The efficacy of fall cover crops as they relate to stream water quality: A paired watershed approach

Three-year report (2014-2016) for the Indiana Soybean Alliance and Indiana Corn Marketing Council

Manchester University, Environmental Studies Program

Principal Investigator: Jerry Sweeten, Ph.D.

Co-Principal Investigator: Herb Manifold, MS

Environmental Studies Scholar: Dylan Scott

Study Rationale:

Indiana is composed of approximately 23 million acres and prior to European settlement it is estimated that about 20 million acres of what is now Indiana was deciduous forest. The remaining 3 million acres consisted of lakes, streams, prairies and various types of wetlands. Today about 5 million acres of forests exist in the State with only about 25% of these forests in northern Indiana. Forests in the north are now relatively small fragmented woodlots rather than large continuous tracks of forests. Today the most continuous forests are found along stream corridors. In other words, as Indiana was being settled there were only small openings in the forest with unmodified watersheds and today there are only small fragments of forests with large expanses of row crop agriculture, highly modified streams, and urban landscapes. While these landscape-level changes since European settlement are well documented, there is no clear scientific account of the ecological/biological conditions that may have occurred prior to this period in history. This is especially true as it relates to stream ecosystems, water quality, and stream biota. Virtually all Indiana watersheds have been modified to some degree including headwater stream modifications and complex subsurface drains across agricultural landscapes. These modifications have contributed to drainage of more than 85% of the original wetlands in the State. These landscape level changes, however, have facilitated the development of a strong agricultural industry in Indiana and one of the best areas in the world to produce food and fiber. Unfortunately, there are external costs of the system as it now exists. Some challenges include excessive loss of soil and nutrients from upland fields along with major upland and instream modified habitats. The loss of this “natural capital” is not particularly good for long-term agricultural profitability, sustainability, soil health, or water quality.

The effects of this “leaky system” are manifest from headwater streams to receiving water bodies such as the Gulf of Mexico, glacial lakes and reservoirs. While stream ecosystem watershed-level issues associated with land use are scientifically identifiable and quantifiable, it has been more difficult to prescribe solutions (particularly for nonpoint source pollutants) that are economically viable and realistic at a temporal and spatial scale necessary to detect improvements in stream ecological integrity. It is unlikely streams in Indiana will ever become like those of pre-European settlement Indiana, however, through careful planning and good science it is realistic to precisely direct resources to those areas of a watershed that will result in the greatest improvement of water quality and improved biological integrity of streams and maintain or improve agricultural productivity. Over the recent past, there has been increased interest across natural resource agencies, agriculture producers, and the scientific community to examine the efficacy of soil and water conservation practices as they relate to nutrient loss (particularly nitrogen and phosphorus), soil erosion, soil health, and stream ecological integrity. While the ecological effects of excess nutrients in small streams are not well understood, it is clear that nutrients can have a dramatic effect on water quality once they enter a reservoir, lake or other receiving waterbody. The Gulf of Mexico and western basin of Lake Erie are two excellent examples. Excessive nitrogen and phosphorus in the Gulf of Mexico has resulted in thousands of square miles of hypoxic conditions with dissolved oxygen levels less than 2 mg/L and aquatic life is unable to exist. Similar effects of excess nitrogen and phosphorus in the western basin of Lake Erie are well documented with periodic significant cyanobacteria blooms and hypoxia. These blooms are well documented and the linked to nitrogen and phosphorus. Sediment in streams as a result of watershed modifications and/or upland soil erosion is perhaps better understood.

By volume sediment in streams continues to be the largest component of nonpoint source pollution with millions of tons of soil moving through stream channels annually. This inorganic sediment, whether suspended in the water column or settling as sedimentation is known to be associated with increased levels of phosphorus and with significant biological responses across many groups of organisms. Sedimentation is known to alter stream habitat and suspended sediment is known affect the early life-stages of sight-feeding fishes like smallmouth bass (*Micropterus dolomieu).* Perhaps the best way to categorize the stream sediment issue is as an "*Aquatic Dust Bowl*". Millions of tons of soil moves through Indiana streams annually. It is perhaps the forgotten pollutant.

Historically, prescribed soil and water conservation practices have focused on slowing the movement of soil and nutrients after they have become entrained and moving off-site. In other words, there is a clear tendency for nutrients and soil to move downward in the landscape and toward streams away from areas of prescribed agronomic benefit. Some examples include: two-stage ditches, grass waterways, buffer strips, and even subsurface drainage. More recently there is growing interest in technologies that keep soil and nutrients in place where they can best be utilized by crops and enhance soil health. One such practice is the use of fall cover crops that are planted during those portions of the year when conventional crops (corn and soybeans mostly) are not in production. While over the recent past the use of cover crops by producers has increased, they have not been widely adopted by most farmers. They are actually somewhat randomly distributed across the landscape making it difficult to quantify their effectiveness spatially and temporally.

In an effort to better understand the agronomic and ecological benefits of fall cover crops and other conservation practices, the purpose of this study is to maintain or advance agricultural productivity, measure export of nutrients and soil, and examine stream biota in two small agricultural watersheds less than 3,000 acres. Beargrass Creek watershed located in northern Indiana and a tributary to the Eel River has been designated as the treatment watershed in this study. The focus and intent is to promote and fund the application of fall cover crops and other conservation practices in Beargrass Creek watershed over a five year period. The second watershed, Pawpaw Creek is a reference watershed and left under "normal" agricultural practices as determined by the individual operator. This experimental design provides valuable data in regards to the current ecological condition of both watersheds and may provide sufficient data to illuminate the effectiveness of fall cover crops as they relate to nutrient and sediment export, and to document changes in the biotic community (fish and invertebrates). This data is consistent with the "Strategy to Reduce Nutrient Pollution through Adoption of Practices that Improve Soil Health and Reduce Nutrient Losses" .

There are a number of reasons why this study provides scientifically relevant data, facilitates awareness, and action regarding the efficacy of fall cover crops and other soil and water conservation practices as they relate to water quality (nutrient and sediment loads) and biological integrity of agricultural streams is important.

1. There is still spatial and temporal uncertainty and lack of scientific evidence that relates conservation practices with an emphasis on fall cover crops to stream ecological integrity.

2. Strong conservation partnerships link agricultural producers, Manchester University, Natural Resources Conservation Service (local and State level), Soil and Water Conservation Districts in Wabash and Miami Counties, Indiana State Association of Soil and Water Conservation Districts, United States Fish and Wildlife Service, Indiana Department of Natural Resources, and the Environmental Defense Fund.

3. Technical equipment was purchased through a grant from the Indiana State Association of SWCDs and is installed and functioning well. Manchester University Environmental Studies Program has the necessary additional equipment and expertise to monitor the fish and benthic macroinvertebrate communities.

4. Manchester University scientists and students have the expertise to provide accurate and unbiased data that will shed light on the efficacy of fall cover crops at this landscape resolution. We have on file a Quality Assurance Project Plan (QAPP) to insure data quality.

5. Cost share money through the Middle Eel River Initiative, Mississippi River Basin Initiative, and Lake and River Enhancement has been and is available to producers.

Materials and Methods

The two watersheds selected for this study are both tributaries of the Eel River in northern Indiana. They include the upper portions of Beargrass Creek (treatment watershed) and the upper portion of Pawpaw Creek (reference watershed) in Wabash County (Figure 1 and Table1 and Table 2). These watersheds were selected because of their spatial position and the fact that both of these streams are currently being monitored in the lower reaches near the confluence with the Eel River as part of a much larger watershed study being conducted by Manchester University on the Eel River. Consequently a five-year data set already exists for the lower portions of both of these streams. Data includes water chemistry(grab samples only), stream habitat, and fish community structure. The watersheds lie on the south side of the Eel River and at the northern edge of the Tipton Till Plain and part of the Eastern Cornbelt Ecoregion. Their landscape position along with interest from producers (we have strong partnerships with producers) makes them suitable for this experimental design. The streams within each watershed are monitored with time-integrated discrete ISCO 6712 water samplers during the months of May and June. The samplers are programmed to collect six water samples daily for analysis during the May-June period. During all other months (July-April), the first rain event that increases stream discharge will be analyzed unless it is too below freezing. Otherwise grab samples are collected weekly for analysis. Water samples are analyzed for total phosphorus, soluble reactive phosphorus, total nitrogen, Nitrate-nitrogen, Kejldahl Nitrogen, Total Nitrogen, and total suspended sediment (turbidity and gravimetrically). In addition, stream discharge has been calculated to determine nutrient and sediment loads. Rainfall along with air and water temperature is recorded once each 30 minutes during each day.

The Qualitative Habitat Evaluation Index (QHEI) and the Index of Biotic Integrity (IBI) for fish community assessment completed annually at 6 sites in Beargrass Creek and 9 sites in Pawpaw Creek (Figure 2).

Table 1. Land use statistics for Beargrass Creek Watershed at County Road 100 East in Wabash County, Indiana.

Beargrass Creek		
Watershed longest flow length: 12,136 ft Watershed average slope: 2.1 percent		
Watershed Area (acres)	2,489.2	
Land use	Soil group	Area(acres)
Agriculture	B	251.4
Agriculture	C	1,963.4
Agriculture	D	0.7
LD-Residential	B	10.8
LD-Residential	C	93.3
Grass/Pasture	B	1.4
Grass/Pasture	C	54
Forest	B	21.2
Forest	C	92.6
Total Area		2,489.2

Table 2. Land use statistics for Pawpaw Creek watershed located in Wabash County, Indiana.

Pawpaw Creek		
Watershed longest flow length: 11,086.4 feet Watershed average slope: 1.8 percent		
Watershed Area (acres)	1,652.6	
Land use	Soil group	Area(acres)
Agriculture	B	124.9
Agriculture	C	1,284.6
HD-Residential	C	2.7
LD-Residential	B	4.9
LD-Residential	C	75.5
Grass/Pasture	B	4.6
Grass/Pasture	C	56.8
Forest	B	14.8
Forest	C	83.4
Total Area		1,652

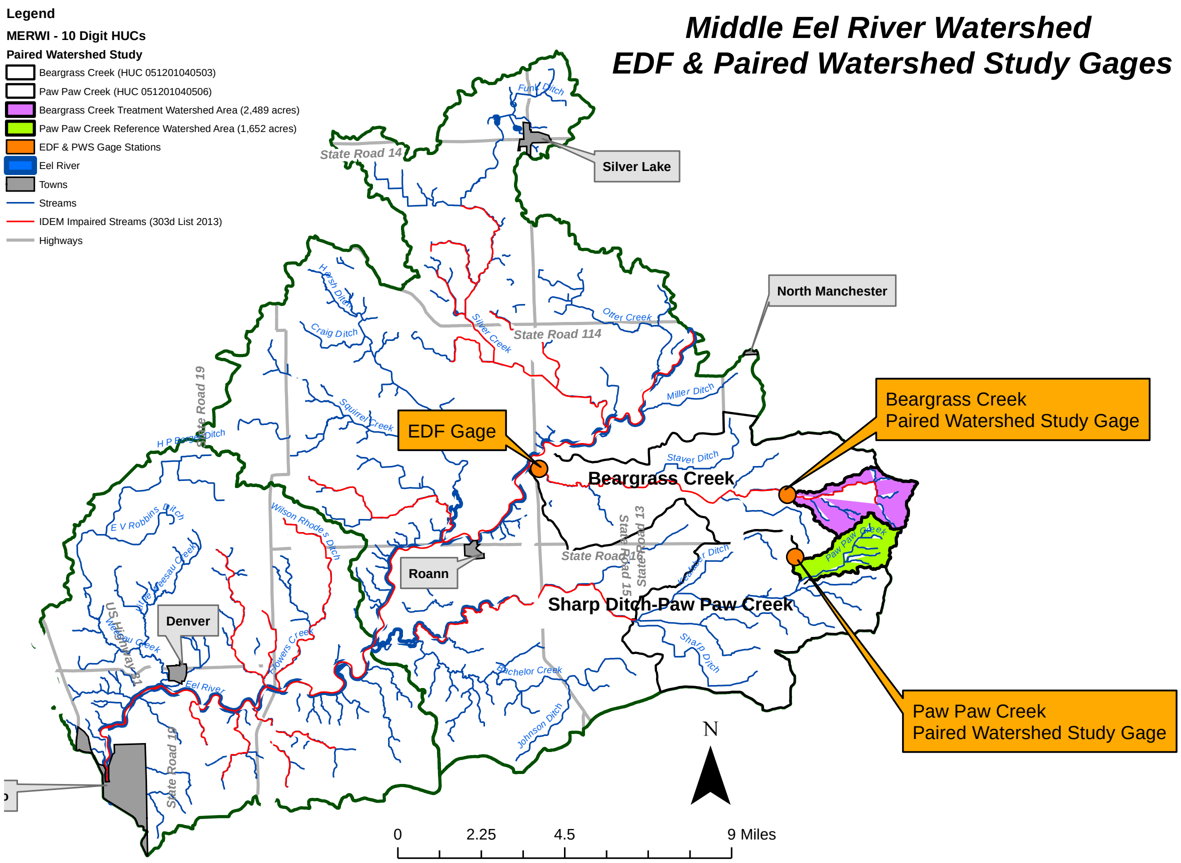

Figure 1. Beargrass Creek in Wabash County, Indiana encompasses 2,489 acres (purple). The most downstream portion of the watershed is at County Road 100 East. This is the watershed that will be treated with fall cover crops and other conservation practices. Pawpaw Creek watershed (green) will be the untreated watershed and is located just south of Beargrass Creek. Pawpaw Creek in Wabash County, Indiana encompasses 1,652 acres. The most downstream portion of the watershed is at County Road 500 North.

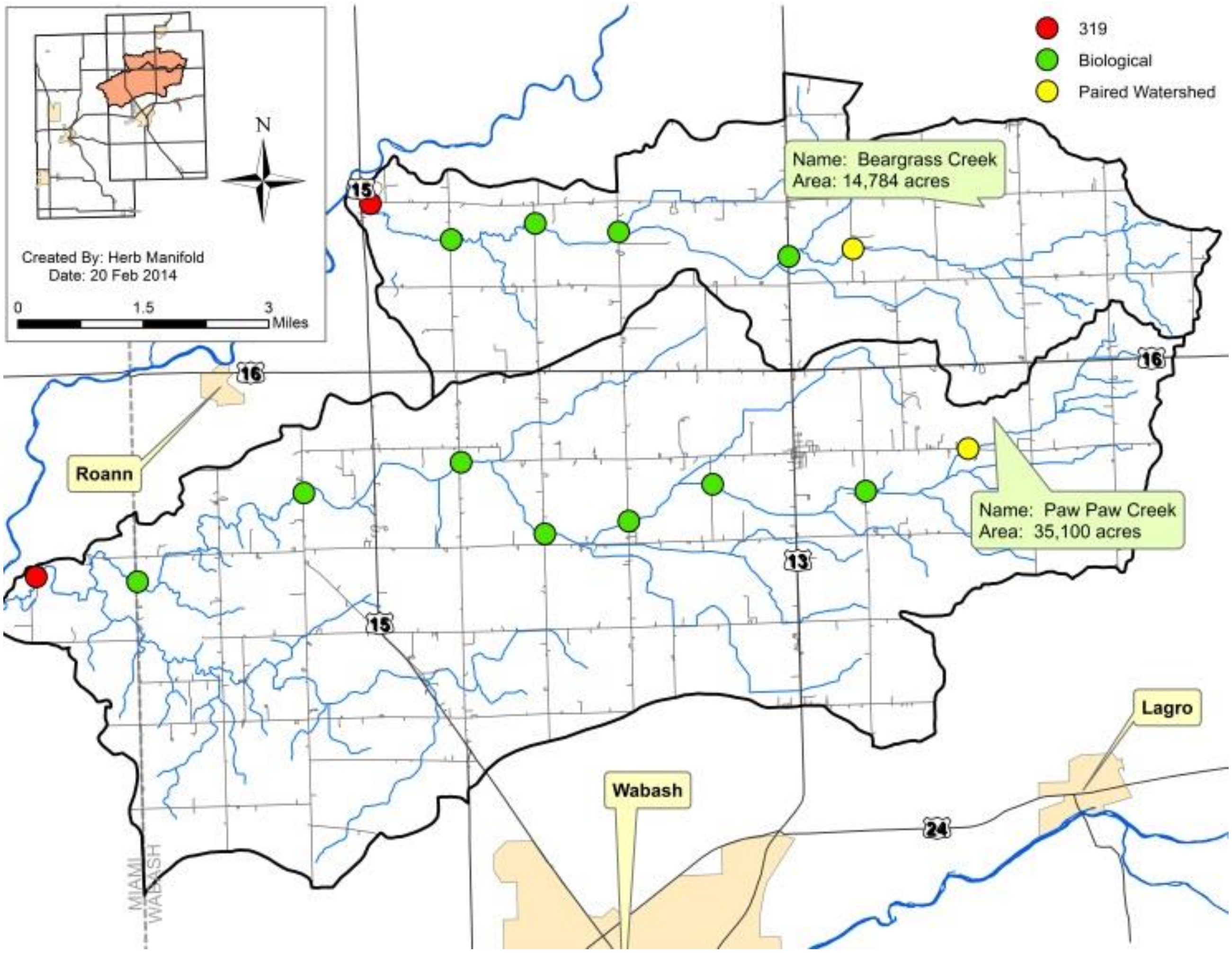

Figure 2. Beargrass watershed (top) and Pawpaw Creek watershed (bottom) with yellow circles that represent the paired watershed gage sites. The green and red circles represent each site where fish and habitat are sampled annually. Red circles are placed at the confluence.

2014-2016 Summary

This paired-watershed research initiative and the partnerships that have emerged has been nothing less than remarkable. I remember clearly the public meetings conducted to explain the project to producers in the watersheds. At first there was some concern about the possibility data could be used for potential new enforcement policies from State and Federal Resource Agencies, but these meetings along with individual on-farm meetings resulted in a high level of trust and interest. In fact, all three water quality gage stations in Beargrass Creek and Pawpaw Creek are located on private farm properties. The local land owners have even helped clear snow and mow grass at the sites to provide access to the gages. This level of trust and cooperation has built cultural bridges of understanding and the intangible human element of scientific research. For the Environmental Studies Program students, resources from this partnership has provided opportunities to learn about farm families who make a living through agriculture. They have had an opportunity to learn about the business of farming along with the myriad of challenges for farmers. Farmers have learned that college students from Manchester University are good young people working hard to understand the complexities of environmental challenges within the context of the human endeavor of agriculture. The relationship has been positive, cooperative, and thoughtful. It turns out farmers have been curious about what kind of fish live in the streams and how much nitrogen, phosphorus, and sediment is really flowing downstream. There have been several farmers visit our laboratory since we began the project.

In addition, the ISA and ICMC resources have been successfully leveraged toward additional grants. In 2014 a grant to help promote upland soil and water conservation was awarded for $15,000 from the United States Fish and Wildlife Service. In 2015 a second grant from the United States Fish and Wildlife Service was awarded for $60,000 to convert nearly 1,500 feet of a poorly functioning drainage ditch to a natural channel design stream (two-stage ditch) on a cooperating private farm (Figure 3). This a novel research project is just upstream from the gage station on Beargrass Creek and has provided an opportunity to examine stream habitat and fish communities before and after construction. We also examined bird and mammals present before construction. Pre-sample data have been collected and post-construction data will be collected in the summer of 2017 and 2018. Water quality parameters also being compared before and after construction. Prior to construction there was severe ditch bank erosion and season fish kills from high biological oxygen demand from tree leaves. The bank erosion has been repaired and there has been sufficient oxygen available for fish to be more than comfortable. The USFWS personnel commented that this continues to be the best paired watershed study in terms of broad-based partnerships and technical merit they are aware.

In 2013 the entire Beargrass Creek watershed (12-digit Hydrologic Unit Code) was selected as a model project for a Conservation Innovation Grant (CIG) administered by the Environmental Defense Fund (EDF). Beargrass Creek was selected because of existing strong partnerships with producers (including the Indiana Corn Marketing Council and Indiana Soybean Alliance), natural resource agencies, and Manchester University. This partnership with EDF and the CIG grant brought additional resources to Beargrass Creek and provided positive assistance across additional areas of need.

New mapping technologies and conservation assessment tools to identify high priority conservation areas, hydrology and geomorphology expertise to prescribe more accurately conservation efforts, and social science surveys to better understand why conservation efforts are adopted by producers (Figure 4). The role of Manchester University in this new partnership was to expand water quality monitoring in Beargrass Creek to include a downstream gage station near the confluence with the Eel River on Beargrass Creek (EDF gage site). This gage was installed during spring 2014 and about 7-miles downstream of the paired-watershed gage station. This additional data has helped to better understand the temporal and spatial nature of nutrient and sediment export from the watershed and a better understanding of the spatial nature of the biological community in both Beargrass Creek and Pawpaw Creek. The EDF partnership provided resources and expertise to make Beargrass Creek watershed a model of agriculture and environmental quality partnerships that is exemplary in the United States. This partnership along with additional new conservation dollars through Mississippi River Basin Initiative ($400,000) and Lake and River Enhancement (IDNR) ($60,000) increased the importance and visibility of the paired watershed project. All of this information about the paired watershed project was shared at a local manure management workshop in late summer 2014. There were nearly 75 producers present at the meeting and there was additional positive support and comments regarding our water quality work. Producers are fully supporting and clearly want to do the right thing. The biggest challenge at this point is to convince a couple of producers who farm in strategic areas of Beargrass Creek paired watershed area to enroll in the use of cover crops and other soil and water conservation efforts.

In 2015 Beargrass Creek was listed as a National Water Quality Initiative watershed by the Natural Resources Conservation Service. This designation provided additional conservation partnership dollars with local producers. In 2015 the paired watershed project along with other initiatives in the Eel basin received recognition nationally by the United States Fish and Wildlife Service. The recognition was in the top ten "watersheds to watch" in the United States as innovative conservation initiatives and partnerships.

In 2016 a grant was awarded from the Indiana Department of Environmental Management 319 Program for $160,000. This grant and financial award was designated directly to conservation cost-share dollars with farmers in Beargrass Creek watershed. We are currently in the middle of the distribution of these resources.

Perhaps one of the most telling water quality success stories that has grown out of all Eel River conservation efforts has been the reintroduction of the federally endangered clubshell mussel. It is unclear what or when clubshell mussels were extirpated from the Eel basin, but there are some dead shells that can be found in various locations. In the summer of 2014, 150 clubshell mussels were placed in the Eel River as part of a pilot study to see if they could survive for one year. When surveyed in 2015, 149 out of the 150 clubshell mussels were found still living. This led to acquisition of 3,000 mussels in 2016. This is a water quality success story. It may take decades before there is evidence of successful reproduction in this rare species.

Based on calculations from the National Fish Habitat Partnership Economic Model, the paired watershed project and partnership with ICMC and ISA has resulted in over $2.2 million of expenditures that resulted in 44.8 jobs and over $6.5 million economic benefit to the local community (Table 3).

Table 3. National Fish Habitat Partnership Economic Model projected calculations for economic impact of conservation grants in the Eel Basin and Paired-Watershed 2013-2016.

Expenditures	**Amount**
Technical Services	$2,176,000
Construction/Labor	$ 93,000
Total	$2,299,000
Results	**Amount**
Jobs	44.8
Total Sales	$4,283,188
Value Added	$2,245,373
Income	$1,829,726

Beargrass Creek and Pawpaw Creek are both typical agricultural watersheds with no urban influence. Both are approximately 85% row crop agriculture and there are many hog, chicken and cattle operations in the watersheds. At the upland Beargrass Creek gage site(treatment watershed), 750 water samples have been analyzed from 2014-2016. At the gage site near the confluence of the Eel River (EDF site), 550 water samples have been analyzed between 2014-2016. At the upland Pawpaw Creek gage site (reference watershed), 725 water samples have been analyzed from 2014-2016. There have been six Manchester University student technicians involved with this project and one Master's student from the University of Minnesota. Herb Manifold worked graduated through the Environmental Studies Program at Manchester University in 2012 and worked two years as the Environmental Studies Scholar (2012-2014). Herb assisted with the installation and early technical work on the paired-watershed research. In 2014 Herb was accepted into the graduate program at the University of Minnesota. His research examined nitrogen throughout Beargrass watershed. His thesis, *"Nitrogen Budget for Beargrass Creek Watershed: A Baseline Study for a 45 Percent Nitrogen Reduction Goal"* helped to set a target for nitrogen reduction in agricultural watersheds.

The paired watershed research initiative has been a remarkable journey. The initiative has provided opportunities in scientific research, teaching, public outreach, positive economic contribution, and opportunities to build a cultural conservation bridge between agriculture and environmental sciences directed toward stream ecological integrity. There is a common thread of care for the earth that sustains humankind notwithstanding slightly different cultural views of how to reach the goal of a strong and viable agricultural industry and ecologically healthy watersheds. These are not mutually exclusive. But for continued forward movement sustainable long-term financial resources will be required. Futuristic projects like Beargrass Creek and Pawpaw Creek will require decades of additional work that must be passed across generations.

<u>Conservation Partnerships:</u>

1. Indiana Association of Soil and Water Conservation Districts
2. Indiana Soy Bean Alliance
3. Indiana Corn Marketing Council
4. United States Fish and Wildlife Service
5. Ohio River Basin Fish Habitat Partnership
6. Environmental Defense Fund
7. Wabash County Soil and Water Conservation District
8. Natural Resources Conservation Service
9. United States Geological Survey
10. Agricultural Producers
11. Manchester University
12. Cargill Foundation
13. Indiana Department of Agriculture
14. Indiana Department of Natural Resources
15. KISTERS of North America
16. ACRES Inc.

Results

The results section of this report consists of tables and graphs that represent data summaries from 2014-2016. The interpretation of this data proves to be more of a challenge at this temporal and spatial scale, but I hope as additional data are collected over the next two years, and perhaps beyond, new patterns and trends will begin to emerge. Three years of data is less than a radar blip, but it is a start and provides a solid scientific approach to illuminate nature's secrets and responses to new and innovative management approaches.

Respectfully submitted by:

Jerry Sweeten

Jerry Sweeten, Ph.D.
Principal Investigator
Professor of Biology and Director of Environmental Studies
Manchester University
Email: jesweeten@manchester.edu
Phone: 260-982-5307

Figure 3. Beargrass Creek natural channel design reconstruction project completed in the fall 2016 and funded by the United States Fish and Wildlife Service.

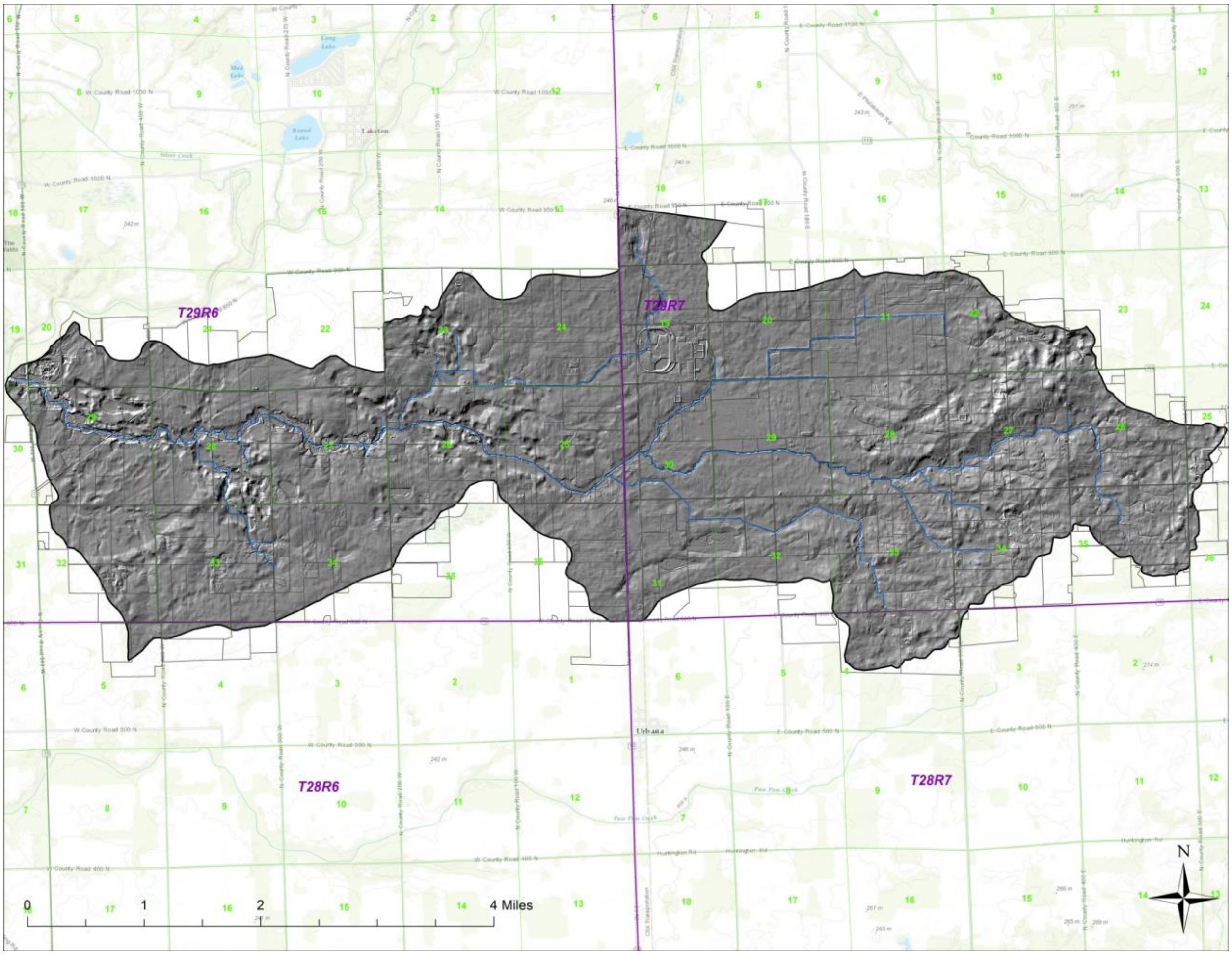

Figure 4. Experimental topographic map of Beargrass Creek watershed, 2015 and developed by Mark Tomer with Environmental Defense Fund CIG grant.

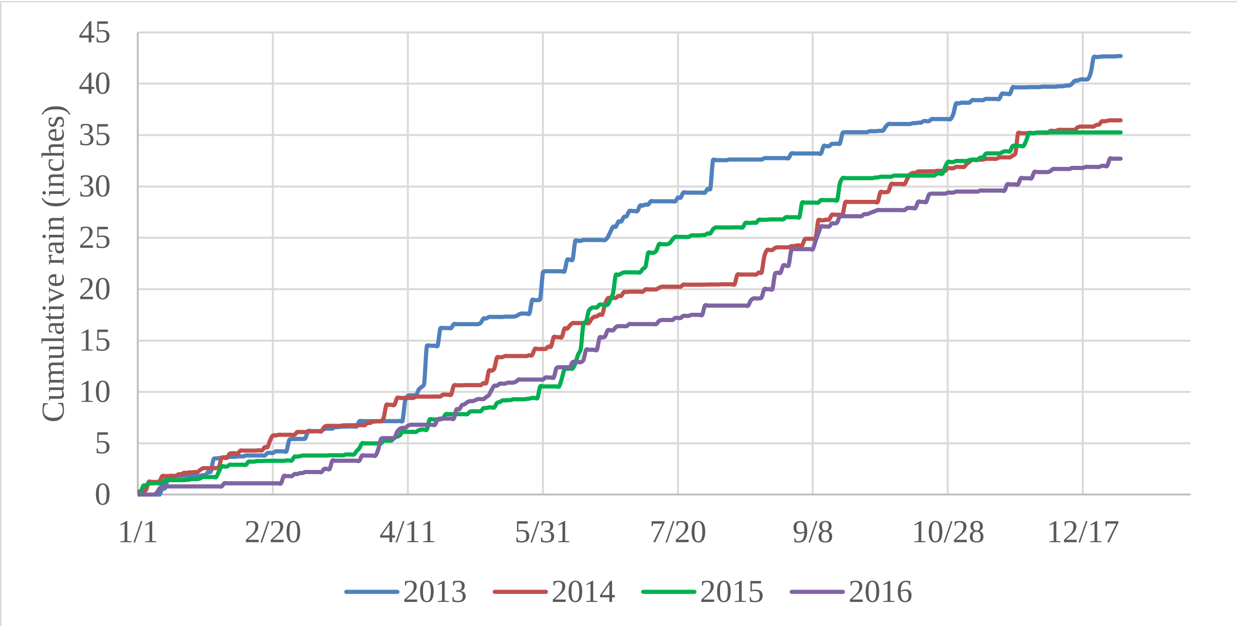

Figure 5. Cumulative rainfall in inches for both Beargrass Creek watershed (treatment) and Pawpaw Creek watershed (reference) from 2013-2016. Note the excessive wet year of 2013 that exceeded 40 inches of rainfall.

Table 3. Comparison of conservation practices, number of acres in conservation programs, % watershed coverage of conservation practices and mass of sediment, nitrogen and phosphorus conserved in 2014 in Beargrass Creek (treatment watershed) and Pawpaw Creek (reference watershed). Source of data, Indiana State Department of Agriculture.

Parameter	Amount (Beargrass Creek)	Amount (Pawpaw Creek)
Total Practices	105	11
Sediment	6,214 Tons	663 Tons
Nitrate-nitrogen	17,872 Pounds	1,896 Pounds
Total Phosphorus	8,821 Pounds	947 Pounds
Conservation Acres	3,646	397
Watershed Acres	14,784	1,660
% watershed conservation acres	25%	23%

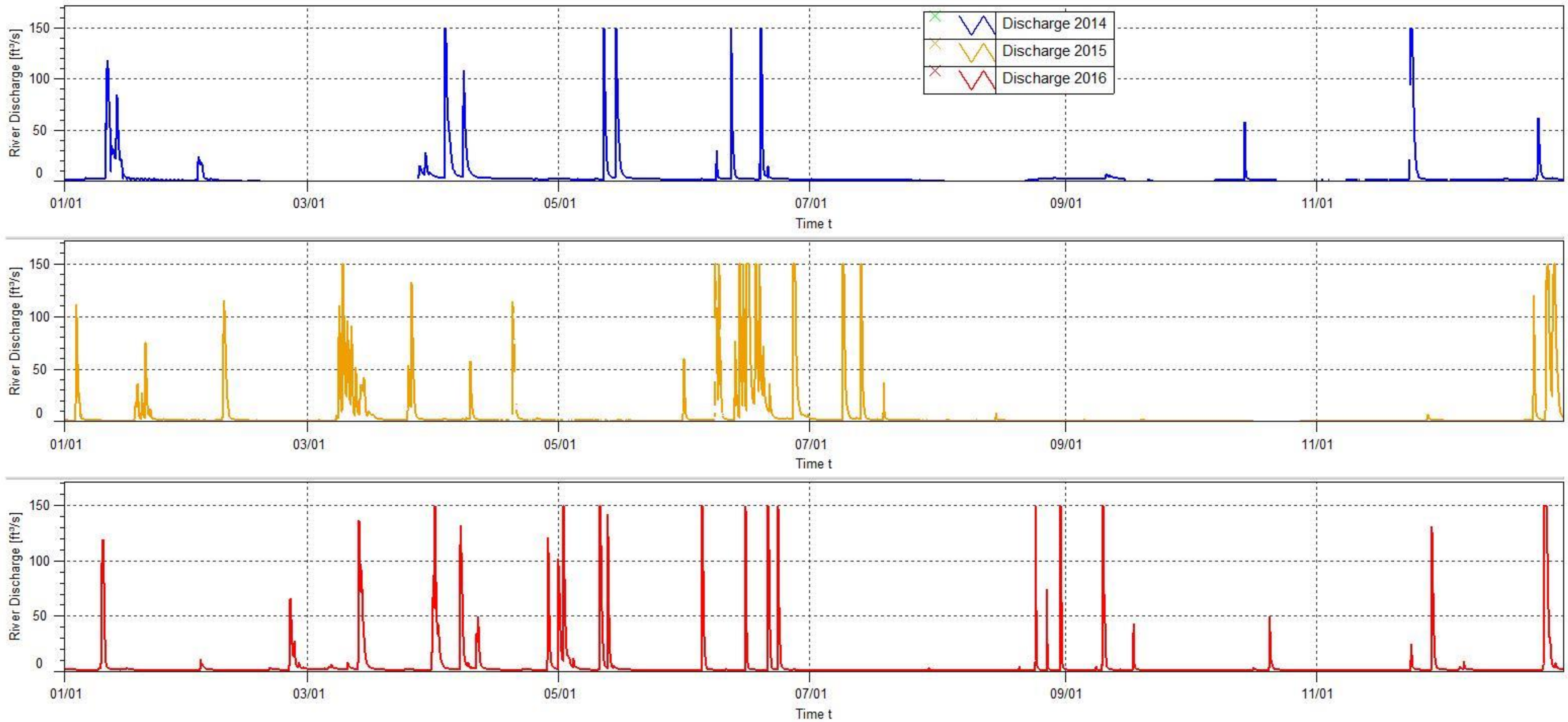

Figure 6. Hydrograph for Pawpaw Creek PWS. The top graph (blue line) is 2014, the middle graph (yellow line) is for 2015, and the bottom graph (red line) is for 2016. These graphs illustrate the temporal variability of stream discharge over the course of the study. One cubic foot equals 7.5 gallons.

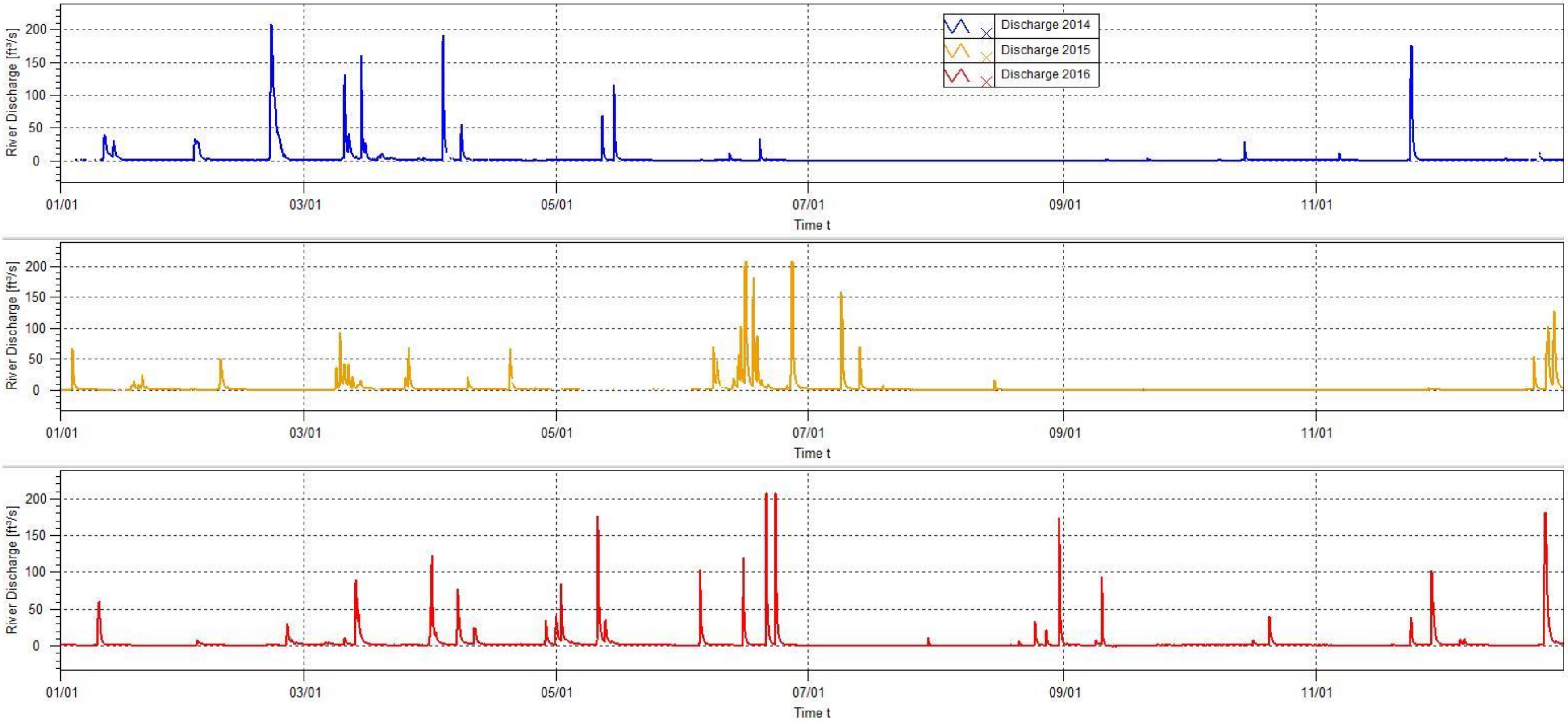

Figure 7. Hydrograph for Beargraass Creek PWS. The top graph (blue line) is 2014, the middle graph (yellow line) is for 2015, and the bottom graph (red line) is for 2016. These graphs illustrate the temporal variability of stream discharge over the course of the study. One cubic foot equals 7.5 gallons.

Water Chemistry and biological data for Beargrass Creek, 2014-2016

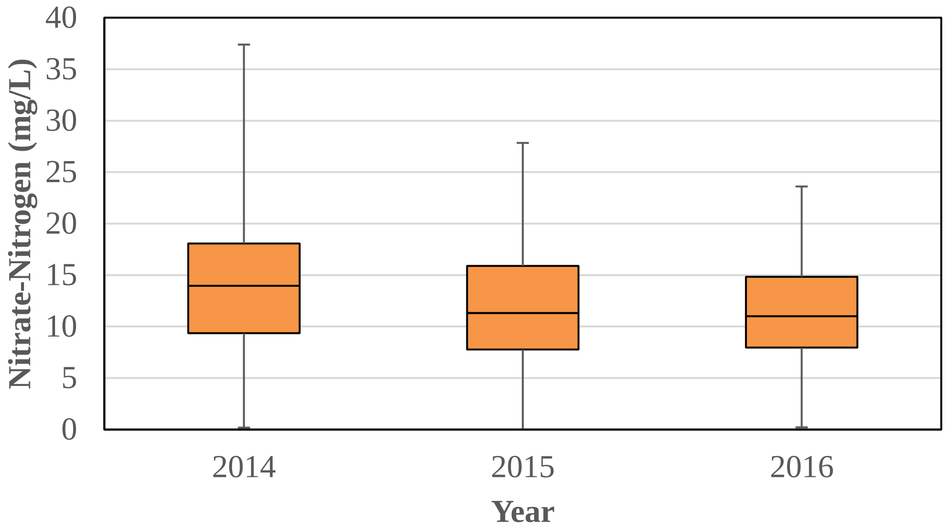

Figure 8. Box and whisker plots for Nitrate-nitrogen at the Beargrass PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the slight downward trend in the median and maximum values. Target value is 1.6 mg/L.

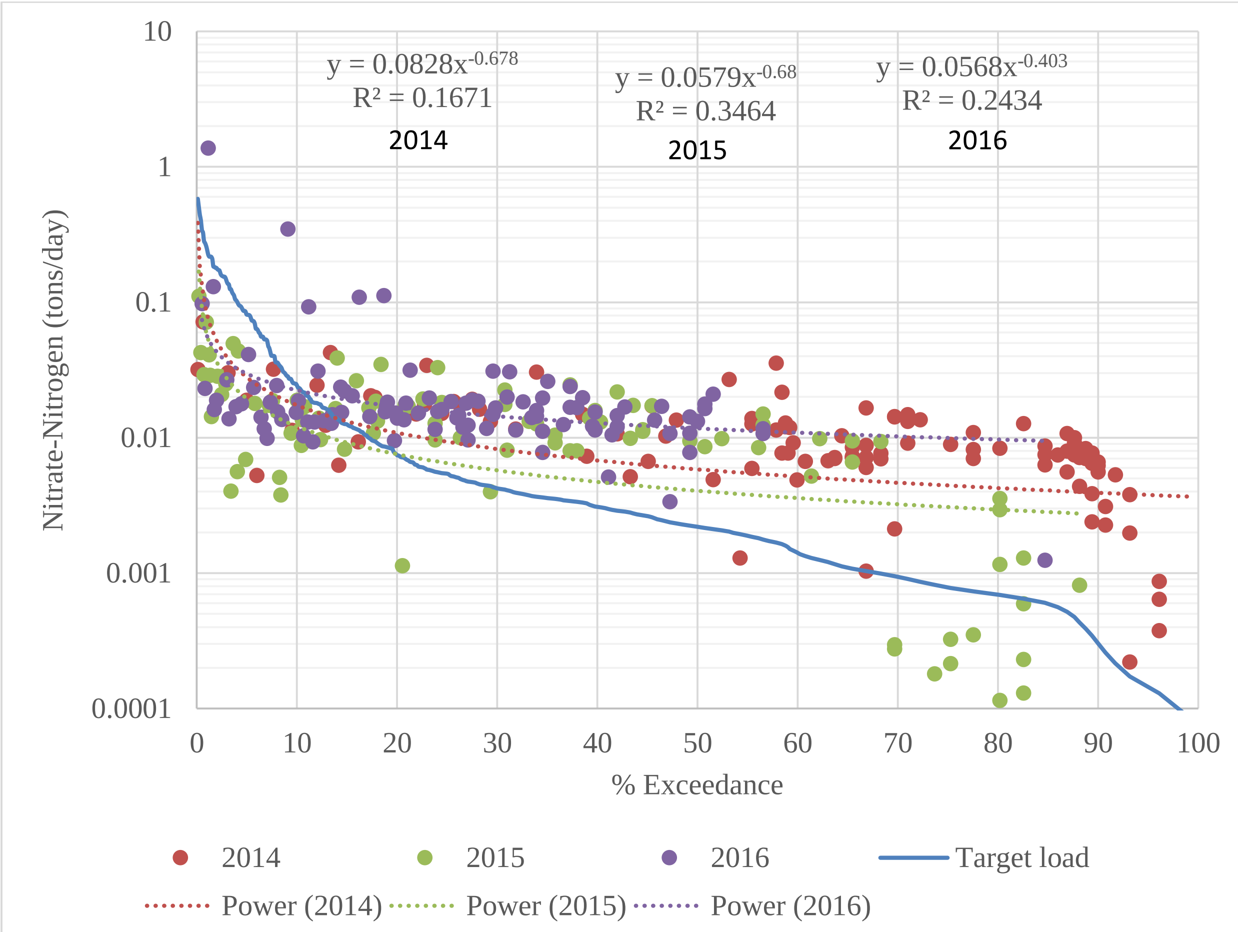

Figure 9. Flow-duration analysis for tons/day of Nitrate-Nitrogen from 2014-2016 for Beargrass Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 74% of the time.

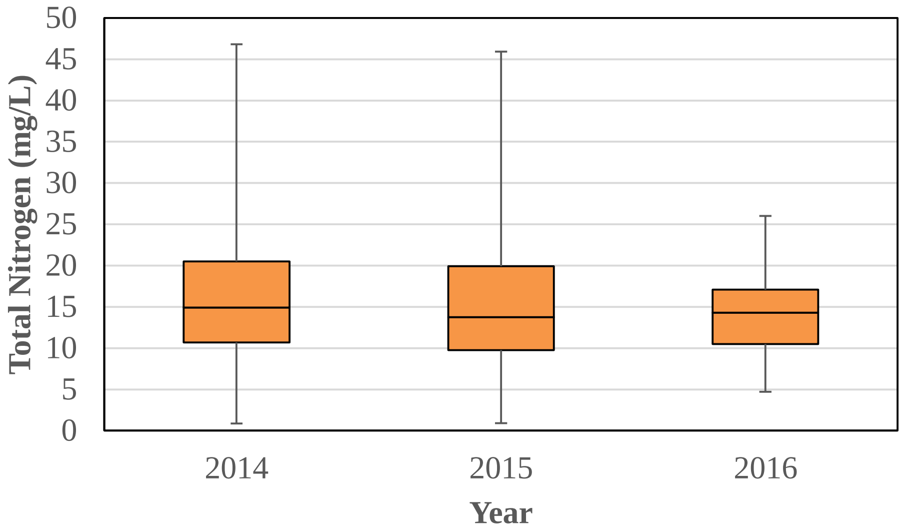

Figure 10. Box and whisker plots for Total Nitrogen at the Beargrass PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the slight downward trend in the median and maximum values.

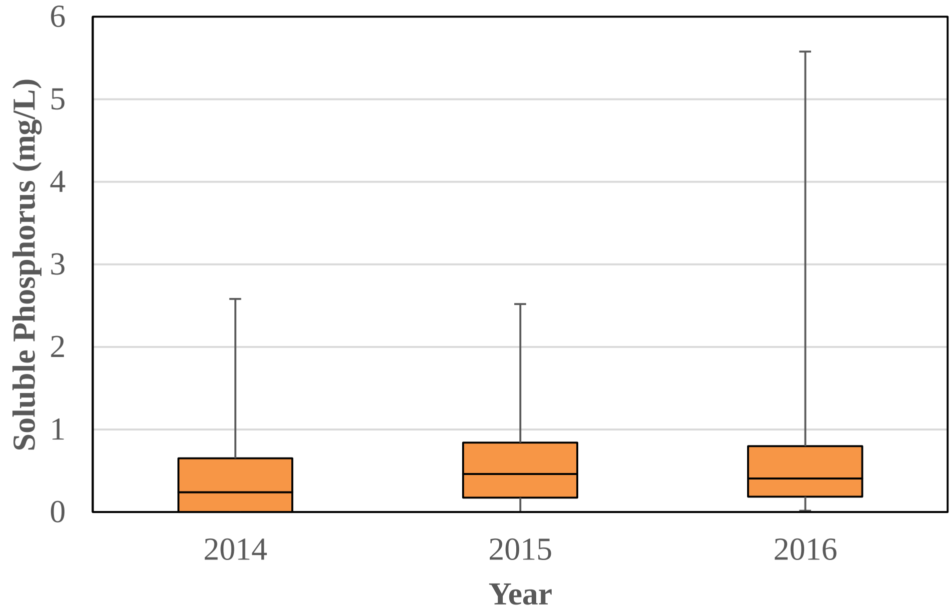

Figure 11. Box and whisker plots for Soluble Reactive Phosphorus the Beargrass PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year.

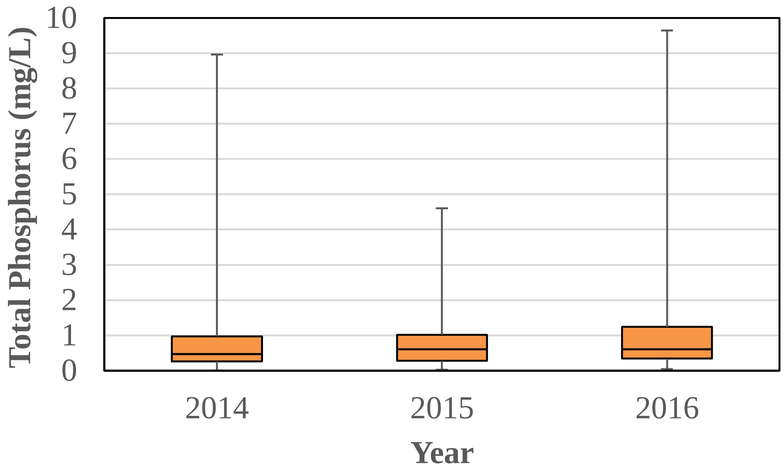

Figure 12. Box and whisker plots for Total Phosphorus at the Beargrass PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the evenness of the medians across years. The target value is 0.076 mg/L.

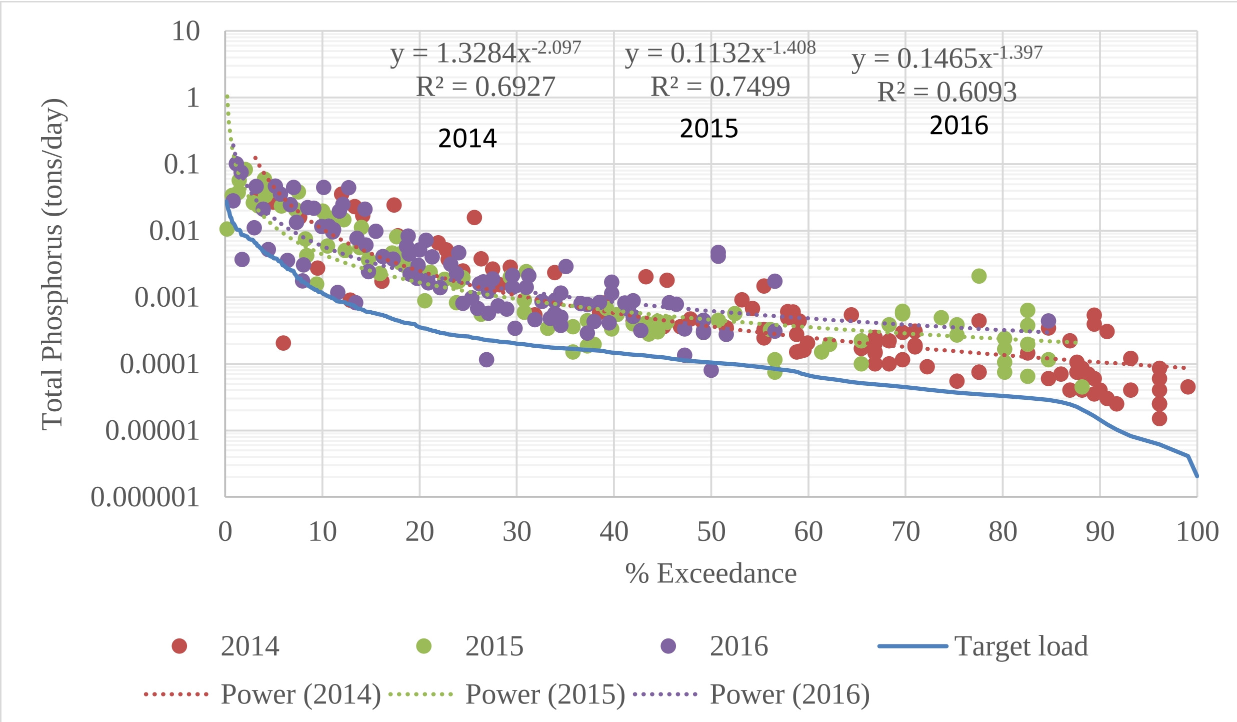

Figure 13. Flow-duration analysis for tons/day of Total Phosphorus from 2014-2016 for the Beargrass Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 97.5% of the time.

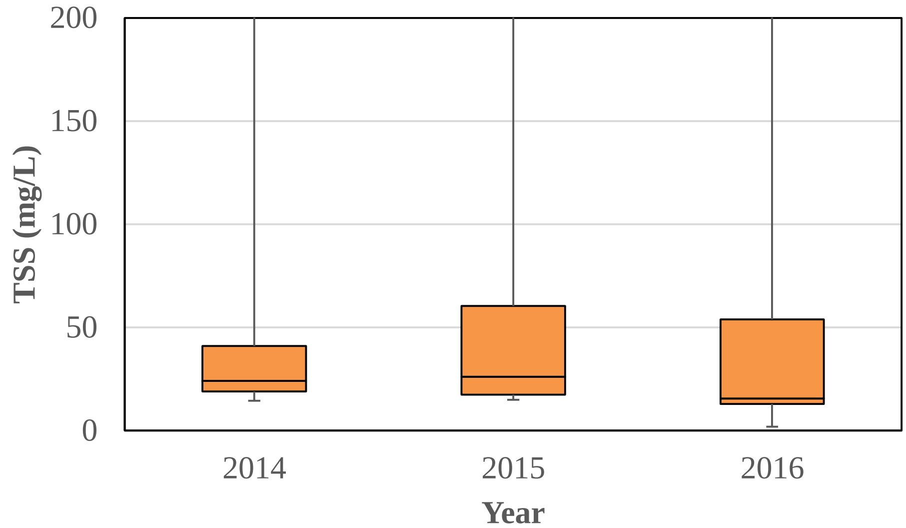

Figure 14. Box and whisker plots for Total Suspended Sediment at the Beargrass PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the slight downward trend in the median and maximum values. The target value is 30 mg/L.

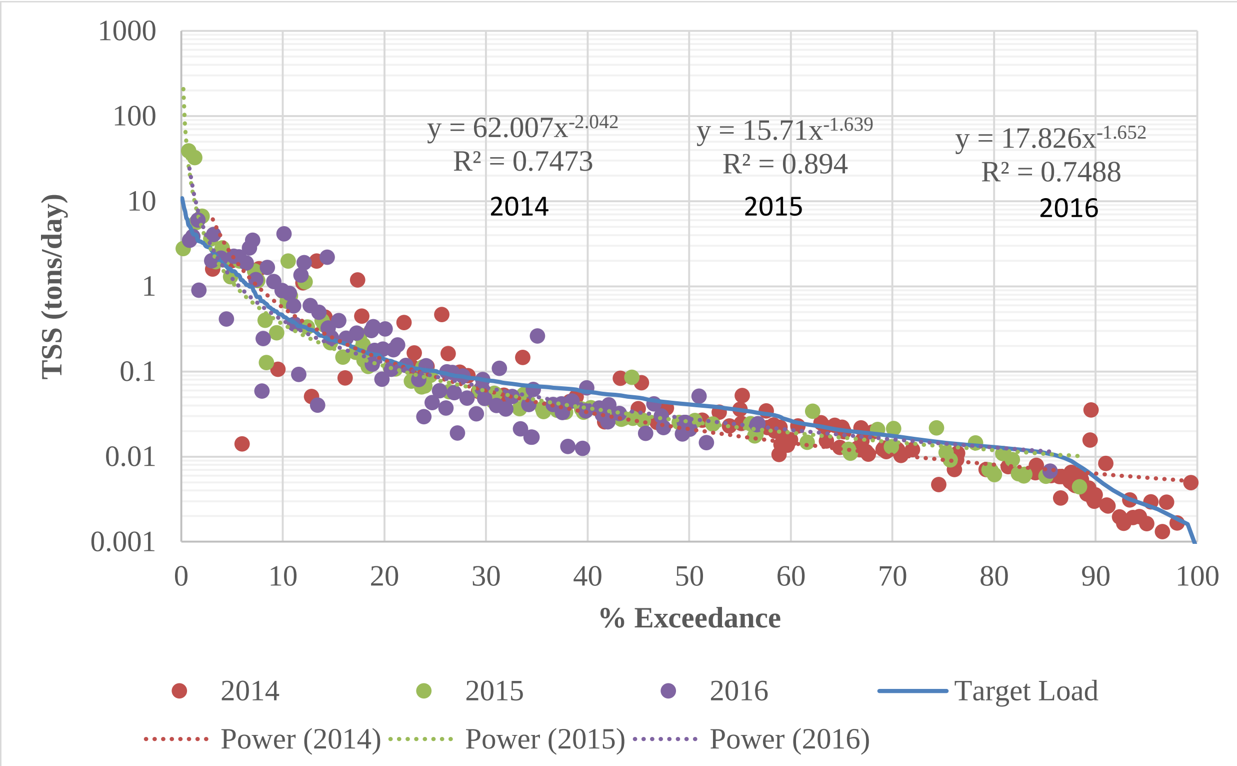

Figure 15. Flow-duration analysis for tons/day of Total Suspended Sediment from 2014-2016 for the Beargrass Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 34% of the time.

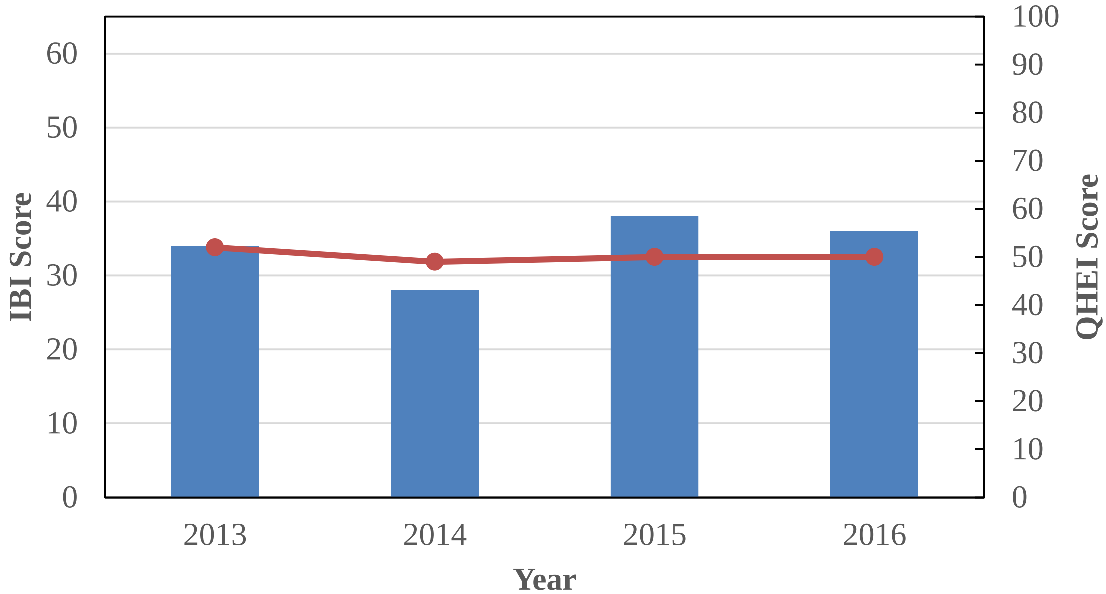

Figure 16. Index of Biotic Integrity (IBI) score and Qualitative Habitat Evaluation Index (QHEI) for the Beargrass Creek PWS gage site from 2013-2016. The target value for the IBI is 40 and the target value for the QHEI is 70. These scores provide a quantitative and qualitative method for evaluation of the fish community and instream habitat.

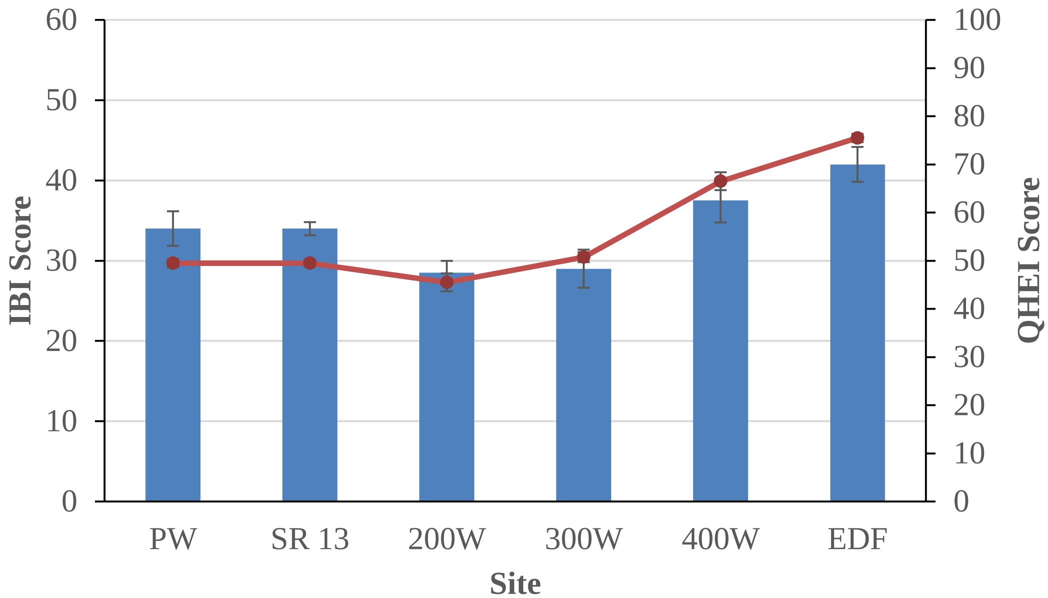

Figure 17. Mean and Standard Error for the Index of Biotic Integrity (IBI) scores and Qualitative Habitat Evaluation Index (QHEI) for the Beargrass Creek PWS gage site from 2013-2016. The target value for the IBI is 40 and the target value for the QHEI is 70. These scores provide a quantitative and qualitative method for evaluation of the fish community and instream habitat.

Table 4. Fish species present at the Beargrass Creek PWS gage station across the years of 2014-2016.

Common Name	Scientific Name
stoneroller	*Campostoma anomalum*
striped shiner	*Luxilus chrysocephalus*
western blacknose dace	*Rhinichthys atratulus*
bluntnose minnow	*Pimephales notatus*
creek chub	*Semotilus atromaculatus*
white sucker	*Catostomus commersoni*
green sunfish	*Lepomis cyanellus*
johnny darter	*Etheostoma nigrum*
orangethroat darter	*Etheostoma spectabile*

Water Chemistry and biological data for Pawpaw Creek, 2014-2016

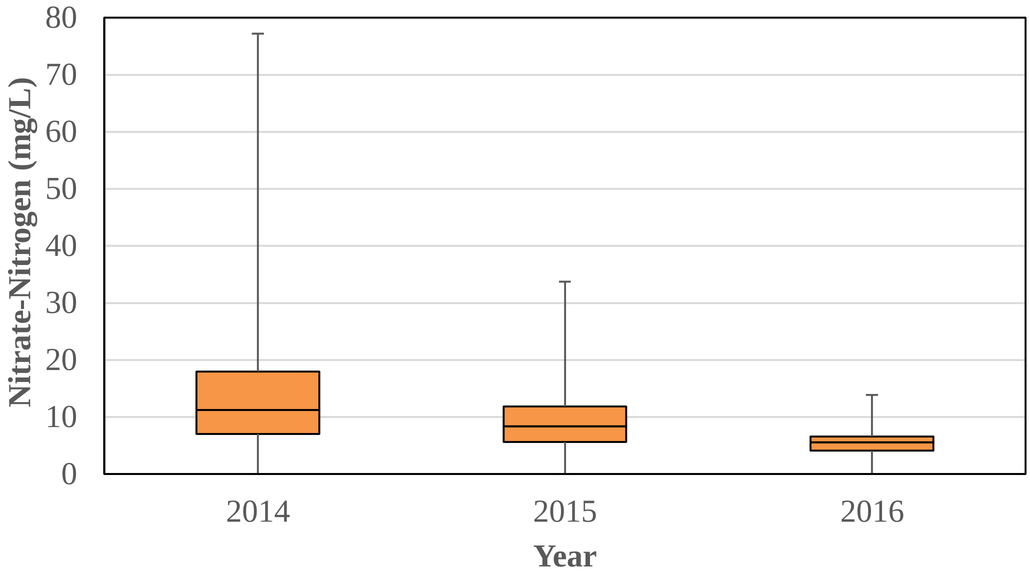

Figure 18. Box and whisker plots for Nitrate-nitrogen at the Pawpaw Creek PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the slight downward trend in the median and maximum values. Target value is 1.6 mg/L.

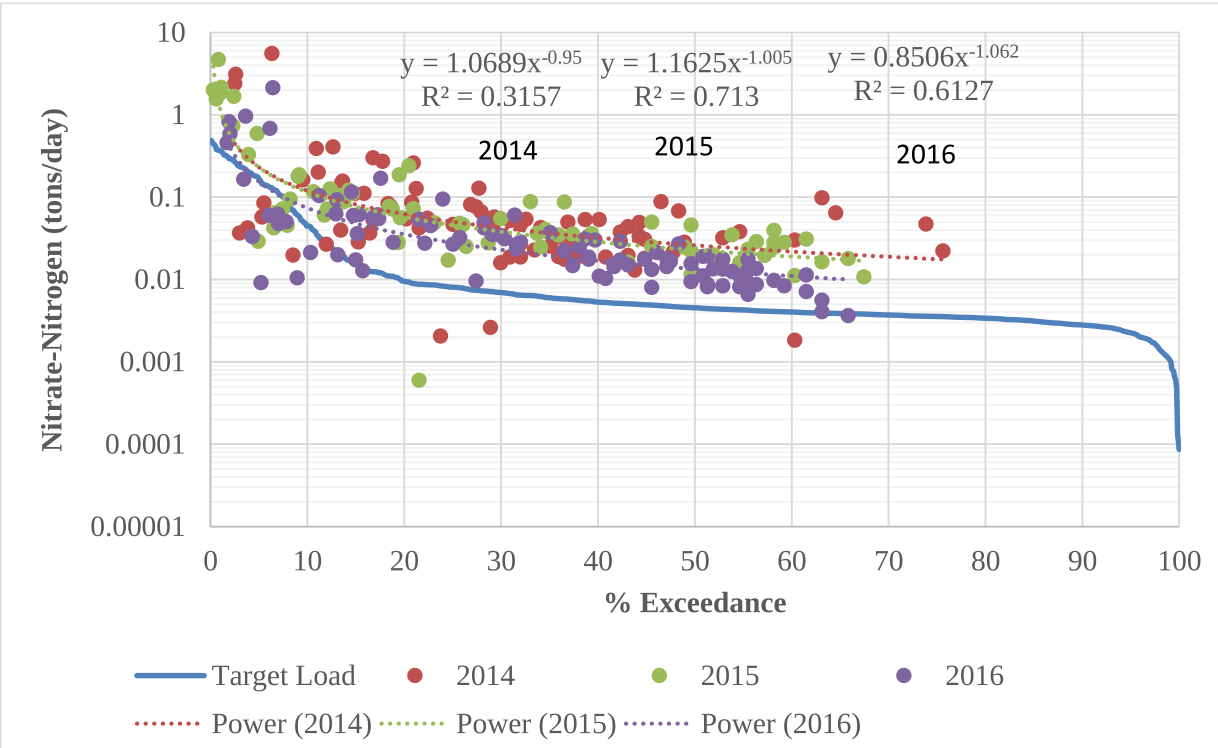

Figure 19. A flow-duration analysis for tons/day of Nitrate-Nitrogen from 2014-2016 for the Pawpaw Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 89.6% of the time.

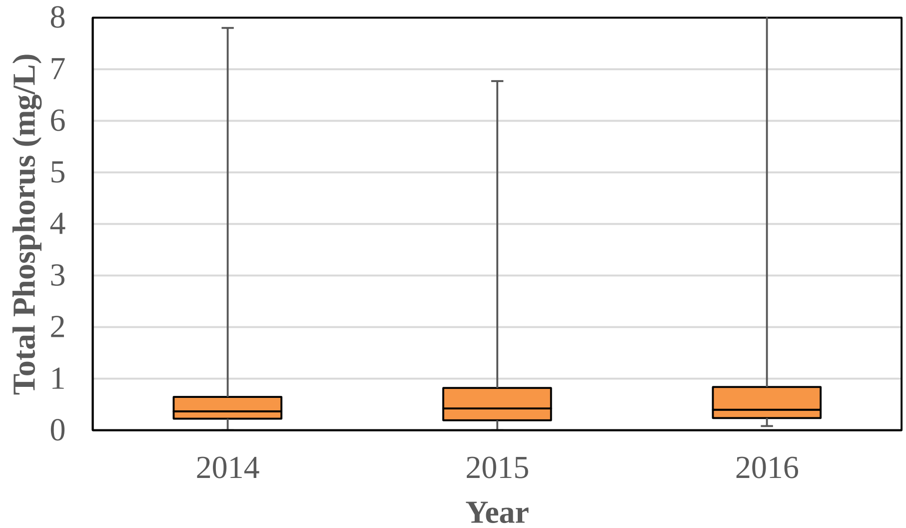

Figure 20. Box and whisker plots for Total Phosphorus at the Pawpaw Creek PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the evenness of the medians across years. The target value is 0.076 mg/L.

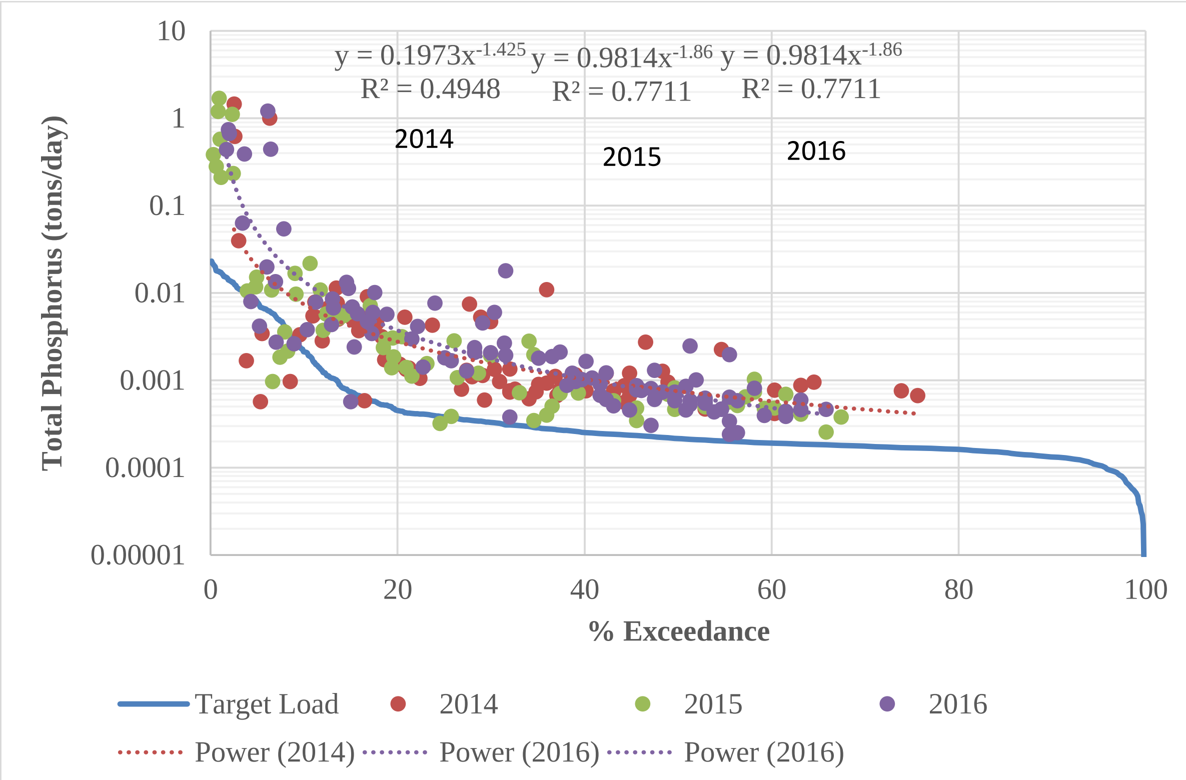

Figure 21. Flow-duration analysis for tons/day of Total Phosphorus from 2014-2016 for the Pawpaw Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 94% of the time.

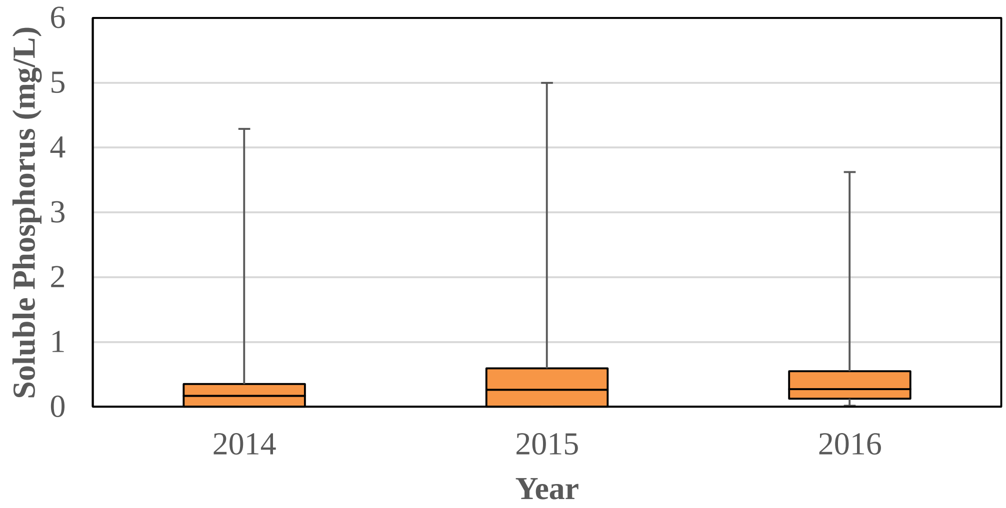

Figure 22. Box and whisker plots for Soluble Reactive Phosphorus the Pawpaw Creek PWS gage station from 2014-2016. The middle line in the box represents the median value (50^{th} percentile) for each year.

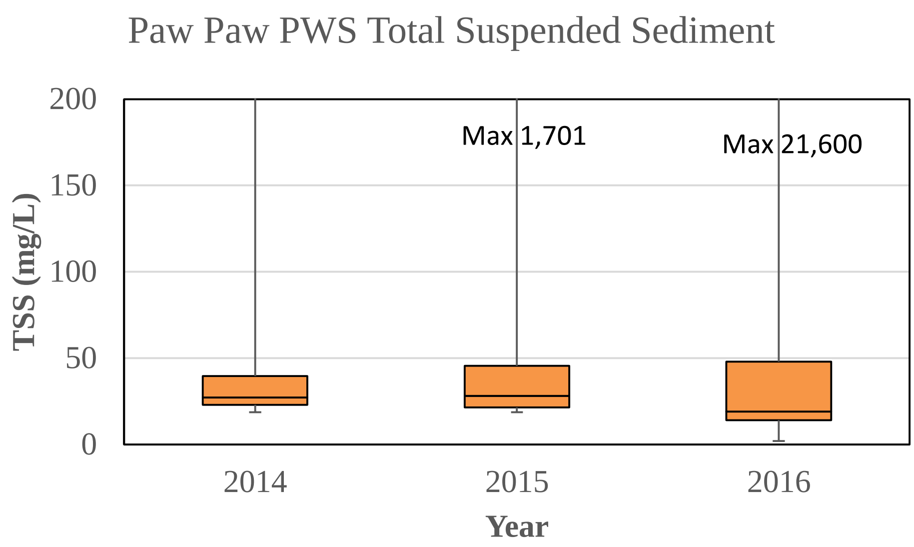

Figure 23. Box and whisker plots for Total Suspended Sediment at the Pawpaw Creek PWS gage station from 2014-2016. The middle line in the box represents the median value (50th percentile) for each year. Note the slight downward trend in the median and maximum values. The target value is 30 mg/L.

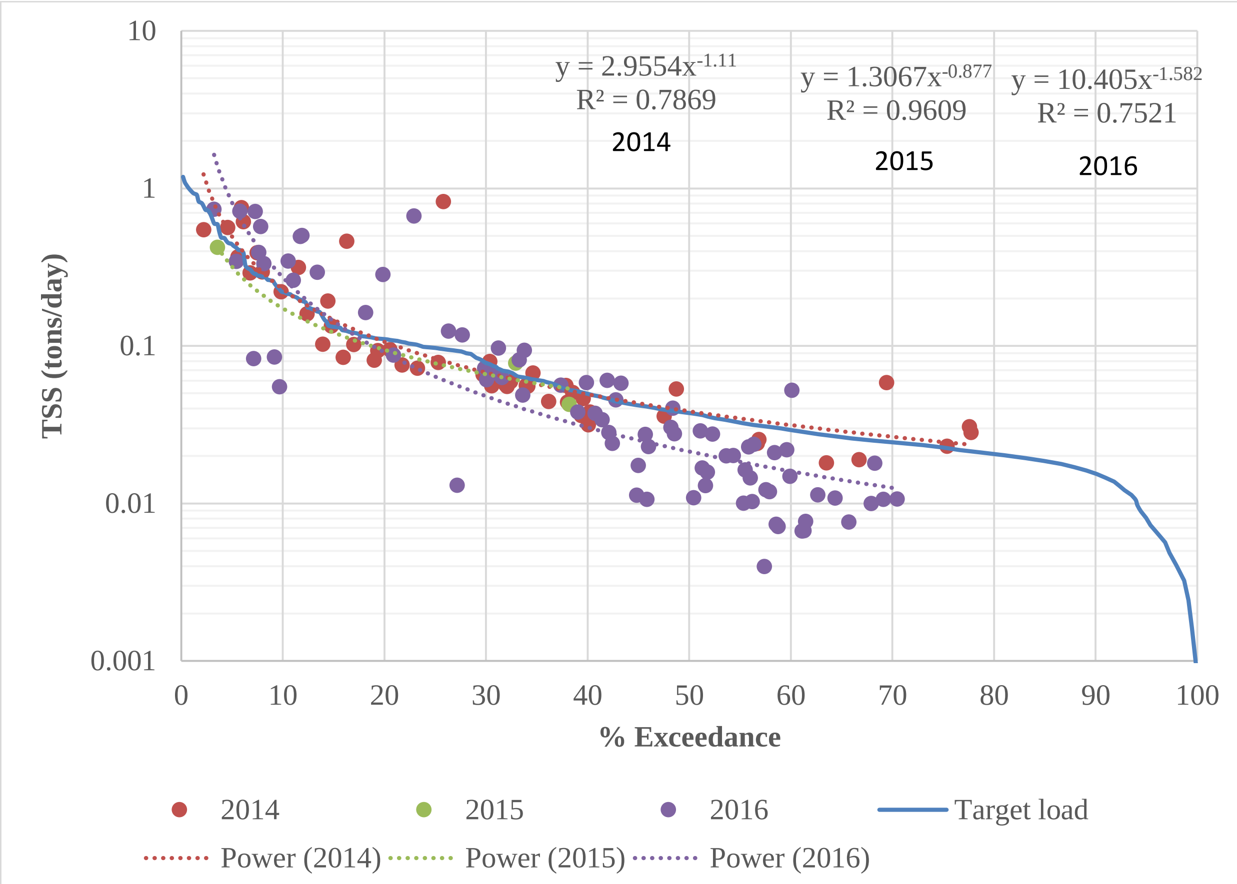

Figure 24. Flow-duration analysis for tons/day of Total Suspended Sediment from 2014-2016 for the Beargrass Creek PWS gage station. The blue line on the graph represents the target load. The target load was exceeded 34% of the time.

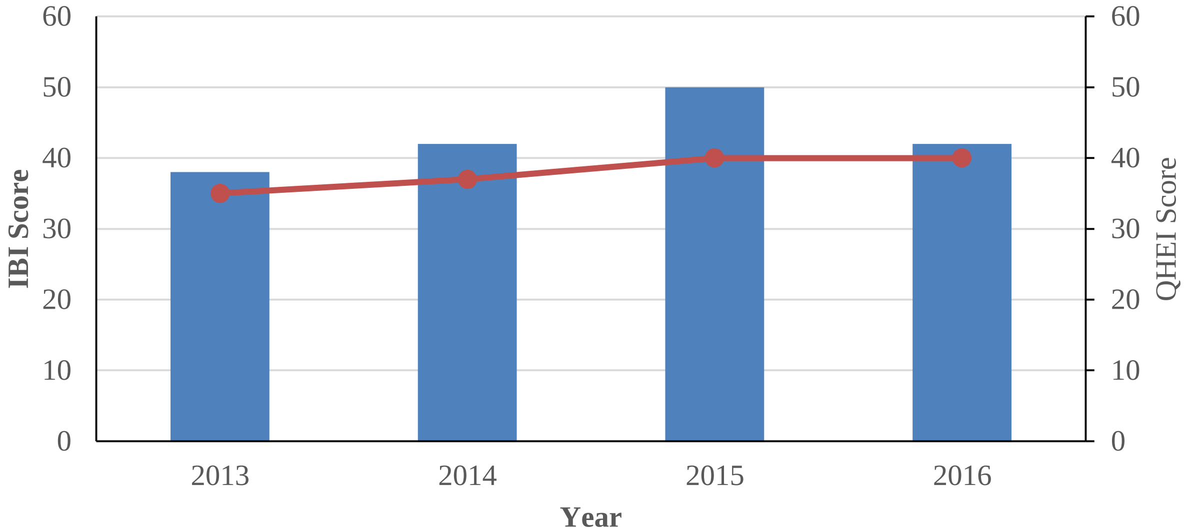

Figure 25. Index of Biotic Integrity (IBI) score (blue bars) and Qualitative Habitat Evaluation Index (QHEI) (red line) for the Pawpaw Creek PWS gage site from 2013-2016. The target value for the IBI is 40 and the target value for the QHEI is 70. These scores provide a quantitative and qualitative method for evaluation of the fish community and instream habitat. Note the relatively high IBI (blue bars) scores relative to the low QHEI (read line) scores.

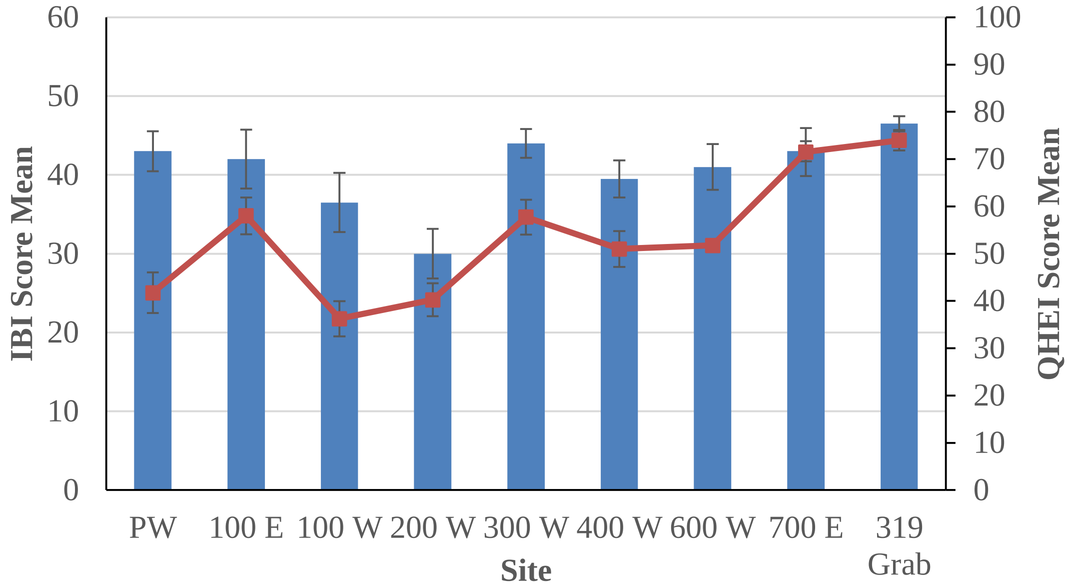

Figure 26. Mean and Standard Error for the Index of Biotic Integrity (IBI) scores (blue bars) and Qualitative Habitat Evaluation Index (QHEI) (red line) for the Pawpaw Creek PWS gage site from 2013-2016. The target value for the IBI is 40 and the target value for the QHEI is 70. These scores provide a quantitative and qualitative method for evaluation of the fish community and instream habitat.

Table 5. Fish species present at the Pawpaw Creek PWS gage station across the years of 2014-2016.

Common Name	Scientific Name
stoneroller	*Campostoma anomalum*
striped shiner	*Luxilus chrysocephalus*
common shinner	*Notropis cornutus*
redfin shiner	*Notropis umbratilis*
golden shiner	*Notemigonus crysoleucas*
bluntnose minnow	*Pimephales notatus*
creek chub	*Semotilus atromaculatus*
creek chubsucker	*Erimyzon oblongus*
black bullhead	*Ictalurus melas*
yellow bullhead	*Ictalurus natalis*
blackstriped topminnow	*Fundulus notatus*
green sunfish	*Lepomis cyanellus*
bluegill	*Lepomis macrochirus*
longear sunfish	*Lepomis megalotis*
orangethroat darter	*Etheostoma spectabile*