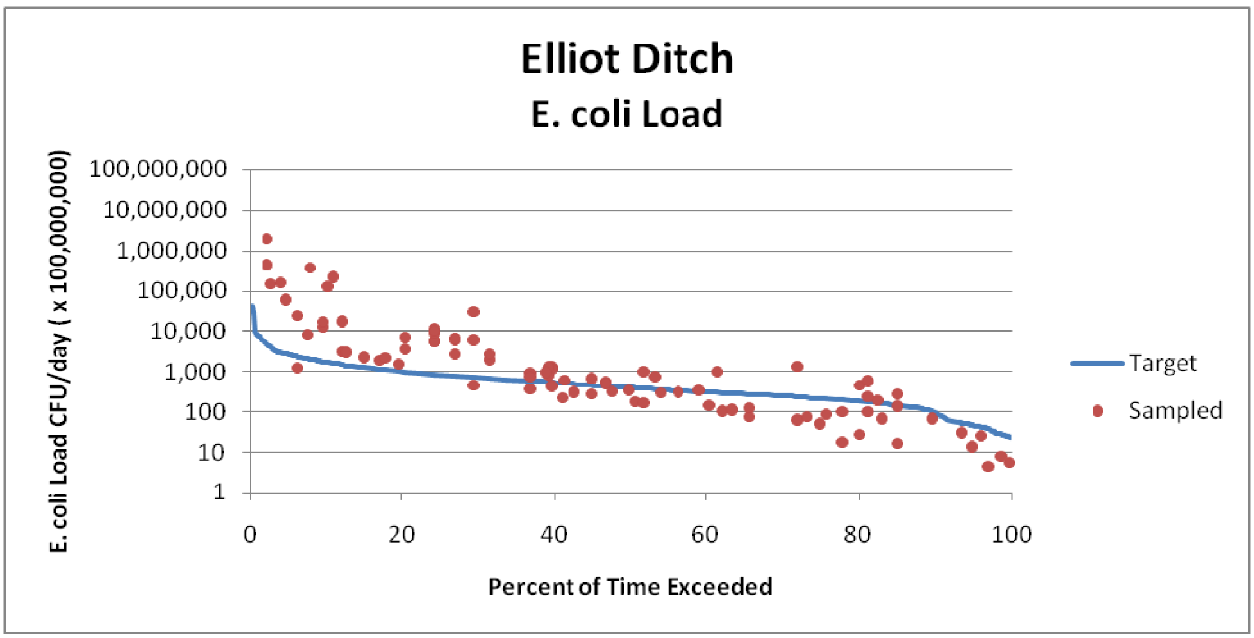

Figure 85. Elliot Ditch *E. coli* load duration curve.

3.3.6 Paired Catchment Evaluation

The watershed monitoring design was selected with the idea of using a paired catchment approach to quantify change in one watershed relative to another. The first step in this evaluation process is to determine whether the relationship between the treatment watershed and the control watershed is strong. Using samples collected through December 2010, acceptable regressions for all parameters (total suspended solids, nitrate+nitrite, total phosphorus and *E. coli*) except total phosphorous in Little Wea Creek are achieved (Figure 86 to Figure 88). With the exception of Little Wea Creek for total phosphorus, these regressions indicate a good choice of watershed pairs. The strongest relationships exist for nitrate+nitrite and total suspended solids. In the future, these relationships will be reviewed with regards to the relationship between watersheds after BMPs are implemented.

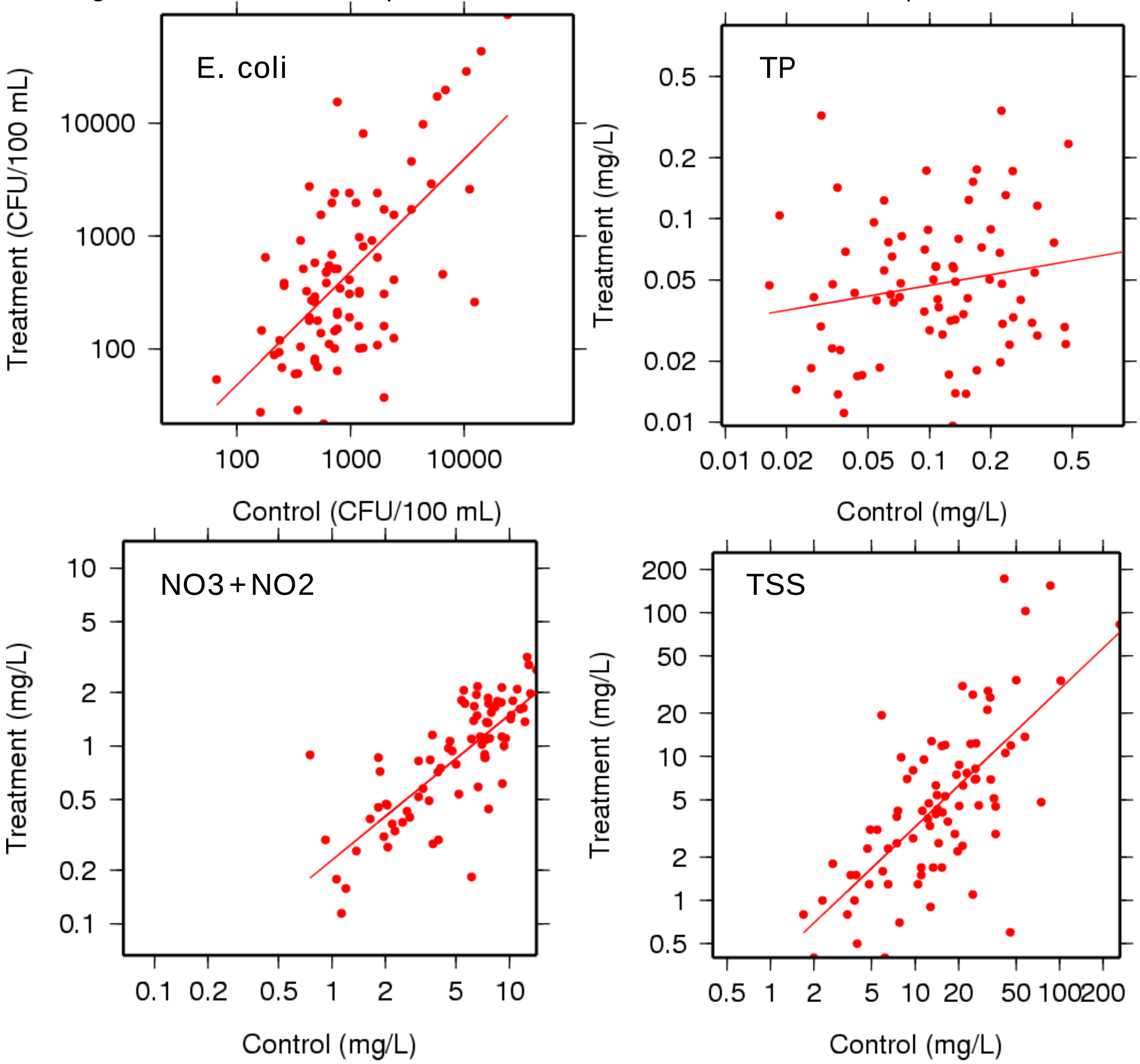

Figure 86. Calibration regression equations for the Elliot Ditch - Little Pine Creek pair (developing-control) for *E. Coli*, total phosphorous, nitrate+nitrite, and total suspended solids.

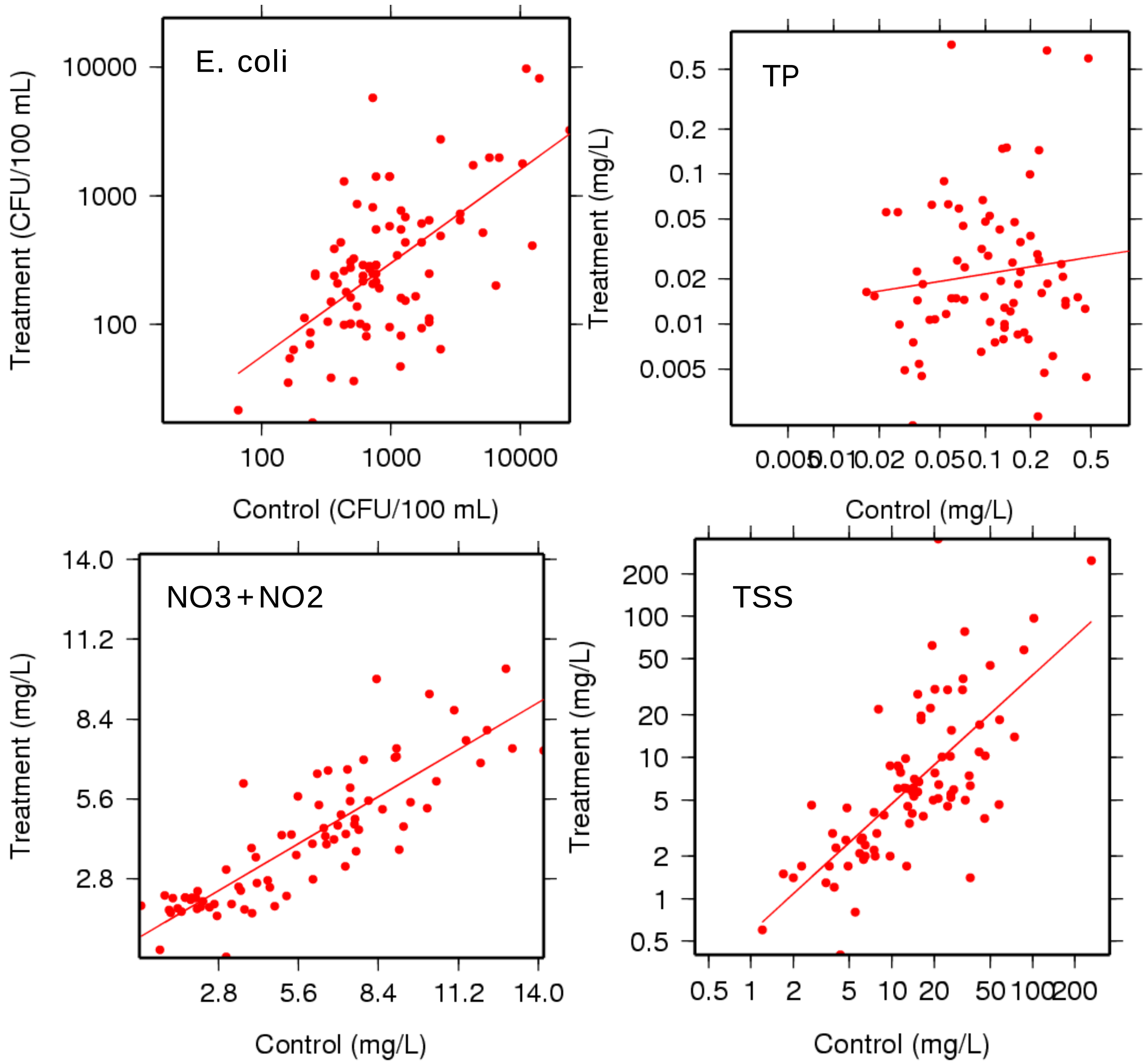

Figure 87. Calibration regression equations for the Little Wea Creek - Little Pine Creek pair (agriculture-control) for *E. Coli*, total phosphorous, nitrate+nitrite, and total suspended solids.

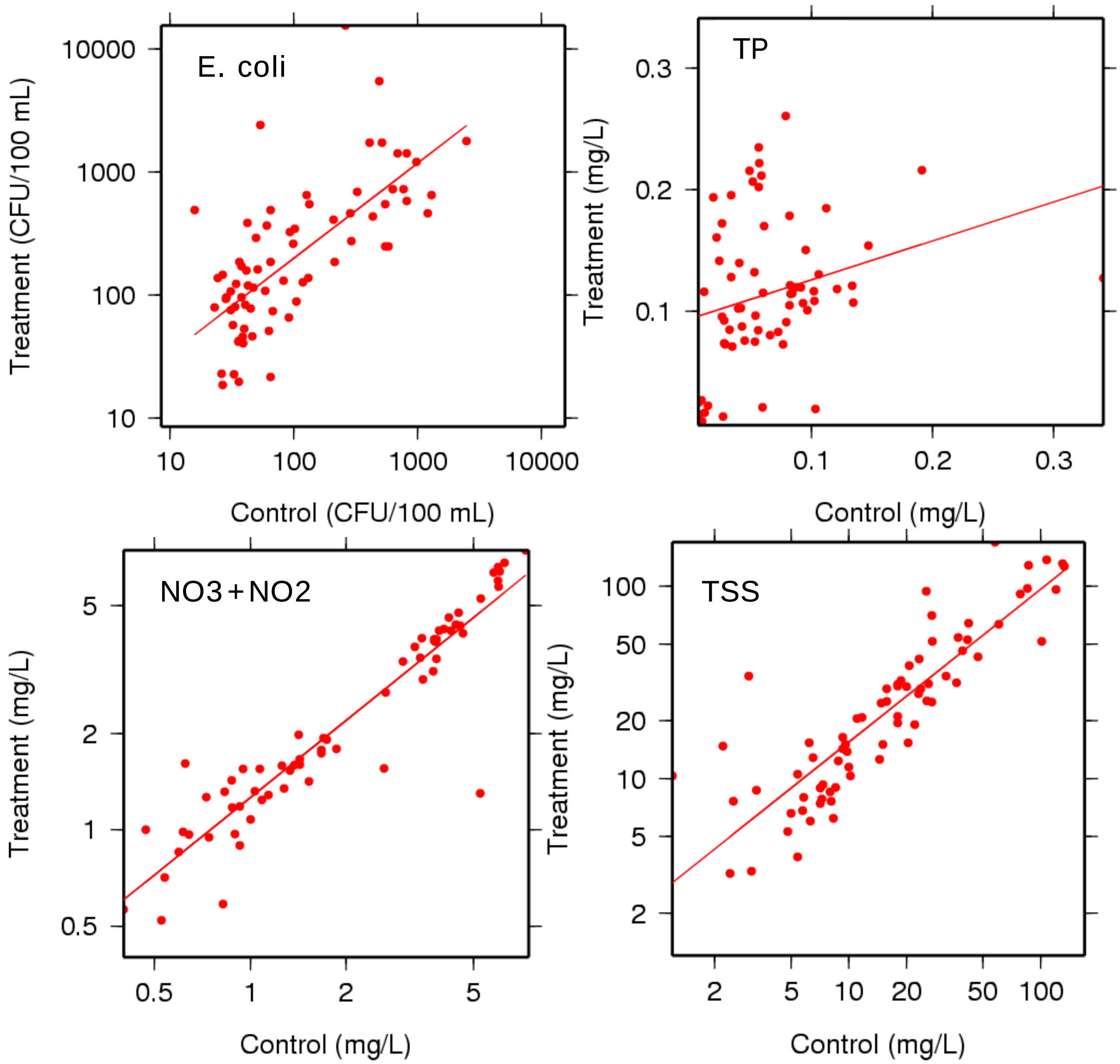

Figure 88. Calibration regression equations for the upstream-downstream Wabash River pair for *E. Coli*, total phosphorous, nitrate+nitrite, and total suspended solids.

3.3.7 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 26 presents the results of QHEI assessments at each of the ten stream sites. Figure 89 details metric and total scores for all sites. Among all the sites, riparian scores were relatively low, contributing to overall lower QHEI scores. The lowest scores occurred at Little Wea Creek and Kellerman Lea Ming Ditch where scores less than the target value (51) were calculated. 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 Indian Creek, Elliot Ditch, and West Fork Kickapoo Creek where cobble substrates and quality pool-riffle complexes were present throughout the stream reach.

Table 26. Qualitative Habitat Evaluation Index (QHEI) scores measured in Region of the Great Bend of the Wabash River watershed.

Stream	Substrate	Cover	Channel	Riparian	Pool/Riffle	Gradient	Total
Little Pine Creek	7.75	9.5	11	6.5	11.25	6	52
Little Wea Creek	12.25	4.75	4	2.38	9	4	36.38
Elliot Ditch	14.33	11	13.67	7.67	12.83	10	69.5
Burnett Creek	11.33	13.67	11.67	7.5	9.33	10	63.5
Kellerman Lee Ming Ditch	5.34	8	5.33	3.83	11	10	43.5
Flint Creek	12.33	10	13	6.17	13.67	6	61.17
East Branch Wea Creek	12.75	13.75	12.25	5.88	12.25	10	66.88
Indian Creek	16.34	13.33	16.33	8	15.83	10	79.83
Kickapoo Creek	14.32	13.67	14.67	8.5	11.67	4	66.83
West Fork Kickapoo Creek	15.33	15	15.67	9.33	11.67	10	77

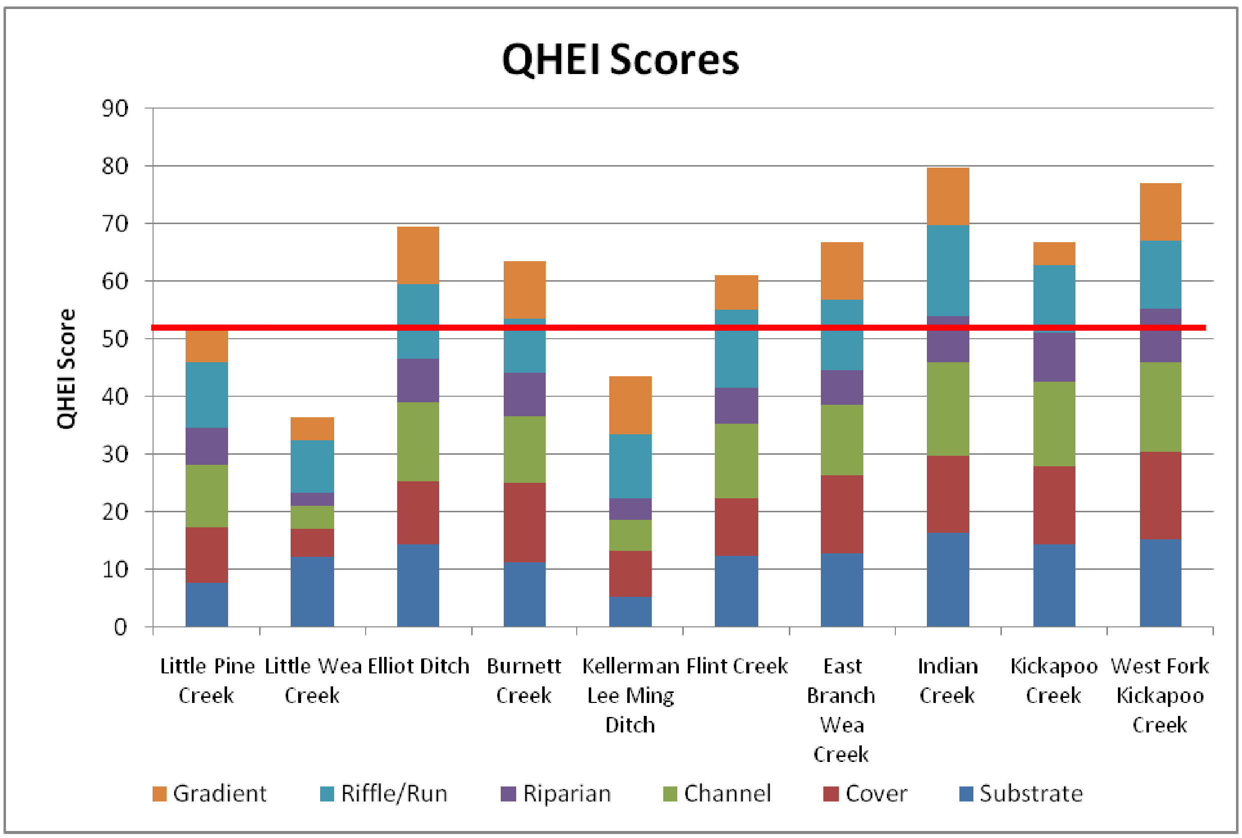

Figure 89. Qualitative Habitat Evaluation Index (QHEI) total and component scores measured for stream sites in Region of the Great Bend of the Wabash River watershed. The red line represents the target value (51).

3.3.8 Fish Community Results

Fish community data collected during sampling indicate that fish communities present in the Region of the Great Bend of the Wabash River watershed generally rate as good (scores of 28-48;Table 27). The lowest mean IBI scores occurred in Kickapoo Creek, Little Pine Creek, Elliot Ditch, and Kellerman Lea Ming Ditch, where scores averaged 37 or less. These sites represent streams impacted by changing water conditions and poor instream habitat. For example, a sample could not be collected in Kickapoo Creek in September 2009 due to lack of water present during the sampling period. The highest scores occurred at Burnett Creek and Flint Creek where cobble substrates dominate instream habitat. Seasonal IBI scores among sites were highly variable, possibly related to normal movement patterns among fish assemblages (Figure 90). A total of 61 fish species were collected over the two-year sampling period. The mean number species for the 2009-2010 period was 15.9 with a low of nine (Kickapoo Creek, Sample VI) and a high of 23 (Little Pine Creek Samples II and VII and Burnett Creek Sample VII).

Table 27. Index of Biotic Integrity (IBI) scores measured at stream sites in the Region of the Great Bend of the Wabash River watershed.

Stream	Jun 2009	Jul 2009	Sept 2009	Nov 2009	Mar 2010	Jun 2010	Aug 2010	Nov 2010	Mean
Little Pine Creek	36	44	38	38	36	30	40	36	37
Little Wea Creek	40	44	48	48	30	32	40	38	40
Elliot Ditch	40	36	38	42	40	38	38	42	39
Burnett Creek	44	50	46	48	34	48	48	48	46
Kellerman Lee Ming Ditch	30	48	36	38	42	36	34	34	37
Flint Creek	50	48	46	52	40	36	48	46	46
East Branch Wea Creek	50	46	44	44	40	44	44	42	44
Indian Creek	46	46	46	48	38	46	44	46	45
Kickapoo Creek	34	44	--	36	30	28	30	42	35
West Fork Kickapoo Creek	40	38	38	42	40	32	40	40	39

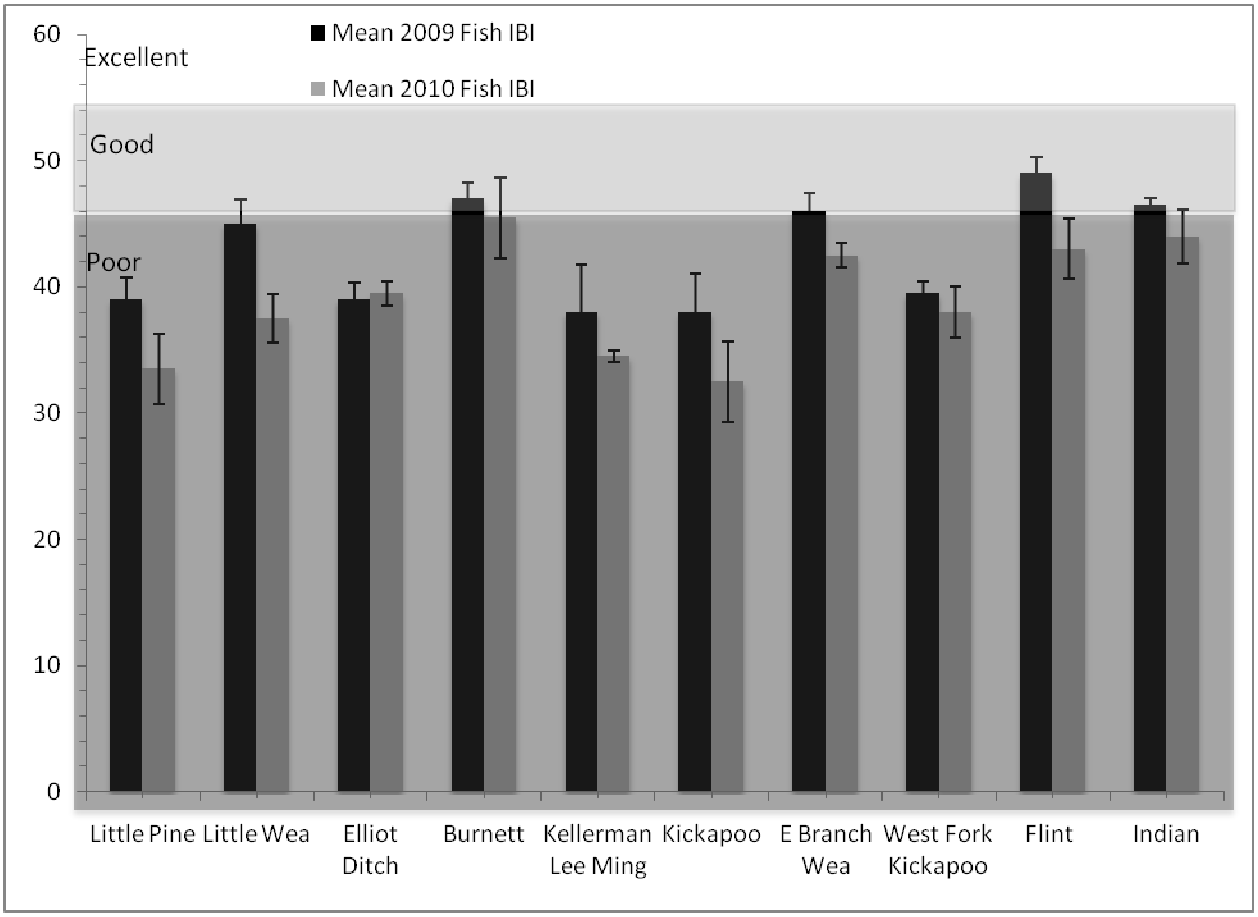

Figure 90. Mean fish Index of Biotic Integrity scores calculated based on stream samples collected in the Region of the Great Bend of the Wabash River watershed during 2009-2010. Error bars indicate standard error of IBI scores among all samples at a given site.

3.3.9 Macroinvertebrate Results

Macroinvertebrate community data collected during sampling indicated a wide range of mIBI scores for stream sites within the Region of the Great Bend of the Wabash River watershed (Table 28). The lowest mean mIBI scores occurred in Kellerman Lea Ming Ditch where the community rated as severely impaired. Little Pine Creek, Elliot Ditch, Little Wea Creek, and Burnett Creek communities all fell within the moderately impaired range based on mean mIBI scores. The highest mean mIBI scores occurred at Flint Creek, East Branch Wea Creek, Indian Creek, and West Fork Kickapoo Creek, where scores indicated that communities were only slightly impaired (Figure 91).

Table 28. Macroinvertebrate Index of Biotic Integrity (mIBI) scores measured at stream sites in the Region of the Great Bend of the Wabash River watershed.

Stream	HBI	# Taxa	# Indiv	% Dom	EPT	EPT: Ct	EPT: Tot	EPT: Chir	Chir	# / Sq	mIBI score
Little Pine Creek	4.75 (5)	10 (2)	108 (2)	75 (1)	4 (4)	51 (3)	0.46 (5)	3.07 (3)	34 (5)	108 (3)	3.1
Little Wea Creek	4.95 (4)	15 (5)	710 (6)	81 (0)	7 (6)	291 (6)	0.38 (4)	1.33 (1)	242 (2)	710 (6)	3.9
Elliot Ditch	4.59 (5)	7 (1)	288 (5)	94 (0)	2 (1)	68 (6)	0.68 (7)	8.87 (4)	65 (4)	288 (6)	3.8
Burnett Creek	5.30 (2)	11 (4)	615 (7)	90 (0)	5 (4)	218 (5)	0.32 (3)	2.40 (2)	329 (1)	615 (7)	3.4
Kellerman Lee Ming Ditch	5.64 (1)	7 (1)	283 (5)	96 (0)	2 (1)	25 (1)	0.10 (1)	0.14 (0)	240 (1)	283 (5)	1.5
Kickapoo Creek	4.33 (5)	10 (2)	148 (3)	73 (1)	6 (5)	86 (5)	0.60 (6)	5.94 (4)	33 (5)	148 (4)	4.0
East Branch Wea Creek	4.36 (6)	12 (4)	601 (5)	82 (0)	6 (6)	310 (6)	0.53 (6)	7.24 (4)	150 (4)	601 (6)	4.4
West Fork Kickapoo Creek	4.42 (6)	12 (3)	416 (5)	77 (0)	6 (5)	183 (6)	0.52 (6)	4.82 (4)	165 (4)	416 (5)	4.2
Flint Creek	4.15 (6)	14 (5)	743 (7)	77 (0)	6 (6)	570 (7)	0.74 (8)	6.94 (5)	104 (2)	743 (7)	5.3
Indian Creek	5.20 (3)	15 (5)	994 (7)	80 (0)	7 (7)	379 (7)	0.40 (4)	1.57 (2)	470 (1)	994 (7)	4.2

Total mIBI score is a mean score for each site based on all sampling events. All other values are means for each individual mIBI category. Means in parentheses are mIBI values associated with each mIBI category, 0-2 = severely impaired, 2-4 = moderately impaired, 4-6 = slightly impaired, and 6-8 = non-impaired.

Final mIBI scores include Hilsenhoff Biological Index (HBI) scores in their calculations. HBI scores rate organic pollution present within a system based on the tolerance of macroinvertebrate species present in samples. High HBI scores indicate high levels of pollution while low scores reflect lower pollution levels. The streams surveyed as part of this study that had the highest HBI scores were Kellerman Lea Ming Ditch, Burnett Creek, and Indian Creek, while West Fork Kickapoo Creek, East Branch Wea Creek, and Flint Creek had the lowest HBI scores, reflecting lower pollutant levels at those sites. Indian Creek had some of the most tolerant taxa observed across all sites, although this site also scored relatively high based on mean mIBI scores (Figure 91). Indian Creek scored higher on mIBI because of the high number of individuals and the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT).

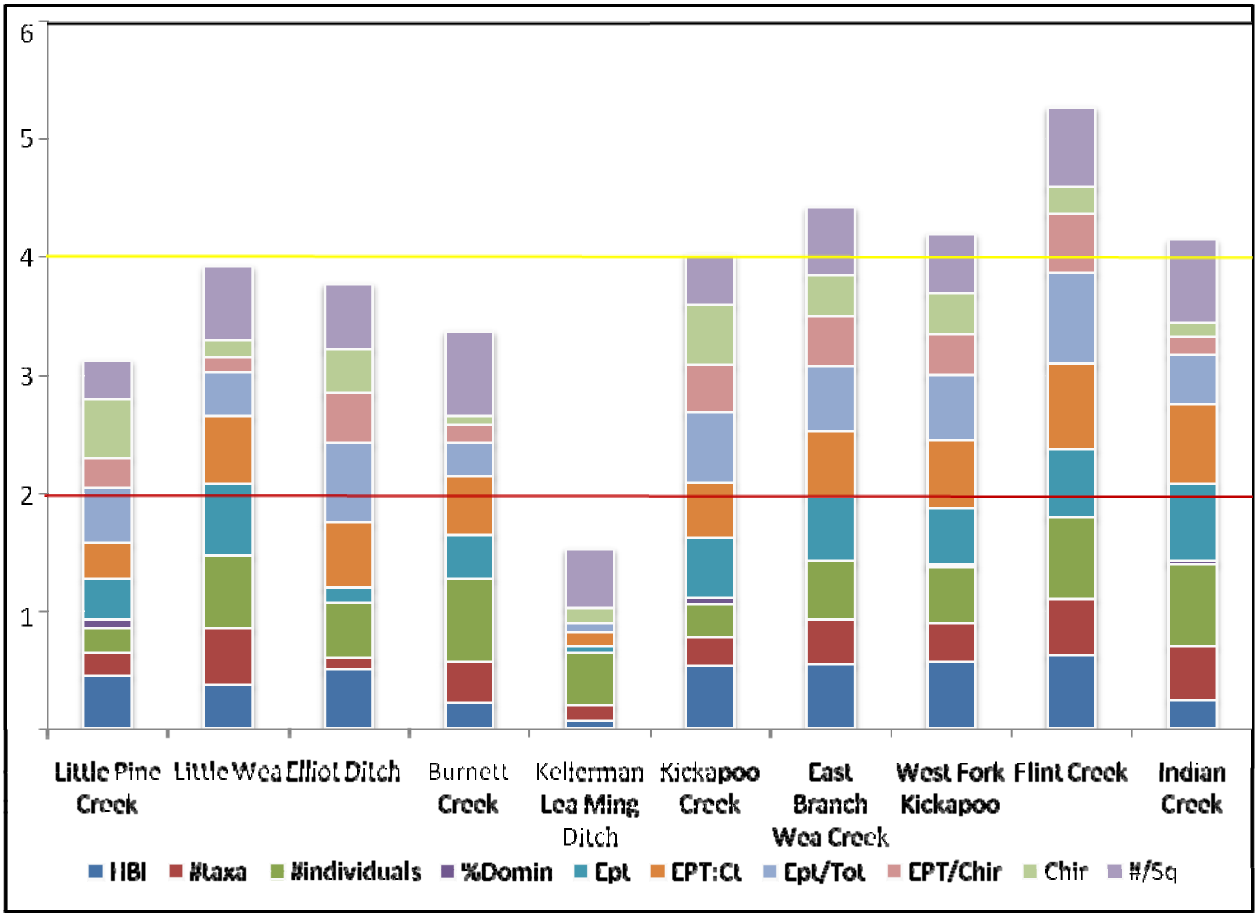

Figure 91. Mean total mIBI and mIBI individual component scores for stream sites sampled in the Great Bend Region of the Wabash River. Mean total mIBI scores below red line were severely impaired and values between the yellow and red lines were moderately impaired. Mean mIBI values above the yellow line were slightly impaired.

3.3.10 Summary and Conclusions

The fish, macroinvertebrate, and QHEI data all indicated some degree of stream degradation for the stream sites assessed, although there was a great amount of variation both between and within sites. The low mean riparian scores among many of the sites indicated that sites were impacted primarily by external components, which include, but are not limited to sedimentation, fertilizer, pesticides, and herbicides associated with human land uses.

The QHEI and mIBI scores for Kellerman Lee Ming Ditch indicated that the stream conditions were impaired. This is likely due to the low gradient of the channel and high amounts of sedimentation associated with this waterway. There was little to no discernable riffle habitat in the stream, and large sections of the stream bottom were covered in loose sand, which likely contributed to the low mIBI and QHEI scores. Little Pine Creek biotic integrity and QHEI scores were lower than most of the other streams despite the fact the sample site was primarily forested. Little Pine Creek is slightly entrenched, with steep banks along one side. Although coarse substrate could often be seen in Little Pine Creek, these substrates were covered by silt during most of the sampling events. Little Wea Creek was severely entrenched, but it had a higher gradient compared to most of the other sites. This allows the riffle zone to remain relatively clear of sediment accumulations. Little Wea Creek IBI scores indicated that the stream was in better condition compared to most of the other sites assessed in this study; however, it still scored in the poor category. The sites with lower mean IBI scores (Kellerman Lee Ming Ditch, Kickapoo Creek, Little Pine Creek) also typically had lower mean QHEI scores.

Sites that were less impaired included Flint Creek, Indian Creek, and East Branch Wea Creek. Burnett Creek had relatively high IBI scores, but mIBI and QHEI scores were slightly lower than expected based solely on IBI scores. The site for Burnett Creek had several riffles and modest sinuosity, giving it higher QHEI scores. However, the sediment present at this site was primarily sand, and this likely limited the number of EPT taxa present at the site. Burnett Creek's IBI scores may have additionally been inflated due to its close proximity to the Wabash River resulting in several species (e.g., sand shiners, bigeye chubs, and northern hog suckers) that were not typically captured at other sites being present within Burnett Creek. Flint Creek scored relatively high in with regard to fish, macroinvertebrate, and habitat indices despite having severely eroded banks along one side of the sample site. Substrate was coarse throughout all of the riffles, creating excellent habitat for aquatic macroinvertebrates and fish that specialize in clean riffle zones. In addition, the pools at Flint Creek were typically deep and relatively silt free, providing excellent habitat for pool species. Indian Creek, which scored higher than all other sites on the QHEI, scored slightly lower than Flint Creek in the IBI and mIBI. The causes for reduced biological assessments in Indian Creek compared to Flint Creek could be due to large amounts of filamentous algae that covered the riffle zones despite the forested riparian zone at the site. The East Branch Wea Creek site scored in most categories very similar to Indian Creek despite the fact that it had a narrow riparian zone and was bordered by row crop agriculture. East Branch Wea Creek had several long riffles with large amounts of vegetation overhanging the stream in and around the pools, thus providing excellent habitat in small patches. The longer riffles provided more area to detect species in both the mIBI and IBI assessments that usually result in higher biological scores (e.g., EPT macroinvertebrates and darter species).

The QHEI score for Elliot Ditch was among the highest observed in our assessments. However, the biological components of Elliot 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. West Fork Kickapoo Creek and Kickapoo Creek were among the smallest of the streams we evaluated, and during the September 2009 sampling and once in July 2010 between sampling events Kickapoo Creek dried throughout our entire site. The decreased biological community stability due to stream channel drying likely resulted in the lower biological scores for both of these sites. Although West Fork Kickapoo never completely dried flow was significantly reduced during the September 2009 sampling.

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) or some other unknown impairment leading to compromised biological integrity. Elliot Ditch would be expected to exhibit high environmental quality based solely on the QHEI, although the biota at that site suggested that there were likely other issues not related to physical habitat that influenced the biological communities and overall environmental quality. Conversely, Little Wea Creek would be considered to be of relatively high environmental quality based on its mIBI and IBI scores, but the mean QHEI score suggested that the physical habitat of the site was degraded and of low environmental quality. It is obvious that incorporating both the biology 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 completed windshield surveys throughout the Region of the Great Bend watershed in spring and fall 2009. Volunteers 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.)

Additionally, stream buffers within Tippecanoe County were analyzed by Tippecanoe County SWCD staff. The analysis was completed using Geographic Information Systems (GIS) by overlaying a 60-foot buffer on either side of the streams throughout the county. These buffers were then cross-referenced with the most recent land use/land cover data (2001). Resultant areas where buffers were limited or lacking were reviewed by volunteers during their watershed inventory assessments. Assessment of streambank erosion and riparian buffers along the Wabash River occurred in July 2010.

3.4.2 Watershed Inventory Results

More than 630 individual road-stream crossings were inventoried by watershed volunteers. A majority of issues identified fall into two categories: stream buffers limited in width or lacking altogether and streambank erosion. Figure 92 details locations throughout the Region of the Great Bend of the Wabash River watershed where problems were identified. Additional assessments will be on-going; therefore, those identified in Figure 92 should not be considered exhaustive. More than 413 miles of tributary streams possessed limited buffers, nearly 327 miles of streambank were eroded, and livestock had access to nearly 20 miles of streams. Additionally, nearly 40 miles of the Wabash River require stabilization and nearly 300 acres of land requires buffering within 120 feet of the Wabash River.

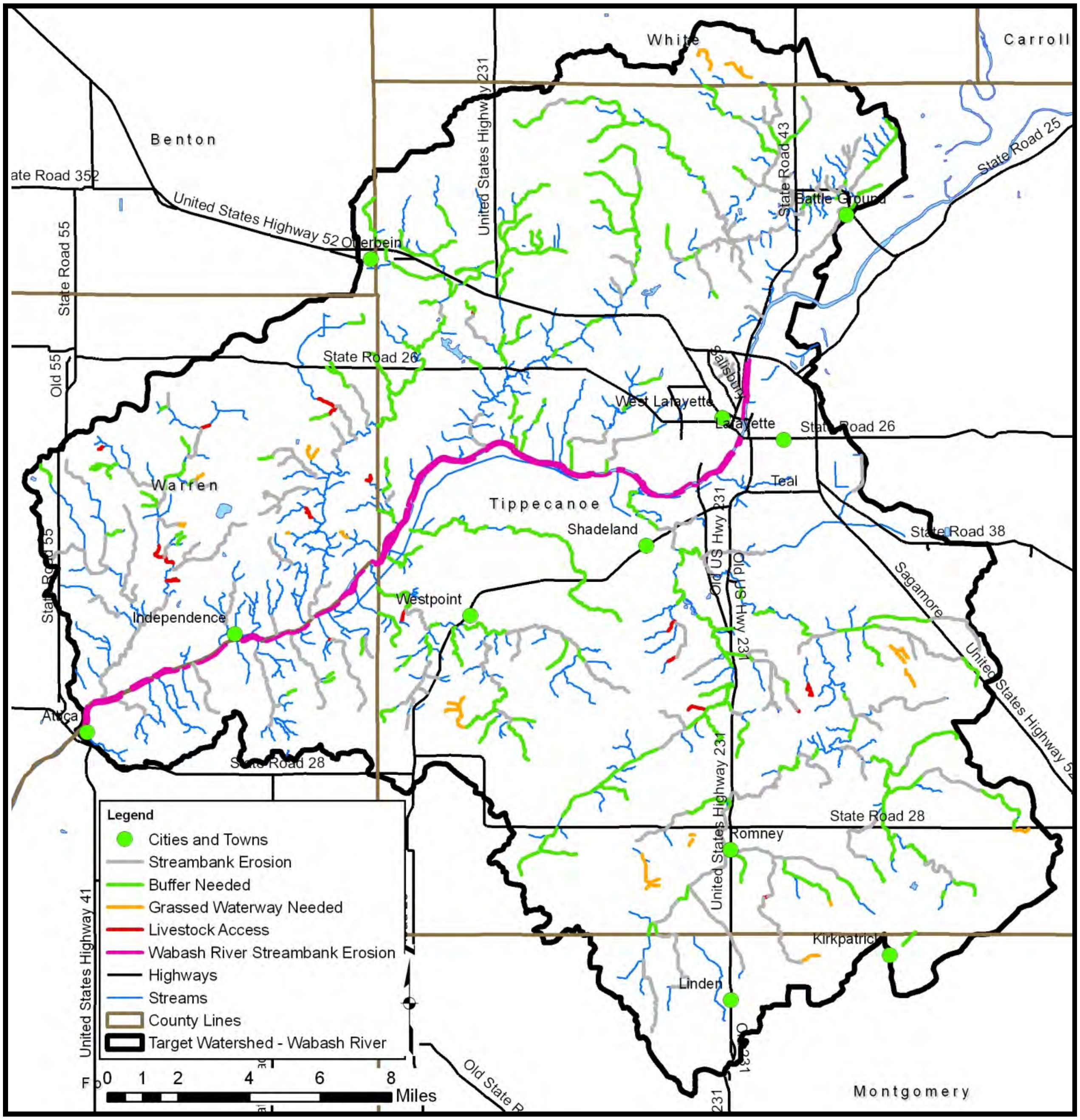

Figure 92. Stream-related watershed concerns identified during watershed inventory efforts. Data used to create this map are detailed in Appendix A.

4.0 WATERSHED INVENTORY II-B: SUBWATERSHED DISCUSSIONS

To gather more specific, localized data, the Region of the Great Bend of the Wabash River watershed was divided into ten subwatersheds (Figure 93). These subwatersheds reflect specific tributary drainages and similar land uses and hydrology. Land uses, soil types, point and non-point watershed concern areas, and historic and current water quality sampling locations and results are detailed below for each subwatershed.

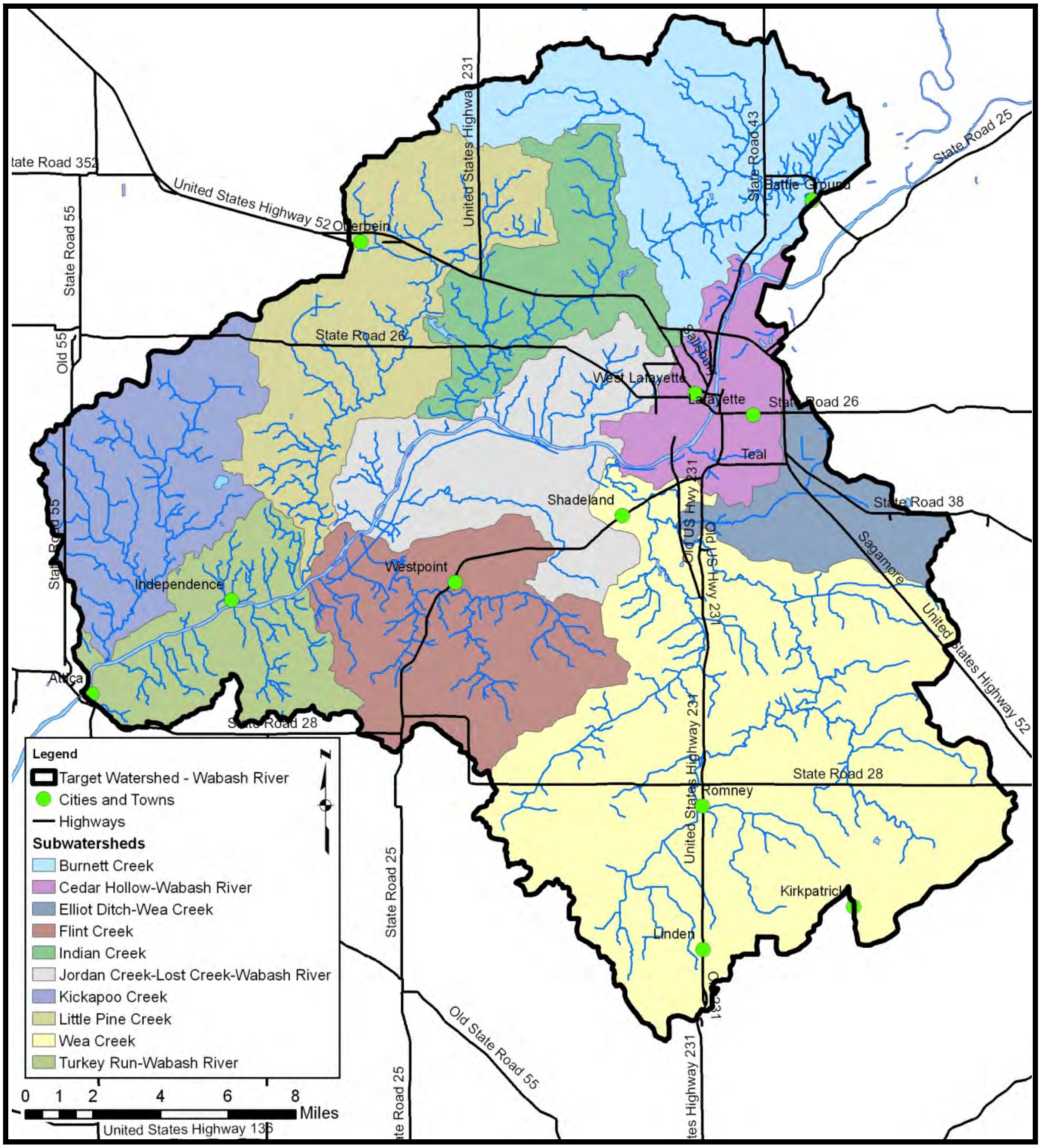

Figure 93. Ten subwatersheds in the Region of the Great Bend of the Wabash River watershed. Data used to create this map are detailed in Appendix A.

4.1 Burnett Creek Subwatershed

Burnett Creek is the most easterly tributary to the Wabash River within the watershed draining portions of White and Tippecanoe counties. The Burnett Creek subwatershed forms the northeastern edge of the Region of the Great Bend of the Wabash River watershed and includes the town of Battle Ground and the northwestern edge of the City of West Lafayette (Figure 94). The Burnett Creek watershed includes two 12-digit HUC watersheds – North Fork Burnett Creek (051201080201) and Headwaters Burnett Creek (051201080202) and drains 34,396 acres or 53.7 square miles. In total, 139 miles of stream are present within the Burnett Creek subwatershed. Of these, approximately five miles are considered impaired for *E. coli* and impaired biotic communities.

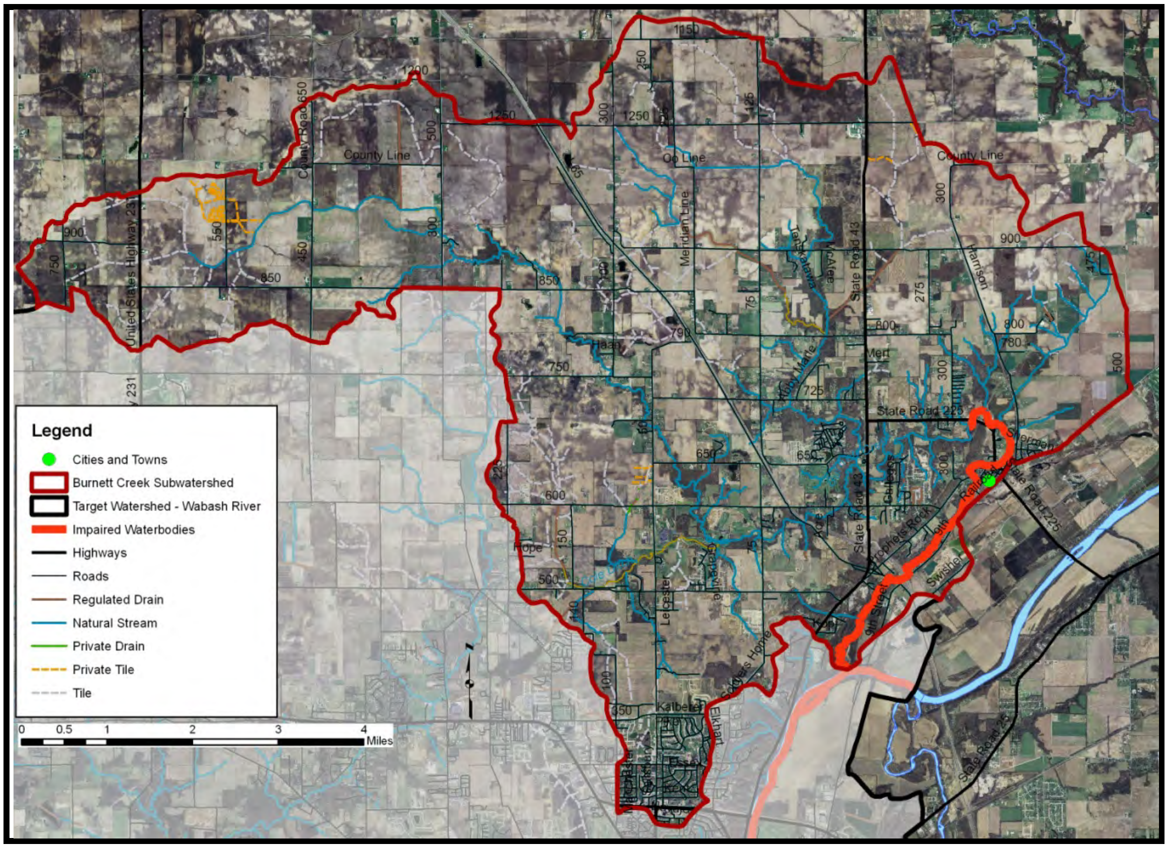

Figure 94. Burnett Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.1 Soils

Soils in the Burnett Creek subwatershed are dominated by those that are located on steeply sloped, easily erodible areas or those that formed under wetland conditions (Figure 95). Highly erodible soils cover 10 square miles or 20% of the Burnett Creek subwatershed. A majority of these soils are located adjacent to the mainstem of Burnett Creek. This is especially concerning due to the extremely high sinuosity present along the length of Burnett Creek. An additional 15.6 square miles or 29% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of Burnett Creek were historically in wetland land uses with nearly 30% of the subwatershed soils developing under wetland conditions. Current estimates indicate that wetlands cover approximately 2.5% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Burnett Creek subwatershed.

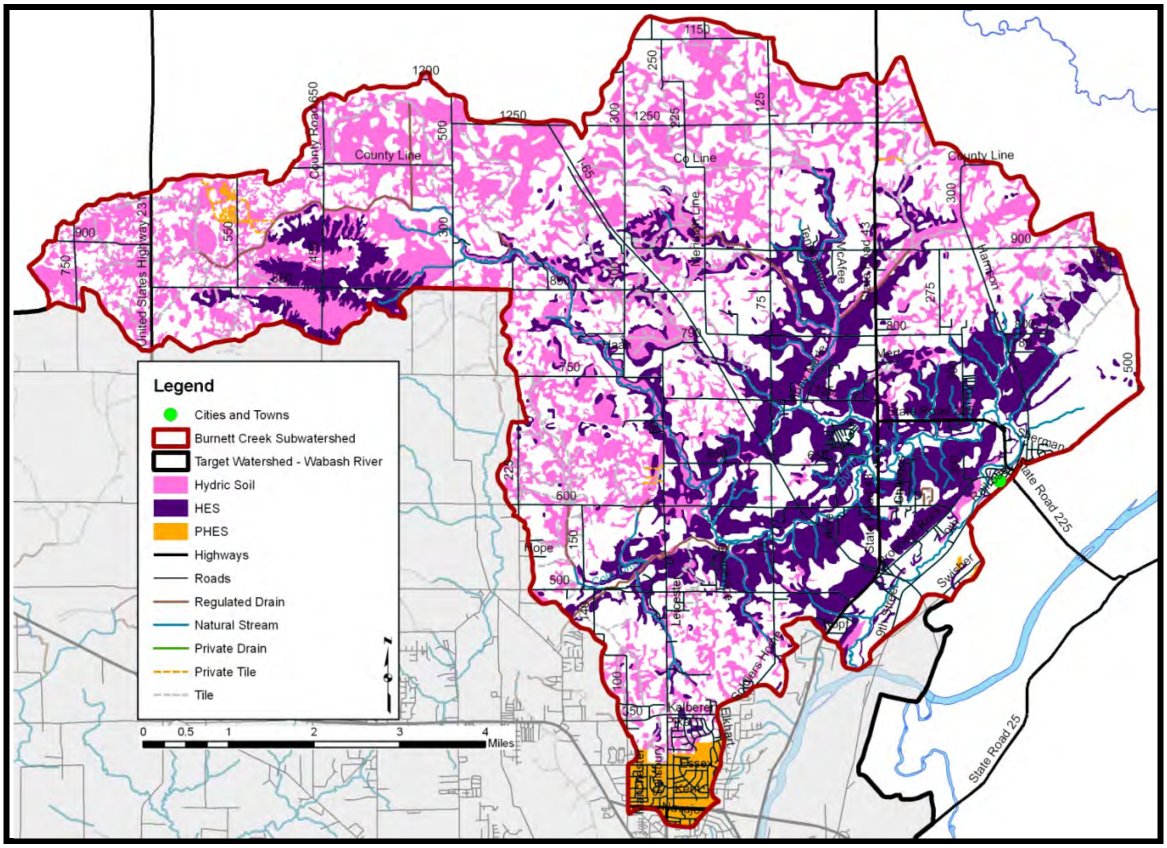

Figure 95. Properties of soils located in the Burnett Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.2 Land Use

Agricultural land uses dominate the Burnett Creek subwatershed accounting for 76% of land use. Urban land uses including the Town of Battle Ground and residential development extending north from West Lafayette and west from Battle Ground account for 10% of the subwatershed land use. Forest and wetland land uses account for 13% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Burnett Creek subwatershed.

Continued development is a concern in the Burnett Creek subwatershed (Figure 96). Eleven entities have subdivisions that have already been platted and partially developed or are slated for future development. In total, areas slated for development cover 450 acres or approximately 1% of the Burnett Creek subwatershed. When comparing 1992 land cover data to 2002 land cover data, approximately 2.75 square miles of agricultural and forested land were developed during that time period. This represents 5% of the Burnett Creek watershed and suggests that residential and commercial development has doubled in the last 15 years. A majority of the development occurred in the southern portion of the watershed adjacent to West Lafayette and Battle Ground. Despite this increase in development, the Burnett Creek subwatershed remains relatively undeveloped with only 2.8% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is a relatively low impervious percentage indicating that runoff from hardscape should not be of great concern in the Burnett Creek subwatershed. However, if development continues at a rate of 5% every 10 years, impervious coverage could become an issue.

A large volume of publicly-owned or publicly-accessible lands are present in the Burnett Creek subwatershed (Figure 96). The Cities of West Lafayette and Battle Ground, Tippecanoe County, the State of Indiana, NICHES Land Trust, and Purdue Research Foundation all own land in the Burnett Creek subwatershed. Additionally, two golf courses (Coyote Crossing and Edgewood Glen), three cemeteries, more than 10 churches, and a Wolf Park are located within the subwatershed. In total, approximately 5% (2.7 square miles) of the Burnett Creek subwatershed are open for public use.

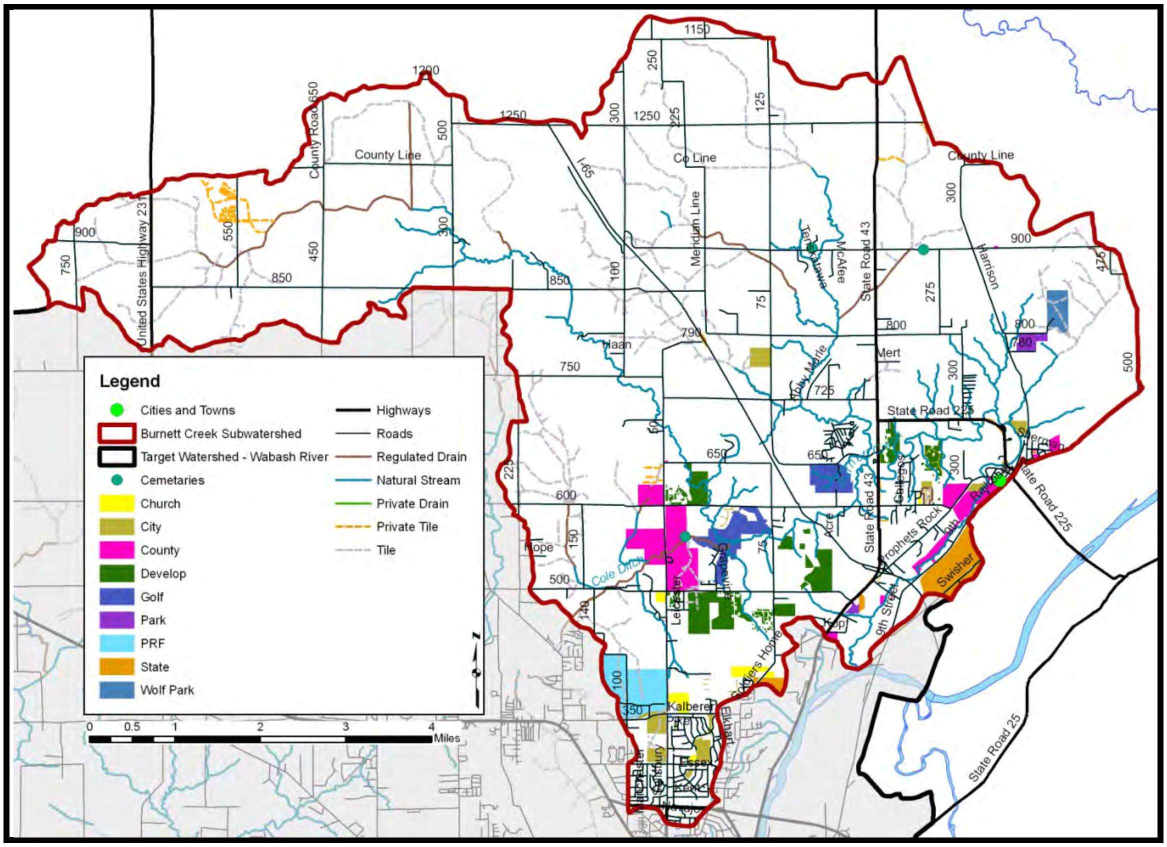

Figure 96. Land ownership and land development in the Burnett Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.1.3 Point Source Water Quality Issues

As detailed above, much of the Burnett Creek subwatershed is in agricultural land uses. However, as West Lafayette and Battle Ground continue to expand, the subwatershed will continue to urbanize. A portion of the subwatershed lies within the MS4 boundary as designated by the (pink) line in Figure 97. Two NPDES-permitted facilities are located within the subwatershed. These facilities serve the Town of Battle Ground and American Suburban Utilities in West Lafayette. Both facilities discharge treated effluent to Burnett Creek. Neither facility's reporting records indicate issues with contamination or non-compliance. Eleven leaking underground storage tanks (LUST) are located adjacent to State Road 43 or within the City of West Lafayette. One open dump site is located near the northeastern edge of the watershed.

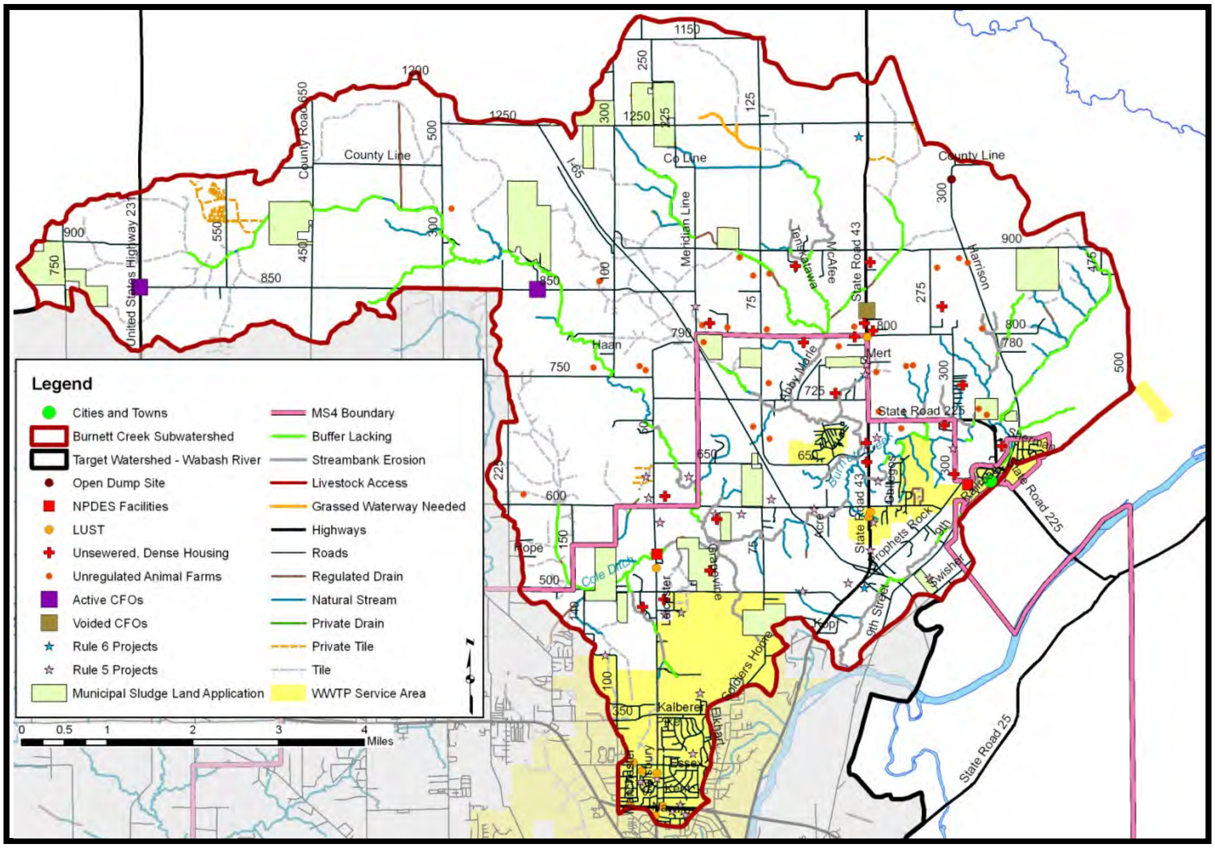

Figure 97. Point and non-point sources of pollution in the Burnett Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.1.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Burnett Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. However, a number of hobby farms and pastures are also located within the Burnett Creek subwatershed (Figure 97). Approximately 300 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to approximately 400 feet of stream within the subwatershed. Three confined feeding operations are also present in the subwatershed with the two active CFOs located in the western portion of the Burnett Creek headwaters and one voided CFO northwest of Battle Ground. Streambank erosion and stream buffering are also of concern within the Burnett Creek subwatershed. In total, nearly 52 miles of stream buffers and 26 miles of streambank stabilization are needed within the subwatershed. An additional 2 miles of headwater streams could benefit from the installation of grassed waterways.

As detailed above, development pressures are relatively high in the Burnett Creek subwatershed. These pressures are detailed in Figure 97 by the unsewered, dense housing locations and the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) All of these development-based, non-point source locations are concentrated within the southern portion of the watershed and typically occur south of County Road 800 North.

4.1.5 Water Quality Assessment

Waterbodies within the Burnett Creek subwatershed have been sampled at approximately 30 locations (Figure 98). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (3 sites), the IDEM (4 sites), the Tippecanoe County Health Department (1 site), and via volunteer monitors through the Hoosier Riverwatch program (4 sites). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by the IDEM (1 site), while the fish community has been assessed by Curry and Spacie (1 site), Fisher et al. (4 sites), and the IDEM (1 site). Mussel surveys were completed by Myers-Kinzie at four sites throughout the subwatershed. Twenty-four sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological sampling effort funding by this project. No stream gages are located in the Burnett Creek subwatershed.

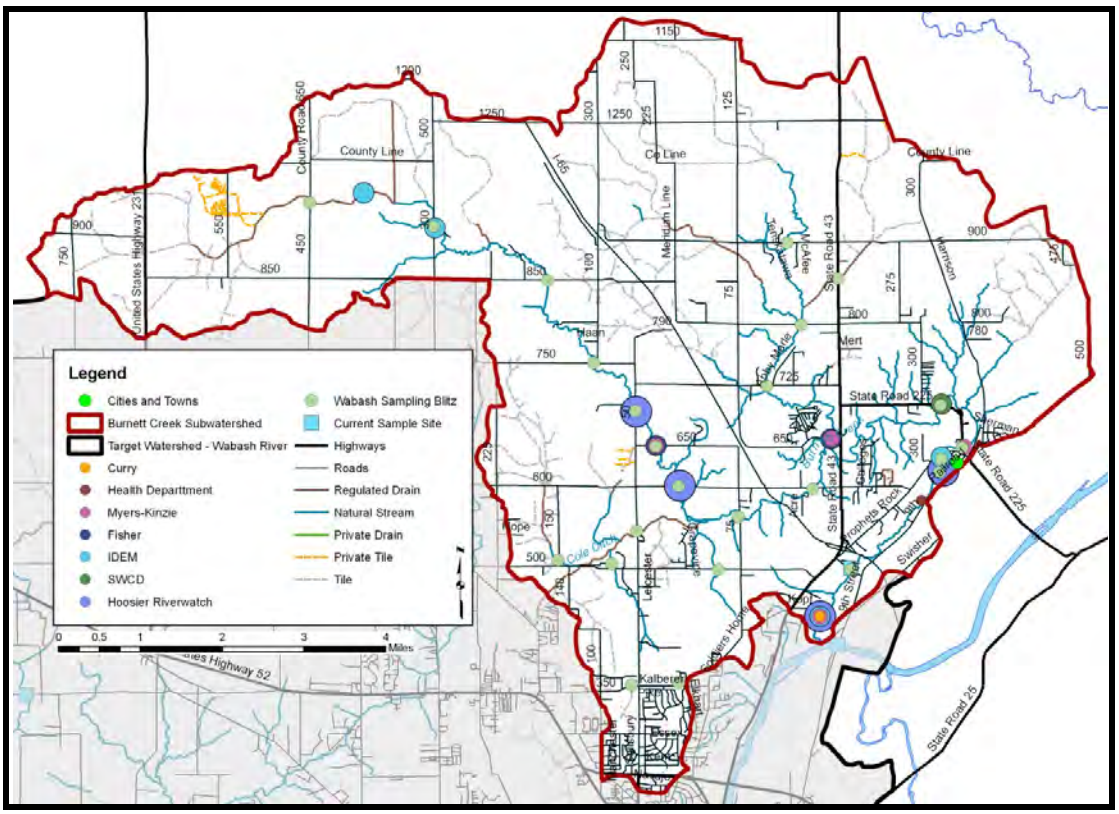

Figure 98. Locations of current or historic water quality data collection in the Burnett Creek subwatershed. Data used to create this map are detailed in Appendix A.

Water Chemistry

Water chemistry data collected from the Burnett Creek subwatershed suggest several parameters of concern including: nitrate-nitrogen, orthophosphate and total phosphorus, turbidity and suspended solids, and *E. coli* (Figure 99). Nitrate-nitrogen concentrations exceeded the target concentration (2 mg/L) during at least 50% of sample events in Burnett Creek at Harrison High School, Burnett Road (9th Street), and County Line Road, and at two headwaters unnamed tributaries. High ammonia-nitrogen concentrations occurred in Grant Cole Ditch (8.9 mg/L) and in Burnett Creek at County Road 50 West (9.0 mg/L). Total phosphorus concentrations were elevated in Burnett Creek at Burnett Road (9th Street), County Line Road, County Road 300 West, County Road 50 West, and in the north fork at County Road 900 North. *E. coli* concentrations in excess of the state standard occurred during more than 50% of sampling events in Burnett Creek at the Battle Field Museum, Harrison High School, Burnett Road (9th Street), Prophet Street, County Road 600 North; in Grant Cole Ditch; and in Beutler Gosma Ditch. Turbidity routinely measured higher than the target concentration at all sites where observations occur. This suggests that Burnett Creek may contain a high background suspended sediment concentration or that the high sinuosity and prevalence of easily erodible soils results in elevated suspended sediment concentrations on a routine basis.

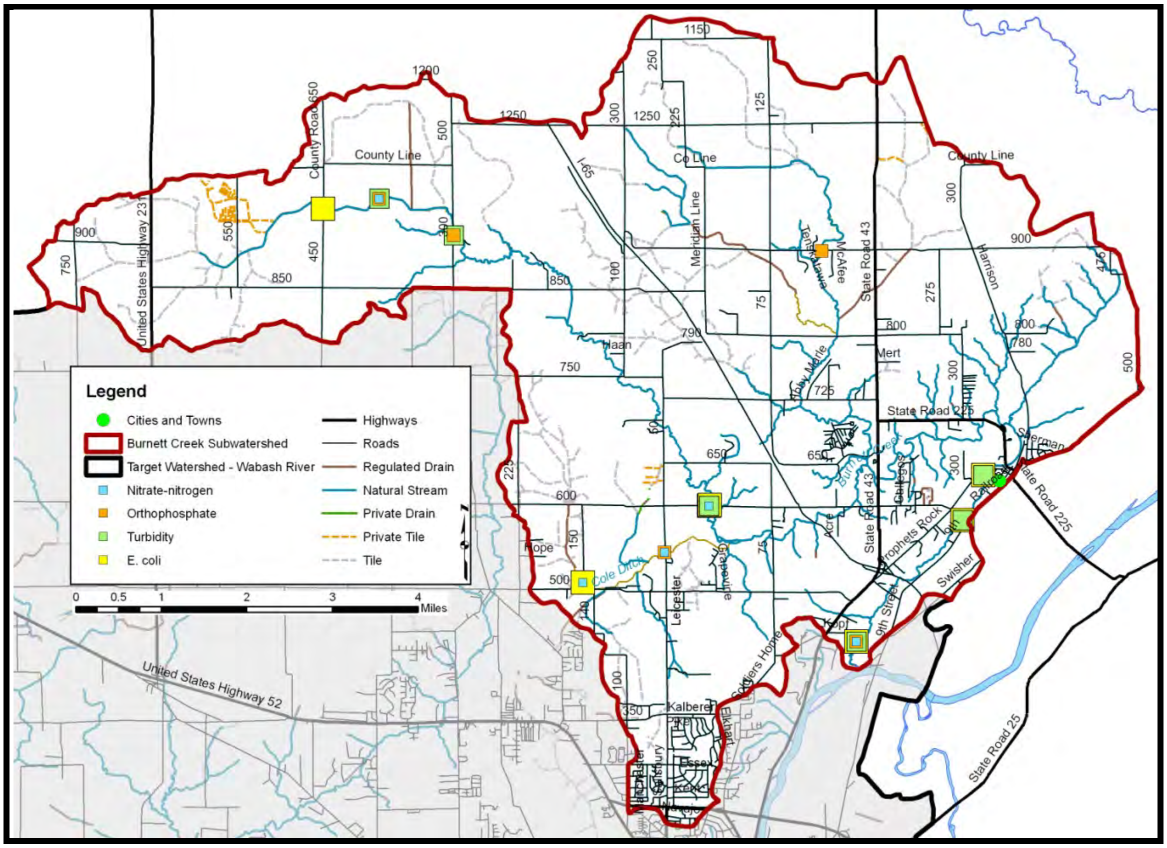

Figure 99. Water quality impairments in the Burnett Creek subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

Volunteer monitors assessed habitat at two sites within the Burnett Creek subwatershed using the Citizen's Qualitative Habitat Evaluation Index (CQHEI). As previously detailed, the CQHEI scores sites based on the presence or absence of specific natural characteristics within a stream reach. Although a comparison scale for the CQHEI has not yet been developed, Hoosier Riverwatch indicates that scores greater than 60 rate as habitat conducive to supporting warm-water biota (IDNR, 2004). Volunteers assessed Burnett Creek's habitat at Harrison High School and at the Tippecanoe Battlefield foot bridge with sites scoring 69 and 78 and between 67 and 83, respectively. Both reaches received low scores for fish habitat (6 to 10 of 25 total points) and for pool development.

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at one site during three assessments. The IDEM completed two assessments of habitat using the QHEI within the Burnett Creek subwatershed, while Purdue University assessed habitat using the QHEI once during the current water quality sampling program. As previously detailed and similarly to the CQHEI, the QHEI scores habitat within a 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 1991 and 1999 with both conducted in Burnett Creek at Burnett Road. Scores (71 and 57, respectively) indicate good quality habitat that is fully in support of the stream's designated aquatic life use. Reductions in substrate and cover scores (18 to 12 and 15 to 7, respectively) suggest that habitat may be declining within Burnett Creek; however, changes may also be due to variation in individual scoring. Overall, riparian, channel, pool, and gradient scores indicate that habitat quality is high within this reach of Burnett Creek. Lack of riffles in this reach and substrate which is increasingly covered by silt may inhibit habitat. Additionally, three Purdue field personnel completed QHEI assessments during the June 2010 fish sampling. The mean of those scores was calculated to assign a QHEI score for the site. The mean QHEI score for Burnett Creek at Burnett Road was 69. This score falls within the range scored by IDEM personnel and indicates that the stream fully supports its aquatic life use designation at this site.

Fish

The IDEM assessed the fish community twice during 1999 at Burnett Road, while Curry and Spacie (1972) and Fisher et al. (1994) assessed one and four sites, respectively. IDEM data indicate that the fish community in Burnett Creek rates as poor scoring 24-28 using the IBI. At the time of the assessment, the community was dominated by tolerant, pioneer species. Curry and Spacie (1972) and Fisher et al. (1994) collected community data but did not calculate IBI scores during their assessments. Species lists during both assessments were similar to those observed during IDEM assessments.

Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). IBI scores were calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 11; Sample II – July 20; Sample III – September 15; and Sample IV – November 6. The 2010 samples were collected as follows: Sample V – March 22; Sample VI – June 21; Sample VII – August 13; and Sample VIII – November 1. Burnett Creek at Burnett Road had an overall mean IBI score of 46, which indicates the community rates as good-fair. There were some obvious seasonal trends in IBI scores. This high average IBI score ties with Flint Creek for the highest quality fish community present within the watershed. The IBI's in the spring and early summer were lower and scores increased as the season progressed. The IBI was highly variable throughout the sampling period with samples ranging from 34 (poor) to 50 (good). The catch was dominated by western blacknose dace, creek chubs, and mottled sculpins.

Macroinvertebrates

The macroinvertebrate community within Burnett Creek was sampled twice by the IDEM. Sampling occurred once in 1991 and again in 1999 with both sample events occurring at Burnett Road. The macroinvertebrate community rated as slightly impaired during both assessments scoring 5.6 and 5.4, respectively. The community was dominated by Hydropsychidae, a relatively-tolerant caddisfly species. Individual metrics indicate low Hilsenhoff Biotic Index (HBI) scores, moderate diversity, high density, and communities dominated by high quality taxa.

Burnett Creek was sampled four times in 2009 and four times in 2010 by Purdue field personnel simultaneous to fish sampling as indicated above. Burnett Creek had a mean mIBI score of 3.4 which indicates that Burnett Creek's macroinvertebrate community is moderately impaired. This low score rates Burnett Creek as the third worst community present in the watershed score better than only Kellerman Lea Ming Ditch and Little Pine Creek. mIBI scores ranged from 0.8 during the June 2009 assessment to 5.2 during the October 2009 assessment. In addition, the mean HBI score was 5.3, indicating that there is a large number of pollution tolerant species present. The HBI scores calculated for Burnett Creek were the highest calculated during this assessment. The macroinvertebrates were dominated by Chironomidae and Simuliidae which are both tolerant dipteran (i.e., fly) families.

Mussels

Myers-Kinzie assessed the mussel community at four locations with the Burnett Creek subwatershed. During the surveys, one species was identified in both fresh dead and weathered dead shells. The cylindrical papershell (*Anodontoides ferussacianus*) is a headwaters species typical of small streams and rivers.

4.1.6 Burnett Creek Subwatershed Summary

The Burnett Creek subwatershed is facing development pressures from the City of West Lafayette. Much of the headwaters of Burnett Creek are used for row crop agriculture, while downstream portions contain a mix of agriculture, subdivisions, and natural areas. Burnett Creek's predominance of highly and potentially highly erodible soils located on steeply sloped lands drained by highly sinuous streams generates a high bed load within Burnett Creek. The continued movement of sediments creates streambank erosion issues within the mainstem and tributaries of Burnett Creek. The high quality habitat is often overshadowed by high sediment concentrations generating moderately impaired biotic communities.

4.2 Cedar Hollow-Wabash River Subwatershed

The Cedar Hollow-Wabash River subwatershed is located directly south of the Burnett Creek subwatershed covering a majority of the Cities of Lafayette and West Lafayette located in the watershed (Figure 93). The Cedar Hollow-Wabash River subwatershed forms the eastern boundary of the Region of the Great Bend of the Wabash River watershed beginning immediately downstream of the confluence of Wildcat Creek and the Wabash River. The subwatershed includes one 12-digit HUC watershed (051201080203) and drains approximately 14,700 acres of 23 square miles (Figure 100). Several small tributaries including Cedar Hollow, which is locally known as Happy Hollow, Durkee's Run, and the unnamed outlet stream from the City of West Lafayette's wastewater treatment plant drain into the Wabash River within this subwatershed. In total 11.2 miles of tributaries and 10 miles of the Wabash River are located within the Cedar Hollow-Wabash River subwatershed.

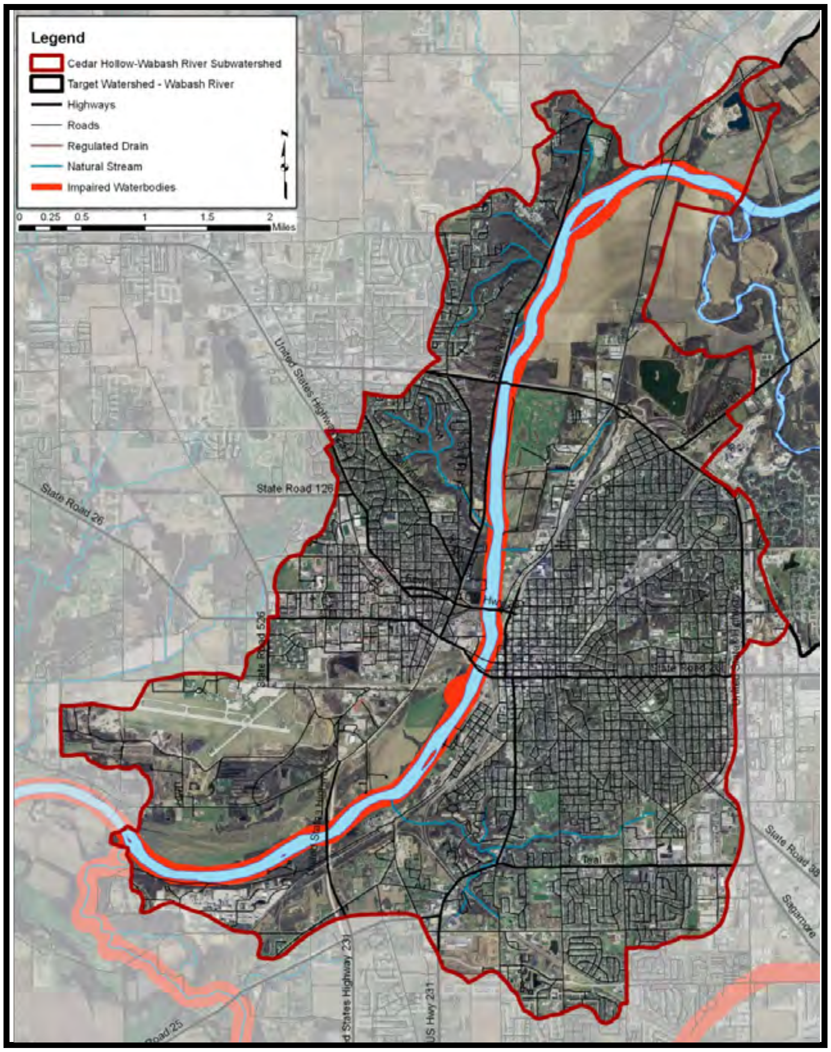

Figure 100. Cedar Hollow-Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.1 Soils

Highly erodible and potentially highly erodible soils predominate in the Cedar Hollow-Wabash River subwatershed (Figure 101). Highly erodible soils cover 2.7 square miles or approximately 9% of the subwatershed, while potentially highly erodible soils cover 6.4 square miles or approximately 28% of the subwatershed. Highly erodible soils cover the northern portion of the watershed from the north subwatershed boundary south to Woodfield Boulevard, border North River Road, and cover a majority of the Happy Hollow and Durkee's Run drainages. Potentially highly erodible soils cover a majority of the City of Lafayette from the subwatershed's eastern and southern boundaries to approximately Elmwood and Sheridan streets. Similarly, PHES cover the northern portion of the City of West Lafayette extending south from Woodfield Boulevard to approximately Meridian Street. The relatively high percentage of erodible soils is concerning when coupled with the high level of development and predominance of impervious surfaces within the subwatershed.

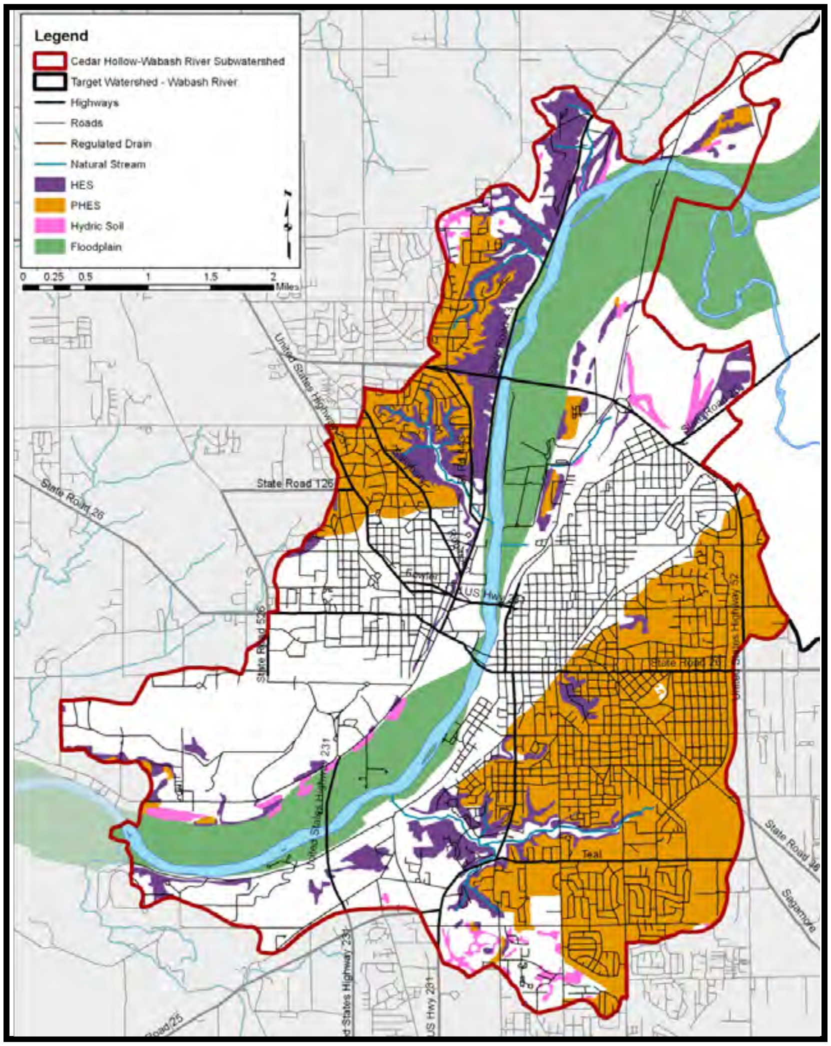

Figure 101. Properties of soils located in the Cedar Hollow-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

The presence of two steeply sloped drainages, Happy Hollow and Durkee's Run, located on highly erodible and potentially highly erodible soils resulted in the formation of deltas within the Wabash River. Richardson and West (1977) studied the deltas at the mouths of Happy Hollow and Durkee's Run in an effort to determine their impact on the Wabash River. As detailed in Figure 102, deltas formed at the mouths of these two tributaries result in displacement of the Wabash River. In the case of Happy Hollow, a braided channel strongly displaced from its original channel results. Conversely, in Durkee's Run a delta formed, however; no resultant channel offset in the Wabash River occurred. Richardson and West (1977) noted no increase in primary delta formation rate or size over their aerial photograph observation period (1920 to 1971).

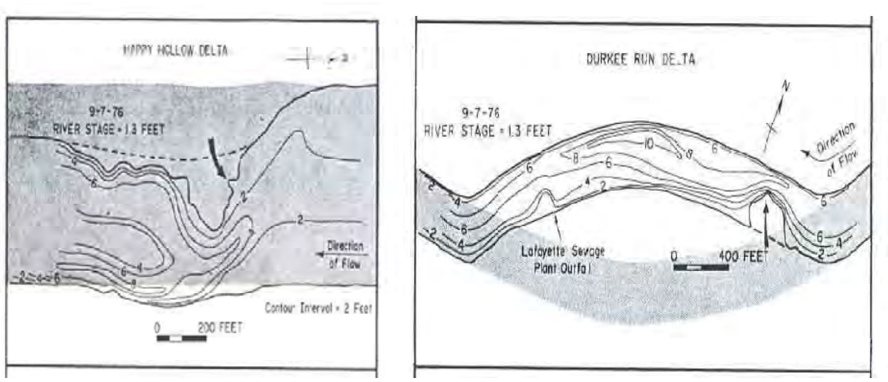

Figure 102. Deltas observed at the mouths of Happy Hollow and Durkee's Run in 1974. Source: Richardson and West, 1977.

4.2.2 Land Use

Urban land uses dominate the Cedar Hollow-Wabash River subwatershed (Figure 103). Urban land uses account for nearly 65% of land making this subwatershed the most urban. The Cedar Hollow-Wabash River subwatershed also contains the most open water with 4.5% of the watershed located within the Wabash River, its floodplain, or in borrow pits or manmade water features. The remaining land use is nearly equally divided between agricultural and natural land uses with 12% of land in agricultural uses and 18% in natural uses such as forests or wetlands. Nearly 30% of the subwatershed is covered by impervious surfaces, which is the highest impervious coverage of any subwatershed. Compared to estimates from the Center for Watershed Protection (CWP), this is a relatively high impervious percentage indicating that runoff from hardscape should be considered of high concern in the Cedar Creek-Wabash River subwatershed. This suggests that continued development of the subwatershed could impair water quality. When comparing 1992 and 2002 land cover data, approximately 14% of the subwatershed was developed during that time period. The development rate in the Cedar Creek-Wabash River is the second highest within any of the subwatersheds. If development continues at that rate, the Cedar Creek-Wabash River subwatershed will be fully developed by 2022.

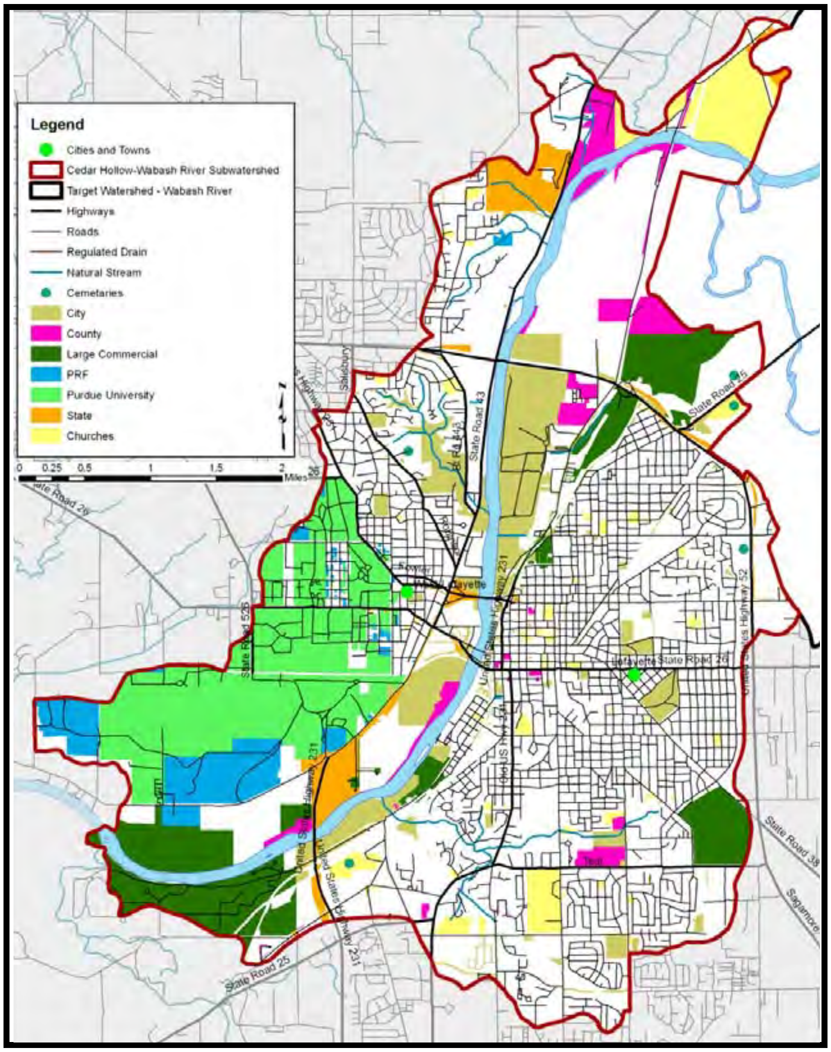

Figure 103. Land ownership in the Cedar Hollow-Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

A large volume of publicly-owned or publicly-accessible lands are present in the Cedar Hollow-Wabash River subwatershed (Figure 103). The Cities of West Lafayette and Lafayette, Tippecanoe County, the State of Indiana, Purdue University, and Purdue Research Foundation all own land in the Cedar Hollow-Wabash River subwatershed. Additionally, five cemeteries, more than 30 churches, and several commercially-owned properties are located within the subwatershed. Commercial owners include Eli Lilly (now Evonik Industries AG), Cargill Incorporated, Alcoa Inc., CSX Transportation, and Fairfield Builders Supply Corporation. Although many of these large commercial properties, especially Eli Lilly, contain publicly accessible, open space these areas are not considered publicly-owned or publicly-accessible land. In total, approximately 25% (5.7 square miles) of the Cedar Hollow-Wabash River subwatershed are open for public use.

4.2.3 Point Source Water Quality Issues

As detailed above, much of the Cedar Creek-Wabash River subwatershed is in urban land uses. Nearly the entire subwatershed lies within the MS4 boundary as designated by the pink line (Figure 104). Stormwater issues are of concern within this subwatershed with all of the combined sewer overflows (CSO) from the cities of West Lafayette and Lafayette draining to the Wabash River within this subwatershed. Additionally, eleven entities maintained a Rule 6 individual property stormwater permit within the last five years and eleven NPDES-permitted facilities are located within the subwatershed. All of the facilities discharge treated effluent to the Wabash River. None of the facilities' reporting records indicate issues with contamination or non-compliance. Approximately 75 leaking underground storage tanks (LUST) and 15 brownfields are located within the subwatershed. Additionally, the only superfund site identified within the watershed occurs in the Cedar Creek-Wabash River subwatershed.

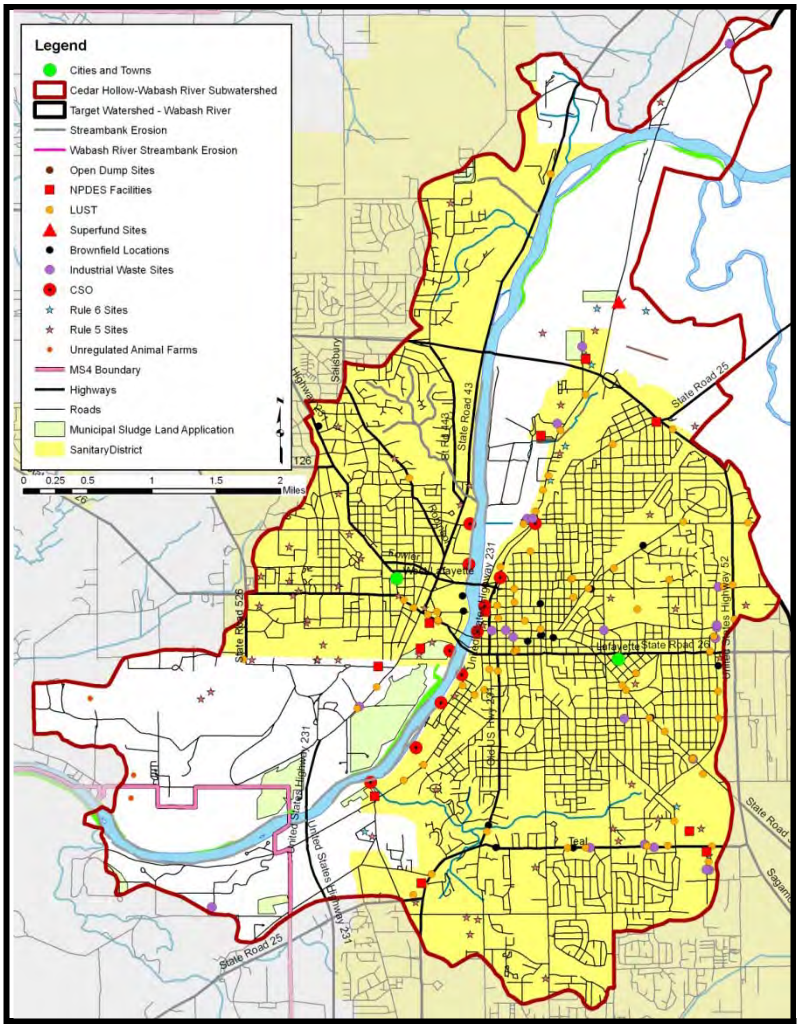

Figure 104. Point and non-point sources of pollution in the Cedar Creek-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

4.2.4 Non-Point Source Water Quality Issues

Agricultural land uses are limited within the Cedar Creek-Wabash River subwatershed. Despite this, a number of hobby farms and pastures are also located within the subwatershed (Figure 104). Approximately 20 horses are located on small farms throughout the subwatershed. None of these animals have access to a waterbody within the Cedar Creek-Wabash River subwatershed. Streambank erosion is of a concern along tributaries and the Wabash River within the subwatershed. Nearly 3 miles of tributary streambank and 8 miles of the Wabash River require stabilization. Additionally, nearly 56 acres of land within 120 feet of the Wabash River remain unbuffered.

As detailed above, development pressures continue to be relatively high in the Cedar Creek-Wabash River subwatershed. These pressures are detailed in Figure 104 by the Rule 5 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process.) These development-based pressures are scattered throughout the urban core in the Cedar Creek-Wabash River subwatershed.

4.2.5 Water Quality Assessment

Waterbodies within the Cedar Hollow-Wabash River subwatershed have been sampled at approximately 20 locations (Figure 105). Four sites were sampled as part of the Wabash Sampling Blitz. All samples were collected from the Wabash River with three sites located on Durkee's Run. Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (1 site), the IDEM (2 sites), the Cities of Lafayette (5 sites) and West Lafayette (3 sites), and via volunteer monitors through the Hoosier Riverwatch program (3 sites). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by Commonwealth Biomonitoring (10 sites), while the fish community has been assessed by Curry and Spacie (4 sites), Fisher et al. (5 sites), the IDNR (1 site), and Pyron and Lauer (4 sites). The USGS maintains a stream gage on the Wabash River at the Brown Street bridge.

Water Chemistry

Water chemistry data was collected from two streams in the Cedar Hollow-Wabash River subwatershed: Durkee's Run and the Wabash River. Results from these samplings suggest several parameters of concern including: turbidity/suspended solids, total Kjeldahl nitrogen, and *E. coli* (Figure 106). Samples from Durkee's Run were collected multiple times during a storm sampling event targeted at determining the impacts of combined sewer overflows on the stream and once as part of the Wabash Sampling Blitz. During the stormwater assessment, *E. coli* concentrations routinely exceeded the state standard reaching concentrations as high as 224,000 colonies/100 mL. The blitz sample measured below the state standard. Total Kjeldahl nitrogen (TKN) concentrations were also elevated during the storm sampling event with concentrations measuring between 0.82 and 6.4 mg/L. These data suggest that during base flow conditions, Durkee's Run likely meets water quality goals; however, under storm conditions water quality within Durkee's Run is likely poor.

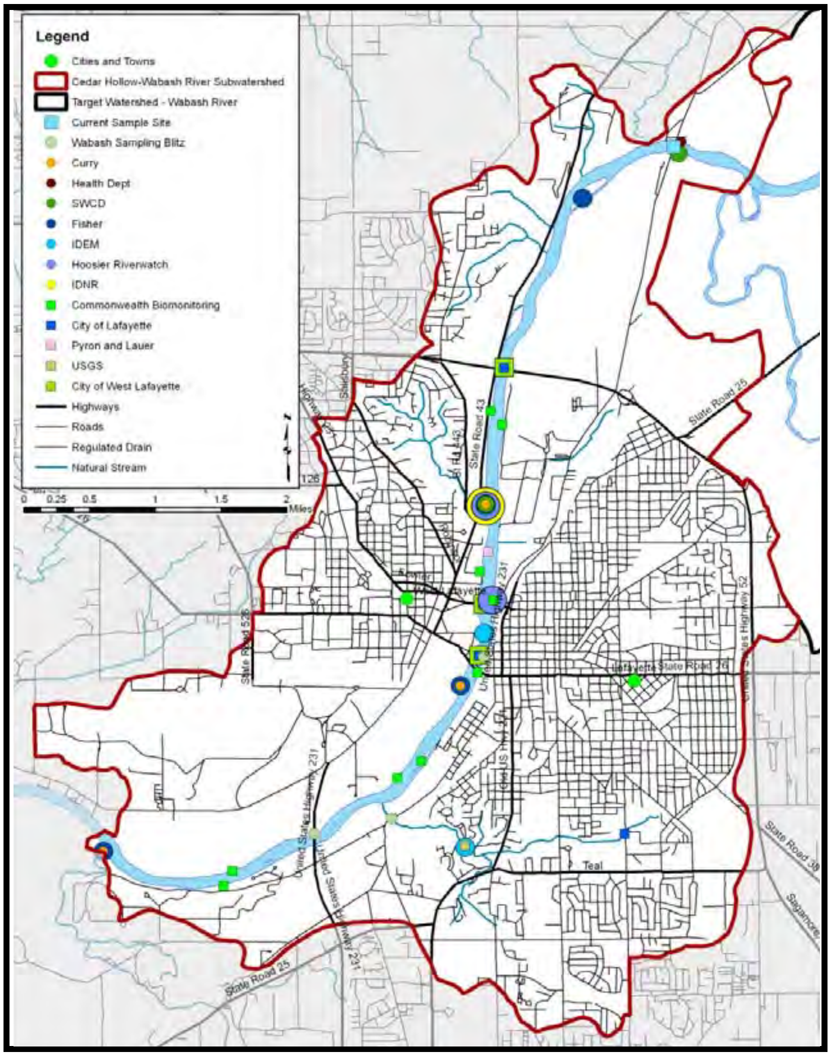

Figure 105. Locations of current or historic water quality data collection in the Cedar Creek-Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

Water chemistry samples are routinely collected under varying conditions in the Wabash River in the Cedar Hollow-Wabash River watershed. The City of West Lafayette collects samples weekly during the growing season from three locations - US 52, US 231, and Riehle Plaza/Pedestrian Bridge. The City of Lafayette sampled these same sites during an effort targeting stormwater sample collection and CSO impact assessment. The Health Department also collects weekly samples at Davis Ferry Bridge. Additional samples have been collected by Hoosier Riverwatch volunteers, the DNR, the IDEM, and Wabash Sampling Blitz volunteers at these sites as well as at Mascouten Park. During each of these assessments, turbidity and *E. coli* concentrations measured in excess of recommended concentrations and/or the state standard. All turbidity measurements recorded within this reach of the Wabash River were in excess of 15 NTU with concentrations measuring as high as 120 NTU. Concentrations averaged 35 NTU with no pattern of increasing or decreasing concentration from upstream to downstream. *E. coli* concentrations were generally in excess of the state standard measuring as high as 20,000 colonies/100 mL during storm flow and 933 colonies/100 mL during base flow conditions.

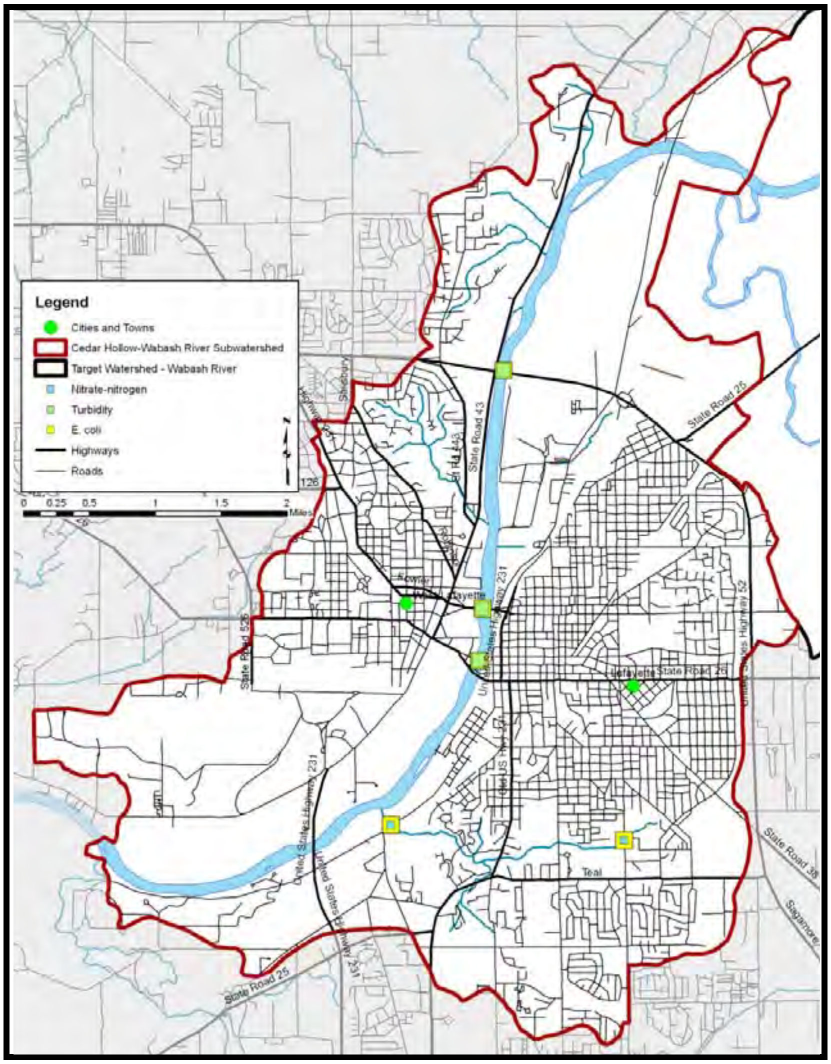

Figure 106. Water quality impairments in the Cedar Creek-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

IDEM used the Qualitative Habitat Evaluation Index (QHEI) to evaluate habitat at one site (Wabash River at Mascouten Park) during three assessments. As previously detailed the QHEI scores habitat within a 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 1991 and 1999 (twice). Scores (61-74) indicate good quality habitat that is fully in support of the streams designated aquatic life use.

Fish

Ball State University assessed the fish community once annually in 2008, while Curry and Spacie (1972) and Fisher et al. (1994) assessed four and five sites, respectively, and IDNR assessed the community at two sites. All of the data suggest that the fish community present in this reach of the Wabash River rate as fair to good. IBI scores ranged from 45 to 49 (good) with 17 to 32 species collected within each sampling event.

Macroinvertebrates

The macroinvertebrate community within the Wabash River at Mascouten Park was sampled twice by the IDEM. Sampling occurred once in 1991 and again in 1999 with both sample events occurring at Mascouten Park. The macroinvertebrate community rated as severely (1.6) and moderately (2.6) impaired, respectively. The community was dominated by Chironomidae, a very tolerant fly species. Individual metrics indicate low Hilsenhoff Biotic Index (HBI) scores, moderate diversity, low density, and communities dominated by poor quality taxa. Annual assessment of the macroinvertebrate community by Commonwealth Biomonitoring occurred at 10 sites from 1995-2010. Data suggest that water quality within the Wabash River is highly variable from year to year. Commonwealth Biomonitoring (2010) indicate that water quality was noticeably impaired in 2001 and 2002 with 2003 to 2010 data indicating improvements in water quality. Most notably, the community at the site downstream of the Lafayette Wastewater Treatment Plant and Durkee Run CSO outfalls was noticeably improved in 2010.

4.2.6 Cedar Creek-Wabash River Subwatershed Summary

The Cedar Creek-Wabash River subwatershed comprises the core urban lands within the Cities of Lafayette and West Lafayette. As such, much of the land use is commercial or residential and large tracts of land are owned by the municipalities, Purdue University, and large commercial entities. This reach of the Wabash River is subjected to multiple combined sewer overflows annually from both the City of Lafayette and the City of West Lafayette. Both cities are in the midst of implementing plans to curtail CSO and stormwater issues. Small, intermittent tributaries and storm drains carry water to the Wabash River within this subwatershed. The quality of water in these tributaries is relatively poor based on limited water quality assessments completed historically. Fish communities within the Wabash River are of high quality; however, elevated nutrient, sediment, and pathogen concentrations could present long-term issues for biota within the river.

4.3 Wea Creek Subwatershed

Wea Creek is the largest tributary to the Wabash River within the Region of the Great Bend watershed. Wea Creek and its tributaries form the southern and eastern boundaries of the watershed covering portions of Tippecanoe and Montgomery counties. The subwatershed includes the southwestern edge of the City of Lafayette, much of incorporated Shadeland, all of the towns of Linden, Romney, and portions of the towns of New Richmond, Clark's Hill, and Dayton. The Wea Creek watershed includes six 12-digit HUC watersheds – Romney Fraley Ditch (HUC 051201080101), East Branch Wea Creek (HUC 051201080102), Haywood Ditch-Wea Creek (HUC 051201080103), Elliot Ditch (HUC 051201080104), Little Wea Creek (HUC 051201080104), and Kenny Ditch-Wea Creek (HUC 051201080106) and drains 104,550 acres or 163.2 square miles (Figure 107). The Elliot Ditch subwatershed is discussed separately due to its unique location and water quality concerns. In total, 292 miles of stream are present within the Wea Creek subwatershed. Of these, approximately 20 miles are considered impaired for *E. coli*, mercury, and PCBs.

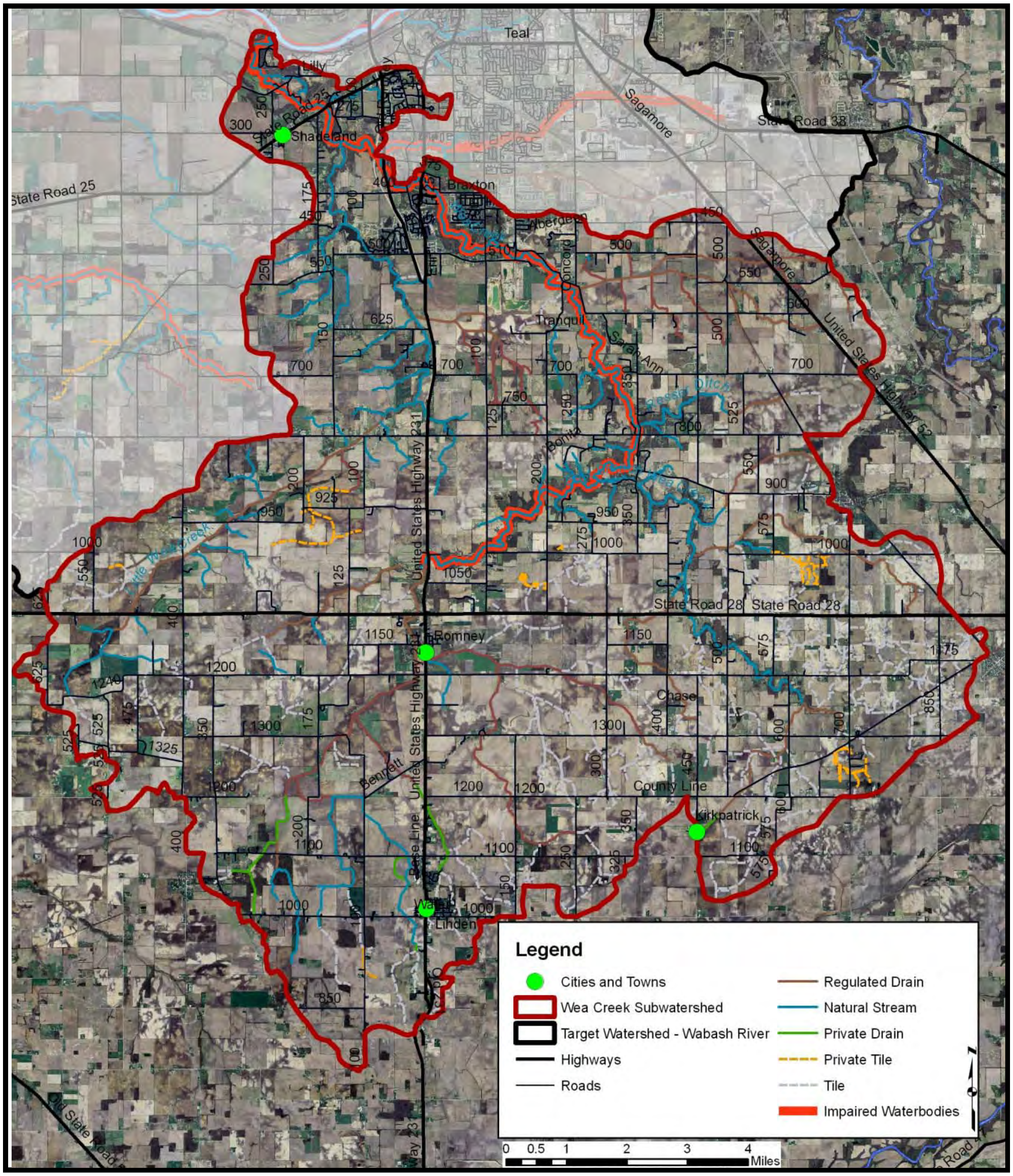

Figure 107. Wea Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.1 Soils

Soils that formed under wetland conditions or those that are located on steeply sloped areas are prevalent in the Wea Creek subwatershed (Figure 108). Highly erodible soils cover 27 square miles or 18% of the Wea Creek subwatershed, while approximately 5 square miles or 3.5% of the watershed are covered by potentially highly erodible soils. These soils are located throughout the watershed and are generally located away from tributaries or the mainstem of Wea Creek. An additional 52 square miles or 36% of the subwatershed are covered by hydric soils. These soils generally lie adjacent to the mainstem of Wea Creek, Little Wea Creek, and several tributaries adjacent to the existing floodplain. Additionally, hydric soils located throughout the watershed indicate that much of the headwaters of Wea Creek were historically in wetland land uses. Current estimates indicate that wetlands cover approximately 2.5% of the subwatershed suggesting that approximately 6% of historic wetlands are still present within the Wea Creek subwatershed.

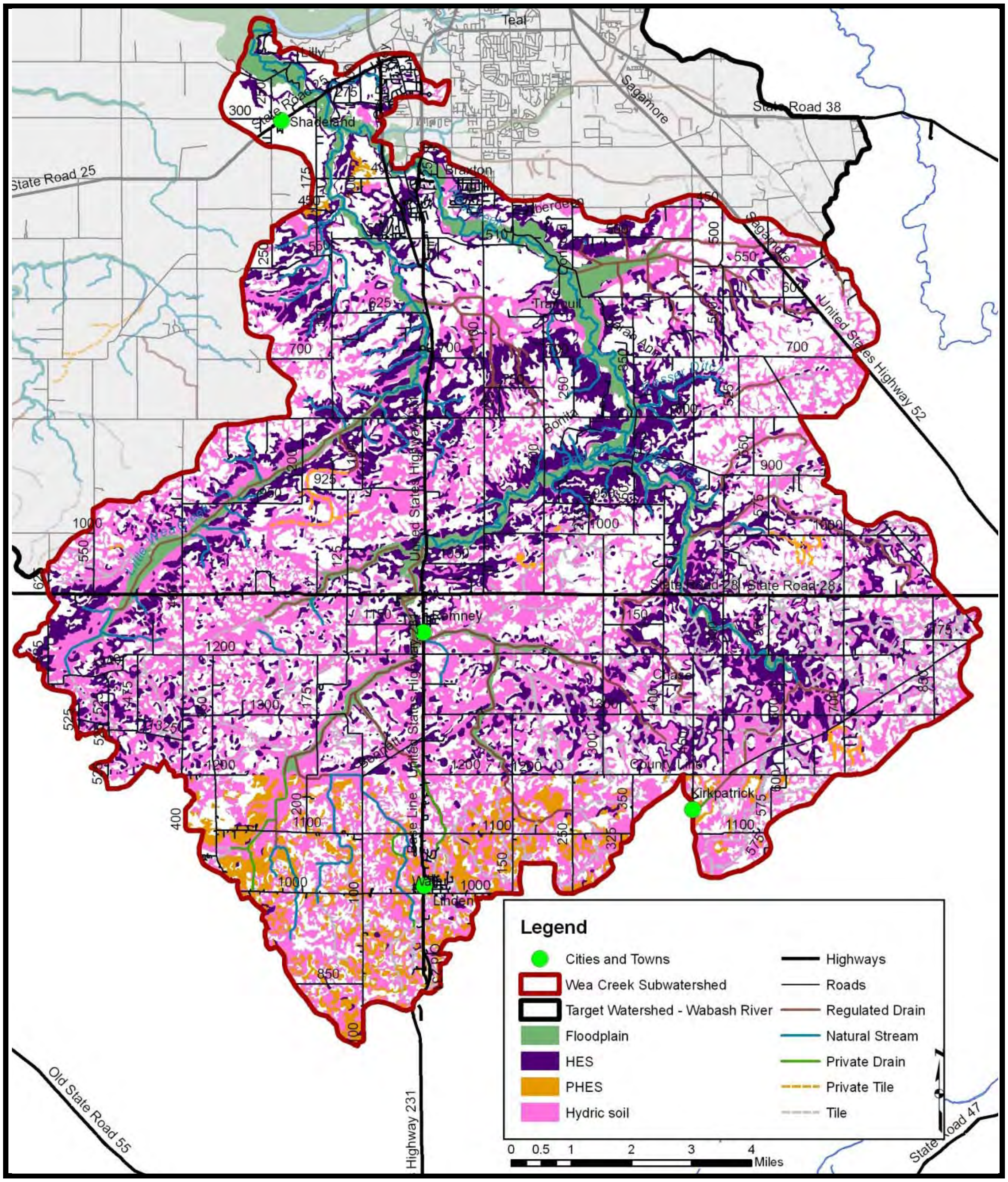

Figure 108. Properties of soils located in the Wea Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.2 Land Use

Agricultural land uses dominate the Wea Creek subwatershed accounting for 80% of land use. Urban land uses including the Towns of Linden, Romney and portions of Clark's Hill, New Richmond, and Dayton account for 7.5% of the subwatershed land use. Forest and wetland land uses account for 8% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Wea Creek subwatershed.

Continued development is a concern in the northern portion of the Wea Creek subwatershed (Figure 109). Eleven entities have subdivisions that have already been platted and partially developed or are slated for future development. In total, areas slated for development cover two square miles or approximately 1.5% of the Wea Creek subwatershed. When comparing 1992 land cover data to 2002 land cover data, approximately 1.1 square miles of agricultural and forested land were developed during that time period. This represents 1.2% of the Wea Creek watershed. A majority of the development occurred in the northern portion of the subwatershed adjacent to Lafayette and Shadeland. Despite this increase in development, the Wea Creek subwatershed remains relatively undeveloped with only 3% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is a relatively low impervious percentage indicating that runoff from hardscape should not be of great concern in the Wea Creek subwatershed.

A variety of publicly-owned or publicly-accessible lands are present in the Wea Creek subwatershed (Figure 109). The Cities of Lafayette, Shadeland, New Richmond, and Linden, Tippecanoe County, the State of Indiana, The Nature Conservancy, Purdue University, and Purdue Research Foundation all own land in the Wea Creek subwatershed. Fifteen cemeteries, more than 10 churches, and several large commercial properties are also located within the subwatershed. In total, approximately 1% (1.6 square miles) of the Wea Creek subwatershed is open for public use.

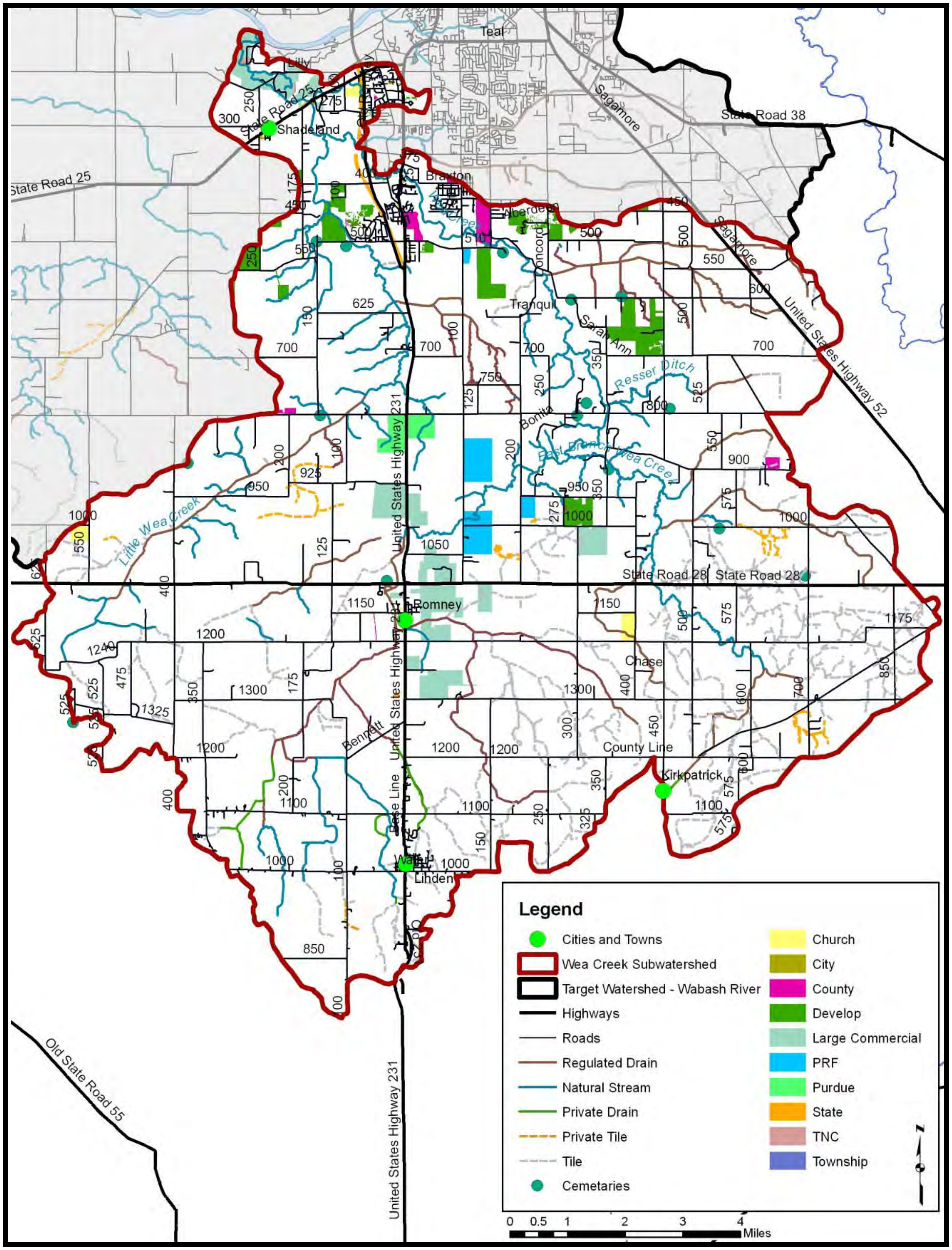

Figure 109. Land ownership and land development in the Wea Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.3.3 Point Source Water Quality Issues

As detailed above, much of the Wea Creek subwatershed is in agricultural land uses. However, as Lafayette continues to expand south, the subwatershed will continue to urbanize. A portion of the subwatershed lies within the MS4 boundary as designated by the (pink) line in Figure 110. Five NPDES-permitted facilities are located within the subwatershed. These facilities serve the Town of Linden, Shadeland and Royal Oaks Estates mobile home parks, Montoyne Elementary, and Evonik (formerly Eli Lilly). None of the facilities' reporting records indicate issues with contamination or non-compliance. These facilities discharge treated effluent to Wea Creek, Stoddard Ditch, and unnamed tributaries. Five leaking underground storage tanks (LUST) are located within the subwatershed with most of them located at Eli Lilly or within Linden.

4.3.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Wea Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. However, a number of hobby farms and pastures are also located within the Wea Creek subwatershed (Figure 110). Approximately 1,100 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to approximately 5 miles of stream within the Wea subwatershed. Nineteen confined feeding operations are also present in the subwatershed with the nine active CFOs located in the headwaters of Little Wea Creek, Dismal Ditch, and Romney-Fraley Ditch. Streambank erosion and buffer limitations are a problem within the Wea Creek subwatershed. In total, 172 miles of streambank need to be buffered while 116 miles of stream are eroding. An additional 4.5 miles of waterway would benefit from the installation of grassed waterways.

As detailed above, development pressures are relatively high in the Wea Creek subwatershed. These pressures are detailed in Figure 110 by the unsewered, dense housing locations and the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) All of these development-based, non-point source locations are concentrated within the northern portion of the watershed and typically occur within the East Branch of Wea Creek watershed near the southern edge of the City of Lafayette.

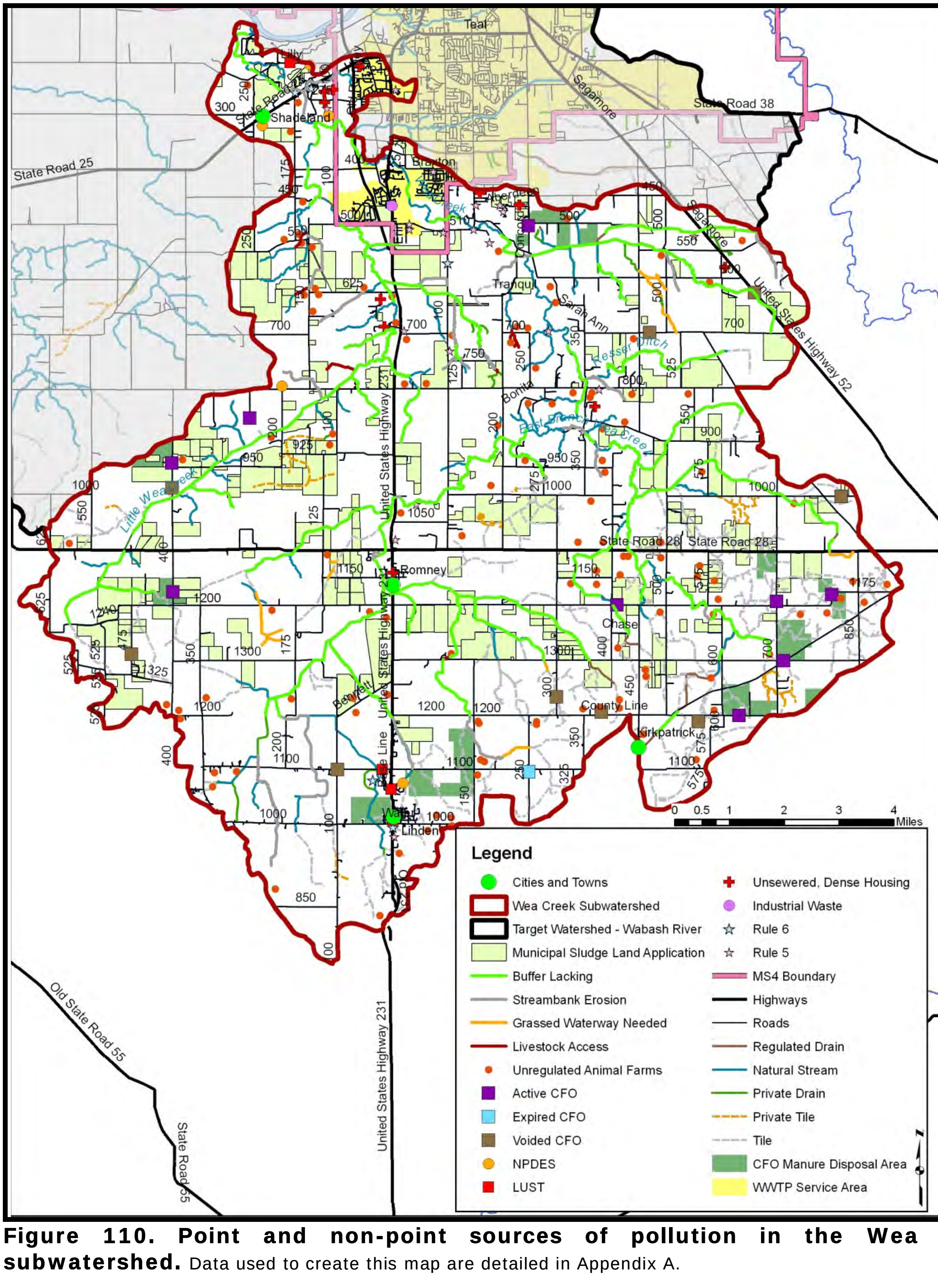

Figure 110. Point and non-point sources of pollution in the Wea Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.3.5 Water Quality Assessment

Waterbodies within the Wea Creek subwatershed have been sampled at approximately 70 locations (Figure 111). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (14 sites), the IDEM (4 sites), the Tippecanoe County Health Department (1 site), and via volunteer monitors through the Hoosier Riverwatch program (4 sites). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by the IDEM (2 sites), while the fish community has been assessed by Curry and Spacie (10 sites) and by Fisher et al. (14 sites). Mussel surveys were completed by Myers-Kinzie at 14 sites throughout the subwatershed. Sixty sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological and water chemistry sampling effort funding by this project. A stream gage is located on Little Wea Creek at County Road 800 South.

Water Chemistry

Water chemistry data collected from the Wea Creek subwatershed suggest several parameters of concern including: nitrate-nitrogen, orthophosphate, turbidity, and *E. coli* (Figure 112). Nitrate-nitrogen concentrations exceeded the target concentration (2 mg/L) during at least 50% of sample events in Wea Creek at US 231 South, Flatt Ditch at County Road 500 East, in Moses Baker Ditch at County Road 1000 South, and in Stoddard Ditch at County Road 1100 South and Bennett Road. Concentrations in Stoddard Ditch measured 24.5 and 10.9 mg/L, respectively. Orthophosphate concentrations were elevated in Stoddard Ditch at County Road 1100 North and at Bennett Road, in Haywood Ditch at State Road 28, in Romney-Fraley Ditch at County Road 1200 North and US 231, and in an unnamed tributary to Wea Creek at County Road 150 East. *E. coli* concentrations in excess of the state standard occurred during more than 50% of sampling events in Wea Creek at Mar-Len Park, County Road 200 South, State Road 28, and at County Road 800 South; in East Branch Little Wea at County Road 350 East; in Little Wea at County Road 800 South, in Woodham Ditch at County Road 725 South, in Kellerman Lea Ming Ditch at State Road 28, in Haywood Ditch at State Road 28, and in Hallstein Ditch at State Road 28. Turbidity routinely measured higher than the target concentration in Wea Creek at Mar-Len Park, at County Road 200 South, at US 231 South, and at County Road 800 South. This suggests that the mainstem of Wea Creek may contain a high background suspended sediment concentration or that the high sinuosity and prevalence of easily erodible soils results in elevated suspended sediment concentrations on a routine basis.

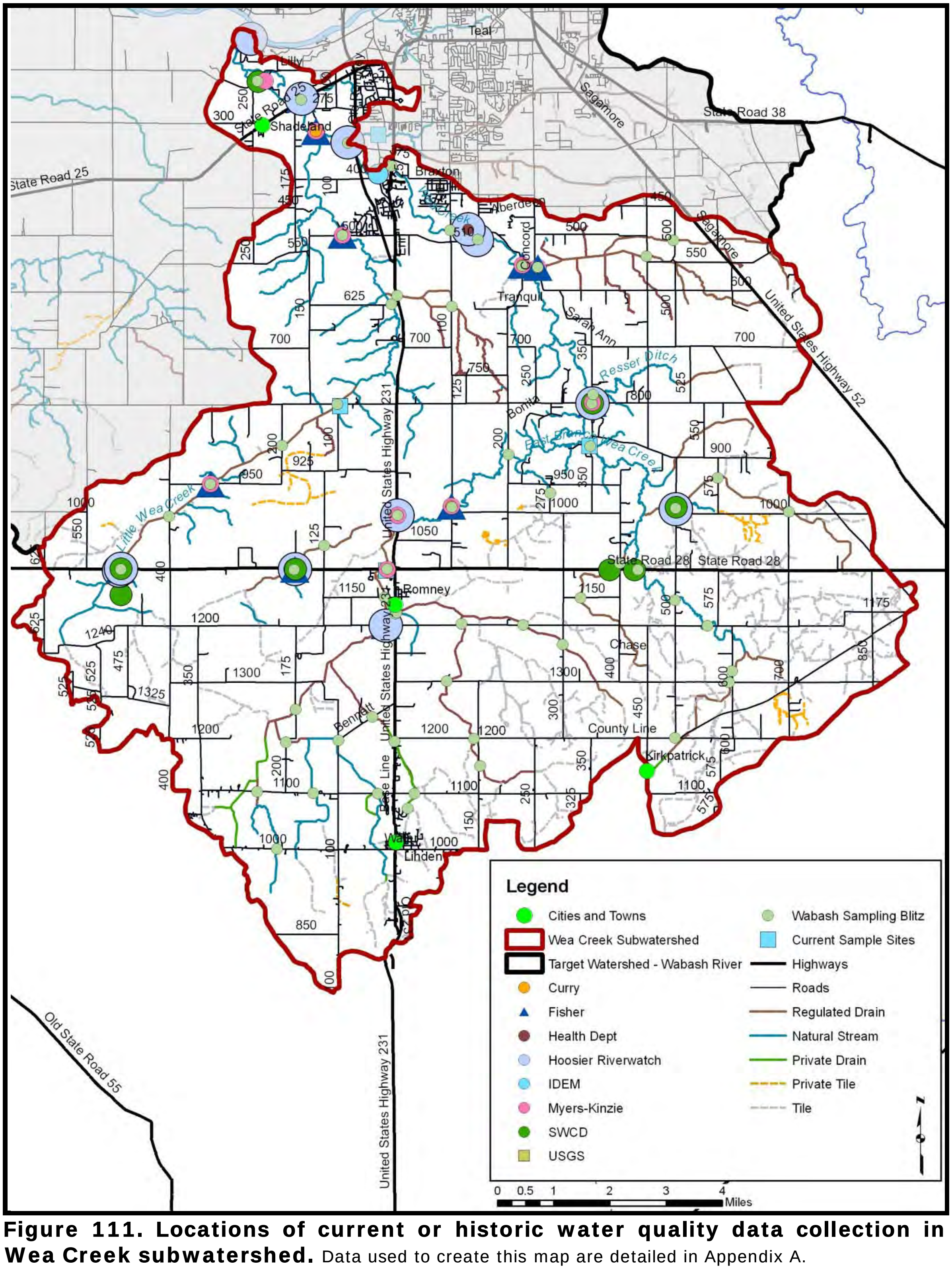

Figure 111. Locations of current or historic water quality data collection in the Wea Creek subwatershed. Data used to create this map are detailed in Appendix A.

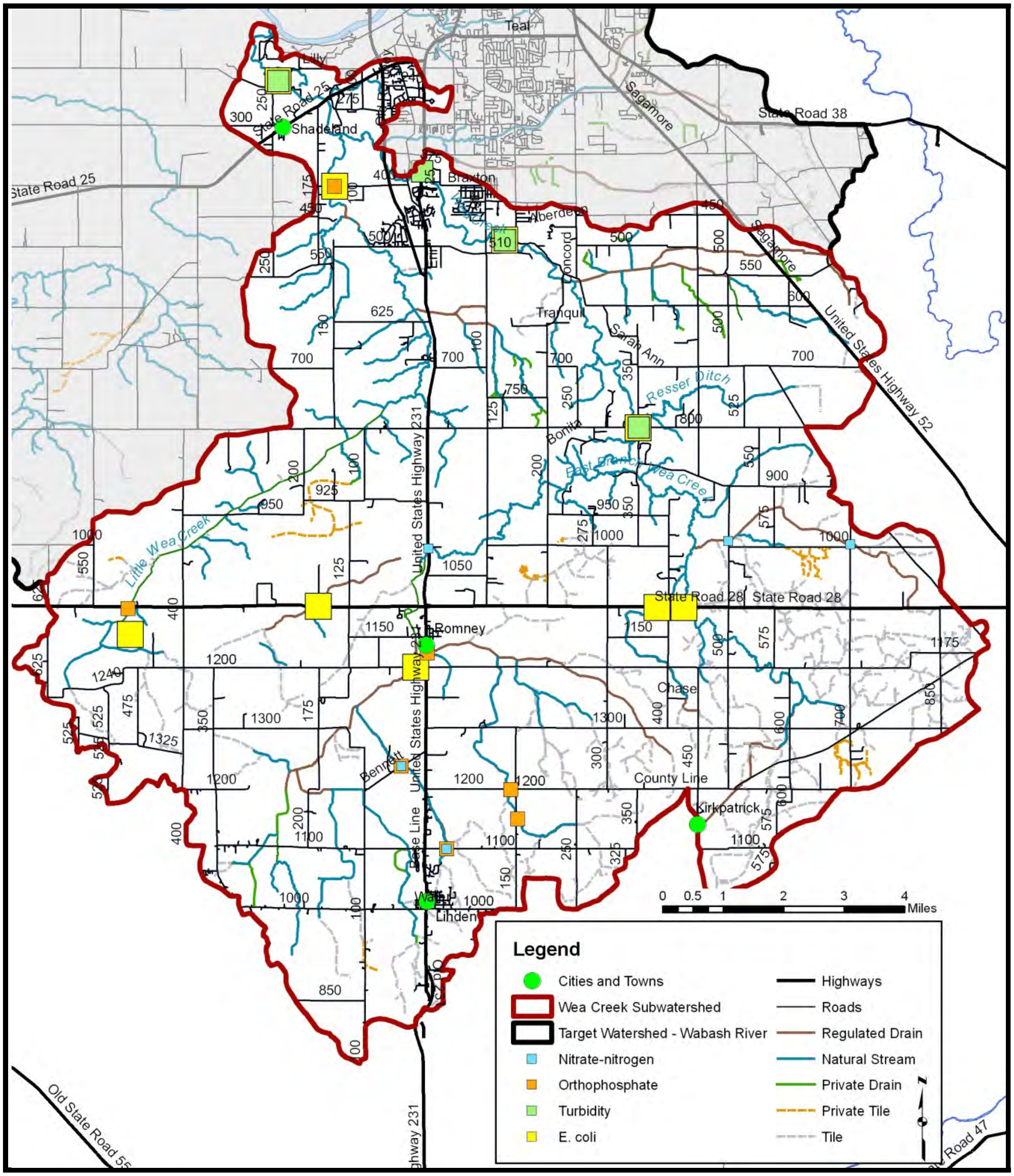

Figure 112. Water quality impairments in the Wea Creek subwatershed.
Data used to create this map are detailed in Appendix A.

Habitat

Volunteer monitors assessed habitat at three sites within the Wea Creek subwatershed using the Citizen's Qualitative Habitat Evaluation Index (CQHEI). As previously detailed, the CQHEI scores sites based on the presence or absence of specific natural characteristics within a stream reach. Although a comparison scale for the CQHEI has not yet been developed, Hoosier Riverwatch indicates that scores greater than 60 rate as habitat conducive to supporting warm-water biota (IDNR, 2004). Volunteers assessed Wea Creek's habitat at US 231, at State Road 25, and at County Road 150 East with sites scoring between 95 and 100, 85, and 83, respectively. All three reaches score very high with fish cover and depth and velocity scoring poorly at the CR 150 East reach.

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at four sites during three assessments. The IDEM completed three assessments of habitat using the QHEI within the Wea Creek subwatershed, while Myers-Kinzie assessed habitat using the QHEI at three sites while assessing the mussel community. As previously detailed and similarly to the CQHEI the QHEI scores habitat within a 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 1991 and 1999 in Wea Creek at County Road 1B and in 1991 at State Road 25. Scores (75, 82, 70 respectively) indicate good quality habitat that is fully in support of the streams designated aquatic life use. Limited riparian development and poor riffle-pool complex development limited habitat at these reaches. During Myers-Kinzie's habitat assessments, habitat also rated well with scores at State Road 25, County Road 800 South, and US 231 rating 66, 65, and 57, respectively. A general lack of instream cover and poor riffle development limited habitat within these three reaches.

Three Purdue field personnel completed QHEI assessments during the June 2010 fish sampling event, and the mean of those scores was calculated to determine QHEI scores for each site visited in the subwatershed. The mean QHEI scores ranged from 32 for Little Wea Creek at County Road 800 South to 63 for East Branch Wea Creek at County Road 350 East. Kellerman Lea Ming Ditch at State Road 28 rated between those scores with a mean score of 47.5. East Branch Wea Creek scored the highest due to its well-developed riffle-run-pool sequence and moderate sinuosity. The pools at East Branch Wea Creek also typically contained structure in the form of woody debris. Little Wea Creek contained moderate flow, but it was significantly channelized and entrenched. There was a riffle present at the Little Wea Creek site, and it remained free of sediment throughout our sampling period. Kellerman Lea Ming Ditch was channelized and entrenched as well; however, a riffle present during extremely low water conditions provides moderate habitat. The substrate throughout the Kellerman Lea Ming Ditch site was sand and silt as well as large amounts of rotting organic material.

Fish

Curry and Spacie (1972) and Fisher et al. (1994) assessed the fish community of the Wea Creek subwatershed at 10 and 14 sites, respectively. Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). IBI scores were calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 10, 11, 16, 18, 19, and 23; Sample II – July 20, 21, 22, and 23; Sample III – September 15, 16, 18, and 23; and Sample IV – November 4, 5, and 6. The 2010 samples were collected as follows: Sample V – March 19, 20, and 22; Sample VI – June 18 and 21; Sample VII – August 10, 11, 12, and 13; and Sample VIII – October 30, 31, and November 1. Fish community assessment of Little Wea Creek at County Road 800 South, East Branch Wea Creek at County Road 350 East, and Kellerman Lea Ming Ditch at State Road 28 resulted in mean IBI scores of 40, 44, and 37, respectively. All scores fell within the poor category. Kellerman Lea Ming Ditch score a mean IBI of 37 falling at the low end of all sites sampled. Kellerman Lea Ming Ditch's scores measured the same as Little Pine Creek and higher than only Kickapoo Creek. Mean score for Kellerman Lea Ming Ditch provide only a portion of the whole picture as IBI scores ranged from 30 (poor) to 48 (good) indicating a wide range of scores throughout the sample season. These results suggest that under specific conditions, the fish communities within Kellerman Lea Ming Ditch are on par with communities present in streams which contain higher quality habitat. East Branch Wea Creek had the highest mean IBI score (44) within the Wea Creek watershed with scores ranging from 40 to 50; however, East Branch Wea Creek ranked fourth among all the sites in the watershed. Little Wea Creek had a mean IBI score just below that of East Branch Wea Creek with a score of 40 (range 30 – 48).

The fish communities present throughout the Wea Creek subwatershed varied as much as their IBI scores. Little Wea Creek was dominated by mottled sculpin, central stonerollers, bluntnose minnows, creek chubs, and rock bass. Despite having a relatively small riffle present at Little Wea Creek, the diversity of darters was high, and five of the six species collected during the study. East Branch Wea Creek was dominated by bluntnose minnows, creek chubs, central stonerollers, and mottled sculpins. Kellerman Lea Ming Ditch contained low species abundances comprised of mostly tolerant species, including white suckers, bluntnose minnows, creek chubs, and mottled sculpins. Only 21 individual darters were collected in Kellerman Lea Ming Ditch compared to 312 at East Branch Wea and 216 at Little Wea over the same sample period. Data from Curry and Spacie, Fisher, and current assessment are not yet available. Results will be added as they become available.

Macroinvertebrates

The macroinvertebrate community within Wea Creek was sampled three times by the IDEM. Sampling occurred at two sites in 1991 (County Road 1B and State Road 25) and again at one site in 1999 (County Road 1B). The macroinvertebrate community rated as slightly and moderately impaired during the 1991 and 1999 assessments at CR 1B scoring 5.6 and 3.0, respectively. During the 1991 assessment, the community was dominated by Philoptomidae, a moderately-tolerant caddisfly species and the community displayed relatively low density and diversity. During the 1999 assessment, Chironomidae dominated the community accounting for a majority of individuals collected. The community at State Road 25 rated as slightly impaired scoring 4.6. Generally, this community lacked diversity with those species present being relatively tolerant.

Purdue field personnel sampled Little Wea Creek at County Road 800, East Branch Wea Creek at County Road 350, and Kellerman Lea Ming Ditch at State Road 28 four times in 2009 and four times in 2010. Little Wea Creek possessed a mean mIBI score of 3.9 with scores ranging from 1.8 during the June 2010 assessment to 5.4 during the November 2009 assessment and a mean HBI score of 4.95. The mIBI for Little Wea Creek indicated moderate impairment. The dominate taxa that contributed to the low mean HBI included members of the Elmidae (riffle beetle, 951 individuals), Chironomidae (non-biting midge, 1939 individuals), Baetidae (mayfly, 355 individuals), and Hydropsychidae (caddisfly, 1440 individuals). East Branch Wea had a mean mIBI score of 4.4 which indicates that it is slightly impaired. mIBI scores ranged from 3.4 during the June 2009 and 5.8 during the July 2010 assessment. The mean HBI score was 4.4 with similar taxa contributing to the overall tolerance score. Dominant aquatic macroinvertebrate abundances for East Branch Wea included members of the Elmidae (riffle beetle, 904 individuals), Chironomidae (non-biting midge, 1201 individuals), Baetidae (mayfly, 903 individuals), and Hydropsychidae (caddisfly, 1196 individuals) families. Kellerman Lea Ming Ditch had a mean mIBI score of 1.5 and a mean HBI score of 5.6, which indicates that the stream was severely impaired with a high abundance of tolerant taxa. Kellerman Lea Ming Ditch scored the poorest of any stream sampled within the watershed. mIBI scores ranged from 0.4 during the June 2009 and November 2009 to 3.0 during the June 2009 assessment. The dominate taxa in the macroinvertebrate samples were members of the Chironomidae (non-biting midge, 1916 individuals) and Hydroptilidae (caddisfly, 81 individuals) families.

Mussels

Myers-Kinzie assessed the mussel community at 14 locations with the Wea Creek subwatershed. During the surveys, eight species were found in live, weathered dead, or fresh dead conditions. Only three sites were absent of mussels. Five sites, Wea Creek at County Road 100 East, County Road 200 East, County Road 800 South, US 231, and Kellerman Lea Ming Ditch at State Road 28, contained six or more species. All observed mussels represent typical headwater species.

4.3.6 Wea Creek Subwatershed Summary

Wea Creek possesses one of the largest drainage of any of the Wabash River tributaries within the Region of the Great Bend of the Wabash River watershed. Much of Wea Creek's watershed is used for row crop agriculture with small developments and remnant forests scattered throughout the subwatershed. The northern portion of the subwatershed is included in the southern edge of the City of Lafayette while much of the southern portion of the watershed is used for livestock production. Water quality within the Wea Creek subwatershed varies greatly. Multiple impairments for elevated nutrient, sediment, and pathogen concentrations occur throughout the subwatershed. Similarly, biotic communities vary more often reflecting habitat conditions rather than water quality concerns.

4.4 <u>Elliot Ditch-Wea Creek Subwatershed</u>

Elliot Ditch is the main urban tributary to Wea Creek and forms a portion of the eastern boundary of the watershed. The Elliot Ditch-Wea Creek subwatershed includes one HUC watershed (HUC 051201080104) and drains 11,850 acres or 18.5 square miles (Figure 113). In total, there are 36.2 miles of streams within the Elliot Ditch subwatershed. Of these, six miles are impaired for impaired biotic communities and PCBs.

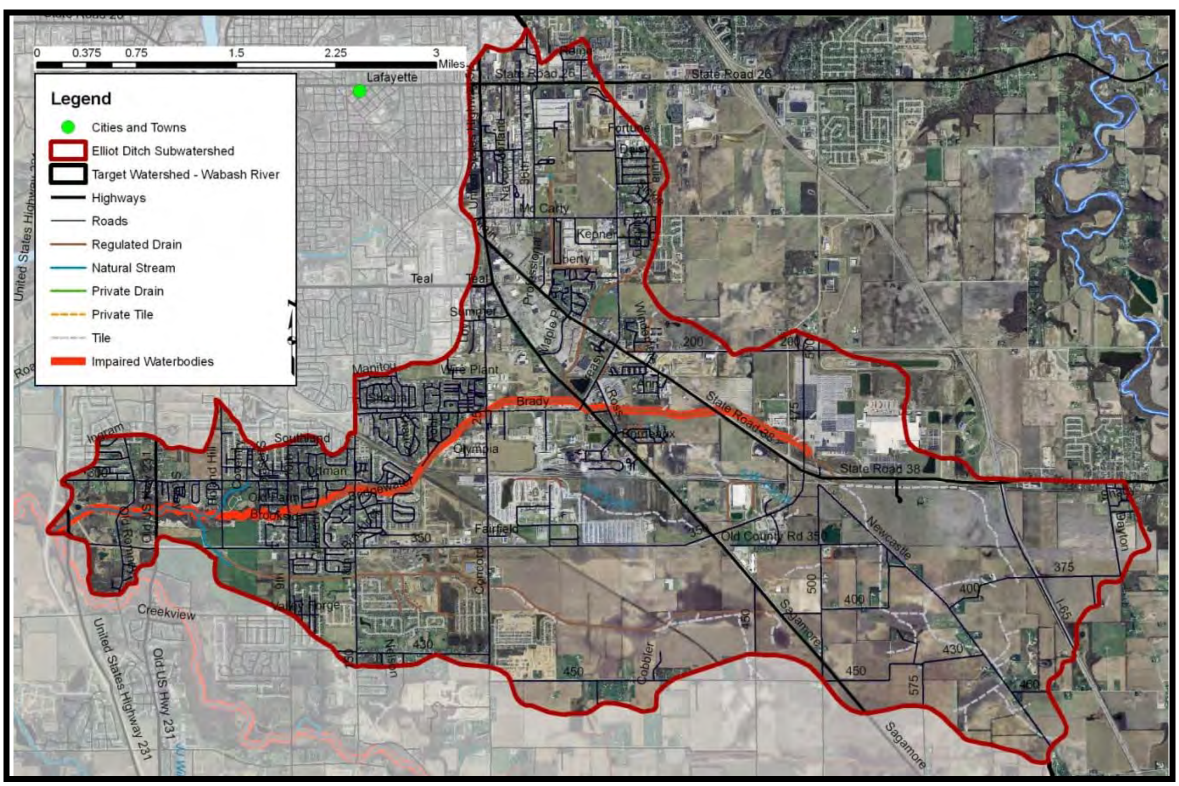

Figure 113. Elliot Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.4.1 Soils

Like the larger Wea Creek subwatershed, soils located on steeply sloped areas or those that formed under wetland conditions are prevalent but not dominant within the Elliot Ditch subwatershed (Figure 114). Soils in the Elliot Ditch subwatershed are dominated by those that are located on steeply sloped, easily erodible areas or those that formed under wetland conditions (Figure 114). Highly erodible soils cover 2 square miles or 10% of the Elliot Ditch subwatershed. A majority of these soils are located adjacent to the Kirkpatrick Ditch and other headwater tributaries. Potentially highly erodible soils cover 2.5 square miles or 13% of the Elliot Ditch subwatershed. These soils cover the entire portion of the City of Lafayette located within the Elliot Ditch subwatershed. An additional 4 square miles or 20% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of Elliot Ditch were historically in wetland land uses with nearly 20% of the subwatershed soils developing under wetland conditions. Current estimates indicate that wetlands cover approximately 3.5% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Elliot Ditch subwatershed.

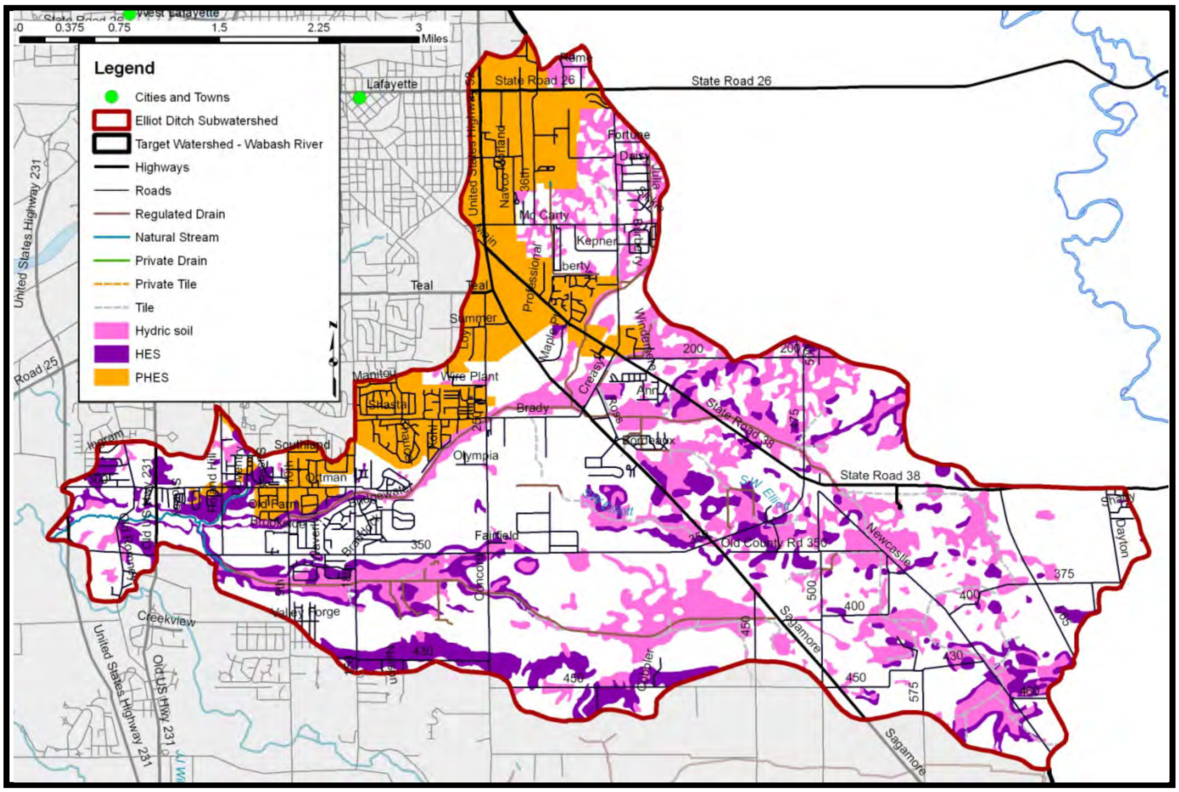

Figure 114. Properties of soils located in the Elliot Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.4.2 Land Use

The Elliot Ditch subwatershed is a watershed in transition. Agricultural and urban land uses are equally dominant within the Elliot Ditch subwatershed with each accounting for 47% of the subwatershed's land use. Approximately 5% of the subwatershed remains in natural land uses while less than 1% of the subwatershed is covered by open water. Based on the dominance of urban land uses, the predominance of impervious surfaces and development rate are naturally elevated.

Continued development is a concern in the Elliot subwatershed (Figure 115). Three entities have subdivisions that have already been platted and partially developed or are slated for future development. In total, areas partially developed or slated for development cover 200 acres or 1.7% of the Elliot Ditch subwatershed. When comparing 1992 land cover data to 2002 land cover data, approximately 4.25 square miles of agricultural and forested land were developed during that time period. This represents 22% of the Elliot Ditch subwatershed a nearly doubling of the urban land uses within the subwatershed. This is the highest rate of development within any of the subwatersheds. A majority of the development occurred in the northern and western portions of the watershed adjacent to Lafayette. Based on this rate of development, it is not surprising that nearly 20% of the Elliot Ditch subwatershed is covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is nearly twice the impervious surface percentage at which runoff from hardscape is of great concern. If development continues at its current rate of 22% every 10 years, impervious coverage could cover the watershed by 2040.

A large volume of publicly-owned or publicly-accessible lands are present in the Elliot Ditch subwatershed (Figure 115). The City of Lafayette, Tippecanoe County, the State of Indiana, the federal government, and Ivy Tech State College all own land in the Elliot Ditch subwatershed. Additionally, two cemeteries and four churches are located within the subwatershed. Commercial owners include Caterpillar, A.E. Staley Manufacturing, Canam Steel, Subaru of Indiana, Lafayette Union Railway Company, Simon Property Group, Wabash National, and Warehouse of Lafayette. Although many of these large commercial properties, especially Subaru, contain publicly accessible, open space these areas are not considered publicly-owned or publicly-accessible land. In total, less than 1% (1.1 square miles) of the Elliot Ditch subwatershed is open for public use.

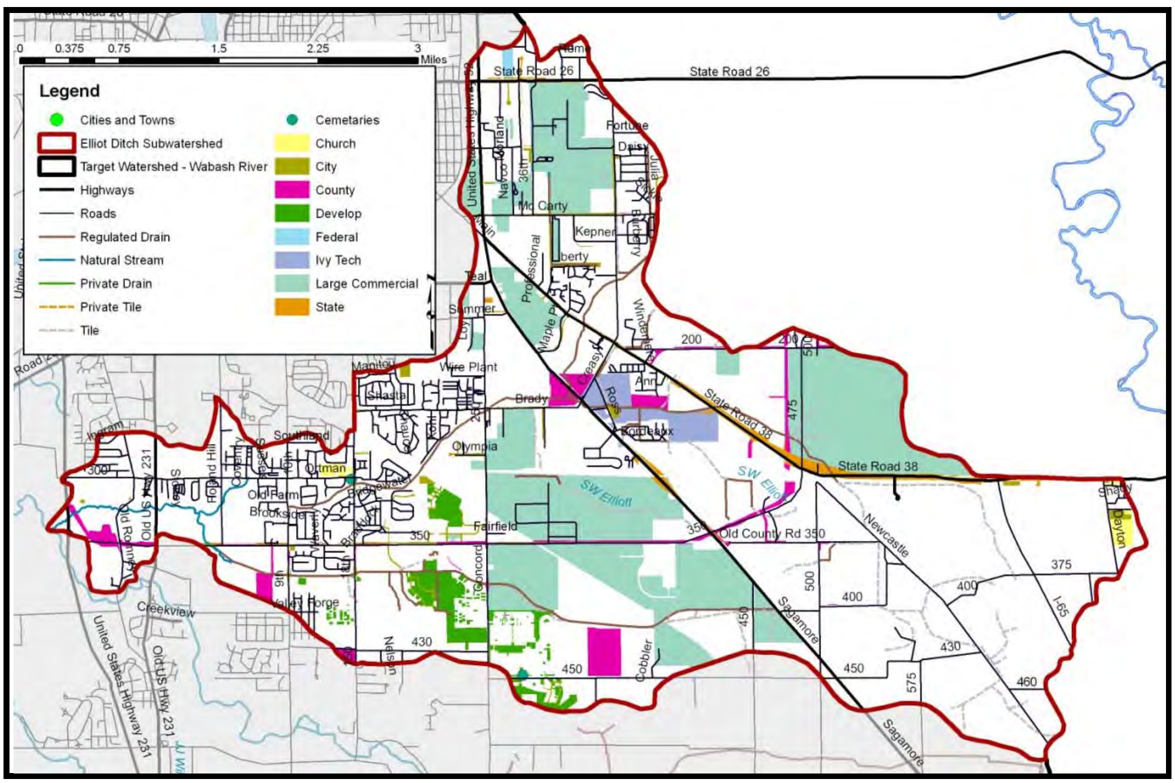

Figure 115. Land ownership and land development in the Elliot Ditch subwatershed. Data used to create this map are detailed in Appendix A.

4.4.3 Point Source Water Quality Issues

As detailed above, much of the Elliot Ditch subwatershed is already developed; however, nearly half the subwatershed is still available for additional development. Much of the subwatershed lies within the MS4 boundary as designated by the (pink) line in Figure 116.

Two NPDES-permitted facilities are located within the subwatershed. Both facilities discharge treated effluent to Elliot Ditch. Neither facility's reporting records indicate issues with contamination or non-compliance. Twenty-five leaking underground storage tanks (LUST) are located within the subwatershed many of which occur adjacent to US 52 within the City of Lafayette and south of Kirkpatrick Ditch. Twelve industrial waste sites are located within the City of Lafayette near the northeastern edge of the watershed.

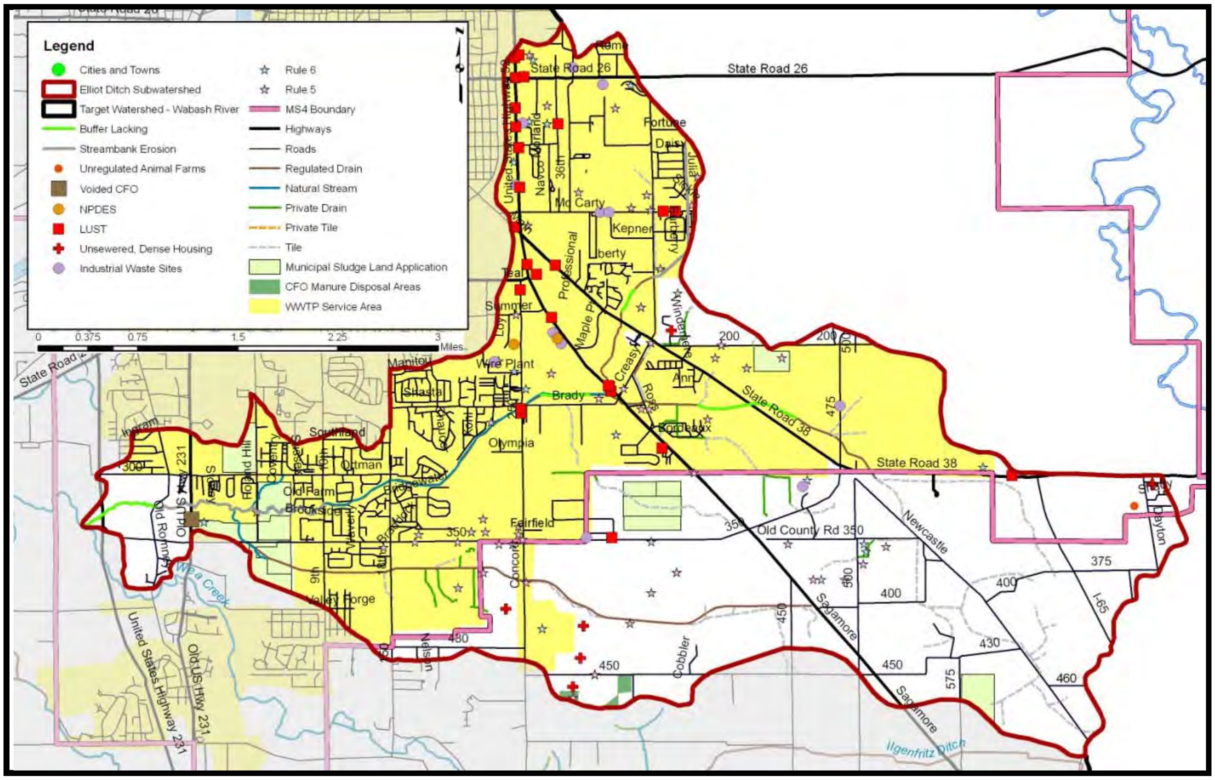

Figure 116. Point and non-point sources of pollution in the Elliot Ditch subwatershed. Data used to create this map are detailed in Appendix A.

4.4.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Elliot Ditch subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, one hobby farm (horses) and one voided confined feeding operation is located within the subwatershed. No livestock have access to waterbodies in the Elliot Ditch subwatershed. Streambank erosion and lack of stream buffers are a problem in the subwatershed with nearly 4 miles of buffers needed and 6.9 miles of streambank erosion occurring within the Elliot Ditch subwatershed. As detailed above, development pressures are relatively high in the Elliot Ditch subwatershed. These pressures are detailed in Figure 116 by the unsewered, dense housing locations and the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) These developments are located throughout the subwatershed and generally occur west of County Road 500 East.

4.4.5 Water Quality Assessment

Waterbodies within the Elliot Ditch subwatershed have been sampled at approximately 18 locations (Figure 117). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (5 sites), the IDEM (1 site), the Tippecanoe County Health Department (1 site), and via volunteer monitors through the Hoosier Riverwatch program (3 sites). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by the IDEM (1 site), while the fish community has been assessed by Curry and Spacie (1 site) and Fisher et al. (1 site). Sixteen sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological and chemistry sampling effort funding by this project. A stream gage was installed on Elliot Ditch at Old Romney Road as part of this project, while the Tippecanoe County Surveyor's office maintains a second gage on Elliot Ditch near Creasy Lane.

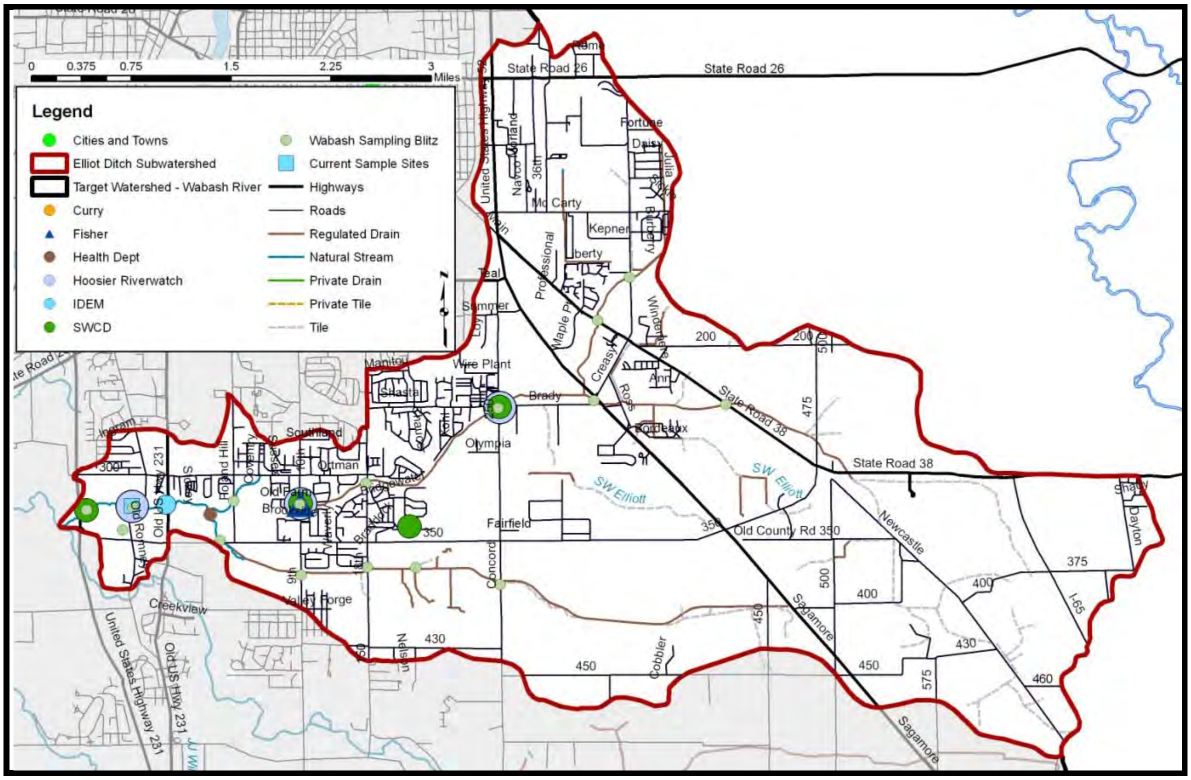

Figure 117. Locations of current or historic water quality data collection in the Elliot Ditch subwatershed. Data used to create this map are detailed in Appendix A.

Water Chemistry

Water chemistry data collected from the Elliot Ditch subwatershed suggest several parameters of concern including turbidity and *E. coli* (Figure 118). *E. coli* concentrations exceeded the state standard in a majority of samples collected from Elliot Ditch at the AOK Campground with concentrations averaging 575 colonies/100 mL, in Elliot Ditch at Concord Road, and in Kirkpatrick Ditch at County Road 150 East. Turbidity concentrations averaged 50 NTU at the AOK Campground suggesting that Elliot Ditch routinely carries a high sediment load. During the Wabash Sampling Blitz, a few sites (3 of 8) along Elliot Ditch exceeded the target concentration for orthophosphate; concentrations in Kirkpatrick Ditch measured lower than the target concentration.

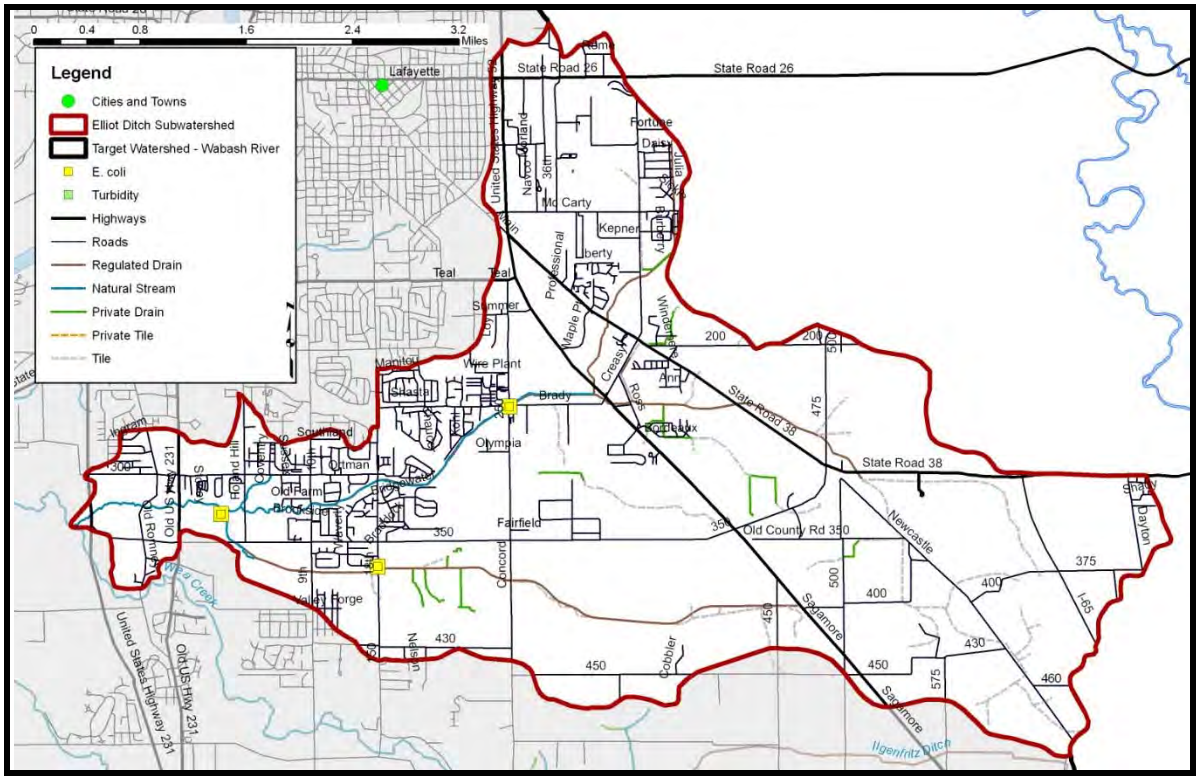

Figure 118. Water quality impairments in the Elliot Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

Habitat

Three Purdue field personnel conducted QHEI assessments during the June 2010 fish sampling, and the mean of those scores was calculated to determine QHEI scores for the study site. Elliot Ditch had a relatively high mean QHEI score of 75. A mean score of 75 suggests that the habitat is in place for taxa to successfully colonize and inhabit the stream. Elliot Ditch had high mean scores for channel (16), substrate (15), and pool/riffle (13).

Fish

Curry and Spacie (1972) and Fisher et al. (1994) assessed the fish community at one site during both assessment periods. Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). A fish IBI score was calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 10; Sample II – July 22; Sample III – September 15; and Sample IV – November 6. The 2010 samples were collected as follows: Sample V – March 22; Sample VI – June 21; Sample VII – August 13; and Sample VIII – October 30. The mean fish IBI score was 39 which indicates that there is some impairment at the site. IBI scores ranged from 36 to 42 all falling in the poor rating range. Elliot Ditch's IBI score place it in the bottom half of all streams sampled. This range of scores was the narrowest of any of the fish communities sampled which suggests that the fish community changes little under varied conditions. There was a fairly even distribution of the dominate taxa with green sunfish (358 individuals), central stonerollers (322), and creek chubs (258).

Macroinvertebrates

The macroinvertebrate community within Elliot Ditch was sampled twice by the IDEM. Sampling occurred once in 1991 and again in 1999 with both sample events occurring at State Road 231. The macroinvertebrate community rated as moderately to severely impaired during both assessments score 2.4 and 2.0, respectively. The community was dominated by Chironomidae, a tolerant fly species, during the 1991 assessment and by Ceratopogonidae and Hydropsychidae, a tolerant midge or sand fly and a relatively-tolerant caddisfly species, respectively. Individual metrics indicate low Hilsenhoff Biotic Index (HBI) scores, low diversity, low density, and communities dominated by low quality, tolerant taxa.

Purdue field personnel sampled macroinvertebrates in Elliot Ditch on four occasions in 2009 and on four occasions in 2010. Mean mIBI and mean HBI scores for Elliot Ditch were 3.8 and 4.6, respectively. mIBI scores ranged from 2.2 during the June 2009 assessment to 5.0 during August 2010. mIBI scores suggest a poor macroinvertebrate community present in Elliot Ditch as the stream rated in the bottom half of streams sampled. The mean mIBI score of 3.8 indicates that the stream is moderately impaired. Baetidae (1061), Chironomidae (519), and Hydropsychidae (502) families dominated the Elliot Ditch biotic community.

4.4.6 Elliot Ditch Subwatershed Summary

The Elliot Ditch subwatershed is considered urbanizing. As such it contains a major portion of industrial Lafayette with subdivision moving outward from Lafayette to cover much of the Elliot Ditch subwatershed. As evidence to its changing land uses, the headwaters of Elliot Ditch are largely row crop agriculture while much of the downstream portion of the watershed are commercial and residential. Much of the Elliot Ditch subwatershed is covered by large, commercially-owned properties. Water quality within Elliot Ditch reflects the watersheds conditions. Much of Elliot Ditch is listed on Indiana's impaired waterbodies list for biotic communities and PCBs. Not surprisingly, the macroinvertebrate and fish communities observed during this project indicate moderate to severe impairment. Water chemistry results indicate high sediment loads and low nutrient concentrations present in Elliot Ditch.

4.5 Jordan Creek-Lost Creek-Wabash River Subwatershed

The Jordan Creek-Lost Creek-Wabash River subwatershed includes a 10-mile segment of the Wabash River and nearly 7.5 miles of small, intermittent tributaries (Figure 119). The Jordan Creek-Lost Creek subwatershed drains portions of Warren and Tippecanoe counties and is comprised of two 12-digit HUC watersheds – Jordan Creek-Wabash River (HUC 151201080502) and Lost Creek-Wabash River (HUC 051201080503). The Jordan Creek-Lost Creek subwatershed drains 26,862 acres or 41.9 square miles.

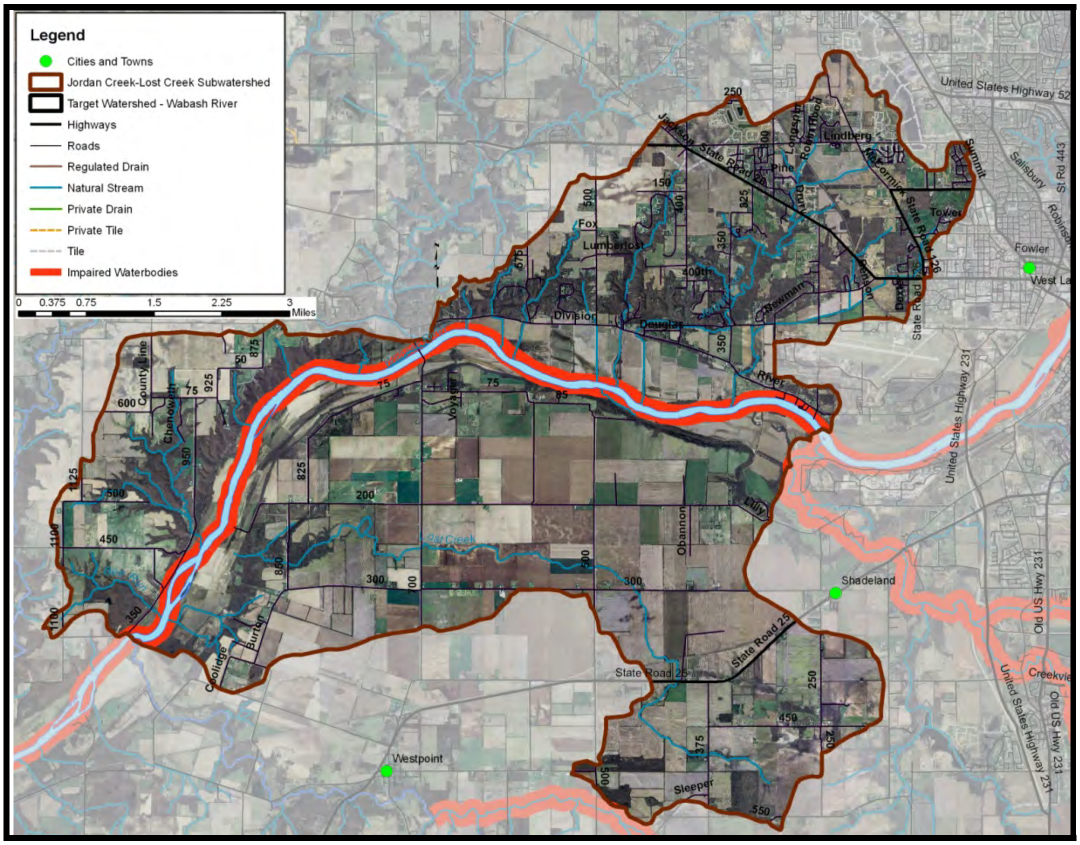

Figure 119. Jordan Creek-Lost Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.1 Soils

Soils in the Jordan Creek-Lost Creek subwatershed reflect the unique geology found on the Wea Plains which occur south of the Wabash River within this subwatershed (Figure 120). Soils located on steeply sloped, easily erodible areas border the north edge of the Wabash River floodplain and cover much of the Jordan Creek, Bee Run, and unnamed tributary drainages. The presence of erodible soils is limited south of the floodplain, as much of this area is covered by the Wea Plain – a flat terrace adjacent to the Wabash River. In total, highly erodible soils cover 28% of the subwatershed while potentially highly erodible soils cover an additional 2% of the subwatershed. An additional, 23% of the watershed is covered by soils which formed under wetland conditions. Many of these soils are located with headwaters of the intermittent tributaries. Current estimates indicate that wetlands cover approximately 4.8% of the subwatershed suggesting that nearly one-fifth of historic wetlands are still present within the Jordan Creek-Lost Creek subwatershed.

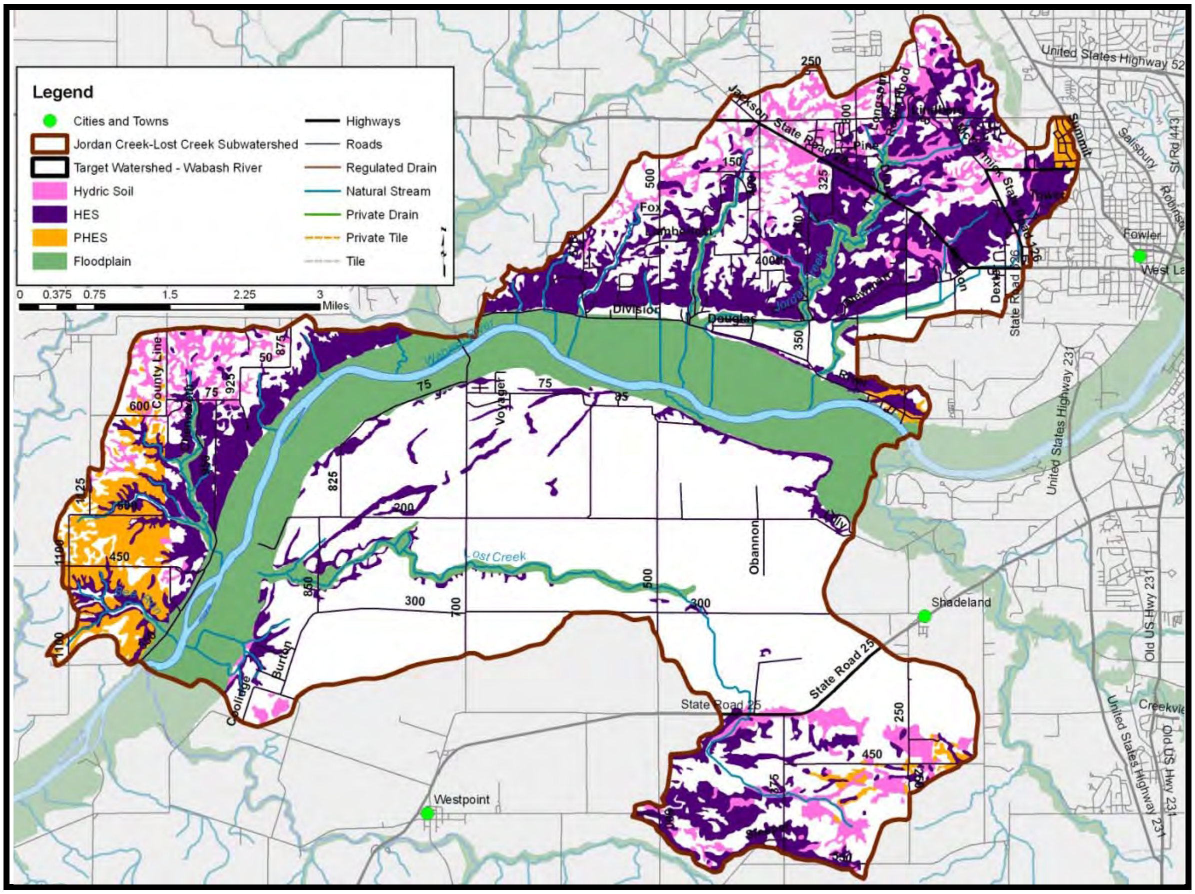

Figure 120. Properties of soils located in the Jordan Creek-Lost Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.5.2 Land Use

Agricultural land uses dominate the Jordan Creek-Lost Creek subwatershed accounting for 67% of land use. Natural land uses account for 23% of the subwatershed indicating that the Jordan Creek-Lost Creek subwatershed contains the highest density of natural land uses in any of the subwatersheds. Urban land uses including the western edge of the Purdue University campus and adjacent residential development along the edge of the City of West Lafayette account for 7% of the subwatershed land use. Open water in the form of farm ponds and the Wabash River covers approximately 2% of the Jordan Creek-Lost Creek subwatershed.

Although development is occurring at a relatively low rate (3.5% over 10 years), continued development is a concern in the Jordan Creek-Lost Creek subwatershed (Figure 121). In total, areas slated for development cover 130 acres or less than 0.5% of the Jordan Creek-Lost Creek subwatershed. When comparing 1992 land cover data to 2002 land cover data, approximately 1.5 square miles of agricultural and forested land were developed during that time period. This represents 3.5% of the Jordan Creek-Lost Creek watershed and suggests that residential and commercial development has doubled in the last 15 years. A majority of the development occurred in the eastern portion of the watershed within and adjacent to the City of West Lafayette. Despite this increase in development, the Jordan Creek-Lost Creek subwatershed remains relatively undeveloped with only 1.2% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed

Protection (CWP), this is a relatively low impervious percentage indicating that runoff from hardscape should not be of great concern in the Jordan Creek-Lost Creek subwatershed.

A large volume of publicly-owned or publicly-accessible lands are present in the Jordan Creek-Lost Creek subwatershed (Figure 121). The Cities of West Lafayette and Shadeland, Tippecanoe County, the State of Indiana, NICHES Land Trust, Purdue University, and Purdue Research Foundation all own land in the Jordan Creek-Lost Creek subwatershed. Additionally, four cemeteries, five churches, and a variety of large number of large, commercial properties are located within the subwatershed. One of these is owned by Eli Lilly (now Evonik Industries AG) and includes a large natural area which is generally open to the public. In total, approximately 14% (6 square miles) of the Jordan Creek-Lost Creek subwatershed are open for public use.

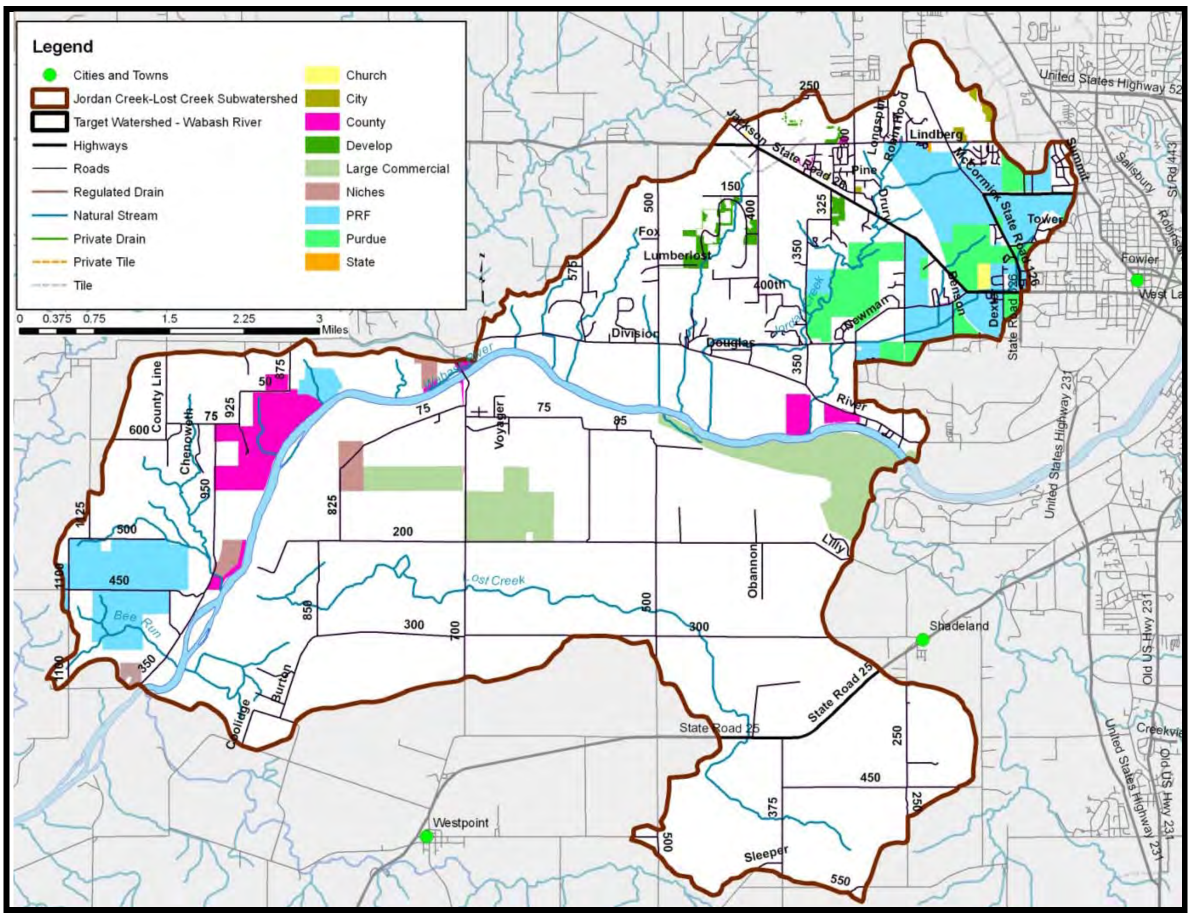

Figure 121. Land ownership and land development in the Jordan Creek-Lost Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.5.3 Point Source Water Quality Issues

As detailed above, much of the Jordan Creek-Lost Creek subwatershed is in agricultural land uses. However, as West Lafayette continues to expand west, the subwatershed will continue to urbanize. A portion of the subwatershed lies within the MS4 boundary as designated by the (pink) line in Figure 122. As such stormwater issues are of concern in the Jordan Creek-Lost Creek subwatershed. However, much of the development is as residential land uses rather than commercial land uses, no other point source concerns have been identified within the Jordan Creek-Lost Creek subwatershed.

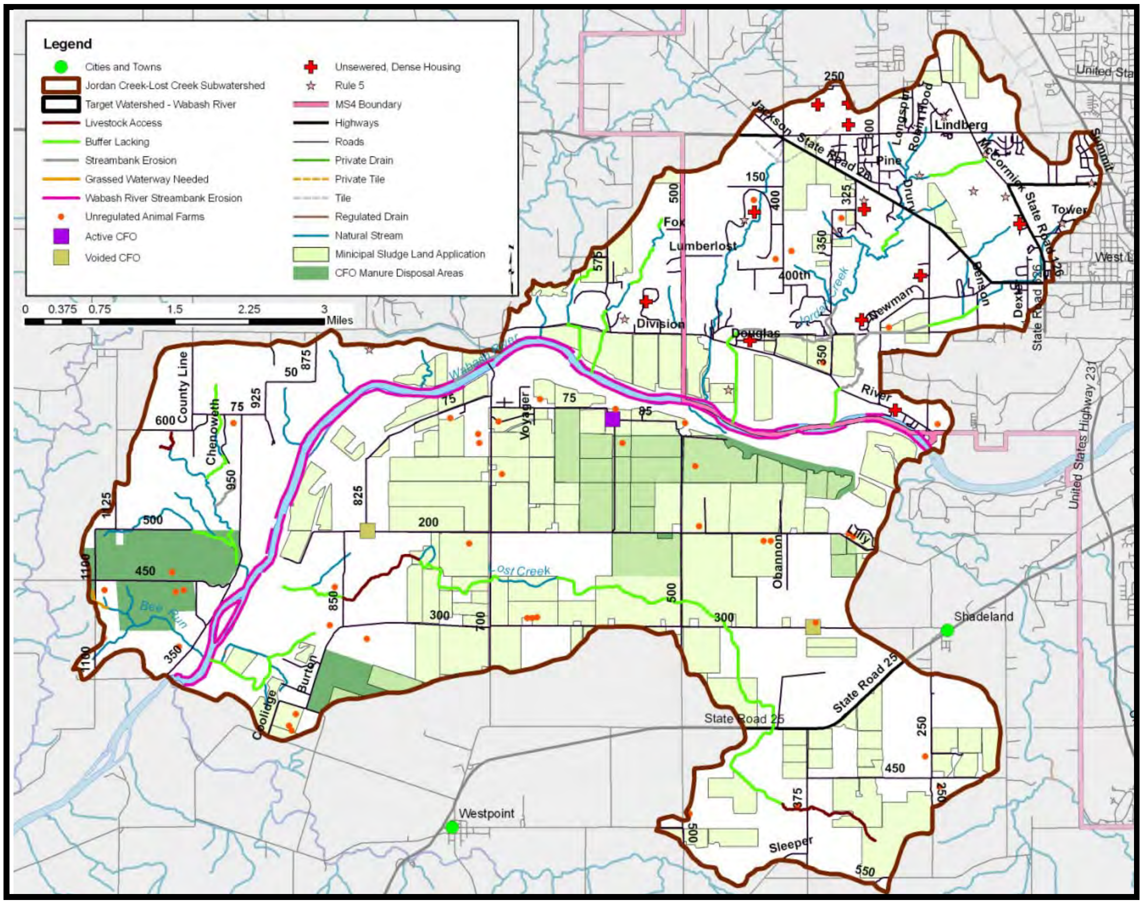

Figure 122. Point and non-point sources of pollution in the Jordan Creek-Lost Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.5.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Jordan Creek-Lost Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. However, a number of hobby farms and pastures are also located within the Jordan Creek-Lost Creek subwatershed (Figure 122). Approximately 570 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to nearly 2.5 miles of stream within the Lost Creek-Jordan Creek subwatershed. One active and two voided confined feeding operations are also present in the subwatershed with the only active CFO located south of the Wabash River east of Granville Bridge. Streambank erosion and stream buffering are also a concern within the subwatershed. Nearly 12.7 miles of streambank are lacking adequate buffers, while 8.5 miles of streambank are eroding. An additional 1,500 feet (0.3 miles) of waterway would benefit from the installation of grassed waterways.

As detailed above, development pressures are relatively high in the Jordan Creek-Lost Creek subwatershed. These pressures are detailed in Figure 122 by the unsewered, dense housing locations and the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) All of these development-based, non-point source locations are concentrated within the MS4 boundary in eastern portion of the subwatershed east of County Road 400 West.

4.5.5 Water Quality Assessment

Waterbodies within the Jordan Creek-Lost Creek subwatershed have been sampled at 17 locations (Figure 123). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (4 sites), the IDEM (1 site), the Tippecanoe County Health Department (2 sites), and via volunteer monitors through the Hoosier Riverwatch program (4 sites). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by the IDEM (1 site), while the fish community has been assessed by Curry and Spacie (2 sites), Fisher et al. (2 sites), the DNR (1 site), and the IDEM (1 site). Ten sites were sampled as part of the Wabash Sampling Blitz and three sites, two biological stations and one chemistry station, are included as part of the current biological sampling effort funding by this project.

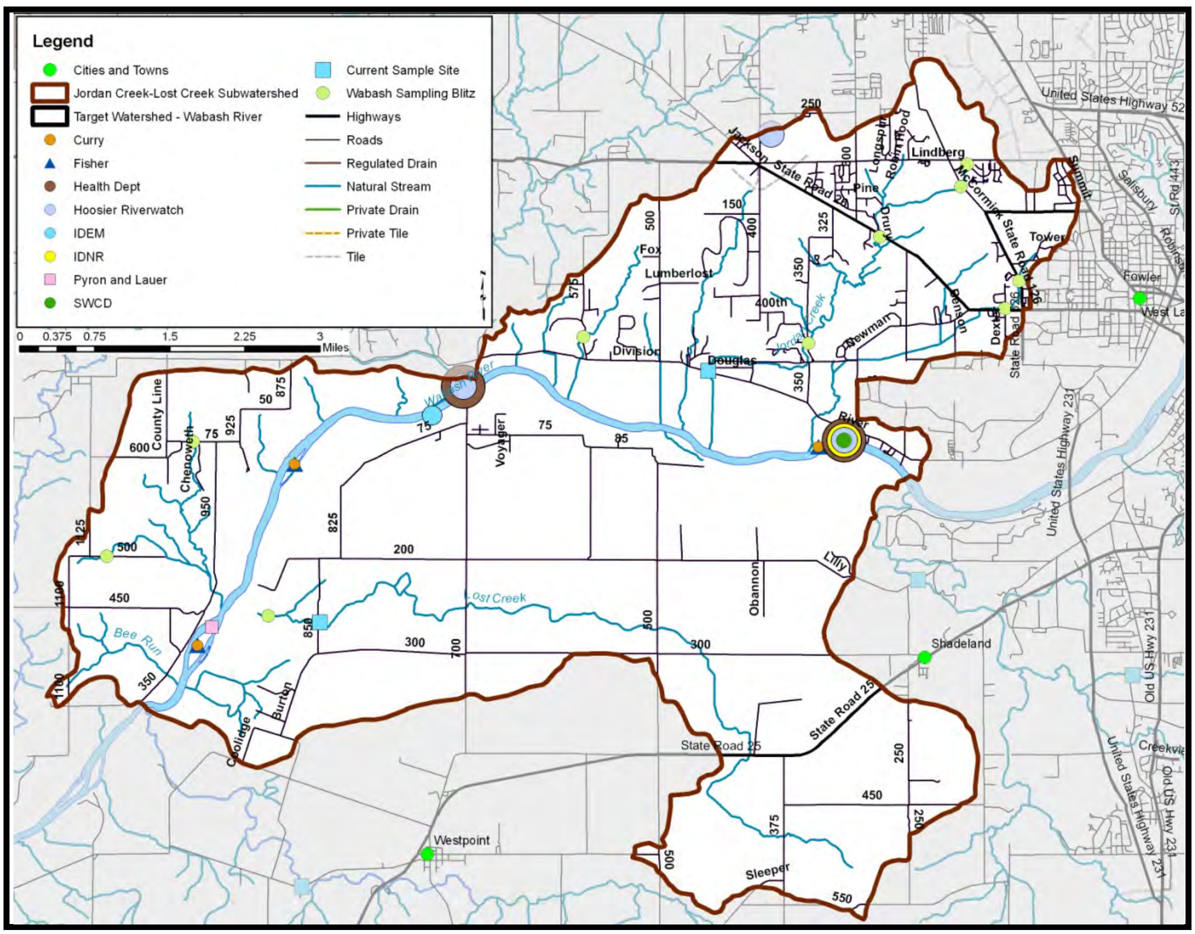

Figure 123. Locations of current or historic water quality data collection in the Jordan Creek-Lost Creek subwatershed.
Data used to create this map are detailed in Appendix A.

Water Chemistry

Water chemistry data collected within the Jordan Creek-Lost Creek subwatershed falls into one of two categories: a singular sampling event, including the Wabash Sampling Blitz, SWCD sampling efforts, or Hoosier Riverwatch sampling, or a long-term monitoring program. Water chemistry samples collected on tributaries to the Wabash River within this subwatershed have only been sampled once. This limits the conclusions that can be drawn based on these data. Nonetheless, sample points suggest the *E. coli* and orthophosphate concentrations exceed the state standard and/or target values. *E. coli* concentrations measured as high as 2,300 colonies/100 mL during a singular sampling event.

The Tippecanoe County Health Department maintains two monitoring stations on the Wabash River at Fort Ouiatenon and at Granville Bridge. Sampling occurs weekly during the growing season. At both locations, all turbidity measurements recorded within this reach of the Wabash River were in excess of 15 NTU with concentrations measuring as high as 120 NTU. Concentrations averaged 35 NTU at Fort Ouiatenon and 59 NTU at Granville Bridge. *E. coli* concentrations were generally in excess of the state standard measuring as high 967 colonies/100 mL during base flow conditions.

The IDEM samples water chemistry at Granville Bridge (County Road 700 West) on a monthly basis. This site also serves as the downstream sampling location for the current project.

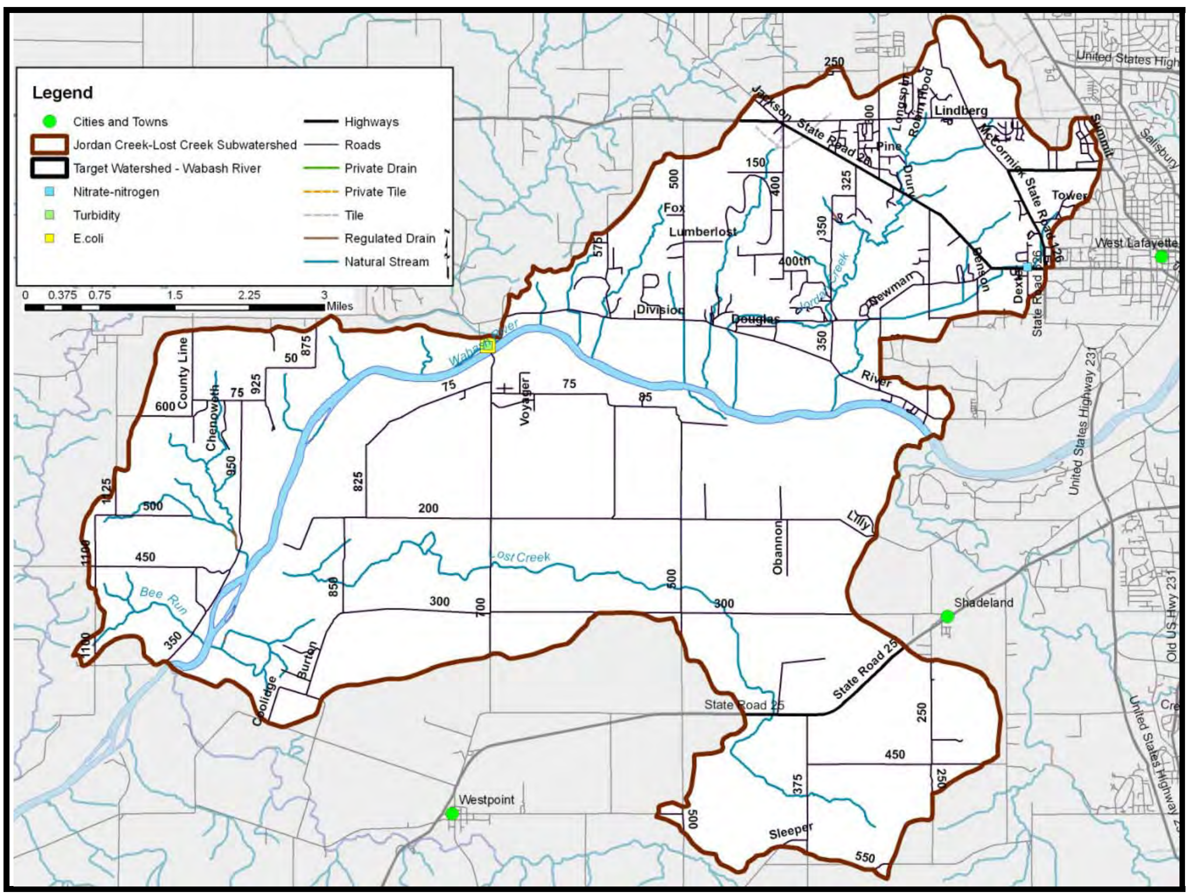

Figure 124. Water quality impairments in the Jordan Creek-Lost Creek subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at one site by the DNR in 1999 at Fort Ouiatenon. As previously detailed, the QHEI scores habitat within a 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. During DNR's assessment, the Fort Ouiatenon reach scored a 49 which indicates moderate habitat quality. Limited substrate, lack of instream cover and riffles, and poor channel development led to low QHEI scores present at this reach during this assessment.

Fish

Ball State University assessed the fish community of the Wabash River within four reaches in the Jordan Creek-Lost Creek subwatershed, while Curry and Spacie (1972) and Fisher et al. (1994) assessed two sites. BSU data indicate that the fish community in the Wabash River rates as fair to good scoring 37-57 using the IBI. Diversity was also good with 14 to 22 species collected within each sampling event.

Macroinvertebrates

The macroinvertebrate community within the Wabash River was sampled once by the IDEM at Granville Bridge in 1999. The macroinvertebrate community rated as moderately impaired scoring 2.8. The community was dominated by *Chironomidae*, a tolerant fly species. Individual metrics indicate low Hilsenhoff Biotic Index (HBI) scores, low numbers of tolerant EPT (*Ephemeroptera, Plecoptera, Trichoptera)* species, and high densities of Chironomidae resulted in poor community metrics.

4.5.6 Jordan Creek-Lost Creek Subwatershed Summary

The Jordan Creek-Lost Creek subwatershed reflects the geological conditions under which this portion of the watershed formed. The Wea Plains covers a majority of this subwatershed. As such, alluvial sands cover much of the watershed. Intermittent tributaries to the Wabash River drain the Jordan Creek-Lost Creek subwatershed with most water entering the Wabash River as groundwater within this subwatershed. Development from the southwestern edge of West Lafayette will likely continue to spread west across this subwatershed. Agricultural row crops and pastures dominate the Jordan Creek-Lost Creek subwatershed. Rating the water quality present in this subwatershed is due to the limited water quality measurements that occurred historically within this subwatershed.

4.6 Indian Creek Subwatershed

Indian Creek drains portions of Tippecanoe County flowing generally southwest from the northwest edge of West Lafayette through properties owned by Purdue University before combining with the Wabash River at Granville Bridge or County Road 700 West (Figure 125). The Indian Creek subwatershed includes one 12-digit HUC watershed – Indian Creek (051201080501) and drains 18,979 acres or 29.6 square miles. In total, 60.3 miles of stream are present within the Indian Creek subwatershed.

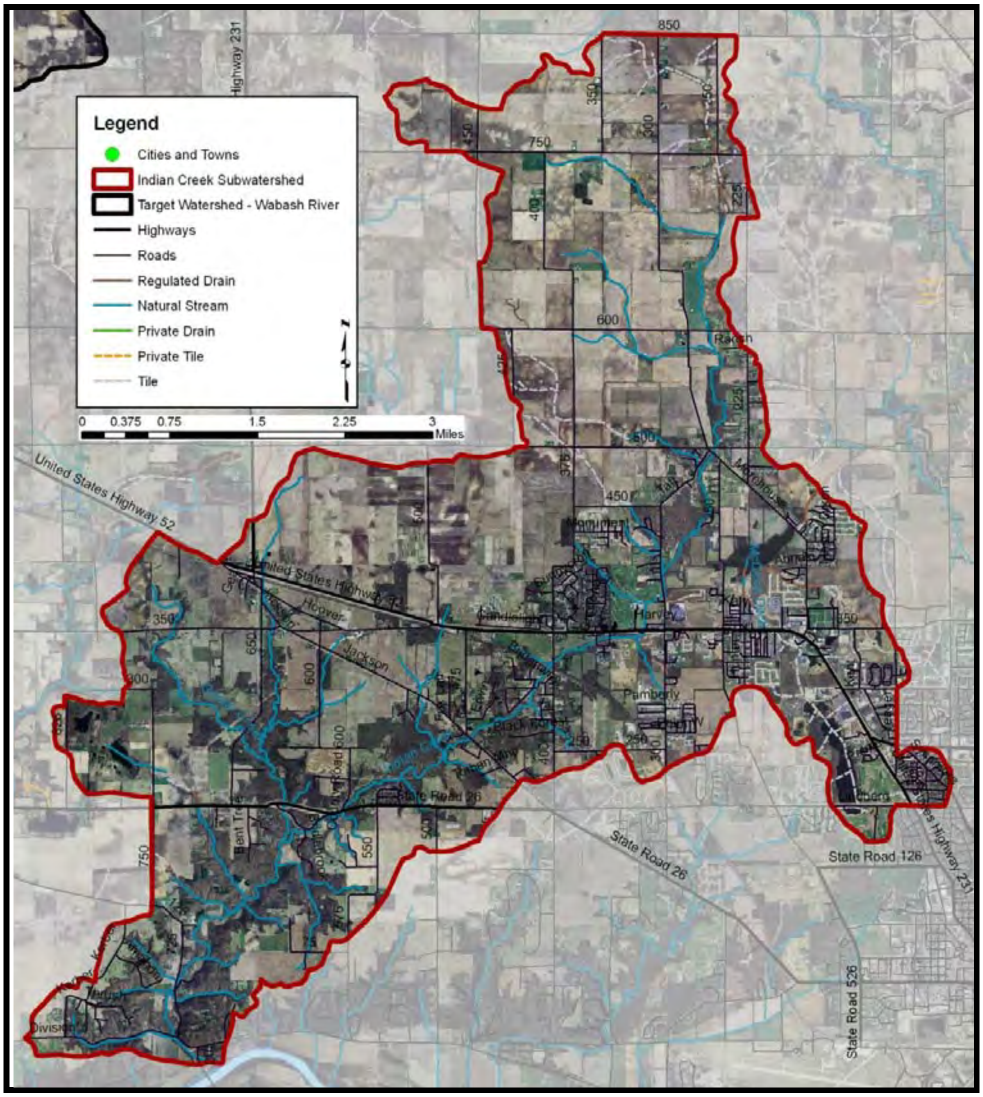

Figure 125. Indian Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.1 Soils

Soils in the Indian Creek subwatershed are dominated by those that are unsuitable for use in septic treatment. Nearly 90% of soils in the Indian Creek subwatershed are rated as severely limited for use in septic treatment. Additionally, soils located on steeply sloped, easily erodible areas prevalent along the length of Indian Creek (Figure 126). Highly erodible soils cover 8.5 square miles or 29% of the Indian Creek subwatershed. This is the highest percent coverage by HES within any of the subwatersheds. An additional 7.7 square miles or 26% of the subwatershed is covered by hydric soils. These soils indicate that much of the headwaters of Indian Creek and areas of the watershed north of US 52 were historically in wetland land uses. Current estimates indicate that wetlands cover approximately 3.5% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Indian Creek subwatershed.

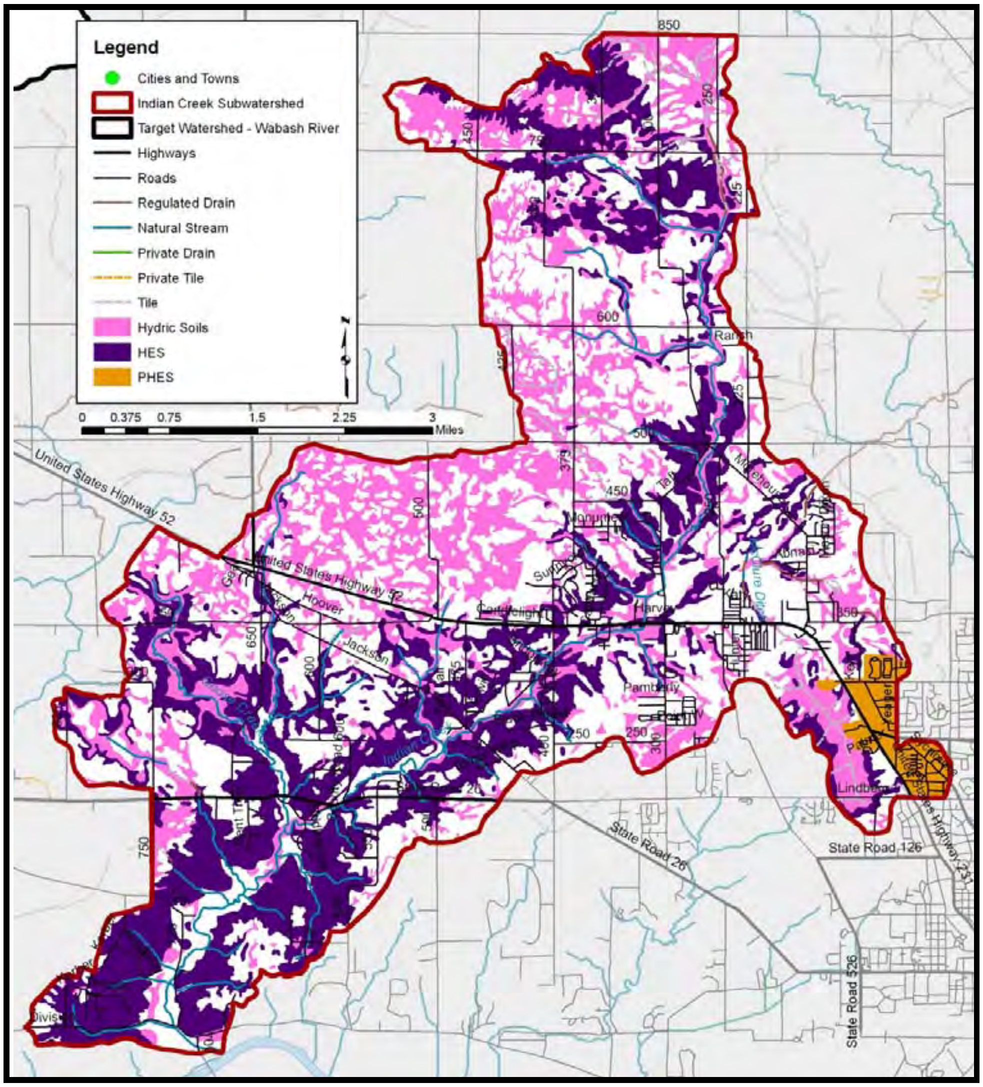

Figure 126. Properties of soils located in the Indian Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.2 Land Use

Agricultural land uses dominate the Indian Creek subwatershed accounting for 62% of land use. Urban land uses including City of West Lafayette account for 14% of the subwatershed land use. Forest and wetland land uses account for 22% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Indian Creek subwatershed.

Continued development is a concern in the Indian Creek subwatershed (Figure 127). When comparing 1992 land cover data to 2002 land cover data, approximately 1.1 square miles of agricultural and forested land were developed during that time period. This represents 8% of the Indian Creek watershed and suggests that residential and commercial development has doubled in the last 15 years. A majority of the development occurred in the southeastern portion of the watershed adjacent to West Lafayette. Despite this increase in development, the Indian Creek subwatershed remains relatively undeveloped with only 3.7% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is a relatively low impervious percentage indicating that runoff from hardscape should not be of great concern in the Indian Creek subwatershed. However, if development continues at a rate of 8% every 10 years, impervious coverage could become an issue.

A large volume of publicly-owned or publicly-accessible lands are present in the Indian Creek subwatershed (Figure 127). The City of West Lafayette, Tippecanoe County, the State of Indiana, Wabash Township, Purdue University, and Purdue Research Foundation all own land in the Indian Creek subwatershed. In total, approximately 5% of the Indian Creek subwatershed are open for public use.

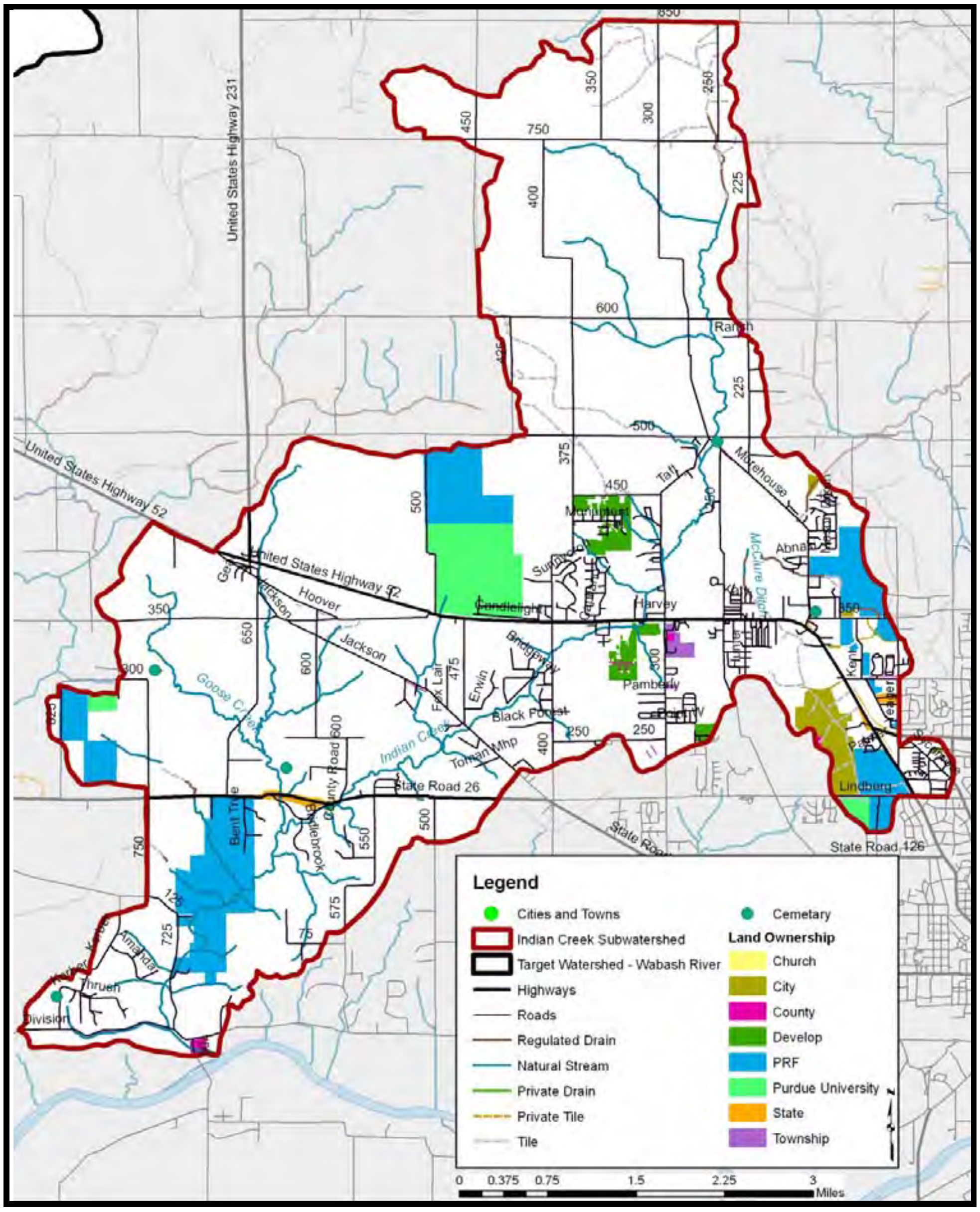

Figure 127. Land ownership and land development in the Indian Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.6.3 Point Source Water Quality Issues

As detailed above, much of the Indian Creek subwatershed is in agricultural land uses. However, as West Lafayette continues to expand, the subwatershed will continue to urbanize. A portion of the subwatershed lies within the MS4 boundary as designated by the (pink) line in Figure 128. Nine leaking underground storage tanks (LUST) are located within the subwatershed generally occurring near US 52. Six industrial waste sites are located within the watershed also occurring within the urban corridor along US 52.

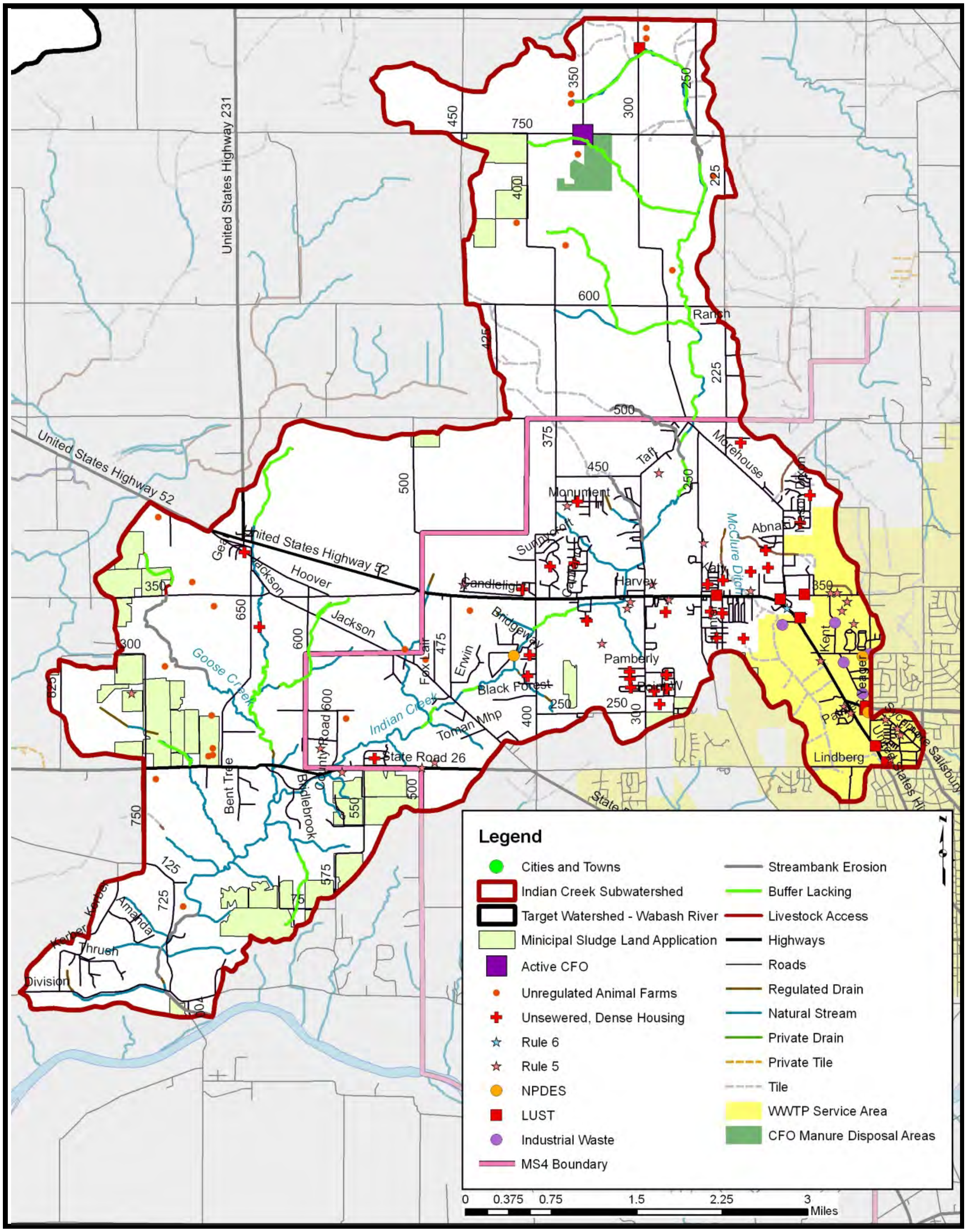

Figure 128. Point and non-point sources of pollution in the Indian Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.6.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Indian Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, a number of hobby farms and pastures are also located within the Indian Creek subwatershed (Figure 128). Approximately 265 cattle, llamas, horses, pigs, and goats are located on small farms throughout the subwatershed. Livestock have access to nearly 0.6 miles of stream within the Indian Creek subwatershed. One confined feeding operation is also present in the subwatershed. Additionally, nearly 32.2 miles of streambank would benefit from the installation of buffers, while 4.7 miles of streambank are eroding.

As detailed above, development pressures are relatively high in the Indian Creek subwatershed. These pressures are detailed in Figure 128 by the unsewered, dense housing locations and the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) All of these development-based, non-point source locations are concentrated within the southeastern portion of the watershed and typically occur within the MS4 boundary.

4.6.5 Water Quality Assessment

Waterbodies within the Indian Creek subwatershed have been sampled at approximately 25 locations (Figure 129). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (5 sites), the Purdue University Little Pine-Indian Watershed Pilot Project (8 sites), and via volunteer monitors through the Hoosier Riverwatch program (2 sites). The fish community has been assessed by Curry and Spacie (3 sites), Rich (3 sites), and Fisher et al. (4 sites). Mussel surveys were completed by Myers-Kinzie at four sites throughout the subwatershed. Thirteen sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological sampling effort funding by this project. No stream gages are currently located in the Indian Creek subwatershed; however, a gage operated within the watershed from 1990 through 2002.

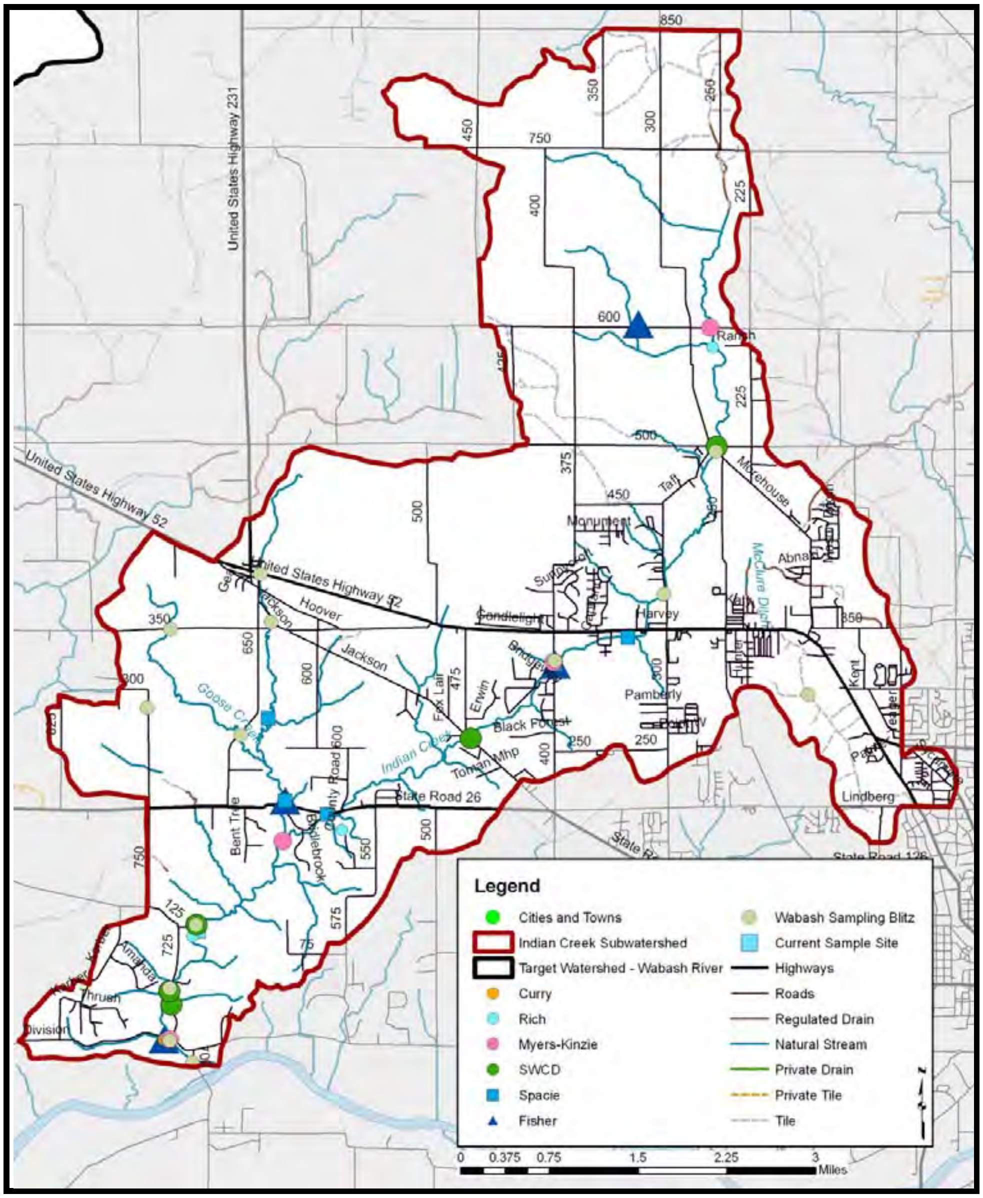

Figure 129. Locations of current or historic water quality data collection in the Indian Creek subwatershed. Data used to create this map are detailed in Appendix A.

Water Chemistry

Limited conclusions can be drawn from the available water chemistry data within the Indian Creek subwatershed. Indian Creek was sampled weekly from 1990 through 2002 as part of the Little Pine-Indian Watershed Pilot Project. Sites were sampled 34 to 173 times over the 12-year sampling period. All other water chemistry data collected within the Indian Creek subwatershed represent singular grab samples. Based on those data, several parameters are suggested to be of concern including nitrate-nitrogen, orthophosphate, total phosphorus, total suspended solids, and *E. coli* (Figure 130). *E. coli* concentration exceeded the state standard in Marshall Ditch and in Indian Creek at Jackson Highway with concentrations exceeding 2,420 colonies/100 mL. Nitrate-nitrogen concentrations exceeded the target concentration in Goose Creek at County Road 650 West and at State Road 26, in Indian Creek at County Road 500 North, Klondike Road, County Road 400 West, Jackson Highway, State Road 26, Martell Forest, and County Road 600 North, and in an unnamed tributary to Indian Creek at County Road 750 West. Orthophosphate concentrations also measured in excess of the target concentration in Goose Creek at US 52 and at County Road 350 North. Total suspended solids concentrations exceeded the target concentration in Indian Creek at County Road 500 North, at Klondike Road, at County Road 400 West, at Jackson Highway, at State Road 26, at Martell Forest, and at County Road 600 North and in Goose Creek at State Road 26.

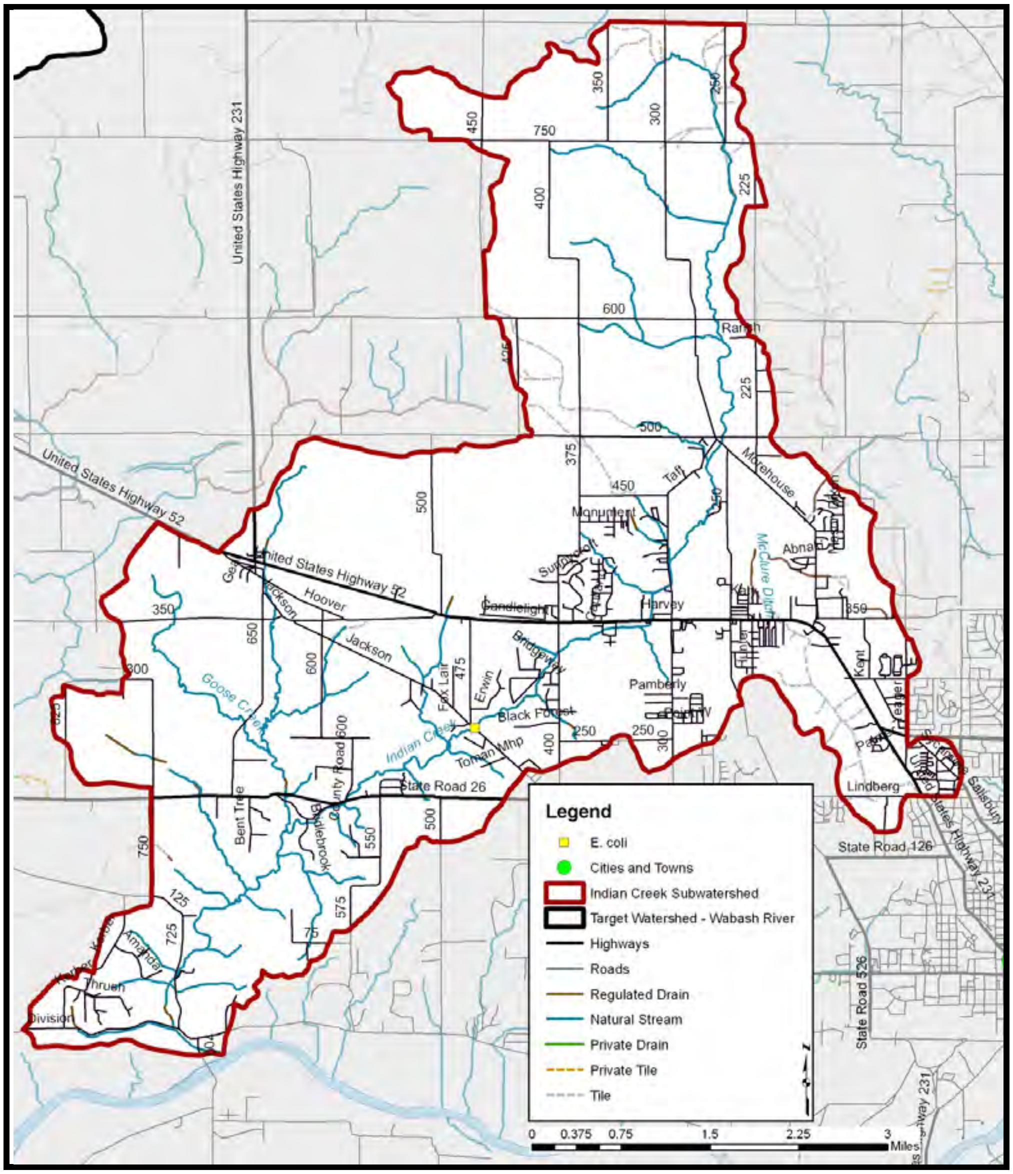

Figure 130. Water quality impairments in the Indian Creek subwatershed.
Data used to create this map are detailed in Appendix A.

Habitat

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at six sites during two assessments. Myers-Kinzie completed four assessments of habitat using the QHEI within the Indian Creek subwatershed, while Rich assessed habitat using the QHEI at three sites while assessing fish communities in Indian Creek. Purdue University assessed habitat once during the current water quality sampling program. Myers-Kinzie assessed habitat in 1994, while Rich completed his assessment in 1999. All assessments occurred along the mainstem of Indian Creek with data suggesting an improvement in habitat quality from 1994 to 1999. All four 1994 assessments scored 50 or fewer points. Sites generally lacked instream cover, riparian quality, and pool-riffle complex development. These scores indicate that habitat in Indian Creek at County Road 400 West, at County Road 600 North, at the Goose Creek confluence, and at Division Road did not meet its aquatic life use designation. Habitat assessment at County Road 600 North in 1999 suggests a modest improvement in habitat quality. Additionally, downstream reaches of Indian Creek rated high quality habitat in 1999 with sites scoring 80 and 84 points respectively at the mouth of Indian Creek at and State Road 26.

Three Purdue field personnel conducted QHEI assessments during the June 2010 fish sampling event, and the mean of those scores was calculated to assign a QHEI score for the survey site. Indian Creek at Martell Forest had the highest mean QHEI score among all the streams assessed in 2010. The mean QHEI score was 76 with substrate (16), cover (15), and channel (16) among the highest scoring categories.

Fish

Curry and Spacie (1972) and Fisher et al. (1994) assessed the fish community at three and four sites, respectively. Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). A fish IBI score was calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 10; Sample II – July 20; Sample III – September 16; and Sample IV – November 6. The 2010 samples were collected as follows: Sample V – March 19; Sample VI – June 21; Sample VII – August 11; and Sample VIII – October 31. The mean IBI score for Indian Creek at Martell Forest was 45 and this was among the highest scores for all the 2009-2010 samples. The fish samples at this site were primarily composed of central stonerollers (1562), mottled sculpin (1269) western blacknose dace (1030), and creek chub (585).

Macroinvertebrates

Indian Creek at Martell Forest was sampled four times in 2009 and four times in 2010. Mean mIBI and mean HBI scores for Indian Creek at Martell Forest were 4.2 and 5.2, respectively. mIBI scores ranged from 3.4 during the June 2009 assessment to 5.0 during the September 2010 assessment. The site is slightly impaired with Chironomidae (3766 total individuals), Hydropsychidae (1486), Baetidae (701), and Simuliidae (671) dominating the macroinvertebrate community.

Mussels

Myers-Kinzie assessed the mussel community at four locations with the Indian Creek subwatershed. During the surveys, no species were identified in any form.

4.6.6 Indian Creek Subwatershed Summary

The Indian Creek subwatershed shows symptoms of increased development and future development pressures indicate that these issues will become more pronounced over time. The headwaters of Indian Creek include the western edge of West Lafayette including portions of Purdue University's campus. Subdivisions developed outside of the sewer lines, recent development, and agricultural pressures in the northern portion of the watershed likely affect water quality conditions in Indian Creek. As observed in other subwatersheds, Indian Creek contains relatively flat headwaters with increasing gradients and soil erodibility occurring as water moves south toward the Wabash River. Relatively large portions of the subwatershed are also publicly owned, presenting both unique opportunities to address water quality concerns with relatively few entities and unique issues associated with addressing these issues. Due to its proximity to Purdue University, Indian Creek has been well studied for years. Water quality data indicate relatively high quality habitat, fish communities, and macroinvertebrate communities with few observations of water chemistry in excess of target concentrations.

4.7 Flint Creek Subwatershed

Flint Creek is the only western flowing tributary to the Wabash River draining portions of Warren and Tippecanoe counties. The Flint Creek subwatershed forms the southwestern edge of the Region of the Great Bend of the Wabash River watershed (Figure 131). The Flint Creek watershed includes two 12-digit HUC watersheds – Flint Run-Flint Creek (HUC 051201080504) and Flint Creek-Wabash River (HUC 051201080507) and drains 29,232 acres or 45.6 square miles. In total, 86 miles of stream are present within the Flint Creek subwatershed. Of these, approximately 5.2 miles are considered impaired dissolved oxygen and nutrients.

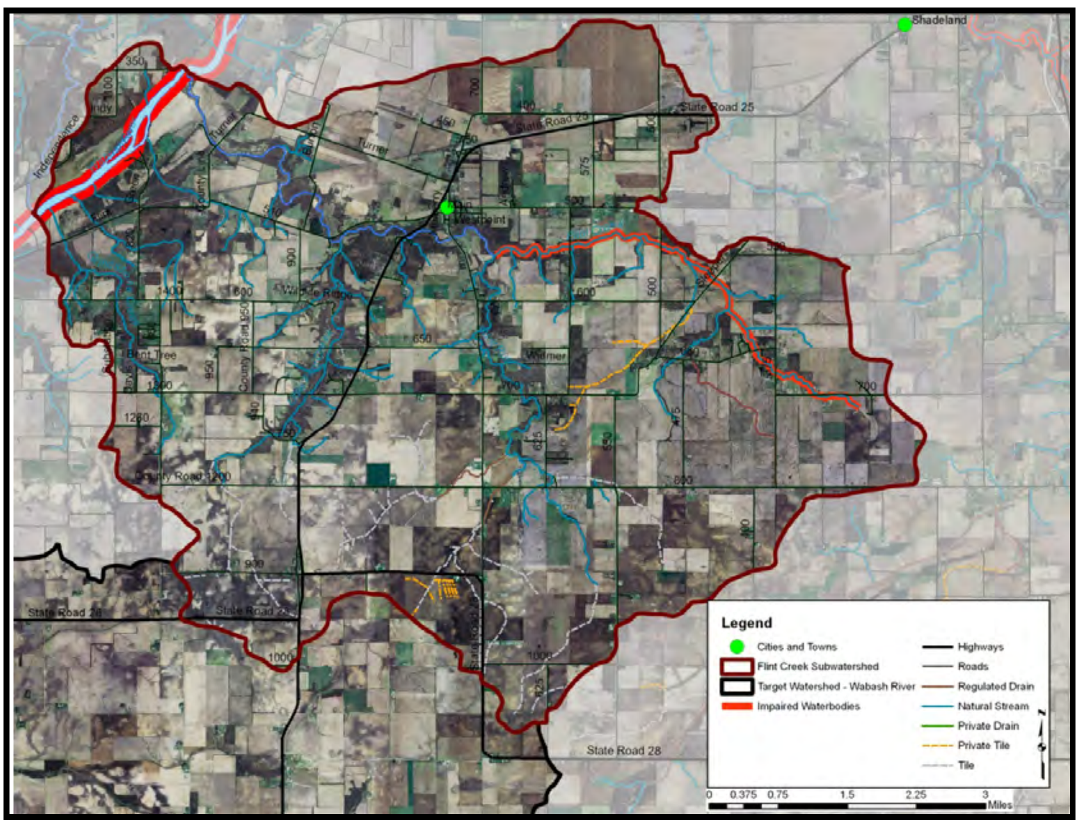

Figure 131. Flint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.1 Soils

Soils in the Flint Creek subwatershed are dominated by those that are not suited for use in treating septic tank effluent. Additionally soils located on steeply sloped, easily erodible areas or highly erodible soils cover 8.5 square miles or 18.6% of the Flint Creek subwatershed (Figure 132). Potentially highly erodible soils cover 1 square mile or 2.3% of the Flint Creek subwatershed. HES and PHES combined cover the lowest percentage of any subwatershed within the Region of the Great Bend of the Wabash River watershed. A majority of these easily erodible soils are located adjacent to the mainstem of Flint Creek and along Flint Run. An additional 15.1 square miles or 33% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of Flint Creek were historically in wetland land uses. Current estimates indicate that wetlands cover approximately 2.95% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Flint Creek subwatershed.

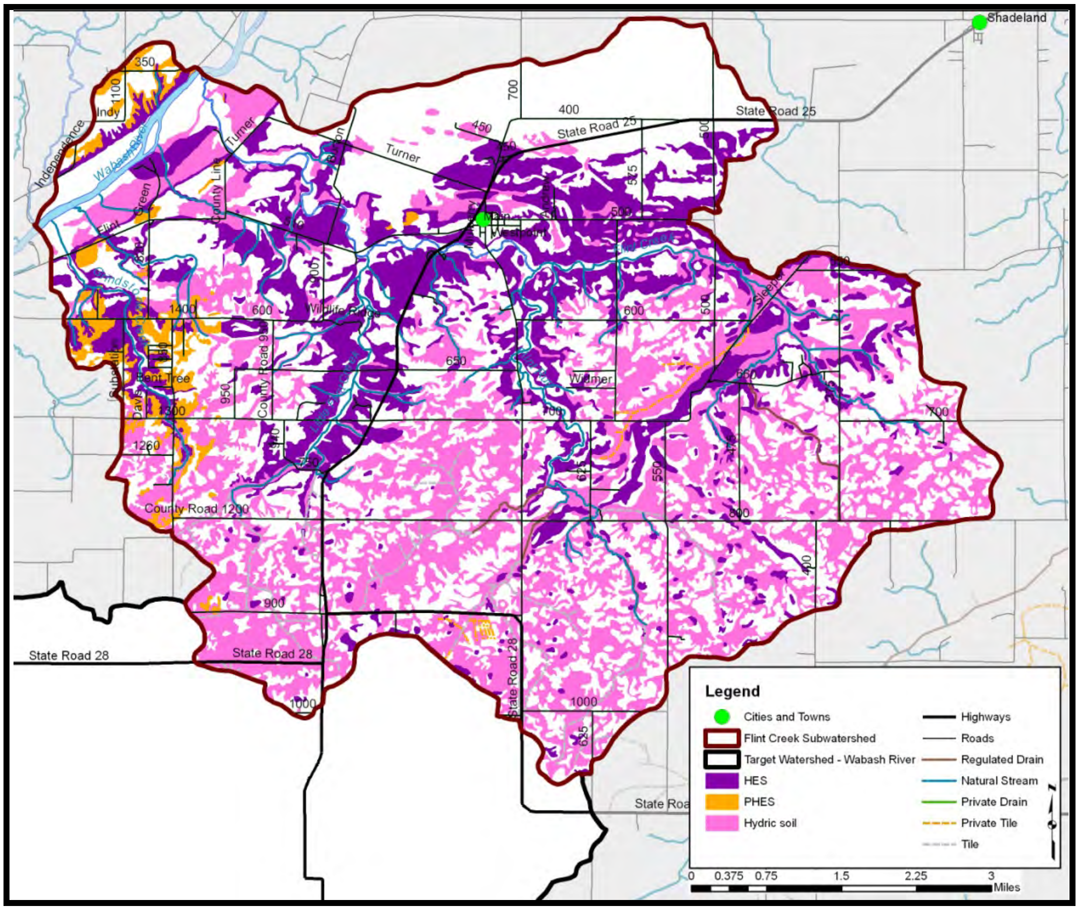

Figure 132. Properties of soils located in the Flint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.2 Land Use

Agricultural land uses dominate the Flint Creek subwatershed accounting for 80% of land use. Urban land uses including the Town of West Point and along the State Road 25 corridor account for 5% of the subwatershed land use. Forest and wetland land uses account for 14% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Flint Creek subwatershed.

Continued development is not a concern in the Flint Creek subwatershed. When comparing 1992 land cover data to 2002 land cover data, approximately 0.4 square miles of agricultural and forested land were developed during that time period. This represents 0.8% of the Flint Creek watershed – the lowest development rate of any of the subwatersheds. Overall, Flint Creek's subwatershed remains relatively undeveloped with only 0.4% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is a very low impervious percentage indicating that runoff from hardscape should not be of great concern in the Flint Creek subwatershed.

4.7.3 Point Source Water Quality Issues

As detailed above, much of the Flint Creek subwatershed is in agricultural land uses. Despite the low urban development, a few point sources are still present within the subwatershed. These include one leaking underground storage tank and one open dump site. The tank is located within West Point while the open dump occurs on an unnamed tributary to the Wabash River in Warren County.

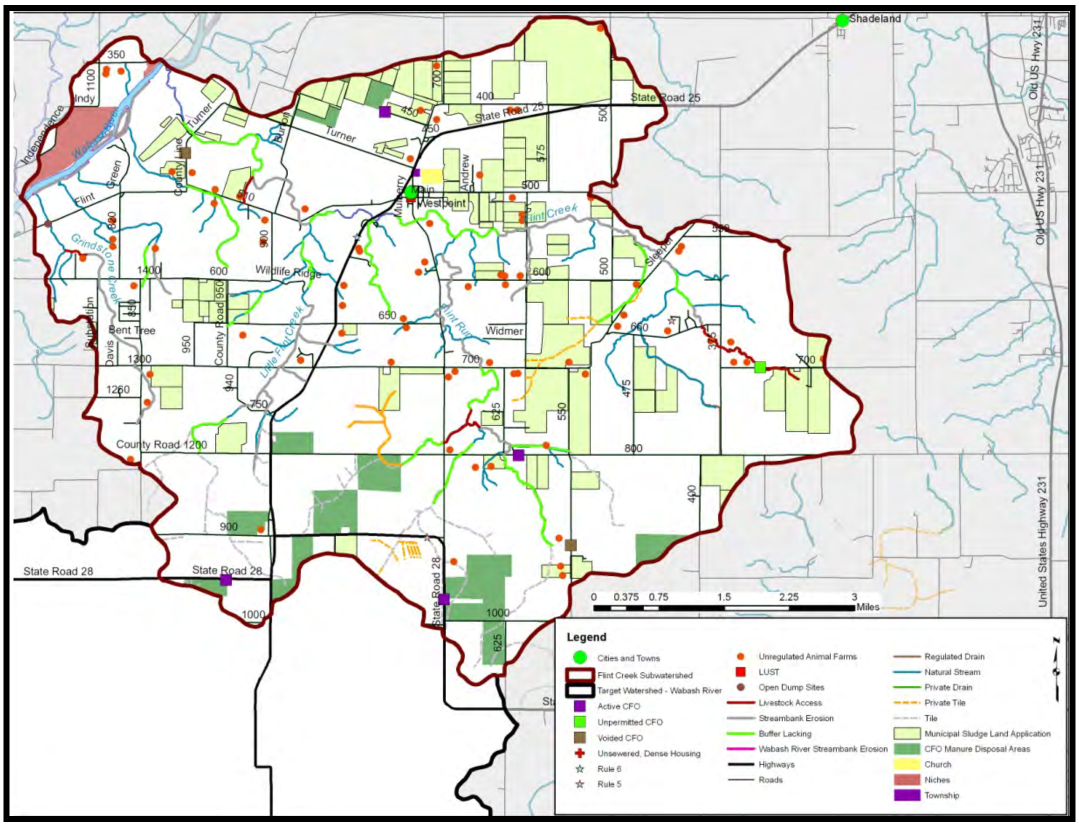

Figure 133. Point and non-point sources of pollution and land ownership in the Flint Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.7.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Flint Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, nearly 80 hobby farms are also located within the Flint Creek subwatershed (Figure 133). Approximately 675 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to nearly 3 miles of stream within the Flint Creek watershed. Nine confined feeding operations are also present in the subwatershed with the six active, two voided, and one unpermitted CFOs are located throughout the subwatershed. Additionally, approximately 47.4 miles of streambank would benefit from buffer installation, while 4.2 miles of streambank require stabilization. An additional 1.9 miles of waterway would benefit from the installation of grassed waterways.

As detailed above, development pressures are low in the Flint Creek subwatershed. However, modest development has occurred with two Rule 5 and one Rule 6 permitted areas within the Flint Creek subwatershed. These pressures are detailed in Figure 133 the Rule 5 and Rule 6 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process. Rule 6 projects are those locations where individual stormwater permits are held.) All of these development-based, non-point source locations are concentrated along the State Road 25 corridor.

4.7.5 Water Quality Assessment

Waterbodies within the Flint Creek subwatershed have been sampled at approximately 20 locations (Figure 134). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (3 sites), the IDEM (11 sites), and via volunteer monitors through the Hoosier Riverwatch program (11 sites). The fish community has been assessed by Curry and Spacie (2 sites), Fisher et al. (3 sites), and the IDEM (1 site). Mussel surveys were completed by Myers-Kinzie at three sites throughout the subwatershed. Eight sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological sampling effort funding by this project. No stream gages are located in the Flint Creek subwatershed.

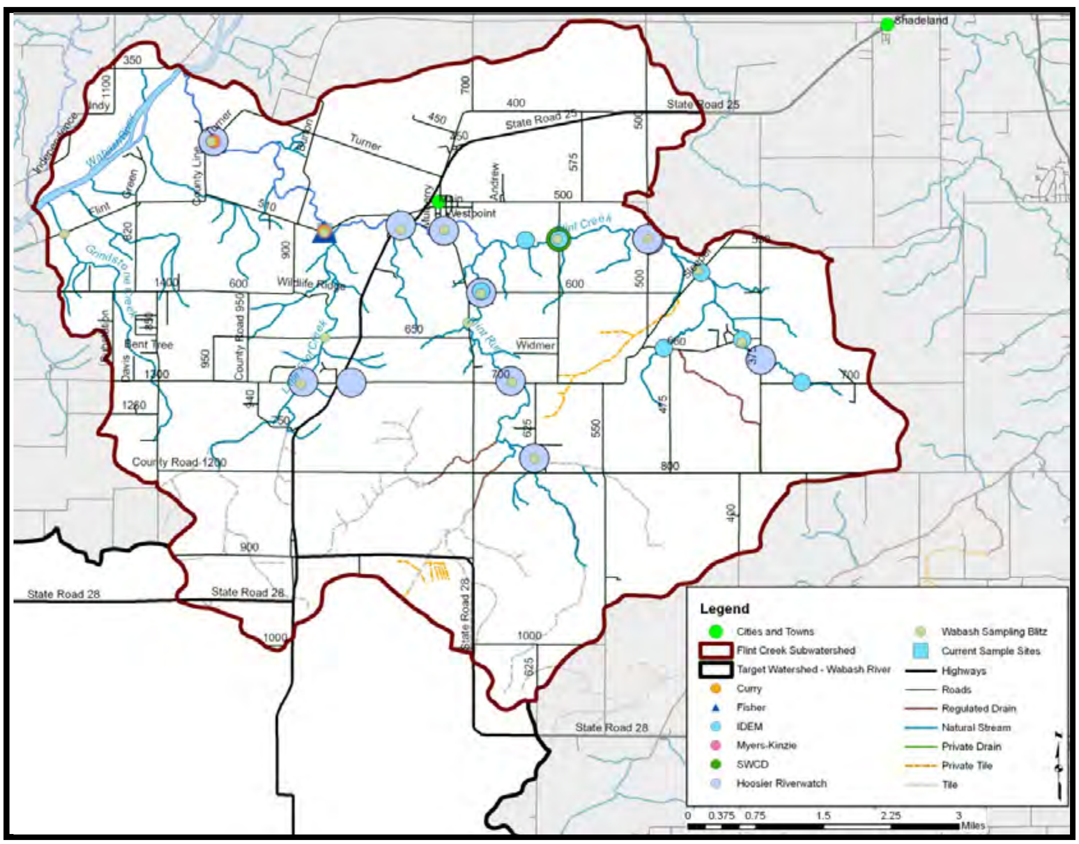

Figure 134. Locations of current or historic water quality data collection in the Flint Creek subwatershed. Data used to create this map are detailed in Appendix A.

Water Chemistry

Water chemistry data collected from the Flint Creek subwatershed suggest several parameters of concern including: orthophosphate and total phosphorus, turbidity and suspended solids, dissolved oxygen, and *E. coli* (Figure 135). Total phosphorus concentrations were elevated in Flint Creek at Sleeper Road, County Road 700 West, County Road 660 South, County Road 600 West, and County Road 500 West and in Flint Run at County Road 700 South. *E. coli* concentrations in excess of the state standard occurred during more than 50% of sampling events in Flint Creek at County Road 400 West, County Road 700 South, and Turner Road. Concentrations measured as high as 3,500 colonies/100 mL. Undersaturated conditions were observed in Flint Creek at County Road 700 South and at County Road 375 West. Dissolved oxygen saturations measured between 45 and 55% at both sites during multiple sampling events. Turbidity routinely measured higher than the target concentration at all sites where observations occur. This suggests that Flint Creek may contain a high background suspended sediment concentration or that the high sinuosity and prevalence of easily erodible soils results in elevated suspended sediment concentrations on a routine basis.

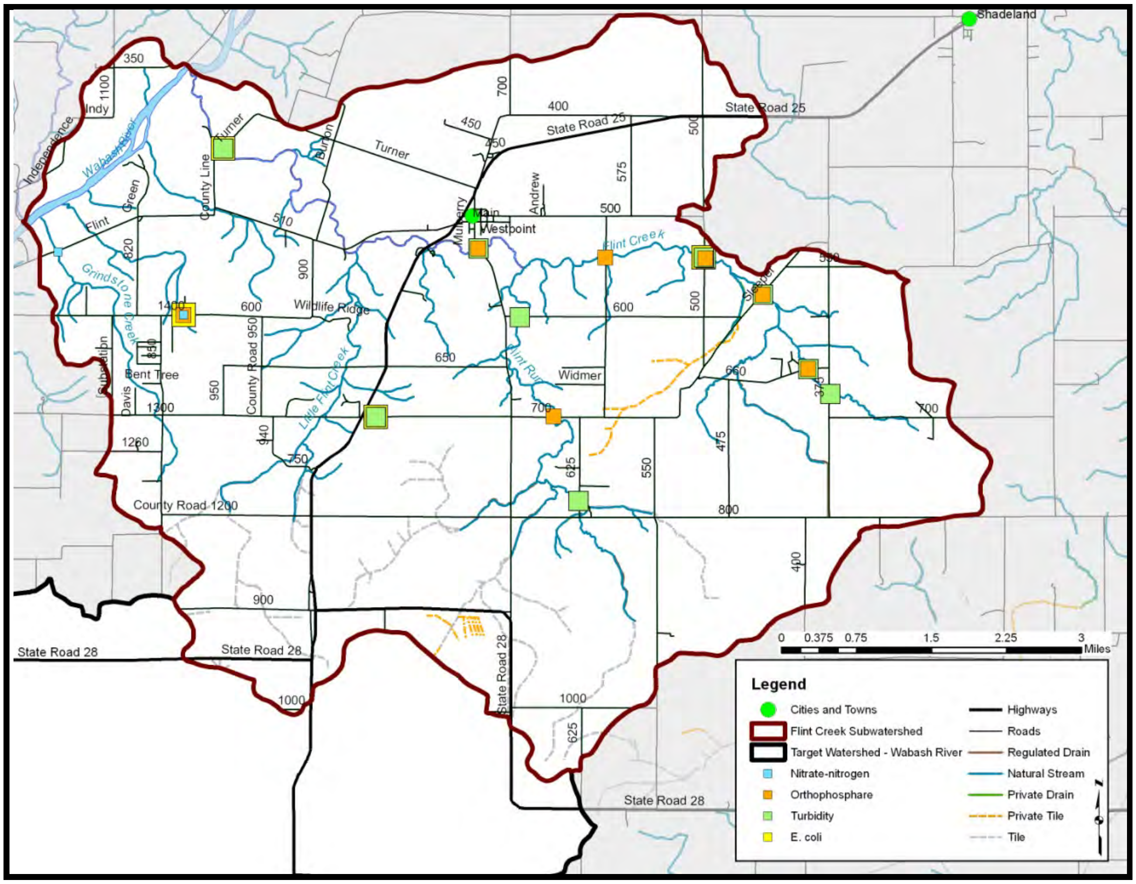

Figure 135. Water quality impairments in the Flint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

Habitat

Volunteer monitors assessed habitat at nine sites within the Flint Creek subwatershed using the Citizen's Qualitative Habitat Evaluation Index (CQHEI). As previously detailed, the CQHEI scores sites based on the presence or absence of specific natural characteristics within a stream reach. Although a comparison scale for the CQHEI has not yet been developed, Hoosier Riverwatch indicates that scores greater than 60 rate as habitat conducive to supporting warm-water biota (IDNR, 2004). Scores ranged from 40.5 at County Road 700 South (west of SR 25) to 75.5 at County Road 700 South (SR 25). Volunteer assessments of Flint Creek at County Road 700 South (west of SR 25), County Road 375 West, and County Road 700 South (west of CR 700 West) indicate that habitat rated poorer than the level at which habitat is conducive to supporting warm-water biota. These reaches received low scores for fish habitat and for riffle-run development.

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at one site during the 1999 fish community assessment. As previously detailed and similarly to the CQHEI, the QHEI scores habitat within a 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. The score (53) indicates good quality habitat that is fully in support of the streams designated aquatic life use. Poor substrate, instream habitat, and pool-riffle complex development scores indicate that habitat could be improved.

Three Purdue field personnel conducted QHEI assessments during the June 2010 fish sampling, and the mean of those scores was calculated to assign a QHEI score for the surveyed site. Flint Creek at County Road 510 South had a mean QHEI score of 61.5 which indicates that the stream meets its aquatic life use. Improving instream cover (8) and adjacent riparian (5.5) would increase the QHEI scores.

Fish

The IDEM assessed the fish community once during 1999 at County Road 600 South, while Curry and Spacie (1972) and Fisher et al. (1994) assessed two and three sites, respectively. IDEM data indicate that the fish community in Flint Creek rates as good scoring 36 using the IBI. At the time of the assessment, the community was limited by the number of minnow and sensitive species with low density and diversity of fish species.

Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). A fish IBI score was calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 18; Sample II – July 22; Sample III – September 23; and Sample IV – November 5. The 2010 samples were collected as follows: Sample V – March 20; Sample VI – June 18; Sample VII – August 11; and Sample VIII – October 31. The mean IBI score for 2009-2010 was 45. The June 2010 sample (36) was considerably lower than any of the other samples (50, 48, 46, 52, 40, 48, and 46). The dominant species included central stonerollers (1150), mottled sculpin (425), western blacknose dace (236), and rainbow darters (200) present within Flint Creek.

Macroinvertebrates

Flint Creek at County Road 510 South was sampled four times in 2009 and four times in 2010. Mean mIBI and mean HBI scores for Flint Creek were 5.3 and 4.1, respectively. The mIBI score ranged between 3.4 during the November 2009 assessment and 6.4 during the October 2010 assessment indicating that the site is slightly impaired. Flint Creek rated the highest quality macroinvertebrate community monitored. The HBI score supports this and was the lowest of all 10 sites sampled in the 2009-2010 sampling. Dominant taxa at Flint Creek include Hydropsychidae (1828 total individuals), Baetidae (1114), Chironomidae (834), Isonychiidae (494), and Heptageniidae (412). Abundances of aquatic macroinvertebrates were relatively high and 5 of the 7 most abundant species are considered Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa.

Mussels

Myers-Kinzie assessed the mussel community at three locations within the Flint Creek subwatershed. During the surveys, two species were identified at one site. Both species, the cylindrical papershell (*Alasmindonta viridis)* and slippershell (*Anodontoides ferussacianus)* were weathered dead shells. Both species are headwaters species typical of small streams and rivers.

4.7.6 Flint Creek Subwatershed Summary

The Flint Creek subwatershed is dominated by agricultural land uses. These lands lie on relatively flat soils with much of the headwaters covered by hydric soils. The mainstem of

Flint Creek is unique to the watershed with shale and cobble dominating the substrate. The habitat scores reflect the unique conditions present within the streams; however, biological community scores indicate that elevated *E. coli*, suspended sediments, and nutrients may inhibit conditions within the Flint Creek watershed. As development and urban land uses are not influences on the Flint Creek subwatershed, addressing narrow buffer strips, livestock access, and streambank erosion concerns throughout the watershed is necessary to improve conditions within Flint Creek.

4.8 Little Pine Creek Subwatershed

Little Creek forms a portion of the northwestern watershed boundary draining portions of Warren, Benton, and Tippecanoe counties. The Little Pine Creek subwatershed includes two 12-digit HUC watersheds – Otterbein Ditch-Little Pine Creek (HUC 051201080505) and Armstrong Creek-Little Pine Creek (HUC 051201080506; Figure 136). In total, Little Pine Creek drains 33,316 acres or 52.1 square miles. In total, 91.5 miles of stream are present within the Little Pine Creek subwatershed. Of these, approximately six miles from just downstream of Green Hill to Little Pine Creek's confluence with the Wabash River are considered high quality or outstanding waters.

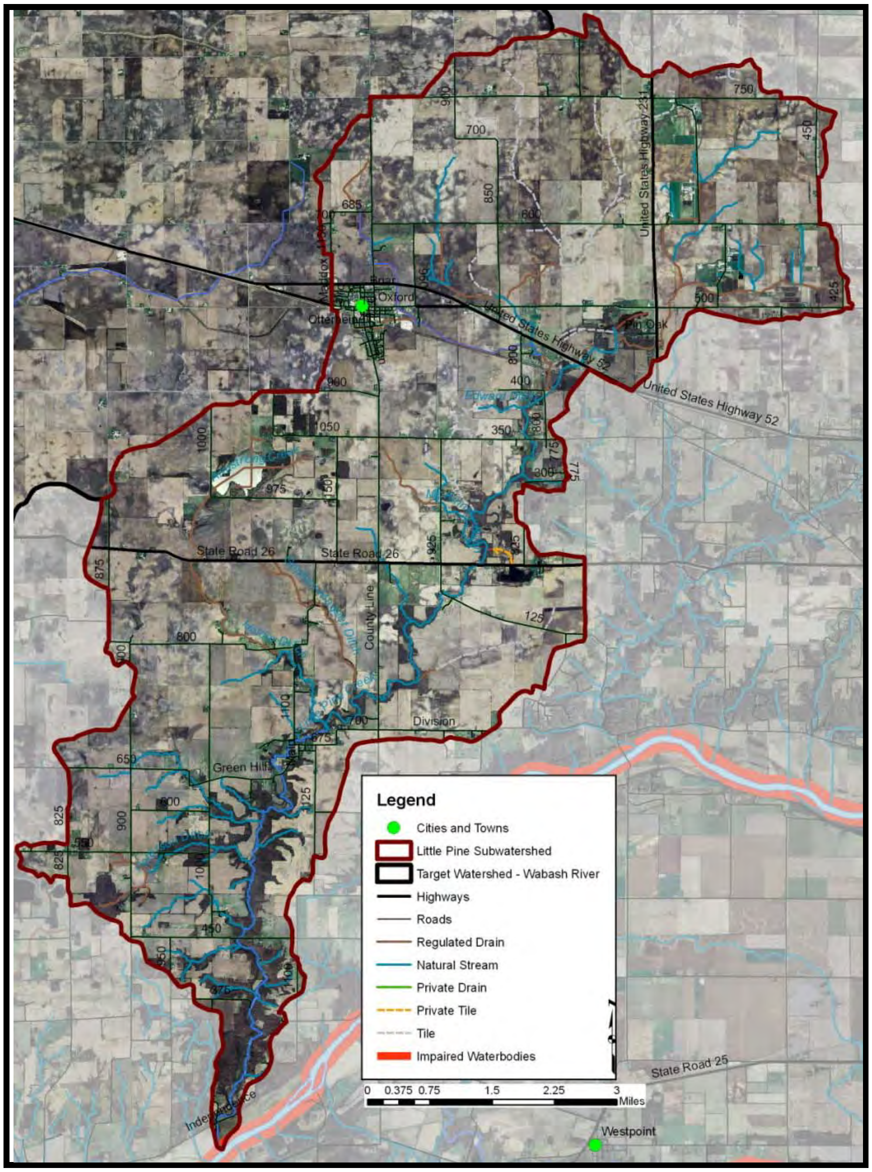

Figure 136. Little Pine Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.1 Soils

Soils in the Little Pine Creek subwatershed are dominated by those that are unsuitable for use in septic treatment. Additionally, soils located on steeply sloped, easily erodible areas cover 4.4 square miles while those considered potentially highly erodible cover an additional 7 square miles (Figure 137). In total, nearly 35% of the watershed is considered highly erodible or potentially highly erodible. A majority of highly erodible soils are located along the lower portion of Little Pine Creek in Tippecanoe County, while potentially highly erodible soils border Little Pine Creek within Warren County. An additional 15.8 square miles or 30% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of Little Pine Creek were historically in wetland land. Current estimates indicate that wetlands cover approximately 3.1% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Little Pine Creek subwatershed.

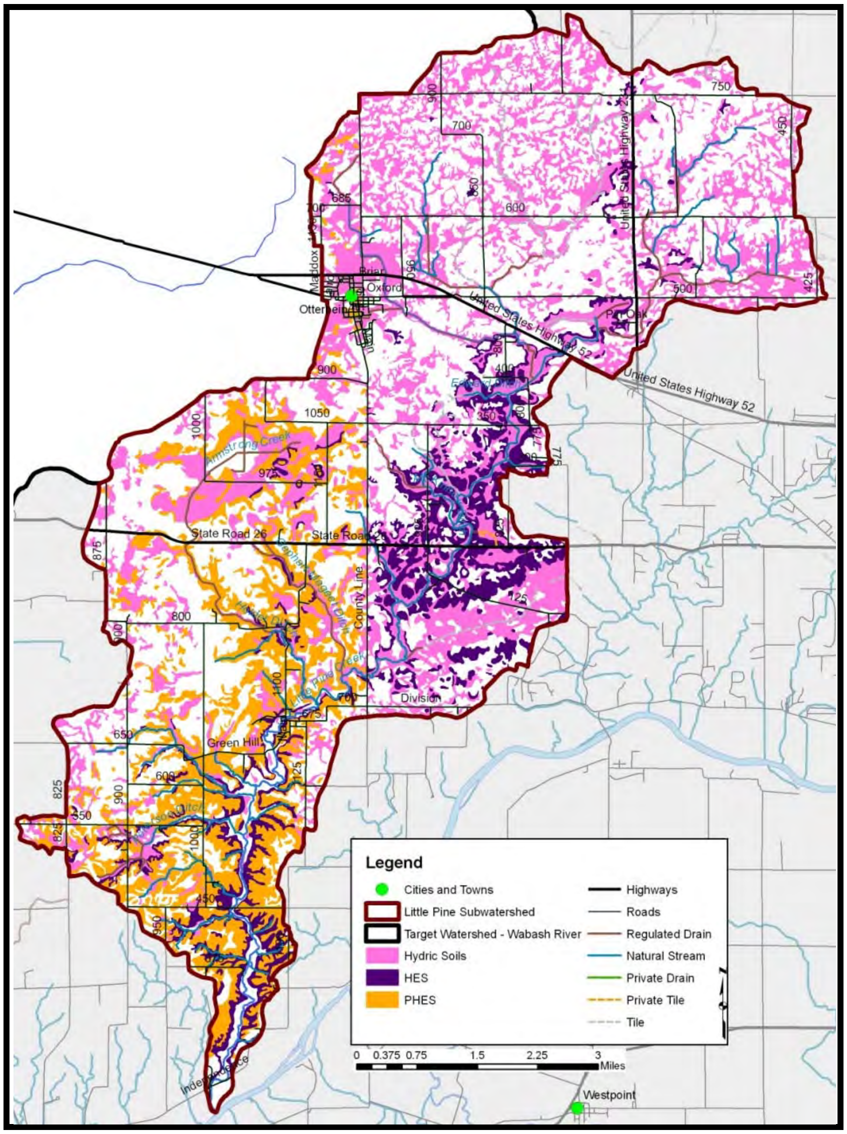

Figure 137. Properties of soils located in the Little Pine Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.8.2 Land Use

Agricultural land uses dominate the Little Pine Creek subwatershed accounting for 84% of land use. Urban land uses including the towns of Otterbein, Green Hill, and Armstrong account for 5.5% of the subwatershed land use. Forest and wetland land uses account for 10% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Little Pine Creek subwatershed.

Continued development is of little concern in the Little Pine Creek subwatershed with no observable development occurring between 1992 and 2002. No observable plans for development were identified during the watershed inventory. Additionally, the Little Pine Creek subwatershed remains relatively undeveloped with only 0.8% of the subwatershed covered by impervious surfaces. Compared to estimates from the Center for Watershed Protection (CWP), this is a low impervious percentage indicating that runoff from hardscape should not be of great concern in the Little Pine Creek subwatershed. A large volume of publicly-owned or publicly-accessible lands are present in the Little Pine Creek subwatershed (Figure 138). NICHES Land Trust, Purdue Research Foundation, and Purdue University own land in the Indian Creek subwatershed. Additionally, three cemeteries and 2 churches are located within the subwatershed. In total, approximately 8% (4.7 square miles) of the Little Pine Creek subwatershed are open for public use.

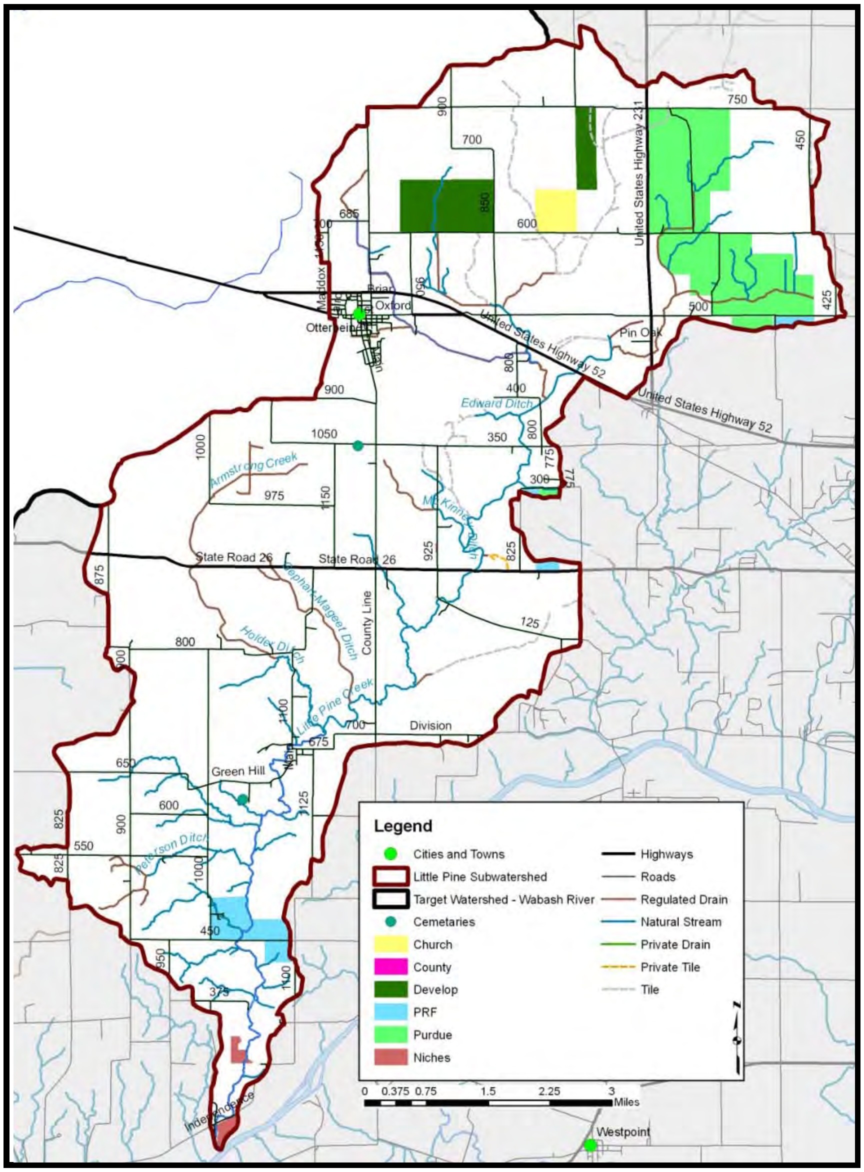

Figure 138. Land ownership and land development in the Little Pine Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.8.3 Point Source Water Quality Issues

As detailed above, much of the Little Creek subwatershed is in agricultural land uses with urban land uses limited to the towns of Otterbein, Green Hill, and Armstrong. One NPDES-permitted facility is located within the subwatershed serving the wastewater needs of Otterbein residents (Figure 139). The facility's reporting records do not indicate issues with contamination or non-compliance. Additionally, one leaking underground storage tank (LUST) is located adjacent to US 52 within the town of Otterbein.

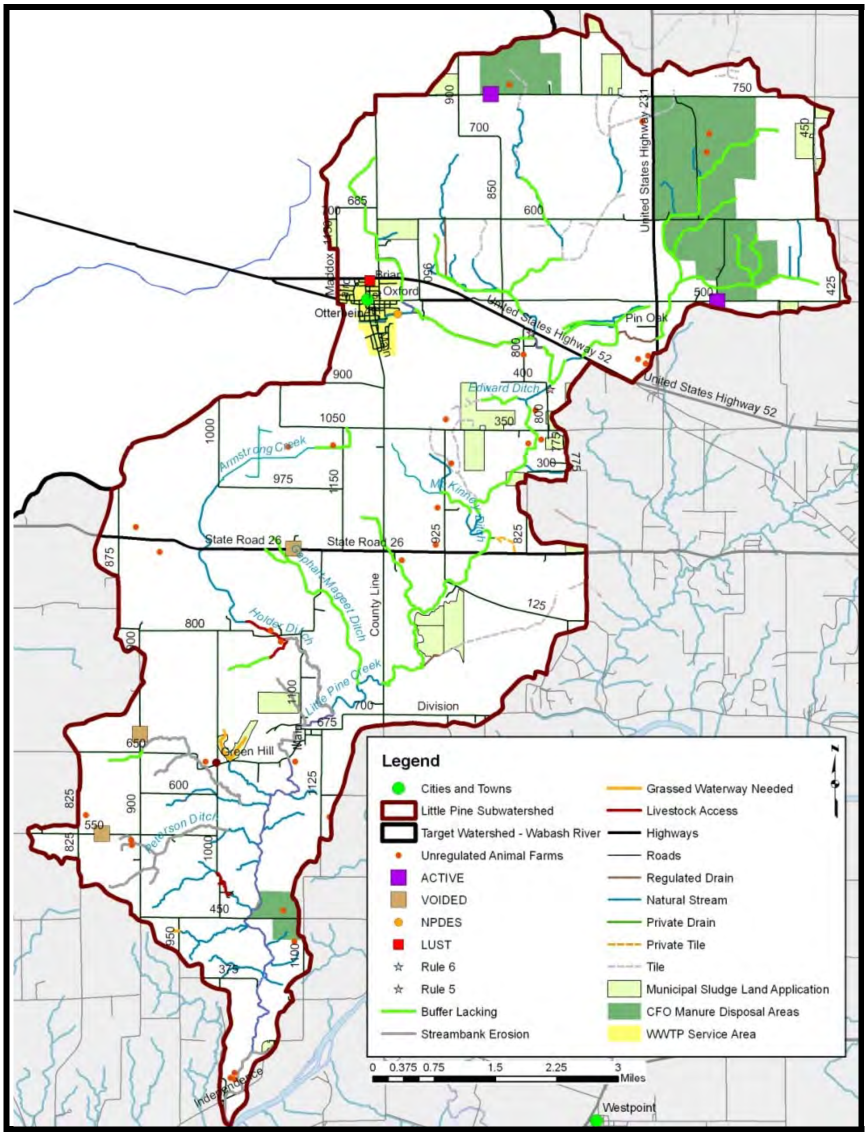

Figure 139. Point and non-point sources of pollution in the Indian Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.8.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Little Pine Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, hobby farms and pastures are located within the Little Pine Creek subwatershed (Figure 139). Approximately 675 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to nearly 3.5 miles of stream within the Little Pine Creek subwatershed. Two active and three voided confined feeding operations are also present in the subwatershed with the two active CFOs located in the northern portion of the Little Pine Creek headwaters. Additionally, buffers are lacking along 62 miles of streambank and 23 miles of streambank are eroding. An additional 1.9 miles of waterway would benefit from the installation of grassed waterways.

As detailed above, development pressures are low in the Little Pine Creek subwatershed. These pressures are detailed in Figure 139 by the Rule 5 locations. (Rule 5 denotes properties where more than one acre of land was disturbed during the land development or alteration process.) All of these development-based, non-point source locations are concentrated within the northern portion of the watershed and typically occur nearly US 52.

4.8.5 Water Quality Assessment

Waterbodies within the Little Pine Creek subwatershed have been sampled at approximately 40 locations (Figure 140). Historic assessments include collection of water chemistry data by the Tippecanoe County SWCD (1 site), the IDEM (3 sites), the Little Pine-Indian Watershed Pilot Project (14 sites), by Purdue researchers at the Purdue Agricultural Farm (7 sites), and via volunteer monitors through the Hoosier Riverwatch program (1 site). Macroinvertebrate samples have been collected by IDEM (2 sites), while the fish community has been assessed by Curry and Spacie (1 site), Fisher et al. (4 sites), and the IDEM (1 site). Mussel surveys were completed by Myers-Kinzie at six sites throughout the subwatershed. Twenty-two sites were sampled as part of the Wabash Sampling Blitz and one site is included as part of the current biological sampling effort funding by this project. A stream gage is located at this sampling site and three historic gages once operated within the Little Pine Creek subwatershed.

Water Chemistry

Water chemistry data collected from the Little Pine Creek subwatershed suggest several parameters of concern including: nitrate-nitrogen, orthophosphate, total suspended solids, and *E. coli* (Figure 141). Nitrate-nitrogen concentrations exceeded the target concentration (2 mg/L) during at least 50% of sample events in Little Pine Creek at County Road 450 North, County Road 800 West, Green Hill Road, County Road 350 North, State Road 26, US Highway 52, Armstrong Road, County Line Road, at High Bridge, and Independence Road; in Peterson Ditch at County Road 1000 East; in Holder Ditch at County Road 1100 East and 1100 West; in Otterbein Ditch at County Road 800 West; in Marshall Ditch at the Purdue Animal Science Farm; in Box Ditch at US 231; and in unnamed tributaries to Little Pine Creek at State Road 26 and County Road 1100 East. Concentrations in excess of the target concentration ranged from 2.1 to 8.9 mg/L. Orthophosphate concentrations were elevated in Little Pine Creek at County Road 800 West and County Road 450 North, in Peterson Ditch at County Road 900 East, and in Otterbein Ditch at County Road 800 West where concentrations measured 2.8 mg/L. Total phosphorus concentrations were in excess in Marshall Ditch at the Purdue Animal Science farm; in Box Ditch at US 231; in Otterbein Ditch at County Road 800 West; in Holder Ditch at County Road 1100 East; in Little Pine Creek at US 52, County Road 800 West, County Road 350 North, County Line Road, Armstrong, Green Hill, and High Bridge. Total suspended solids concentrations measured higher than target concentrations in Marshall Ditch at the Purdue Animal Science farm; in Box Ditch at US 231; in Otterbein Ditch at County Road 800 West; in Holder Ditch at County Road 1100 East; in Little Pine Creek at US 52, County Road 800 West, County Road 350 North, County Line Road, Armstrong, Green Hill, and High Bridge. *E. coli* concentrations in excess of the state standard occurred during more than 50% of sampling events in Little Pine Creek at County Road 125 North, in Marshall Ditch at County Road 600 North, in Holder Ditch at County Road 1100 East and State Road 26, and in Otterbein Ditch at County Road 500 North.

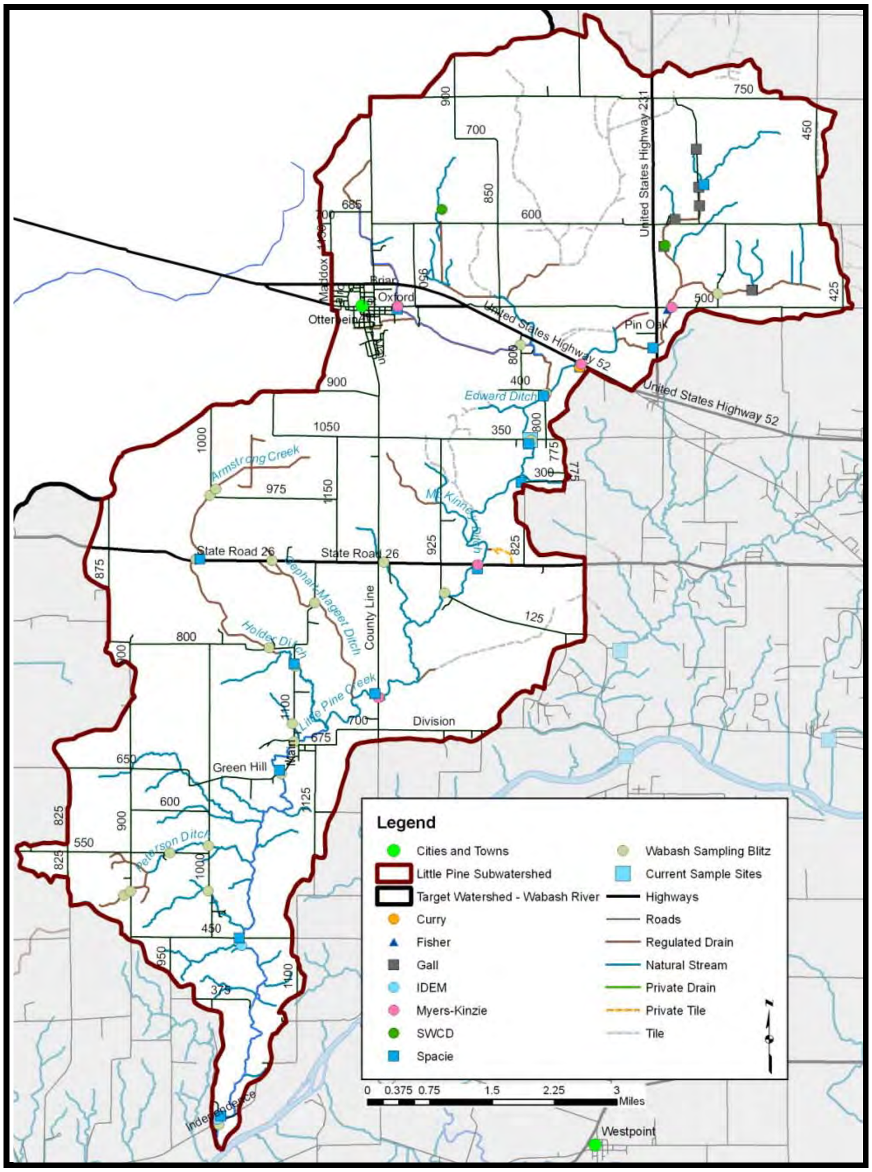

Figure 140. Locations of current or historic water quality data collection in the Little Pine Creek subwatershed.
Data used to create this map are detailed in Appendix A.

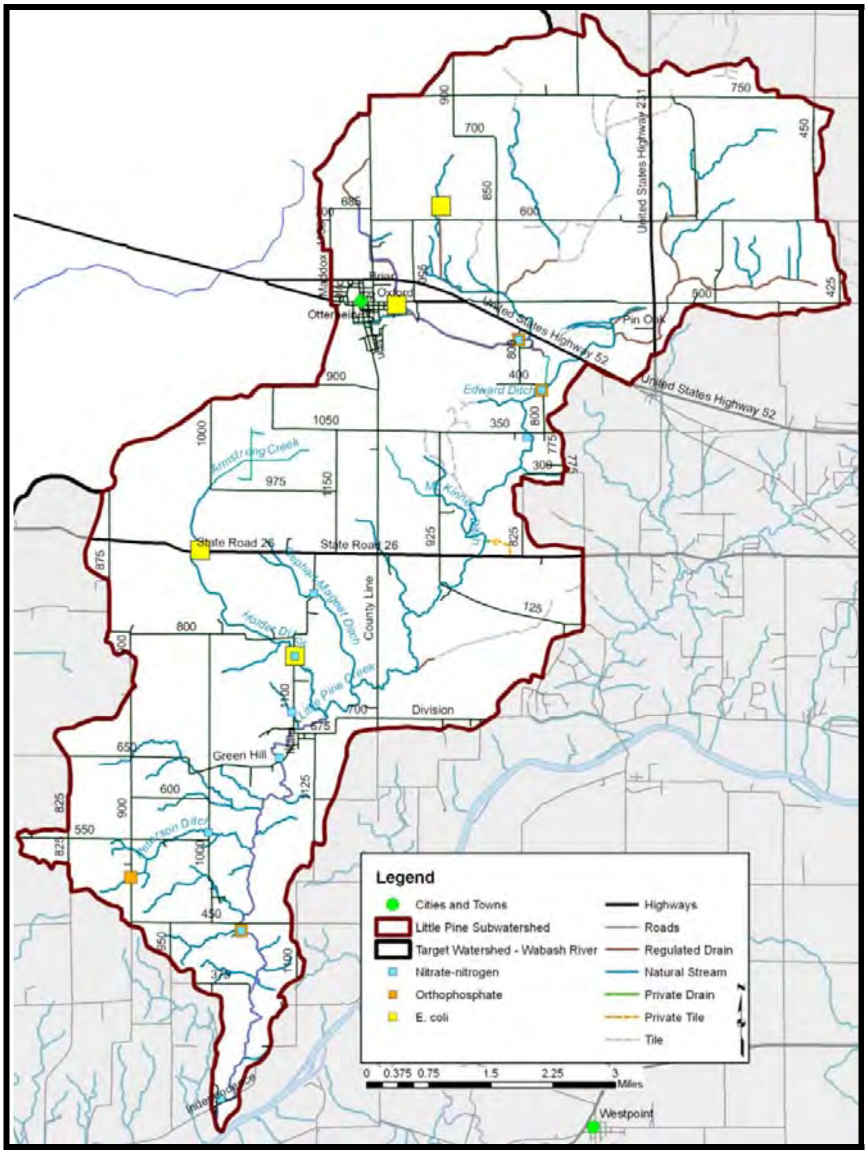

Figure 141. Water quality impairments in the Little Pine Creek subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at two sites during two separate assessments. As previously detailed, the QHEI scores habitat within a 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 1991 at Black Rock Road and 1999 at County Road 450 North. Scores (57 and 66, respectively) indicate good quality habitat that is fully in support of the streams designated aquatic life use. Overall, limited substrate and cover quality and poor riffle scores indicate that habitat quality could be improved within these reaches of Little Pine Creek.

Three Purdue field personnel conducted QHEI assessments during the June 2010 fish sampling, and the mean of those scores was calculated to assign a QHEI scores for the survey site. Little Pine Creek north of County Road 350 North had a mean QHEI score of 55.5 and is in attainment of its aquatic life use. Little Pine Creek at that site contained poor substrate (7) and instream cover (8) and improving those scores would result in improved habitat scores.

Fish

The IDEM assessed the fish community once during 1999 at County Road 450 North, while Curry and Spacie (1972) and Fisher et al. (1994) assessed one and four sites, respectively. IDEM data indicate that the fish community in Little Pine Creek rates as good scoring 44 using the IBI. At the time of the assessment, the community contained the highest diversity of any of the historically assessed tributary sites. Purdue field personnel sampled the fish community on multiple occasions in 2009 and 2010. Sampling methods followed Simon (1991). A fish IBI score was calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 23; Sample II – July 20; Sample III – September 16; and Sample IV – November 5. The 2010 samples were collected as follows: Sample V – March 19; Sample VI – June 21; Sample VII – August 12; and Sample VIII – October 31. The mean IBI score for Little Pine Creek north of County Road 350 North was 37 and with scores ranging from 30 to 44. Scores in 2009 (mean=39) were higher than in 2010 (mean=34). Bluntnose minnow (256), creek chubs (217), green sunfish (162), and white suckers (159) dominated the catch.

Macroinvertebrates

The macroinvertebrate community within Little Pine Creek was sampled twice by the IDEM. Sampling occurred once in 1991 at Black Rock Road and again in 1999 at County Road 450 North. The macroinvertebrate community rated as moderately impaired at Black Rock Road and as slightly impaired at County Road 450 North scoring 3.4 and 5.0, respectively. During the 1991 assessment, the community was dominated by the very tolerant Chironomidae, or black fly family. The dominance of this family limited the community present in this reach resulting in a moderately impaired community. During the 1999 assessment, a limited number of taxa occurred in relatively low density; however, the community was dominated by Hydropsychidae, a relatively-tolerant caddisfly family. This combination resulted in a slightly impaired community.

Purdue field personnel sampled Little Pine Creek north of County Road 350 North four times in 2009 and four times in 2010. The mean mIBI and mean HBI scores for Little Pine Creek north of County Road 350 North were 3.1 and 4.75, respectively. mIBI scores ranged from 1.0 during the May 2009 assessment to 4.4 during the October 2010 assessment. These scores indicate moderate to severe impairment of the biological community. Total abundances were relatively low compared to other sites and the dominant taxa consisted of Chironomidae (274 total individuals), Hydropsychidae (181), and Baetidae (125).

Mussels

Myers-Kinzie assessed the mussel community at six locations with the Little Pine Creek subwatershed. During the surveys, two sites (Otterbein Ditch at County Road 500 North and Little Pine Creek at County Road 500 North) were lacking in species, while a live Eastern floater (*Pyganodon gradis*) was observed in Little Pine Creek at US 52. Three species, Wabash pigtoe (*Fusconaia flava*), Eastern floater (*Pyganodon gradis*), and fatmucket (*Lampsilis siliquoidea*), were found in live, weathered dead, and fresh dead conditions in Little Pine Creek at County Line Road. The two most diverse sites surveyed by Myers-Kinzie occurred in Little Pine Creek at State Road 26 and County Road 800 West where nine and eight species were observed, respectively.

4.8.6 Little Pine Creek Subwatershed Summary

The Little Pine Creek subwatershed is similar to those throughout the Region of the Great Bend of the Wabash River watershed. The headwaters of Little Pine Creek are located on relatively flat, hydric soils with slopes and erodiblity increasing as water moves south toward the Wabash River. Land use within the Little Pine Creek subwatershed is largely agricultural with natural land uses (10%) and small towns (5%) accounting for the remainder of land uses within the subwatershed. Purdue University owns a large portion of the headwaters of Little Pine Creek. As such, their land uses directly impact water quality within the system. This ownership also allowed for extensive historical assessment of the Little Pine Creek subwatershed. Based on these data and those collected as part of the current study, nutrient concentration in Little Pine Creek are extremely high, while sediment and *E. coli* concentrations also exceed target concentrations. Biotic communities found within Little Pine Creek and its tributaries reflect the varied habitat found within subwatershed streams as much as the elevated nutrient and sediment concentrations.

4.9 Turkey Run-Wabash River Subwatershed

The Turkey Run-Wabash River subwatershed is the most westerly group of tributaries to the Wabash River within the watershed draining portions of Fountain and Warren counties. The Turkey Run-Wabash River subwatershed forms the Western edge of the Region of the Great Bend of the Wabash River watershed and includes one 12-digit HUC watershed (HUC 051201080510; Figure 142). The Turkey Run-Wabash River subwatershed drains 19,582 acres or 30.6 square miles. In total, 8 miles of the Wabash River and 53.5 miles of tributaries are present within the Turkey Run-Wabash River subwatershed. Of these, approximately 6.5 miles are considered impaired for *E. coli*, nutrient, dissolved oxygen, PCBs, and mercury.

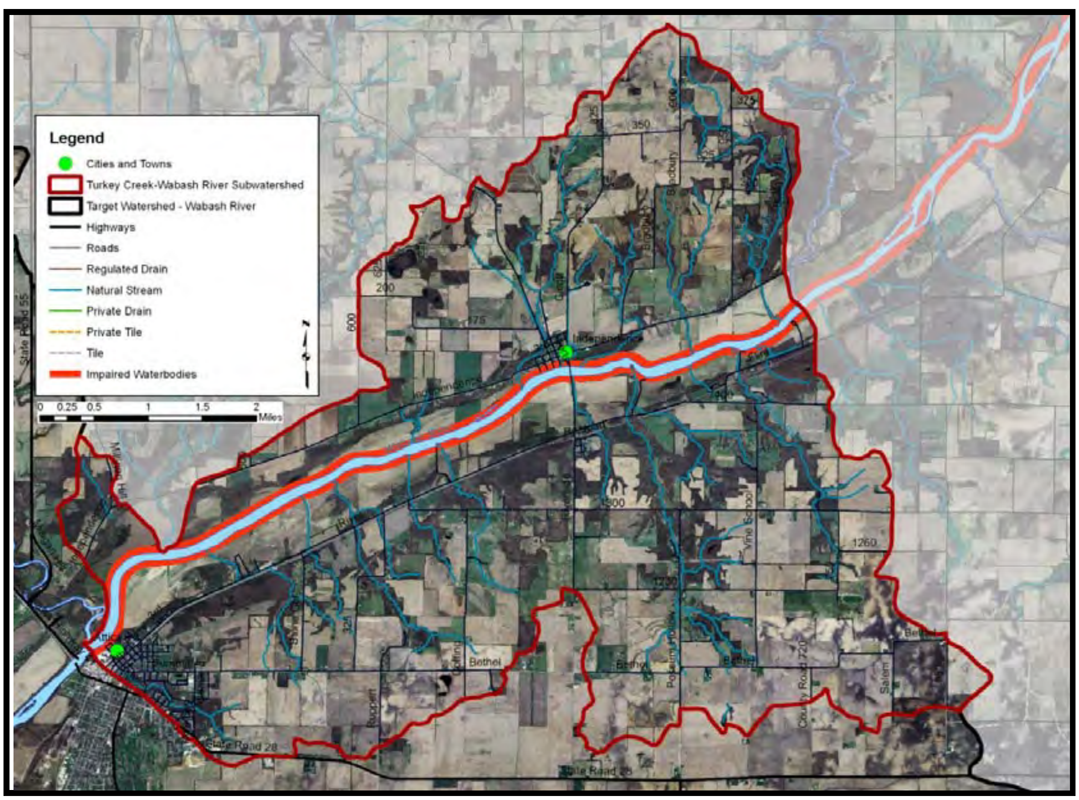

Figure 142. Turkey Run-Wabash subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.1 Soils

Soils in the Turkey Run-Wabash River subwatershed are dominated by those that are located on steeply sloped, easily erodible areas (Figure 143). Highly erodible soils cover 4.3

square miles or 14% of the Turkey Run-Wabash River subwatershed, while potentially highly erodible soils cover 10.4 square miles or 34% of the subwatershed. HES and PHES line the drainages of nearly every tributary within the watershed and abut the floodplain of the Wabash River on both the north and south banks. An additional 4 square miles or 13% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of many of the intermittent tributaries were historically in wetland land uses. Current estimates indicate that wetlands cover approximately 5% of the subwatershed suggesting that nearly one-third of historic wetlands are still present within the subwatershed.

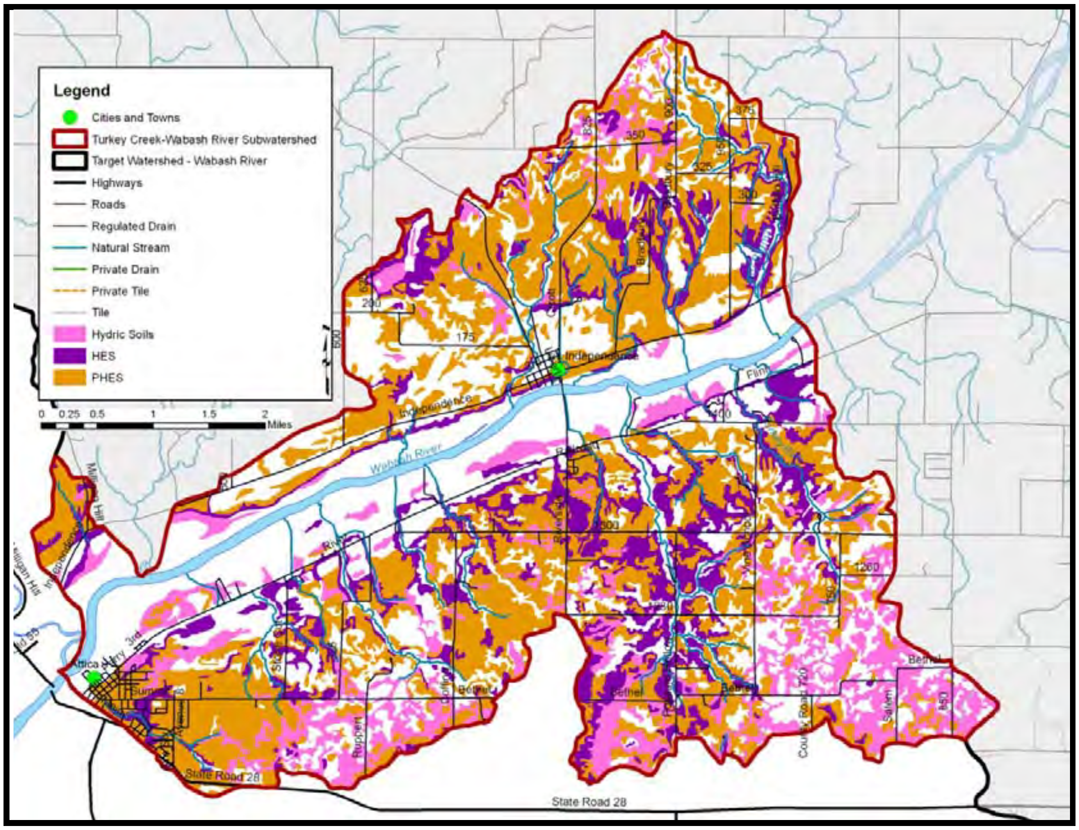

Figure 143. Properties of soils located in the Turkey Run-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

4.9.2 Land Use

Agricultural land uses dominate the Turkey Run-Wabash River subwatershed accounting for 63% of land use. Urban land uses including a portion of the City of Attica and the towns of Riverside and Independence account for 6.5% of the subwatershed land use. Forest and wetland land uses account for 28% of the subwatershed, while open water in the form of farm ponds covers 2.5% of the Turkey Run-Wabash River subwatershed. Natural land uses in the Turkey Run-Wabash River account for the largest portion of any subwatersheds' land use.

4.9.3 Point Source Water Quality Issues

Development within the City of Attica accounts for the only sources of point sources within the Turkey Run-Wabash River subwatershed. Two leaking underground storage tanks are located within Attica. Additionally, two small development projects (represented by Rule 5 in Figure 144) occurred in the subwatershed within the last 10 years.

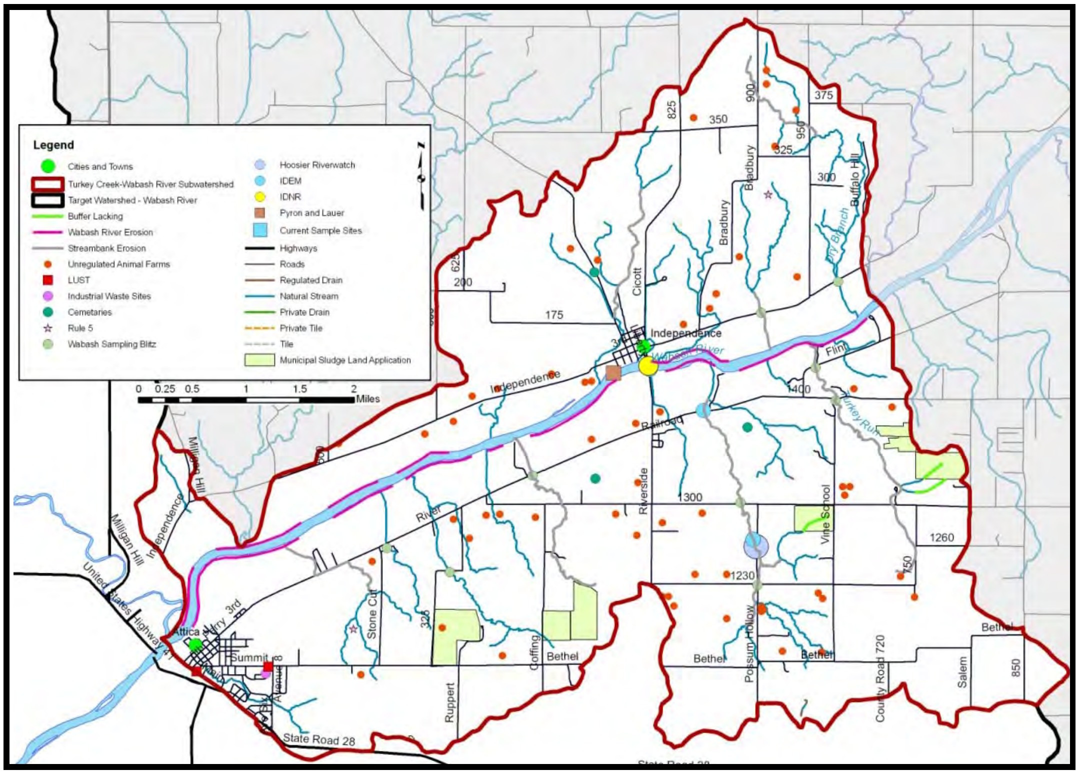

Figure 144. Non-point sources of pollution and locations of current or historic water quality data collection in the Turkey Run-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

4.9.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Turkey Run-Wabash River subwatershed and a corn-soybean rotation predominates in the agricultural land use. More than 55 hobby farms are also located within the Turkey Run-Wabash River subwatershed (Figure 144). Approximately 555 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Additionally, stream buffers are lacking along 1.5 miles of streambank and an additional 24.9 miles of tributary streambanks and 2.6 miles of Wabash River banks need to be stabilized.

4.9.5 Water Quality Assessment

Waterbodies within the Turkey Run-Wabash River subwatershed have been sampled at approximately 12 locations (Figure 144). Historic assessments include collection of water chemistry data by the IDEM (2 sites), the DNR (2 sites), and via volunteer monitors through the Hoosier Riverwatch program (1 site). Macroinvertebrate samples have been collected by Hoosier Riverwatch volunteers and by the IDEM (2 sites), while the fish community has been assessed by the DNR (1 site), Ball State University (1 site), and the IDEM (1 site). Thirteen sites were sampled as part of the Wabash Sampling Blitz. No stream gages are located in the Turkey Run-Wabash River subwatershed.

Water Chemistry

Most the water chemistry assessments occurred as part of single sampling event, which makes drawing conclusions from these singular sample results difficult. Water chemistry data collected from the Turkey Run-Wabash River subwatershed suggest several parameters of concern including: nitrate-nitrogen, turbidity, and *E. coli* (Figure 145). Nitrate-nitrogen concentrations exceeded the target concentration (2 mg/L) during at least 50% of sample events in Opossum Hollow at County Road 600 East, in Grindstone Creek at Flint Road, in Turkey Run at County Road 1400 North, and in an unnamed tributary to the Wabash River at County Road 325 North. Turbidity levels were elevated in Opossum Hollow at County Road 600 East with concentrations measuring as high as 350 NTU by the IDEM in 1999. *E. coli* concentrations in excess of the state standard occurred during more than 50% of sampling events in Opossum Hollow at County Road 600 East.

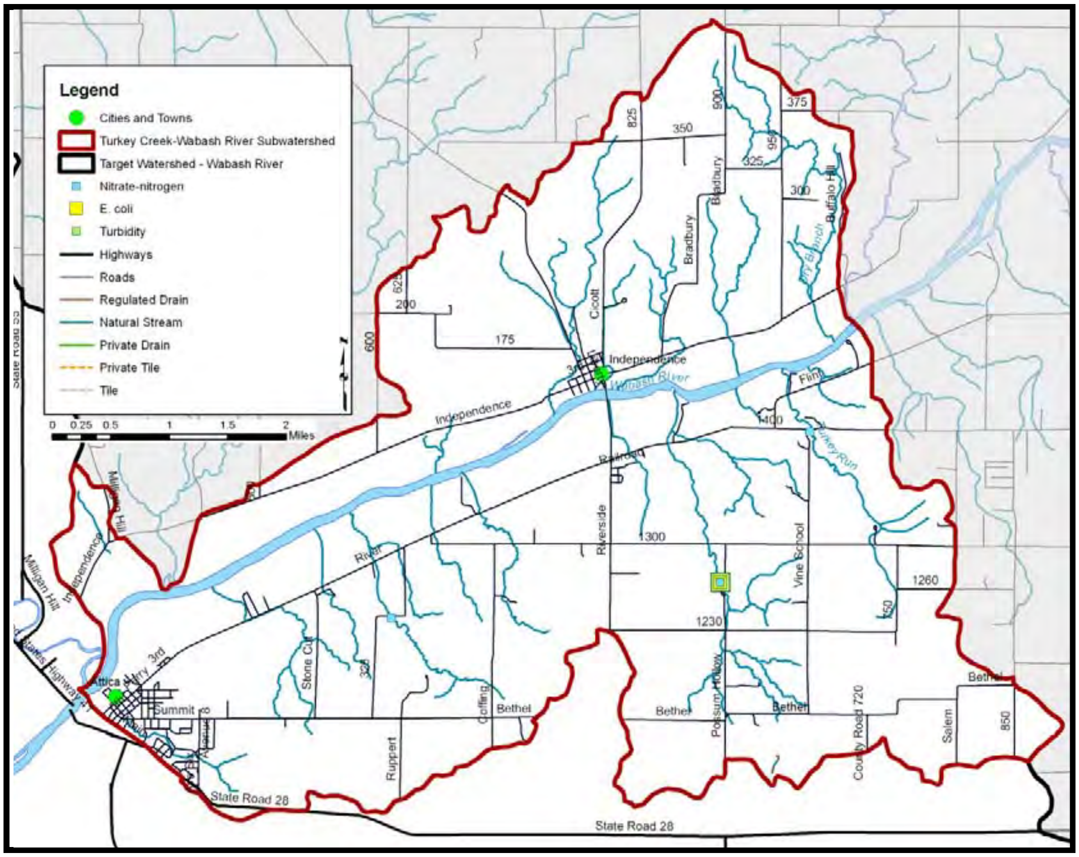

Figure 145. Water quality impairments in the Turkey Run-Wabash River subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at five sites during three assessments. IDEM assessed habit at two locations in Opossum Hollow as part of macroinvertebrate assessments completed in 1991 (River Road) and 1999 (River Road and County Road 600 East). The DNR assessed habitat within the Wabash River in 1999 with assessments occurring near Independence and Attica. As previously detailed, the QHEI scores habitat within a 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. All assessments indicate that habitat within Opossum Hollow and the Wabash River a sufficient to support aquatic biota. Opossum Hollow habitat rated well with habitat quality increasing from upstream (52 at County Road 600 East) to downstream (64 at River Road). Habitat within the Wabash River rated relatively similarly between the two sites with habitat near Independence rating lower (57) than that at Attica (64). Limited substrate, poor instream cover, and the absence of riffles resulted in the moderate habitat scores.

Fish

The DNR assessed the Wabash River fish community twice during 1999 at Independence and Attica. Similarly, Ball State University assessed the fish community twice in 2008 at the same two reaches. The IDEM assessed Opossum Hollow's fish community once in 1999. IDEM and BSU assessments indicate good quality fish communities with each reach rating an IBI of 42 to 44 (good). The DNR did not calculate IBI scores. Nonetheless, data indicate good density and diversity within the two Wabash River reaches.

Macroinvertebrates

The macroinvertebrate community within Opossum Hollow was assessed three times by the IDEM. Sampling occurred once at County Road 600 East in 1999 and twice at River Road, once in 1991 and once in 1999. The macroinvertebrate community rated as slightly impaired during the 1991 assessment scoring 5.0. The community was dominated by Hydropsychidae, a relatively-tolerant caddisfly species. Individual metrics indicate low Hilsenhoff Biotic Index (HBI) scores, moderate diversity, high density, and communities dominated by high quality taxa. During the 1999 assessment, both sites rated as moderately impaired scoring 3.0 and 2.6 at CR 600 East and River Road, respectively. Both sites exhibited a density of tolerant individuals with limited density and diversity overall. During the 1999 assessments, the communities were dominated by the very tolerant Chironomidae, or black fly family.

4.9.6 Turkey Run-Wabash River Subwatershed Summary

The geologic conditions present within the Turkey Run-Wabash River watershed create features unique to the Region of the Great Bend of the Wabash River watershed. The relatively flat, hydric soil dominated headwaters give way to steeply sloped, highly erodible stream channels which flow short distances to the Wabash River. Much of the land use within the Turkey Run-Wabash River subwatershed reflects the limitations of these conditions with agricultural production and livestock housed on flat or gently sloped portions of the watershed and forested habitat lining many of the steep stream channels. The Turkey Run-Wabash River watershed contains the highest percentage of natural (forest or wetland) land uses within the Region of the Great Bend of the Wabash River watershed. Due to its largely rural nature, most land in the Turkey Run-Wabash River watershed is privately owned and although the City of Attica may undergo expansion in the coming years, development pressures within this subwatershed are low. The limited water quality data collected within the subwatershed supports the relatively natural conditions present in the Turkey Run-Wabash River subwatershed. Habitat scores suggest that moderately good macroinvertebrate and fish populations should occur within these streams. Observations indicate that biotic communities are moderately good. Additional water quality data is necessary to more completely identify water quality problems within this subwatershed.

4.10 <u>Kickapoo Creek Subwatershed</u>

Kickapoo Creek is one of the most westerly tributary to the Wabash River within the watershed draining portions of Warren County. The Kickapoo Creek subwatershed forms the western edge of the Region of the Great Bend of the Wabash River watershed (Figure 146). The Kickapoo Creek watershed includes two 12-digit HUC watersheds – Headwaters Kickapoo Creek (051201080508) and West Fork Kickapoo Creek (051201080509) and drains 25,080 acres or 39.1 square miles. In total, 60 miles of stream are present within the Kickapoo Creek subwatershed.

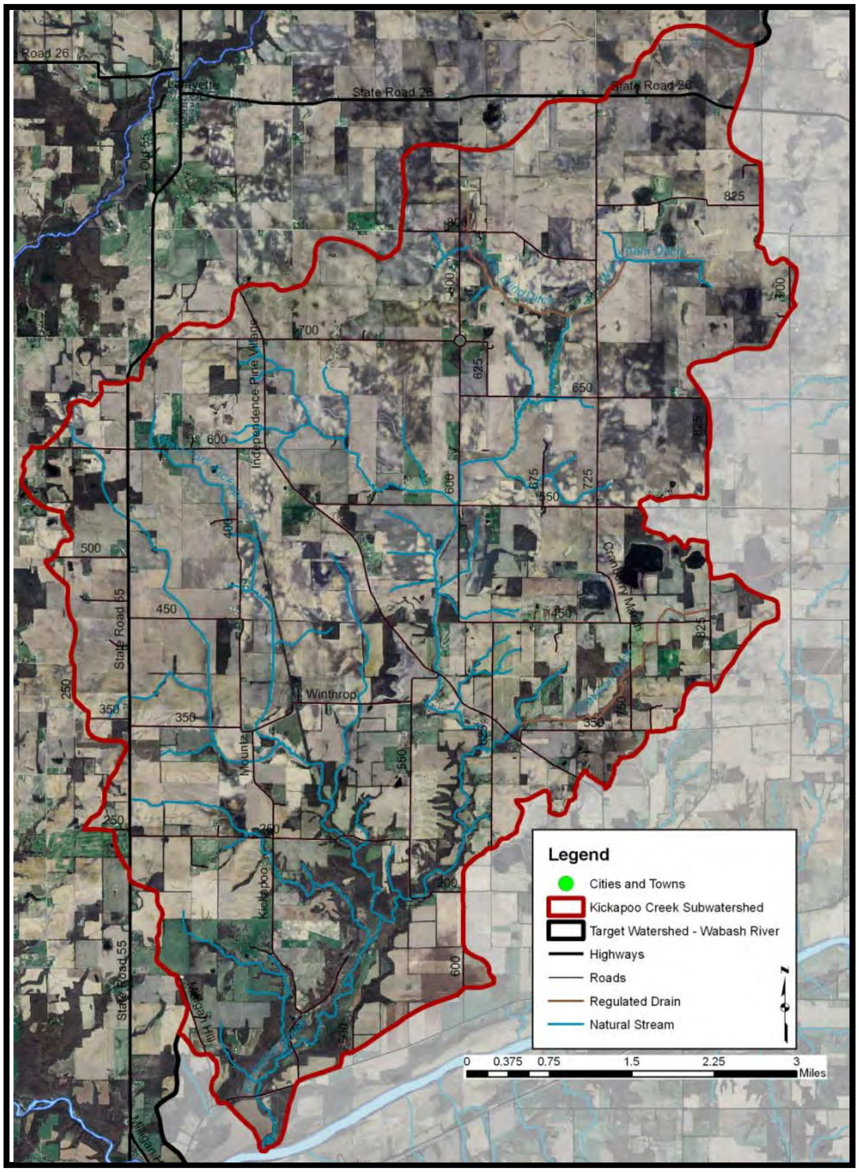

Figure 146. Kickapoo Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.1Soils

Soils in the Kickapoo Creek subwatershed are dominated by those that are unsuited for septic treatment. Nearly 95% of soils rating as severely limited for use in septic treatment. Soils located on steeply sloped, easily erodible areas are also prevalent with highly erodible soils cover 2.8 square miles (7%) and potentially highly erodible soils covering 15.3 square miles (39%; Figure 147). A majority of these soils are located adjacent to the mainstem and tributaries to Kickapoo Creek. An additional 8.7 square miles or 22% of the subwatershed are covered by hydric soils. These soils indicate that much of the headwaters of Kickapoo Creek were historically in wetland land uses. Current estimates indicate that wetlands cover approximately 2% of the subwatershed suggesting that less than 10% of historic wetlands are still present within the Kickapoo Creek subwatershed.

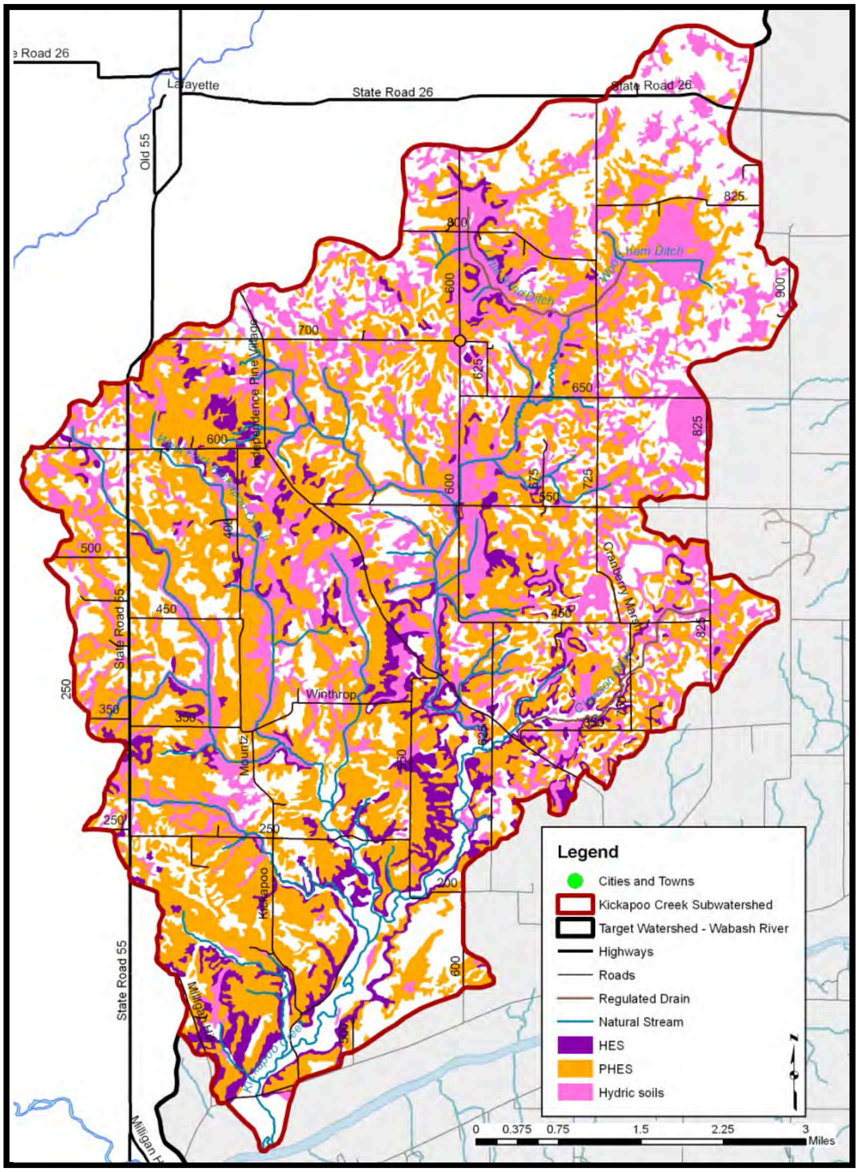

Figure 147. Properties of soils located in the Kickapoo Creek subwatershed. Data used to create this map are detailed in Appendix A.

4.10.2 Land Use

Agricultural land uses dominate the Kickapoo Creek subwatershed accounting for 83% of land use. Urban land uses account for 3.5% of the subwatershed land use. Forest and wetland land uses account for 13% of the subwatershed, while open water in the form of farm ponds covers less than 1% of the Kickapoo Creek subwatershed.

4.10.3 Point Source Water Quality Issues

No point source water quality concerns were identified within the Kickapoo Creek subwatershed

4.10.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Kickapoo Creek subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, a number of hobby farms and pastures are also located within the Kickapoo Creek subwatershed (Figure 148).

Approximately 450 cattle, llamas, horses, sheep, and goats are located on small farms throughout the subwatershed. Livestock have access to nearly 22 miles of streams in the Kickapoo Creek subwatershed. Additionally, nearly 48.3 miles of streambank erosion and 13.4 miles of streams lacking buffers occur within the subwatershed. Nearly 5 miles of waterway would benefit from the addition of grassed waterways.

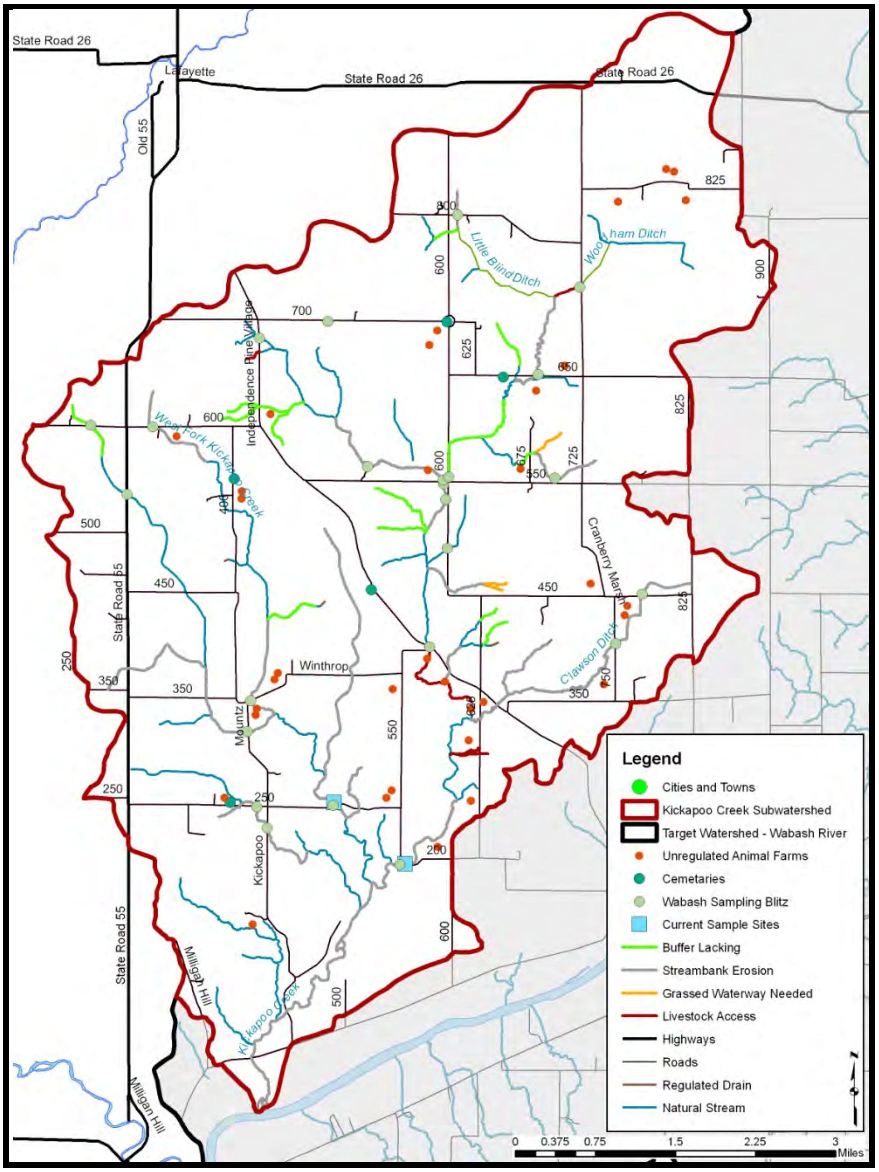

Figure 148. Non-point sources of pollution and locations of current or historic water quality data collection in the Kickapoo Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.5 Water Quality Assessment

Waterbodies within the Kickapoo Creek subwatershed have only been sampled as part of the Wabash Sampling Blitz. Twenty-four sites were sampled as part of that effort. Additionally, two sites are included as part of the current biological sampling effort funding by this project. No stream gages are located in the Kickapoo Creek subwatershed.

Water Chemistry

Due to the extremely limited historic water chemistry data set, very limited conclusions can be drawn about water chemistry in the Kickapoo Creek subwatershed. Water chemistry data collected from the Kickapoo Creek subwatershed as part of the Wabash Sampling Blitz suggest several parameters of concern including: nitrate-nitrogen, orthophosphate, and *E. coli*. Nitrate-nitrogen concentrations exceeded the target concentration (2 mg/L) at an unnamed tributary to Kickapoo Creek at County Road 550 North. Orthophosphate concentrations were elevated in the West Fork Kickapoo Creek at State Road 55 and at County Road 600 North and in Little Blind Ditch at County Road 800 North. *E. coli* concentrations in excess of the state standard occurred in Kickapoo Creek at County Road 600 East, West Fork Kickapoo Creek at Kickapoo Road, and in an unnamed tributary to Kickapoo Creek at County Road 600 East.

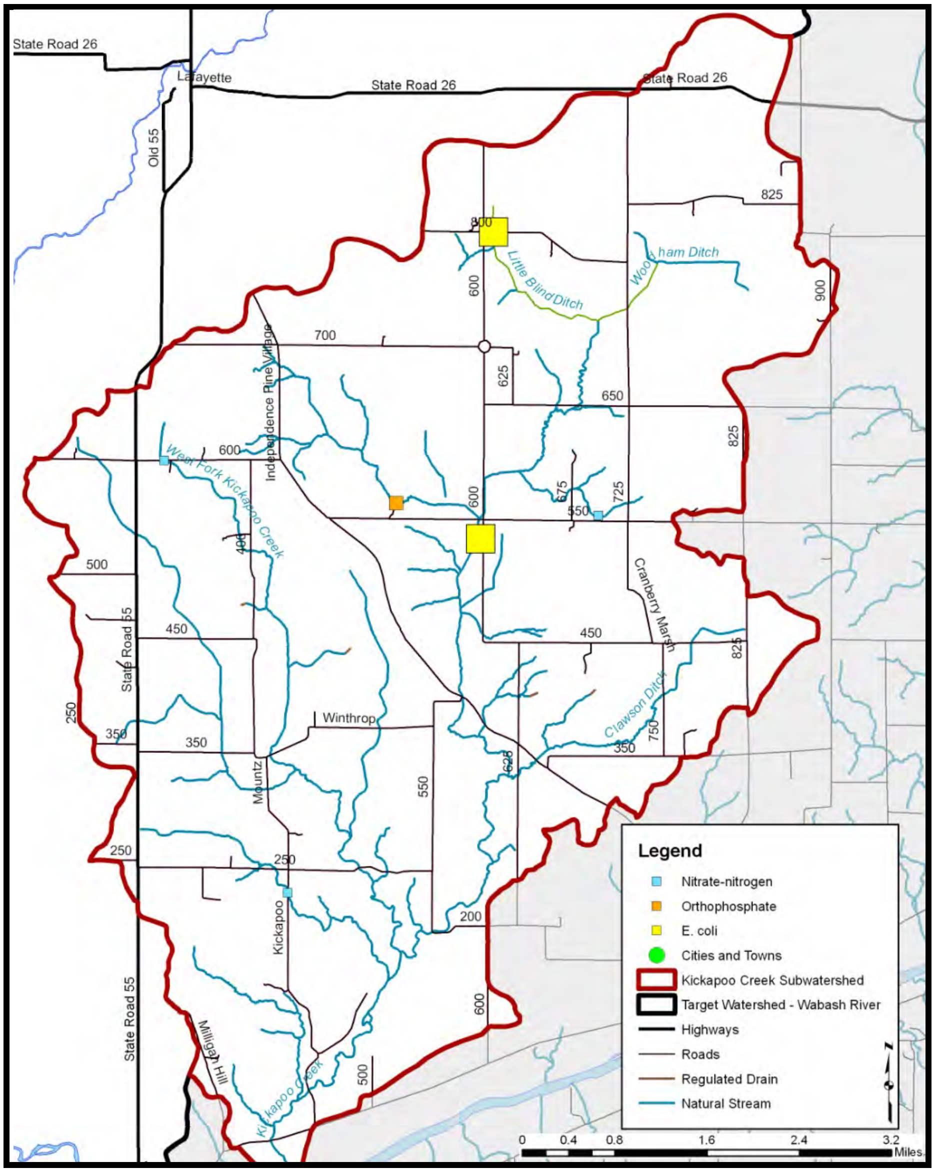

Figure 149. Water quality impairments in the Kickapoo Creek subwatershed. Data used to create this map are detailed in Appendix A.

Habitat

The Qualitative Habitat Evaluation Index (QHEI) was used to evaluate habitat at one site during three assessments. As previously detailed habitat within a 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.

Three Purdue field personnel conducted QHEI assessments during the June 2010 fish sampling, and the mean of those scores was calculated to assign QHEI scores for each site. Kickapoo Creek at County Road 500 East had a mean QHEI value of 56 which is considered to be fully supporting of aquatic life. West Fork Kickapoo Creek at County Road 250 North scored better with a mean QHEI score of 75. West Fork Kickapoo Creek scored higher than Kickapoo Creek in substrate (16 and 10), riparian condition (10 and 8), and gradient (10 and 4). Improvements to substrate and riparian condition may help improve the habitat for aquatic biota within Kickapoo Creek. More importantly, the intermittent nature exhibited by Kickapoo Creek has more of an impact on biota within the stream than substrate, riparian, or gradient conditions. Kickapoo Creek was noted to be dry during the September sample in 2009 and during the June and August sample events in 2010.

Fish

Purdue fish sampling in the Kickapoo Creek Subwatershed in 2009 and 2010 occurred at Kickapoo Creek at County Road 500 East and West Fork Kickapoo Creek at County Road 250 North. Sampling methods followed Simon (1991). Index of Biotic Integrity (IBI) scores were calculated for each sampling event. In 2009, sample collection occurred as follows: Sample I - June 16 at Kickapoo Creek and June 23 at West Fork Kickapoo Creek; Sample II – July 21 at West Fork Kickapoo Creek and July 23 at Kickapoo Creek; Sample III – September 24 at West Fork Kickapoo, Kickapoo was dry throughout the month of September; and Sample IV – November 4 for both streams. The 2010 samples were collected as follows: Sample V – March 20 at both streams; Sample VI – June 18 at West Fork Kickapoo and June 21 at Kickapoo Creek; Sample VII – August 10 at both streams; and Sample VIII – October 31at both streams. Mean IBI scores for Kickapoo Creek ranged from 30 to 44 with a mean of 35. Kickapoo Creek possessed a high IBI of 44 in July of 2009 and was dry during the September 2009 sampling event. Subsequently IBIs greater than 42 were not recorded. These IBI scores generated the lowest mean IBI score of any sampled. The dominant species in the Kickapoo Creek samples were creek chubs with 377 individuals, green sunfish (317), and central stonerollers (122). West Fork Kickapoo Creek possessed a higher mean IBI at 39 and contained much denser populations with central stonerollers (963), western blacknose dace (893), and mottled sculpin (722) observed in highest density. Although West Fork Kickapoo contained greater numbers of individuals, the mean IBI score was relatively low due to a majority of the species being more tolerant. These tolerance values caused a decrease in IBI scores when they are present in high abundances.

Macroinvertebrates

Purdue field personnel collected macroinvertebrate samples in Kickapoo Creek at County Road 500 East and West Fork Kickapoo Creek at County Road 250 North four times each in 2009 and four times each in 2010. Mean mIBI scores for Kickapoo Creek and West Fork Kickapoo Creek were very similar (4.0 and 4.2, respectively), as were the mean HBI scores (4.3 and 4.4, respectively). mIBI scores for Kickapoo Creek typically measured as moderately to slightly impaired ranging from 2.0 to 4.8 while West Fork Kickapoo Creek scores ranged from 2.2 to 6.0 generally falling within the slightly impaired rating. Both streams contained the same three dominant taxa, but the abundances of these taxa were different. Chironomidae was most abundant in both Kickapoo Creek and West Fork Kickapoo Creek (230 and 1317), followed by Hydropsychidae (184 and 660), and Beatidae (156 and

336). The differences in abundance are likely a result of Kickapoo Creek's tendency to dry in mid to late summer during the 2009-2010 sampling years.

4.10.6 Kickapoo Creek Subwatershed Summary

The Kickapoo Creek is dominated by agricultural land uses, soils, and land ownership. As such, water quality concerns noted during watershed inventory and monitoring efforts mesh with these land uses and conditions. Livestock access, limited riparian buffers, and streambank erosion typify conditions present in the Kickapoo Creek subwatershed. The impacts of these conditions on the Wabash River are difficult to quantify due to the limited water quality data currently available.

5.0 WATERSHED INVENTORY III: WATERSHED INVENTORY SUMMARY

Several important factors and relationships become apparent when the Region of the Great Bend of the Wabash River 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

Several 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. Figure 150 highlights those locations within the Region of the Great Bend of the Wabash River watershed where concentrations of these parameters measured higher than the target concentrations. Sample sites are mapped only if a majority of samples collected at those sites exceeded the target concentration. Elevated nitrate-nitrogen concentrations were observed in Burnett Creek, Little Pine Creek, Opossum Hollow, Flint Creek, Indian Creek, and in the Wabash River. Similarly, Burnett Creek, Flint Creek, Little Pine Creek, Indian Creek, and the Wabash River contained elevated total phosphorus concentrations, while the Wabash River, Wea Creek, Burnett Creek, Indian Creek, Little Pine Creek, and Flint Creek contained high turbidity or total suspended solids concentrations. Burnett Creek, Flint Creek, Indian Creek, Durkee's Run, Wea Creek, Kellerman Lea Ming Ditch and the Wabash River contained *E. coli* concentrations in excess of the state standard.

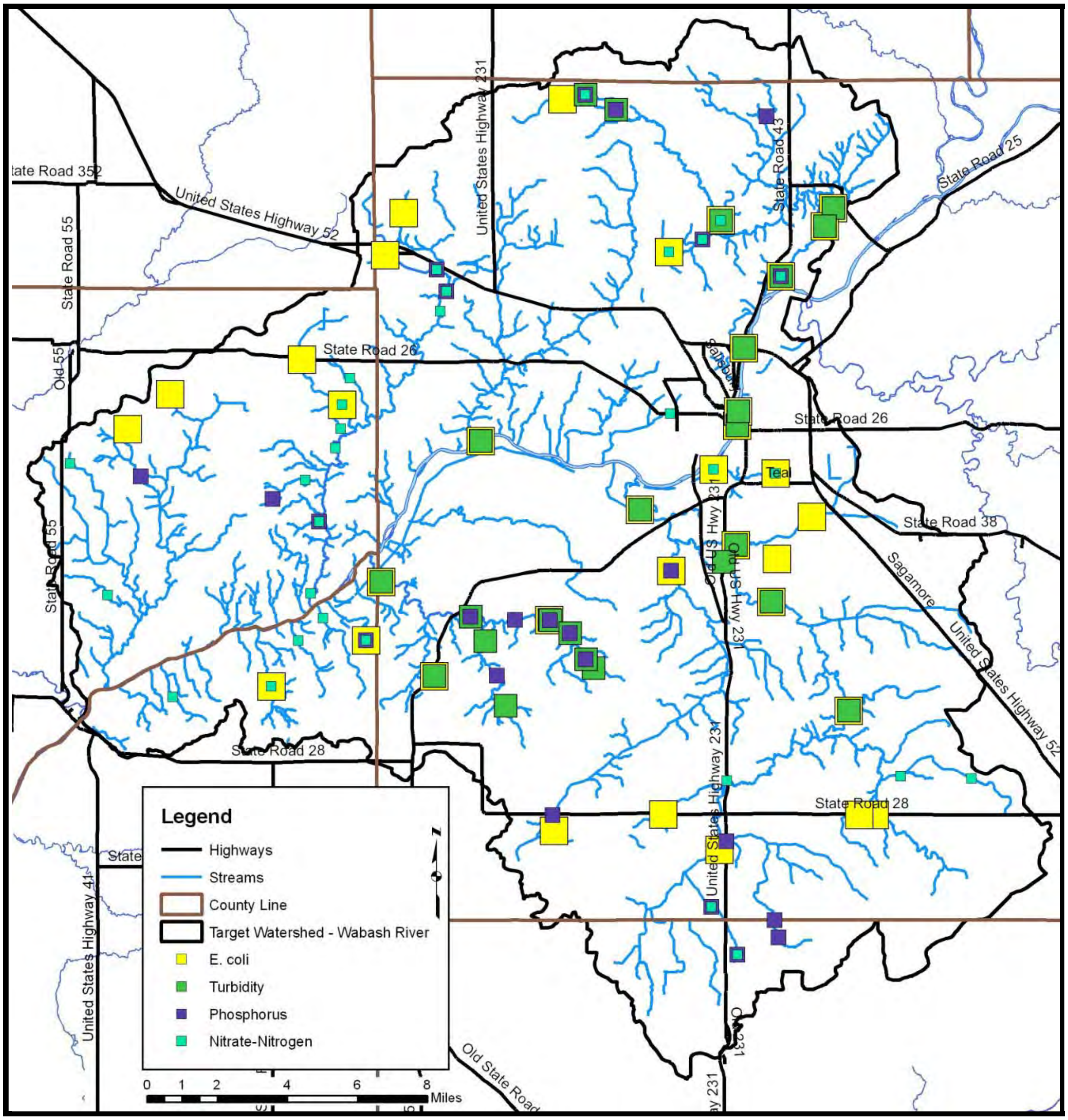

Figure 150. Locations where water chemistry concentrations exceed target concentrations during current and historic water chemistry assessments. Data used to create this map are detailed in Appendix A.

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 29. This list represents a work in progress and additional concerns may be added as the steering and monitoring committees work through data analysis. 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. The few that were rated as outside the committee's purview include flooding concerns and road salt issues. Both concerns were rated as an issue by the committee; however, the steering committee indicated that these issues could be solved through long-term successes related to other concerns.

Table 29. Analysis of stakeholder concerns.

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Agricultural BMPs should be utilized more	Yes	Buffer strip, streambank erosion, conventional till fields, etc identified during tour	Yes	No	Yes
Urban BMPs should be utilized more	Yes	Potential installation locations abound	Yes	No	Yes
Individuals are unaware of BMP implementation options	Yes-urban/ rural; No-agricultural	Urban BMP information not publicized; Ag BMPs implemented as possible and interested – general knowledge level is good	Yes	No	Yes
Green/LID practices and LEED are underutilized	Yes	Limited documentation of LID implementation available; limited promotion at this time	Yes	No	Yes
Too much physical waste enters the Wabash and its tributaries	Yes	DeTrash event removes six garbage bins of trash annually	Yes	No	Yes
Public lacks knowledge about the river and its tributaries' water quality	Yes	Data is not publicized	Yes	No	Yes
Public does not feel a sense of ownership for the River	Yes	75% of the population recognizes the Wabash as a key feature; however, <40% are claim a willingness to take action	Yes	No	Yes
Individuals use too much fertilizer and/or pesticide	No data available at this time	Levels of pesticide and fertilizer have not been quantified	No	No	Yes
Personal care/ pharmaceutical products concentrations are too high in the Wabash	Yes for tributaries; No for Wabash River	Animal antibiotics were found at stream and WWTP sites while disinfectant and replacement hormones were found only in WWTP samples	Yes	No	Yes
Partnerships between existing organizations are under-utilized	Yes	Anecdotal evidence suggests overlap and limited coordination between groups	Yes	No	Yes

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Private landowners are unaware of their obligations related to streams running through their property (snag clearing, permits)	Yes	Anecdotal from stakeholders	No	No	Yes
Tile drainage negatively impacts water quality and water flow	Yes	Approximately 42% of the watershed is drained by tile drains.	Yes	No	Yes
CSOs need to be corrected	Yes	Combined 15 CSO locations in Lafayette/ West Lafayette	Yes	No	Yes
Too much untreated stormwater enters the Wabash	Yes	Yes – 15 storm drain overflow locations along the Wabash	Yes	No	Yes
Water contact is unhealthy	Yes	E. coli concentrations exceed state standard	Yes	No	Yes
Too many locations where animals can access watershed streams	Yes	91,100 lineal feet of livestock access identified	Yes	No	Yes
Pet waste litters public areas as individuals do not clean up after their pets.					
Sediment and erosion control is needed	Yes	High turbidity concentrations observed in a majority of stream sites; erosion present along 864,000 lineal feet	Yes	No	Yes
Septic systems are not properly maintained	No watershed specific data available at this time	Stout (2003) states that a majority of Tippecanoe County private septic systems have 'outdated technology releasing large amounts of septic effluent into the groundwater annually"	Yes	No	Yes
Septic systems are not efficient enough and regulations relating to them are not enforced	No	Stout (2003) indicated that Tippecanoe County septic systems underwent periodic assessment and evaluation	Yes	No	Yes

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Buffers are needed in transitional areas and along the Wabash/its tributaries	Yes	Lack of buffers or need for grassed waterways observed along 1,190,109 lineal feet	Yes	No	Yes
Nutrient/algae concentration are too high in the Wabash and its tributaries	Yes	25% of sites exceeded the target concentrations	Yes	No	Yes
Industrial permit requirements are not enforced resulting in too high of industrial inputs	Not as stated	Industrial permits are enforced; however, some violations occurred over the last 3 years (2007-2009).	Yes	No	Yes
Invasive and exotic species are present throughout the watershed; no plan is in place to eliminate/ reduce their spread	No data available at this time	Not quantified at this time	Yes	No	Yes
Natural areas are not contiguous limiting the corridors for wildlife population	Yes	Land use and tree cover maps detail locations where tree corridors do not connect	Yes	No	Yes
Density and diversity of fish in the Wabash and its tributaries is lower than historic levels	Suggested by data collected along the length of the River; however, any declines in native diversity are difficult to detect due to increases in exotic species' populations.	According to Simon (2006) the native fish biodiversity in the Wabash River has declined and invasive non-natives have increased. Pyron et al (2006) found that diversity changed but only at a large scale. Guenther and Space (2006) found an increase in habitat generalists due to impoundments in the upper Wabash.	Yes	No	Yes
Tippecanoe County Regional Plan needs to be revised/ re-evaluated	Yes	Regional plan authored in 1981	Yes	No	Yes

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Natural and wildlife areas need to be created	Yes/no	Several natural/ wildlife areas are present throughout the watershed; continuity is lacking	Yes	No	Yes
Not enough trails along the Wabash	Personal opinion	Trails are present but length could be expanded	Yes	No	Yes
Access to the Wabash is limited by parking and lack of boat rental/ramps	Yes	Three ramps to the Wabash are present within this reach; no boat liveries or docks are available	Yes	No	Yes
Development rates exceed infrastructural support	Yes	80 unsewered, dense housing locations (20+ houses/sq mile) mapped in the watershed	Yes	No	Yes
Fish consumption is unhealthy	Yes	Fish consumption advisories exist for the Wabash River, Elliot Ditch, and Wea Creek	Yes	No	No
Road salts negatively impact stream biota	No data available at this time	Not quantified at this time	No	Yes	No
Flooding occurs with higher frequency and duration than in the past	No	Available data suggest no change in flooding; more investigation is necessary	No	Yes	No

Following a review of the stakeholder concerns, the steering committee determined the following concerns identified by the public to be outside of this project's approach. Therefore, these concerns will not be addressed in this watershed management plan: 1) Patterns of Flooding (road impairments, small storms lend big effect) and 2) Flood Prevention – role of bridges, control structures, etc. cost/benefit of structures.

6.0 PROBLEM AND CAUSE IDENTIFICATION

After evaluation of stakeholder concerns and completion of the watershed inventory, watershed problems can be summarized as detailed in Table 30. Problems represent the condition that exists due to a particular concern or group of concerns. Table 30 details potential causes of problems identified in Table 31.

Table 30. Problems identified for the Region of the Great Bend of the Wabash River watershed based on stakeholder and inventory concerns.

Concerns:	Problems:
• Agricultural Best Management Practices (BMP) should be utilized more • Urban BMPs should be utilized more • Individuals are unaware of BMP implementation options. • Green or low impact development (LID) practices and LEED certification possibilities are underutilized.	Individuals lack knowledge of what could/should be implemented, where to cite practices, and how to fund implementation.
• Too much physical waste is entering the river and its tributaries. • The public lacks knowledge about the river and its tributaries' water quality. • The public does not feel a sense of ownership for the river or its watershed. • Individuals use too much fertilizer and pesticide. • Best management practice methods should be utilized more within the watershed. • Private landowners are unaware of their obligations related to streams running through their property. • Green or low impact development (LID) practices and LEED certification possibilities are underutilized. • Concern that too much medication and too high of pharmaceutical concentrations are entering the river.	A unified education plan is lacking.
• Partnerships between existing organizations are under-utilized. • Individuals are unaware of BMP implementation options. • Private landowners are unaware of their obligations related to streams running through their property	A unified information source targeting the average citizen is needed.
• Agricultural Best Management Practices (BMP) should be utilized more • Urban BMPs should be utilized more • There is too much tile drainage to the Wabash River and its tributaries. • Combined sewer overflows (CSOs) within Lafayette and West Lafayette need to be corrected. • Too much untreated stormwater enters the Wabash River. • There are too many locations where animals have access to watershed streams. • Sediment and erosion control is needed. • Septic systems are not efficient enough or maintained correctly and regulations relating to them are not enforced. • Buffers and transitional natural areas are needed along the Wabash River and its tributaries. • Individuals use too much fertilizer and pesticide. • Nutrient and algae concentrations are too high within the Wabash River and its tributaries. • Industrial permit requirements are not routinely met.	Nutrient concentrations threaten the health of the Wabash River and its tributaries.

Concerns:	**Problems:**
• Agricultural Best Management Practices (BMP) should be utilized more • Urban BMPs should be utilized more • Combined sewer overflows (CSOs) within Lafayette and West Lafayette need to be corrected. • Too much untreated stormwater enters the Wabash River. • There are too many locations where animals have access to watershed streams. • Sediment and erosion control is needed. • Septic systems are not maintained correctly and regulations relating to them are not enforced. • Buffers and transitional natural areas are needed along the Wabash River and its tributaries. • Individuals use too much fertilizer and pesticide. • Nutrient and algae concentrations are too high within the Wabash River and its tributaries.	Area streams are cloudy and turbid.
• Combined sewer overflows (CSOs) within Lafayette and West Lafayette need to be corrected. • Too much untreated stormwater enters the Wabash River. • Septic systems are not maintained correctly and regulations relating to them are not enforced. • Water contact is unhealthy. • There are too many locations where animals have access to watershed streams. • Pet waste litters public areas as individuals do not clean up after their pets.	Area streams are listed by IDEM as impaired for recreational contact.
• Invasive and exotic species are present throughout the watershed and we do not have a plan to eliminate or reduce their presence or spreading. • Natural and wildlife areas are not contiguous limiting the corridors for wildlife populations. • Density and diversity of fish in the Wabash River is lower than historical levels.	Habitat is fragmented within the watershed and limited within watershed streams thereby limiting biotic communities.
• The Tippecanoe County regional plan should be revised and/or re-evaluated to address development in the watershed. • Natural and wildlife areas should be created. • There are not enough trails along the Wabash River. • Access to the Wabash River is limited by lack of parking, publicly-available boats, and boat ramps or access sites. • Development rates exceed infrastructural support.	Competing land uses limit management practice implementation and recreation opportunities
• Natural and wildlife areas should be created. • There are not enough trails along the Wabash River. • Access to the Wabash River is limited by lack of parking, publicly-available boats, and boat ramps or access sites.	River/natural area accessibility needs to be increased.

Table 31. Potential causes of identified problems in the Region of the Great Bend of the Wabash River watershed.

Problems:	Potential Causes:
• Individuals lack knowledge of what could/should be implemented, where to cite practices, and how to fund implementation. • A unified education plan is lacking. • A unified information source targeting the average citizen is needed. • Education of citizens is needed regarding correct pharmaceutical disposal.	• Educational efforts targeting funders, local agencies, and the public are lacking. • A single source of water quality related information lacking.
Nutrient concentrations threaten the health of the Wabash River and its tributaries.	Nutrient concentrations exceed target values set by this project.
Area streams are cloudy and turbid.	Suspended sediments and/or turbidity exceed target values set by this project.
Area streams are listed by IDEM as impaired for recreational contact.	E. coli concentrations exceed target values and the state standard.
Habitat is fragmented within the watershed and limited within watershed streams thereby limiting biotic communities.	• Terrestrial: Competing land uses and lack of cohesive regional plan. • Aquatic: Poor habitat and/or poor water quality limits the biotic community.
Competing land uses limit implementation and recreation opportunities	Unified land use and recreation plans are lacking.
River/natural area accessibility needs to be increased.	Unified source of recreational information is not available.

7.0 CRITICAL AND PRIORITY AREA DEFINITION

Critical areas are defined by the areas where sources of water quality problems occur in high density. These areas indicate locations where best management practices are necessary to address nonpoint sources of pollution. Priority areas are those areas of the watershed where high quality conditions occur. These areas indicate the need for best management practices to continue to protect the higher quality conditions observed within the area. The steering committee selected a step-wise process to determine critical and priority areas. Initially, all potential sources of identified problems were detailed, and then GIS and water quality data were reviewed. All historic and current water quality data were used in critical area prioritization if they were collected using standardized procedures and in a professional manner. Volunteer data collected and analyzed in a laboratory were used for prioritization. Based on these data, the areas of greatest concern were identified generating critical areas. Additionally, biological data were reviewed to identify high quality communities which serve as priority areas.

7.1 Source Identification: Key Pollutants of Concern

Nonpoint pollution sources are varied, yet common throughout almost any watershed. Several earlier sections of this document, including the previous section, denote potential sources of the pollutants of concern in the Region of the Great Bend of the Wabash River watershed. These and other potential sources of these causes are discussed in further details in subsequent sections. A summary of potential sources identified in the Region of the Great Bend of the Wabash River watershed for each of our concerns is listed below:

Nutrients (Nitrogen and Phosphorus):

- Conventional cropping practices
- Wastewater treatment discharges
- Industrial discharges (NPDES facilities permitted for nutrients)
- Agricultural and residential fertilizer
- Poor riparian buffers
- Streambank and bed erosion
- Construction activities
- Animal waste
- Confined feeding operations
- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Atmospheric deposition
- Altered hydrology (ditching and draining, fish passage limitations, altered stream courses)
- Flooding

E. coli:

- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)
- Urban runoff (pet waste, Combined Sewer Overflows)

Sediment:

- Conventional cropping practices
- Streambank and bed erosion
- Poor riparian buffers
- Floodplain restoration
- High velocities or increased urban runoff (impervious surfaces)
- Construction activities
- Livestock access to streams
- Altered hydrology (ditching and draining, fish passage limitations, altered stream courses)
- Flooding

7.2 Potential Sources of Pollution

All of the potential sources identified by the steering committee as listed above were ranked for each parameter. Potential sources that received more than 50% of the total possible votes were included as potential sources for further investigation. Prioritized potential sources were then reviewed to determine appropriate mechanisms for quantifying the impact of each potential source. GIS and water quality data were used to evaluate the volume of each potential source within each subwatershed. Appendix J contains tables detailing each potential source within each subwatershed and the mechanism used to determine the volume of each potential source in each subwatershed. Table 32 through Table 39 detail prioritized potential sources of pollution for each problem identified in the Region of the Great Bend of the Wabash River watershed.

Table 32. Potential sources causing nutrient problems.

Problems:	Nutrient concentrations threaten the health of the Wabash River and its tributaries.
Potential Causes:	Nutrient concentrations exceed target values set by this project.
Potential Sources:	• 25 livestock access areas identified in Romney-Fraley Ditch, East Branch Wea Creek, Little Wea Creek, Kenny Ditch-Wea Creek, Indian Creek, Lost Creek-Wabash River, Flint Run-Flint Creek, Armstrong Creek-Little Pine Creek, Flint Creek-Wabash River, and Headwaters Kickapoo Creek subwatersheds. • 15 Combined Sewer Overflows (CSO) identified in the Cedar Hollow-Wabash River and Elliot Ditch subwatersheds. • 410 unregulated animal operations housing more than 4,560 animals throughout the watershed. The highest density of animals were observed in the Romney-Fraley Ditch (32 operations, 300 animals), East Branch Wea Creek (37 operations, 430 animals), Lost Creek-Wabash River (33 operations, 430 animals), Flint Creek-Wabash River (15 operations, 400 animals), and Turkey Run-Wabash River (57 operations, 500 animals) subwatersheds. • 245 miles of stream lack adequate buffers or grassed waterways. East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 miles), and Flint Creek-Wabash River (22 miles) subwatersheds include streams which require improvement of more than 50% of their buffers. • 247 miles of stream lack adequate stabilization including Romney-Fraley Ditch (16 miles), East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 mile), and Otterbein Ditch-Little Pine Creek (19 miles) subwatersheds where more than 50% of stream miles require stabilization. • 198 square miles of drained cropland are located throughout the watershed. Romney-Fraley Ditch, East Branch Wea Creek, Haywood Ditch-Wea Creek, Little Wea Creek, Kenny Ditch-Wea Creek, North Fork Burnett Creek, Headwaters Burnett Creek, Indian Creek, Flint Run-Flint Creek, Otterbein Ditch-Little Pine Creek, and Headwaters Kickapoo Creek subwatersheds contain greater than 30% coverage by drained cropland. • Manure from confined feeding operations is applied on 14.3 acres in the Otterbein Ditch-Little Pine Creek, Jordan Creek, Lost Creek, Indian Creek, East Branch Wea Creek, Little Wea Creek, Romney-Fraley Ditch, Flint Run-Flint Creek, and Flint Creek-Wabash River subwatersheds. • Unknown volumes of fertilizer and pesticides are applied on lawns adjacent to storm drains, streams and the Wabash River within the urban portion of the watershed. • Pet and yard wastes are improperly disposed of within the urban portion of the watershed. • Failing septic systems add nutrients to the system within the rural portion of the watershed.

Table 33. Potential sources causing sediment problems.

Problems:	Area streams are cloudy and turbid.
Potential Causes:	Suspended sediments and/or turbidity exceed target values set by this project.
Potential Sources:	• 25 livestock access areas identified in Romney-Fraley Ditch, East Branch Wea Creek, Little Wea Creek, Kenny Ditch-Wea Creek, Indian Creek, Lost Creek-Wabash River, Flint Run-Flint Creek, Armstrong Creek-Little Pine Creek, Flint Creek-Wabash River, and Headwaters Kickapoo Creek subwatersheds. • 245 miles of stream lack adequate buffers or grassed waterways. East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 miles), and Flint Creek-Wabash River (22 miles) subwatersheds include streams which require improvement of more than 50% of their buffers. • 247 miles of stream lack adequate stabilization including Romney-Fraley Ditch (16 miles), East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 mile), and Otterbein Ditch-Little Pine Creek (19 miles) subwatersheds where more than 50% of stream miles require stabilization. • 15.4 square miles of cropland are located within the 100-year floodplain. The highest densities of cropped floodplain occur within the Haywood Ditch-Wea Creek, Little Wea Creek, Kenny Ditch-Wea Creek, Cedar Hollow-Wabash River, Jordan Creek, Wabash River, Lost Creek-Wabash River, Flint Creek-Wabash River, and Turkey Run-Wabash River subwatersheds. • 15.7 squares miles of impervious surfaces cover the watershed. More than 3% impervious surfaces were observed in the Elliot Ditch (19%), Headwaters Burnett Creek (3%), Cedar Hollow-Wabash River (28%), and Indian Creek (4%) subwatersheds. • 231 Rule 5 permits were issued to entities within the watershed over the past 5 years. A majority of development occurred within the Elliot Ditch, Kenny Ditch-Wea Creek, Headwaters Burnett Creek, Cedar Hollow-Wabash River, Indian Creek, and Jordan Creek-Wabash River subwatersheds

Table 34. Potential sources causing *E. coli* problems.

Problems:	Area streams are listed by IDEM as impaired for recreational contact.
Potential Causes:	*E. coli* concentrations exceed target values and the state standard.
Potential Sources:	• 25 livestock access areas identified in Romney-Fraley Ditch, East Branch Wea Creek, Little Wea Creek, Kenny Ditch-Wea Creek, Indian Creek, Lost Creek-Wabash River, Flint Run-Flint Creek, Armstrong Creek-Little Pine Creek, Flint Creek-Wabash River, and Headwaters Kickapoo Creek subwatersheds. • 15 Combined Sewer Overflows (CSO) identified in the Cedar Hollow-Wabash River and Elliot Ditch subwatersheds. • 410 unregulated animal operations housing more than 4,560 animals throughout the watershed. The highest density of animals were observed in the Romney-Fraley Ditch (32 operations, 300 animals), East Branch Wea Creek (37 operations, 430 animals), Lost Creek-Wabash River (33 operations, 430 animals), Flint Creek-Wabash River (15 operations, 400 animals), and Turkey Run-Wabash River (57 operations, 500 animals) subwatersheds. • Manure from confined feeding operations is applied on 14.3 acres in the Otterbein Ditch-Little Pine Creek, Jordan Creek, Lost Creek, Indian Creek, East Branch Wea Creek, Little Wea Creek, Romney-Fraley Ditch, Flint Run-Flint Creek, and Flint Creek-Wabash River subwatersheds. • Failing septic systems add nutrients to the system within the rural portion of the watershed.

Table 35. Potential sources causing habitat problems.

Problems:	Habitat is fragmented within the watershed and limited within watershed streams thereby limiting biotic communities.
Potential Causes:	Terrestrial: Competing land uses and lack of cohesive regional plan. Aquatic: Poor habitat and/or poor water quality limits the biotic community.
Potential Sources:	• 245 miles of stream lack adequate buffers or grassed waterways. East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 miles), and Flint Creek-Wabash River (22 miles) subwatersheds include streams which require improvement of more than 50% of their buffers. • 247 miles of stream lack adequate stabilization including Romney-Fraley Ditch (16 miles), East Branch Wea Creek (19 miles), Haywood Ditch-Wea Creek (11 miles), Indian Creek (32 miles), Flint Run-Flint Creek (14 mile), and Otterbein Ditch-Little Pine Creek (19 miles) subwatersheds where more than 50% of stream miles require stabilization. • 15.7 squares miles of impervious surfaces cover the watershed. More than 3% impervious surfaces were observed in the Elliot Ditch (19%), Headwaters Burnett Creek (3%), Cedar Hollow-Wabash River (28%), and Indian Creek (4%) subwatersheds. • Poor IBI scores (<36) occurred in the Haywood Ditch, Elliot Ditch, North Fork Burnett Creek, Headwaters Burnett Creek, Indian Creek, Otterbein Ditch-Little Pine Creek, and West Fork Kickapoo Creek subwatersheds. • Poor mIBI scores (<2.2) occurred in the Elliot Ditch, Cedar Creek, Jordan Creek, and Lost Ditch subwatersheds. Although the scores are not a source, the fact that these scores occurred at these sites indicate a source of habitat issues within these streams. • Poor QHEI (<51) or CQHEI (<60) scores occurred in the Indian Creek, Otterbein Ditch-Little Pine Creek, Armstrong Creek-Little Pine Creek, and Flint Creek-Wabash River subwatersheds. Although the scores are not a source, the fact that these scores occurred at these sites indicate a source of habitat issues within these streams. • Romney-Fraley Ditch, East Branch Wea Creek, Elliot Ditch, Headwaters Burnett Creek, Indian Creek, Jordan Creek, and Flint Run-Flint Creek subwatersheds all contain 1 or more road crossing per stream mile.

Table 36. Potential sources causing education problems.

Problems:	• Individuals lack knowledge of what could/should be implemented, where to cite practices, and how to fund implementation. • A unified education plan is lacking. • A unified information source targeting the average citizen is needed.
Potential Causes:	• Educational efforts targeting funders, local agencies, and the public are lacking. • A single source of water quality related information lacking.
Potential Sources:	N/A

Table 37. Potential sources causing development problems.

Problems:	Competing land uses limit implementation and recreation opportunities
Potential Causes:	Unified land use and recreation plans are lacking.
Potential Sources:	N/A

Table 38. Potential sources causing accessibility problems.

Problems:	River/natural area accessibility needs to be increased.
Potential Causes:	Unified source of recreational information is not available.
Potential Sources:	N/A

Table 39. Potential sources causing pharmaceutical problems.

Problems:	Pharmaceutical concentrations too high.
Potential Causes:	Pharmacies and the general public need to be educated about the impacts of personal care and pharmaceutical products.
Potential Sources:	N/A – sources cannot be identified at this time, thus this problem is being treated as an education issue.

7.3 Critical and Priority Area Determination

Using the list of potential sources developed for each parameter of concern as a base, the steering committee developed a mechanism for determining critical areas based on each parameter. GIS-based mapping data were used as a source of data for many parameters. The water quality database built from historic and current water chemistry data were used as a basis for decision-making. For each parameter, the steering committee generated a series of answers through which areas of concern were limited. This limitation allowed for the prioritization of the areas of greatest concern which became critical areas. Additionally, the biological communities observed throughout the watershed were reviewed to identify high quality communities. These areas serve as priority areas. Loading calculations were used as a check on critical area determinations and are detailed in subsequent sections.

7.3.1 Critical Areas for Nitrate-Nitrogen

Nitrate-nitrogen was the nitrogen form on which our critical area determination occurred. Nitrate-nitrogen is readily available in the Region of the Great Bend of the Wabash River watershed entering surface water via human and animal waste, urban fertilizer use, and via tile drains on agricultural lands. It is also the nitrogen form on which we have the most watershed-wide information. Nitrate-nitrogen critical areas were determined by four criteria:

- Drained cropland exceeds 60% of subwatershed coverage;
- Impaired waterbodies listing for nutrients;
- Nitrate-nitrogen concentrations exceeds the target concentration (2 mg/L) at 25% or more subwatershed sample sites;
- Nitrate-nitrogen concentrations exceeds the target concentration (2 mg/L) 10% or more of the time at concentrated sample sites (>40 samples collected within one year)

Based on these criteria, Romney-Fraley Ditch, East Branch Wea Creek, North Fork Burnett Creek, Headwaters Burnett Creek, Flint Run-Flint Creek, Otterbein Ditch-Little Pine Creek, and Elliot Ditch serve as critical areas for nitrate-nitrogen.

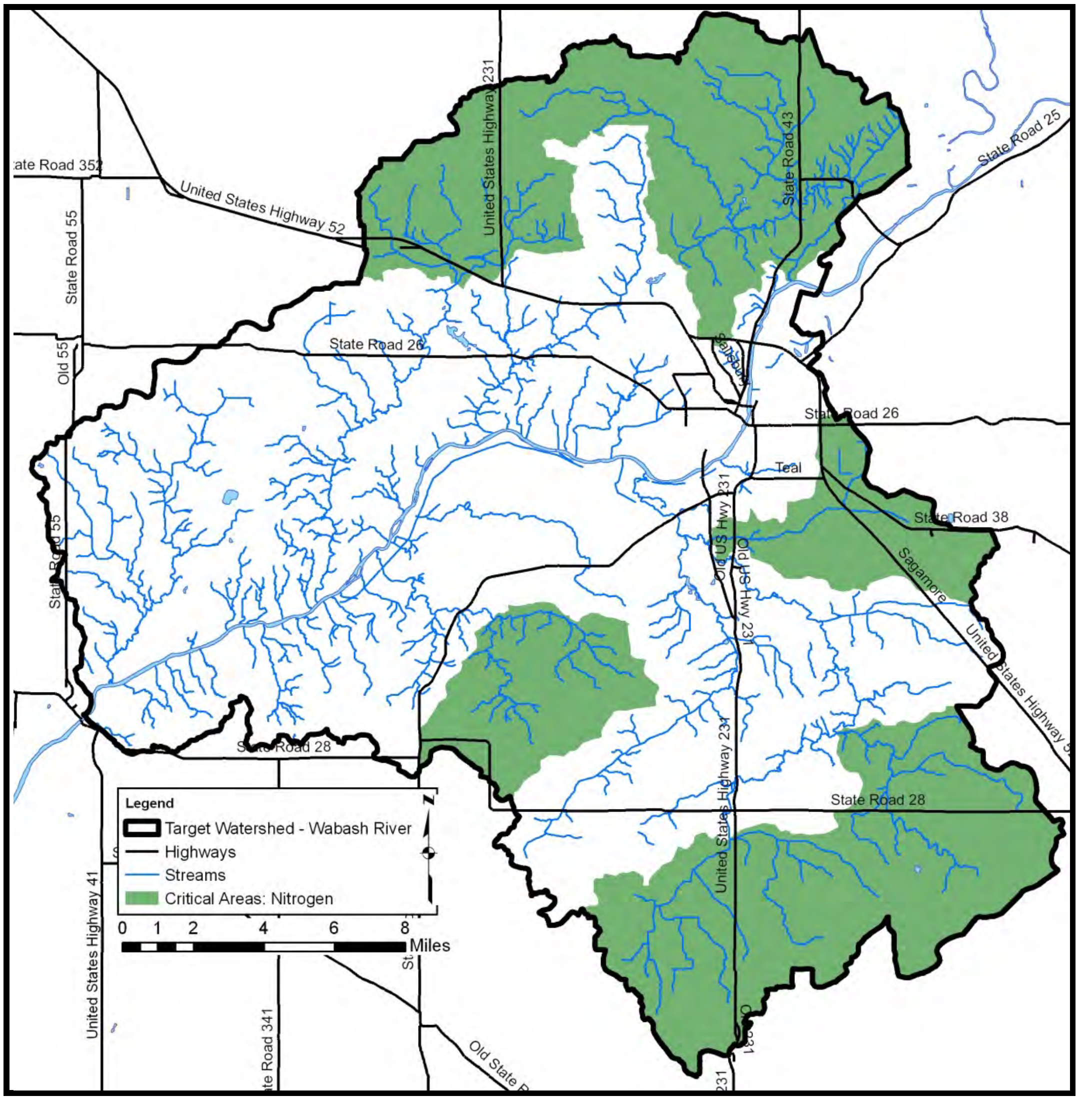

Figure 151. Nitrate-nitrogen based critical areas in the Region of the Great Bend of the Wabash River watershed.
Data used to create this map are detailed in Appendix A.

7.3.2 Critical Areas for Phosphorus

Total phosphorus was the phosphorus form on which our critical area determination occurred. Total phosphorus enters streams in the Region of the Great Bend of the Wabash River watershed through human and animal waste, streambank and bed erosion, unfiltered runoff, fertilizer use, and stormwater runoff. Total phosphorus critical areas were determined by six criteria:

- Areas lacking buffers exceeding 50% of the stream length within the subwatershed;
- Areas of streambank and bed erosion exceeding 50% of the stream length within in the subwatershed;
- Impervious surfaces cover 3% or more of the subwatershed;
- Impaired waterbodies listing for nutrients;
- Total phosphorus concentrations exceed the target concentration (0.08 mg/L) at 10% or more subwatershed sample sites;

- Total phosphorus concentrations exceed the target concentration (0.08 mg/L) 10% or more of the time at concentrated sample sites (>40 samples collected within one year).

Based on these criteria, Haywood Ditch-Wea Creek, East Branch Wea Creek, Flint Run-Flint Creek, Flint Creek-Wabash River, Cedar Hollow-Wabash River, Elliot Ditch, Headwaters Burnett Creek, Indian Creek, and Otterbein Ditch-Little Pine Creek serve as critical areas for total phosphorus. Figure 152 details total phosphorus based critical areas.

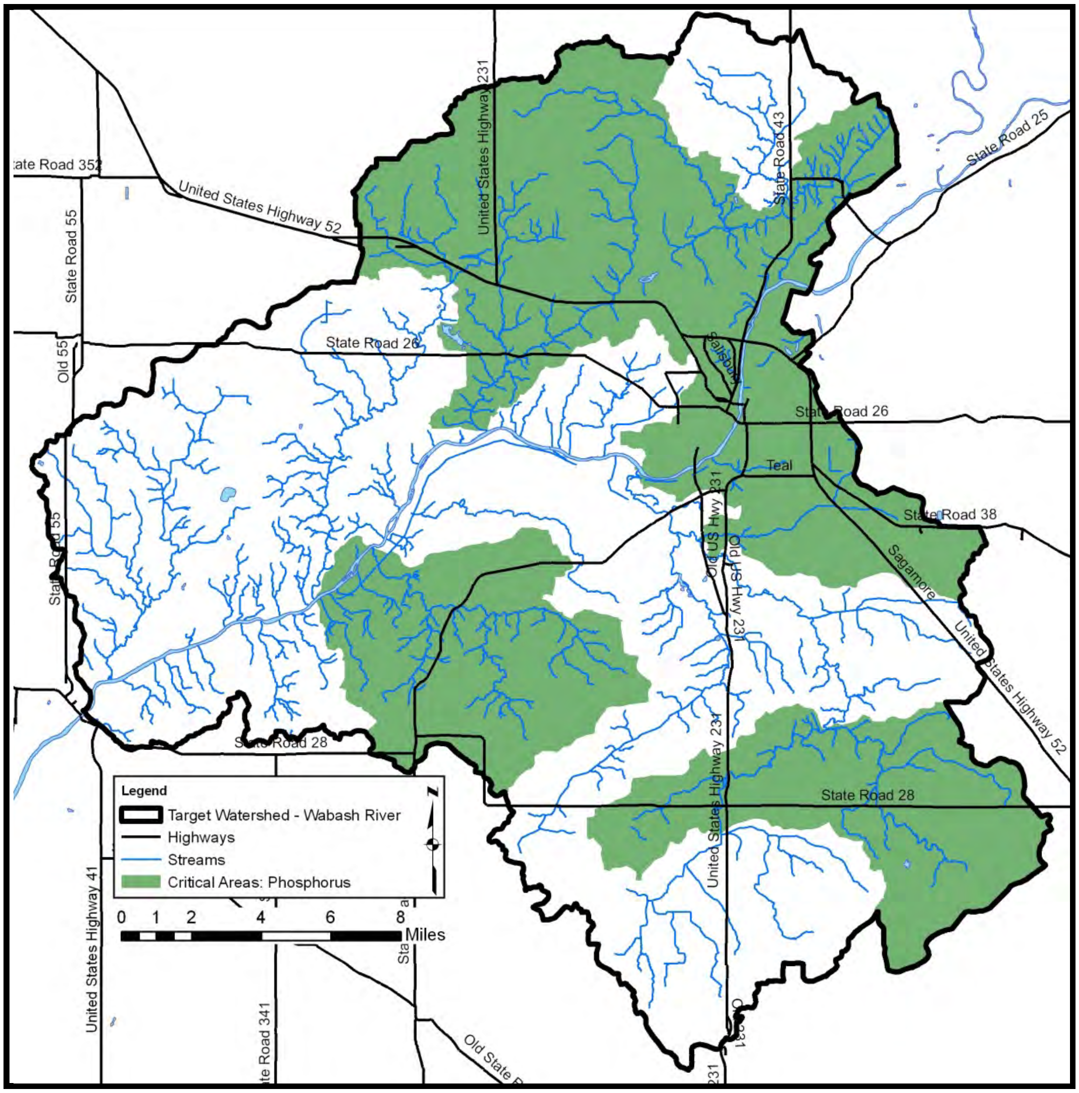

Figure 152. Total phosphorus based critical areas in the Region of the Great Bend of the Wabash River watershed.
Data used to create this map are detailed in Appendix A.

7.3.3 Critical Areas for Sediment

Total suspended solids were used to determine sediment-based critical areas. Total suspended solids enter streams in the Region of the Great Bend of the Wabash River watershed through streambank and bed erosion, unfiltered runoff, agricultural land use in floodplains, development, livestock access, and stormwater runoff. Total suspended solids critical areas were determined where three or more of the criteria needed to be met. Decisions included:

- Areas needing buffers exceeding 50% of the stream length within the subwatershed;
- Areas of streambank and bed erosion exceeding 50% of the stream length within in the subwatershed;
- Impervious surfaces covering 3% or more of the subwatershed;
- Agricultural lands in floodplains;
- Livestock access areas;
- Total suspended solids concentrations exceed the target concentration (25 mg/L) at 20% or more subwatershed sample sites;
- Total suspended solids concentrations exceed the target concentration (25 mg/L) 10% or more of the time at concentrated sample sites (>40 samples collected within one year).

Based on these criteria, East Branch Wea Creek, Elliot Ditch, Haywood Ditch-Wea Creek, Headwaters Burnett Creek, Indian Creek, Flint Run-Flint Creek, Flint Creek-Wabash River, Otterbein Ditch-Little Pine Creek, Cedar Hollow-Wabash River, Jordan Creek, all livestock access areas, and all agricultural land within floodplains serve as critical areas for total suspended solids. Figure 153 details total suspended solids based critical areas.

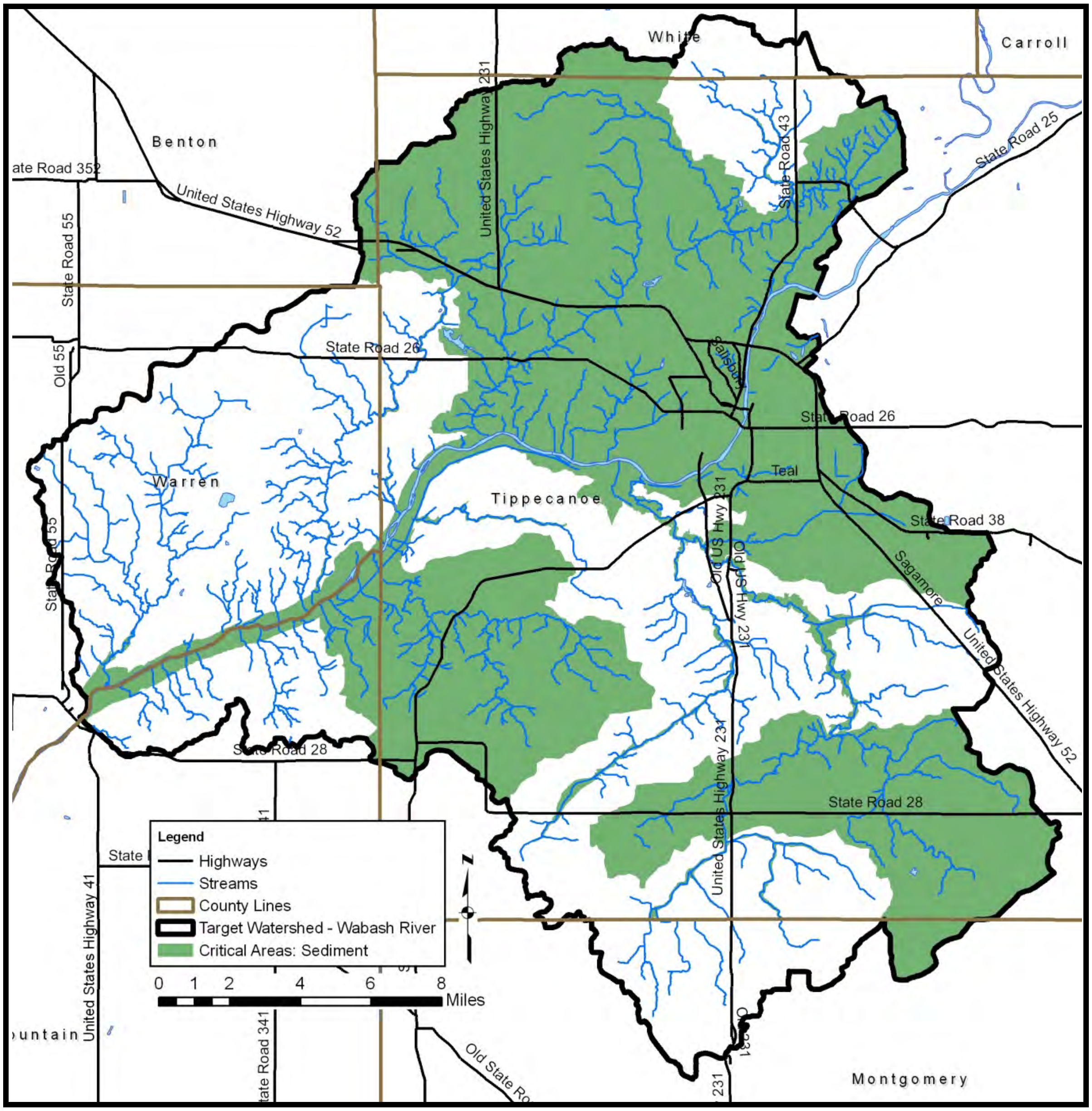

Figure 153. Total suspended solids based critical areas in the Region of the Great Bend of the Wabash River watershed.
Data used to create this map are detailed in Appendix A.

7.3.4 Critical Areas for *E. coli*

E. coli was used to determine our critical areas. *E. coli* enters streams in the Region of the Great Bend of the Wabash River watershed through human and animal waste, livestock access, and infrastructure issues. *E. coli* critical areas were determined by four criteria including:

- Livestock access areas;
- Impaired waterbodies listing for *E. coli*;
- E. coli concentrations exceed the target concentration (235 colonies/100 mL) at 30% or more subwatershed sample sites;
- E. coli concentrations exceeds the target concentration (235 colonies/100 mL) 10% or more of the time at concentrated sample sites (>40 samples collected).

Based on these criteria, East Branch Wea Creek, Kenny Ditch-Wea Creek, Headwaters Burnett Creek, Cedar Hollow-Wabash River, Flint Creek-Wabash River, Otterbein Ditch-Little Pine Creek, Elliot Ditch, Little Wea Creek, and all livestock access areas serve as critical areas for *E. coli*. Figure 154 details *E. coli* based critical areas.

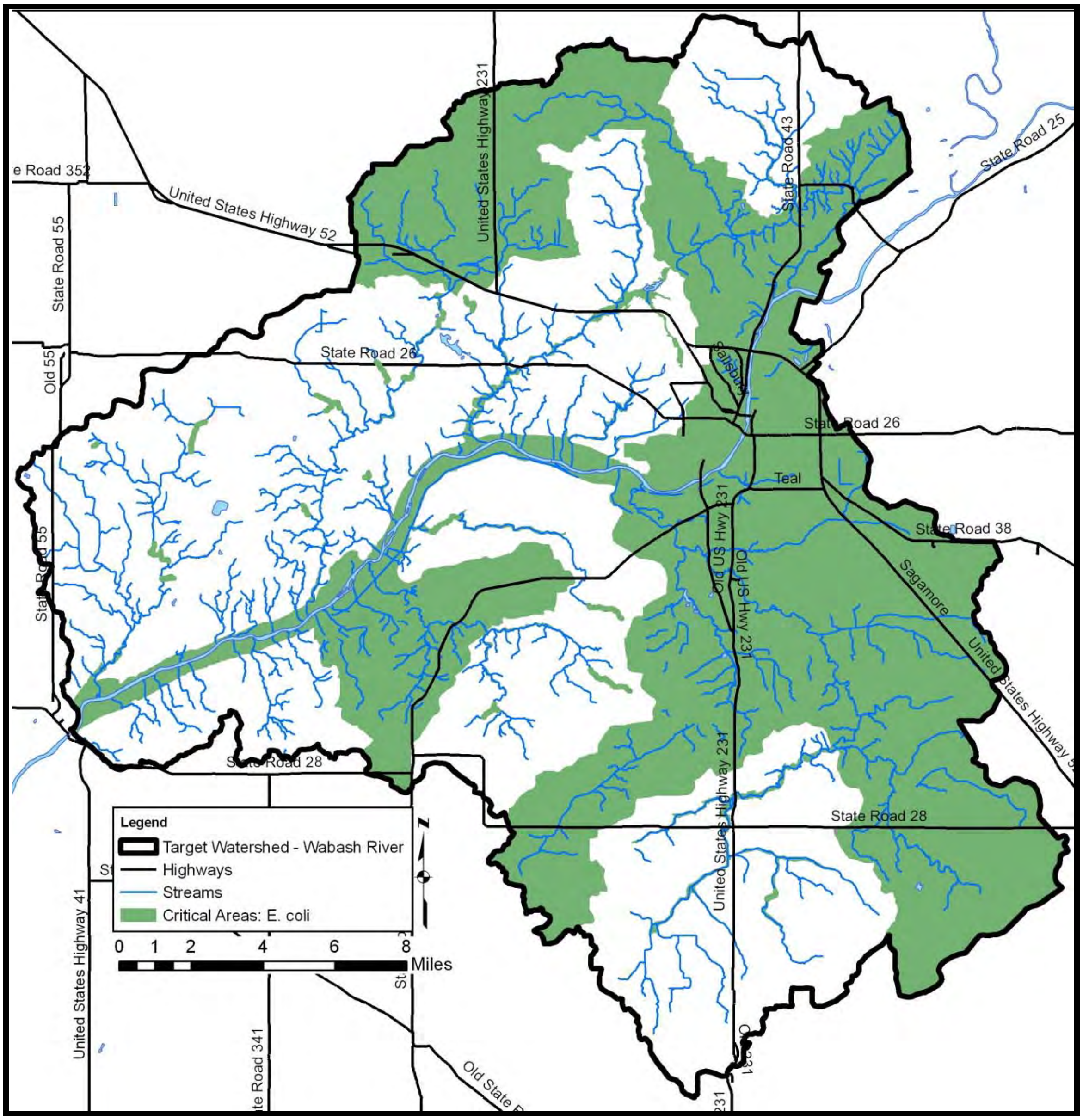

Figure 154. *E. coli* based critical areas in the Region of the Great Bend of the Wabash River watershed. Data used to create this map are detailed in Appendix A.

7.3.5 Critical Areas for Habitat

Habitat and biological data were used to determine habitat-based critical areas. Due to the limited watershed-wide habitat data currently available, results from biological monitoring were also used to assess limitations and determine critical areas. Habitat limitations were identified based on streambank and bed erosion, poor filtration, impervious surfaces, and impediments due to road crossings. Habitat-based critical areas were determined by six criteria with subwatersheds meeting three or more requirements and those areas located within the Wabash River floodplain. Criteria include:

- Areas needing buffers exceeding 50% of the stream length within the subwatershed;
- Areas of streambank and bed erosion exceeding 50% of the stream length within in the subwatershed;
- Impervious surfaces cover 3% or more of the subwatershed;
- More than one stream-road crossing per mile of surface waterbody;
- Subwatersheds where one or more IBI scores less than 36 were recorded;
- Subwatersheds where one or more mIBI scores less than 2.2 were recorded.

Based on these criteria, East Branch Wea Creek, Elliot Ditch, Headwaters Burnett Creek, Indian Creek, Flint Run-Flint Creek, Haywood Ditch-Wea Creek, and Otterbein Ditch-Little Pine Creek subwatersheds serve as critical areas for habitat. Figure 155 details habitat based critical areas.

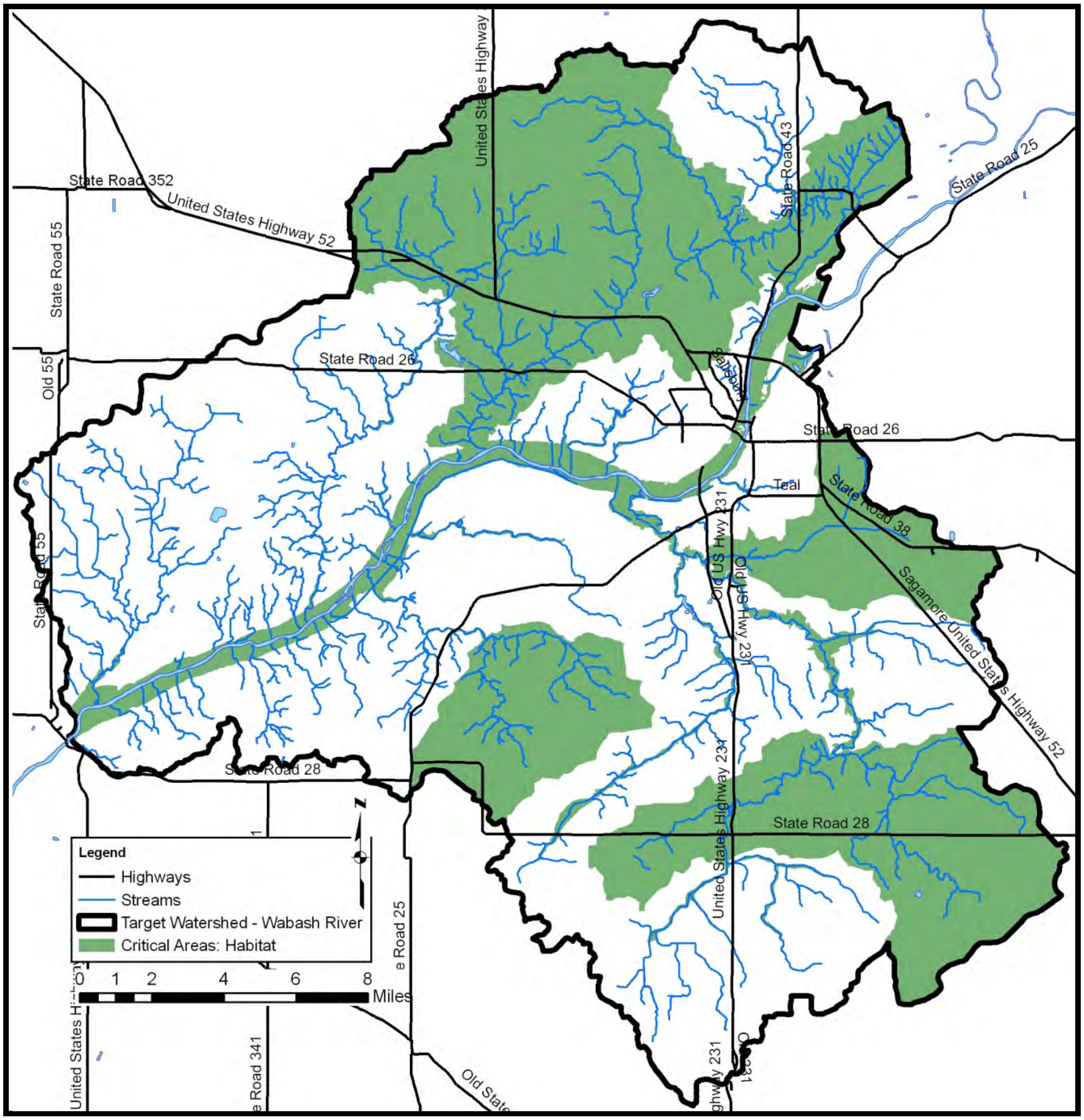

Figure 155. Habitat-based critical areas in the Region of the Great Bend of the Wabash River watershed. Data used to create this map are detailed in Appendix A.

7.3.6 Priority Areas

Based on a review of fish and macroinvertebrate assessments, Turkey Run-Wabash River and Armstrong Creek-Little Pine Creek subwatersheds should be considered priority areas. Both subwatersheds contain high quality habitat, fish, and macroinvertebrate communities. Figure 156 details priority and critical areas in the Region of the Great Bend of the Wabash River watershed.

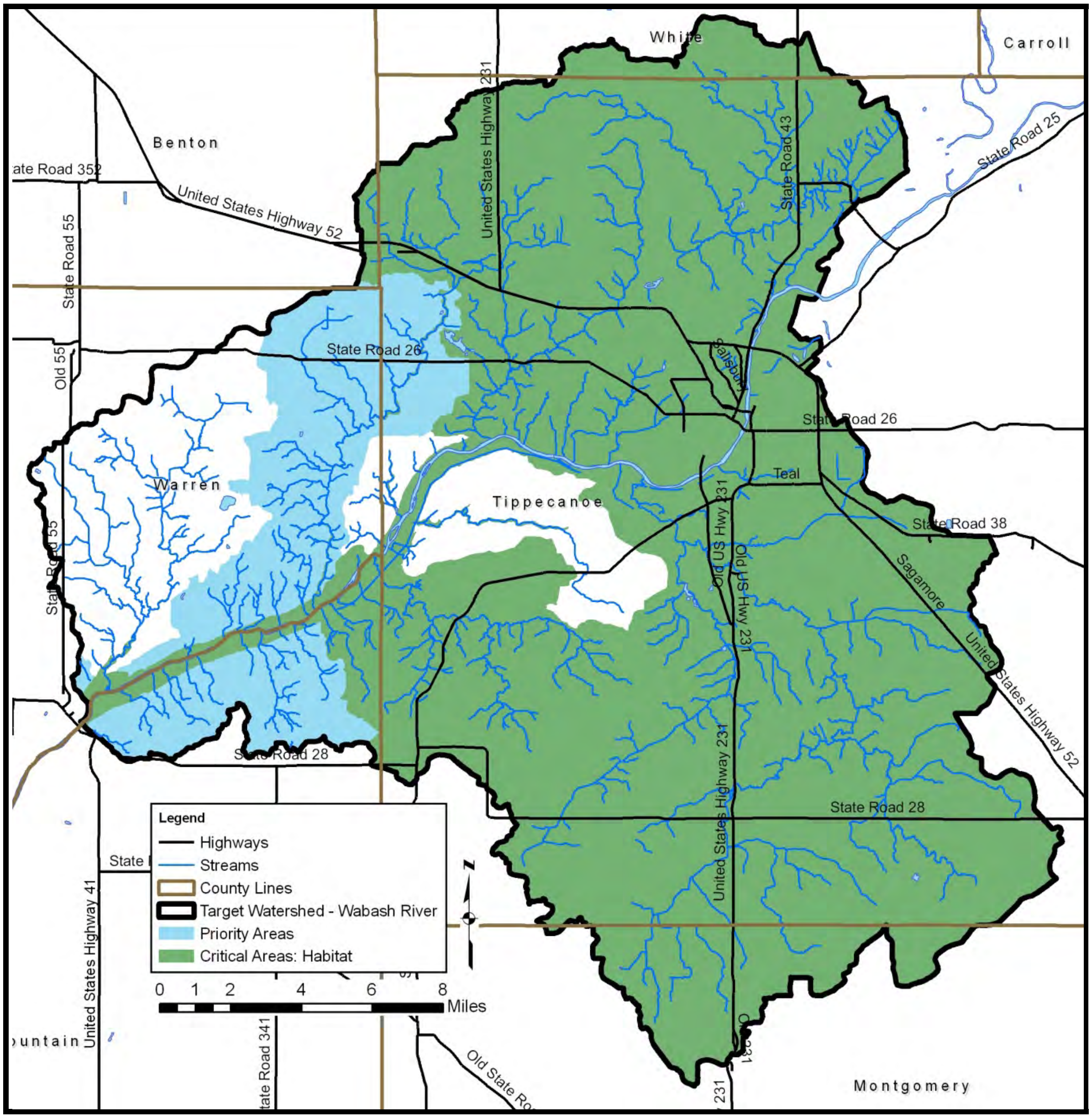

Figure 156. Priority and critical areas in the Region of the Great Bend of the Wabash River watershed. Data used to create this map are detailed in Appendix A.

8.0 CRITICAL LOAD ESTIMATION

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA details sources of nonpoint pollution to include: urban runoff, construction activities, manmade modifications to stream hydrology, agriculture, irrigation pumping and water returns, solid waste disposal, atmospheric deposition, streambank erosion, and more. The critical sources identified within the Region of the Great Bend of the Wabash River watershed are detailed above. The magnitudes of each source are expressed in

Table 32 through Table 39. These data were generated using available watershed maps and information and are generally useful for detailing water quality problems within portions of the watershed where monitoring data are not available.

Another mechanism for determining sources of nonpoint pollution is hydrologic simulation models. Hydrologic models detail the transport of pollutants across the land surface as surface runoff. Rain water flows over the land and through the groundwater collecting pollutants including sediment and nutrients as it moves. The soil characteristics and land uses influence the way that water moves through the system and each hydrologic model simulates the movement in a different way. These computer models provide useful information which can serve as a baseline for future land use changes. They also serve as a check on the critical area determinations made using water chemistry sample and GIS-based watershed data.

8.1 Current Load Estimation

Watershed loading rates can be estimated using a variety of loading models for a variety of parameters. A tabular-based nonpoint source pollution loading model (L-THIA) was used to assess the nonpoint source pollution of three of the pollutants of concern: total nitrogen, total phosphorus, and total suspended solids. The L-THIA Estimate Nonpoint Source Pollutant model (L-THIA) provides a basis for comparison of runoff for these pollutants within each 12-digit subwatershed. It should be noted that L-THIA calculates loading based on 14-digit subwatersheds, not 12-digit subwatersheds. In order for calculation of runoff volume and nonpoint source pollutant loading to occur on a 12-digit subwatershed level, a series of modifications and comparisons occurred. They are described as follows:

1. The Region of the Great Bend of the Wabash River watershed map was created with 12-digit and 14-digit HUC overlays.
2. A list of 12-digit HUCs and their corresponding 14-digit HUCs was generated.
3. In cases where one or more 14-digit HUCs comprise one 12-digit HUC, the 14-digit HUCs were listed and the individual loadings calculated then added together.
4. For 12-digit HUCs which approximate 14-digit HUC boundaries, the 14-digit HUC boundary was utilized for the calculation.

In total, 1.0 million pounds of nitrogen, 294,000 pounds of phosphorus, and 25.6 million pounds of sediment loading occurs within the Region the Great Bend of the Wabash River watershed (Table 40). The Turkey Run-Wabash River and East Branch Wea Creek subwatersheds contain the highest nitrogen, phosphorus, and sediment loading rates. When loading rates are normalized by area, the Turkey Run-Wabash River subwatershed contains the highest nitrogen areal loading rate, while the Flint Run-Flint Creek subwatershed contains the highest phosphorus and sediment areal loading rates. The Flint Run-Flint Creek possesses the second highest areal nitrogen loading rate, while the Turkey Run-Wabash River subwatershed contained the highest phosphorus areal loading rate and East Branch Wea Creek contains the highest suspended solids areal loading rate. Using data generated by the L-THIA model, the Turkey Run-Wabash River, East Branch Wea Creek, and Flint Run-Flint Creek subwatersheds should be considered priority areas for reducing nitrogen, phosphorus, and sediment loading to the Wabash River.

Table 40. Estimated annual loads for each 12-digit subwatershed modeled using L-THIA.

Subwatershed	Area (acres)	Current Nitrogen Load (lb/yr)	Current Phosphorus Load (lb/yr)	Current Sediment Load (lb/yr)
Romney-Fraley Ditch	23,386	70,722	20,876	1,716,461
East Branch Wea Creek	18,365	90,709	26,825	2,207,038
Haywood Ditch-Wea Creek	11,289	36,156	10,678	886,297
Elliot Ditch	11,897	37,481	10,189	1,212,702
Little Wea Creek	21,394	65,210	19,264	1,597,399
Kenny Ditch-Wea Creek	18,219	47,627	14,134	1,165,143
North Fork Burnett Creek	11,607	41,081	12,141	1,015,400
Headwaters Burnett Creek	22,789	56,389	16,583	1,418,293
Cedar Hollow-Wabash River	14,697	53,064	14,767	1,647,252
Indian Creek	18,979	63,397	18,335	1,693,298
Jordan Creek-Wabash River	10,010	30,640	8,915	802,835
Lost Creek-Wabash River	16,852	42,701	12,566	1,039,723
Flint Run-Flint Creek	13,977	84,883	25,026	2,055,876
Otterbein Ditch-Little Pine Creek	13,186	47,296	13,569	1,279,411
Armstrong Creek-Little Pine Creek	20,130	39,936	11,755	969,878
Flint Creek-Wabash River	15,255	39,238	11,514	948,224
Headwaters Kickapoo Creek	15,266	37,257	10,905	895,269
West Fork Kickapoo Creek	9,814	23,957	6,971	573,509
Turkey Run-Wabash River	19,582	102,351	29,920	2,457,021
Total Watershed Load		**1,010,095**	**294,933**	**25,581,030**

As detailed above, critical areas were prioritized based on field observations and water monitoring results. These efforts contradict results from L-THIA modeling. L-THIA indicates that Turkey Run-Wabash River, East Branch Wea Creek, Flint Run-Flint Creek, and Romney-Fraley Ditch contain higher nitrate-nitrogen loads, while Jordan Creek-Wabash River, West Fork Kickapoo, Haywood Ditch-Wea Creek, Elliot Ditch, and Headwaters Kickapoo Creek contain the lowest nitrate-nitrogen loading rates. These findings do not follow field and water quality observations where Romney-Fraley Ditch, East Branch Wea Creek, North Fork and Headwaters Burnett Creek, Flint Run-Flint Creek, Otterbein Ditch-Little Pine Creek, and Elliot Ditch were identified as the most critical areas for reducing nitrate-nitrogen loading. With regards to total phosphorus, Turkey Run-Wabash River, Flint Run-Flint Creek, and East Branch Wea Creek were identified by L-THIA as having the highest loading rates. Few of these were identified as critical areas using observations and water quality data suggesting that modifications to L-THIA may be required to truly model the Region of the Great Bend of the Wabash River watershed. Similarly, Turkey Run-Wabash River, East Branch Wea Creek, Flint Run-Flint Creek, and Romney-Fraley Ditch were identified by L-THIA as the areas of greatest concern. All of L-THIA's results indicate that tweaks to the model are needed in order to generate quality information about the Region of the Great Bend of the Wabash River. These data suggest that tile drainage and streambank erosion may play large factors in conditions present in this watershed.

For model results to be useful in source identification and critical area prioritization, they need to approximate measured results. Table 41 is based on a comparison of three of the 12-digit subwatersheds with three subwatersheds in which weekly monitoring and quarter hour stage measurement occurs. Based on the comparison, the following conclusions about the usefulness of L-THIA to estimate nitrogen, phosphorus, and sediment loads in the Region of the Great Bend of the Wabash River are as follows:

- Nitrogen concentrations measured in agricultural watersheds, Little Wea and Little Pine creeks, are ten times higher than nitrogen concentrations estimated using L-THIA. This is as expected as L-THIA uses soil and land use information to evaluate surface runoff and is unaware of increased nitrogen transport rates due to tile drainage in agricultural lands. The addition of an estimate of subsurface tile drainage based on soil parent material maps (Owens and Schmidt, unpublished) and nitrate runoff based on soil type (Ale, unpublished) generates a better approximation; however, even the combination of the surface estimate (L-THIA) and the subsurface estimate does not generate a good approximation of the measured nitrate concentrations.
- Phosphorus concentrations calculated by L-THIA are nearly double those measured at stream monitoring locations. However, as they are within the same order of magnitude, these estimates will be used as generated by L-THIA.
- Measured sediment loading rates are approximately triple concentrations estimated using L-THIA. As indicated with regard to phosphorus modeling results, monitoring results suggest that sediment generated from overland flow accounts for approximately one-third of the sediment present in the stream system. Studies in the Minnesota River conducted for TMDL development determined that more than two-thirds of the current sediment load is generated from non-field sources, such as streambank erosion, ravines, and channel erosion (Senjem, 2008).

Based on this assessment, L-THIA may not be the most appropriate model to use to estimate nitrogen loading rates throughout the largely agricultural, tile drained Region of the Great Bend of the Wabash River watershed. Additionally, quantification of non-surface water sources of sediment and phosphorus is necessary. Table 41 details the measured, L-THIA modeled, and additional estimates of nitrogen, phosphorus, and sediment within the three monitored subwatershed. More appropriate models for nitrogen will continue to be explored for use in nitrogen load estimation. It should be noted that all computation models have assumptions and limitations. Nonetheless, the conditions of the L-THIA model provide useful information for targeting and prioritizing subwatersheds for phosphorus and sediment loads.

Table 41. Comparison of modeled results to monitoring station loading calculations measured March 2009 through April 2010 in lb/acre/year.

Nitrogen				
Subwatershed	**Measured**	**Modeled Surface**	**Estimated Subsurface**	**Total**
Elliot Ditch	3.2	3.1	6.3	9.4
Little Wea Creek	37.6	3.1	14.7	17.8
Little Pine Creek	30.2	3.6	20.6	24.2
Phosphorus				
Subwatershed	**Measured**	**Modeled Surface**		**Total**
Elliot Ditch	0.4	0.9		0.9
Little Wea Creek	0.5	1.0		1.0
Little Pine Creek	0.5	0.9		0.9
Sediment				
Subwatershed	**Measured**	**Modeled Surface**	**Estimated Erosion**	**Total**
Elliot Ditch	369.5	101.9	152.9	254.8
Little Wea Creek	239.6	97.0	112.0	209.0
Little Pine Creek	227.6	74.7	145.5	220.2

Based on the results from comparing modeled loading rates to measured loading rates within the three monitored subwatersheds, loading rates for the remaining subwatersheds throughout the Region of the Great Bend of the Wabash River were recalculated. Those results are displayed in Table 42. Due to the issues associated with L-THIA model results, the estimated loads detailed below will be used to complete load reduction estimation. However, it should be noted that these values contain inherent errors suggesting that the L-THIA model combined with the suggested modifications generate poor results compared to monitored data. Nonetheless, these modeled results will be used as a surrogate for loading rates throughout the watershed, while measured results will be used in the monitored subwatersheds.

Table 42. Estimated annual loads for each 12-digit subwatershed using modeled results from L-THIA and estimated non-surface runoff loading.

Subwatershed	Area (acres)	Current Nitrogen Load (lb/yr)	Current Phosphorus Load (lb/yr)	Current Sediment Load (lb/yr)
Romney-Fraley Ditch	23,386	515,812	20,876	4,291,153
East Branch Wea Creek	18,365	467,675	26,825	5,517,594
Haywood Ditch-Wea Creek	11,289	94,095	10,678	2,215,743
Elliot Ditch*	11,897	38,391	5,300	2,849,972
Little Wea Creek*	21,394	805,028	10,002	4,870,112
Kenny Ditch-Wea Creek	18,219	243,832	14,134	2,912,858
North Fork Burnett Creek	11,607	273,650	12,141	2,538,499
Headwaters Burnett Creek	22,789	152,034	16,583	3,545,733
Cedar Hollow-Wabash River	14,697	56,485	14,767	4,118,130
Indian Creek	18,979	340,667	18,335	4,233,245
Jordan Creek-Wabash River	10,010	82,712	8,915	2,007,088
Lost Creek-Wabash River	16,852	91,501	12,566	2,599,308
Flint Run-Flint Creek	13,977	372,516	25,026	5,139,691
Otterbein Ditch-Little Pine Creek*	13,186	398,710	6,834	4,872,216
Armstrong Creek-Little Pine Creek	20,130	317,523	11,755	2,424,695
Flint Creek-Wabash River	15,255	177,096	11,514	2,370,561
Headwaters Kickapoo Creek	15,266	252,958	10,905	2,238,173
West Fork Kickapoo Creek	9,814	93,591	6,971	1,433,772
Turkey Run-Wabash River	19,582	223,347	29,920	6,142,553
Total Watershed Load		**4,997,624**	**274,047**	**66,321,095**

*Monitored data used for loading rate.

8.2 Load Reduction Estimation

As detailed in Section 3, the steering committee selected water quality targets that are more stringent than many of the state standards or recommended concentrations. Table 43 details target concentrations for our parameters of concern. Using flows calculated at the three tributary monitoring stations over a one year sampling period, target loads were calculated for each subwatershed (Table 44). To calculate estimated target loads, the average annual flow for the three gaging stations was calculated. Flows were then scaled by watershed size to calculate flow rates for each subwatershed. These scaled flow rates were then multiplied by the target concentrations displayed in Target loads were then subtracted from the current estimated loads (Table 44) generating a target load reduction for each subwatershed (Table 45) and for the entire watershed (Table 46). Figure 157 through Figure 159 detail load reductions by parameter for each subwatershed.

Table 43. Target concentrations for parameters of interest in the Region of the Great Bend of the Wabash River watershed.

Parameter of Concern	Water Quality Benchmark
Nitrate-nitrogen	<2.0 mg/L
Total phosphorus	<0.08 mg/L
Total suspended solids	<25 mg/L
E. coli	<235 colonies/100 mL

Table 44. Estimated target loads by subwatershed needed to meet water quality target concentrations in the Region of the Great Bend of the Wabash River watershed.

Subwatershed	Area (acres)	Target Nitrogen Load (lb/yr)	Target Phosphorus Load (lb/yr)	Target Sediment Load (lb/yr)
Romney-Fraley Ditch	23,386	80,028	3,201	1,000,353
East Branch Wea Creek	18,365	62,846	2,514	785,576
Haywood Ditch-Wea Creek	11,289	38,632	1,545	482,895
Elliot Ditch	11,897	35,533	1,421	444,169
Little Wea Creek	21,394	66,240	2,650	828,001
Kenny Ditch-Wea Creek	18,219	62,346	2,494	779,331
North Fork Burnett Creek	11,607	39,720	1,589	496,498
Headwaters Burnett Creek	22,789	77,985	3,119	974,816
Cedar Hollow-Wabash River	14,697	50,294	2,012	628,675
Indian Creek	18,979	64,947	2,598	811,840
Jordan Creek-Wabash River	10,010	34,255	1,370	428,185
Lost Creek-Wabash River	16,852	57,668	2,307	720,856
Flint Run-Flint Creek	13,977	47,830	1,913	597,876
Otterbein Ditch-Little Pine Creek	13,186	55,160	2,206	689,498
Armstrong Creek-Little Pine Creek	20,130	68,886	2,755	861,075
Flint Creek-Wabash River	15,255	52,203	2,088	652,543
Headwaters Kickapoo Creek	15,266	52,241	2,090	653,014
West Fork Kickapoo Creek	9,814	33,584	1,343	419,801
Turkey Run-Wabash River	19,582	67,011	2,680	837,634
Total Watershed Load		**1,047,411**	**41,896**	**13,092,633**

Table 45. Calculated load reduction by subwatershed needed to meet water quality targets in the Region of the Great Bend of the Wabash River watershed.

Subwatershed	Nitrogen Reduction (lb/yr)	Phosphorus Reduction (lb/yr)	Sediment Reduction (lb/yr)
Romney-Fraley Ditch	435,784	17,675	3,290,801
East Branch Wea Creek	404,829	24,311	4,732,018
Haywood Ditch-Wea Creek	55,464	9,133	1,732,848
Elliot Ditch*	2,858	3,878	2,405,803
Little Wea Creek*	738,788	7,353	4,042,111
Kenny Ditch-Wea Creek	181,486	11,640	2,133,527
North Fork Burnett Creek	233,930	10,552	2,042,001
Headwaters Burnett Creek	74,048	13,464	2,570,917
Cedar Hollow-Wabash River	6,191	12,755	3,489,455
Indian Creek	275,720	15,737	3,421,405
Jordan Creek-Wabash River	48,457	7,545	1,578,903
Lost Creek-Wabash River	33,832	10,259	1,878,451
Flint Run-Flint Creek	324,686	23,113	4,541,815
Otterbein Ditch-Little Pine Creek*	343,550	4,628	4,182,719
Armstrong Creek-Little Pine Creek	248,637	8,999	1,563,620
Flint Creek-Wabash River	124,893	9,426	1,718,018
Headwaters Kickapoo Creek	200,717	8,815	1,585,159
West Fork Kickapoo Creek	60,007	5,628	1,013,971
Turkey Run-Wabash River	156,336	27,239	5,304,919
Total Reduction	**3,950,213**	**232,150**	**53,228,462**

*Monitored data used for loading rate.

Table 46. Current and target loads in pounds/year and load reduction needed to meet water quality target concentrations in the Region of the Great Bend of the Wabash River watershed.

Parameter of Concern	Current Load	Target Load	Reduction Needed
Nitrogen (lb/yr)	4,997,623	1,047,411	3,950,213 (79%)
Phosphorus (lb/yr)	274,046	41,896	232,150 (85%)
Suspended Sediment (lb/yr)	66,321,094	13,092,633	53,228,462 (80%)
E. coli (col/100 ml/yr)			

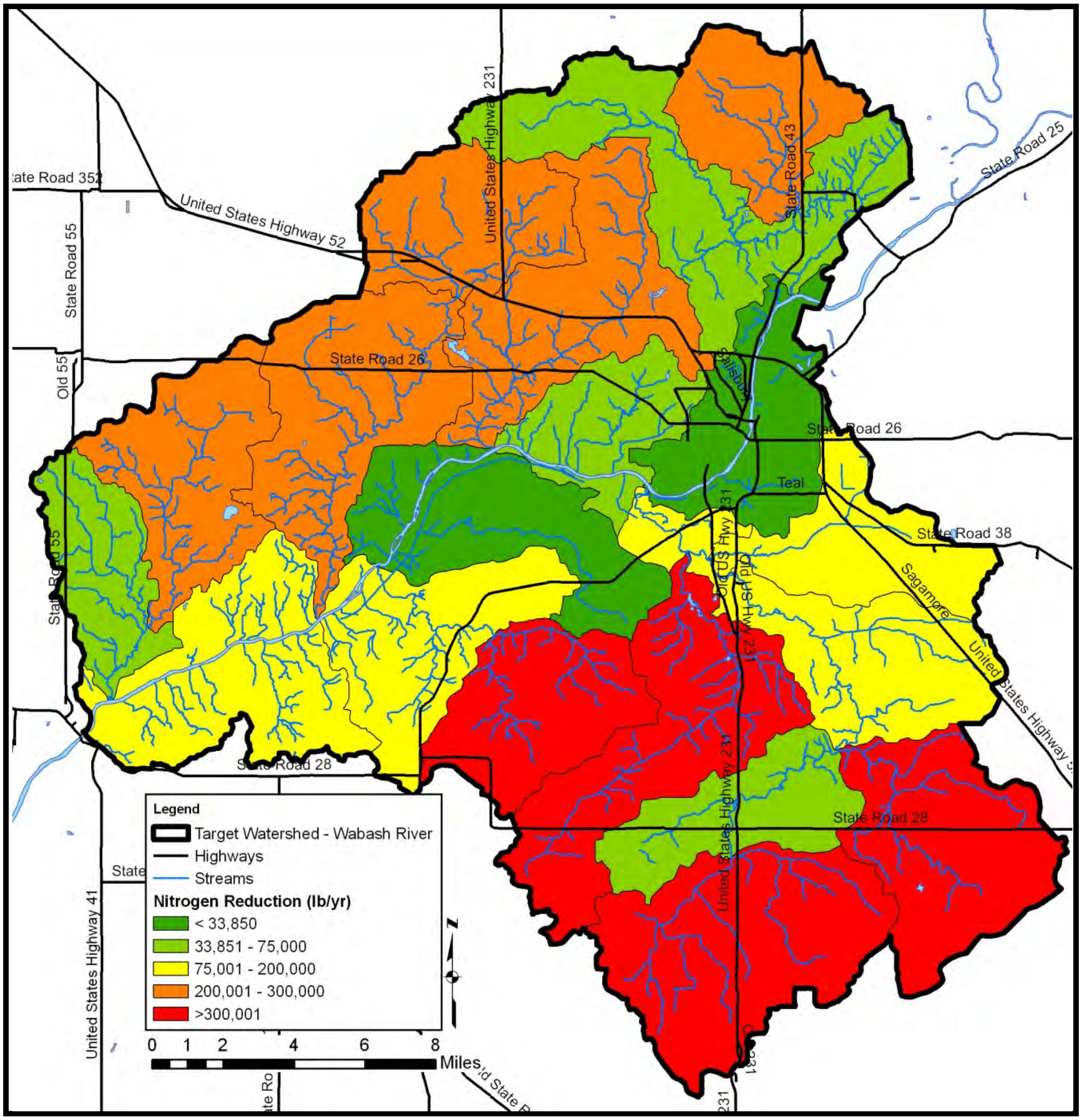

Figure 157. Total nitrogen loading reduction estimated using L-THIA.
Data used to create this map are detailed in Appendix A.

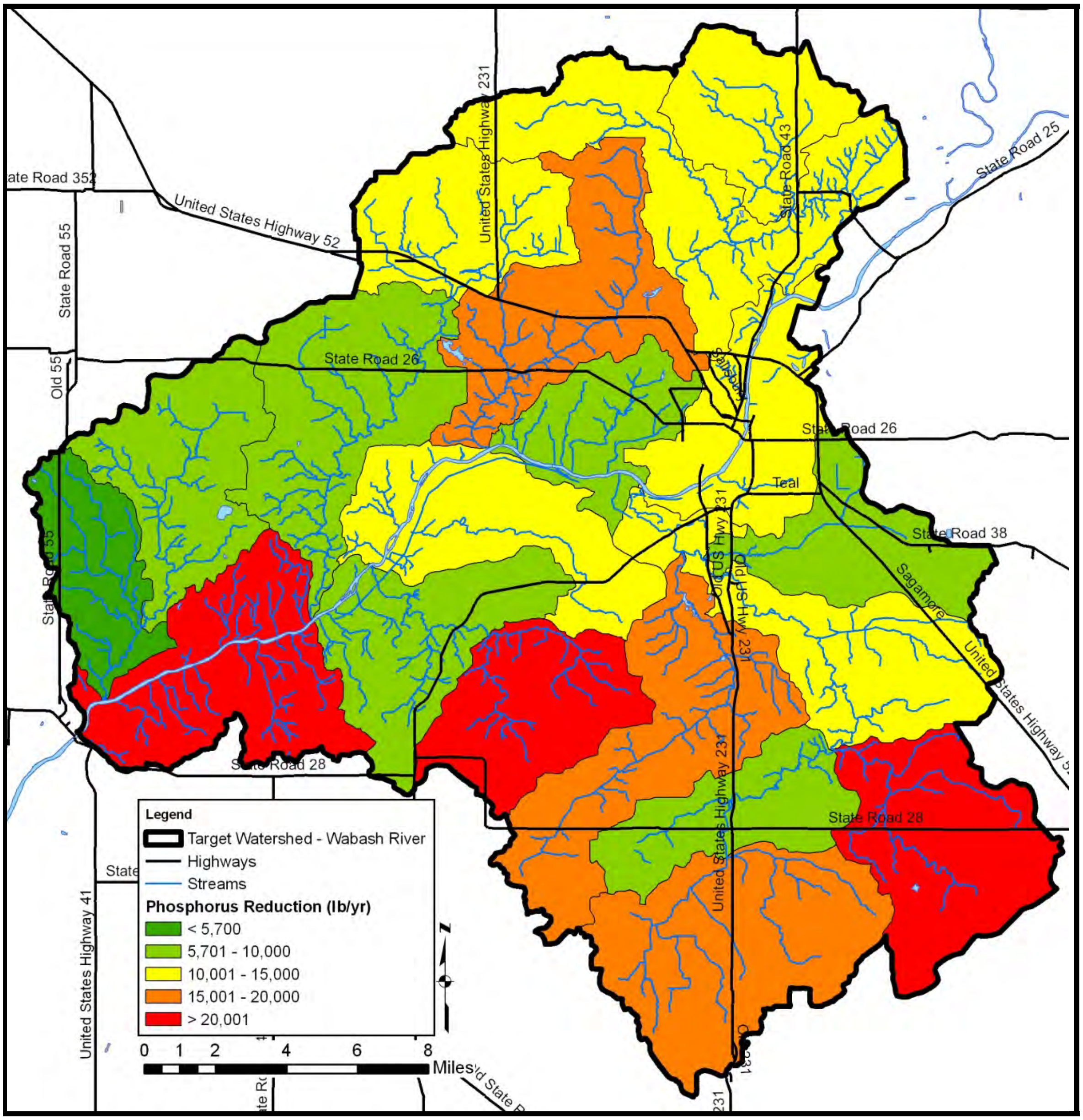

Figure 158. Total Phosphorus loading reduction estimated using L-THIA.
Data used to create this map are detailed in Appendix A.

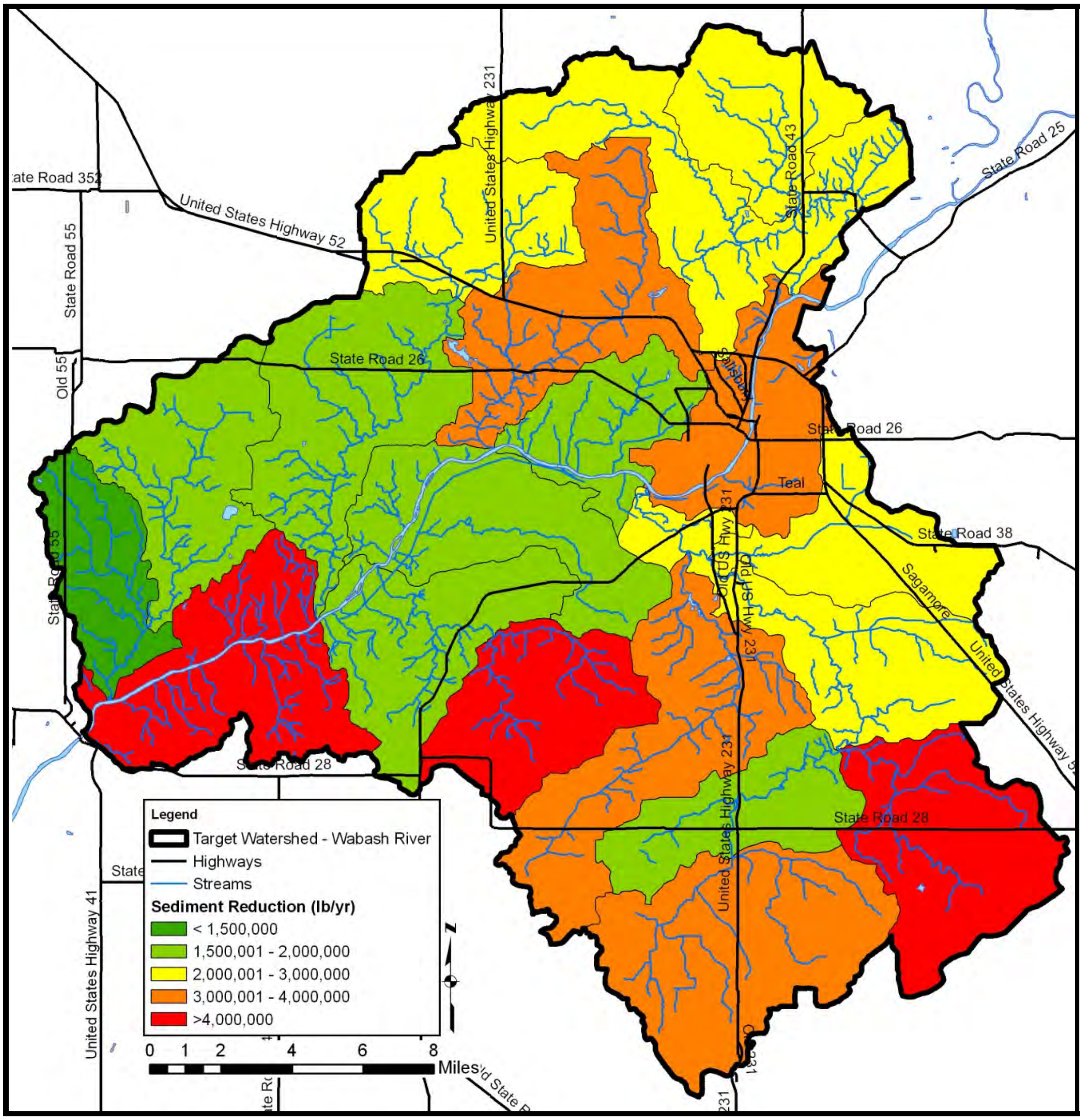

Figure 159. Total suspended sediment loading reduction estimated using L-THIA. Data used to create this map are detailed in Appendix A.

9.0 IMPROVEMENT MEASURE SELECTION

A wide variety of practices are available for on-the-ground implementation. Many of these practices will result in the reduction of sediment, nutrient, and E. coli loading to the Wabash River within the Region of the Great Bend of the Wabash River watershed. A list of potential best management practices was reviewed by the project steering committee and project partners. From this list, the practices which were deemed most appropriate and most likely to successfully meet loading reduction targets were identified. The selected best management practices were categorized as agricultural or urban. It should be noted that no practice list is exhaustive and that additional techniques may be both possible and necessary to reach water quality goals.

9.1 Best Management Practices

9.1.1 Agricultural Best Management Practices

Agricultural best management practices are implemented on agricultural lands, typically row crop agricultural lands, in order to protect water resources and aquatic habitat while improving land resources and quality. These practices control nonpoint source pollutants reducing their loading to the Wabash River by minimizing the volume of available pollutants. Potential agricultural best management practices designed to control and trap agricultural nonpoint sources of pollution include:

- Alternate Watering Systems
- Bioreactors
- Buffer Strip (Shrub/Tree)
- Conservation Tillage (No till end goal)
- Cover Crop
- Drainage Water Management
- Filter Strip (grass)
- Livestock Restriction or Rotational Grazing
- Manure Management Planning
- Nutrient/Pest Management Planning
- Prairie Restoration
- Reforestation
- Two Stage Ditch
- Septic System Upgrades
- Streambank Stabilization
- Wetland Construction or Restoration

Alternate Watering Systems

Alternative watering systems provide an alternate location for livestock to seek water rather than using a surface water source. This removes the negative impacts of livestock access to streams including direct deposit of manure and bank erosion and destabilization, while improving the health of livestock by providing a clean water source and better footing while drinking. This results in less *E. coli*, phosphorus, nitrogen, and sediment entering a surface waterbody. Two main types of alternative watering systems are used including pump systems and gravity systems.

Bioreactors

Bioreactors use bacteria to digest organic materials including manure, remnant plant material, and woody debris. Bioreactors typically generate energy, water, and fertilizer. Bioreactors use a series of tanks and treatment processes to separate cellulose-based materials from oils and gases. Materials are then broken down into carbon dioxide or methane gas and ethanol.

Buffer Strip / Filter Strip

Installing natural buffers or filters along major and minor drainages in the watershed helps reduce the nutrient and sediment loads reaching surface waterbodies. These practices are used throughout the Region of the Great Bend of the Wabash River watershed with nearly 47% of agricultural survey respondents indicating that they currently use filter or buffer strips on their agricultural operation. Buffers provide many benefits including restoring hydrologic connectivity, reducing nutrient and sediment transport, improving recreational opportunities and aesthetics, and providing wildlife habitat. Sediment, phosphorus, nitrogen, and *E. coli* are at least partly removed from water passing through a naturally vegetated buffer. The percentage of pollutants removed depends on the pollutant load, the type of vegetation, the amount of runoff, and the character of the buffer area. The most effective buffer width can vary along the length of a channel. Adjacent land uses, topography, runoff velocity, and soil and vegetation types are all factors used to determine the optimum buffer width.

Many researchers have verified the effectiveness of filter strips in removing sediment from runoff with reductions ranging from 56-97% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction in sediment load occurs within the first 15 feet of installed buffer. Smaller additional amounts of sediment are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrients like those of nitrate and phosphorus, and atrazine and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor of up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Both filter strips and buffer strips should be designed as permanent plantings to treat runoff and should not be considered part of the annual rotation of adjacent cropland. Filter strips should receive only sheet flow and should be installed on stable banks. A mixture of grasses, forbs, and herbaceous plants should be used. In more permanent plantings, shrubs and trees should be intermingled to form a stable riparian community.

Conservation Tillage

Conservation tillage refers to several different tillage methods or systems that leave at least 30% of the soil covered with crop residue after planting (Holdren et al., 2001). Tillage methods encompassed by conservation tillage include no-till, mulch-till, ridge-till, zero till, slot plant, row till, direct seeding, or strip till. The purpose of conservation tillage is to reduce sheet an rill erosion, maintain or improve soil organic matter content, conserve soil moisture, increase available moisture, reduce plant damage, and provide habitat and cover for wildlife. The remaining crop residue helps reduce soil erosion and runoff volume.

Several researchers have demonstrated the benefits of conservation tillage in reducing pollutant loading to streams and lakes. A comprehensive comparison of tillage systems showed that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (Conservation Technology Information Center, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). Conservation tillage is widely used throughout the watershed with 70% of agricultural survey respondents indicating that they currently use conservation tillage. Only 3% of respondents indicate that they are unfamiliar with conservation tillage.

Cover Crop

Cover crops include legumes, such as clover, hairy vetch, field peas, alfalfa, and soybean, and non-legumes, such as rye, oats, wheat, radishes, turnips, and buckwheat which are planted prior to or following crop harvest. Cover crops typically grow for one season to one year and are typically grown in non-cropping seasons. Cover crops are used to improve soil quality and future crop harvest by improving soil tilth, reducing wind and water erosion, increasing available nitrogen, suppressing weed cover, and encouraging beneficial insect growth. Cover crops reduce phosphorus transport by reducing soil erosion and runoff. Both wind and water erosion move soil particles that have phosphorus attached. Sediment that reaches water bodies may release phosphorus into the water. The cover crop vegetation recovers plant-available phosphorus in the soil and recycles it through the plant biomass for succeeding crops. Runoff water can wash soluble phosphorus from the surface soil and crop residue and carry it off the field. Cover crops are a familiar conservation practice throughout the watershed; however, only 40% of agricultural survey respondents indicate that they are currently using cover crops. Nearly equal percentages of agricultural land owners indicate limited and full knowledge of cover crops.

Drainage Water Management

Subsurface tile drainage is an essential water management practice on highly productive fields. As a result of tile drainage, nitrate carried in drainage water enters adjacent surface waterbodies. Drainage water management is necessary to reduce nitrate loads entering adjacent surface waterbodies from tile drainage networks. Drainage water management uses water control structures within lateral drains to vary the depth of tile outlets. Typically, the outlet is raised after harvest to limit outflow from the tile and reduce nitrate transport to adjacent waterbodies; lowered in the spring and fall to allow tile water to flow freely from the field to adjacent waterbodies; and raised in the summer to help store water making it available for crops (Frankenberger et al., 2006). Drainage water management can be used in concert with a suite of other conservation practices including cover crops and conservation tillage.

Grassed Waterway

Grassed waterways are natural or constructed channels established for transport of concentrated flow at safe velocities using adequate channel dimensions and proper vegetation. They are generally broad and shallow by design to move surface water across farmland without causing soil erosion. Grassed waterways are used as outlets to prevent rill and gully formation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large water flows downslope. These waterways can also be used as outlets for water released from contoured and terraced systems and from diverted channels. This BMP can reduce sediment concentrations of nearby waterbodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and absorption by soil. The waterways can also provide wildlife corridors and allows more land to be natural areas.

Livestock Restriction or Rotational Grazing

Livestock that have unrestricted access to a stream or wetland have the potential to degrade the waterbody’s water quality and biotic integrity. Only 30% of agricultural landowners responding to the social indicator survey indicate that they have livestock. Of those agricultural landowners that own livestock, nearly 30% use grazing management plans. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream ecosystems indirectly. Trampling and removal of vegetation through grazing of riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in a wetland or riparian zone decreasing the area’s ability to infiltrate water runoff. Removal of vegetation in a wetland or riparian zone also limits the area’s ability to filter pollutants in runoff. The degradation of a waterbody’s water quality and habitat typically results in the impairment of the biota living in the waterbody.

Restoring areas impacting by livestock grazing often involves several steps. First, the livestock in these areas should be restricted from the wetland or stream to which they currently have access. If necessary an alternate source of water should be created for the livestock. Second, the wetland or riparian zone where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. Minimally, it involves installing filter strips along banks or wetland edge and replanting any denuded areas. Finally, if possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading, particularly nitrate-nitrogen loading, to the adjacent waterbody. Complete restoration of aquatic areas impacted by livestock will help reduce pollutant loading, particularly nitrate-nitrogen, sediment, and pathogens.

A livestock exclusion system is a system of permanent fencing (board, barbed, etc) installed to exclude livestock from streams and areas, not intended for grazing. This will reduce erosion, sediment, and nutrient loading, and improve the quality of surface water. Education and outreach programs focusing on rotational grazing and exclusionary fencing are important in the success of this BMP.

Nutrient / Pest Management Planning

Nutrient management is the management of the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize the transport of applied nutrients into surface water or groundwater. This practice is used on roughly half of agricultural lands within the watershed. Of those agricultural producers not currently using nutrient or pest management planning, nearly 80% indicate a general unfamiliarity with the practice. Nutrient management seeks to supply adequate nutrients for optimum crop yield and quantity, while also helping to sustain the physical, biological, and chemical properties of the soil. A nutrient budget for nitrogen, phosphorus, and potassium is developed considering all potential sources of nutrients including, but not limited to, animal manure, commercial fertilizer, crop residue, and legume credits. Realistic yields are based on soil productivity information, potential yield, or historical yield data based on a 5-year average. Nutrient management plans specify the form, source, amount, timing, and method of application of nutrients on each field in order to achieve realistic production levels while minimizing transport of nutrients to surface and/or groundwater.

Manure Management Planning

Large volumes of manure are generated by both small, unregulated animal operations and by confined feeding operations located throughout the Region of the Great Bend watershed. Many entities have manure management plans in place and are currently using these plans to manage the volume of manure produced on their facility. Manure management planning includes consideration of the volume and type of manure produced annually, crop rotations by field, the volume of manure and nutrients needed for each crop, field slope, soil type, and manure collection, transportation, storage, and distribution methods. Manure management planning uses similar techniques to nutrient management planning with regards to nutrient budgets.

Animal waste is a major source of pollution to waterbodies. To protect the health of aquatic ecosystems and meet water quality standards, manure must be safely managed. Good management of manure keeps livestock healthy, returns nutrients to the soil, improves pastures and gardens, and protects the environment, specifically water quality. Poor manure management may lead to sick livestock, unsanitary and unhealthy conditions for humans and other organisms, and increased insect and parasite populations. Proper management of animal waste can be done by implementing BMPs, through safe storage, by application as a fertilizer, and through composting. Proper manure management can effectively reduce *E.coli* concentrations, nutrient levels and sedimentation. Manure management can also be addressed in education and outreach to encourage farmers to participate in this BMP.

Prairie Restoration

Restoration of prairies within the northern portion of the watershed is a viable way to restore historic habitat. Prairies provide deep soils which have historically been used to aid in crop production, reduce sediment and nutrient transport, and restore nutrient and organic carbon to soils. Prairie restoration typically includes planting of grasses and forbs with deep roots. Restoration of permanent vegetation is used on 44% of retired agricultural land within the Region of the Great Bend of the Wabash River watershed. Not all of this vegetation is prairie plants and this is indicated by the fact that 15% of agricultural producers indicate that they are restoring native plant communities.

Reforestation

Reforestation is the restocking of existing forests and woodlands which have been depleted. Reforestation can be used to improve the quality of human life by reducing pollution and dust from the air and rebuild natural habitats and ecosystems.

Two-Stage Ditch

When water is confined to stream or ditch channel it has the potential to cause bank erosion and channel down-cutting. Current ditch design generates narrow channels with steep sides. Water flowing through these systems often result in bank erosion, channel scour and flooding. A relatively new technique focuses on mitigating these issues through an in-stream restoration called a two-stage ditch. The design of a two-stage ditch incorporates a floodplain zone, called benches, into the ditch by removing the ditch banks roughly 2-3 feet about the bottom for a width of about 10 feet on each side. This allows the water to have more area to spread out on and decreases the velocity of the water. This not only improves the water quality, but also improves the biological conditions of the ditches where this is located.

The benefits of a two-stage ditch over the typical agricultural ditch include both improved drainage function and ecological function. The two-stage design improves ditch stability by reducing water flow and the need for maintenance, saving both labor and money. It also has the potential to create and maintain better habitat conditions. Better habitats for both terrestrial and marine species are a great plus when it comes to the two-stage ditch design. The transportation of sediment and nutrients is decreased considerably because the design allows the sorting of sediment, with finer silt depositing on the benches and courser material forming the bed.

Wetland Construction or Restoration

Visual observation and historical records indicate at least a portion of the Region of the Great Bend of the Wabash River watershed has been altered to increase its drainage capacity. Riser tiles in low spots on the landscape and tile outlets along the waterways in the watershed confirm the fact that the landscape has been hydrologically altered. This hydrological alteration and subsequent loss of wetlands has implications for the watershed's water quality. With nearly 60% of agricultural land owners indicating a lack of knowledge about wetland restoration, this practice offers a high potential to improve water quality within the watershed. Wetlands serve a vital role in storing water and recharging the groundwater. When wetlands are drained with tiles, the stormwater reaching these wetlands is directed immediately to nearby ditches and streams. This increases the peak flow velocities and volumes in the ditch. The increase in flow velocities and volumes can in turn lead to increased stream bed and bank erosion, ultimately increasing sediment delivery to downstream water bodies. Wetlands also serve as nutrient sinks at times. The loss of wetlands can increase pollutant loads reaching nearby streams and downstream waterbodies.

Restoring wetlands in the watershed could return many of the functions that were lost when these wetlands were drained. Through this process, a historic wetland site is restored to its historic status. These restored systems store nutrients, sediment, and *E. coli* while also increasing water storage and reducing flooding. Wetlands also provide additional habitat, stormwater mitigation, and recreational opportunities.

9.1.2 Urban Best Management Practices

Development and the spread of impervious surfaces are occurring throughout the Region of the Great Bend of the Wabash River watershed. The highest concentrations of development are located adjacent to the Lafayette-West Lafayette urban core including Battle Ground and around Attica. As impervious surfaces continue to spread throughout the watershed, the volume and velocity of stormwater entering the Wabash River will also increase. The best way to mitigate stormwater impacts is to infiltrate, store, and treat stormwater onsite before it can run off into the Wabash River. Urban best management practices designed to complete these actions are as follows:

- Bioretention Practices
- Concrete Grid Pavement
- Detention Basin Retrofit
- Grass Swale
- Green Roof
- Infrastructure Retrofit
- Pet Waste Control
- Phosphorus-free Fertilizers
- Porous Pavement
- Rain Barrel
- Rain Garden
- Street Sweeping
- Trash Control and Removal
- Urban Wildlife Population Control

Bioretention Practices

Bioretention practices use biofiltration or bioinfiltration to filter runoff by storing it in shallow depressions. Bioretention uses plant uptake and soil permeability mechanisms in a variety of manners typically in combination. Potential practices include sand beds, pea gravel overflow structures, organic mulch layers, plant materials, gravel underdrains, and an overflow system to promote infiltration. Bioinfiltration can also be used to treat runoff from parking lots, roads, driveways and other areas in the urban environment. Bioretention should not be used in highly urbanized areas rather, it should be used in areas where on-site storage space is available.

Detention Basin Retrofit

Traditionally, detention basins are large, open, unvegetated basins designed to hold water for short periods of time following a rain event (dry detention basin) or continuously (wet detention basin). Retrofits of detention basins are redesigned to hold water for longer periods of time with the goal of reducing sediment flow from the basin or provide filtration of stormwater before it enters the basin through the use of urban pond buffers. Additionally, oils, grease, nutrients, and pesticides can also settle in the retrofitted basin. The nutrients are then used by the plants for growth and development.

Grass Swale

Grass swales are used in urban areas and are often considered landscape features. Swales are graded to be linear with a shallow, open channel of a trapezoidal or parabolic shape. Vegetation which is water tolerant is planted within the channel which promotes the slowing of water flow through the system. Swales reduce sediment and nutrients as water moves through the swale and water infiltrates into the groundwater. Based on social indicator data, nearly 60% of urban residents are unfamiliar with grass swales, while 8% are currently using this practice to reduce stormwater runoff impacts.

Green Roof

A green roof is a building partially or completely covered with vegetation and a growing medium planted on top of a waterproof membrane. Irrigation and drainage systems are carry water from the roof through the plant material and medium to the building drainage system. Green roofs absorb rainwater, provide installation, reduce air temperatures, and provide habitat for wildlife. Green roofs can retain up to 75% of rainwater gradually releasing it via condensation and transpiration while retaining sediment and nutrients. Green roofs can be installed on any type of roof – slanting to flat – with an ideal slope of 25%. Nearly 45% of urban residents indicate unfamiliarity with the use of a green roof; <1% of urban residents responding to the social indicator survey indicate that they are currently using a green roof.

Infrastructure Retrofit

Typical stormwater infrastructure includes pipe and storm drains, or hard infrastructure, to convey water away from hard surfaces and into the stormwater system. Retrofitting these structures to implement low impact development techniques, use green practices, and introduce plants and filters to reduce sediment and nutrient concentrations contained in stormwater. Many of the treatments listed in this section can be utilized to retrofit infrastructure including pervious pavement, green roofs, constructed wetlands, rain gardens, and more. In order for the installation to meet a "retrofit" requirement, existing infrastructure must already be in place, subsequently removed, and replaced with green infrastructure.

Pervious Pavement

Pervious pavement comes in many forms including porous pavement and modular block pavement. Both types of pervious pavement can be installed on most any travel surface with a slope of 5% or less. Urban residents of the Region of the Great Bend of the Wabash River watershed indicate a general lack of knowledge with regards to pervious pavement. Only 13% indicated that they know how to use pervious pavement with 1.2% of respondents indicating current use of pervious pavement.

Pervious pavement has the approximate strength characteristics of traditional pavement with the ability to percolate water into the groundwater system. The pavement reduces sediment and nutrient transmission into the groundwater as water moves through the pores in the pavement. When installed, porous pavement includes a stone layer, filter fabric, and a filter layer covered by porous pavement. Correctly mixed porous pavement eliminates fine aggregates found in typical pavements. Porous asphalt is a type of porous pavement which includes a mix of Portland cement, coarse aggregates, and water that results in the formation of interconnected voids.

Modular pavement consists of individual blocks made of pervious material such as sand, gravel, or sod interspersed with strong structural material such as concrete. The blocks are typically placed on a sand or gravel base and designed to provide a load-bearing surface that is adequate to support personal vehicles, while allowing infiltration of surface water into the underlying soils. They usually are used in low-volume traffic areas such as overflow parking lots and lightly used access roads. An alternative to pervious and modular pavement for parking areas is a geotextile material installed as a framework to provide structural strength. Filled with sand and sodded, it provides a completely grassed parking area.

Pet Waste Control

Pet waste cannot be considered the predominant waste product within a watershed nor the one that produces the greatest impact. Nonetheless, the cumulative impact of pet waste within a watershed can produce a major impact on water quality. Pet waste contains bacteria and parasites, organic matter, phosphorus, nitrogen, and *E. coli* and can carry diseases including *Campylobacteriosis*, *Slamonellosis*, and *Toxocarisis*. Studies indicate that the average dog produces 13 pounds of nitrogen, 2 pounds of phosphorus, and 1,200 pounds of sediment annually (Miles, 2007). Given the estimated number of dogs within Tippecanoe County (38,820), the impact of this volume of nutrients and sediment on the Wabash River could be detrimental. Of urban residents that indicate they own a pet, 36% indicate that they properly dispose of pet waste, while 64% indicate limited knowledge and that they are not currently disposing of pet waste.

Many options for managing pet waste are available with most efforts focusing on educational options to turn pet waste from an 'out of sight, out of mind' issue to one that every pet owner considers for their pet. Pet waste can be flushed, resulting in waste traveling to the wastewater treatment plant or through the septic system for treatment, buried, where it gradually breaks down over time with nutrients entering the soil and microorganisms converting diseases and bacteria into less benign forms, or trashed, resulting in potential landfill issues. Ordinances, signage, and public education are needed to inform the community about options for treating pet waste issues.

Phosphorus-free Fertilizers

Phosphorus-free fertilizers are those fertilizers that supply nitrogen and minor nutrients without the addition of phosphorus. Phosphorus increases algae and plant growth which can cause negative impacts on water quality within aquatic systems. The Clear Choices, Clean Water (2010) program estimates that a one acre lawn fertilized with traditional fertilizer supplies 7.8 pounds of phosphorus to local waterbodies annually. Given that 75% of urban residents within the Region of the Great Bend of the Wabash River Watershed indicate either limited knowledge or that they don't use phosphorus free fertilizers, there is great potential for reducing urban sources of phosphorus by targeting this practice. Established lawns take their nutrients from the soil in which they grow and need little additional nutrients to continue plant growth. Fertilizers are manufactured in a variety of forms including that without phosphorus. Phosphorus-free fertilizer should be considered for use in areas where grass is already established.

Protecting Open Space and Natural Areas

Several techniques can be used for protecting natural areas and open space in both public and private ownership. Several entities throughout the watershed assist with the transfer of lands into protective status. Other open space can be protected using conservation design development techniques, and is more likely to be managed by homeowner associations.

Rain Barrel

A rain barrel is a container that collects and stores rainwater from your rooftop (via your home's disconnected downspouts) for later use on your lawn, garden, or other outdoor uses. Rainwater stored in rain barrels can be useful for watering landscapes, gardens, lawns, and trees. Rain is a naturally soft water and devoid of minerals, chlorine, fluoride, and other chemicals. In addition, rain barrels help to reduce peak volume and velocity of stormwater runoff to streams and storm sewer systems. Although rain barrels don't specifically reduce nutrient or sediment loading to waterbodies, their presence can reduce the first flush of water reaching storm drains. This impact is great especially in portions of the watershed where combined sewers are still in operation. Although a high percentage of urban residents indicated a general knowledge of rain barrels, only 3% of survey respondents indicate that they have installed a rain barrel. Furthermore, 75% of respondents indicate a willingness to consider installing a rain barrel.

Rain Garden

Rain gardens are small-scale bioretention systems that be can be used as landscape features and small-scale stormwater management systems for single-family homes, townhouse units, some small commercial development, and to treat parking lot or building runoff. Rain gardens provide a landscape feature for the site and reduce the need for irrigation, and can be used to provide stormwater depression storage and treatment near the point of generation. These systems can be integrated into the stormwater management system since the components can be optimized to maximize depression storage, pretreatment of the stormwater runoff, promote evapotranspiration, and facilitate groundwater recharge. The combination of these benefits can result in decreased flooding due to a decrease in the peak flow and total volume of runoff generated by a storm event. Additionally, rain gardens can be designed to provide a significant improvement in the quality of the stormwater runoff. Within the Region of the Great Bend of the Wabash River watershed, there is a general lack of knowledge about rain gardens and their cost, installation efforts needed, and water quality benefit. Nearly 60% of urban residents that responded to the social indicator survey stated that they had never heard of rain gardens. Less than 10% indicated familiarity with rain gardens or that they had rain garden installed on their property.

Street Sweeping

Street sweeping removes accumulated pollutants including debris, sediment, salt, trash, trace metals, and more while improving aesthetics, controlling dust, and decreasing the volume of materials accumulating in storm drains. Street sweeping is currently practices in many urban areas including the Cities of Lafayette and West Lafayette. Each city maintains a schedule of main roads which undergo routine cleaning. Additional arterial streets within the cities or sweeping of streets within smaller municipalities throughout the watershed could benefit water quality in the Wabash River.

Trash Control and Removal

Trash and debris located throughout urban areas indicate that these materials can have a significant negative impact on water quality within the Wabash River. A majority of trash observed occurs adjacent to streets, road right of ways, and sidewalks throughout the urban portions of the watershed. Surveys in larger urban areas indicate that plastic bottles, Styrofoam cups, and paper are the most common trash items found in or adjacent to storm drains. It is necessary to quantify the impacts of trash on the Wabash River and the cities' wastewater treatment facilities to determine if it is necessary to address trash in ways currently not occurring within the watershed.

Urban Wildlife Population Control

Wildlife populations located within urban areas can negatively impact water quality. Deer, Canada geese, raccoons, squirrels, and other animals can reach nuisance levels within urban areas. To control the population, a survey of the types of animals present, the volume of each species, the health and wellness of the populations, and habitat availability must be surveyed. Within the cities of Lafayette and West Lafayette, nuisance populations of Canada geese, raccoons, and squirrels are present in various locations. Control of the goose population by habitat modification and relocation are the most likely scenarios for control.

9.1.3 Preventative and System-Wide Practices

The protection of open space, preservation of habitat corridors, and mitigation of impacts from watershed-wide impacts are important management practices. These practices can be used throughout the Region of the Great Bend of the Wabash River watershed in locations where specific conditions occur. Potential management practices designed to address these issues are as follows:

- Fish Passage Improvement
- Greenways and Trails
- Habitat Corridor Identification and Improvement
- Low-impact Development
- Point Source Discharge Reduction
- Septic System Care and Maintenance
- Smart Growth/Liveable Communities Practices
- Streambank Stabilization
- Threatened and Endangered Species Protection

Fish Passage Improvement

Fish passage issues are typically considered of utmost importance for salmonid and trout species. Although the Region of the Great Bend of the Wabash River does not support a coldwater fishery, restriction of fish passage is still of concern. Existing highway culverts are the primary source of fish passage restriction. Many of these structures were installed prior to the consideration of impacts of barriers to fish passage or the needs of fish species. Specific locations where fish passage barriers exist were mapped as part of the Watershed Inventory. As these bridges are slated for improvement or repair, discussion of fish passage mitigation will be included.

Greenways and Trails

Greenways can provide a large number of functions and benefits to nature and the public. For plants and animals, greenways provide habitat, a buffer from development, and a corridor for migration. Greenways located along streams include riparian buffers that protect water quality by filtering sediments and nutrients from surface runoff and stabilizing streambanks. By buffering the stream from adjacent developed land use, riparian greenways offset some of the impacts associated with increased impervious surface in a watershed. Maintaining a good riparian buffer can mitigate the negative impacts of approximately 5% additional impervious surface in the watershed.

Habitat Corridor Identification and Improvement

Protection of habitat corridors requires a multi-phase program including identification of appropriate habitat corridors, development of a corridor management plan, and creation of an improvement plan. Most long-term corridor protection will require land transfer into protected status. There are several options for land transfer ranging from donation to fee simple land purchase. Donations can be solicited and encouraged through incentive programs. Outright purchase of property offers a secondary options and is frequently the least complicated and most permanent protection technique, but is also the most costly. A conservation easement is a less expensive technique than outright purchase that does not require the transfer of land ownership but rather a transfer of use rights. Conservation easements might be attractive to property owners who do not want to sell their land at the present time, but would support perpetual protection from further development. Conservation easements can be donated or purchased.

Several techniques can be used for protecting natural areas and open space in both public and private ownership. The first step in the process is to identify and prioritize properties for protection. The highest priority natural areas should be permanently protected by the ownership or under the management of public agencies or private organizations dedicated to land conservation. Other open space can be protected using conservation design development techniques, and is more likely to be managed by homeowner associations.

Low Impact Development

Low Impact Development (LID) is a land development or re-development process that works in concert with nature to manage stormwater at the source, or as close as possible to the source. Preservation of open space, recreation of natural landscape features, reduction of impervious surface coverage, and utilization of on-site drainage to treat stormwater are the key features of low impact development. This technique uses a suite of practices highlighted above including bioretention, rain gardens, green or vegetated roofs, rain barrels, pervious pavement, and more. LID can be used anywhere as part of a new development, redevelopment, or retrofit of existing development or infrastructure. If used correctly, LID can restore a watershed’s hydrologic and ecological function.

Point Source Discharge Reduction

Several point source permitted discharges are located throughout the Region of the Great Bend of the Wabash River watershed. These include large wastewater treatment plants, like those that service the cities of Lafayette and West Lafayette; small wastewater treatment and package plants, like those in Battle Ground, Otterbein, Linden and elsewhere; and manufacturer-operated NPDES facilities. A majority of the facilities permitted throughout the watershed operate within their permitted requirements with regards to water discharges. Eleven combined sewer overflows are located within the watershed and are controlled by the cities of Lafayette and West Lafayette. Both cities are in the process of implementing long-term control plans focused on reducing combined sewer overflow impacts to the Wabash River and although WREC cannot assist them with infrastructure changes, WREC can lead the charge to reduce the volume of water entering the stormwater system, promote successes to improve water quality leaving any NPDES-permitted facility, and highlight efforts to reduce impacts to the Wabash River.

Septic System Care and Maintenance

Septic, or on-site waste disposal systems, are the primary means of sanitary flow treatment outside of incorporated areas including, Lafayette, West Lafayette, Battle Ground, Attica, Linden, and Otterbein. Because of the prohibitive cost of providing centralized sewer systems to many areas, septic tank systems will remain the primary means of treatment into the future. Annual maintenance of septic systems is crucial for their operation, particularly the annual removal of accumulated sludge. The cost of replacing failed septic tanks is about $5,000-$15,000 per unit based on industry standards.

Property owners are responsible for their septic systems under the regulation of the County Health Department. When septic systems fail, untreated sanitary flows are discharged into open watercourses that pollute the water and pose a potential public health risk. Septic systems discharging to the ground surface are a risk to public health directly through body contact or contamination of drinking water sources. Additionally, septic systems can contribute significant amounts of nitrogen and phosphorus to the watershed. Therefore, it is imperative for homeowners not to ignore septic failures. If plumbing fixtures back up or will not drain, the system is failing. Funding for this practice is limited.

Smart Growth/Liveable Communities Practices
Like low impact development, smart growth or liveable communities preserves natural lands and natural features and protects water quality. However, smart growth goes farther focusing on improving resident's everyday lives through their home, health, local schools, tax structure, daily commute, economic growth potential, and natural environment. Smart growth communities are new developments or revitalized communities focused on neighborhoods with shops, offices, schools, businesses, churches, parks, and infrastructure within walking or biking distance or providing public transportation to facilitate community use. Smart growth practices can be used in existing communities by highlighting walkability, preserving or recreating open space, encouraging community stakeholder involvement, providing an opportunity of housing options, and making use of compact building structures. Although much of the urban area within the Region of the Great Bend of the Wabash River is already developed, smart growth can be used to revitalize communities or neighborhoods and focus new development.

Streambank Stabilization
Streambank stabilization or stream restoration techniques are used to improve stream conditions so they more closely mimic natural conditions. The most feasible restoration options return the stream to natural stream conditions without restoring the stream to its original condition. Restoration and stabilization options are limited by available floodplain, modifications to natural flows, and development structure locations. Reestablishment of riparian buffers, restoration of stream channels, stabilization of eroding stream banks, installation of riffle-pool complexes, and general maintenance can all improve stream function while reducing sediment and nutrient transport into and within the system.

Threatened and Endangered Species Protection
Threatened and endangered species are those plant and animal species whose survival is in peril. Federally and state listed species identified within the Region of the Great Bend of the Wabash River watershed are highlighted in the Watershed Inventory. Threatened species are those that are likely to become endangered in the foreseeable future. Federally endangered species are those that are in danger of extinction throughout all or a significant portion of their range. A state-endangered species is any species that is in danger of extinction as a breeding species in Indiana.

Protecting threatened and endangered species requires consideration of their habitat including food, water, and nesting and roosting living space for animals and preferred substrate for plants and mussels. Corridors for species movement are also necessary for long-term protection of these species. Protection of habitat can include providing clean water and available food but likely requires protection of the physical living space and associated corridor. Conservation management plans should be developed for each species, if they are not already in place. Such plans should consider habitat needs including purchase or protection of adjacent properties to current habitat locations, hydrologic needs, pollution reduction, outside impacts, and other techniques necessary to protect threatened and endangered species.

9.2 Best Management Practice Measure Selection
Table 47 details selected agricultural best management practices by critical area, while Table 48 details urban best management practices by critical area. Each critical area and the selected best management practices are based on subwatershed characteristics and available water quality data.

Table 47. Agricultural best management practices suggested for each critical area by parameter.

Critical Area	Reason for Being Critical	Suggested BMP
Livestock access points	E. coli, TSS, Nutrients	Alternative watering system Education and outreach Livestock exclusion fencing Nutrient/manure management
East Branch Wea Creek, Kenny Ditch-Wea Creek, Headwaters Burnett Creek, Flint Creek-Wabash River, Otterbein Ditch-Little Pine Creek, Elliot Ditch, Little Wea Creek	*E. coli*	Livestock restriction fencing Septic system maintenance Manure management planning Point-source discharge reduction Alternative watering system Education and outreach
Romney-Fraley Ditch, East Branch Wea Creek, North Fork Burnett Creek, Flint Run-Flint Creek, Otterbein Ditch-Little Pine Creek, Elliot Ditch	Nitrate-nitrogen/Total nitrogen	Cover crops Filter strips/Buffer strips Nutrient management planning Pesticide management planning Manure management planning Streambank stabilization Conservation tillage Prairie Restoration Two-stage ditch Bioreactor installation Feeding operation management Drainage water management Education and outreach Septic system maintenance Floodplain restoration
Haywood Ditch-Wea Creek, East Branch Wea Creek, Flint Run-Flint Creek, Flint Creek-Wabash River, Elliot Ditch, Headwaters Burnett Creek, Indian Creek, Otterbein Ditch-Little Pine Creek	Total Phosphorus	Cover crops Filter strips/Buffer strips Nutrient management planning Pesticide management planning Manure management planning Streambank stabilization Conservation tillage Prairie Restoration Two-stage ditch Bioreactor installation Feeding operation management Education and outreach Wetland restoration Septic system maintenance Floodplain restoration Smart growth practices Low-impact development

Critical Area	Reason for Being Critical	Suggested BMP
East Branch Wea Creek, Elliot Ditch, Haywood Ditch-Wea Creek, Headwaters Burnett Creek, Indian Creek, Flint Run-Flint Creek, Flint Creek-Wabash River, Otterbein Ditch- Little Pine Creek	Total Suspended Solids	Cover crops
		Filter strips/Buffer strips
		Pesticide management planning
		Streambank stabilization
		Conservation tillage
		Prairie restoration
		Two-stage ditch
		Bioreactor installation
		Education and outreach
		Wetland restoration
		Floodplain restoration
		Smart growth practices
		Low-impact development
East Branch Wea Creek, Elliot Ditch, Headwaters Burnett Creek, Haywood Ditch-Wea Creek, Otterbein Ditch-Little Pine Creek, Indian Creek, Flint Run-Flint Creek	Habitat	Filter strips/Buffer strips
		Wetland restoration
		Corridor identification and restoration
		Education and outreach
		Streambank stabilization
		Exotic species control
		Restore stream hydrology

Table 48. Urban best management practices suggested for each critical area by parameter.

Critical Area	Reason for Being Critical	Suggested BMP
Cedar Hollow-Wabash River and Elliot Ditch	*E. coli*	Pet waste control
		Ordinance/Education of local planners
		Urban wildlife population control
		Point source discharge reduction
		CSO reduction
Elliot Ditch	Nitrate-nitrogen	Grass swale
		Green roof
		Rain garden
		Urban wildlife population control
		Point source discharge reduction
Cedar Hollow-Wabash River and Elliot Ditch	Total Phosphorus	Detention basin retrofits
		Pet waste control
		Ordinance/Education of local planners
		Urban wildlife population control
		CSO reduction
		Green roof
		Grass swale
		Rain garden
		Urban wildlife population control
		Porous pavement
		Phosphorus-free fertilizer
		Low-impact development
		Smart growth practices

Critical Area	Reason for Being Critical	Suggested BMP
Cedar Hollow-Wabash River and Elliot Ditch	Total Suspended Solids	Detention basin retrofits
		Ordinance/Education of local planners
		Green roof
		Grass swale
		Rain garden
		Porous pavement
		Low-impact development
		Smart growth practices
		Urban buffer (pond)
Elliot Ditch; Cedar Hollow-Wabash River	Habitat	Low-impact development
		Smart growth practices
		Fish passage improvement
		Habitat corridor improvement
		Urban wildlife population control

9.3 Load Reduction by Best Management Practice

Load reduction calculations were estimated for nitrogen, phosphorus and sediment based on the potential best management practices to be implemented within the Region of the Great Bend of the Wabash River watershed. Table 49 details the volume of each practice to be installed over 5 years and 30 years, respectively and the expected load reductions for each best management practice. Practices to be installed and volumes of each are based on the critical areas identified above and on specific goals, objectives, and strategies detailed in subsequent sections.

Table 49. Load reductions achieved by installation of each best management practice or strategy over five and thirty years.

Practice	Volume of Practice Installed		Nitrogen Reduction (lb)		Phosphorus Reduction (lb)		Sediment Reduction (lb)	
	5 years	30 years	5 years	30 years	5 years	30 years	5 years	30 years
Bioreactors	10 acres	100 acres	104	1,040	0	0	0	0
Conservation Tillage	2,500 acres	11,250 acres	28,600	128,700	1,530	6,885	511,125	2,300,063
Cover Crop	3,500 acres	15,750 acres	36,400	163,800	0	9,639	0	1,717,380
Drainage Water Management	1,000 acres	30,000 acres	4,473	209,664	0	0	0	0
Filter Strip	750 acres	3,375 acres	10,920	42,937	765	3,008	132,893	522,533
Fish Passage Improvement	N/A	N/A	--	--	--	--	--	--
Grassed Waterway	16,000 feet	72,000 feet	53	226	2	8	1,739	7,392
Green Roof	education	15 roofs	4	8	0.7	1.5	250	500
Greenways and Trails	N/A	N/A	--	--	--	--	--	--
Habitat Corridor Improvement	N/A	N/A	--	--	--	--	--	--
Livestock Restriction	90,000 feet	90,000 feet	1,390,366	1,390,366	90,909	90,909	18,221,811	18,221,811
Low Impact Development	education	education	--	--		--		--
Manure Management	1,500 acres	9,000 acres	24,960	24,960	1,836	1,836	245,340	245,340
Nutrient/Pest Management	12,500 acres	50,000 acres	61,360	217,360	4,012	14,212	0	0
Pet Waste Control	10% waste	25% waste	30,280	75,700	4,658	11,646	280,556	1,717,380
Phosphorus-Free Fertilizer	1,000 lawns	15,000 lawns	0	0	702	10,530	0	0
Porous Pavement	16 acres	96 acres	1,019	6,394	50	301	19,008	120,049
Prairie Restoration	20 acres	120 acres	2,912	5,824	122	245	88,595	177,190
Rain Barrel	450 barrels	3,000 barrels	0	0	0	0	0	0
Rain Garden	75 gardens	450 gardens	13	38	1	2	889	2,668
Septic System Maintenance	education	education	--	--	--	--	--	--
Smart Growth Practices	education	education	--	--	--	--	--	--
Streambank Stabilization	1,000 feet	10,000 feet	0	0	1,020	10,200	204,450	2,044,500
Septic System Upgrades	education	education	--	--	--	--	--	--
T&E Species Protection	N/A	N/A	--	--	--	--	--	--
Trash Control and Removal	education	education	--	--	--	--	--	--
Two Stage Ditch	2 miles	10 miles	26,358	131,789	0	0	1,151,462	5,757,312
Wetland Restoration	500 acres	2,000 acres	2,293	9,173	181	723	105,633	422,530
Wetland Cell Construction	education	Education	--	--	--	--	--	--
Original Load (lb)			4,997,623	4,997,623	274,046	274,046	66,321,094	66,321,094
Total Load Reduction (lb)			1,620,113	2,407,977	105,788	160,145	20,963,750	33,256,647
Percent Reduction Achieved			32%	48%	39%	58%	32%	50%