6.0 PROBLEM AND CAUSE IDENTIFICATION

6.1 Identifying Problems from Concerns & Inventory Analysis

Excluding concerns from Table 22 that the steering deemed outside the scope of the WMP (grayed out), Table 23 correlates public concerns and inventory analysis to problems in the watershed. Table 24 then addresses the potential causes of those problems.

Table 23. Problems identified for the Deer Creek-Sugar Creek watershed based on stakeholder and inventory concerns.

Public Concern and Inventory Analysis	Problems
• Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed. • Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed. • Dead animals in Deer Creek (anecdotal). • Waste from livestock is increasing the *E. coli* concentrations in watershed bodies. • Hog sewage is stagnating in Little Deer Creek. • The volume of manure produced in the watershed. • There is a lack of manure management in areas of the watershed. • Some CFO facilities are storing manure too close to the creek. • There have been several manure spills/fish kills in the watershed. • Bio-solids issues. • Manure is being applied throughout the watershed. • Nitrogen concentrations exceed suggested levels. • Phosphorus concentrations exceed suggested levels. • There are limited buffers along Buck Creek which are contributing to poor water quality, and unstable banks.	Nutrient concentrations exceed target values set by this project.

Public Concern and Inventory Analysis	Problems
• Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed. • Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed. • Livestock is negatively impacting water quality. • There are unregulated animal farms within the watershed. • Turbidity/sediment exceeds recommended levels by USEPA. • Poor soil quality is present throughout the watershed. • Care of soil quality and erosion • Stream bank erosion occurs along the waterbodies within the watershed. • There are limited buffers along Buck Creek which are contributing to poor water quality, and unstable banks	Area streams are cloudy and turbid.
• Fish populations have been negatively affected by the water quality. • Macroinvertebrate populations have been negatively affected by the water quality. • Wildlife areas should be encouraged and protected within the watershed. • Lack/decrease of wetlands within the watershed. • There are invasive species issues within the watershed.	Habitat is limited within watershed streams.
• Fish populations have been negatively affected by the water quality. • Macroinvertebrate populations have been negatively affected by the water quality. • Nitrogen concentrations exceed suggested levels. • Phosphorus concentrations exceed suggested levels. • *E. coli* concentrations exceed the state of Indiana's suggested level.	Area streams are listed by IDEM as impaired for recreational contact.
• Educational programs addressing conservation practices, recycling, climate change, and disposing of chemicals need to be developed.	A unified education plan is not currently in place.

Public Concern and Inventory Analysis	Problems
• Pesticide concentrations in Deer Creek. • Too few agricultural best management practices are located in the Deer Creek-Sugar Creek watershed. • Develop long term monitoring stations on Deer Creek/Wabash River. • There are limited buffers along Buck Creek which are contributing to poor water quality, and instable banks. • Stream bank erosion occurs along the waterbodies within the watershed.	Individuals lack knowledge of about what they can do to improve the watershed.

6.2 Identifying Potential Causes of Problems

Table 24. Potential causes of identified problems in the Deer Creek-Sugar Creek watershed.

Problems	Potential Causes
Nutrient concentrations exceed target values set by this project.	Area streams have nutrient levels exceeding the suggested target levels of 1.0 mg/L for nitrate-nitrogen and 0.3 mg/L of total phosphorus.
Area streams are cloudy and turbid.	Turbidities exceed target standards of 9.89 NTU.
Habitat is limited within watershed streams.	Impaired biotic communities occur within the watershed.
Area streams are listed by IDEM as impaired for recreational contact.	*E. coli* concentrations exceed target values and the state standard.
A unified education plan is not currently in place.	Individuals lack knowledge of their impact on the watershed.
Individuals lack knowledge about what they can do to improve the watershed.	A targeted implementation program is lacking throughout the watershed.

6.3 Identifying Key Pollutants of Concern

Nonpoint pollution sources are varied, yet common, throughout almost any watershed. A summary of the key pollutants of concern in the Deer Creek-Sugar Creek watershed and their potential sources 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
- Need for 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

6.4 Identifying Potential Sources of Pollutants

The steering committee used GIS, water quality data, and other available data to evaluate the potential sources of nonpoint pollution in the Deer Creek-Sugar Creek watershed. Table 25 to Table 30 detail the most significant potential sources of pollution for each of the problems identified in Table 23.

Table 25. Potential sources causing nutrient problems.

Problems:	Nutrient concentrations exceed target values set by this project.
Potential Causes:	Area streams have nutrient levels exceeding the suggested target levels of 2.0 mg/L for nitrate-nitrogen and 0.08 mg/L of total phosphorus.
Potential Sources:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 1 (not recently problematic) Combined Sewer Overflow (CSO) identified in the South Fork of Deer Creek subwatersheds. • More than 256,000 animals are housed in confined feeding operations (CFOs) within the Deer Creek-Sugar Creek watershed. The highest density of animals occurs in the Buck Creek, Paint Creek, Sugar Creek, Deer Creek and Little Deer Creek subwatersheds. • 306 unregulated animal operations house nearly 2,725 animals throughout the watershed. The highest density of animals was observed in the Deer Creek-McCloskey Ditch, Buck Creek, Paint Creek and Bachelor Run subwatersheds. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • 243 square miles of drained cropland are located throughout the watershed. Headwaters of Deer Creek, Bachelor Run, Buck Creek, South Fork of Deer Creek and Sugar Creek subwatersheds contain greater than 80% coverage by drained cropland. • Manure from confined feeding operations is applied on 42.4 square miles throughout the watershed. The highest density of manure application occurs in the Buck Creek, Sugar Creek, Little Deer Creek, Headwaters of Deer Creek, and Bachelor Run subwatersheds. • Four wastewater treatment plants and 42 unsewered dense housing areas are located within the Deer Creek-Sugar Creek watershed. South Fork of Deer Creek, Headwater of Deer Creek, Deer Creek, Sugar Creek and Buck Creek watersheds contain the highest densities of unsewered dense housing areas. • Wastewater treatment plant sludge is being applied to more than 22 square miles in the Deer Creek-McCloskey Ditch, Little Deer Creek, South Fork of Deer Creek, Paint Creek, Buck Creek and Headwaters of Deer Creek subwatersheds. • Unknown volumes of fertilizer and pesticides are applied on lawns adjacent to storm drains and streams within the urban and suburban portions of the watershed. • Pet and yard wastes are improperly disposed of within the urban and suburban portions of the watershed. • Failing septic systems add nutrients to the system within the rural portion of the watershed.

Table 26. Potential sources causing sediment problems.

Problems:	Area streams are cloudy and turbid.
Potential Causes:	Turbidities exceed target standards of 9.89 NTU.
Potential Sources:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • 243 square miles of drained cropland are located throughout the watershed. Headwaters of Deer Creek, Bachelor Run, Buck Creek, South Fork of Deer Creek and Sugar Creek subwatersheds contain greater than 80% coverage by drained cropland.

Table 27. Potential sources causing habitat problems.

Problems:	Habitat is limited within watershed streams.
Potential Causes:	Impaired biotic communities occur within the watershed.
Potential Sources:	• 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • Poor IBI scores (<36) occurred in the Deer Creek subwatershed on tributaries to Deer Creek. • Poor mIBI scores (<2.2 old; <30 new) occurred in the Headwaters of Deer Creek, Little Deer Creek, Paint Creek, Deer Creek, Buck Creek and 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. • Poor QHEI (<51) or CQHEI (<60) scores occurred in the Bachelor Run, Deer Creek, Buck Creek and 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. • Many subwatersheds have undergone extensive hydromodification, including agricultural ditches and drains

Table 28. 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:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 1 (not recently problematic) Combined Sewer Overflow (CSO) identified in the South Fork of Deer Creek subwatersheds. • Four wastewater treatment plants and 42 unsewered dense housing areas are located within the Deer Creek-Sugar Creek watershed. South Fork of Deer Creek, Headwater Deer Creek, Deer Creek, Sugar Creek and Buck Creek watersheds contain the highest densities of unsewered dense housing areas. • More than 256,000 animals are housed on confined feeding operations (CFOs) within the Deer Creek-Sugar Creek watershed. The highest density of animals occurs in the Buck Creek, Paint Creek, Sugar Creek, Deer Creek and Little Deer Creek subwatersheds. • 306 unregulated animal operations house nearly 2,725 animals throughout the watershed. The highest density of animals was observed in the Deer Creek-McCloskey Ditch, Buck Creek, Paint Creek and Bachelor Run subwatersheds. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • Manure from confined feeding operations is applied on 42.4 square miles throughout the watershed. The highest density of manure application occurs in the Buck Creek, Sugar Creek, Little Deer Creek, Headwaters of Deer Creek, and Bachelor Run subwatersheds. • Wastewater treatment plant sludge is being applied to more than 22 square miles in the Deer Creek-McCloskey Ditch, Little Deer Creek, South Fork of Deer Creek, Paint Creek, Buck Creek and Headwaters of Deer Creek subwatersheds. • Failing septic systems add nutrients to waterbodies within the rural portion of the watershed.

Table 29. Potential sources causing education problems.

Problems:	A unified education plan is not currently in place.
Potential Causes:	Individuals lack knowledge of their impact on the watershed.
Potential Sources:	N/A

Table 30. Potential sources causing limited practice implementation.

Problems:	Individuals lack knowledge of about what they can do to improve the watershed.
Potential Causes:	A targeted implementation program is lacking.
Potential Sources:	N/A

7.0 LOAD ESTIMATES

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA notes that sources of nonpoint source pollution include: urban runoff, construction activities, solid waste disposal, atmospheric deposition, streambank erosion, and more. Inventory data in Table 25 through Table 30 identify potential sources of nonpoint pollution within the watershed. These tables – generated using GIS, water quality data, windshield surveys, local knowledge, and other sources of data – are useful for generally identifying water quality problems. Two methods have been used to understand the loading of nutrients, sediment, and pathogens in waterbodies in the Deer Creek-Sugar Creek watershed: measured results from the monitoring regime and modeled results. Each method can estimate both the current load and the reduction in load needed to reach target concentrations. These methods each present advantages and disadvantages for understanding the loading in this watershed in particular. The steering committee considered the model results, available before the monitoring was completed, in order to draft long term goals and critical areas. When the measured results from the monitoring became available, the steering committee gave careful consideration to a comparison between the two before making final decisions about long term goals, short term goals, and critical areas.

7.1 Monitoring results

Results from monitoring data can be used to estimate loads of nonpoint source pollution. Concentrations of nutrients, sediments, and pathogens taken at sampling sites can be combined with flow data to estimate the current loads in those waterbodies. Target loads for those waterbodies can also be calculated using available flow data.

As discussed in section 3.3, twelve monitoring sites were sampled every other week from August 2012 through August 2013. There is clear value in using these measurements from the Deer Creek-Sugar Creek watershed to estimate loads and load reductions. However, there are some limitations in the measured dataset. Sampling methods did not allow for continuous flow measurements at each site, so data from several USGS gages were used to approximate flow. Samples collection began in a period of intense drought and was completed in a period of more normal precipitation. The dataset can therefore give us an interesting contrast between low flow and high flow conditions, but on the whole, it isn't representative of a typical annual precipitation and stream flow cycle.

7.2 L-THIA Model

Hydrologic simulation models, another mechanism to determine nonpoint pollution sources and estimate loads, can be used to model the transport of pollutants across the land surface as surface runoff. Rain water flows over the land and through the groundwater, collecting pollutants such as sediment and nutrients as it moves. Soil characteristics and land uses influence the way water moves through the system, and each hydrologic model simulates the movement in a different way. These computer models provide load estimates which can serve as a baseline against which to compare changes in land use and their impacts on water quality.

The Long Term Hydrologic Impact Analysis model, L-THIA, was used to assess the nonpoint source loading rates of three pollutants of concern in the watershed: total nitrogen, total phosphorus, and suspended solids. L-THIA combines land use and soil type inputs with a localized 30-year rainfall record (1963-1993) to produce estimates of runoff volume and pollutant loads. The Basic Spreadsheet L-THIA was loaded with the

acreages of both land use and soil type within each subwatershed; thus L-THIA provides results ideal for comparing and determining which subwatersheds may require the most load reductions. The long-term rainfall assumptions made by L-THIA even out drought and flooding conditions. L-THIA is also widely available, free, easy to use, and recommended by IDEM for use in watershed management planning.

However, the model has its limitations as well. L-THIA does not model *E. coli* loads. The long-term rainfall assumptions are unable to predict loading that result from storms and turbulent runoff events. L-THIA assumes a nation-wide average contribution of a given pollutant from an acre of agricultural land; without calibration, L-THIA may over or under estimate the actual contributions of agricultural land in the watershed. In addition, the degree to which a particular acre of soil has been developed or compacted should ideally be fed into the model as a downgraded soil type with a higher runoff potential; however information this fine grained is not available on a watershed-wide basis. Thus the model may under-predict the runoff potential of certain soil types. Finally, L-THIA estimates runoff volumes only, and loading that result from tile drainage, streambank erosion, livestock access, nutrient application, or point source pollution will not be present in L-THIA's results. The L-THIA model results provide a broad picture of watershed loading, but they cannot provide a detailed prediction of loading in this watershed.

7.3 Annual Load Estimates

L-THIA-modeled runoff volume and nonpoint source pollutant loading based on total acreages of land use and soil types within each of Deer Creek-Sugar Creek's subwatersheds. In total, the model predicts that 696,000 pounds of nitrogen, 204,000 pounds of phosphorus, and 16.8 million pounds of sediment loading occurs within the Deer Creek-Sugar Creek watershed annually (Table 31). Little Deer Creek subwatershed is modeled as the largest contributor of nitrogen, phosphorus, and sediment loads to the watershed, followed by the South Fork of Deer Creek and the Buck Creek subwatersheds. When loading rates are normalized by area and represented in pounds per acre per year, Buck Creek is modeled as the highest contributor of nitrogen, phosphorus, and total suspended sediments per acre, followed by the Little Deer Creek and South Fork of Deer Creek subwatersheds (Table 32).

Concentration results from monitoring efforts can be multiplied by flow data to calculate loading measured between August 2012 and August 2013. The load at each sample site represents the loading from the land that drains to that site. Many sample sites are located close to the drainage point of a subwatershed, making possible a comparison between the measured load and the modeled load for a subwatershed. However, some sites only partially drain a subwatershed; in order to compare, measured results have been scaled up to match the drainage of the equivalent modeled subwatershed in Table 33 through Table 35.

Table 31. L-THIA-modeled annual load estimates for each subwatershed, ranked by total contributions – in pounds per year.

Ranked Contributions	Current Nitrogen Load		Current Phosphorus Load		Current Sediment Load	
	Subwatershed	*(lb/yr)*	Subwatershed	*(lb/yr)*	Subwatershed	*(lb/yr)*
Highest	Little Deer Creek	*136,497*	Little Deer Creek	*40,049*	Little Deer Creek	*3,297,033*
	South Fork of Deer Creek	*91,858*	South Fork of Deer Creek	*26,894*	South Fork of Deer Creek	*2,215,319*
	Buck Creek	*85,370*	Buck Creek	*25,146*	Buck Creek	*2,069,969*
	Bachelor Run	*77,346*	Bachelor Run	*22,729*	Bachelor Run	*1,868,415*
	Deer Creek	*68,028*	Deer Creek	*19,893*	Deer Creek	*1,634,413*
	Sugar Creek	*57,335*	Sugar Creek	*16,766*	Sugar Creek	*1,380,467*
	Headwaters of Deer Creek	*52,773*	Headwaters of Deer Creek	*15,319*	Headwaters of Deer Creek	*1,261,022*
	Paint Creek	*45,533*	Paint Creek	*13,361*	Paint Creek	*1,099,945*
	Deer Creek-McCloskey Ditch	*42,472*	Deer Creek-McCloskey Ditch	*12,495*	Deer Creek-McCloskey Ditch	*1,028,458*
Lowest	Wabash River	*38,956*	Wabash River	*11,307*	Wabash River	*931,603*
Totals		696,169		203,960		16,786,645

Table 32. L-THIA-modeled annual load estimates for each subwatershed, ranked by normalized contributions – in pounds per acre per year.

Ranked Contributions (Normalized)	Annual Nitrogen Load		Annual Phosphorus Load		Annual Sediment Load	
	Subwatershed	*(lb/acre/yr)*	Subwatershed	*(lb/acre/yr)*	Subwatershed	*(lb/acre/yr)*
Highest	Buck Creek	*11.41*	Buck Creek	*3.36*	Buck Creek	*276.73*
	Little Deer Creek	*3.92*	Little Deer Creek	*1.15*	Little Deer Creek	*94.70*
	South Fork of Deer Creek	*3.61*	South Fork of Deer Creek	*1.06*	South Fork of Deer Creek	*87.15*
	Bachelor Run	*3.36*	Bachelor Run	*0.99*	Bachelor Run	*81.12*
	Sugar Creek	*3.12*	Sugar Creek	*0.91*	Sugar Creek	*75.23*
	Deer Creek	*2.66*	Deer Creek	*0.78*	Deer Creek	*64.02*
	Paint Creek	*2.41*	Paint Creek	*0.71*	Paint Creek	*58.30*
	Wabash River	*1.93*	Wabash River	*0.56*	Wabash River	*46.17*
	Deer Creek-McCloskey Ditch	*1.48*	Deer Creek-McCloskey Ditch	*0.43*	Deer Creek-McCloskey Ditch	*35.76*
Lowest	Headwaters of Deer Creek	*1.41*	Headwaters of Deer Creek	*0.41*	Headwaters of Deer Creek	*33.63*

Table 33: Measured vs. Modeled Nitrogen Load Estimates

				Nitrogen				
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Load*	Modeled Load	Comparison: monitor/model	Measured Load*	Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	1,015,437	52,773	1924%	27.08	1.41
SFD9	South Fork Deer Creek	39.72	98%	620,118	91,858	675%	24.39	3.61
MD8	Deer Creek-McCloskey Ditch	44.94	35%	563,993	42,472	1328%	19.61	1.48
LDD7	Little Deer Creek	54.40	97%	1,164,669	136,497	853%	33.45	3.92
PC5	Paint Creek	29.48	47%	624,287	45,533	1371%	33.09	2.41
BR4	Bachelor Run	35.99	100%	1,028,934	77,346	1330%	44.67	3.36
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	6,562,910	514,508	1276%	33.84	2.65
SC2	Sugar Creek	28.67	100%	910,525	57,335	1588%	49.62	3.12
BC1	Buck Creek	11.69	96%	524,015	85,370	614%	70.06	11.41

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured nitrogen loads are approximately ten times higher than modeled nitrogen loads. The surface water estimates for the L-THIA model do not allow for an accurate estimate of nitrogen transported by tile drainage or increased runoff over compacted or disturbed soils. The national average for nitrogen runoff per agricultural acre may underestimate local conditions. Additional spikes of nitrogen loading due to high flow runoff events, shown in Figure 56, may also go unaccounted for in the model. However, the measured and modeled results both point to the Buck Creek subwatershed as having the highest nitrogen load in pounds per acre per year.

Table 34: Measured vs. Modeled Phosphorus Load Estimates

				Phosphorous				
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Load*	Modeled Load	Comparison: monitor/model	Measured Load*	Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	32,921	15,319	215%	0.88	0.41
SFD9	South Fork Deer Creek	39.72	98%	15,470	26,894	58%	0.61	1.06
MD8	Deer Creek-McCloskey Ditch	44.94	35%	10,655	12,495	85%	0.37	0.43
LDD7	Little Deer Creek	54.40	97%	24,678	40,049	62%	0.71	1.15
PC5	Paint Creek	29.48	47%	20,858	13,361	156%	1.11	0.71
BR4	Bachelor Run	35.99	100%	24,700	22,729	109%	1.07	0.99
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	133,098	150,741	88%	0.69	0.78
SC2	Sugar Creek	28.67	100%	19,233	16,766	115%	1.05	0.91
BC1	Buck Creek	11.69	96%	8,737	25,146	35%	1.17	3.36

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured phosphorus loads are in some cases lower than modeled phosphorus loads, but results for the subwatersheds are within the same order of magnitude.

Table 35: Measured vs. Modeled Sediment Load Estimates

				Total Suspendid Solids				
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Load*	Modeled Load	Comparison: monitor/model	Measured Load*	Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	20,010,763	1,261,022	1587%	533.63	33.63
SFD9	South Fork Deer Creek	39.72	98%	7,071,473	2,215,319	319%	278.19	87.15
MD8	Deer Creek-McCloskey Ditch	44.94	35%	5,901,862	1,028,458	574%	205.18	35.76
LDD7	Little Deer Creek	54.40	97%	13,977,532	3,297,033	424%	401.49	94.70
PC5	Paint Creek	29.48	47%	1,929,996	1,099,945	175%	102.30	58.30
BR4	Bachelor Run	35.99	100%	9,093,648	1,868,415	487%	394.83	81.12
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	105,712,210	12,404,605	852%	545.12	63.97
SC2	Sugar Creek	28.67	100%	9,731,940	1,380,467	705%	530.32	75.23
BC1	Buck Creek	11.69	96%	2,504,193	2,069,969	121%	334.79	276.73

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured sediment loads are on average five times higher than modeled sediment loads. The national average for sediment runoff per agricultural acre may underestimate local conditions, and the model does not take into account streambank erosion or livestock access, which could be contributing to the higher loads measured. Additional spikes of sediment loading due to high flow runoff events, shown in Figure 58, may also go unaccounted for in the model.

Because the L-THIA does not model *E. coli*, our monitoring measurements are the only source of data to estimate annual *E. coli* concentrations in this watershed (Table 36). Annual concentrations are used instead of annual loading because it is difficult to determine the weight of bacteria cells. Annual concentrations, expressed as the number of colony forming units (cfu) are estimated by multiplying measured concentrations by stream flow.

Table 36: Measured *E. coli* Load Estimates

				E. coli	
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Load*	Measured Load*
	Name	Size (sq mi)	% of subwatershed(s)	cfu/yr	cfu/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	971,091,275,103,353	25,896,457,908
SFD9	South Fork Deer Creek	39.72	98%	414,132,175,299,640	16,291,588,328
MD8	Deer Creek-McCloskey Ditch	44.94	35%	299,921,281,499,032	10,426,967,094
LDD7	Little Deer Creek	54.40	97%	504,186,355,449,550	14,482,287,455
PC5	Paint Creek	29.48	47%	137,768,217,723,814	7,302,460,390
BR4	Bachelor Run	35.99	100%	421,507,719,832,816	18,300,960,396
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	3,188,848,185,249,390	16,443,718,887
SC2	Sugar Creek	28.67	100%	206,920,604,130,396	11,275,712,720
BC1	Buck Creek	11.69	96%	190,152,613,424,739	25,421,472,383

*scaled to equivalent subwatershed size

7.4 Load Reduction Estimates

Water quality targets are used to calculate target loads, which are then subtracted from the annual loads to estimate the load reductions needed. Load reductions for each subwatershed play an important role in selecting critical areas and determining long-term goals. As discussed in section 3.1, the steering committee selected water quality target concentrations according to state recommended concentrations. Table 37 lists the target concentrations for our parameters of concern.

The difference between measurement- and model-derived target loads can be explained by the difference in flow estimates. L-THIA estimates runoff based on land use, soil type, and a localized 30-year rainfall average. However, it may underestimate runoff if soils have been compacted or disturbed; and the model does not account for tile drainage, which could contribute a significant amount to stream flow in this predominately agricultural watershed. Measured target loads are based on flow data from two local USGS gauges, giving a more accurate picture of localized stream flow for the timeframe during which samples were drawn. However, the extreme precipitation variations (drought year conditions) in a shorter timeframe (one year of data collection) weaken the reliability of the measured flow data as a baseline against which to measure future change.

Table 37. Target concentrations for parameters of interest in the Deer Creek-Sugar Creek Watershed.

Parameter of Concern	Water Quality Benchmark
Nitrate –Nitrogen	Max: 1.0 mg/L
Total Phosphorus	Short Term Target Max: 0.3 mg/L
Total Suspended Solids (TSS)	Max: 15.0 mg/L
E. coli	Max: 235 cfu/100mL in a single sample – OR – Max Geometric Mean of 125 cfu/100mL from 5 equally spaced samples over a 30 day period

L-THIA estimates target loads by multiplying predicted runoff by target concentrations. Measured data can also be used to estimate target loads by multiplying stream flow by target concentrations. Measured and modeled target loads are shown in Table 38. *E. coli* targets are calculated to the geometric mean concentration.

Table 38: Measured vs. Modeled Target Load Estimates

				Nitrogen		Phosphorous		Sediment		E. coli
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Target Load*	Modeled Target Load	Measured Target Load*	Modeled Target Load	Measured Target Load*	Modeled Target Load	Measured Target Load*
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr	lb/yr	lb/yr	lb/yr	lb/yr	cfu/yr
DCM10	Headwaters of Deer Creek	58.59	96%	144,880	13,265	43,464	3,979	2,173,204	198,969	82,203,299,280,285
SFD9	South Fork Deer Creek	39.72	98%	98,299	22,229	29,490	6,669	1,474,481	333,439	55,773,486,225,378
MD8	Deer Creek-McCloskey Ditch	44.94	35%	64,892	9,899	19,468	2,970	973,380	148,489	36,818,930,532,743
LDD7	Little Deer Creek	54.40	97%	134,608	32,250	40,382	9,675	2,019,118	483,748	76,374,834,692,956
PC5	Paint Creek	29.48	47%	52,381	10,718	15,714	3,215	785,711	160,771	29,720,178,305,490
BR4	Bachelor Run	35.99	100%	89,117	18,415	26,735	5,525	1,336,760	276,227	50,564,081,316,228
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	750,207	123,517	225,062	37,055	11,253,103	1,852,762	425,658,159,400,578
SC2	Sugar Creek	28.67	100%	53,979	13,734	16,194	4,120	809,692	206,008	30,627,276,664,203
BC1	Buck Creek	11.69	96%	21,961	19,713	6,588	5,914	329,414	295,689	12,460,369,555,105

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Table 39 compares the load reductions derived from the measured data and the modeled data. The L-THIA model doesn't account for any subsurface runoff or in-stream erosion, thus it appears to underestimate suspended solids and water soluble nutrients such as nitrate. L-THIA appears to overestimate phosphorus, however, possibly because the model inputs for phosphorus runoff may not be calibrated to conditions in the watershed.

L-THIA's 30-year rainfall input assumes consistent flow conditions, whereas the monitoring spans nearly half a year of severe drought and includes a number of storm events. In examining the measured results from each sample site, (Figure 50 through Figure 54), it is interesting to note that the majority of the individual samples collected, particularly for total suspended solids and phosphorus, meet target concentrations. However, it appears that high flow events, likely the result of storm events, correspond with spikes in concentration, well above target levels. Concentrations sampled during these storm events seem to substantially contribute to the high loads represented in the monitoring results, offering an additional potential explanation for the disparity between the modeled and the measured data. Measured results suggest that on-the-ground practices which are already installed (Appendix F) maintain phosphorus concentrations below target levels during times of low to moderate flow, but additional practices are needed to prevent phosphorus loading spikes during high flow events.

The importance of storm or high flow events shown in these charts also reveals the necessity of using load duration curve analysis to determine which sites are in exceedance of their targets. Load duration curves model the target concentrations according to flow. Only those sites where a majority of the samples exceed the modeled target during a high flow event (i.e. those events greater than 20% normal flow) will be considered in exceedance (Figure 55 to Figure 59). Rather than lower the parameter targets, the steering committee selected this method to determine site exceedances in Figure 95.

Based on a thorough discussion of the discrepancies between the modeled and measured data, the steering committee decided to base the long-term load reduction goals on the L-THIA model. Additionally, the committee selected scaled goals to attempt to address the issues of substantial loading during storm events in the short term. Measured data were used to identify the storm-based exceedances measured as part of the water quality monitoring effort. L-THIA-derived reductions nitrogen, phosphorus, and sediment for each subwatershed are listed in Table 40 and mapped in Figure 96 through Figure 98. These reductions exceed the Wabash River TMDL reductions, which require a 4% reduction in phosphorus and no reduction in nitrate in Deer Creek (TetraTech, 2007).

Long term goals for *E. coli* reductions will be based on measured data. The average *E. coli* reduction for the watershed (averaged from sample sites DCD3, SC2, and BC1, which cover all drainage in the watershed except for the Wabash River subwatershed) is 88.3%, which exceeds the Wabash River TMDL required *E. coli* reduction of 87% for Deer Creek (TetraTech, 2007).

Table 39: Measured vs. Monitored Load Reduction Estimates

		Nitrogen				Phosphorous			
Monitoring Site	**Equivalent Subwatershed(s)**	Measured Reduction*		Modeled Reduction		Measured Reduction*		Modeled Reduction	
	Name	lb/yr	percent	lb/yr	percent	lb/yr	percent	lb/yr	percent
DCM10	Headwaters of Deer Creek	870,557	86%	39,509	75%	none	0%	11,339	74%
SFD9	South Fork Deer Creek	521,819	84%	69,629	76%	none	0%	20,225	75%
MD8	Deer Creek-McCloskey Ditch	499,101	88%	32,573	77%	none	0%	9,525	76%
LDD7	Little Deer Creek	1,030,061	88%	104,248	76%	none	0%	30,375	76%
PC5	Paint Creek	571,907	92%	34,815	76%	none	0%	10,146	76%
BR4	Bachelor Run	939,817	91%	58,931	76%	none	0%	17,205	76%
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	5,812,703	89%	390,990	76%	none	0%	113,686	75%
SC2	Sugar Creek	856,546	94%	43,601	76%	3,039	16%	12,646	75%
BC1	Buck Creek	502,055	96%	65,657	77%	2,149	25%	19,232	76%

		Sediment				*E. coli*	
Monitoring Site	**Equivalent Subwatershed(s)**	Measured Reduction*		Modeled Reduction		Measured Reduction*	
	Name	lb/yr	percent	lb/yr	percent	cfu/yr	percent
DCM10	Headwaters of Deer Creek	17,837,559	89%	1,062,053	84%	888,887,975,823,068	92%
SFD9	South Fork Deer Creek	5,596,992	79%	1,881,880	85%	358,358,689,074,263	87%
MD8	Deer Creek-McCloskey Ditch	4,928,482	84%	879,969	86%	263,102,350,966,290	88%
LDD7	Little Deer Creek	11,958,414	86%	2,813,284	85%	427,811,520,756,594	85%
PC5	Paint Creek	1,144,285	59%	939,175	85%	108,048,039,418,325	78%
BR4	Bachelor Run	7,756,888	85%	1,592,189	85%	370,943,638,516,588	88%
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	94,459,107	89%	10,551,843	85%	2,763,190,025,848,810	87%
SC2	Sugar Creek	8,922,249	92%	1,174,459	85%	176,293,327,466,192	85%
BC1	Buck Creek	2,174,779	87%	1,774,280	86%	177,692,243,869,634	93%

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Table 40: L-THIA-derived load reductions for each subwatershed.

	Nitrogen			Phosphorous			Sediment		
Subwatershed	lb/yr	lb/acre/yr	percent	lb/yr	lb/acre/yr	percent	lb/yr	lb/acre/yr	percent
Headwaters of Deer Creek	39,509	1.05	75%	11,339	0.30	74%	1,062,053	28.32	84%
South Fork Deer Creek	69,629	2.74	76%	20,225	0.80	75%	1,881,880	74.03	85%
Deer Creek-McCloskey Ditch	32,573	1.13	77%	9,525	0.33	76%	879,969	30.59	86%
Little Deer Creek	104,248	2.99	76%	30,375	0.87	76%	2,813,284	80.81	85%
Paint Creek	34,815	1.85	76%	10,146	0.54	76%	939,175	49.78	85%
Bachelor Run	58,931	2.56	76%	17,205	0.75	76%	1,592,189	69.13	85%
Deer Creek	51,286	2.01	75%	14,871	0.58	75%	1,383,294	54.18	85%
Sugar Creek	43,601	2.38	76%	12,646	0.69	75%	1,174,459	64.00	85%
Buck Creek	65,657	8.78	77%	19,232	2.57	76%	1,774,280	237.20	86%
Wabash River	29,234	1.45	75%	8,391	0.42	74%	785,780	38.94	84%

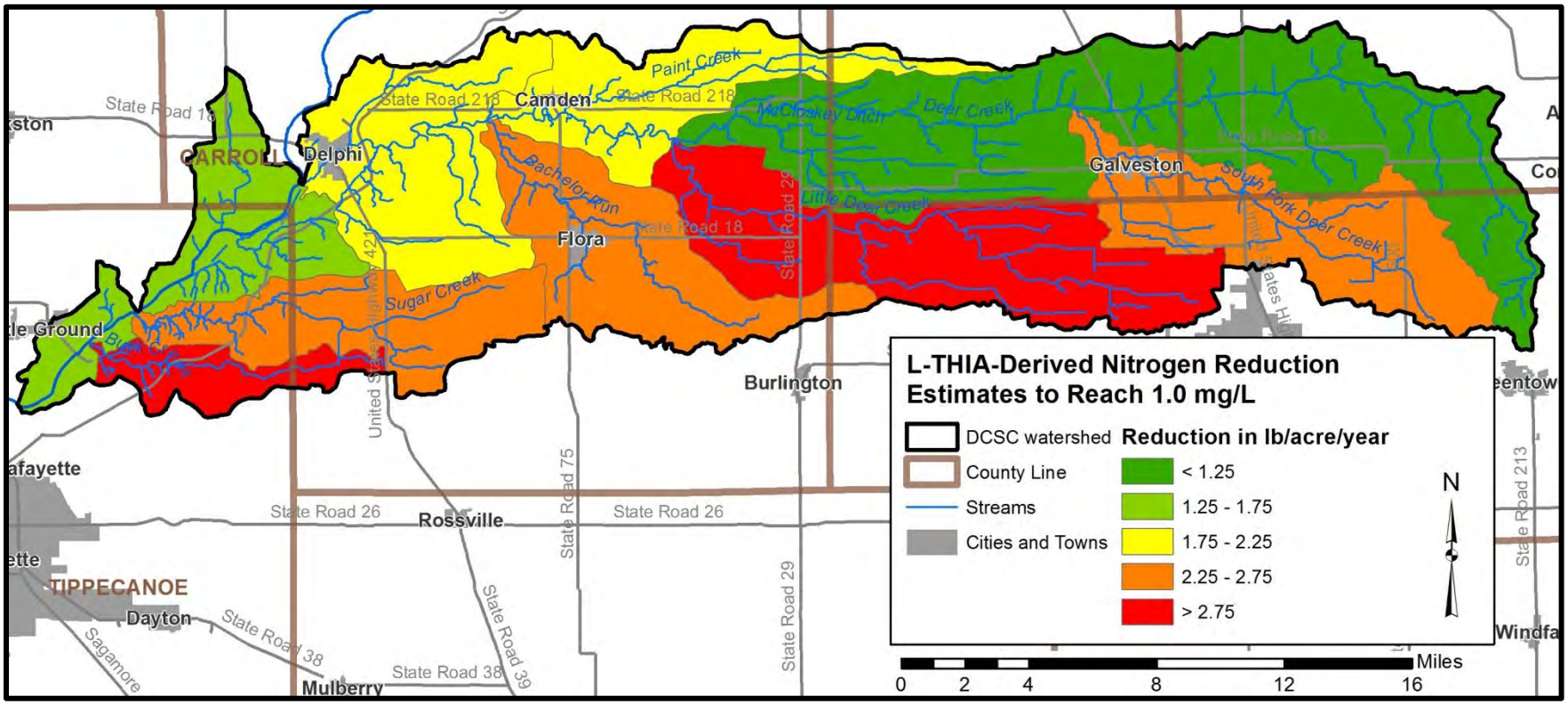

Figure 96. L-THIA-derived nitrogen reduction estimates by subwatershed.
Data used to create this map are detailed in Appendix A.

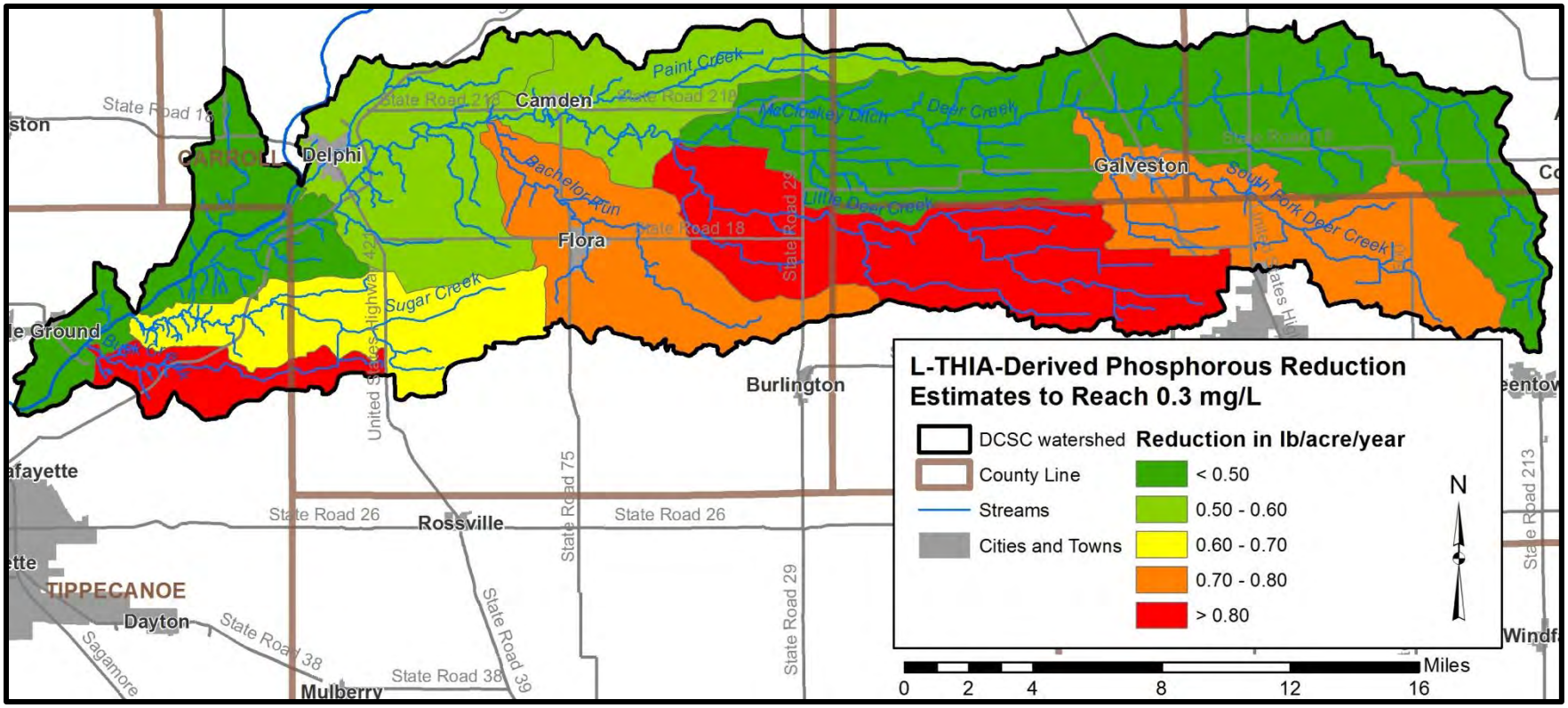

Figure 97. L-THIA-derived phosphorus reduction estimates by subwatershed.

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

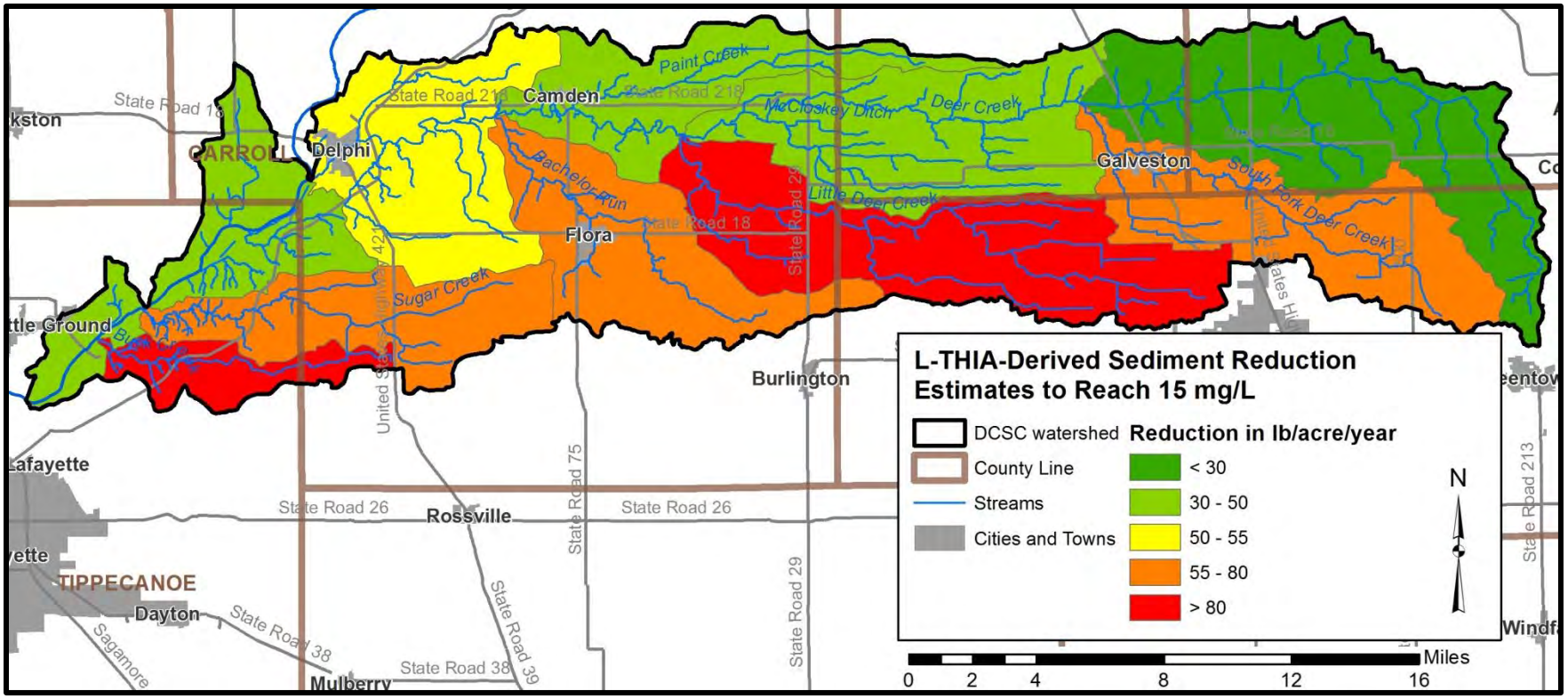

Figure 98. L-THIA-derived sediment reduction estimates by subwatershed.

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

8.0 DEFINING CRITICAL AREAS

In order to focus conservation practice implementation, it is necessary to identify critical areas in the watershed which are experiencing the most problems and the worst impairments. Targeting the implementation of best management practices to these areas will help focus remediation where it is most needed.

Land use in Deer Creek-Sugar Creek is not varied, and many inventoried issues appear to be ubiquitous throughout the watershed, such as: agricultural land use, tile drained soils, soils used for septic treatment, hydric soils, and wetland loss. Though these issues contribute to pollution and degraded water quality throughout the watershed and need to be remedied, due to their widespread nature they cannot be used to narrow down critical areas which contribute the most loading and pollution.

However, the steering committee did identify inventoried issues of high concern, which include: total number of animals located on small, unregulated farms and confined feeding operations; acreage permitted for manure and sludge application; streambank erosion; water quality impairments; and concentrations which exceed targets for nutrients, sediment and *E. coli*. When tallied subwatershed-by-subwatershed, these issues illuminate the subwatersheds generating the most of each pollutant.

Critical areas are first determined one parameter at a time: for nutrients, sediment, and *E. coli*. The sections below summarize and tabulate the inventoried issues of high concern (listed above), monitored data, modeled data, and impaired waterbodies. To determine the final set of critical areas, the critical areas for each parameter are layered on top of one another to generate a tiered system: areas critical for 3 parameters are considered “high priority,” and areas critical for none of the parameters are considered “no priority.” The high, medium, and low critical areas are represented in Figure 102 in section 8.4, and these will guide the milestones and targets for the implementation plan and action registers in Chapters 10 and 11.

8.1 Critical Areas for by Nutrients

Based on the summarized data in Table 41, the yellow-highlighted subwatersheds are the most critical areas for nitrogen and phosphorus loading, including subwatersheds scoring 6 or greater out of 10 parameters. These subwatersheds are mapped in Figure 99.

Table 41. Critical Areas for Nutrients

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 25. Potential sources causing nutrient problems.										
Highest density of regulated (CFO) animals				●	●		●	●	●	
Highest density of unregulated farm animals			●		●	●			●	
More than 10% of streams lack adequate stabilization	●	●	●	●	●			●		●
Highest density of manure application	●			●		●		●	●	
WWTP sludge applied to more than 22 sq mi	●	●	●	●	●				●	
From Table 21. Monitoring samples exceeding targets during high flow events.										
Nitrate-nitrogen	●	●	●	●	●	●	●	●		N/A
Total Phosphorus								●		N/A
From Table 40. L-THIA load reductions.										
Greater than 2.25 lb/acre/year load reduction needed to meet nitrogen target (orange and red in Table 44)		●		●		●		●	●	
Greater than 0.70 lb/acre/year load reduction needed to meet phosphorus target (orange and red)		●		●		●			●	
From Figure 25. Impaired waterbody locations										
Streams with nutrient impairments	●	N/A	●	●	●		●		●	
Score	5	5	5	8	6	5	3	6	7	1

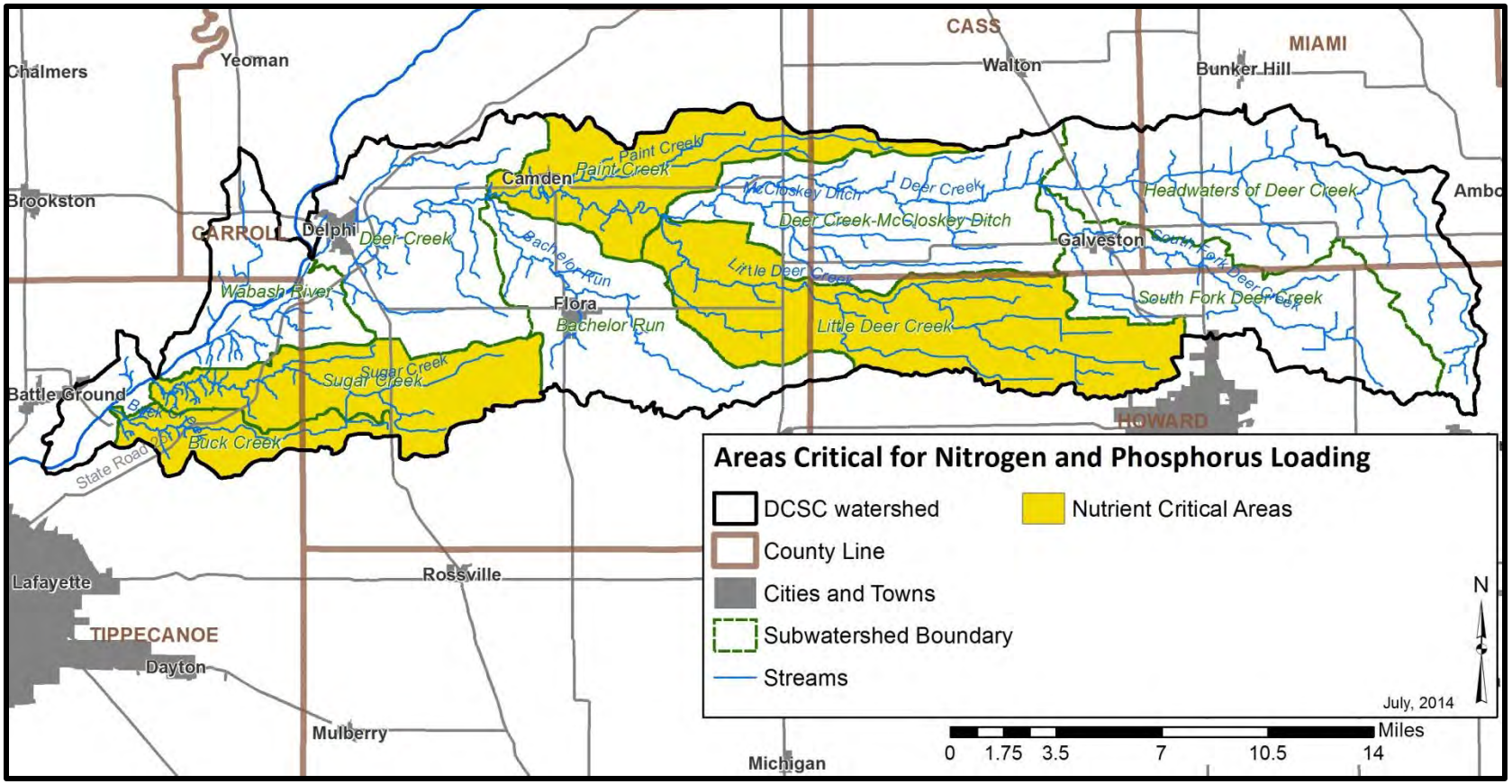

Figure 99. Areas Critical for Nutrients

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

8.2 Critical Areas for *E. coli*

Based on the summarized data in Table 42, the green-highlighted subwatersheds are the most critical areas for *E. coli* loading, including subwatersheds scoring 4 or more out of 6 parameters. These subwatersheds are mapped in Figure 100.

Table 42. Critical areas for *E. coli*

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 28. Potential sources causing *E. coli* problems.										
Highest density of regulated (CFO) animals				●	●		●	●	●	
Highest density of unregulated farm animals			●		●	●			●	
Highest density of manure application	●			●		●		●	●	
WWTP sludge applied to more than 22 sq mi	●	●	●	●	●				●	
From Table 21. Monitoring samples exceeding targets during high flow events.										
E. coli	●	●	●	●	●	●	●	●		N/A
From Figure 25. Impaired waterbody locations										
Streams with *E. coli* impairments	●	N/A	●	●	●	●	●	●	●	●
Score	4	2	4	5	5	4	3	4	5	1

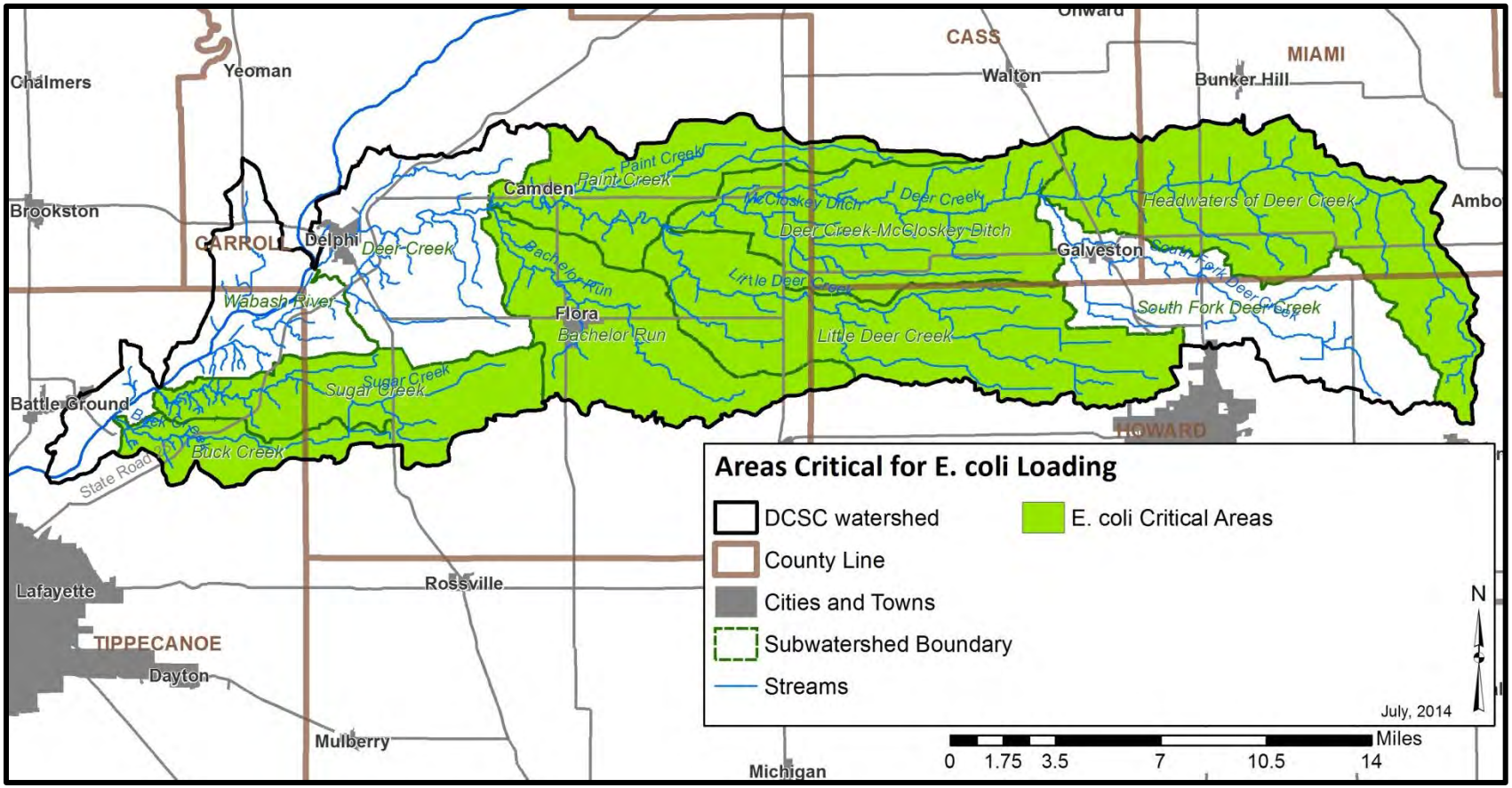

Figure 100. Areas Critical for *E. coli*

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

8.3 Critical Areas for Sediment

Based on the summarized data in Table 43, the brown-highlighted subwatersheds are the most critical areas for sediment loading, including subwatersheds scoring 3 out of 3 parameters. These subwatersheds are mapped in Figure 101.

Table 43. Critical Areas for Sediment

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 26. Potential sources causing sediment problems.										
More than 10% of streams lack adequate stabilization	●	●	●	●	●			●		●
From Table 21 Monitoring samples exceeding targets during high flow events.										
Sediment	●	●	●	●		●	●	●		N/A
From Table 40. L-THIA-derived load reductions										
Greater than 55 lb/acre/year load reduction needed to meet sediment target (red and orange in Table 44)		●		●		●		●	●	
Score	2	3	2	3	1	2	1	3	1	2

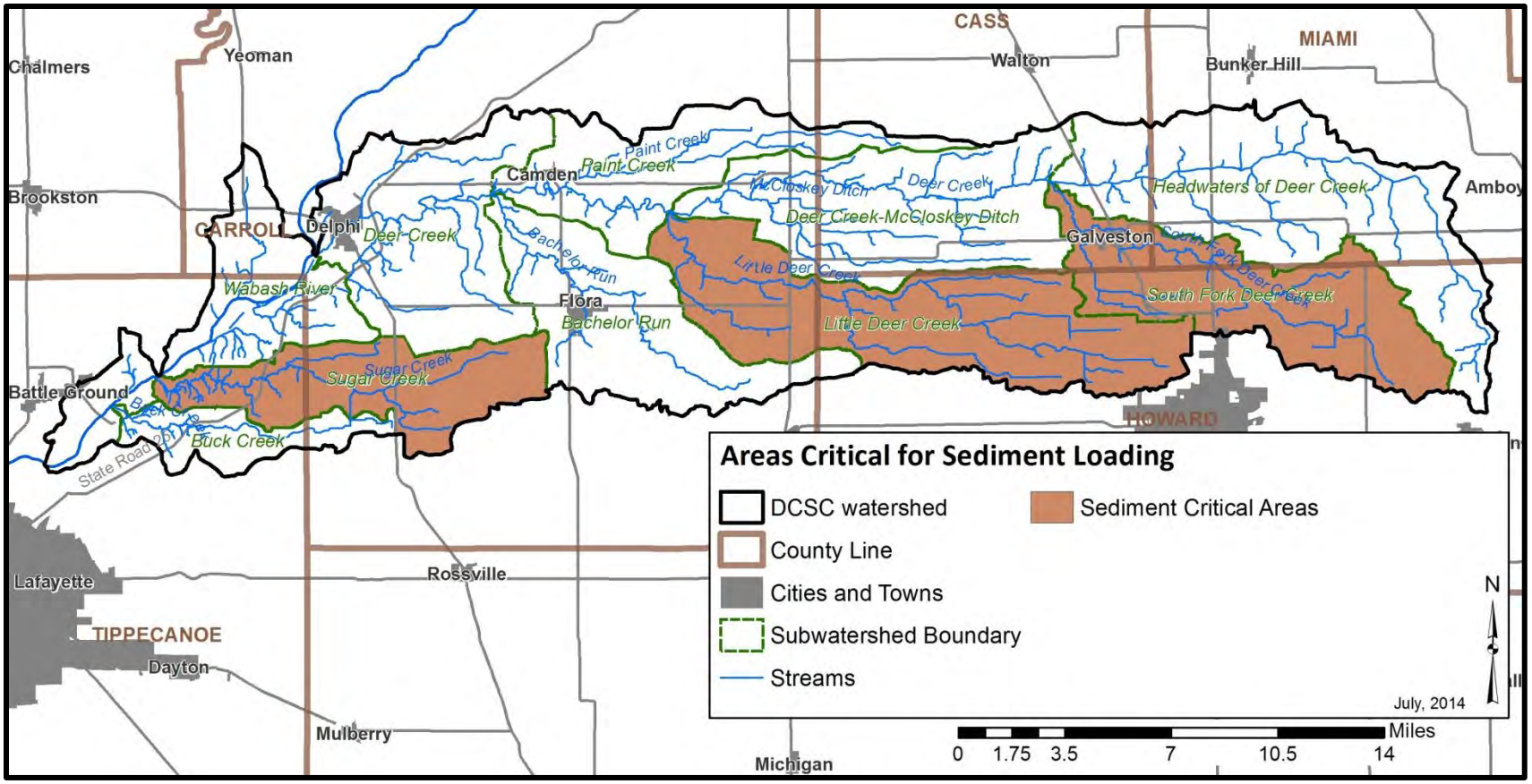

Figure 101. Areas Critical for Sediment

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

8.4 Critical Areas for Impaired Natural Aquatic Habitat

Based on water quality data collected in 2012-2013, summarized in section 3.3.9, areas in the watershed most critically impaired natural habitat includes the Headwaters of Deer Creek, South Fork of Deer Creek, Deer Creek-McCloskey Ditch, and Buck Creek subwatersheds.

8.5 Critical Areas Summary

The steering committee elected to prioritize issues of water quality in an attempt to remedy sources of pollutants in the watershed before turning to natural habitat restoration. The combined extent of all areas critical for nutrients, *E. coli*, or sediment covers 8 of the 10 subwatersheds. In an effort to further prioritize and target an implementation plan, the three pollutant critical areas are stacked to create a tiered hierarchy of priority areas. Areas critical for all three parameters are considered high priority and will be the first to receive targeted actions. Implementation will then target areas critical for 2 parameters, and then areas critical for just 1 parameter. Table 44 shows the combined tally of parameters for each subwatershed, and the final critical areas in the Deer Creek-Sugar Creek watershed are mapped in Figure 102.

Table 44. Stacked Parameters to Determine Highest Priority Critical Areas

Subwatershed	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	**Little Deer Creek**	Paint Creek	Bachelor Run	Deer Creek	**Sugar Creek**	Buck Creek	Wabash River
Priority	*Low*	*Low*	*Low*	***High***	*Med*	*Low*	*0*	***High***	*Med*	*0*
Areas Critical for Nitrogen and Phosphorus (Table 41)										
Areas Critical for *E. coli* (Table 42)										
Areas Critical for Sediment (Table 43)										

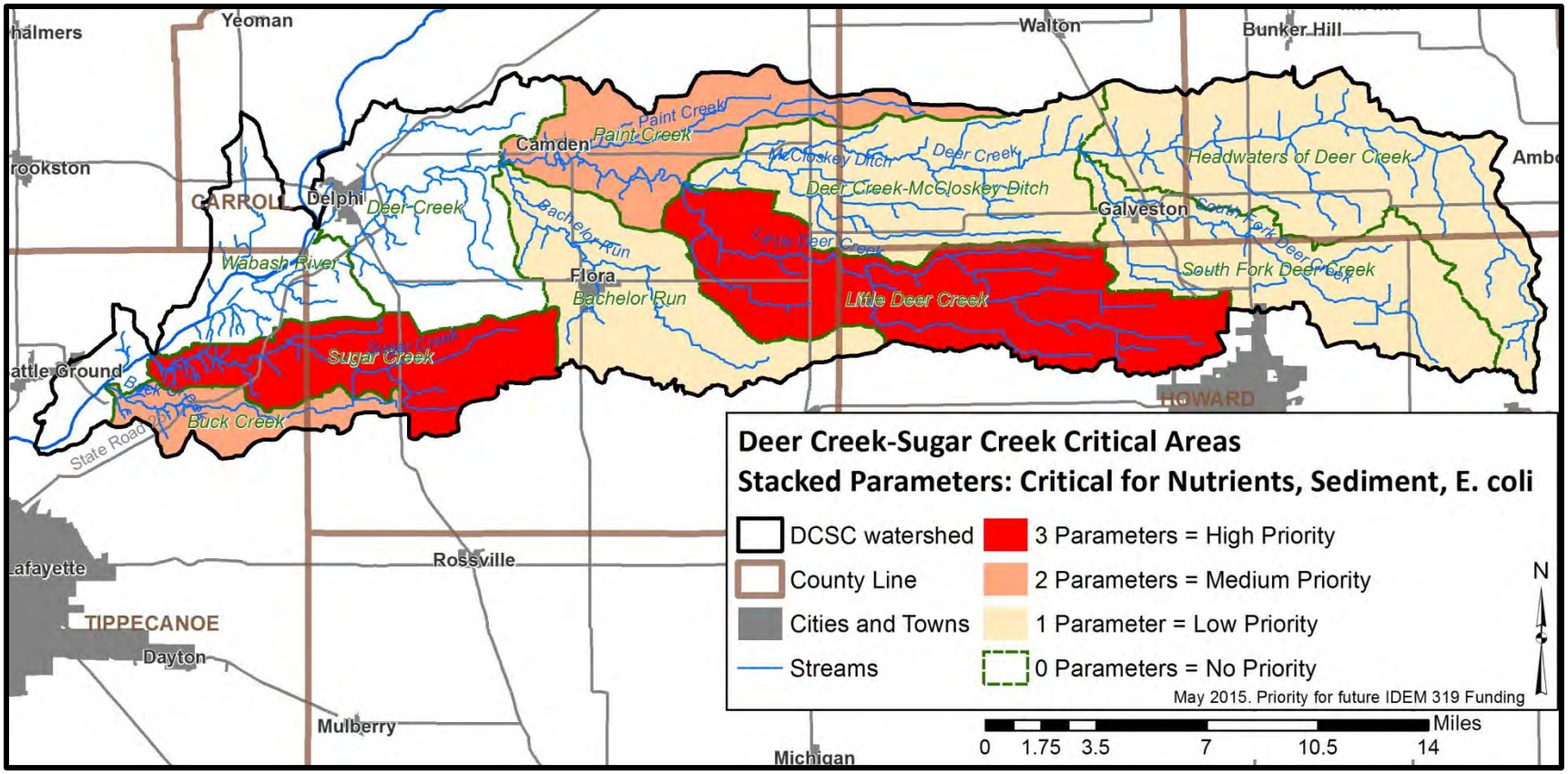

Figure 102. Critical Areas in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Table 45 summarizes data from Table 33 through Table 39 from Chapter 7.0, presenting current loads, reductions, and targets from the measured dataset, which the steering committee deemed to be a more conservative measure of current loading and needed reductions.

Table 45. Current loads, reductions and targets for high priority, medium priority and low priority subwatersheds.

HIGH PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Little Deer Creek	1,164,669	24,678	13,977,532
Sugar Creek	910,525	19,233	9,731,940
Total	**2,075,194**	**43,911**	**23,709,472**
	Reduction lb/yr		
Little Deer Creek	1,030,061	-15,704	11,958,414
Sugar Creek	856,546	3,039	8,922,248
Total	**1,886,607**	**-12,665**	**20,880,662**
	Target lb/yr		
Little Deer Creek	134,608	40,382	2,019,118
Sugar Creek	53,979	16,194	809,692
Total	**188,587**	**56,576**	**2,828,810**

MEDIUM PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Paint Creek	624,287	20,858	1,929,996
Buck Creek	524,015	8,737	2,504,193
Total	**1,148,302**	**29,595**	**4,434,189**
	Reduction lb/yr		
Paint Creek	571,906	5,144	1,144,285
Buck Creek	502,054	2,149	2,174,779
Total	**1,073,960**	**7,293**	**3,319,064**
	Target lb/yr		
Paint Creek	52,381	15,714	785,711
Buck Creek	21,961	6,588	329,414
Total	**74,342**	**22,302**	**1,115,125**

LOW PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Headwaters of Deer Creek	1,015,437	32,921	20,010,763
South Fork of Deer Creek	620,118	15,470	7,071,473
Deer Creek-McCloskey Ditch	563,993	10,655	5,901,862
Bachelor Run	1,028,934	24,700	9,093,648
Total	**3,228,482**	**83,746**	**42,077,746**
	Reduction lb/yr		
Headwaters of Deer Creek	870,557	-10,543	17,837,559
South Fork of Deer Creek	521,819	-14,020	5,596,992
Deer Creek-McCloskey Ditch	499,101	-8,813	4,928,482
Bachelor Run	939,817	-2,036	7,756,888
Total	**2,831,294**	**-35,411**	**36,119,921**
	Target lb/yr		
Headwaters of Deer Creek	144,880	43,464	2,173,204
South Fork of Deer Creek	98,299	29,490	1,474,481
Deer Creek-McCloskey Ditch	64,892	19,468	973,380
Bachelor Run	89,117	26,735	1,336,760
Total	**397,188**	**119,157**	**5,957,825**

9.0 GOAL SETTING

Based on thorough examination and comparison between water quality data measured results and modeled load estimates, the steering committee developed goals to address key pollutants of concern within the identified critical areas. Scaled goals serve as means for measuring progress towards the long-term goal. Because measurements were taken in partially low flow, drought conditions, the data in Table 45 suggest that no phosphorus reductions are needed in the short and long term. However, actions taken to reduce both nitrogen and sediment loading will necessarily have a positive impact on phosphorus loading as well and advance water quality towards the long term phosphorus reduction goal.

9.1 Reduce Nutrient Loading

Nitrogen Goals:

In the short term, by 2025, reduce nitrate-nitrogen loading from 2 million lb/yr to just under 190,000 lb/yr (a 91% reduction) in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce nitrate-nitrogen loading from 1.1 million lb/yr to 74,000 lb/yr (a 93% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek subwatersheds.

In the long term, by 2045, reduce nitrate-nitrogen loading from 3.2 million lb/yr to 400,000 lb/yr (an 88% reduction) in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

Phosphorus Goals

No short term goal for 2025, except for the reduction of phosphorus as a by-product of the implementation of nitrogen and sediment –reducing best management practices in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce phosphorus loading from 30,000 lb/yr to 22,000 lb/yr (a 25% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek Subwatersheds.

No long term goal for 2045, except for the reduction of phosphorus as a by-product of the implementation of nitrogen and sediment –reducing best management practices in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

9.2 Reduce Sediment Loading

In the short term, by 2025, reduce sediment loading from nearly 24 million lb/yr to 3 million lb/yr (an 88% reduction) in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce sediment loading from 4.4 million lb/yr to 1.1 million lb/yr (a 75% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek subwatersheds.

In the long term, by 2045, reduce sediment loading from 42 million lb/yr to 6 million lb/yr (an 85% reduction) in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

9.3 Improve Biological Communities

Goal: Improve water quality and restore natural aquatic habitat in the Deer Creek-Sugar Creek watershed so that streams meet their aquatic life use designation by the year 2035.

Scaled Goal: Implement goals 9.1, 9.2 and 9.4 to improve water quality before addressing natural aquatic habitat issues.

9.4 Reduce E. coli Loading

Long-term Goal: Reduce *E. coli* concentrations in the Deer Creek-Sugar Creek watershed critical areas by 87% by the year 2035.

Scaled Goal: Reduce *E. coli* concentrations such that the watershed streams exceed the state standard (235 cfu/100 mL) in no more than 20% of samples in 2020, particularly during storm events.

9.5 Increase Public Awareness and Participation

Long-Term Goal: Increase public awareness and knowledge about the waterways in the Deer Creek-Sugar Creek watershed and what individuals and communities can do to improve the quality of those waterways by the year 2035.

Scaled Goal: By 2020, improve community awareness of water quality issues specifically related to nutrient loading and aquatic habitat alteration; close the gap between watershed producers and landowners who are familiar with and would like to try conservation practices and those who put them into practice; and target established crop and animal producers and leaders in the farming community and foster farmer-to-farmer mentorship.

10.0 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 into the Wabash River and its tributaries in the Deer Creek-Sugar Creek Watershed. A list of potential best management practices was reviewed by the steering committee with technical assistance from local NRCS agents. From this list, the practices which were deemed most appropriate and most likely to successfully meet loading reduction targets were identified. 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.

10.1 Best Management Practices

10.1.1 Agricultural Best Management Practices

Agricultural best management practices are implemented on agricultural lands, including row crop and animal feed lot facilities, 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
- Animal Mortality Facility
- Bioreactors
- Composting Facility
- Conservation Tillage
- Cover Crop
- Drainage Water Management
- Field Border or Filter Strip
- Forage and Biomass Planting
- Grade Stabilization Structure
- Grassed Waterway
- Livestock Restriction or Prescribed Grazing
- Manure Management Planning
- Mulching
- Nutrient and Pest Management
- Streambank Stabilization
- Tree & Shrub Establishment
- Two Stage Ditch
- Water and Sediment Control Basin
- Wetland Creation, Enhancement, and 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. Livestock pipelines and lined waterways or outlets can also be included in this practice.

Animal Mortality Facility

An animal mortality facility is an on-farm facility for the treatment or disposal of livestock and poultry carcasses for routine and catastrophic mortality events. This practice can reduce impacts to surface and groundwater resources and decrease the spread of pathogens. This practice is applicable to operations where animal carcass treatment or disposal is needed. However, these facilities may not be used for catastrophic mortality resulting from disease. All runoff is diverted away from such facilities, which should be located down gradient from springs and wells and above the 100-year floodplain if possible to prevent contamination (FOTG Code 316, NRCS, 2011).

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.

Composting Facility

A composting facility is a structure to facilitate the controlled anaerobic decomposition of manure or other organic material by microorganisms into a biologically stable organic material that is suitable for use as a soil amendment. It can reduce the pollution potential and improve the handling characteristics of organic waste solids and produce a soil amendment that adds organic matter and beneficial organisms, provides slow-release plant-available nutrients, and improves soil conditions (FOTG Code 317, NRCS, 2011).

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 and 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 47% of survey respondents indicating that they currently use conservation tillage. Less than 1% of respondents indicate that they are unfamiliar with conservation tillage.

Cover Crop

Cover crops include legumes, such as clover, hairy vetch, field peas, and alfalfa 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 fairly familiar conservation practice throughout the watershed with 30% of survey respondents indicating that they are currently using cover crops; however, 26% of survey respondents indicate that they are only somewhat familiar with this practice.

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.

Field Borders and 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 Deer Creek-Sugar Creek Watershed with nearly 35% of survey respondents indicating that they currently use vegetated riparian buffers for agricultural operations. Buffers provide many benefits including restoring hydrologic connectivity, reduction 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., 1993; 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 border. 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 field borders 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.

Forage and Biomass Planting

This practice establishes pasture, hay, or biomass production. In addition to maintaining livestock nutrition and health, it can reduce soil erosion and improve soil and water quality (FOTG Code 512, NRCS, 2011).

Grade Stabilization Structure

A grade stabilization structure is used to stabilize and control soil erosion in natural and artificial channels. It can prevent the formation or advance of gullies, enhance environmental quality, and reduce pollution hazards. Special attention is given to maintaining or improving habitat for fish and wildlife (FOTG Code 410, NRCS, 2011).

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 Prescribed (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. 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 impactied 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. Field office technical guide (FOTG) coded practices which can be included in a livestock exclusion system include Access Control (472), Fence (382), and Heavy Use Protection Area (561). Education and outreach programs focusing on rotational grazing and exclusionary fencing are important in the success of this BMP.

Manure Management Planning

Large volumes of manure are generated by both small, unregulated animal operations and by confined feeding operations located throughout the Deer Creek-Sugar Creek 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. Specific technical practices that can be included in manure management planning can include waste storage facilities and waste utilization.

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.

Mulching

Mulching is the application of plant residues to the land surface. This can help conserve soil moisture, moderate soil temperature, provide erosion control, facilitate the establishment of vegetative cover, improve soil quality, and reduce airborne particulates. This practice can be used alone or in combination with other practices (FOTG Code 484, NRCS, 2011).

Nutrient and Pest Management

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 by roughly 60% of the watershed survey respondents. 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.

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.

Tree & Shrub Establishment

Tree & shrub establishment is the establishment of woody plants for forest products, wildlife habitat, long-term erosion control, water quality improvement, waste treatment, storage of carbon in biomass, improving or restoring natural diversity, or enhancing aesthetics. On a larger scale, reforestation can be used to restock existing forests and woodlands which have been depleted. This practice can be applied on any appropriately prepared site where woody plants can be grown (FOTG Code 612, NRCS, 2011).

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 above 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 coarser material forming the bed.

Water and Sediment Control Basin

A water and sediment control basin is an earthen embankment constructed across the slope of a minor watercourse to form a sediment trap and water detention basin with a stable outlet. This practice can reduce watercourse and gully erosion, trap sediment, and reduce downstream runoff. It is particularly applicable where watercourse or gully erosion is a problem and where sheet and rill erosion is controlled by other conservation practices. It can help in areas where sediment in runoff is severe, though it needs to be placed where adequate outlets can be provided (FOTG Code 638, NRCS, 2011).

Wetland Creation, Enhancement, and Restoration

Visual observation and historical records indicate at least a portion of the Deer Creek-Sugar Creek 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. 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.

10.1.2 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 Deer Creek-Sugar Creek watershed in locations where specific conditions occur. Potential management practices designed to address watershed impairment issues are as follows:

- Greenways and Trails
- Habitat Corridor Identification and Improvement
- Point Source Discharge Reduction
- Septic System Care and Maintenance
- Streambank Stabilization
- Threatened and Endangered Species Protection
- Urban Practices

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. Existing trails in the watershed are located in Prophetstown State Park, in the Delphi area, and east of Galveston (Figure 32).

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 land purchase. Donations can be solicited and encouraged through incentive programs. Outright purchase of property is frequently the least complicated and most permanent protection technique; it is also the most costly. A conservation easement is a less expensive technique 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 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.

Point Source Discharge Reduction

Several point source permitted discharges are located throughout the Deer Creek-Sugar Creek watershed. These include municipal wastewater treatment plants, like those that service Galveston, Camden, Flora, and Delphi and several manufacturer-operated NPDES facilities such as the Indiana Packers Corporation, SAYCO, Northwestern Elementary and High School, and Maple Lawn Village mobile home park. A majority of the facilities permitted throughout the watershed operate within their permitted requirements with regards to water discharges. Although WREC and Carroll County SWCD cannot assist them with infrastructure changes, watershed stakeholders 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.

As detailed in the inventories for each subwatershed, there are a number of non-permitted point sources in the Deer Creek-Sugar Creek watershed as well. These include several dozen leaking underground storage tanks, industrial waste sites in Delphi and Flora, and a number of brownfields and open dumps.

Septic System Care and Maintenance

Septic, or on-site waste disposal systems, are the primary means of sanitary flow treatment throughout most of the watershed. 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.

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 Deer Creek-Sugar Creek 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.

Urban Practices

Though only 10% of the watershed is classified as urban land use, there are some best management practices which could be considered for helping to improve water quality, particularly in areas, such as the City of Delphi and in the Towns of Flora, Camden, and Galveston, where development and impervious surfaces are more prevalent. The best way to mitigate the impacts of impervious surfaces is to infiltrate, store, and treat stormwater onsite before it can run off into nearby streams and tributaries.

- **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 be used in areas where on-site storage space is available.

- **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.

- **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.
    - 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.

- **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. 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.

- **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.

10.2 Best Management Practice Measure Selection

The steering committee considered the list of best management practices (BMPs), and in an interactive exercise, identified which practices may best reduce the loading of nutrients, *E. coli*, and sediment and help improve aquatic habitat. Table 46 summarizes the results of this discussion, showing which BMPs would best address the parameters of concern in each of the Critical Areas. This selection process relied upon the technical expertise of the district conservationists on the steering committee, as well as local knowledge about which practices are currently installed in the watershed and which might be most easily adopted or expanded. A complete list of best management practices currently installed in the watershed can be found in Appendix F. Specific load reductions for these practices is discussed in the next section based on available data.

Table 45. Best Management Practices suggested for critical areas by parameter

Critical Areas	Reason for Being Critical	Suggested BMP
Little Deer Creek, Paint Creek, Sugar Creek, and Buck Creek subwatersheds & livestock access areas	Critical Areas for Nutrients (Nitrogen and Phosphorus) (refer to Table 41)	Alternate Watering Systems
		Animal Mortality Facility
		Bioreactor
		Composting Facility
		Consider soil characteristics to minimize runoff
		Cover Crops
		Diversion Structures
		Drainage Water Management
		Education and Outreach
		Filter Strips
		Forage and Biomass Planting
		Grassed waterway
		Livestock Restriction or Rotational Grazing
		Manure Management Planning
		Nutrient Management & Variable Rate Application
		Prescribed Grazing
		Residue and Tillage Management
		Service Septic Systems
		Tree/Shrub Establishment
		University Fertilization Recommendations
		Wetland Enhancement, Restoration

Critical Areas	Reason for Being Critical	Suggested BMP
Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, Bachelor Run, Sugar Creek, and Buck Creek subwatersheds and livestock access areas	Critical Areas for *E. Coli* (refer to Table 42)	Alternate Watering Systems
		Animal Mortality Facility
		Composting Facility
		Diversion Structures
		Education and Outreach
		Livestock Restriction or Rotational Grazing
		Manure Management Planning
		Prescribed Grazing
		Service Septic Systems
		Wetland Creation
South Fork Deer Creek, Little Deer Creek, and Sugar Creek subwatersheds and livestock access areas	Critical Areas for Soil Erosion and Total Suspended Solids (refer to Table 43)	Consider soil characteristics to minimize runoff
		Cover Crops
		Education and Outreach
		Field Border
		Filter Strips
		Grade Stabilization Structure
		Grassed waterway
		Livestock Restriction or Rotational Grazing
		Prescribed Grazing
		Residue and Tillage Management
		Tree/Shrub Establishment
		Two Stage Ditch
		Water and Sediment Control Basin
		Wetland Enhancement, Restoration

Critical Areas	Reason for Being Critical	Suggested BMP
Headwaters of Deer Creek, South Fork Deer Creek, Deer Creek-McCloskey Ditch, Buck Creek	Impaired Natural Aquatic Habitat (refer to Section 4.3.9)	Alternate Watering Systems
		Cover Crops
		Education and Outreach
		Field Border
		Filter Strips
		Livestock Restriction or Rotational Grazing
		Nutrient and Pest Management & Variable Rate Application
		Service Septic Systems
		Tree/Shrub Establishment
		Wetland Enhancement, Restoration

10.3 Load Reduction by Best Management Practice

Load reduction calculations were estimated for nitrogen, phosphorus, and sediment based on estimated current loads in high, medium, and low priority areas and removal efficiencies from the EPA Region 5 model and the Spreadsheet Tool for Estimating Pollutant Load (STEPL). The load reductions shown in Table 46 are listed for practices which would directly reduce nitrogen, phosphorus or sediment loading, and assumptions are listed with each example. Load reductions are not available for all parameters for all BMPs.

Table 46. Load Reductions per Best Management Practice.

Best Management Practice	Assumptions	Estimated Load Reduction Per Practice			Unit of Reduction
		Nitrogen	Phosphorus	Sediment	
Animal Mortality Facility		16.25	0.09	0.00	lb/animal
Bioreactors	Applies to tile-drained soils only	20.31	0.00	0.00	lb/acres
Composting Facility		16.25	0.10	0.00	lb/animal
Conservation Tillage		22.34	0.44	86.36	lb/acre
Cover Crop		20.31	0.44	46.06	lb/acre
Drainage Water Management		13.65	0.00	101.33	lb/acre
Field Border	Buffers: 30' wide	28.43	0.73	74.85	lb/acre
Filter Strip (grass)	Buffers: 30' wide	28.43	0.73	74.85	lb/acre
Forage and Biomass Planting		28.43	0.73	74.85	lb/acre
Grade Stabilization Structure		8.94	0.87	103.63	lb/acre
Grassed Waterway		8.94	0.87	103.63	lb/acre
Livestock Restriction	Livestock Exclusion: 10' wide	30.46	0.73	86.36	lb/acre
Prescribed Grazing		11.08	0.25	16.31	lb/acre
Nutrient/Pest Management Planning					
Livestock Producers (Manure mgmt planning)	Manure management could be applied to approximately 25% of cropland	12.19	0.29	34.54	lb/acre
Non-livestock Producers (Nutrient mgmt planning)		8.12	0.19	34.54	lb/acre
Tree/Shrub Establishment		28.43	0.73	74.85	lb/acre
Two Stage Ditch	Two Stage Ditch: 30' wide	4.87	0.00	46.06	lb/acre
Water & Sediment Control Basin		28.43	0.68	80.60	lb/acre
Wetland Enhnancement, Restoration		8.96	0.26	89.24	lb/acre

11.0 INDICATORS, STRATEGIES, AND MILESTONES FOR REACHING GOALS

Implementation of policies, programs, and practices will improve water quality and watershed conditions within the Deer Creek-Sugar Creek watershed, helping reach goal statements (listed in Chapter 9.0) for high, medium, and low priority critical areas by 2045. Activities to be completed as part of this watershed management plan are identified in the action register in Table 47. Measurement of the success of implementation is a necessary part of any watershed project. Both social indicator and water quality data will be used to measure observable changes following implementation.

11.1 Indicators of Success

Water quality, social, and administrative indicators will be used to monitor progress towards successful achievement of the goals for the high, medium, and low priority critical areas. Water quality indicators will include monitoring orthophosphate, nitrate-nitrogen, and ammonia-nitrogen. Monitoring of total phosphorus, nitrate-nitrogen, turbidity, fish, macroinvertebrate, habitat, and *E. coli* will occur as part of the Hoosier Riverwatch volunteer program. Social indicator surveys will occur ten years after implementation begins, with results of these surveys compared to results observed during the planning phase of this project. Administrative indicators will be listed with each strategy below.

11.2 Action Register of Strategies, Milestones, and Cost Estimates

In addition to the long term strategy of continuing water quality monitoring, using both professional and volunteer monitoring options, Table 47 details strategies and milestones for implementing goals in the watershed, with strategies listed for meeting goals in high priority (by 2025), medium priority (by 2035), and low priority (2045) critical areas. Strategies for the high priority critical areas are particularly aggressive because of the large calculated load reduction, based on measured data from professional water quality monitoring, needed to meet target loads. Based on measured water quality conditions in 2012 and 2013, meeting target loads will require blanketing the critical areas with best management practices. These numbers are based on climatic conditions present at the time of water quality sampling, including severe drought and catastrophic rain events. Changes in climatic conditions based on subsequent water quality testing may result in the reduction of required BMPs to meet target loads. Strategies listed in the action register assume that BMPs will be installed in high priority areas first, or as much as is reasonably possible, before moving on to medium and low priority areas.

Table 47. Action Register for Strategies and Milestones in the Deer Creek-Sugar Creek Watershed.

Goal	Strategy	Target Audience	Milestone	Cost	Possible Partners	Technical Assistance
Nutrients, Sediment, *E.coli*	Increase cover crop acreage by 46,237 acres in high priority areas by 2025, by 10,000 acres in medium priority areas by 2035, and by 50,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	$12,500*	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension, Notre Dame, Howard County Surveyor	SWCDs, NRCS, RCPP
			Create a contractors list for specific cover crop seeding in 2015.	$500		
			Develop cover crop demonstration area highlighting various species by 2016.	$2,000		
			Host cover crop workshop in 2015 and biennially thereafter through 2045 at an appropriate location within the watershed.	$1,000		
			Annually, identify additional cover crop funding options.	$1,000		
			Annually from 2015-2025 implement 4,625 acres, from 2025-2035 implement 1,000, and from 2035-2045 implement 5,000 of cover crop in the appropriate critical areas.	$4.3 Million		
			Install 106,237 acres of cover crops by 2045.			
Nutrients, *E. coli*	Increase the use of manure management by 11,559 acres in high priority areas by 2025, 2,500 acres in medium priority areas by 2035, and 18,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of manure management planning. Tours will occur from 2015 to 2045 at an appropriate location in the watershed.	$2,500		
			Seek financial incentives for landowners to implement manure management (2016).	$1,000		
			Annually from 2015-2025 implement 1,156 acres, from 2025-2035 implement 250 acres and from 2035-2045 implement 1,800 acres of manure management in the appropriate critical areas.	$945,740		
			Implement 32,059 acres of manure management by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase conservation buffer (filter strips, field border, riparian buffer) by 152 acres in high priority areas by 2025, by 130 acres in medium priority areas by 2035, and by 190 acres in low priority areas by 2045.	Agricultural landowners and operators, Urban and rural landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension DNR	SWCDs, NRCS, DNR
			Develop a field day highlighting management and development of buffer habitats and host annually from 2015 through 2045 at an appropriate location within the watershed .	$5,000		
			Submit grant application for restoration and easement purchase to increase zones of protection with emphasis on partners and water monitoring in 2015.	$1,000		
			Seek financial incentives for landowners to establish field borders/buffers as well as promote existing programs/incentives (2016).	$1,000		
			Identify and map areas for comprehensive watershed inventory of conservation practices.	$5,000		
			Annually from 2015-2025 implement 15.2 acres, from 2025-2035 implement 13 acres and from 2035-2045 implement 19 acres of conservation buffer in the appropriate critical areas.	$177,000		
			Install 472 acres of conservation buffer by 2045.			
Nutrients, *E. coli*	Increase the use of nutrient management by 34,678 acres in high priority areas by 2025, 5,313 acres in medium priority areas by 2035, and 15,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of nutrient management planning from 2015-2045 at an appropriate location in the watershed.	$2,500		
			Seek financial incentives for landowners to implement nutrient management (2016).	$1,000		
			Annually from 2015-2025 implement 3,468 acres, from 2025-2035 implement 531 acres and from 2035-2045 implement 1,500 acres of nutrient management in the appropriate critical areas.	$439,928		
			Implement 54,991 acres of nutrient management by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase wetland restoration by 19,504 acres in high priority areas by 2025, by 20 acres in medium priority areas by 2035, and by 55 acres in low priority areas by 2045.	Agricultural landowners and operators, Suburban and rural landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, DNR, SWCDs, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension	SWCDs, NRCS, IDNR
			Develop a list of potential wetland restoration sites and conduct 10 one-on-one meetings annually with individual landowners starting in 2015.	$5,000		
			Increase awareness about existing programs.	$1,000		
			Seek financial incentives for landowner to restore wetlands.	$1,000		
			Annually from 2015-2025 implement 1,950 acres, from 2025-2034 implement 2 acres and from 2035-2045 implement 5.5 acres of wetland restoration in the appropriate critical area.	$58.7 Million		
			Restore 19,579 acres of wetland by 2045.			
Nutrients	Increase landowner awareness on the use of drainage water management; install drainage management structures on 40,000 acres in high priority areas by 2025, by 50 acres in medium priority areas by 2035, and by 50 acres in low priority areas by 2045.	Agricultural landowners and operators	Identify and seek financial incentives for landowners to install drainage water management practices.	$1,000	Wabash River RC&D, SWCDs, DNR, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension	SWCDs, NRCS, Purdue University
			Develop an education plan including demonstration day and printed materials targeting drainage water management, seeking farmer-to-farmer mentorship if possible.	*see note		
			Implement education plan (2015-2045).	**see note		
			Host annual workshop or presentation for landowners highlighting the benefits of drainage water management from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Target installing a demonstration in 2017.	$3,000		
			Annually from 2015-2025 install drainage water management structures to treat 4,000 acres, from 2025-2035 implement treatment on 5 acres and from 2035-2045 implement treatment on 5 acres in appropriate critical areas.	$126,000		
			Install 1,002 structures treating no less than 40-50 acres by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase the use of a conservation system approach by 6,400 acres in high priority areas by 2025 and by 10,000 acres in medium priority areas by 2035, by 10,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of the conservation system in an operating area from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Seek financial incentives for landowners to establish the system (2016).	$1,000		
			Implement 1,300 acres of the conservation system (includes cover crop, no till, nutrient management, pesticide management, and waste utilization) annually from 2015-2025, 1,000 acres annually from 2025-2035 in medium priority areas, and 1,000 acres annually in low priority areas.	$300,000		
Nutrients, Sediment, Habitat, *E. coli*	Restrict livestock access from watershed streams from 47,520 linear feet in high priority area by 2025, 4,400 linear feet in medium priority areas by 2035, and 17,600 linear feet in low priority areas by 2045.	Landowners with livestock access to watershed streams	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension
			Develop a targeted education program in 2015 based on areas observed to allow livestock access to streams. Conduct outreach to those landowners and provide technical and financial assistance for restricting access.	*see note		
			Implement education plan (2015-2045).	**see note		
			Develop individual livestock on-site restriction plans which may include provision of alternate water systems, livestock fencing, and rotational grazing.	$1,500		
			Annually from 2015-2025 restrict livestock access from 4,752 linear feet, annually from 2025-2035 restrict access from 440 lineal feet and annually from 2035-2045 restrict access from 1,760 lineal feet in appropriate critical areas.	$83,424		
			Restrict livestock from 69,520 linear feet by 2045.			

Nutrients	Increase landowner awareness on the use of bioreactors by 2025. Install bioreactors to treat tile-drained soils: 100 acres in high priority areas by 2025, 10 acres in medium priority areas by 2035, and 10 acres in low priority areas by 2045.	Agricultural landowners and operators, Urban and rural landowners	Identify and seek financial incentives for landowners to establish bioreactors.	$1,000	Wabash River RC&D, SWCDs, TNC, NRCS, USDA, IWF, NICHES, DNR, Purdue Extension	SWCDs, NRCS, Purdue Extension
			Develop an education plan including demonstration day and printed materials targeting the use of bioreactors.	*see note		
			Host annual workshop or presentation for landowners highlighting the benefits of bioreactors from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Install bioreactors to treat 10 acres of tile drainage annually from 2015-2025, 1 acre of tile drainage annually from 2025-2035 and 1 acre of tile drainage annually from 2035-2045 in appropriate critical areas.	$54,000		
			Target demonstration areas to be installed in 2025 and install bioreactors to treat 120 acres of tile drained soils by 2045.			
Sediment	Increase conservation tillage acreage by 46,237 acres in high priority areas by 2025, by 6,375 acres in medium priority areas by 2035, and by 50,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Host annual no till workshop from 2015-2045 in an appropriate location in the watershed..	$5,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop cost-share program in 2015.	*see note		
			Host annual no till breakfast (2015-2045) at an appropriate location in the watershed.	$6,000		
			Continue to perform annual tillage transect and promote results to watershed stakeholders.	$5,000		
			Conduct site visits with landowners to promote no till.	$1,000		
			Increase conservation tillage from 4,623 acres annually from 2015-2025, 635 acres annually from 2025-2035 and in 5,000 acres annually from 2035-2045 in appropriate critical areas.	$2.6 Million		
			Install 102,612 acres of conservation tillage by 2045.			

Sediment	Increase awareness of landowners on the use of two-stage ditches. Install 2 miles of two stage ditch in high priority areas by 2025, 2 miles in medium priority areas by 2035, and 7 miles in low priority areas by 2045.	Agricultural landowners and operators	Develop an education plan including demonstration day and printed materials targeting two stage ditches.	*see note	Wabash River RC&D, Howard County, SWCDs, DNR, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension, Surveyors offices, Notre Dame, Howard County Surveyor	SWCDs, NRCS, Purdue University, RCPP
			Implement education plan (2015-2045).	$15,000		
			Host annual workshop or presentation for landowners highlighting the benefits of two stage ditches from 2015-2045 at an appropriate location in the watershed.	$5,000		
			Install 0.2 miles of two-stage ditch annually from 2015-2025, 0.2 miles of two-stage ditch annually from 2025-2035 and 0.7 miles of two-stage ditch annually from 2035-2045 in appropriate critical areas.	$709,632		
			Install 11 miles of two-stage ditches by 2045.			
Habitat, Sediment	Increase landowner awareness about streambank stabilization options and alternatives and stabilize streambanks as possible through 2045.	Agricultural landowners and operators, Urban and rural landowners	Identify potential demonstration sites where low and high cost stabilization techniques can be displayed.	$1,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension, Surveyors offices, DNR	SWCDs, NRCS, DNR
			Complete installation of demonstration site highlighting low and high cost streambank stabilization options.	$100,000		
			Host a series of field and demonstration days targeting streambank stabilization installation, completed projects, and maintenance issues.	$3,000		
			Develop a cost-share program as interest is generated.	*see note		
			Identify funding sources.	$1,000		
			Stabilize streambanks as possible through 2045.	$20-100/foot		

Sediment	Increase the use of grassed waterways by 76 acres in high priority areas by 2025, by 75 acres in medium priority areas by 2035, and by 75 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field day highlighting management and development of grassed waterways and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners to establish grassed waterways (2016).	$1,000		
			Increase grassed waterway usage by 7.6 acres annually from 2015-2025, by 7.5 acres annually from 2025-2035 and by 7.5 acres annually from 2035-2045 in appropriate critical areas.	$39,550		
			Implement 226 acres grassed waterways by 2045.			
Sediment	Increase the use of prescribed grazing or grazing management practices on 876 acres in high priority areas by 2025, on 200 acres in medium priority areas by 2035, and on 500 acres in low priority areas by 2045.	Agricultural landowners and operators	In 2017, develop inventory of areas currently using prescribed grazing or grazing management practices.	$1,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			In 2017, conduct targeted mailing highlighting conservation options to all identified livestock producers.	$1,000		
			In 2017, conduct one-on-one site visits with individual livestock producers, as possible, to discuss prescribed grazing.	$1,000		
			Implement 87.6 acres of prescribed grazing annually from 2015-2025, 20 acres annually from 2025-2035 and 50 acres annually from 2035-2045 in appropriate critical areas.	$55,160		
			Implement 1,576 acres of prescribed grazing or grazing management practices by 2045.			

Nutrients, *E. coli*	Install animal mortality/animal composting facilities to process 2000 animals in high priority areas by 2025, 2000 animals in medium priority areas by 2035, and 51,000 animals in low priority areas by 2045.	Livestock-producing agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field day highlighting animal mortality/composting facilities and host annually starting in 2015.	$5,000		
			Seek financial incentives for landowners to establish animal mortality/composting facilities (2015).	$1,000		
			Install 2 facilities from 2015-2025, 2 facilities from 2025-2035 and 5 facilities annually from 2035-2045 in appropriate critical areas.	$4.5 Million		
			Install 55 facilities (treating ~1,000 animals each) by 2045.			
Nutrients, Sediment	Increase the use of forage and biomass planting by 87 acres in high priority areas by 2025, by 50 acres in medium priority areas by 2035, and by 50 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field forage day and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for forage and biomass planting (2015).	$1,000		
			Increase forage and biomass planting by 9 acres annually from 2015-2025, 5 acre annually from 2025-2035 and 5 acres annually from 2035-2045 in appropriate critical areas.	$7,480		
			Install 187 acres of forage and biomass planting by 2045.			

Nutrients, Sediment	Increase use of grade stabilization structures by 11 acres in high priority areas by 2025, by 4 acres in medium priority areas in 2035, and by 20 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a grade stabilization workshop and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for grade stabilization structures (2015).	$1,000		
			Increase the use of grade stabilization structures by 1.1 acres annually from 2015-2025, by 0.4 acres annually from 2025-2035 and by 2 acres annually from 2035-2045 in appropriate critical areas.	$122,500		
			Install 35 acres of grade stabilization structures by 2045.			
Nutrients, Sediment, Habitat	Increase tree and shrub establishment by 47,113 acres in high priority areas by 2025, by 500 acres in medium priority areas by 2035, and by 500 acres in low priority areas by 2045.	Agricultural landowners and operators, Stream/ditch-adjacent landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop tree & shrub workshop and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for tree & shrub establishment (2015).	$1,000		
			Establish 4,711 acres of trees and shrubs annually from 2015-2025, 50 acres annually from 2025-2035 and 50 acres annually from 2035-2045 in appropriate critical areas.	$32.7 million		
			Install 48,113 acres of tree & shrub by 2045.			
Nutrients, Sediment, *E. coli,* Habitat	Increase water quality treatment via WASCOBs treating 21 acres in high priority areas by 2025, 5 acres in medium priority areas by 2035, and 5 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop water and sediment control basin field day and host biennially from 2015 through 2045 at an appropriate location within the watershed.	$5,000		
			Seek financial incentives for landowners for water and sediment control basins (2015).	$1,000		
			Install one structure annually from 2015-2025, from 2025-2035 and 2035-2045 in appropriate critical areas.			
			Install6 structures treating no less than 5.2 acres (31 acres treatment) each by 2045.	$24,500		

Public Awareness: Targeted Education Programs	Conduct a watershed-wide Sampling Blitz at least once annually through 2035.	Community volunteers, Businesses, Charter schools, Youth groups, Scout groups	Conduct annual sampling blitzes through 2035 ($2,000/year).	$40,000	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston, FFA, Community Organizations	Purdue University Soils Lab
			Develop education component for the sampling blitz (2015) and implement in concert with each sampling blitz.	$5,000		
			Develop annual planned dates for the sampling blitz to include it on annually-printed community calendars.	$500		
			Continue preparation of subwatershed maps following sampling to highlight results and changes in water quality.	$500		
			Develop a list of kid-friendly sample sites and ensure that sampling methods are adapted to encourage children's participation.	$500		
			Consider developing an adopt-a-site option for groups to sample during each event.	$1,000		
			Identify opportunities for businesses to participate in the blitz via employee sharing or other options.	$1,000		
			Evaluate event and determine continuation of the event annually and at the end of 2025.	$5,000		
Public Awareness: Targeted Education Programs	Host field days and demonstration events at least annually through 2035.	Community Volunteers, Producers	Host biennial water quality workshops from 2015-2045 to continue to educate stakeholders on watershed functions and emphasize individual impact on water quality. Workshops will move throughout the watershed.	$30,000	University of Purdue, County SWCDs, NRCS, Cover Crop Systems Initiatives (CCSI), CTIC, Seed and Equipment representatives, Producers	University of Purdue, County SWCDs, NRCS, CCSI, CTIC
			Host annual field days or partner with CCSI to demonstrate cover crops and promote soil health.	$60,000		
			Partner with Howard County to host demonstration days to demonstrate installation of two-stage ditch no less than once every 10 years.	$15,000		

Public Awareness: Targeted Education Programs	Strengthen liaison with local area planning commissions to support water quality related policies.	Local elected officials	Present Watershed Management Plan and Cost Share Program to local area planning commissions once in 2016.	$2,000	Counties, ACPs, SWCDs	University of Purdue, SWCDs, NRCS, ISDA
			Annually, or as needed, provide assistance and feedback to area plan commissions when water quality related policies are examined and updated.	$3,000		
Public Awareness: Targeted Education Programs	Continue quarterly Hoosier Riverwatch-based volunteer monitoring through 2025.	Community volunteers, Businesses, Charter schools, Youth and Scout groups	Continue annual training and consider retraining volunteers as needed.	$2500	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston, FFA, Community Organizations	Hoosier Riverwatch-certified trainer, IDNR Hoosier Riverwatch program staff
			Continue recruiting volunteer monitors.	$3,000		
			Annually, profile volunteers and their monitoring efforts on partner websites and through marketing effort.	$2,500		
			Complete quarterly sampling through 2045.	$40,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Develop a partner and volunteer tracking list by 2015.	Community members targeted by each identified strategy	Develop a list of potential partner groups and identify a contact within each group by 2017.	$3,000	Cities, counties, community groups	Cities, counties, community groups
			Identify a method of contacting partner groups and approach each potential partner no less than annually to explore opportunities.	$5,000		
			Develop a volunteer tracking database and utilize this to track volunteer involvement by 2017.	$3,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Share and communicate past, current, and future activities on a regular basis through 2025.	Community members targeted by each identified strategy	Complete updates to the DCSC website quarterly and provide that information to partners for update to their websites as well.	$5,000	Purdue University, City of Delphi, Town of Camden, Town of Flora, Town of Galveston, Counties, County SWCDs, Community organizations, Chambers, Festival Planning Committees	Purdue University, City of Delphi, Town of Camden, Town of Flora, Town of Galveston, Counties, County SWCDs
			Host annual public meetings or events at which the public can comment on watershed efforts.	$10,000		
			Develop a message for county fairs annually and attend county fairs for Cass, Carroll, Howard, Miami, and, Tippecanoe counties on an annual basis. Attend additional county fairs as appropriate.	$25,000		
			Create pamphlets, brochures, and marketing materials as needed and distribute through partner organizations, on websites, and via direct mailings and meetings.	$10,000		
			Create press releases quarterly or as needed.	$1,000		
			Annually attend local events and festivals in Delphi, Flora, Camden, and Galveston to promote efforts and events.	$10,000		
			Provide information to existing newsletter publishers such as SWCDs and others as identified no less than annually.	$5,000		
			Explore the potential and need for a semi-annual or quarterly newsletter in paper and electronic format and produce as determined through 2025.	$5,000		
			Explore ways in which the website, webinars, phone apps, and social media can most effectively target and assist in educating various communities in the watershed. Implement social media strategy.	$5,000		
			Annually host awards for water quality and land stewardship.	$5,000		
			Partner with the Carroll SWCD to host a booth at Ag Days annually.	$5,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Build on existing youth education programs.	School groups, youth-targeted groups	Partner with the Carroll SWCD to host a booth at Ag Days annually.	$5,000	SWCDs, local schools, FFA, other youth organizations as appropriate	Local SWCDs, NRCS, ISDA, CCSI, CTIC
			Increase FFA involvement in field days, sampling, and other activities as needed.	$5,000		
			Investigate the potential for a youth-based Deer Creek float trip (ala Arrowhead Country RC&D) and implement annually as possible.	$10,000		
			Coordinate with local schools to incorporate water quality issues into High School curriculums.	$5,000		
			Organize High School field trips to examine demonstration sites and problem areas, developing problem-solving activities and competitions. Host high school field trips no less than once every four years.	$15,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Work with local groups and partners to highlight local streams and the Wabash River and natural aspects of the watershed.	Community members targeted by each identified strategy	Annually, create one walking tour, one Google Earth tour, and quarterly podcasts highlighting unique features, green practices, unique features (natural areas, parks), and activities in the watershed from 2015-2025.	$60,000	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston SWCDs, Consultants, Web developers, School groups, Community groups organizing local festivals, video developers, marketers	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston SWCDs, Consultants, Web developers, School groups, Community groups organizing local festivals, video developers, marketers
			Increase awareness of natural areas with annual photo and art competitions.	$10,000		
			Explore opportunities to partner with local community events and festivals to highlight the streams in the watershed. Attend no less than one festival annually.	$2,000		
			Develop videos targeted at adult community groups (20 minutes) and kids groups (10 minutes) and create list of potential partner groups at which presentation could occur. Present to 5 partner groups annually.	$20,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Promote hands-on opportunities to improve natural areas and the streams in the watershed.	Nature enthusiast, Children	In 2017, identify partner organizations which host field days, work days, and clean-up events.	$2,000	NICHES, DNR, SWCDs,	NICHES, DNR, SWCDs,
			Annually, identify partner opportunities to promote field days throughout the watershed and post to a central website or calendar.	$5,000		
			Annually, identify partner work days for river clean-up, exotic species control, or habitat restoration opportunities.	$5,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Increase natural areas information flow to service organizations.	Service organizations	In 2017, create a list of service organizations throughout the watershed.	$3,000	DNR, NICHES, SWCD	DNR, NICHES, SWCD
			Annually, meet with two service organizations to present information on water quality, agricultural practices, natural land preservation, or the Deer Creek-Sugar Creek Watershed	$5,000		
			Annually, request assistance from service organizations on natural areas maintenance, clean-up events, Sampling Blitz, or other volunteer opportunities.	$1,000		
			Annually recognize service groups for their participation by honoring the most active group relative to natural areas conservation and improvement and/or volunteerism.	$2,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Place high quality photographs in 20 professional offices by 2025.	People using professional services	In 2017, identify and hire a photographer to develop a natural areas and DCSC watershed-based portfolio.	$5,000	WREC, NICHES, local Arts Foundations	photographers
			In 2017, identify 10 professional offices for photograph placement and complete placement in 2018.	$2,000		
			By 2025, identify a total of 20 professional offices for photograph placement and complete placement.	$2,000		
			Annually, rotate photographs to maintain fresh views of natural resources.	$3,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	By 2015, become a supporter of WBAA to promote water quality.	WBAA listening audience	In 2017, identify a funding mechanism to purchase weekly spots on WBAA.	$2,200	Identified partners	WBAA staff
			In 2017, develop a calendar of weekly water quality messages.	$5,000		
			In 2017, identify partners to assist with message development and delivery.	$2,000		
			Complete weekly water quality message for WBAA through 2025.	$5,000		

*One cost-share program and one education plan will be developed covering all strategies identified. Development costs of each plan are for one-half of the Watershed Coordinator's time for two quarters plus meeting materials.

**Implementation of the education plan includes salary for the Watershed Coordinator to implement education and outreach over five years.

12.0 TRACKING EFFECTIVENESS

The overall success of a watershed management plan depends upon the implementation of action items as outlined by the plan's goals. Below are measurable success indicators or milestones which will help stakeholders in the Deer Creek-Sugar Creek track their progress and aid in updating and revising the watershed management plan as goals, objectives, and strategies are met. Strategies to achieve scaled goals are designed a 5-year implementation schedule. Regular water quality monitoring, social indicator surveys, and tracking of administrative successes associated with objectives and strategies is necessary to help realize actual water quality targets. Indicators identified below will be tracked and reported on a quarterly basis.

12.1 Indicator Tracking

Measuring stakeholder successes towards goals and assessing progress toward the vision of Deer Creek, Sugar Creek and their tributaries is vital. Stakeholders will complete the following concrete milestones as they work towards each goal. Interim measures or indicators will help stakeholders evaluate their progress towards chosen goals. For each goal, a series of indicators are detailed below. Indicator tracking will be completed by the Wabash River Enhancement Corporation. To request information on the status of progress towards goals, contact the Wabash River Enhancement Corporation at 200 North 2nd St, Lafayette, Indiana, 47901, or via phone at (765) 520-8505.

12.1.1 Water Quality Indicators

Water quality indicators are measurements of water chemistry, instream biota, or instream and riparian habitats. As part of our effort to show a measureable change in water quality, volunteer water quality monitoring will continue within the Deer Creek-Sugar Creek watershed throughout the implementation period. Water quality indicators will be measured as detailed below through 2045. After the first five years of implementation, indicators will be used to track implementation progress as follows:

- Nitrate-nitrogen and total phosphorus will be measured quarterly during the growing season at the twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will indicate a statistically significant improvement in water quality when compared with pre-implementation samples and will show a decreasing trend, with more samples annually meeting the target level for nitrate-nitrogen of 1 mg/L and for total phosphorus of 0.3 mg/L.
- Total suspended solids will be measured quarterly during the growing season at the twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will indicate a statistically significant improvement in water quality when compared with pre-implementation samples and will show a decreasing trend, with more samples annually meeting the target level for total suspended solids of 15 mg/L.
- *E. coli* will be measured monthly during the growing season at twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the state standard.

- Macroinvertebrate communities (mIBI), fish communities (IBI) and in-stream habitat (QHEI) will be monitored annually at the twelve Hoosier Riverwatch stations (see Section 3.3.1 for details on station locations). After five years of implementation, mIBI and IBI scores and instream cover and riparian habitat QHEI metric scores will show an increasing trend with each year's score measuring higher than scores recorded during the previous year.

Water quality indicators will be tracked using the Hoosier Riverwatch water quality database. These data will be considered along with the historic data and data collected during the planning phase of this project. Data will be updated quarterly and reported to the steering and monitoring committees on an annual basis. Additional monitoring will supplement the volunteer monitoring as additional funding allows.

12.1.2 Social Indicators

Social indicators provide information about stakeholder awareness, attitudes, capacity, and behaviors that directly affect water quality improvement and protection. Social indicators will be used as follows:

- Changes in knowledge about Deer Creek, Sugar Creek, and their tributaries.
- Changes in knowledge about and attitudes towards practices to improve water quality.
- Changes in knowledge about conservation and land practices.
- Changes in awareness about watershed activities, concerns, and accomplishments.
- Changes in participation in watershed, creek and tributary activities.
- Participation in cost-share and education programs.

Social indicator data will be tracked in both the planning phase and the post-implementation survey. If possible, comparisons between these data will be generated. Surveys will be completed by Purdue University five years after implementation begins and will cost $20,000. Results will be reported to the steering committee when data are available.

12.1.3 Administrative indicators

Administrative indicators provide information that water quality and social indicator data cannot. These indicators are used to track program participation, strategy completion, and goal attainment. Administrative indicators will be used to track the following:

- Attendance at workshops and field days.
- Emails sent, read, and responses received.
- Conservation practice installation including anticipated load reduction, size, and timing.
- Photo monitoring of installed practices.
- Media hits (newspaper stories, radio stories, website hits).
- Number of educational materials distributed.

Administrative indicators will be tracked using a database in which date of activity, number of attendees or participants, and an activity description will be recorded. Installed practices will be tracked in a project database using Geographic Information Systems. Administrative

indicator tracking will occur as part of the cost-share and education programs and will be completed by the WREC Watershed Coordinator. Data will be reported to the steering committee no less than annually with updates to the database occurring quarterly.

12.2 Future Considerations

There are several considerations stakeholders should keep in mind as they implement the Deer Creek-Sugar Creek Watershed Management Plan. Many of these considerations are noted in the proceeding sections of this text, but due to their importance, they warrant reiteration.

12.2.1 Water Quality Monitoring

An active water quality monitoring program will continue within the Deer Creek-Sugar Creek watershed. Water chemistry, habitat, and biological monitoring will continue as part of the Hoosier Riverwatch volunteer monitoring program in an effort to show changes in water quality.

A monitoring committee will be convened annually to discuss results of water quality monitoring and to provide recommendations to the steering committee for watershed management plan refinements. The following will be considered at annual monitoring committee meetings:

- Have implemented best management practices been effective in improving water quality?
- Should a different suite of best management practices be used?
- Have water quality goals been achieved?
- Have water quality goals changed?
- Has the density of exotic species changed?

12.2.2 Social Indicator Monitoring

As detailed above, monitoring of social indicators will occur five years after implementation begins and no less than every 10 years after that. Additional social indicator surveys will be scheduled during each phase of implementation. The education committee will be convened following each survey (2020, 2030, 2040) to review results and identify changes in social indicator data. After each social indicator assessment, the following will be considered at annual education committee meetings:

- Are watershed stakeholders more informed about water quality concerns and watershed issues?
- Have methods for distributing information to stakeholders been effective?
- Have the desired uses of the Wabash River tributaries in the Deer Creek-Sugar Creek watershed changed?

12.2.3 Permits, Easements, and Agreements

Permission to implement any on-the-ground implementation project must be obtained from property owners prior to installation occurring. Likewise, any instream or near-stream restoration activities will likely require permits. All permits will be obtained by the Wabash River Enhancement Corporation prior to any work beginning.

12.2.4 Installed Practice Monitoring

Annually, a practice technical committee will be convened to review installed best management practices and successes or failures of installed practices. Members from the following organizations will be contacted and asked to serve on this committee: Soil and Water Conservation District personnel, Natural Resource Conservation Service personnel, The Nature Conservancy staff, County surveyors, IDEM representatives, IDNR representatives, County Health Department staff, engineering, stormwater and sewer staff from Delphi, Flora, Camden and Galveston, Purdue University Physical Facilities staff, and NICHES Land Trust staff. Other members will be invited as identified. The board will meet annually to review the following:

- Location and number of best management practices installed.
- Annual plans for best management practice installation.
- Potential areas for collaboration on best management practice installation.
- Grant funding opportunities and potential project targets.

12.2.5 Plan Tracking

Each strategy will be tracked on a quarterly basis. Work completed towards each strategy will be documented in a tracking database which will include scheduled and completed activities, numbers of individuals attending or efforts completed toward each objective, and load calculations or monitoring results for each goal, objective, and strategy. Overall project progress will be tracked by measureable items such as workshops held, BMPs installed, meetings held, etc. Load reductions will be calculated for each BMP installed. These values and associated project details including BMP type, location, length of conservation commitment, easement, size, cost, installer, and more will be tracked over time in a single database. Individual landowner contacts and information will be tracked for both identified and installed projects.

Information about the project and updates on implementation can be found on the project website:

12.2.6 Plan Revision

The steering committee of the Deer Creek-Sugar Creek watershed will continue to meet on a regular basis for the purpose of plan implementation. Annually, this committee will review findings of the education, monitoring, and implementation committees. The steering committee will review project efforts according to the management plan's goals, objectives, and strategies no less than every five years.

This watershed management plan is meant to be a living document. Revisions and updates to the plan will be necessary as stakeholders begin to implement the plan and as stakeholders become more active in implementing the plan and as subsequent water quality monitoring may warrant adjustments to initial load conditions. The Wabash River Enhancement Corporation and the Carroll County Soil and Water Conservation District will be jointly responsible for holding and revising the Deer Creek-Sugar Creek Watershed Management Plan as appropriate based on stakeholder feedback.

This plan may be adapted or blended with other watershed management plans to effectively create living documents which cover larger-scale projects and capitalize on potential shared resources.

Updated project information can be found at http://www.wabashriver.net/deer-creek-sugar-creek/ or by contacting:

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