# Otter Creek *E. coli* and Geochemistry Analysis

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Group Project from ISU ENVI 460: Conservation and Sustainability

Independent Research with Carlos Montanez and James H. Speer

**Abstract**

The Otter Creek watershed is located in west-central Indiana, draining nearly 124 square miles in Clay, Parke, and Vigo Counties that drains into the Wabash River. This creek is of high recreational value for fishing and canoeing, and the Indiana Department of Environmental Management (IDEM) had identified many stretches of the creek to have high levels of Escherichia coli (*E. coli*) so we decided to continue studying this watershed to locate potential sources of *E. coli* and to examine the geochemistry of the sediments in the creek. We took water samples from five areas of the creek and tested these samples for *E. coli*. To test the samples, we used *E. coli* test kits with tablets that gave us a positive or negative result. All five of the water samples tested positive for *E. coli*. Our other interest was to test the sediment along the banks of the creek for heavy metal contamination. We collected six soil samples from the same five locations that the water samples were taken, but they were collected on the bank of the creek. We used the x-ray fluorescence (XRF) spectrometer in the biogeochemistry lab to test the samples for heavy metal contamination. The XRF tests revealed low potassium concentrations at Roberts Road, iron concentrations at the Rosedale site that were 63.4% higher than the average, silicon and zinc concentrations at the Rosedale site that were 62% elevated, and slightly higher than normal lead content at the Rosedale site. We concluded that further inspection of the Rosedale Road site is required to find the origin of the elevated anomalies.

## Introduction

Elevated *E. coli* levels are the leading cause of stream water quality impairments in the United States. The U.S. Environmental Protection Agency (USEPA) estimates that a minimum of 748,072 km of streams are contaminated with *E. coli*, potentially posing a risk to human health (Pandey and Soupir, 2013). In 2009, the Indiana Department of Environmental Management (IDEM) conducted a survey of Otter Creek. The cause of the survey was an *E. coli* contamination. IDEM suggested the sources of *E. coli* contamination could be pastures, agriculture, urban and rural runoff, land application of manure, and malfunctions of home sewage disposal systems.

*E. coli* bacteria naturally live in the intestines of healthy humans and animals. Most varieties of *E. coli* are harmless or cause relatively brief diarrhea. However there are strains, such as *E. coli* O157:H7, that can cause severe abdominal cramps, bloody diarrhea and vomiting. Healthy adults usually recover from an *E. coli* O157:H7 infection within a week. Older adults and young children are at a greater risk of developing a life-threatening form of kidney failure from the O157:H7 strain of *E. coli* (Meyer, 2015). It is estimated that 265,000 *E. coli* infections occur each year in the United States, the strain O157:H7 causing about 36% of those infections (Seidu, *et al.,* 2015).

*E. coli* and many other bacteria make up some 70 percent of fecal matter by weight. Since *E. coli* is an important member of the bacterial flora found in the human colon, and that as many as 50 percent of dairy and beef cattle herds carry the *E. coli* O157:h7 strain, the presence of *E. coli* is used as an indication of fecal contamination of water. Water supplies may be contaminated in several ways, including inadequate sewage treatment and runoff from irrigation of land where fertilizers containing animal waste have been used (Seidu *et al.*, 2015).

Along with the *E. coli* testing of the creek, we performed XRF tests on sediment samples taken from the creek banks. XRF spectrometer is an x-ray instrument used for non-destructive chemical analysis of rocks, minerals, sediments, and fluids. The XRF process tests samples for their levels of elements such as potassium, lead, uranium, arsenic, zircon, zinc, copper, nickel, iron, manganese, chromium, vanadium, antimony, cadmium, aluminum, silicon, chlorine, and magnesium. The evaluation of major and trace elements in materials by XRF is done when radiation from the instrument knocks an electron out of the nucleus of an atom and one of the electrons from the shells falls into the nucleus to replace it, discharging a set amount of energy that can be related to the element being detected (Suhailly *et al.*, 2014). Heavy metal enters the environment from natural and anthropogenic sources (Ali *et al.*, 2013). Sources of excess heavy metal deposition in soil include agriculture, mining, smelting, electroplating, and other industrial activities.

The Otter Creek Watershed includes 220 miles of stream and drains 124 square miles (IDEM 2014). The watershed includes portions of Clay, Parke, and Vigo county and includes parts of the following cities: North Terre Haute, Seelyville, Staunton, Brazil, and Carbon (Figure 1). The land in the watershed is mainly a mixture of forest and agriculture or pastureland that includes many head of cattle, horses, pigs, and sheep (Figure 2).

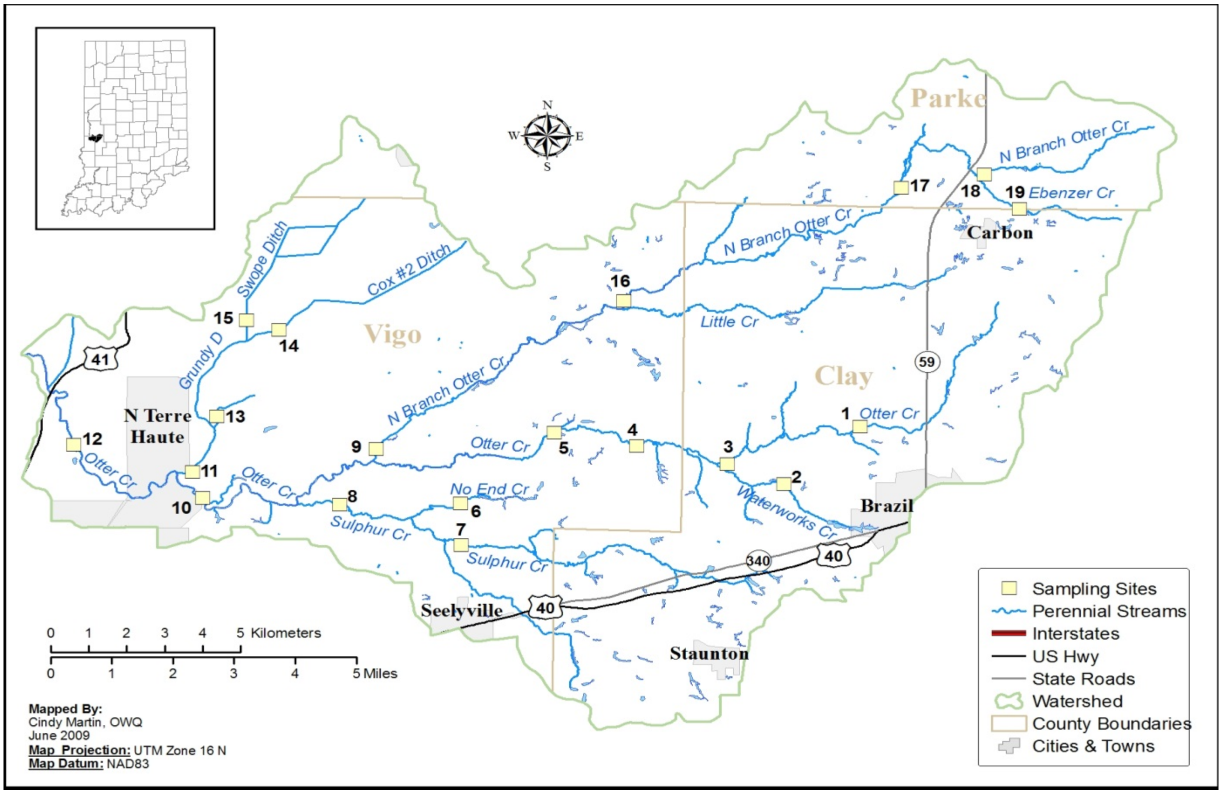


Figure 1: The Otter Creek Watershed including all of its named branches and the IDEM sampling locations (map created by Cindy Martin 2009).

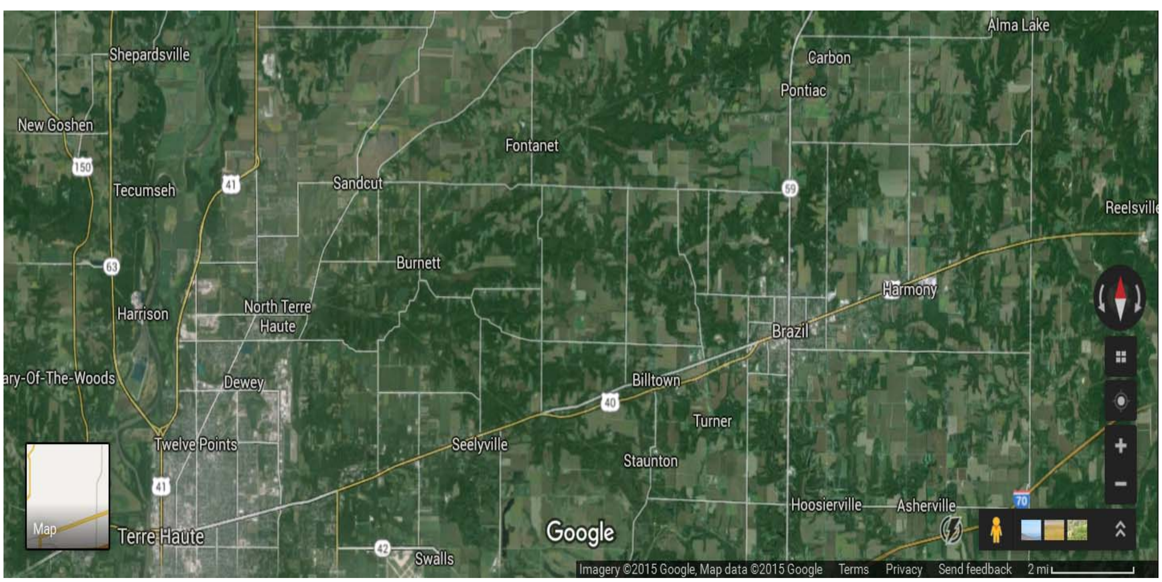


Figure 2: Google Maps image of the Otter Creek Watershed that shows the mix of forest and agricultural land.

IDEM has surveyed the streams in the Otter Creek Watershed in 2008 (Figure 3) and again in 2014 (Figure 4) for *E. coli* contamination and found a great increase from a few stretches of contamination in the stream to almost every stretch showing presence of *E. coli* (IDEM 2014). This Total Maximum Daily Load report from IDEM has raised enough concern about the watershed that a community group called the Ouabache Land Conservancy has brought together a group community organizations and individuals to apply for an IDEM 319 grant that was submitted in September 2015. The work that is reported on here was completed in an Indiana State University ENVI 460: Conservation and Sustainability course and later followed up with an independent research project from Carlos Montanez under the supervision of Dr. James H. Speer.

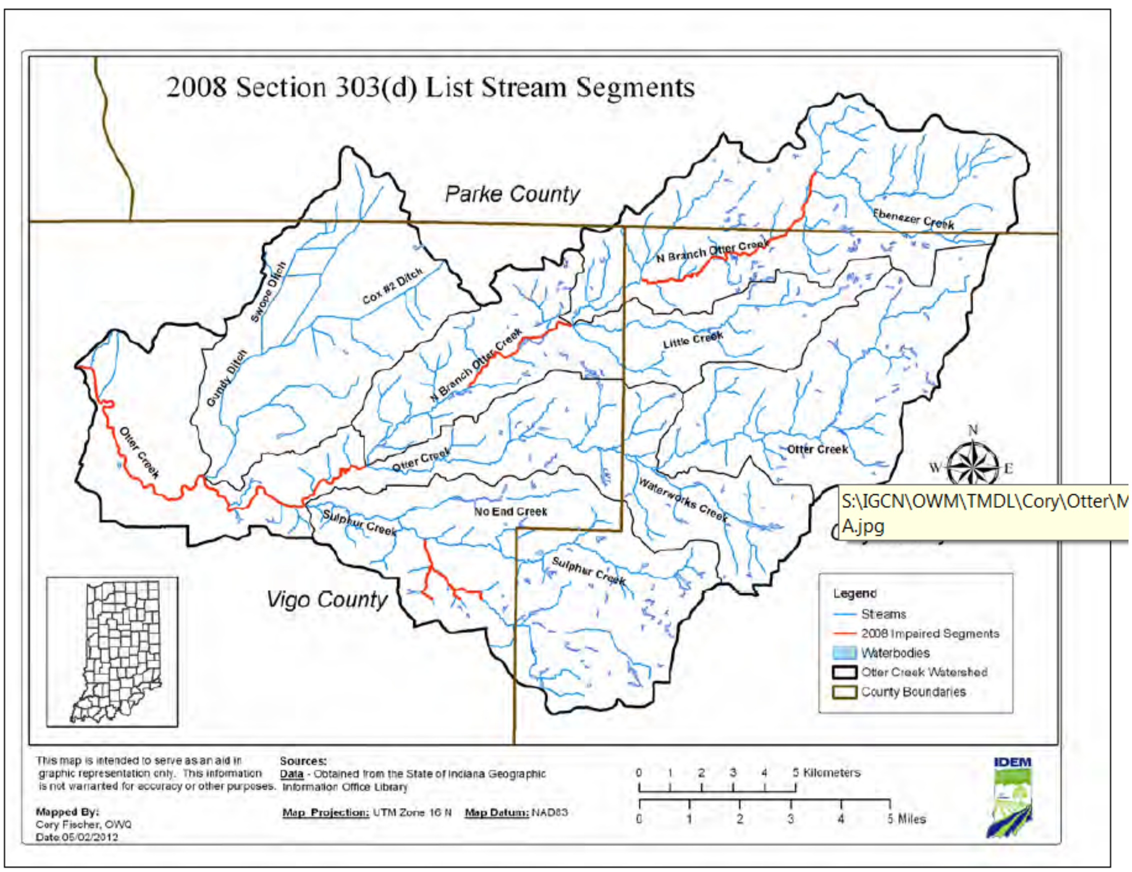


Figure 3: Streams listed on the 2008 Section 303(d) list in the Otter Creek Watershed of impaired stretched of Otter Creek from the IDEM 2014 TMDL Report.

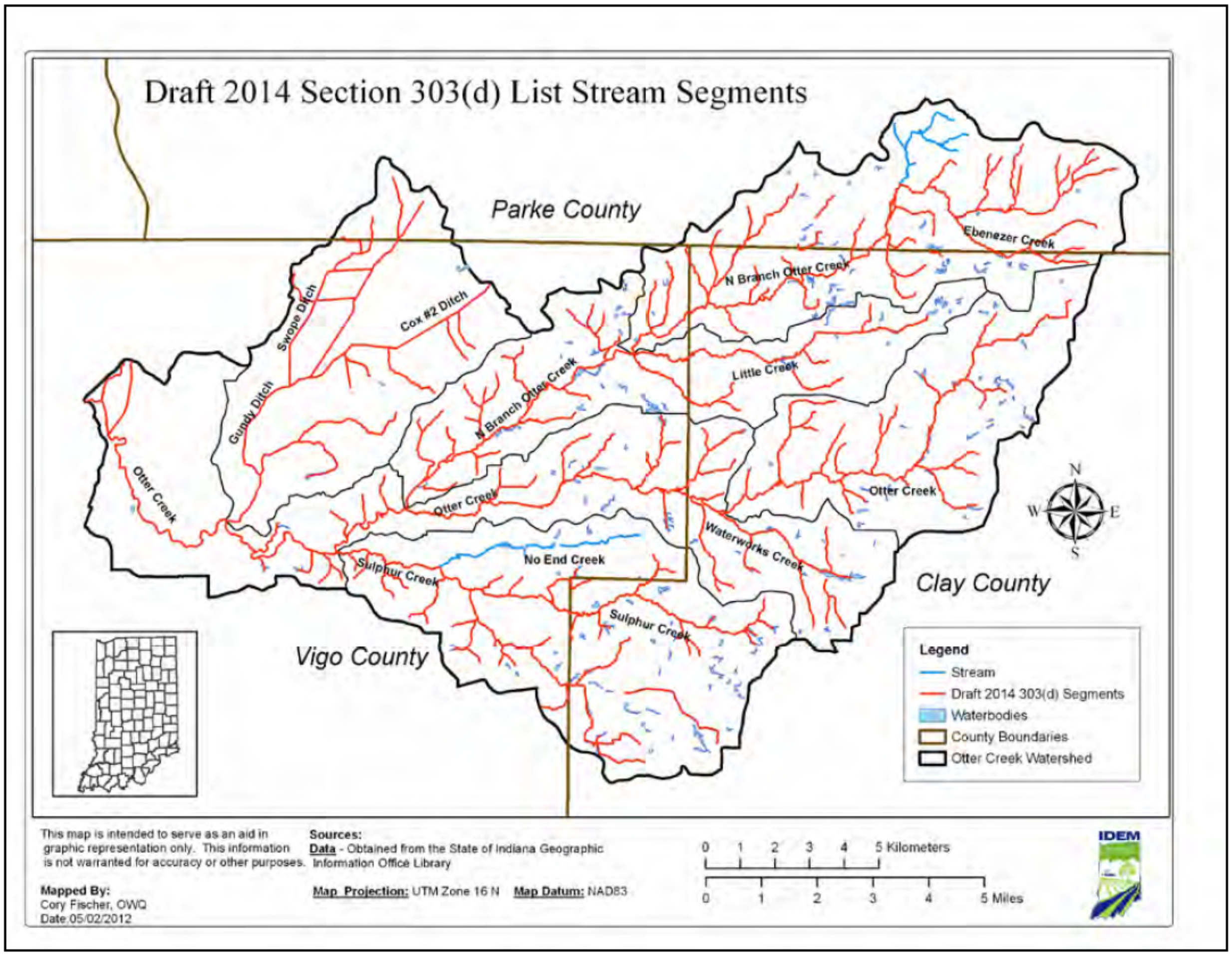

Figure 4: Streams listed on the 2014 Section 303(d) list in the Otter Creek Watershed of impaired stretched of Otter Creek from the IDEM 2014 TMDL Report.

**Methods**

In December 2015, we drove through much of the watershed, taking back roads that frequently crossed different stretches of Otter Creek and its tributaries. During these travels, we took photographs of many of the common observations along the drive using a Pentax WG-10 camera.

In spring 2015, we collected five water samples from six locations along the creek for *E. coli* testing in an presence/absence test. These sampling locations were  at road crossings at Clinton

Street, Rosedale Road, Roberts Road, Hasselburger Avenue, and Highway 41 which intersected with the creek. We put each of those samples in separate glass vial and added an *E. coli* testing tablet to the vial. To culture the sample, the vials had to be covered in aluminum foil and placed upright for 48 hours. After 48 hours, we uncovered the vials and compared the color of the sample to the color card. In general, red meant a negative result and yellow meant the sample was positive for *E. coli*.

We also collected six soil samples from the same locations as the water samples, but along the bank of the creek. We placed the samples in whirl-paks and used x-ray fluorescence (XRF) to test the heavy metals levels in each of the samples through the film of the bag. We compared these levels with the levels that are currently deemed as safe for each of the metal components. In December 2015, we collected four more sediment samples for XRF analysis and completed a dashboard survey of the watershed starting at Mill Pond and driving through back roads along branches of the creek back to the location where the North Branch of Otter Creek crosses Hwy 59 north of Carbon, Indiana (Figure 5).


Figure 5: We took samples with a soil auger, collected the top three inches in a whirl-pak bag and measured the elemental concentration through the bag with the XRF.

**Results**

During our dashboard survey of the area, we observed much forest area around the streams and extensive agricultural land as well (Figure 6). Many plots of land had livestock such as cattle, horses, miniature horses, and sheep. The density of animals was never observed to be very high. A railroad crosses through the area and a conservation club is located in the middle of the watershed.

Each of the six water samples were bright yellow, meaning they were positive for *E. coli* (Figure 7). *E. coli* has been found to be present in almost all of the stretches of Otter Creek in the IDEM 2014 report and we were able confirm that result with the presence of *E. coli* at each of our test sites in April 2015.


Figure 6: Images from our dashboard tour on December 4th, 2015. We observed a fairly stable watershed with much forested land and agriculture. We also saw many head of cattle, horses, and miniature horses, although the densities were not very high.

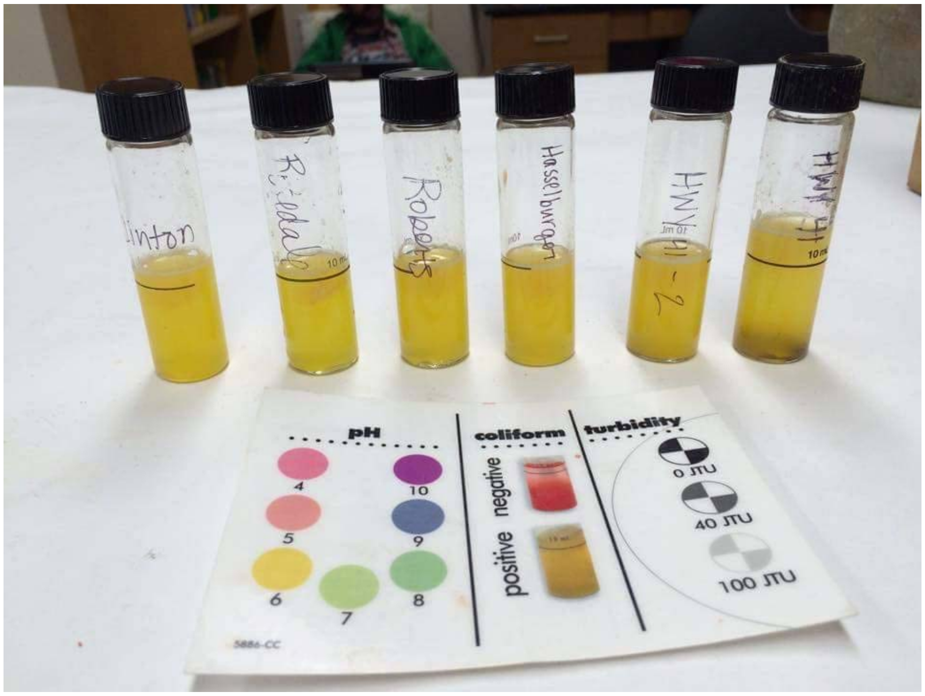


Figure 7: Each of the six sites tested positive for *E. coli* as represented by their yellow color.
The pattern of elemental concentrations was consistent across the sites with relatively high levels of Iron, Manganese, Zircon, Strontium, Zinc, and Rubidium (Figure 6). Most of the levels were below the EPA Critical Continuous Concentration and Critical Maximum Concentration levels suggesting that the elemental concentrations in Otter Creek are safe for aquatic life.

XRF samples were taken at 10 locations between the two sample expeditions. These samples were clumped together for the analysis in this paper. Concentrations were relatively higher for iron, zircon, manganese, strontium, zinc, and rubidium (Figure 8). None of the individual sample sites stood out from the others as being consistently higher than the others and concentrations did not seem to increase as we moved downstream.

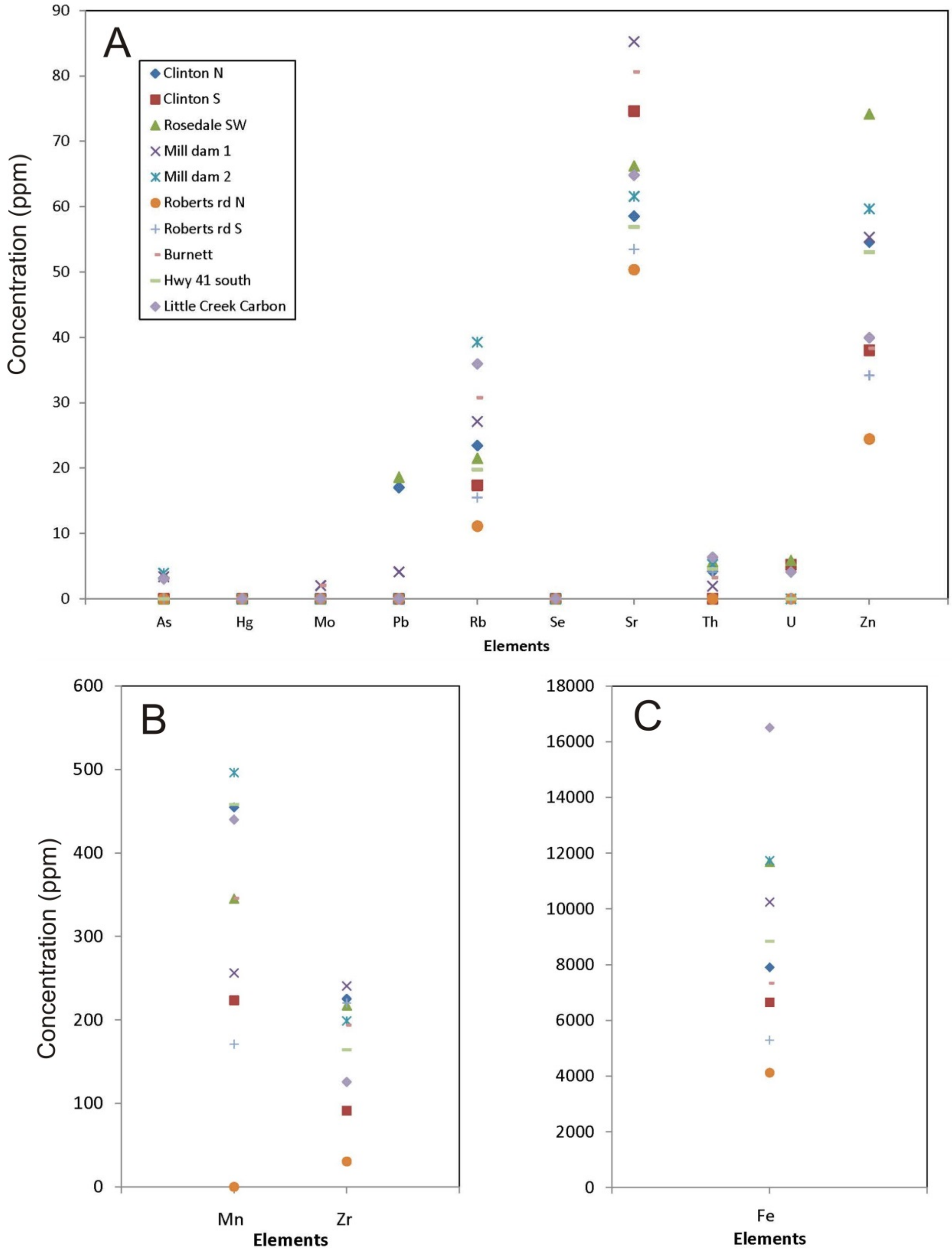


Figure 8: Elemental concentrations in the sediment along Otter Creek collected at rode crossings of the different branches of the creek. Sites are organized from west (downstream – top) to east (upstream – bottom). Samples were collected in April 2015 and December. A shows the main suite of elements and the other charts B (Mn and Zn) and C (Fe) were drawn with a different vertical axis because of the values for each element.

**Discussion**

As already noted, certain strains of *E. coli* can pose a significant threat to human health. Further tests would be required to deduce the amount of *E. coli* contamination and the strains involved in the contamination of Otter Creek. We also suggest that quantitative analysis of *E. coli* is likely to better locate the sources of the contaminant expecting that values would rise near the sources of pollution.

The higher levels of iron, zircon, manganese, strontium, zinc, and rubidium were found at all sites but most of these were below the EPA published values for Critical Continuous Concentration levels and are not a major concern for the watershed,  Although, any continuous consumption of heavy metals by humans can be a concern and should be monitored through child blood tests since children are most susceptible to the dangers of heavy metal poisoning. The signs and symptoms of lead poisoning in children may include developmental delay, learning difficulties, weight loss, abdominal pain, vomiting, constipation, and hearing loss. Although children are primarily at risk, lead poisoning is also dangerous for adults. Signs and symptoms in adults may include abdominal pain, constipation, declines in mental functioning, ain, numbness or tingling of the extremities, memory loss, reduced sperm count, and miscarriage or premature birth in pregnant women (Coles, et al., 2014). Eating or drinking too much zinc in a short period of time can lead to adverse health effects, such as stomach cramps, nausea and vomiting. Eating large amounts of zinc for longer periods may cause anemia, nervous system disorders, damage to the pancreas and lowered levels of “good” cholesterol. There is no evidence that zinc causes cancer in humans (Zhan, et al., 2014). Complications that can arise from ingesting too much iron include chronic fatigue, joint pain, liver disease, irregular heart rhythm, heart attack or heart failure, hair loss, or infertility (Jeż-Walkowiak, et al., 2015).

**Conclusions**

From our study, we concluded that Otter Creek is indeed contaminated with *E. coli*, but further tests would be required to determine the amount, source, and strain type of the contamination. These further tests should include analysis of the strain of *E. coli* and quantitative analysis of *E. coli* at each sampling site that was collected by IDEM so that we can pinpoint higher concentrations of this bacteria to help direct us to the source of contamination. We should also realize that the source is true not a point source and simply an accumulation of due to small loads of manure from livestock throughout the watershed. The XRF tests revealed that all of the sites within our study area are not contaminated by heavy metals. We observed many potential partners in the watershed including the Vigo County Conservation Club, Otter Creek Middle School, Terre Haute North Vigo High School, the local fire departments in each town, and the town mayors in Terre Haute, Brazil, Staunton, Seelyville, and Carbon. The condition of the watershed looks quite good, but raising awareness of Otter Creek for recreation and wildlife habitat should increase its value to the local residents who would then hopefully be willing to work to reduce the *E. coli* in the creek to improve its condition and increase quality of life in the area.

## References


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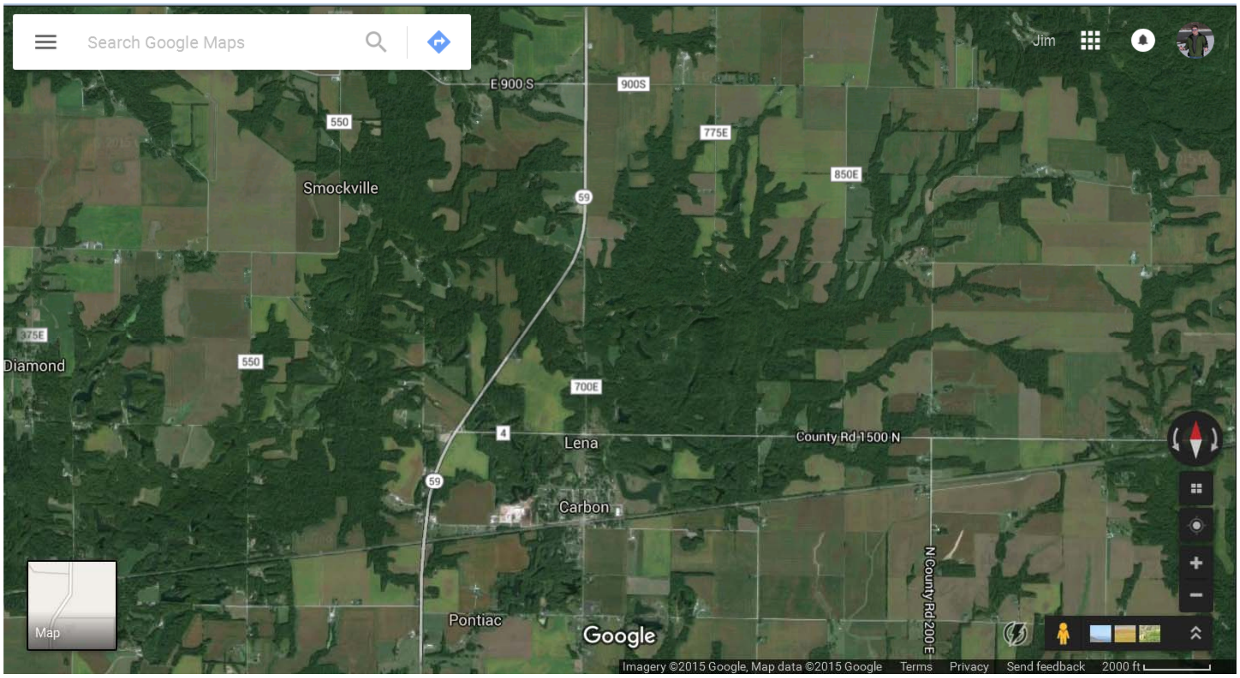
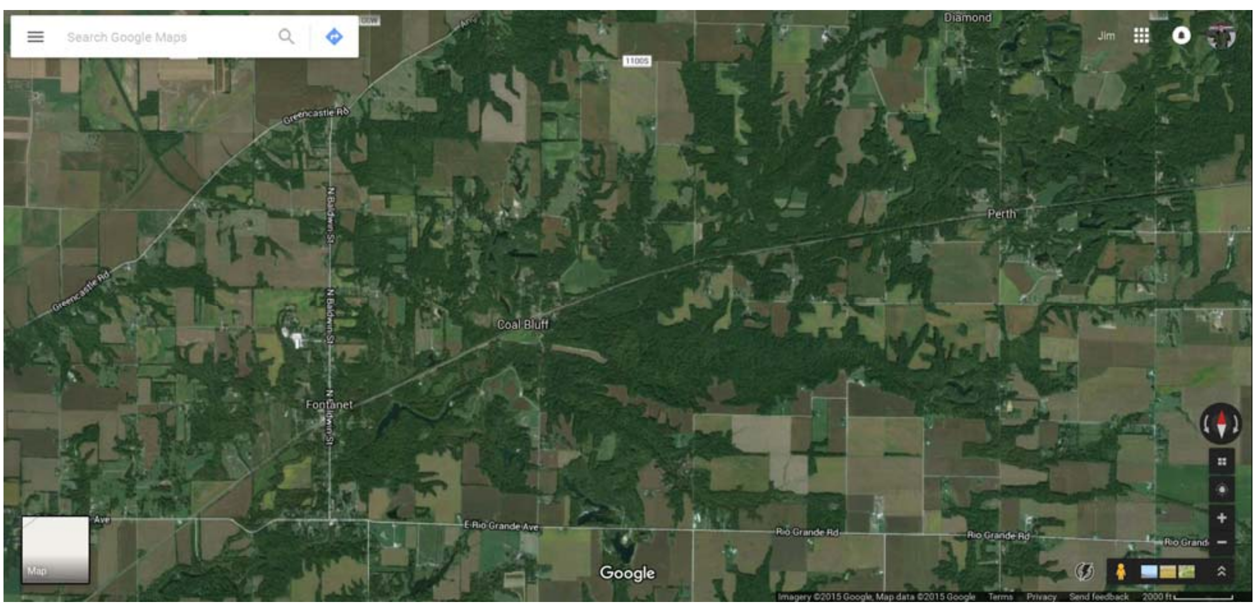
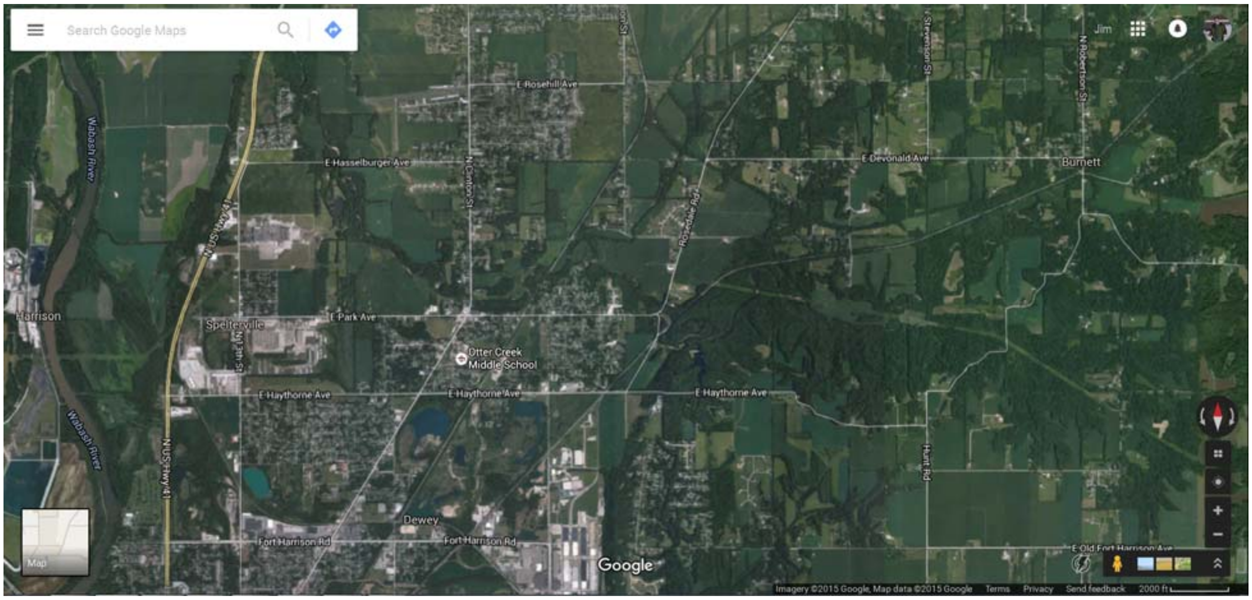
## Appendix A: Satelite images of the Otter Creek Watershed from Google Maps.





Search Google Maps
Jim
E Rosehill Ave
E Hasselburger Ave
E Devonald Ave
Burnett
N Stevenson St
N Robertson St
Wabash River
N US Hwy 41
Rosedale Rd
Harrison
Spelterville
E Park Ave
Otter Creek
Middle School
E Haythorne Ave
E Haythorne Ave
E Haythorne Ave
Wabash River
N US Hwy 41
Hunt Rd
Dewey
Fort Harrison Rd
Fort Harrison Rd
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**Appendix B: Graphics and tables from the IDEM 2014 report.**

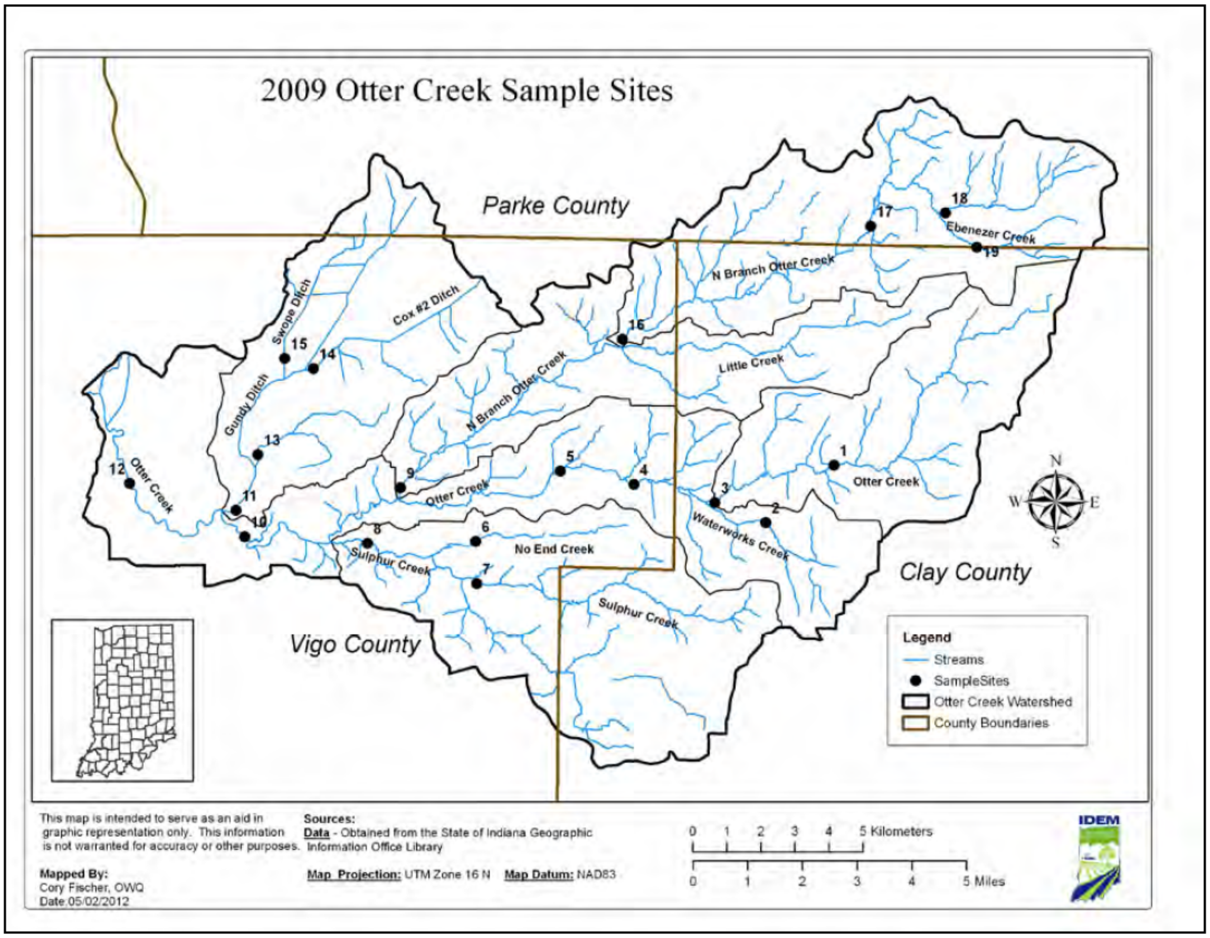


***Figure 3. Sampling Locations in 2009 Otter Creek Watershed TMDL***

From the IDEM 2013 TMDL Report

Table 2. Section 303(d) List Information for the Otter Creek Watershed for 2008 and 2014.

| Watershed (10-digit HUC) | Subwatershed (12-digit HUC) | Previous AUID 2008 | 2008 Section 303(d) Listed Impairment | New AUID 2014 | Updated Impairments to be Listed 2014 |
|---|---|---|---|---|---|
| 0512011104 | Headwaters Otter Creek 051201110401 | INB1132_T1021 | | INB1141_01 | *E. coli* |
| | North Branch Otter Creek 051201110402 | INB1134_02 | | INB1142_01 | *E. coli* |
| | | | | INB1142_01A | *E. coli* |
| | | | | INB1142_01B | *E. coli* |
| | | | | INB1142_01C | *E. coli* |
| | | INB1134_T1002 | | INB1142_01_T1001 | *E. coli* |
| | | INB1134_T1002 | | INB1142_01_T1002 | |
| | | INB1134_02 | *E. coli* | INB1142_01_T1003 | *E. coli* |
| | | INB1134_T1006 | | INB1142_01_T1004 | *E. coli* |
| | | INB1134_02 | *E. coli* | INB1142_01_T1005 | *E. coli* |
| | Little Creek-North Branch Otter Creek 051201110403 | INB1135_T1032 | *E. coli* | INB1143_01 | *E. coli* |
| | | INB1135_T1001 | | INB1143_T1001 | *E. coli* |
| | | | | INB1143_T1001A | *E. coli* |
| | | INB1135_T1003 | | INB1143_T1002 | *E. coli* |
| | Sulphur Creek 051201110404 | INB1136_00 | | INB1144_01 | *E. coli* |
| | | INB1136_T1033 | *E. coli,* Sulfates | INB1144_T1001 | *E. coli* |
| | | | | INB1144_T1001A | *E. coli* |
| | | INB1136_00 | | INB1144_T1002 | |
| | Gundy Ditch 051201110405 | INB1137_00 | | INB1145_01 | *E. coli* |
| | | INB1137_00 | | INB1145_T1001 | *E. coli* |
| | | INB1137_00 | | INB1145_T1002 | *E. coli* |
| | Wastewaters Creek-Otter Creek 051201110406 | INB1133_T1002 | | INB1146_01 | *E. coli* |
| | | | | INB1146_T1001 | *E. coli* |
| | | INB1138_T1023 | | INB1146_02 | *E. coli* |
| | | INB1138_T1023 | *E. coli*, pH, Sulfates, TDS | INB1146_03 | *E. coli* |

-Only the *E. coli* impairments are being addressed in this TMDL

From the IDEM 2013 TMDL Report

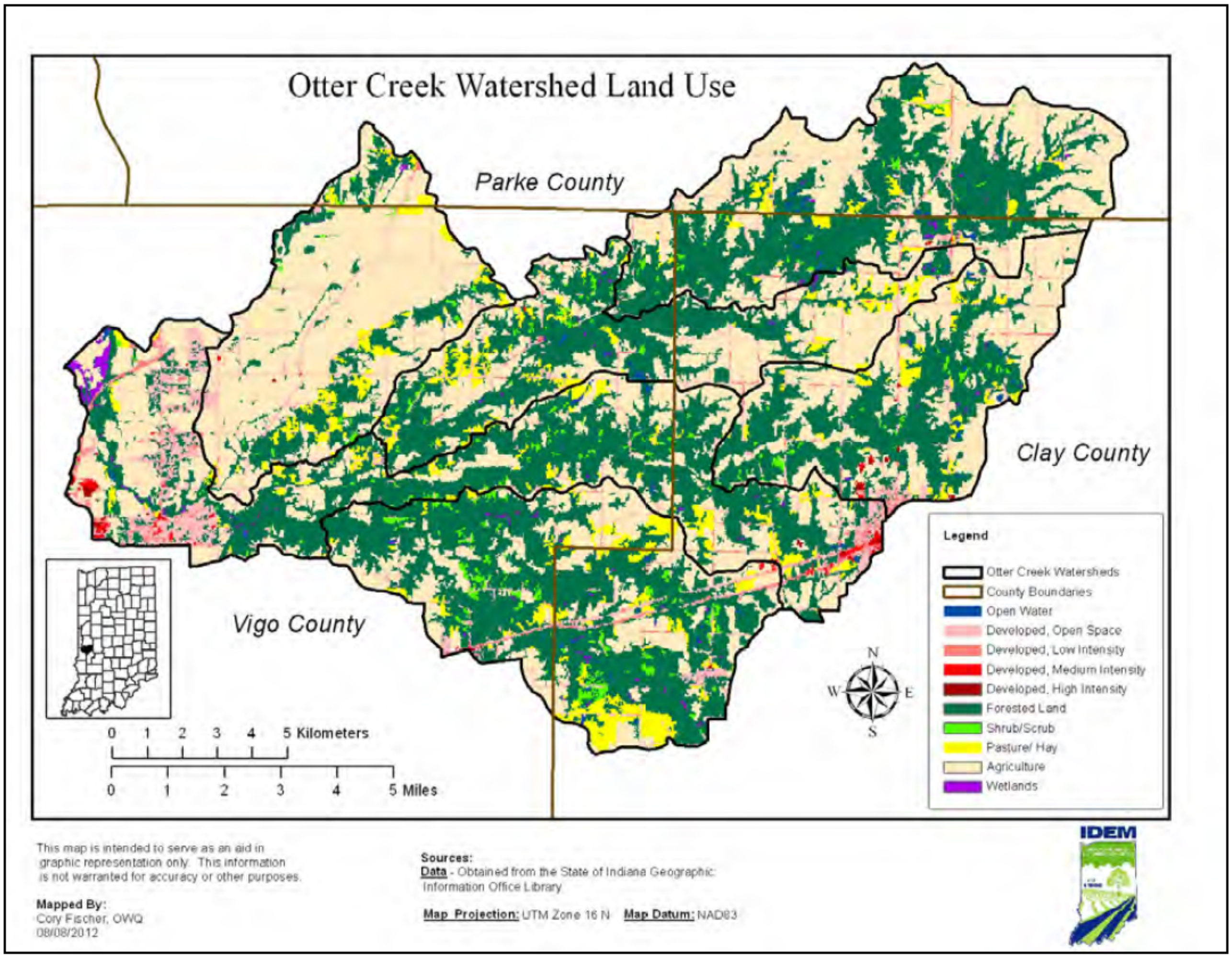


***Figure 6. Land Use in the Otter Creek Watershed***

From the IDEM 2013 TMDL Report

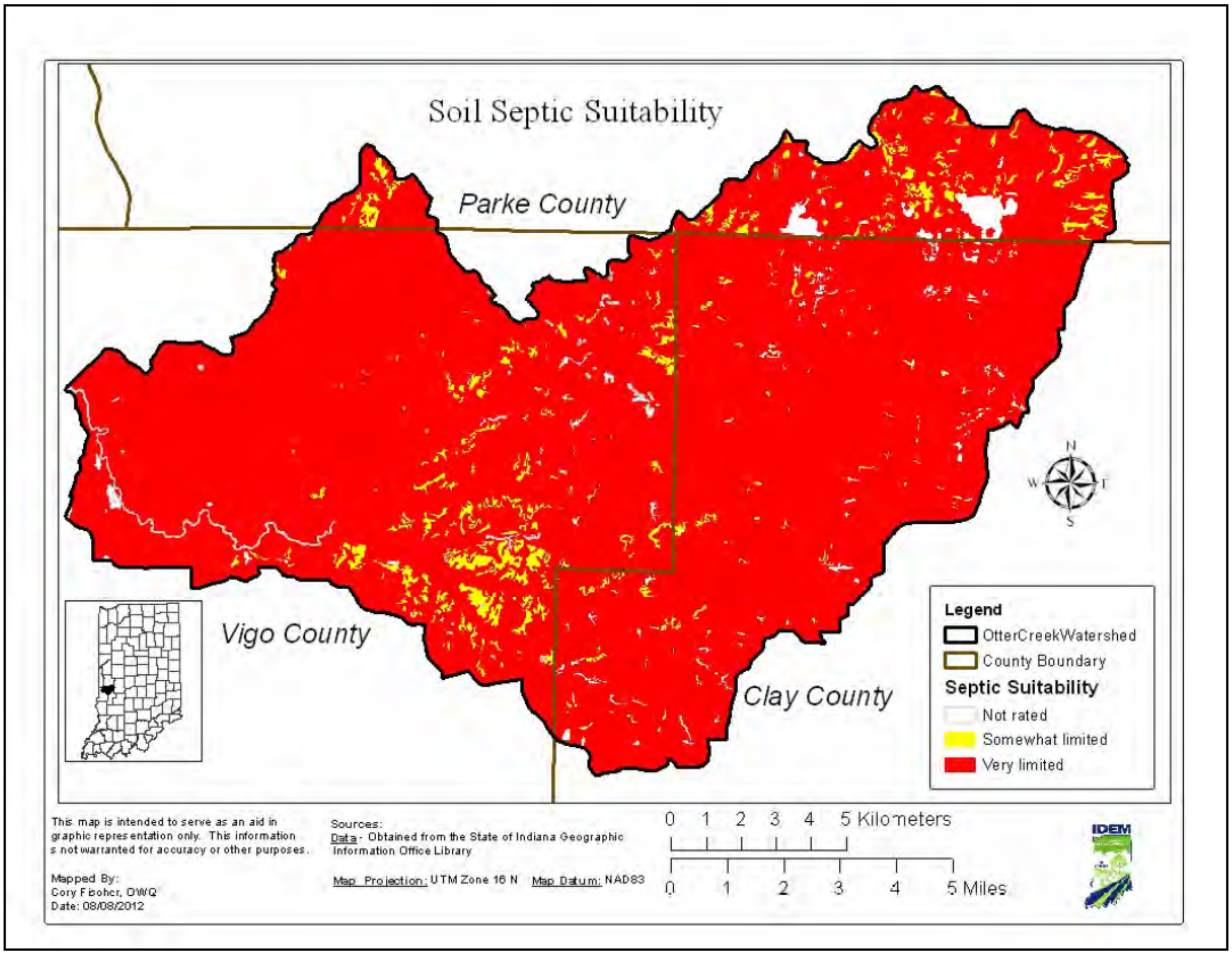


***Figure 11. Suitability of Soils for Septic Systems in the Otter Creek Watershed***

From the IDEM 2013 TMDL Report

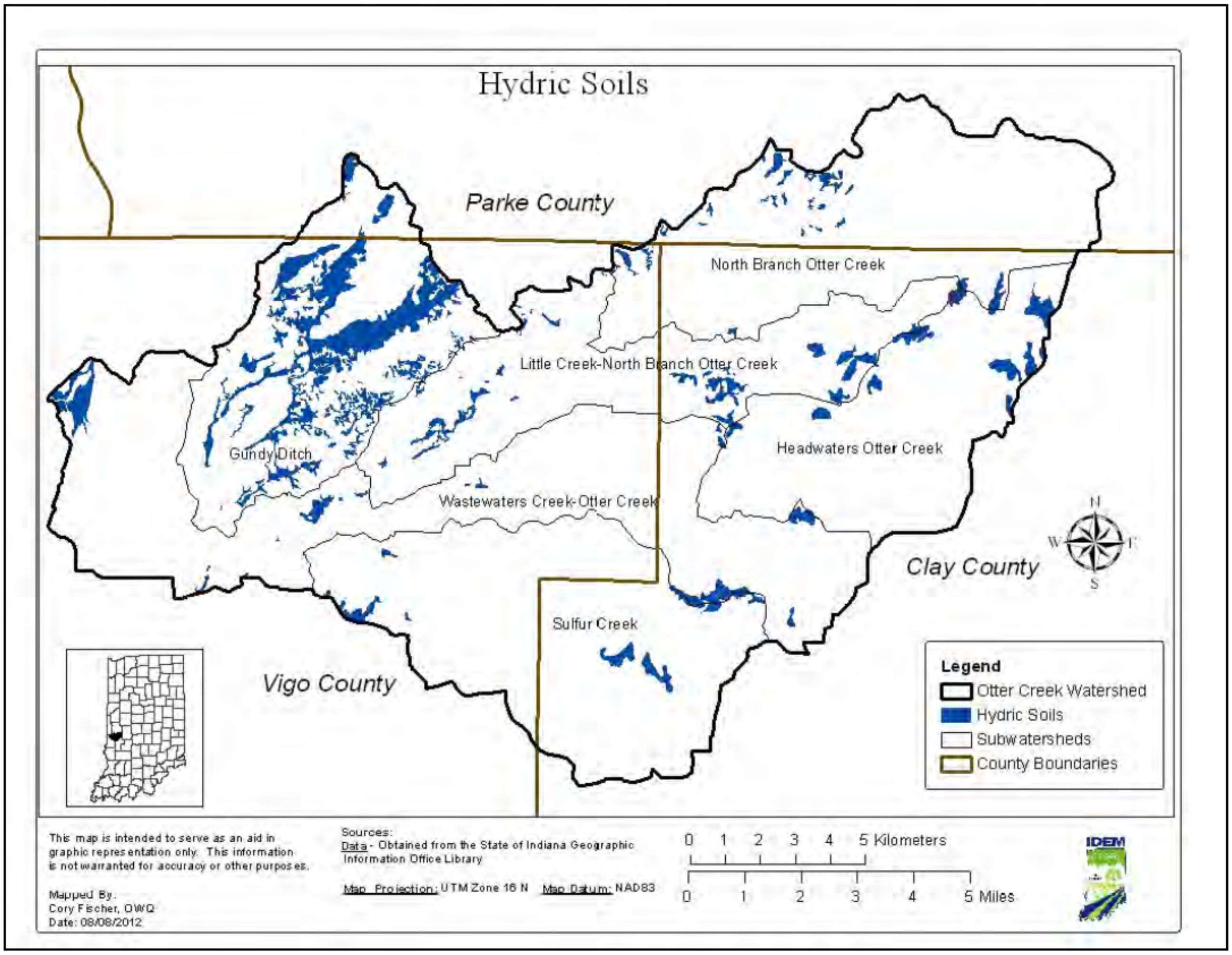


***Figure 12. Hydric Soils in the Otter Creek Watershed***

From the IDEM 2013 TMDL Report

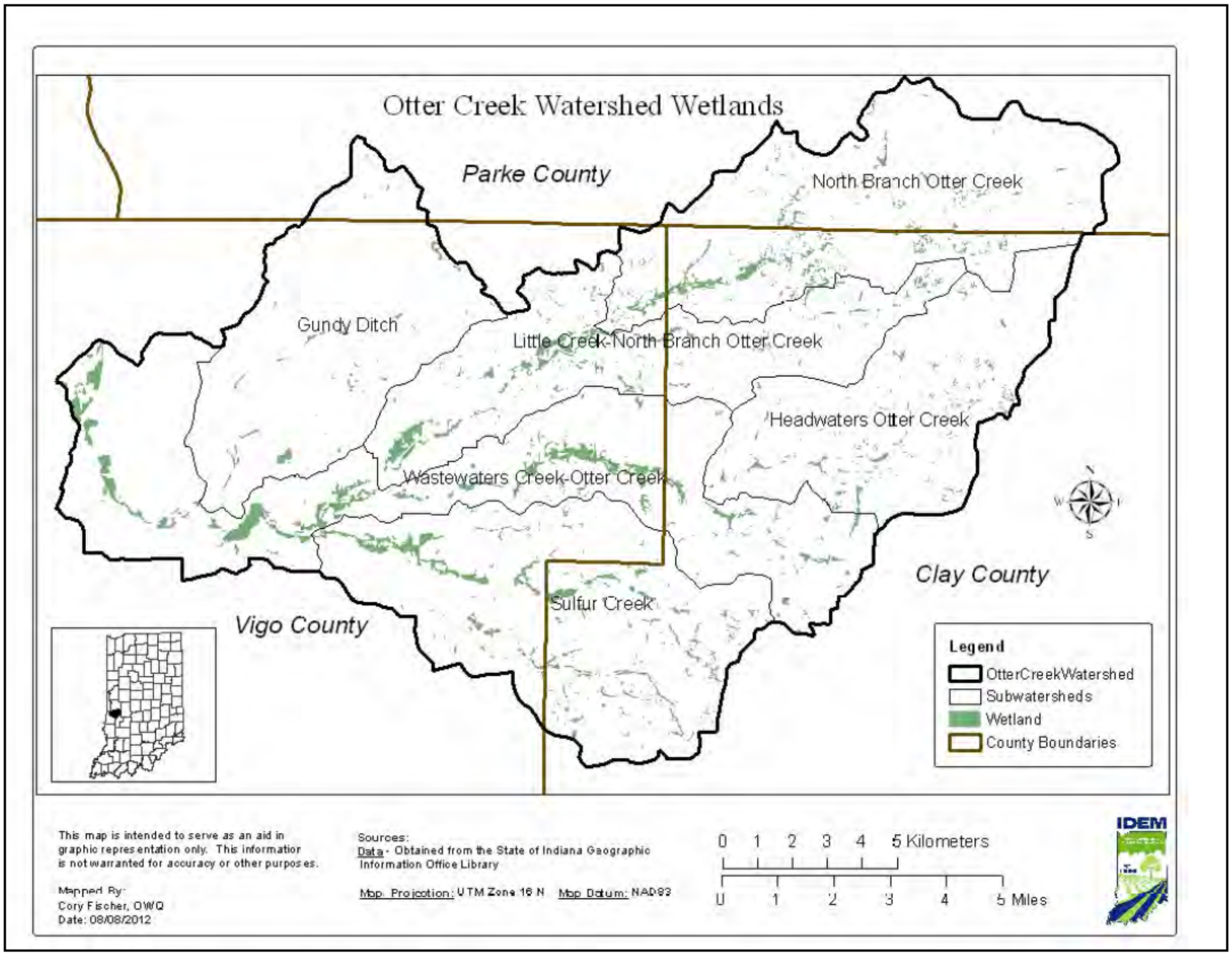


***Figure 13. Wetlands in Otter Creek Watershed***

From the IDEM 2013 TMDL Report

Table 8. HEL/Potential HEL Total Acres in the Counties in the Otter Creek Watershed

| County | HEL/Potential HEL Soil Types | Acres |
|---|---|---|
| Clay | Chetwynd Loam | 444.26 |
| | Cincinnati silt loam | 642.47 |
| | Fairpoint shaly silty clay loam | 2,380.15 |
| | Hickory loam | 4,501.65 |
| | Hickory silt loam | 389.58 |
| | Parke silt loam | 183.62 |
| | **Total:** | **8,541.73** |
| Parke | Cincinnati-Hickory complex | 538.87 |
| | Hennepin-Russell complex | 22.38 |
| | Hickory complex | 1,614.28 |
| | Negley soils | 9.35 |
| | Parke Silt Loam | 1.51 |
| | Princeton fine sandy loam | 17.54 |
| | Russell silt loam | 9.31 |
| | **Total:** | **2,213.24** |
| Vigo | Alford silt loam | 1,387.37 |
| | Cincinnati silt loam | 342.89 |
| | Fox clay loam | 17.79 |
| | Hickory loam | 4,504.71 |
| | Negley Loam | 579.67 |
| | Parke silt loam | 143.91 |
| | Princeton fine sandy loam | 334.46 |
| | Rodman gravelly loam | 88.57 |
| | Strip mines | 839.05 |
| | **Total:** | **8,238.42** |

From the IDEM 2013 TMDL Report

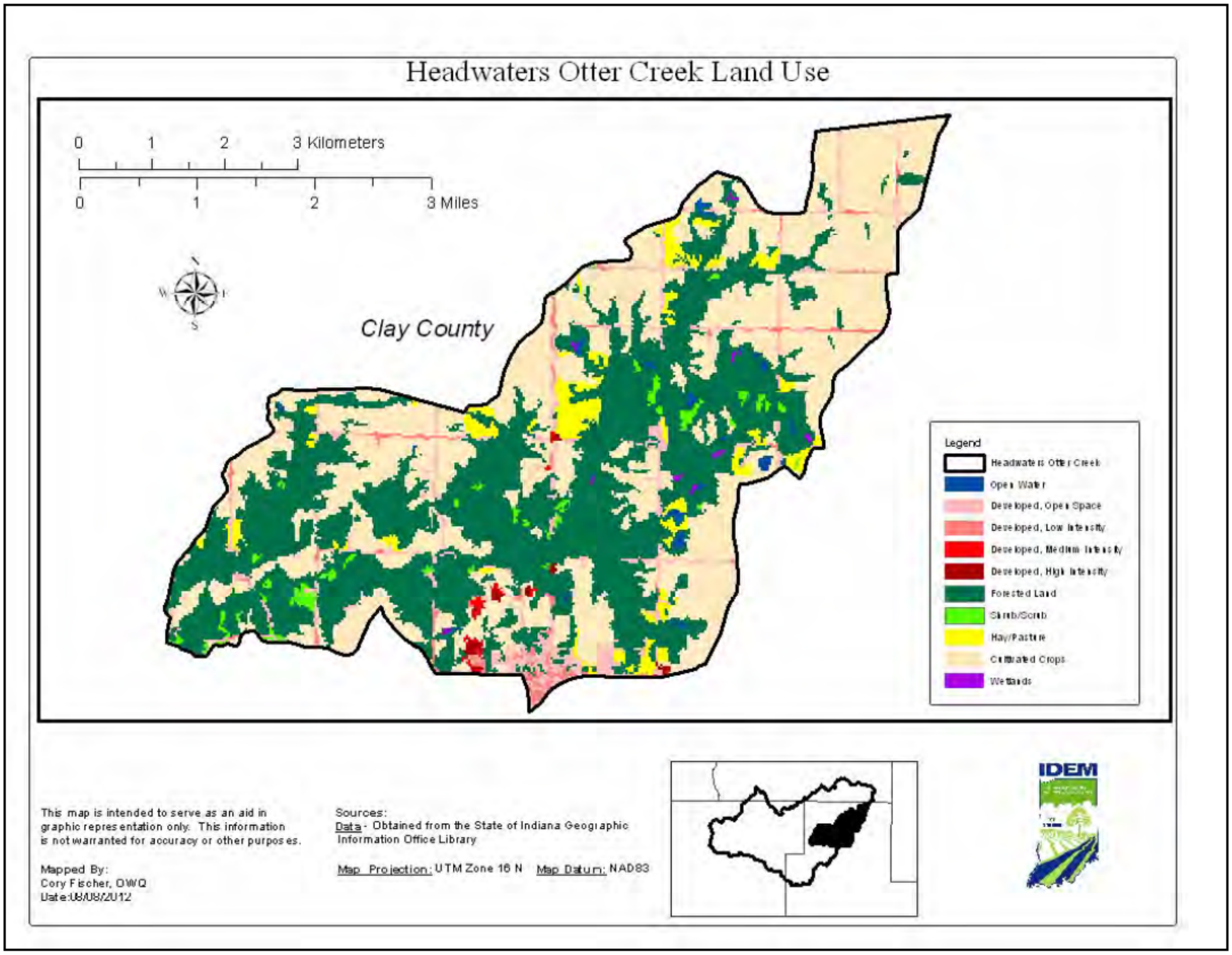


***Figure 15. Land Use in the Headwaters Otter Creek Subwatershed***

From the IDEM 2013 TMDL Report

Table 63. List of Potentially Suitable BMPs for the Otter Creek Watershed

| | Pollutant | | | Point Sources | | | | Nonpoint Sources | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Implementation Activities** | **Bacteria** | **Nutrients** | **Sediment** | **WWTPs** | **Regulated Stormwater Sources** | **CAFOs** | **Illicitly Connected "Straight Pipe" Systems** | **Cropland** | **Pastures and Livestock Operations** | **CFOs and AFOs** | **Streambank Erosion** | **Onsite Wastewater Treatment Systems** | **Wildlife/Domestic Pets** |
| Disinfection of primary effluent - chlorination | X | | | X | | | | | | | | | |
| Disinfection of primary effluent - ozonation | X | | | X | | | | | | | | | |
| Disinfection of primary effluent – UV disinfection | X | | | X | | | | | | | | | |
| Biological nutrient removal | | X | | X | | | | | | | | | |
| Inspection and maintenance | X | X | X | X | X | X | | | | | | X | |
| Outreach and education and training | X | X | X | X | X | X | X | X | X | X | X | X | X |
| System replacement | X | X | | | | | X | | | | | X | |
| Conservation tillage/residue management | X | X | X | | | | | X | | | | | |
| Cover crops | X | X | X | | | | | X | | | X | | |
| Filter strips | X | X | X | | X | X | | X | X | X | X | | |
| Grassed waterways | X | | X | | | X | | X | | X | X | | |
| Riparian forested/herbaceous buffers | X | X | X | | | X | | X | X | X | X | | X |
| Manure handling, storage, treatment, and disposal | X | X | | | | X | | | | X | | | |
| Composting | X | X | | | X | | | | | | | | |
| Alternative watering systems | X | | X | | | X | | | X | X | X | | |
| Stream fencing (animal exclusion) | X | X | X | | | X | | | X | | X | | |
| Prescribed grazing | X | X | X | | | | | | X | | X | | |
| Conservation easements | X | X | X | | | | | | | | | | |
| Two-stage ditches | | X | X | | | | | | | | | | |
| Rain barrel | | X | X | | X | | | | | | | | |
| Rain garden | | X | X | | X | | | | | | | | |
| Street rain garden | | X | X | | X | | | | | | | | |
| Block bioretention | | X | X | | X | | | | | | | | |
| Regional bioretention | | X | X | | X | | | | | | | | |
| Porous pavement | | X | X | | X | | | | | | | | |
| Green alley | | X | X | | | | | | | | | | |
| Green roof | | X | X | | X | | | | | | | | |
| Levee or dike modification or removal | | X | X | | | | | | | | | | |

From the IDEM 2013 TMDL Report

| Implementation Activities | Pollutant | | | Point Sources | | | | Nonpoint Sources | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bacteria | Nutrients | Sediment | WWTPs | Regulated Stormwater Sources | CAFOs | Illicitly Connected “Straight Pipe” Systems | Cropland | Pastures and Livestock Operations | CFOs and AFOs | Streambank Erosion | Onsite Wastewater Treatment Systems | Wildlife/Domestic Pets |
| Stormwater planning and management | X | X | X | X | X | | | | | | X | X | X |
| Comprehensive Nutrient Management Plan | X | X | | | | | | X | | X | | | |
| Constructed Wetland | X | X | X | X | | | X | X | | | | | X |
| Critical Area Planting | | | X | | | | | | X | | X | | |
| Drainage Water Management | | X | | | | | | X | | | | | |
| Heavy Use Area Pad | X | | X | | | | | | X | | | | |
| Nutrient Management Plan | | X | | | | | | X | | | X | | |
| Terrace | | | X | | | | | X | | | | | |
| Land Reconstruction of Mined Land | | | X | | | | | | | | X | | |
| Sediment Basin | | X | X | | | | | | | | | | |
| Pasture and Hay Planting | X | X | X | | | | | X | X | X | X | | X |
| Streambank and Shoreline Protection | | | X | | | | | X | X | X | X | | X |
| Conservation Crop Rotation | | X | X | | | | | X | X | X | | | |
| Field Border | X | X | | | | | | X | X | X | | | X |
| Waste Treatment Lagoon | X | X | | | | X | | | X | X | | | |
| Conservation Crop Rotation | X | X | X | | | | | X | | | X | | |

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Table 64. Recommended Implementation Activities by Subwatershed

| Subwatershed | PPIA Rank | Potential Implementation Actions |
|---|---|---|
| Wastewaters Creek- Otter Creek | 1 | Outreach, education, and training |
| | | Manure handling, storage, treatment, and disposal |
| | | Comprehensive Nutrient Management Plan |
| | | Storm water planning and management |
| | | Conservation easements |
| Sulphur Creek | 2 | Outreach, education, and training |
| | | Manure handling, storage, treatment, and disposal |
| | | Comprehensive Nutrient Management Plan |
| | | Storm water planning and management |
| | | Grazing land management |
| North Branch Otter Creek | 3 | Outreach, education, and training |
| | | Filter strips |
| | | Septic System replacement |
| | | Stream fencing (animal exclusion) |
| | | Grazing land management |
| Gundy Ditch | 4 | Outreach, education, and training |
| | | Storm water planning and management |
| | | Septic System replacement |
| | | Grassed waterways |
| | | Stream fencing (animal exclusion) |
| Little Creek- North Branch Otter Creek | 5 | Outreach, education, and training |
| | | Filter strips |
| | | Septic System replacement |
| | | Grassed waterways |
| | | Stream fencing (animal exclusion) |
| Headwaters Otter Creek | 6 | Outreach, education, and training |
| | | Filter strips |
| | | Septic System replacement |
| | | Stream fencing (animal exclusion) |
| | | Grazing land management |

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Table 65. Summary of Programs Relevant to Sources in the Otter Creek Watershed

| Source | State NPDES program | Local agencies/programs | Section 319 program | Section 205(j) program | ISDA Division of Soil Conservation | IDNR Division of Fish and Wildlife | USDA's Conservation of Private Grazing Land Initiative | USDA's Conservation Reserve Program | USDA's Conservation Technical Assistance | USDA's Environmental Quality Incentives Program | USDA's Small Watershed Program and Flood Prevention Program | USDA's Watershed Surveys and Planning | USDA's Wetlands Reserve Program | USDA's Wildlife Habitat Incentives Program |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WWTPs and Industrial Facilities | X | | | | | | | | | | | | | |
| Regulated Storm water Sources | X | | | | | | | | | | | | | |
| Illicitly Connected "Straight Pipe" Systems | X | X | | | | | | | | | | | | |
| Cropland | | X | X | X | X | X | | X | X | X | X | X | X | |
| Pastures and Livestock Operations | | X | X | X | X | X | X | X | X | X | X | X | | |
| CFOs | X | | | | | X | | | | | | | | |
| Streambank Erosion | | X | X | X | X | X | X | | X | X | X | X | | |
| Onsite Wastewater Treatment Systems | | X | | | | | | | | | | | | |
| Wildlife/Domestic Pets | X | X | X | | | | | | | | | | | |
| In-stream Habitat | X | X | X | | | | | | | | | | | X |

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