Stantec

Indian Creek Watershed Plan

Table of Contents

2.0 Water Resource Issues

2.1 INTRODUCTION

This chapter addresses:

- Water Quality Problems previously identified by existing data and reports.
- Water Quality Problems recently discovered as a result of the Indian Creek Watershed monitoring conducted through this project.
- The causes of Water Quality Problems including the identification of specific pollutants or processes that cause or contribute to impairments.
- The sources of Water Quality Problems involving the identification of point and nonpoint sources of pollutants that cause or contribute to impairments.
- Recognized Data Gaps through the process of Sinkhole Inventory.
- The Prioritization of Water Quality Problems based on input gathered from public meetings and the Steering Committee.

2.2 BACKGROUND

In 1972 Congress enacted the Clean Water Act to restore and maintain the chemical, physical, and biological integrity of the nation's water resources. The goal of the Clean Water Act is to conserve water for recreational, agricultural and industrial uses, as well as for use as a public water supply and as a means to propagate fish and aquatic life.
Indiana's water quality goals stated in Article 2 of the Indiana Administrative Code. The goals are to restore and maintain the chemical, physical, and biological integrity of the waters of the state (327 IAC 2-1-1.5).
Each body of water is subject to water quality standards identified by its use (ex. drinking water supply, aquatic life support) and is then evaluated by numerical or narrative criteria to support that use (Refer to 327 IAC 2-1 for Indiana's water quality standards). When multiple uses have been designated for a body of water, the strictest applicable standards apply. Designated uses for waters in the Indian Creek Watershed include:

- Full-Body Contact Recreation
- Warm Water Aquatic Community
- Fish Consumption
- Water Supply (public, industrial, agricultural water supply at the point of withdrawal)

2.3 PREVIOUSLY IDENTIFIED WATER QUALITY PROBLEMS

IDEM uses monitoring and assessment programs to collect data and assess each water body's designated uses according to the water quality criteria in Indiana's streams, rivers and lakes. An overview of water quality monitoring programs and water quality assessment results is provided below, along with identified water quality impairments documented in the Indian Creek Watershed. This summary of historical and current water quality assessment results was used to identify data gaps.

The Surveys Section of IDEM's Office of Water Quality's Water Quality Assessment Branch provides the water quality and hydrological data required to assess Indiana's waters through Watershed/Basin Surveys and Stream Reach Surveys. These surveys evaluate the degree to which water quality standards are being met and if each body of water's designated uses are accurately assigned. Indiana streams and lakes are monitored and water quality is assessed on a five-year rotating basin cycle. Results are reported every two years, with the most recent results published as the Indiana Integrated Water Monitoring and Assessment Report 2006 (IDEM, 2006)

2.3.1 Water Quality Monitoring Programs

IDEM's Office of Water Quality (OWQ) Water Quality Assessment Branch has operated multiple surface water quality monitoring programs statewide, including stations within the Indian Creek Watershed. The monitoring programs, which have been outlined in the Surface Water Monitoring Strategy, were designed to collect data regarding the physical, chemical, and biological integrity of Indiana's waterbodies (IDEM, 2001).

IDEM monitored fourteen stations within the Indian Creek Watershed between 1996 and 2006. These monitoring stations are shown in the table and figure below.

Table 2.1. Indian Creek IDEM Monitoring Stations

Site Id	Stream Name	Location	County
OBS080-0001	Little Indian Creek	Banet Road	Floyd
OBS080-0004	Little Indian Creek	Near Galena	Floyd
OBS080-0005	Indian Creek	at Greenville Road, NW of Georgetown	Floyd
OBS080-0007	Georgetown	Parent Lake	Floyd
OBS080-0008	Indian Creek	Navilleton Road	Floyd
OBS090-0002	Indian Creek	Southern Railroad	Harrison
OBS090-0004	Indian Creek	at SR 335 near Corydon Junction	Harrison
OBS090-0005	Indian Creek	Landmark Way	Harrison
OBS090-0007	Indian Creek	Pleasant Valley Road	Harrison
OBS100-0001	Indian Creek	Rocky Hollow Road	Harrison
OBS100-0004	Indian Creek	City Park South of Corydon, SR 135	Harrison
OBS100-0005	Indian Creek	Corydon City Park, off SR 135 S	Harrison
OBS100-0006	Indian Creek	at Lickford Bridge Road	Harrison
OBS100-0007	Indian Creek	Downstream of Little Indian Creek at Corydon	Harrison

Hoosier Riverwatch monitored a total of five (5) sites on June 25, 2001. A review of the Hoosier

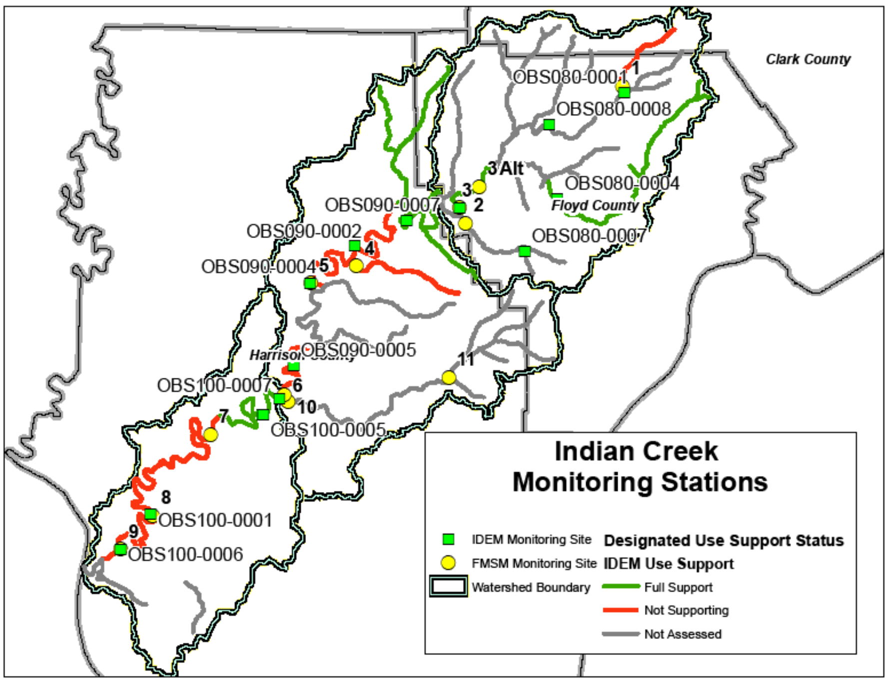

Figure 2.1. Indian Creek Monitoring Stations

Riverwatch database indicates that these sites were only monitored once. Sites are summarized in the table below. Since single sample events are generally considered insufficient to understand water quality conditions and trends, the assessments that follow rely on IDEM data and assessments.

Table 2.1. Hoosier Riverwatch Monitoring Sites in Indian Creek Watershed

Site #	Location
246	Indian Creek at Renn Road
249	Indian Creek at Stiller Road
250	Indian Creek at Old Vincennes Road
251	Little Indian Creek at back of trucking firm on SR 150
252	Little Indian Creek at Phil Scharf's house off Duffy Road

2.3.2 Water Quality Assessments

IDEM conducts assessments of data collected in order to evaluate which waterbodies are correctly designated and if the proper standards are being attained. Results of the most recent, as well as several historical assessments are presented below. The most recent water quality and biological data collected by IDEM are summarized in **Appendix 2.1**.

2006 Integrated Report: Section 305(b) of the Clean Water Act requires states to prepare and submit a Water Quality Inventory Report to the U.S. Environmental Protection Agency (USEPA) every two years. This report describes the condition of Indiana's waterbodies and states whether or not standards with respect to the waterbodies' designated uses are being upheld (ex. aquatic life, fish consumption, drinking water supply and recreational use). Waterbodies that did not meet one or more of their designated uses were placed on the 303(d) List of Impaired Waterbodies, also published every two years.

In 2002, USEPA issued guidelines requesting that states integrate the Water Quality Inventory Report (305b) and 303(d) List of Impaired Waterbodies. The first Indiana Integrated Water Monitoring and Assessment Report was submitted to USEPA in 2002. The 2006 Integrated Water Quality Monitoring and Assessment Report is Indiana's third integrated report (IDEM 2006). USEPA Integrated Report Guidance requested that states use five lists to document the condition of their waterbodies. IDEM assesses recent data using published assessment methods and assigns each water body to a category of stream use attainment as described in the **Table 2.3** below. A water body can be assigned to only one category.

Table 2.3. Indiana Categories of Stream Use Attainment

Category	Definition
1	Attaining the water quality standard for all designated uses and no use is threatened.
2	Attaining some of the designated uses; no use is threatened; and insufficient or no data and information are available to determine if remaining uses are attained or threatened.
3	Insufficient information to determine if any designated use is attained.
3A	Little or no information is available with which to make an assessment.
3B	Available data suggest that a problem may exist but more information is needed to verify whether impairment exists or will occur within the next two years.
4	Standard is not supported or is threatened for one or more designated uses but does not require the development of a TMDL.
4A	TMDL has been completed and approved by USEPA.
4B	Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.
4C	Nonsupport of the water quality standard is not caused by a pollutant.
5	Category 5 comprises the 303(d) List. The water body does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants.
5A	Impaired or threatened for one or more designated uses by a pollutant(s), and require a TMDL.
5B	The waterbodies are impaired due to a Fish Consumption Advisory for PCBs or mercury, or both (TMDL not required).
5C	Impaired or threatened for one or more designated uses by a pollutant(s), and require a TMDL, which is expected to be completed prior to the next listing cycle.

Source: IDEM, 2006.

A TMDL (Total Maximum Daily Load), established under section 303(d) of the federal Clean Water Act, is a calculation of the maximum amount of pollutant that a water body can receive and still meet water quality standards, and allocates pollutant loadings among point and non-point sources. States must develop TMDLs that achieve water quality standards, allowing for seasonal variations and an appropriate margin of safety. A TMDL is a quantitative assessment of water quality problems, contributing sources, and load reductions or control actions needed to restore and protect individual water bodies.

Indian Creek Watershed assessment results and categories for 2006 are presented in **Table 2.4**.

Table 2.4. Indian Creek Water body Assessment Results

Water body Segment Name	Water body Segment ID	Length (Miles)	Aquatic Life	Primary Contact	Fish Consumption	Category
Little Indian Creek (North)	INN0482_00	3.87	N	X	X	5A
Indian Creek-South Trib	INN0491_00	8.84	F	X	P	3A
Indian Creek-Crandall Branch	INN0494_00	15.43	F	N	P	5A
Indian Creek	INN0495_T1050	4.75	X	N	P	3A
Indian Creek	INN0496_T1051	4.20	X	N	P	5A
Indian Creek-North Karst Area	INN04A1_00	6.27	X	X	N	3A
Indian Creek-Devils Backbone	INN04A3_00	17.02	N	N	P	5A
Indian Creek-Blue Spring	INN04A4_00	4.89	X	X	P	3A

Source: IDEM, 2006.

Use Categories: F = Full Support, P = Partial Support, N = Not Supporting, X = Not Assessed.

Only segments which include a drinking water intake are assessed by IDEM for drinking water use. Since drinking water in the Indian Creek Watershed is provided through groundwater sources, IDEM did not assess drinking water use in this watershed.

Category 3A: Little or no information is available with which to make an assessment. Category 5A: Impaired or threatened for one or more designated uses by a pollutant(s), and require a TMDL.

Georgetown Lake was classified by IDEM as “mesotrophic” in the 2006 Integrated Report. Mesotrophic is a term applied to clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients. These lakes are of intermediate clarity, depth and temperature.

Over time, IDEM will collect additional data and information on Category 3A waters to determine if classified designated uses are being met. The impairments affecting the Category 5A waters are shown in the table below and **Appendix 2.2.**

Table 2.5. Category 5A Waters (Impaired & TMDL Required)

Basin	HUC	County	Waterbody Segment ID	Waterbody Segment Name	Impairment
Ohio Tributaries	5140104080020	Floyd	INN0482_00	Little Indian Creek (North)	Impaired Biotic Communities
Ohio Tributaries	5140104090040	Harrison	INN0494_00	Indian Creek-Crandall Branch	E. Coli
Ohio Tributaries	5140104090060	Harrison	INN0496_T1051	Indian Creek	E. Coli
Ohio Tributaries	5140104100030	Harrison	INN04A3_00	Indian Creek-Devils Backbone	Dissolved Oxygen
Ohio Tributaries	5140104100030	Harrison	INN04A3_00	Indian Creek-Devils Backbone	E. Coli

Source: IDEM, 2006.

IDEM published a schedule for TMDL development with the 2008 Integrated Report. Based on this schedule, IDEM anticipates developing TMDLs for the Indian Creek Watershed between 2017 and 2023. Note that this schedule may be amended at IDEM's discretion with USEPA approval.

By developing and implementing this watershed plan, the Indian Creek Watershed Subcommittee is taking a proactive approach to addressing impairments prior to IDEMs TMDL development. An anticipated benefit of this long term watershed plan is to reduce the TMDL burden on the Indian Creek Watershed communities by implementing watershed improvements outside of the regulatory context of the TMDL.

Fish Consumption Advisory: Since 1972, members from the Indiana State Department of Health (ISDH), Department of Environmental Management (IDEM), and Department of Natural Resources (IDNR) have met to discuss the findings of recent fish monitoring data and to develop the new statewide Fish Consumption Advisory (FCA). Indiana's fish consumption advisories are issued by ISDH. However, IDEM collects and manages about 98% of the data used to develop the fish advisories for the State through previously described programs (ISDH 2006). Criteria for the 2006 Indiana Fish Consumption Advisory were developed from the Great Lakes Sport Fish Advisory Task Force (ISDH 2006).

The FCA is based on the statewide collection and analysis of fish samples for contaminants found in fish tissue, such as polychlorinated biphenyls (PCBs), pesticides, and heavy metals (e.g. mercury). These contaminants collect in the soil, water, sediment, and in microscopic animals. They are typically found in greater amounts among larger, older, predatory fish. PCBs and pesticides are likely to be stored in the fat of fish due to the fact that they absorb mercury from their food which then gets tightly bound to their muscles.

Several waterbodies in Indian Creek Watershed partially support fish consumption as a designated use due to slightly elevated mercury concentrations. In addition, the Indiana State Department of Health has issued a statewide advisory to limit consumption of carp from all Indiana waters because this species is commonly contaminated with PCBs. The advisory is summarized in the table below.

Table 2.6. Statewide Carp Fish Consumption Advisory

Advisory Group	Carp Size (inches)	Description	
		Women of childbearing years, nursing mothers and children under 15	Other Adults
1		Limit to 1 meal per week	Unlimited consumption
2		One meal per month	One meal per week
3	15-20	No consumption (Do Not Eat)	One meal per month
4	20-25	No consumption (Do Not Eat)	One meal every two (2) months
5	Over 25	No consumption (Do Not Eat)	No consumption (Do Not Eat)

Source: ISDH, 2006. Note: A meal is defined as 8 ounces (before cooking) of fish for a 150-pound person or 2 ounces of uncooked fish for a 40-pound child.

Unified Watershed Assessment: A Unified Watershed Assessment (UWA) is one of 111 Action Items of the Clean Water Action Plan of 1998. The Clean Water Action Plan included incentives directed toward accelerating the control of nonpoint source pollution in America and prioritized watersheds for nonpoint source pollution remediation. The UWA, a multi-agency effort to prioritize watershed restoration needs in each state, was developed through the cooperation of state, federal, and local agencies, as well as the general public. The Guidelines for completing the UWA, published by the USEPA in June 1998, charged the USDA Natural Resources Conservation Service (NRCS) and the state water quality agency (IDEM) with organizing the assessment process. The watersheds in the state were prioritized for restoration work through the evaluation of water quality data, natural resource concerns, and human activities that have the potential to impact water quality.

1999-2000 UWA: In the first version of the UWA, HUC-8 watersheds were prioritized according to the present condition of the water in lakes, rivers, and streams. The data provided information about the water column, organisms living in the water, or the suitability of the water for supporting aquatic ecosystems. The measured parameters were scored from one to five, with one representing good water quality and five representing degraded water quality (IDEM OWQ 2001). This assessment involved multiple organizations and recognized impaired and healthy watersheds.
Scores for each HUC-8 watershed were compiled, and the watersheds were grouped into four categories as per the USEPA guidance (USEPA 1998). The four categories are as follows:

> **Category I**. Watersheds in need of restoration: waters do not meet designated uses or other natural resource goals. 25% or more of the waters that have been assessed do not meet state water quality standards. (Note that in some watersheds, only a very small percentage of waters have been recently assessed.)
> **Category II.** Watersheds that on average meet state water quality goals and require attention to sustain water quality. In most of these watersheds, there is habitat which is recognized as critical for threatened or endangered species.
> **Category III.** Watersheds with pristine or sensitive aquatic systems on federal or state managed lands.
> **Category IV**. Watersheds with insufficient data to make an assessment.

The Indiana UWA identified eleven (11) HUC-8 watersheds for restoration funding during 1999-2000 (IDEM 2001). In this initial assessment, the Blue-Sinking HUC 8, including the Indian Creek Watershed, was not identified as a priority.

2000-2001 UWA: For 2000-2001 UWA, Indiana used additional data sources to identify the resource concerns and stressors for each of the HUC-11 subwatersheds. Due to the potential of human activities to impact the ecosystem, this refined UWA included a more thorough examination, allowing water resource managers to focus on areas where restoration was most critical. The UWA aimed to identify areas where the interests of two or more partner agencies converged in order to achieve a more effective allocation of resources for restoration and protection activities. The information included in the UWA was designed to assist local groups in prioritizing watershed activities and providing a starting point for watershed planning. The amended UWA was designed to have the following benefits:

- Provide a logical process for targeting funds, which may be expanded or updated without changing the basic framework.
- Provide information at a finer resolution (HUC-11 vs. HUC-8) to agencies and local groups interested in watershed assessment.
- Identify data gaps.
- Compliment other assessments, such as the 305(b) Report and 303(d) List.

The 2000-2001 UWA was conducted at the subwatershed (HUC-11) scale and assigned a score ranging from 1 (good water quality or minimum impairment) to 5 (degraded water quality or heavily impacted) for 15 parameters. Subwatersheds with higher scores were given a higher priority. Assessment parameters and Indian Creek Watershed scores are shown in the table below. The middle and lower HUCs (05140104090 and 05140104100) were identified for priority funding due to multiple scores of 4, while the upper HUC (051401004100) received higher-quality scores and therefore did not meet these criteria. Selected assessment parameters are detailed below.

Table 2.7. HUC Scores for Each Parameter Assessed in the Unified Watershed Assessment

HUC-11 Watershed	Mussel Diversity and Occurrence	Aquatic Life Use Support	Recreation Use Attainment	Stream Fishery	Lake Fishery	Eurasian Milfoil Infestation Status	Lake Trophic Status	Critical Biodiversity Resource	Aquifer Vulnerability	Population Using Surface Water for Drinking	Residential Septic System Density	Degree of Urbanization	Density of Livestock	% Cropland	Mineral Extraction Activities
05140104080 Upper Indian Creek	ND	ND	ND	ND	ND	ND	ND	2	4	3	5	2	3	1	1
05140104090 Mid-Indian Creek	ND	ND	ND	2	ND	ND	ND	4	1	3	4	2	4	1	2
05140104100 Lower Indian Creek	4	ND	ND	4	ND	ND	ND	4	3	3	3	2	4	1	2

Source: IDEM OWQ, 2001. ND = no data.

Mussel Diversity and Occurrence: This indicator measures the incidence of freshwater mussel beds, with consideration given to the rarity and diversity of the species found. Scores of 4 indicated either degraded diversity or rare species in Lower Indian Creek, with insufficient data for the remainder of the watershed. Report authors noted that this indicator should be interpreted carefully.

Stream Fishery: This indicator is a measure of the quality of the small mouth bass community in streams based on the catch per unit effort. A score of 4 for Lower in Indian Creek indicates that fisheries were degraded.

Critical Biodiversity Resource: This indicator is a measure of the level of concern for reported endangered and threatened species or other biological communities of concern. A score of 4 was given to Middle and Lower Indian Creek, which has had between 150 and 299 threatened or endangered species reports filed with the State. This indicates a comparatively high number of biological resources in the watershed that may need protection.

Residential Septic System Density: USEPA has stated that a residential septic system density greater than 40 per square mile is a potential water quality problem (IDEM 2001). A score of 5 was given to Upper Indian Creek because the septic system density in this area was above the recommended level.

Density of Livestock: This parameter is a measure of the number of swine, poultry, cattle, and sheep animal units reported through the 1997 Census of Agriculture. As with the stream fisheries, HUC-11 watersheds were ranked by quintile. A score of 4 given to Mid and Lower Indian Creek due to a high livestock density when compared to the rest of the State.

2.4 RECENT WATER QUALITY CONDITIONS

The Indian Creek Watershed Plan Subcommittee of the Harrison County Regional Sewer District developed a plan to conduct additional water quality monitoring. The purpose of the monitoring program was to collect additional data for impaired segments and to assess water quality conditions in previously unassessed reaches. Both water quality and biological monitoring were included.

2.4.1 Indian Creek Watershed Monitoring Design

Initially 15 sites were evaluated for sampling and 11 sites were selected to be included in the final monitoring program. A Site Reconnaissance Report was prepared to document the 15 sites investigated. This report is provided as **Appendix 2.3**.

This program included 10 sites for bacteria and water quality monitoring and 5 sites for biological monitoring. A targeted sampling design was used in order to meet the goals for the monitoring program. Sites were located in reaches that were identified as impaired for primary contact or biological uses, that had known or suspected pollution sources, and those not recently sampled by IDEM or other entities to address data gaps. Monitoring sites are shown in the figure and table below.

Table 2.8. Indian Creek Watershed Monitoring Sites

Site #	IDEM Site ID	Location	WQ	AQL	Rationale
1	OBS080-0001	Indian Creek North at Banet Road, IDEM Site OBS080-0001		X	303(d) Segment – Aquatic Life
2		Georgetown Creek below Georgetown at Malinee Ott Road	X		Unassessed reach below Georgetown
3	OBS080-0005	Indian Creek above Georgetown Creek, IDEM Site OBS080-0005	X		Floyd County drainage, near County boundary, developing
4		Crandall Branch above SR335 Bridge	X		303(d) Segment – Recreation (may be an artifact of mapping?)
5	OBS090-0004	Indian Creek above SR355 Bridge, IDEM Site OBS090-0004	X		303(d) Segment – Recreation
6		Indian Creek above Little Indian Creek at Water Street	X		Downstream end of HUC, 303(d) Segment – Recreation, above WWTP, receives Corydon runoff
7		Indian Creek at Mathis Road bridge	X	X	Upstream end of 303(d) Segment – Recreation, Aquatic Life
8	OBS100-0001	Indian Creek above Rocky Hollow Road Bridge, IDEM Site OBS100-0001	X	X	303(d) Segment – Recreation, Aquatic Life
9	OBS100-0006	Indian Creek above Lickford Road Bridge, IDEM Site OBS100-0006	X	X	303(d) Segment – Recreation, Aquatic Life
10		Little Indian Creek above Water Street Bridge	X	X	Major tributary, classified as “unassessed” by IDEM
11		Little Indian Creek below Lanesville at State Road 62	X		Upper reach of major tributary classified as “unassessed” by IDEM, downstream of Lanesville and Lanesville STP
		Number of Sites	**10**	**5**	

WQ – water quality sampling site. AQL – aquatic life sampling site.

The following parameters were monitored and results were compared with applicable Indiana Water Quality Standards (327 IAC 2-1). Note that in the original monitoring design, three base flow and three elevated flow samples were to be collected. However, because of severe drought conditions, five samples were collected under base flow and one sample was collected under elevated flow. The elevated sample event took place on August 21, 2007 (sample event #6). Samples were analyzed for the water quality parameters shown in the table below.

Table 2.9. Water Quality Monitoring Parameters

Chemical	Physical	Biological
Total Phosphorus (TP)	Dissolved Oxygen (DO)	E. coli
Ortho-Phosphorus (PO4)	pH	Benthic Macroinvertebrate
Total Kjeldahl Nitrogen (TKN)	Temperature (T)	Habitat
Nitrate-Nitrogen (NO3)	Specific Conductivity (SC)	
Total Ammonia (NH3+NH4)	Turbidity	
Total Solids (TS)	Stream Flow	

E. coli: In accordance with State water quality standards for calculation of geometric mean, 5 evenly spaced E. coli and flow samples were collected during a 30-day period. One set of 5 samples was collected at each of 10 sites. Flow readings were collected concurrently.

Water Quality: Six water quality sample events were conducted at each of the 10 sites. Samples were collected under base flow (3 events) and elevated flow (3 events) to evaluate water quality over a range of hydrologic conditions. Grab samples were analyzed for Total Kjeldahl Nitrogen (TKN), Nitrate-Nitrogen (NO3), Total Ammonia (NH3+NH4), Total Phosphorus (TP), Ortho-Phosphorous (PO4), and Total Solids (TS). Field parameters and flow were collected concurrently.

Biological: Biological (benthic macro invertebrate) data was collected at 5 sites. Samples were collected between July and October 2007. Field parameters and flow were collected concurrently at each site. Water quality data were collected concurrently at 4 of 5 sites.

Qualitative habitat was measured using the Qualitative Habitat Evaluation Index (QHEI). The QHEI was developed by the Ohio EPA and has been used extensively as a tool for the qualitative assessment of riparian and aquatic habitat. The tool addresses substrate condition, fish cover, stream shape, human interference, stream cover, erosion, depth, velocity, and presence and quality of riffles and runs. Habitat data was collected at 11 sites.

Field Parameters: Field parameters collected during each sample event include: pH, Dissolved Oxygen (DO), Temperature (T), Specific Conductivity (SC), Turbidity.

Flow: Flow records for the Indian Creek Watershed were examined. There was not a flow gage in the Indian Creek Watershed with sufficient historical data and accuracy to allow a quantitative approach to determine flow conditions; therefore a qualitative approach was devised.

Since water quality often exhibits a strong relationship with flow, monitoring was designed to include consideration of flow condition (i.e. base flow and elevated flow). The flow condition for sampling was qualitatively determined by evaluating recent precipitation and comparing current flow to the long term daily median for the nearby USGS Gage 03302220 Buck Creek near New Middletown. Dry conditions were defined as 3 or more days of dry conditions and wet conditions were defined as greater than 0.25 inches of wet precipitation or snowmelt. Since this amount of precipitation does not always produce runoff due to soil moisture deficits, base flow and elevated flow conditions were also defined. Base flow was defined for this study as less than the long term daily median flow and elevated flow is greater than the 65th percentile. This qualitative approach was necessary because USGS no longer operates flow gages in the Indian Creek Watershed. However, because a drought occurred during the sample period, five (5) samples were collected under low flow conditions and one (1) sample was collected under elevated flow conditions. The elevated sample event took place on August 21, 2007 (sample event #6).

The sample design is summarized in the table below. Additional information is included in the Quality Assurance Project Plan, provided as **Appendix 2.4** to this watershed plan.

Table 2.10. Sample Design Summary

Sample Type	# Parameters	# Sites	# Sample Events	# Results
E. Coli	1	10	5	50
Water Quality	6	10	6	360
Biological	1	5	1	5
Field Parms	5	11	6	330
Flow	1	11	11	115
Habitat	1	11	1	11

2.4.2 Indian Creek Watershed Monitoring Results

Results of the monitoring program are summarized below; data are provided in **Appendix 2.5**.

Table 2.2. Water Quality Monitoring Results Summary

Characteristic Name	Units	# Results	Minimum Value	Average Value	Maximum Value	Criteria or Comparison Value
Dissolved oxygen (DO)	mg/L	63	**0.08**	7.8	**16.2**	**4.0 mg/l minimum;** Maximum < 12
E. Coli	CFU / 100 ml	56	1	172.8	**2,200**	**125 (geometric mean); 576 maximum**
Nitrogen - nitrate+nitrite	mg/L	56	0.1	0.8	**5.9**	5
Orthophosphate	mg/L	65	0.03	0.1	**2.15**	0.3
pH	su	63	6.91	7.7	8.88	**6.0-9.0**
Phosphorus, total	mg/L	66	0.03	0.1	**2.88**	0,3
Solids, total	mg/L	65	**162**	**284.1**	**475**	261
Specific conductance	us/cm	61	190	416.8	720	**1,200**
Stream Flow	ft/sec	101	-0.72	1.1	28.3	-
Temperature, water	C	63	13	20.8	29.8	**Criteria tables**
Total Ammonia	mg/L	66	0.1	0.1	0.8	**Calculate un-ionized ammonia**
Total Dissolved Solids	mg/L	43	145	219.3	362	-
Total Kjeldahl Nitrogen	mg/L	66	0.1	0.6	1.5	5
Turbidity	NTU	62	1.13	12.7	**80.2**	25

Note: Numerical criteria shown in bold, other comparison values in plain text. Concentrations exceeding the criteria or comparison value are shown in bold.

With the exception of bacteria and dissolved oxygen, all water quality samples met the required water quality criteria. Results for these parameters are discussed in detail in the sections that follow and **Section 2.7** outlines estimated load reduction targets for bacteria.

Elevated concentrations of nutrients (phosphorus and nitrogen) are discussed in **Section 2.5.5.** However, load reduction estimates were not calculated for nutrients because water quality criteria have not yet been adopted and the relationship between nutrients and dissolved oxygen is complex. Therefore, additional information regarding appropriate nutrient concentrations for this watershed are needed prior to calculating load reduction targets.

Bacteria: Bacteria data were collected between July 18, 2007 and August 15, 2007, with five (5) samples collected in 30 days. This sample design supported direct comparison to water quality criteria for E. coli. The water quality criteria for the recreational season is provided below.

> ***E. Coli Criteria:*** *April 1 – October 31: Geometric mean of 5 samples collected within a 30-day period shall be less than 125 MPN / 100 ml and no single sample can exceed 576 MPN / 100 ml.*

Bacteria data are summarized in **Table 2.12**. Results indicate that recreational contact criteria were met below Corydon. If additional sampling performed by IDEM confirms this result, de-listing could be pursued in this lower portion of the watershed.

Results indicate that recreational criteria were not met in the Indian Creek above Georgetown Creek and Indian Creek above Crandall Branch. Recreational criteria were also not met Georgetown Creek and Crandall Branch tributaries. Crandall Branch had previously been listed for recreational impairment by IDEM. Georgetown Creek had been classified by IDEM as unassessed. The potential sources of bacteria were evaluated using the Bacteria Indicator Tool developed by USEPA. The tool and results are discussed in **Chapter 2.4.**

Table 2.12. Indian Creek Watershed Bacteria Results

Site	Description	Geometric Mean	Maximum Concentration	Criteria Met?
2	Georgetown Creek below Georgetown at Malinee Ott Road	194	300	No
3	Indian Creek above Georgetown Creek, IDEM Site OBS080-0005	147.2	430	No
4	Crandall Branch above SR335 Bridge	779.2	2,200	No
5	Indian Creek above SR355 Bridge, IDEM Site OBS090-0004	268.8	410	No
6	Indian Creek above Little Indian Creek at Water Street	93.3	180	Yes
7	Indian Creek at Mathis Road bridge	19.4	32	Yes
8	Indian Creek above Rocky Hollow Road Bridge, IDEM Site OBS100-0001	46.8	177	Yes
9	Indian Creek above Lickford Road Bridge, IDEM Site OBS100-0006	44.2	132	Yes
10	Little Indian Creek above Water Street Bridge	119.2	140	Yes
11	Little Indian Creek below Lanesville at State Road 62	118.8	226	Yes

Water Quality: Water quality samples were collected during 6 events between July 18, 2007 and September 24, 2007. Since the lower 17 miles of Indian Creek (i.e., Devil's Backbone segment) is included on the 303(d) List of Impaired Waters due to low dissolved oxygen, these data are summarized in the table below.

Indiana water quality criteria establish that the minimum concentration of dissolved oxygen shall be above 4.0 mg/l at all times and the average over a 24-hour period shall be above 5.0 mg/l at all times.

Sites 7, 8, and 9 were used to better understand water quality in the 17 mile long Devils Backbone segment of lower Indian Creek. As shown in the table below, the dissolved oxygen criteria were met in all six samples collected at Sites 7 and 8. The dissolved oxygen criterion was not met at Site 9, where the minimum concentration was 3.1 mg/l DO. This site is located in Ohio River backwater in a watershed that loses significant flow to the karst system. Therefore, this lower reach often has little or no stream flow. Agricultural operations are similar throughout the reach characterized by these three sites, and no other sources of pollution were identified. Therefore, the portion of the reach characterized by Sites 7 and 8 could be considered as meeting water quality criteria. Site 9 could be considered affected by natural conditions that may preclude attaining water quality criteria for dissolved oxygen.

Table 2.13. Indian Creek Watershed Dissolved Oxygen Results

Site	Description	Minimum Concentration (mg/l)	Average Concentration (mg/l)	Criteria Met?
2	Georgetown Creek below Georgetown at Malinee Ott Road	4.6	7.4	Yes
3	Indian Creek above Georgetown Creek, IDEM Site OBS080-0005	5.7	7.0	Yes
4	Crandall Branch above SR335 Bridge	6.4	8.1	Yes
5	Indian Creek above SR355 Bridge, IDEM Site OBS090-0004	4.5	6.0	Yes
6	Indian Creek above Little Indian Creek at Water Street	7.6	10.2	Yes
7	Indian Creek at Mathis Road bridge	5.6	7.3	Yes
8	Indian Creek above Rocky Hollow Road Bridge, IDEM Site OBS100-0001	6.3	7.2	Yes
9	Indian Creek above Lickford Road Bridge, IDEM Site OBS100-0006	3.1	4.9	No
10	Little Indian Creek above Water Street Bridge	7.7	9.8	Yes
11	Little Indian Creek below Lanesville at State Road 62	4.9	10.6	Yes

Benthic Macroinvertebrates and Habitat: Macroinvertebrate samples were collected from four locations within the Indian Creek Watershed on September 20, 2007 the sampling locations were as follows:

- **Site 1** – Indian Creek North at Banet Road – This site was dry and not sampled
- **Site 6** – Indian Creek above Little Indian Creek at Water Street in Corydon, (duplicate)
- **Site 7** – Indian Creek at Mathis Road bridge,

- **Site 8** – Indian Creek above Rocky Hollow,
- **Site 10** – Little Indian Creek above the Water Street bridge.

The drought of 2007 had a severe impact on the Indian Creek drainage. Two of the four sites were pooled-up with no flow in the riffle areas (Sites 7 and 8). At the two sites with flow (Sites 6 and 10), the flow was so reduced that it was barely sufficient in the riffle areas to carry invertebrates into the sampling net. Furthermore, the riffles were so reduced by the drought that only one third of a meter was sampled quantitatively. Virtually all bank habitats, i.e. undercut banks, root wads, etc., were out of the water. The only consistently available habitats were Justicia (water willow) beds and bedrock.
The MIBI was only calculated for Sites 6 and 10 where quantitative data was collected. The macroinvertebrate data, including a taxa list and metric data, are presented in **Appendix 2.5**.

Table 2.14. Benthic Macroinvertebrate Data Summary

Site	Macroinvertebrate Index of Biotic Integrity (MIBI)	Qualitative Result
Site 6 - Indian Creek above Little Indian Creek at Water Street in Corydon	40	Poor
Site 6 (Duplicate) - Indian Creek above Little Indian Creek at Water Street in Corydon	43.9	Fair
Site 7 -Indian Creek at Mathis Road bridge	Not assessed	
Site 8 - Indian Creek above Rocky Hollow	Not assessed	
Site 10 – Little Indian Creek above the Water Street bridge	43.2	Fair

These MIBI values are the result of two factors, the habitat reduction due to the severe drought and elevated nutrients. The macroinvertebrate communities from all sites are made up principally of organisms that are found in nutrient enriched streams. The elevated nutrients may have probably arisen from urban sources such as the Corydon Wastewater Treatment Plant (WWTP) and rural agricultural practices (livestock grazing and row crops). The highest taxa richness and EPT values were observed at station 7 (42 and 11, respectively), a portion of the stream that had only hyporheic flow. However, all sites had low taxa richness and EPT values, again at least in part due to the severe drought.

Habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) concurrently with benthic marcoinvertebrate sample collection. Since habitat conditions can influence water quality, habitat data were collected at all Indian Creek monitoring sites. Results are summarized below and data are provided in **Appendix 2.5**. A review of the individual components of the QHEI score indicates that flow-related habitat characteristics scored low, due in part to the severe drought.

Table 2.15. Indian Creek Watershed Habitat Results

Site	Description	Habitat Score	Qualitative Result
1	Indian Creek North at Banet Road, IDEM Site OBS080-0001	46	Fair
2	Georgetown Creek below Georgetown at Malinee Ott Road	39.5	Poor
3	Indian Creek above Georgetown Creek, IDEM Site OBS080-0005	61	Good
4	Crandall Branch above SR335 Bridge	61.5	Good
5	Indian Creek above SR355 Bridge, IDEM Site OBS090-0004	40	Not Assessed
6	Indian Creek above Little Indian Creek at Water Street	42	Poor
7	Indian Creek at Mathis Road bridge	62	Good
8	Indian Creek above Rocky Hollow Road Bridge, IDEM Site OBS100-0001	55.5	Fair
9	Indian Creek above Lickford Road Bridge, IDEM Site OBS100-0006	63.5	Good
10	Little Indian Creek above Water Street Bridge	36	Poor
11	Little Indian Creek below Lanesville at State Road 62	58	Good

2.5 BACTERIA INDICATOR TOOL

Previously identified water quality problems as well as Indian Creek Watershed monitoring results identify bacteria as the main pollutant of concern in Indian Creek. To gain a better understanding of sources and loadings bacteria in the watershed, the EPA Bacteria Indicator Tool (BIT) was used.

2.5.1 Tool Selection

EPA's Bacteria Indicator Tool (BIT) was chosen because it can be used to estimate relative contributions of bacteria sources on a watershed basis. The tool is used to develop input data for the Hydrological Simulation Program Fortran (HSPF) water quality model within BASINS. The tool estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forest, built-up, and pastureland), as well as the asymptotic limit for that accumulation should no wash-off occur. The BIT also estimates the direct input of fecal coliform bacteria to streams from grazing agricultural animals and failing septic systems. The tool does not calculate the amount of fecal coliform to reach stream from land based sources. When the BIT is used in conjunction with HSPF, land-based source estimates can be generated. However, development of an HSPF model was beyond the scope of this watershed plan. More information on EPA's Bacteria Indicator Tool can be found at the following website: http://www.epa.gov/waterscience/ftp/basins/system/BASINS3/bit.htm

2.5.2 Bacterial Input Tool Development

While BIT does assume a direct contribution from septics and cattle in streams, it does not simulate transport to streams or sinkholes from nonpoint sources of bacteria. The tool's outputs for nonpoint source contributions are reflected as bacteria accumulation on land. Only a fraction of the land-based bacteria reaches the stream. Therefore, the BIT outputs were used to compare relative importance of the bacteria sources.

The BIT was applied on the HUC-14 subwatershed level to provide output that would allow for the comparison between subwatersheds. There are 24 HUC-14 subwatersheds in the Indian Creek Watershed, shown in **Table 2.16**.

Table 2.16 Bacterial Indicator Tool Subwatersheds

BIT Watershed	HUC 14	HUC Watershed Name
1	05140104080020	Little Indian Creek (north)
2	05140104080050	Indian Creek-Jersey Park Creek
3	05140104080010	Indian Creek-Headwaters (Floyd)
4	05140104080040	Indian Creek-Middle Fork
5	05140104080100	Indian Creek-Richland Creek
6	05140104080090	Georgetown Creek
7	05140104080060	Little Indian Creek-Headwaters
8	05140104080030	Indian Creek-Galena
9	05140104080070	Little Indian Creek-Lower
10	05140104080080	Indian Creek-above Georgetown Creek
11	05140104090020	Corn Creek
12	05140104090030	Indian Creek-Corydon Junction Karst Area
13	05140104090040	Indian Creek-Crandall Branch
14	05140104090010	Indian Creek-south trib (Sec 36)
15	05140104090050	Indian Creek- Raccoon Branch
16	05140104090090	Little Indian Creek (Lanesville)
17	05140104090060	Indian Creek-Brush Heap Creek
18	05140104090070	Little Indian Creek-North Karst Area
19	05140104090080	Little Indian Creek-South Karst Area
20	05140104090080	Little Indian Creek-South Karst Area
21	05140104100010	Indian Creek-North Karst Area
22	05140104100030	Indian Creek-Devils Backbone
23	05140104100020	Indian Creek-East Karst Area
24	05140104100040	Indian Creek-Blue Spring

2.5.3 Bacterial Input Tool Data

The Bacteria Indicator Tool used inputs such as land use, livestock numbers, population, septic system density and failure, grazing patterns, wildlife numbers, and manure application rates.

Land Use Land Cover: GIS data were used to derive acres of land use types for each subwatershed. Land Cover in Indiana (2001), derived by the USGS was used.

Animal Census: A combination of USDA Census of Agriculture data and confined feeding operations data was used to determine the number of livestock animals in each subwatershed. Livestock numbers were available by county from USDA and by confined feeding operation from IDEM. Data were retrieved from the following websites:

http://www.nass.usda.gov/QuickStats/Create_County_Indv.jsp http://www.nass.usda.gov/QuickStats/Create_County_All.jsp

Manure Application: IDEM provided data for manure application rates.

Grazing: County extension offices provided data on grazing patterns in the area.

Septic Systems: County health departments provided information on the percent of population using septic systems and the estimated septic system failure rates.
Information on pet contribution was readily available and therefore was not included. It was assumed that all cattle have access to streams. Topographic information and flow simulation is not included in the BIT. In steeper topography that occurs largely in the northern half of the watershed in Floyd County, cattle tend to graze in valley bottoms. In the rolling topography of Harrison County, cattle pastures tend to include areas farther from streams. Only a portion of the bacteria from land-based sources reaches streams or groundwater.

2.5.4 Bacterial Input Tool Results

The tool provided output data in counts/acre/ day of fecal coliform from land-based sources - forestland, cropland, pastureland, built-up land, as well as direct (in-stream) estimations of count/day contributions from septic systems and cattle in streams.

Forest, Cropland, Pasture, and Built-Up Land: As shown in the chart below, pasture and crop have the highest accumulation rate of bacteria. Both forested and developed (i.e. Built-up) lands in the Indian Creek Watershed accumulate less than 1 percent of the total bacteria counts/day.

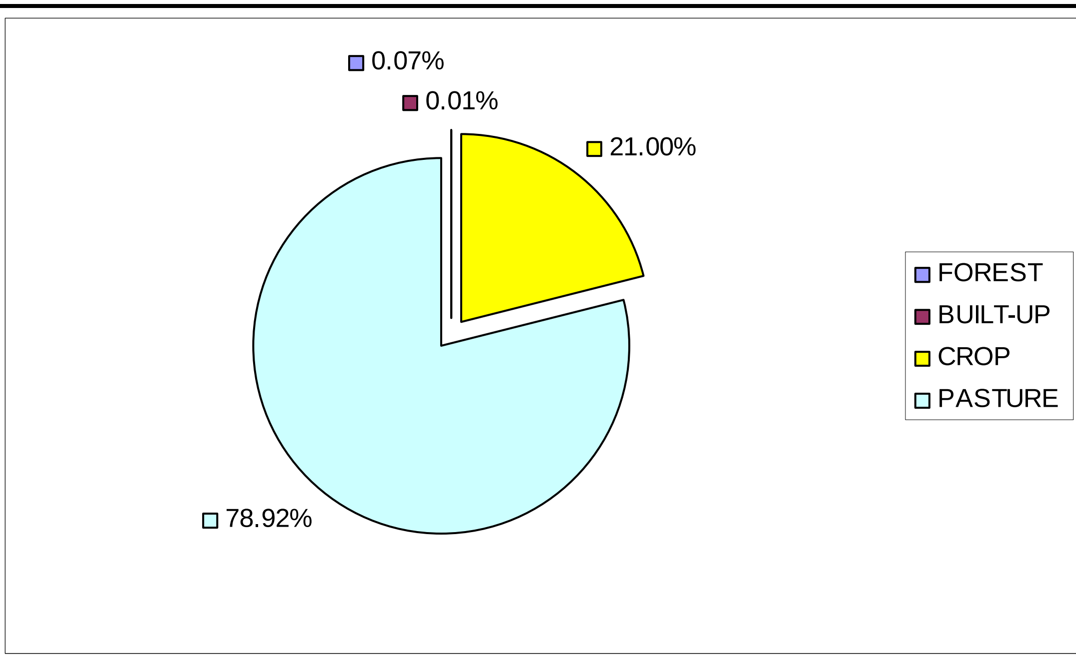

Figure 2.2. Percent Accumulation of Bacteria from Land-Based Sources

Bacterial accumulation rates, expressed as fecal coliform counts/acre/day were mapped by subwatershed in **Figure 2.3**. Subwatersheds 11, 19, 20, 21, and 23 are estimated to have the highest nonpoint source counts of bacteria in the watershed, reaching up to 9.9 billion counts/acre/day of fecal coliform in the Little Indian Creek South – Karst Area subwatershed (HUC 05140104090080). A graph showing sources of bacteria in each subwatershed is provided in **Figure 2.4.**

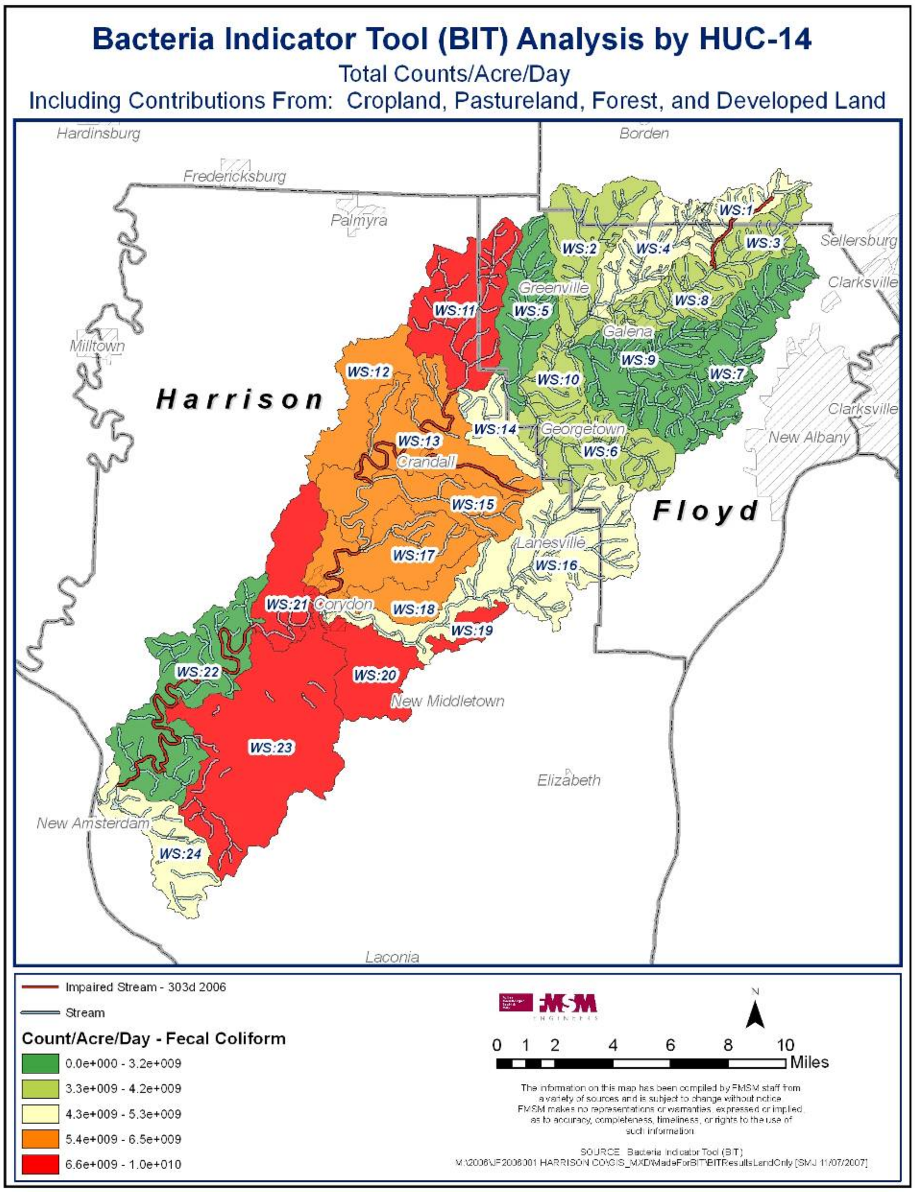

Figure 2.3. BIT Results for Land Based Bacteria Sources

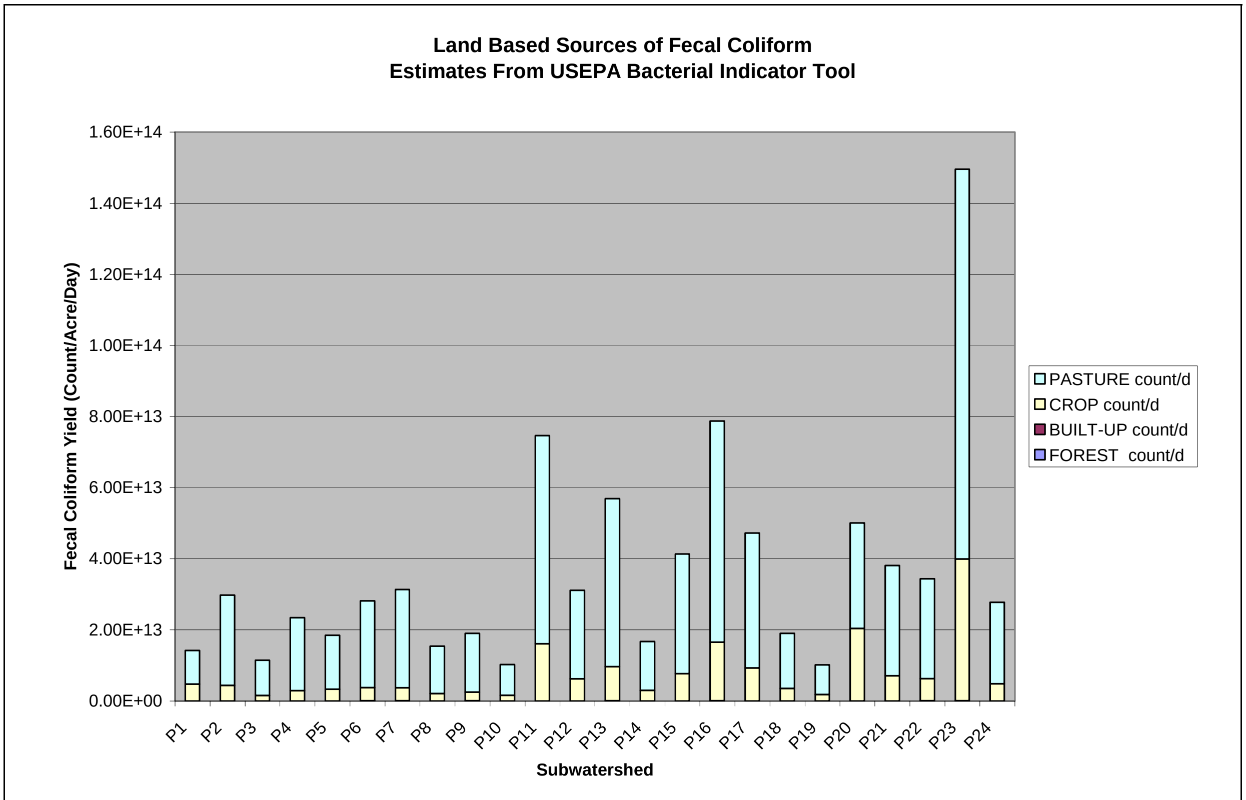

Figure 2.4. BIT Results - Land Based Bacteria Sources

Cattle in Streams and Septic Systems: Two maps were produced to show additional direct contributions of fecal coliform from cattle in stream and failing septic systems. The model does not take into consideration livestock exclusion practices currently in place. Cattle in streams are shown by the BIT to contribute over one-thousand times the count/day of fecal coliform to stream than failing septic systems; however this trend does not account for relative human health concern.

As shown in **Figure 2.5**, subwatersheds in Harrison County contribute more bacteria to the stream from cattle in stream, than subwatersheds in Floyd and Clark counties.
The subwatersheds in Floyd County contribute higher counts of bacteria from septic systems than the subwatersheds in Harrison. **See Figure 2.6.**

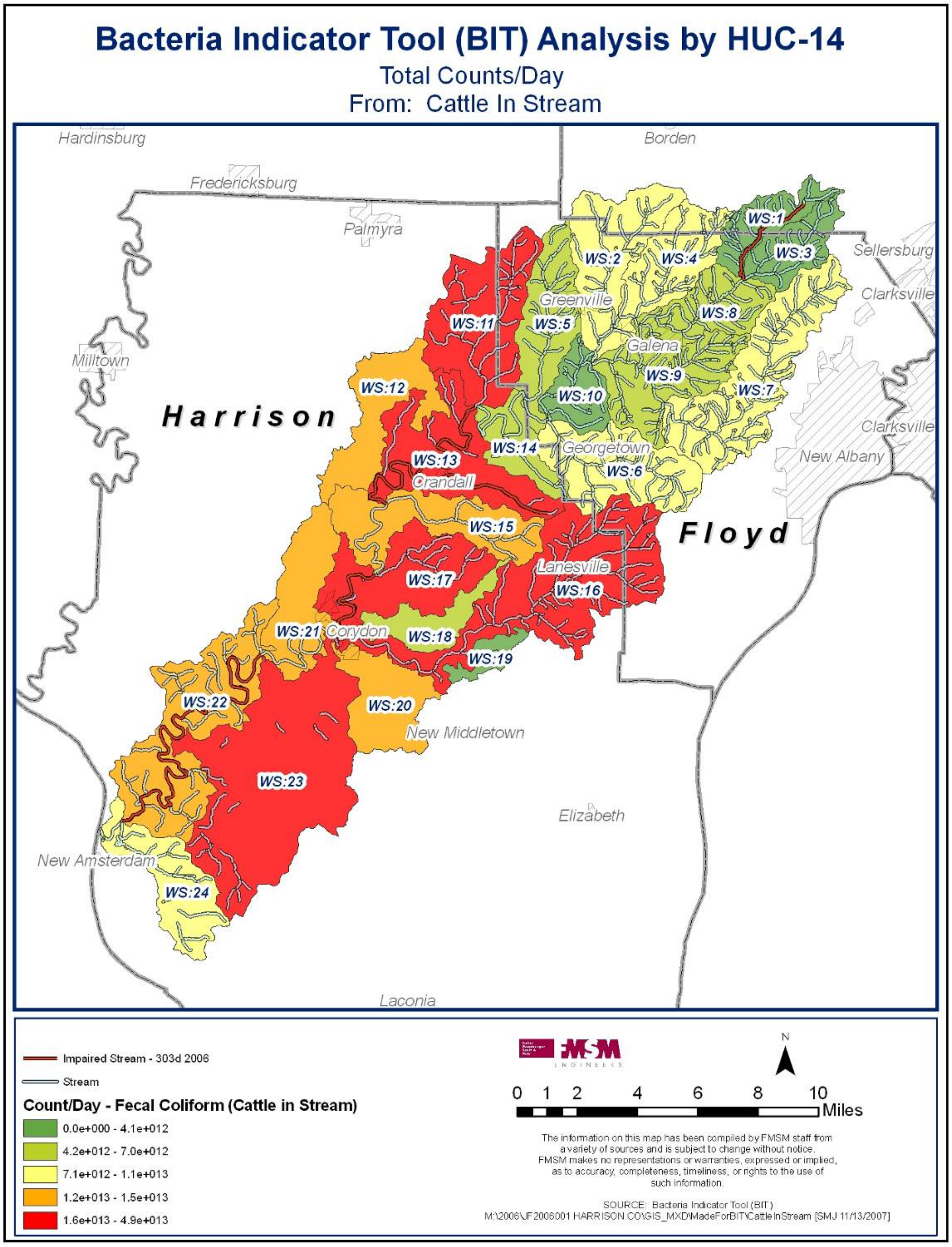

Figure 2.5. BIT Results for Cattle in Streams

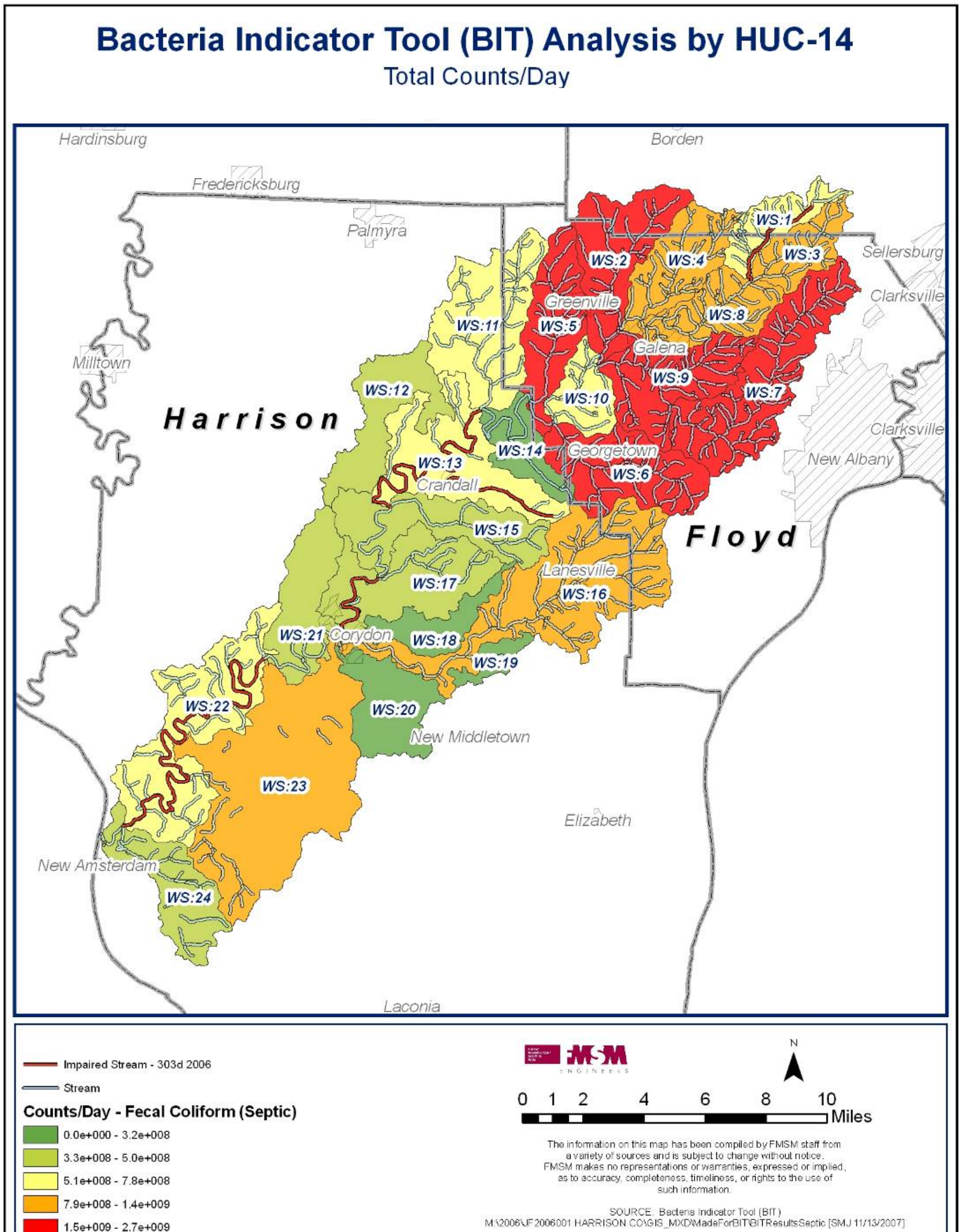

Figure 2.6. BIT Results for Septic Systems

Figures 2.7 and 2.8 below depict in-stream contribution of bacteria from septics and cattle in streams.

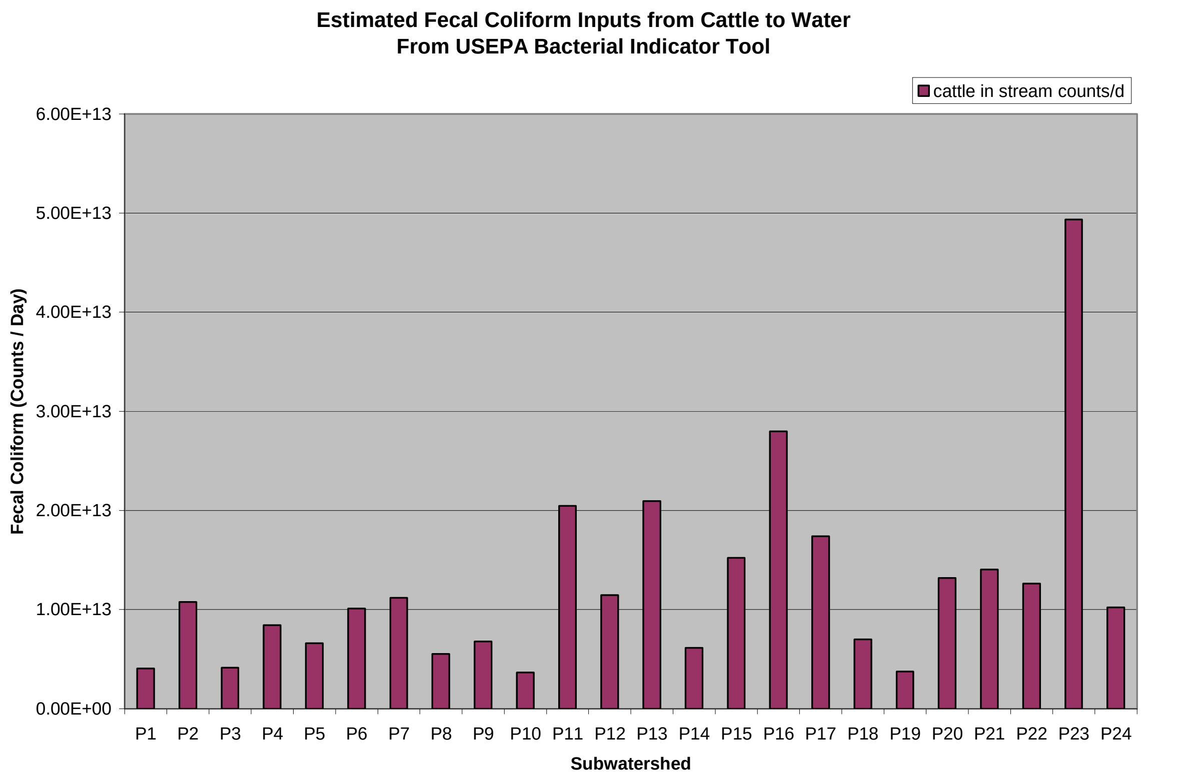

Figure 2.7. BIT Result for Cattle in Streams

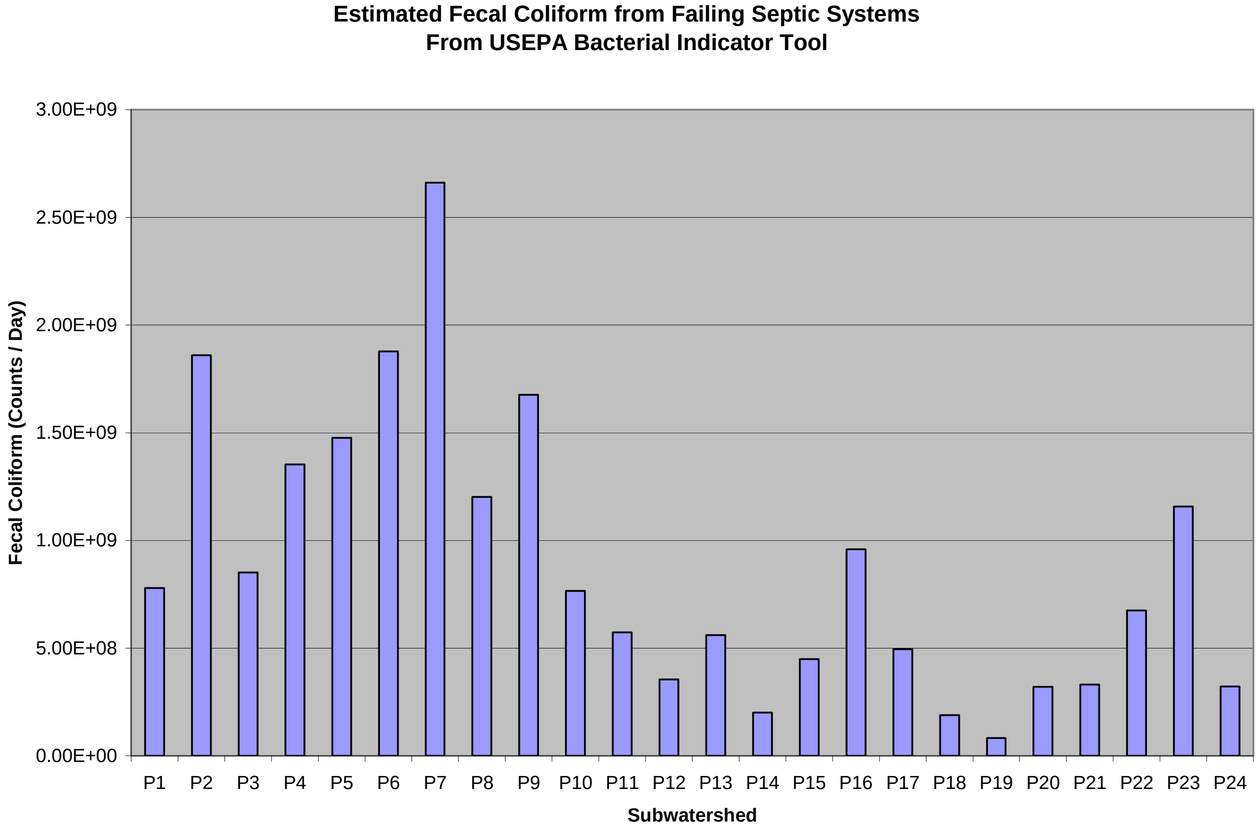

Figure 2.8. BIT Result for Septic Systems

2.6 CAUSES AND SOURCES OF WATER QUALITY PROBLEMS

Pollution sources may be categorized as point sources or nonpoint sources (NPS). Point source pollution refers to pollution that can be traced back to a specific, identifiable source, such as a pipe, ditch, or other outlet. Point sources include the following:

- Wastewater discharges, including large and small wastewater treatment plants.
- Stormwater discharges including regulated discharges from industrial activity and municipal separate storm sewer systems (MS4s).
- Discharges from Confined Feeding Operations (CFOs), and Concentrated Animal Feeding Operations (CAFOs).

As of February 2007, there were eighteen (18) NPDES-permitted facilities in the Indian Creek Watershed, and fifteen associated outfalls. Overall, facilities are in compliance with permit requirements. Only one facility has been in violation in since 1996, and that situation is being monitored in a manner satisfactory to IDEM (IDEM 2006). The Towns of Corydon and

Lanesville both operate publicly owned wastewater treatment plants that serve the community. There are several semi-public treatment plants or "package plants" that are used to treat sewage for subdivisions, schools, and other small facilities that are too far from a large WWTP to treat waste in a cost-effective manner. Several private plants are also in operation, including two that provide pretreatment before releasing waste to the Corydon Municipal STP. One facility is State-owned, and is the only facility which has been in violation of its permits. NPDES facilities are illustrated in **Appendix 2.2** and shown in the table below.

Table 2.17. NPDES Facilities in Indian Creek Watershed

Permit Number	Facility Name	Facility Type	City	County	Receiving Water or Facility
IN0020893	Corydon Municipal STP	Public	Corydon	Harrison	Indian Creek
IN0031178	Galena Elementary and Floyd Central High Schools	Semi-Public	Floyds Knobs	Floyd	Little Indian Creek
IN0038385	Dairy Dip Car Wash	Private	New Salisbury	Harrison	Indian Creek
IN0040215	Lanesville Municipal STP	Public	Lanesville	Harrison	Little Indian Creek
IN0043923	Wymberly Woods Utilities	Semi-Public	Floyds Knobs	Floyd	Yellow Fork to Little Indian Creek
IN0045942	Lanesville Welcome Center I-64	State	Lanesville	Harrison	Lazy Creek to Indian Creek
IN0050032	Highlander Point Shopping Center	Semi-Public	Floyds Knobs	Floyd	Unnamed tributary to Little Indian Creek
IN0050181	Chimneywood Sewage Works	Semi-Public	Clarksville	Floyd	Unnamed tributary to Little Indian Creek
IN0052019	Highlander Village Subdivision	Semi-Public	Galena	Floyd	Unnamed tributary to Little Indian Creek
IN0052159	Country View Subdivision	Semi-Public	Floyds Knobs	Floyd	Yellow Fork to Little Indian Creek
IN0054101	Deerwood Environmental	Semi-Public	Floyds Knobs	Floyd	Little Indian Creek
IN0055794	Huber Family Restaurant	Semi-Public	Borden	Clark	Unnamed Tributary to Thompson Creek to Indian Creek
IN0058564	Greenville Elementary School	Semi-Public	Greenville	Floyd	Richland Creek to Indian Creek
IN0058572	Floyds Knobs Elementary School	Semi-Public	Floyds Knobs	Floyd	Little Indian Creek
IN0059382	Jacobi's Car Wash and Store	Private	Galena	Floyd	Ditch to Little Indian Creek
IN0059803	Clean Car Auto Wash Corp.	Private	Floyds Knobs	Floyd	Ditch to Little Indian Creek
INP000117	Tyson Foods, Inc.	Private	Corydon	Harrison	Corydon Municipal STP
INP000153	Daramic Incorporated	Private	Corydon	Harrison	Corydon Municipal STP

Source: IDEM OWQ, 2002.

Nonpoint sources are indirect and diffuse. They can include:

- Stormwater runoff from unregulated communities or lands
- Failing septic systems
- Contaminated groundwater discharges to streams
- Air deposition.

Land uses in the Indian Creek Watershed are quickly changing as development spreads from the Louisville Metro area. The I-64 corridor is undergoing rapid expansion and previously fallow or agricultural land is being converted for residential, commercial, and industrial uses.

With increasing development comes an increase in impervious area or hard surfaces, which prevents rainwater absorption into the soil. Greater impervious area also means that the volume of stormwater runoff generated will increase, and that the runoff will be exposed to more pollutants before it enters a stream – including oil and grease form parking lots and roadways, nutrients from over-fertilized lawns, bacteria from pet wastes, and other chemicals related to household wastes. An increase in the volume and velocities of water transported to streams is also likely and can lead to erosion and streambank failure.

2.6.1 Causes and Sources of Recreational Use Impairments

Recreational designated use impairments are caused by elevated bacteria (E. coli). In the Indian Creek Watershed, 36.7 miles (four segments) are impaired by bacteria. This issue is common in Indiana and throughout the United States.

E. coli is generally used as an indicator of harmful bacteria loading because it is easier and less expensive to monitor than pathogenic organisms, and it is derived solely from the intestinal tract of warm-blooded animals. Fecal coliform bacteria are present in soil as well as in animals.

Indiana water quality standards require that the geometric mean of five (5) E. coli samples collected in a thirty (30)-day period should not exceed 125 colony forming units (CFU) per 100 milliliters, and a single sample should not exceed 576 CFU per 100 milliliters.

IDEM sampled seven (7) sites for E. coli bacteria in 2000 and 2005. Six (6) of the seven (7) sites did not meet the water quality criteria for E. coli. Concentrations of E. coli bacteria at all sites ranged from 20 CFU per 100 milliliters to 4,500 CFU per 100 milliliters. Geometric mean concentrations ranged from 128 to 423 CFU per 100 milliliters and single sample maximum concentrations ranged from 180 to 4,500 CFU per 100 milliliters. IDEM bacteria data are summarized in **Appendix 2.1**.

Possible sources of elevated bacteria may include human sources such as wastewater treatment plants that are not in compliance with disinfection requirements, failing septic systems, and straight pipes. Animal sources include pets, wildlife, and livestock. It is important to note that pathogenic (i.e. disease causing) organisms occur in both human and animal wastes. Available data and information related to each of these sources is discussed below.

The following sources of bacteria were evaluated:

- **Direct**: Cattle in creek, straight pipes, non-compliant wastewater treatment plants, sanitary sewer overflows (SSO), stormwater discharges and dry weather discharges from the stormwater system which indicate illegal sanitary sewer connection or other illicit discharge to stormwater system.
- **Indirect**: Overland runoff from pastures, manure piles, pet waste, wildlife and failing septic systems.

Compliance at Regulated Facilities: IDEM provided effluent quality data for a recent 5-year interval, summarized in the table below. These data indicated that several regulated facilities in the watershed had E. coli violations, including the Woods of Lafayette (12), and Lanesville Welcome Center (8) had the most violations for E. coli. Sanitary sewer overflows have not been reported in the Indian Creek Watershed.

Table 2.18. National Pollution Discharge Elimination System (NPDES) Violations

Map Reference ID Number	NPDES Permit #	Facility Name	Total # of Violations (03/2002 - 02/2007)	# of E. coli Violations (03/2002 - 02/2007)	Most Recent E. Coli Violation (03/2002-02/2007)
1	IN0020893	Corydon Municipal WWTP	1	0	N/A
2	IN0031178	Galena Elem & Floyd Central HS	6	1	5/31/2006
3	IN0038385	Dairy Dip Car Wash	1	0	N/A
4	IN0040215	Lanesville Municipal STP	10	5	9/30/2006
5	IN0043923	Wymberly Sanitary Works, Inc	1	0	N/A
6	IN0045942	Lanesville Welcome Center I-64	81	8	5/31/2006
7	IN0050032	Highlander Point Shopping Cent	0	0	N/A
8	IN0050181	Chimneywood Sewage Works, Inc.	16	0	N/A
9	IN0052019	Galena WWTP	22	0	N/A
10	IN0052159	Country View Subdivision	1	0	N/A
11	IN0054101	Woods Of Lafayette's WWTP	46	12	6/30/2006
12	IN0055794	Huber Family Restaurant	37	0	N/A
13	IN0058564	Greenville Elementary School	55	0	N/A
14	IN0058572	Floyd Knobs Elementary School	15	0	N/A
15	IN0059382	Jacobi's Car Wash & Store	32	11	10/31/2002
16	IN0059803	Cleancar Auto Wash Corp.	42	0	N/A
17	INP000117	Tyson Foods, Inc.	2	0	N/A
18	INP000153	Daramic Incorporated	7	0	N/A

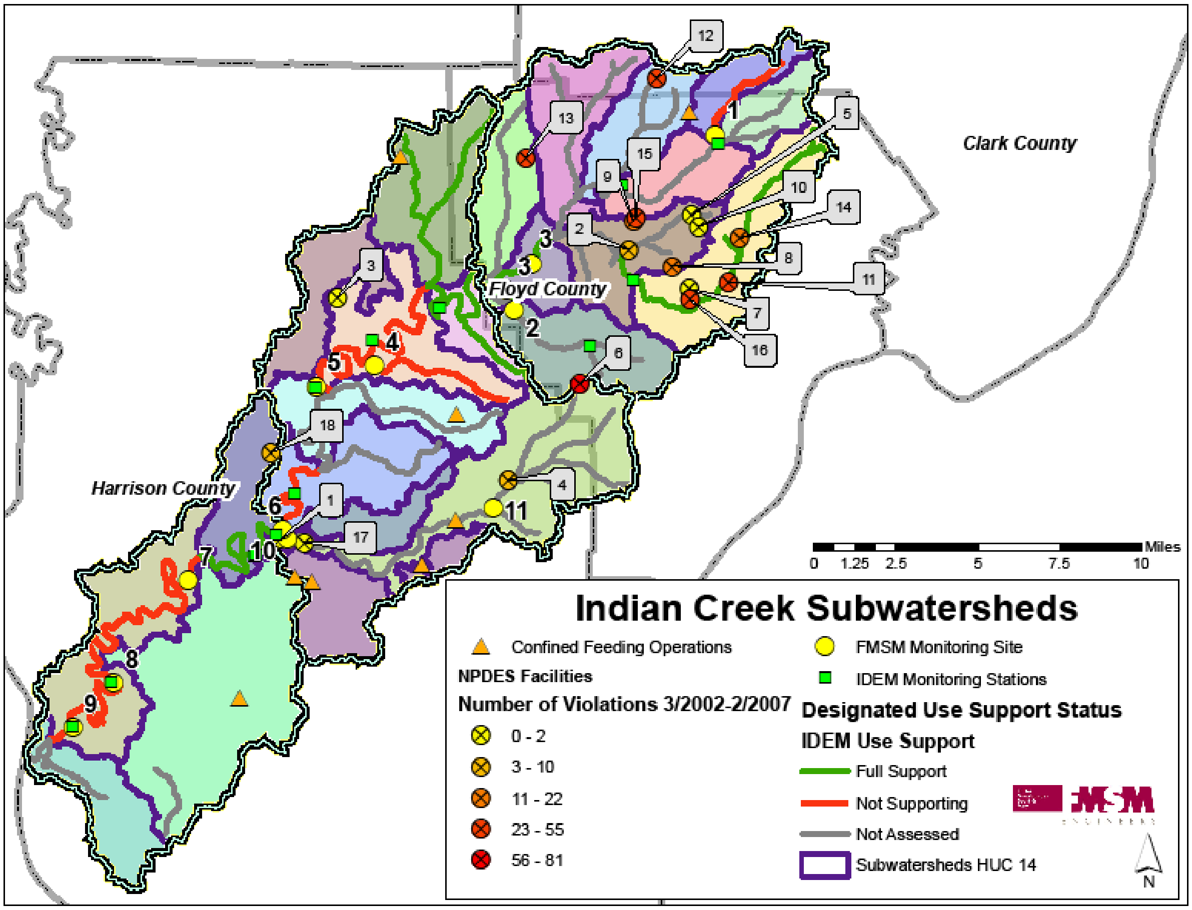

Figure 2.9. Indian Creek NPDES Facility Compliance

Stormwater: Stormwater runoff can carry oxygen consuming wastes, toxic substances, nutrients, sediment, and bacteria to area streams. It can also become contaminated by failing or inappropriately located septic systems. In order to control pollutants from stormwater systems, regulated communities are required to implement six minimum controls (MCMs), including:

1. Public education and outreach
2. Public participation and involvement
3. Illicit discharge detection and elimination
4. Construction site runoff controls
5. Post-construction stormwater management
6. Municipal operations pollution prevention and good housekeeping

Communities regulated in the Stormwater Program are required to adopt ordinances to control runoff from construction sites, post construction sites, and illicit discharges. Ordinances to control runoff associated with construction are an important tool to control sediment. Illicit discharge ordinances are an important control for bacteria and other wastewater pollutants. These ordinances require communities to identify and eliminate non-stormwater discharges into the stormwater system.

Currently, Floyd County is regulated under this program and is in its third year of implementing the first stormwater permit. Among other accomplishments, Floyd County had mapped 64,940 feet (13.2 miles) of stormwater conveyance, and 540 stormwater outfalls as of December 2007. All outfalls had been screened for illicit discharges, and one possible illicit discharge had been detected. The possible illicit discharge, associated with a potentially failing septic system, is being investigated. Harrison County is currently not regulated by the Stormwater Program, but is developing a comprehensive stormwater ordinance.

Septic Systems and Straight Pipes: Septic systems are very common in the Indian Creek Watershed, even though soil conditions are not ideal for their use. Thirty-one percent (31%) of 29,087 households in Floyd County use septic systems. Eighty percent (80%) of Harrison County's 12,917 households use septic systems as per the Hoosier Environmental Council's Watershed Restoration Toolkit. Thus, there are approximately 9,000 septic systems in Floyd Count and approximately 10,000 septic systems in Harrison County. Data to support this analysis on a watershed basis were not available. Additional information is provided in Chapter 1.4.

Although septic systems work best on large lots with deep permeable soils, there are a variety of system designs available that can overcome some of the obstacles that are encountered on less than ideal sites. However, poor sitting design, installation or maintenance of septic systems can result in surface ponding in yards, polluted groundwater, and impacted streams and wells. Systems may also be "straight-piped" or discharged directly to a stream, which is illegal in the State of Indiana (327 IAC 5-1-1.5).

Concern regarding failing septic systems was documented in the Harrison County Stormwater and Wastewater Feasibility Study (Harrison County, 2003), which indicated that up to 70% of the septic systems in Harrison County are "functioning improperly" (Harrison County, 2003). Discussions with staff of both the Floyd and Harrison County Health Departments indicated that septic systems are a significant problem. In the highly karst terrain in the southern portion of this watershed, septic system failures may go undetected because effluent is transported to underground channels rather than surfacing.

Failing septic systems may be a major source of E. coli pollution in the watershed and they can also contribute phosphate, phosphorus and nitrogen as ammonia or nitrate. However, as discussed in subsequent sections, nutrient problems were not widespread.
Harrison County Health Department has begun to compile complaints and other information regarding septic system issues. Municipalities routinely respond to reports of, and inspect for, illicit connections and failing systems. There is interest in identifying resources to further investigate the condition and failure rate of septic systems in this watershed and developing a series of strategies to address the issue. The number of straight pipes in the watershed is currently unknown.

Animal Sources: As of June 2004, six (6) Confined Feeding Operations and one (1) Confined Animal Feeding Operation were regulated by IDEM in the Indian Creek Watershed.

Indiana law defines a Confined Feeding Operation (CFO) as any animal feeding operation engaged in the confined feeding of at least 300 cattle, or 600 swine or sheep, or 30,000 fowl, such as chickens, turkeys or other poultry.

Confined animal feeding operations (CAFO) are defined as:

- 700 mature dairy cows
- 1,000 veal calves
- 1,000 cattle other than mature dairy cows
- 2,500 swine above 55 pounds
- 10,000 swine less than 55 pounds
- 500 horses
- 10,000 sheep or lambs
- 55,000 turkeys
- 30,000 laying hens or broilers with a liquid manure handling system
- 125,000 broilers with a solid manure handling system
- 82,000 laying hens with a solid manure handling system
- 30,000 ducks with a solid manure handling system
- 5,000 ducks with a liquid manure handling system

Compliance data provided by IDEM indicated that the one CAFO facility, Tyson Foods, was regulated for bacteria, and that this facility was in compliance with bacteria limits during the last 5 years, see **Table 2.11**.

The USDA National Agricultural Statistics Service provides livestock census data by county. Data for Clark, Floyd and Harrison Counties are summarized in the table below. (http://www.nass.usda.gov/QuickStats/Create_County_Indv.jsp).

Table 2.19. Livestock, Poultry and Farms in Clark, Floyd, and Harrison Counties

	Cattle		Hogs		Horses		Poultry	
	Head	Farms	Head	Farms	Head	Farms	Head	Farms
Clark	10,972	288	2,288	18	865	144	84	29
Floyd	2,621	135	70	7	598	103	162	10
Harrison	19,640	607	3,184	30	1522	279	1,122,449	52
Total	33,233	1,030	5,542	55	2985	526	1,122,695	91

Source: ISDA DSC, 2004.

Clark and Floyd County have developed illicit discharge ordinances which prohibit non-stormwater discharges into the stormwater system, including the improper disposal of animal waste; Harrison County is in the process of developing a comprehensive stormwater ordinance which addresses prohibited discharges.

2.6.2 Causes and Sources of Aquatic Life Impairments: Low Dissolved Oxygen

The State water quality criteria for dissolved oxygen (DO) requires concentrations of at least five (5) milligrams per liter per calendar day average and at least four (4) milligrams per liter in any sample (327 IAC 6(b)(3)).

Eleven (11) of twelve sites monitored for DO by IDEM in the Indian Creek Watershed had acceptable levels of DO. Five DO samples were collected at Indian Creek at Lickford Bridge Road (Site OBS100-006) in July and August of 2000. Four of the 5 samples were below 5 milligrams per liter, with concentrations ranging from 2.5 to 7.8 milligrams per liter (mg/l), average 4.3 mg/l DO. As a result, IDEM listed one (1) stream segment, Devil’s Backbone (17.2 miles), as impaired for DO in 2006. Data collected upstream at Indian Creek at Rocky Hollow Road (OBS100-001) indicated acceptable levels of DO. These data are summarized in **Appendix 2.1**.

Low DO may be caused by “organic enrichment” and/or low flow or stagnant water. Organic enrichment refers to elevated nutrients and pH, algal blooms, and oxygen depletion. Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and may cause other organisms to die.

Nutrient data were not collected by IDEM at the Indian Creek at Lickford Bridge Road (Site OBS100-006). However nutrient data collected by IDEM at Indian Creek at Rocky Hollow Road (OBS100-001) indicated very low levels of total phosphorus (maximum concentration of 0.063 mg/l) and nitrate (0.005 mg/l). A watershed survey did not indicate watershed sources of nutrients between these sites.

Therefore, the low DO levels may be attributed to low flow and backwater from the Ohio River. Backwater is introduced into the lower reaches of the watershed when the water surface elevation of the Ohio River is higher than the water surface elevation of Indian Creek. Ohio River water enters the lower reaches of Indian Creek and greatly reduces or stops flow in Indian Creek. “Losing streams” may also contribute to low DO. Segments of Indian Creek are considered “losing streams” and a portion of their flow is diverted into underground karst features. This may result in low flow and stagnant water near karst features.

2.6.3 Causes and Sources of Aquatic Life Impairments: Aquatic Habitat

IDEM monitored fish communities and habitat using the Index of Biotic Integrity (IBI) and Qualitative Habitat Evaluation Index (QHEI) at four locations in the Indian Creek Watershed. Three sites on the Indian Creek mainstem were not impaired. One site, on Little Indian Creek (Site OBS080-001), was identified as impaired. IBI scores of less than 36 are considered impaired and this site had a score of 24. This location, Little Indian Creek North (INN0482_00) was listed on the 303d list for Aquatic Life Impairments (3.87 miles) based on this fish community assessment. Results are summarized in the following table.

Table 2.20. Fish Community and Habitat Data Summary

Site #	Location	Fish Community IBI Score	Habitat Score (of 100)
OBS080-0001	Little Indian Creek at Banet Road	24 Impaired	57
OBS080-0008	Indian Creek at Navilleton Road	38 Full Support	48
OBS090-0002	Indian Creek at Southern Railroad	54 Full Support	59
OBS090-0002	Indian Creek at Landmark Way	50 Full Support	92

Source: IDEM, 2006.

The quality of the aquatic community may be affected by numerous factors, including water quality, habitat and climatic conditions (e.g., drought, flood). The IBI score has been calibrated to address the influences of ecoregion and drainage area. The watershed of the impaired site is relatively small (4.7 square miles). The watershed draining to this location is primarily agriculture and forestry.

Fish species such as darters and smallmouth bass, which indicate good water quality, were present at this site. IDEM collected water quality data at the time of sampling and during the summer of 2000. Dissolved oxygen was at levels that are supportive of aquatic life (>8 mg/l for all samples), pH was within criteria limits (between 7.5 and 8.2 pH units) and nutrients were low (total phosphorus less than 0.08 mg/l and nitrate less than 0.9 mg/l). Specific conductivity was 240 us/cm, temperature was 20.5 C and turbidity was 6.6 NTU. These fish community and water quality data indicate that water quality around the time of sampling was within acceptable ranges and may not be a significant contributor to the impairment.

The habitat at Little Indian Creek at Banet Road (IDEM Site OBS080-0001) was suboptimal. The following in-stream habitat scores were given:

- Substrate Score – 13 (20 maximum)
- Instream Cover Score – 7 (20 maximum)
- Channel Morphology – 12 (20 maximum)
- Riparian Zone & Bank Erosion Score – 6 (10 maximum)
- Pool/Glide Quality Score – 4 (12 maximum)
- Riffle/Run Score Quality – 5 (8 maximum)
- Gradient Score – 10 (10 maximum)
- **Total habitat score – 57 (100 maximum)**

These scores indicate that in-stream cover, pool/glide quality, riparian zone/ bank erosion and channel morphology were less than ideal.

2.6.4 Causes and Sources of Fish Consumption Impairments

The fish consumption advisories, applied to waterbodies in the Indian Creek Watershed, are caused by elevated mercury and polychlorinated biphenyls (PCBs) contamination.

Mercury: Mercury is a naturally occurring metal. Elemental mercury is a liquid that occurs in some ore deposits. It may also be concentrated around hot springs. The health hazards of mercury exposure depend on the form of mercury to which an individual is exposed. The greatest health hazards have been attributed to exposure to methylmercury. Methylmercury is highly soluble in water and is concentrated in fish and shellfish. Species higher on the food chain typically bioaccumulate more mercury throughout their lifespan. Consumption of fish containing high levels of methylmercury can lead to health concerns especially for women and small children. Chronic mercury exposure can result in mood swings and severe nervous disorders. Both short-term and long-term exposure to high mercury levels has been found to cause kidney damage.

There is no evidence of local pollution from mercury such due to contaminated sites and industries, such as metal-refining operations. Therefore, the largest likely contributor to mercury contamination regionally is the combustion of fossil fuels. USEPA is currently implementing additional regulations to control emissions from coal-fired power plants. The goal is to reduce mercury and other air-pollutants in the long term.

Polychlorinated Biphenyls (PCBs): PCBs are man-made chemicals that were once manufactured and widely used for their physical properties, including heat resistance, non-flammability, electrical conductance, and chemical stability. These substances were used in a wide variety of applications, including plastics, paints, and electrical equipment. In the 1960s and 1970s, PCBs were discovered to be less chemically stable than previously thought through their detection in streams and wildlife. Because of concerns over health effects associated with PCBs, including reproductive and immune system disorders and cancer, PCBs were banned by Congress in 1976 through the Toxic Substances Control Act (USEPA 2006). Although the Indian Creek Watershed had no streams identified by IDEM as contaminated for PCBs, there is a statewide fish consumption advisory for carp greater than 15 inches in length.

2.6.5 Other Water Quality Concerns: Nutrients and Solids

Nutrients: The major nutrients of concern for stream systems are phosphorus and nitrogen. Phosphorus and nitrogen are found in commercial fertilizers, manure, and other crop production enhancers, as well as in human waste. These nutrients are found naturally in streams and are required for a healthy aquatic ecosystem. However, excess nutrients can lead to eutrophication, excessive algae growth contributing to decreased levels of dissolved oxygen. In extreme cases, fish kills can result. Elevated nutrients are most detrimental during periods of high temperature and low flow conditions.

Indiana’s has not yet established eutrophication criteria for nitrate; the threshold for for nitrate at potable water supply intakes is 10 mg/L. However, a concentration of 5 mg/l nitrate was used for planning purposes in this watershed to provide an “early warning system” for elevated nitrates. While the State has not set a criterion for phosphorus, levels greater than, or equal to, 0.3 mg/L are used by IDEM to indicate eutrophication. Monitoring results, criteria and comparison values are shown in **Table 2.21.**

Table 2.21. Nutrient Data Summary

Characteristic Name	Units	# Results	Minimum Value	Average Value	Maximum Value	Criteria or Comparison Value
Nitrogen - nitrate+nitrite	mg/L	56	0.1	0.8	**5.9**	5
Total Kjeldahl Nitrogen	mg/L	66	0.1	0.6	1.5	5
Orthophosphate	mg/L	65	0.03	0.1	**2.15**	0.3
Phosphorus, total	mg/L	66	0.03	0.1	**2.88**	0,3
Solids, total	mg/L	65	**162**	**284.1**	**475**	261
Turbidity	NTU	62	1.13	12.7	**80.2**	25
Stream Flow	ft/sec	101	-0.72	1.1	28.3	-
Dissolved oxygen (DO)	mg/L	63	**0.08**	7.8	**16.2**	**4.0 mg/l minimum;** Maximum < 12

Elevated concentrations of nitrate, total phosphorus and orthophosphate wree found at Site 11. Little Indian Creek below Lanesville at State Road 62, a previously unassessed reach. This site is located downstream of Lanesville and the Lanesville WWTP.

Total solids were also found to be elevated. Since most of the samples were collected during warm weather and low flow conditions, these total solids concentrations may be associated with algal activity.

The Office of the Indiana State Chemist (OISC) publishes fertilizer data annually, including the tonnage sold. **Table 2.22.** provides an estimate of the fertilizer sales, and thus potentially used, in the Indian Creek Watershed based on 2005 OISC data.

Table 2.22. Estimate of 2005 Nutrient Applications in the Indian Creek Watershed

County	% County in ICW	X	Total Nutrients (tons)		X 2,000 lbs/ton	Nutrients in IWC (lbs)	
			N	P2O5		N	P2O5
Clark	2.8%	X	5646.3	6950.1	X 2000	158	194
Floyd	58.0%	X	190.5	108.7	X 2000	220,934	126,150
Harrison	32.9%	X	3588.9	2117.0	X 2000	2,361,529	1,392,979
Total						**2,582,621**	**1,519,323**

Source: OISC, 2005.

However, agricultural practices are in place to reduce nutrient, pesticide, and sediment runoff from corn and soybeans, as shown in the following tables.

Table 2.23. Conservation Tillage in Indian Creek Watershed, Corn

County	No-Till		Mulch-Till		Reduced Till		Conventional		County Rank for % No-Till
	Acres	%	Acres	%	Acres	%	Acres	%	
Clark	9,773	63	455	3	682	4	4,546	30	8
Floyd	1,176	79	0	0	0	0	321	21	2
Harrison	20,716	88	0	0	600	3	2,102	9	1
Total	31,655	79	455	1	1,282	3	6,969	17	

Source: ISDA DSC, 2004.
Note: There are 89 counties in Indiana

Table 2.24. Conservation Tillage in Indian Creek Watershed, Soybeans

County	No-Till		Mulch-Till		Reduced Till		Conventional		County Rank for % No-Till
	Acres	%	Acres	%	Acres	%	Acres	%	
Clark	15,683	73	0	0	682	3	3,637	18	14
Floyd	1,711	70	0	0	214	9	535	22	28
Harrison	15,312	93	0	0	901	5	300	2	1
Total	**32,706**	**84**	**0**	**0**	**1,797**	**5**	**4,472**	**11**	

Source: ISDA DSC, 2004.
Note: There are 89 counties in Indiana

Evidence of the success of conservation tillage in reducing chemical transport to streams is documented in the following table**.** USGS, under cooperative agreement with IDEM, monitored 149 organic chemicals in the Indian Creek near Galena (Site OBS080-004) in 2000. The following levels were detected (all were very low):

Table 2.25. Pesticides Detected in Indian Creek Watershed

Parameter	Concentration (parts per billion)
Bromacil (ug/L)	0.1
Malathion (ug/L)	0.1
Metolachlor (ug/L)	0.2
Oxadiazon (ug/L)	1.1
Simazine (ug/L)	0.08

Source: IDEM, 2006.

Clark and Floyd County have developed illicit discharge ordinances which prohibit the improper disposal of fertilizers; Harrison County is in the process of developing a similar comprehensive stormwater ordinance.

2.7 TARGET LOAD REDUCTIONS

In order to determine the overall effectiveness of recommended management measures identified in this plan, it is important to have an understanding of the target loads that result in meeting surface water quality criteria and existing pollutant loads in the watershed. Because concentrations in the impaired subwatersheds varied significantly, the target load reductions were calculated separatel for the monitored tributary subwatersheds and also for the two impaired locations on the Indian Creek mainstem. Target loads were calculated as follows:

- Research the average annual flow USGS Gaging Station 03302500 Indian Creek at State Road 335 (44.5 cubic feet per second, cfs; Drainage Area 129 square miles, 0.34 cfs/ sq.mi.)

- Where water quality criteria were not met, use water quality criteria and average monitored concentrations of bacteria from this study to estimate target loads at the water quality standard and pollutant loads for the portion of the watershed above Corydon.

Table 2.26. E.Coli Load Reduction Target Summary

Load Paramter	Site 2. Georgetown Creek above Indian Creek	Site 3. Indian Creek above Georgetown Creek	Site 4. Crandall Branch above Indian Creek	Site 5. Indian Creek below Crandall Branch
Drainage Area (sq. mi)	11.3	78.75	13.7	129
Flow-Yield (cfs/sq.mi)	0.34	0.34	0.34	0.34
Average Flow (cfs)	3.9	27	4.7	44.3
Target Average Concentration (cfu/100 ml)	125	125	125	125
Target Load (cfu/yr)	4.3 E+12	3.0 E+13	5.3 E+12	4.9 E+13
Average Concentration (cfu/100 ml)	194	147.2	779.2	268.8 cfu/100 ml
Estimated Existing Load (cfu/yr)	6.7 E+12	3.5 E+13	3.3 E+13	1.1 E+14
Estimated Load Reduction (cfu/yr)	2.4 E+12	5.4 E+12	2.8 E+13	5.7 E+13
% Load Reduction	35.5%	15.1%	84.5%	53.4%

Notes: Site 2: Georgetown Creek below Georgetown at Malinee Ott Road
Site 3: Indian Creek above Georgetown Creek, IDEM Site OBS080-0005
Site 4: Crandall Branch above SR335 Bridge
Site 5: Indian Creek above SR355 Bridge, IDEM Site OBS090-0004

The Bacterial Indicator Tool results provide insight into potential sources of bacteria in each of these subwatersheds. Results for subwatersheds above the monitoring sites were summed to develop the table below.

Table 2.27. Bacterial Loads for Target Subwatersheds

Parameter	Site 2. Georgetown Creek above Indian Creek	Site 3. Indian Creek above Georgetown Creek	Site 4. Crandall Branch above Indian Creek	Site 5. Indian Creek below Crandall Branch
Subwatersheds **(1)**	6	1-10	13	1-11, 13-14
Acres	7,240	55,907	8,803	76,847
Forest (FC/d)	1.62 E10	1.70 E11	3.22 E10	2.43 E11
Built (FC/d)	1.35 E10	4.41 E10	2.37 E9	4.69 E10
Crop (FC/d)	3.73 E12	3.03 E13	9.62 E13	5.90 E13
Pasture (FC/d)	2.44 E13	1.71 E14	4.72 E13	2.91 E14
Cattle in Stream (FC/d)	1.01 E13	7.12 E13	2.1 E13	1.19 E14
Failing Septics (FC/d)	1.88 E9	1.45 E10	5.61 E8	1.58 E10
Bacteria Yield (FC/D/Ac)	**5.29 E9**	**4.89 E9**	**8.85 E9**	**6.10 E9**

(1) Subwatersheds are shown in Table 2.16.

This table shows that bacteria from pasture and cattle in streams are likely to be important contributors to elevated bacteria in these subwatersheds. Although the bacterial contribution from failing septic systems is less than agricultural sources, exposure to pathogens from human sewage can pose a significant public health risk. Therefore, strategies that reduce bacteria from pastures, cattle in streams and septic system sources are considered to be priorities.

The per unit benefits of strategies to address these sources is summarized in the table below, based on estimates derived from the Bacterial Indicator Tool. As shown below, the anticipated load reduction from removing a single failing septic system from the watershed is 6.89 E7 FC/day. The anticipated load reduction from removing cattle from streams is 1.03 E11 FC/day per animal (assuming beef cattle). These per unit load reduction benefit values can be used to estimate the benefits of strategies as they are implmented.

Table 2.28. Load Reduction Benefits

Bacterial Source	Load Reduction Benefit
Failing Septic System	6.89 E7 FC/day/septic
Pasture	1.04 E11 FC/day/animal unit (beef cattle)
Cattle in Stream	1.03 E11 FC/day/animal unit (beef cattle)

Another important consideration for watershed improvement <u>and</u> watershed protection is the status of riparian areas. Healthy riparian areas serve numerous important functions:

- Reduce pollutant loads from overland runoff (bacteria, nutrients, sediment)
- Protect streambanks from erosion during high flows
- Habitat for wetland, semi-aquatic and aquatic species of plants and animals
- Shade streams, which can improve water quality during summer low –flow conditions

The status of riparian buffers in the Indian Creek watershed was estimated using the 2001 Land Cover for Indiana (USGS, 2001). A 6-meter buffer on each side of the stream was generated using GIS. Land use within that buffer is shown in Table 2.29 below. This 6-meter width was chosen because studies have shown that buffers of approximately 20 feet on each side of the stream can provide significant benefits. For example, a 75% reduction in bacteria using a 20 foot buffer was reported in “Efficacy and Economics of Riparian Buffers on Agricultural Lands” (J. Pizzimenti, 2002). Specific strategies for buffers are included in Chapter 3.

Table 2.29. Land Use Along Indian Creek Watershed Streams

Land Use	Buffer Area (Acres)	Percent
Deciduous Forest	332.08	39.7%
Evergreen Forest	9.70	1.2%
Mixed Forest	3.08	0.4%
Woody Wetland	18.95	2.3%
Emergent/Herbaceous Wetland	0.02	0.002%
	363.83	43.60%
Pasture/ Hay	322.66	38.6%
Row Crop	120.51	14.4%
Urban/Recreational Grasses	0.68	0.1%
Residential	17.97	2.2%
Mixed Urban Built-Up	3.10	0.4%
Transitional	0.05	0.01%
Open Water	7.13	0.9%
Total	**835.93**	**100.0%**

Some important considerations and opportunities arise from this analysis. Key findings are:

- With about 40% of the stream buffer areas in forest and wetland, there are significant conservation opportunities in this watershed. Maintaining these existing buffers, and re-establishing wetland buffers will help to keep this watershed intact as the area grows. This makes good economic sense because numerous studies have shown that property values are at a premium near high quality environmental features such as well-buffered, good quality streams.

- With over 50% of the stream buffer areas in agricultural uses, there are opportunities for expanding efforts to encourage farmers to establish and maintain health riparian buffers. Economic considerations are very important for the success of this practice. At a public meeting for this waterhsed plan, several farmers reported that buffer payments from agricultural agencies are not keeping pace with premiums for ethanol producing crops (e.g., corn). Drought, such as the one experienced in 2007, also results in farmers relying more on riparian areas for grazing.

It is also important to note that the USGS Landcover data provides a statewide estimate of landcover, but does not provide data on farm-specific practices.

2.8 ADDRESSING DATA GAPS: PILOT SINKHOLE INVENTORY

As discussed in Chapter 1, the geology of the Indian Creek Watershed is highly prone to development of karst features such as sinkholes, springs and caves. However, site specific data on sinkhole locations were not readily available. Sinkhole locations are an important consideration in watershed management because pollutants can be rapidly transported to groundwater systems without the benefit of soil filtration. Issues such as septic system failure may be masked because inadequately treated sewage can be transported downward into underground channels rather than surfacing, as occurs in non-karst systems.

Sinkholes that have been modified to change the flow of stormwater to the karst system are regulated under the USEPA's Underground Injection Control (UIC) program. This program is designed to protect drinking water supplies. The owners of modified sinkholes are required to provide an inventory form to USEPA. USEPA utilizes the inventory as needed to evaluate potential sources of drinking water contamination. If a discharge to a sinkhole contributes to contamination of a potable water supply, USEPA utilizes this program and requires the discharge to be treated or redirected. Additional information regarding the UIC program can be found at this website: http://www.epa.gov/safewater/uic/.

Through this watershed project, a pilot method was initiated to inventory sinkholes in the watershed using GIS analysis. The inventory consisted of compiling existing data, advanced analysis of GIS data, aerial review, field verification, and statistical analysis. These steps are described below.

The final product for the Indian Creek Watershed Pilot Sinkhole Inventory was a shapefile and Federal Geographic Data Committee (FGDC) standard metadata of GIS-predicted sinkholes. Existing data from Harrison County and the Lanesville Corridor project, as well as field inventory data collected in this project were included.

2.8.1 Existing Data

Harrison County Engineers Office: Eighteen sinkholes have been improved upon by Harrison County. The Harrison County Engineer supplied a shapefile of the locations of 18 visually plotted sinkholes (April, 2007). Eight (8) of these sinkholes lay within the Indian Creek Watershed boundaries.

Lanesville Corridor Project: FMSM conducted a project for Harrison County to evaluate routes for the proposed corridor connecting Interstate 64 and State Route 64 near Lanesville. As part of the geotechnical exploration, a field inventory of sinkholes along the proposed corridor routes was identified. Nine (9) sinkholes in the Indian Creek Watershed were mapped using GPS in this project.

Indiana Geological Survey: The Indiana Geological Survey (IGS) website was queried and the office was contacted. IGS provided a GIS shapefile of sinking stream basins and sinkhole basins. This dataset provided a general indication of the types of karst features in the Indian Creek Watershed, but did not contain specific sinkhole locations. IGS data and additional information on karst systems are available at this website: http://igs.indiana.edu/

2.8.2 Advanced Analysis of GIS Data

Sinkholes are typically characterized by bowl-shaped depressions in the earth to which water drains. In topographic data, sinkholes are represented by closed contour depressions. GIS software was used to identify closed contour depressions in contour data generated from LIDAR data. The centroid of the closed contour depression was identified using GIS data to create point locations for possible sinkholes.

Harrison County: Harrison County provided 2 foot and 4 foot contours that they generated from LIDAR data. To generate GIS locations of possible sinkholes further geoprocessing to identify the centroid of closed-depression contours was conducted. This analysis produced 14,687 possible sinkhole locations in the Harrison County region of the Indian Creek Watershed.

Floyd and Clark Counties: The USGS Kentucky Water Science Center is conducting the regional Karst Hydrology Initiative project. This multi-year effort included advanced analysis of digital elevation model (DEM) data to identify possible sinkholes. Additional information regarding the Karst Hydrology Initiative project is available at the following website: http://ky.water.usgs.gov/projects/cjt_karst/index.htm

In the Floyd and Clark County portions of the Indian Creek Watershed, the resolution of the available DEM was 10-meter (~30 feet) and 30-meter (~90 feet). USGS Kentucky Water Science Center processed DEM data in a manner similar to that described above to obtain the center of 163 closed contour depressions in the Floyd and Clark County portions of the watershed. USGS provided draft data and metadata for use in this project.

Table 2.30. GIS-Derived Sinkhole Data Summary

Data Source	Number of Closed Depression Contours Identified
Harrison County Engineers Office	8
Lanesville Corridor Project	9
Harrison County LIDAR Data	14,688
USGS Karst Hydrology Initiative	163
Total	**14,868**

2.8.3 Aerial Photography Review

Sinkholes are not the only closed contour depressions found in a typical topography. Other natural and man-made depressions are also present in most areas, including drainage features, ponds and quarries. The occurrence of non-sinkhole closed depression contours leads to over-estimation of the number of sinkholes and incorrect locations.

Conversely, identification of sinkholes in forested areas, steep terrain, and newly formed sinks may be precluded, potentially leading to under-estimation. However, despite these limitations, this dataset provides some initial planning level information regarding the potential for sinkhole locations.

A review of high resolution aerial photography was performed on a subset of the GIS-derived sinkholes to characterize the features as either probable sinkhole or probable non-sinkhole. Random sampling was used to select the GIS-derived sinkholes for aerial review.

The volume of stormwater is typically higher and the quality of stormwater is typically lower in developed areas, making sinkholes in urbanized areas of greater interest for the purposes of this watershed plan. In addition, implications for existing or new infrastructure and homes are potentially more significant and costly to manage in developed and developing areas. Therefore, USGS land use categories were used to classify the GIS-derived sinkholes into two groups: developed and undeveloped. As shown in the table below, below, 297 GIS-derived sinkholes were located in developed land uses; the remaining features were located in undeveloped land uses.

Table 2.31. GIS-Derived Sinkholes by Land Use

USGS Land Use Classification	GIS-Derived Sinkholes
Developed Land Subtotal	297
Undeveloped	14,569
Subtotal	**14,868**
Field Confirmed – Non-Sinkhole	-2
Total	**14,866**

Features were evaluated using aerial photography from the 2005 Statewide Orthophotography Project and classified as either probable sinkhole or probable non-sinkhole.

Table 2.32. Aerial Review Summary

Land Use Classification	Number of Probable Sinkholes	% of Probable Sinkholes	Number of Probable Non-Sinkholes	% of Probable Non-Sinkholes	# of GIS Derived Sinkholes Evaluated
Developed	138	50%	136	50%	274
Undeveloped	719	49%	750	51%	1,469
Total					**1,743**

2.8.4 Field Verification

Field verification using GPS was performed on 18 potential sinkholes. Of these, 2 sinkholes were confirmed non-sinkholes and removed from the final dataset.

The resulting GIS dataset, includes point locations of the 14,866 GIS-derived sinkholes with attribute fields that identify the source data (i.e., Harrison County Engineer's Office, Lanesville Project, Harrison County LIDAR, USGS Karst Hydrology Initiative), the aerial review status (yes/no), aerial review result (probable sinkhole/probable non-sinkhole), field review status (yes/no) and field review result (confirmed sinkhole/confirmed non-sinkhole). The GIS coverage and metadata are included with the CD that accompanies this watershed plan.