WATERSHED TREND REPORT

WEST STUDY BASIN

2012 - 2019

Report Version 1: 6/21/24

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Introduction

Sanitation District No. 1 (SD1), a clean-water agency which serves over 30 communities in Campbell, Kenton, and Boone Counties, Kentucky, as both a wastewater and a storm water utility, is implementing an adaptive watershed management approach to cost-effectively meet numerous regulatory requirements (e.g., Combined Sewer Overflow (CSO) Program, Municipal Separate Storm Sewer System (MS4) Program, Total Maximum Daily Load (TMDL) Program, etc.) to address environmental impacts associated with sewer overflows and storm water runoff in the communities it serves. In complying with these regulatory requirements, SD1 is applying a comprehensive approach for identifying impairments. In 2009, SD1 developed Watershed Characterization Reports for 16 watersheds to relate instream conditions to watershed characteristics. The results of these Watershed Characterization Reports were used to identify impaired watersheds and prioritize them for consideration of control alternatives associated with sewer overflow mitigation[1].

SD1 is undertaking a long-term effort to collect and compile data that describes the water quality conditions of Northern Kentucky (NKY) streams. This information is compiled at a basin scale and a watershed scale to relate instream conditions to watershed characteristics. Figure 1 shows the four study basins (East, Central, North and West) that are used to group NKY watersheds into logical reporting units.

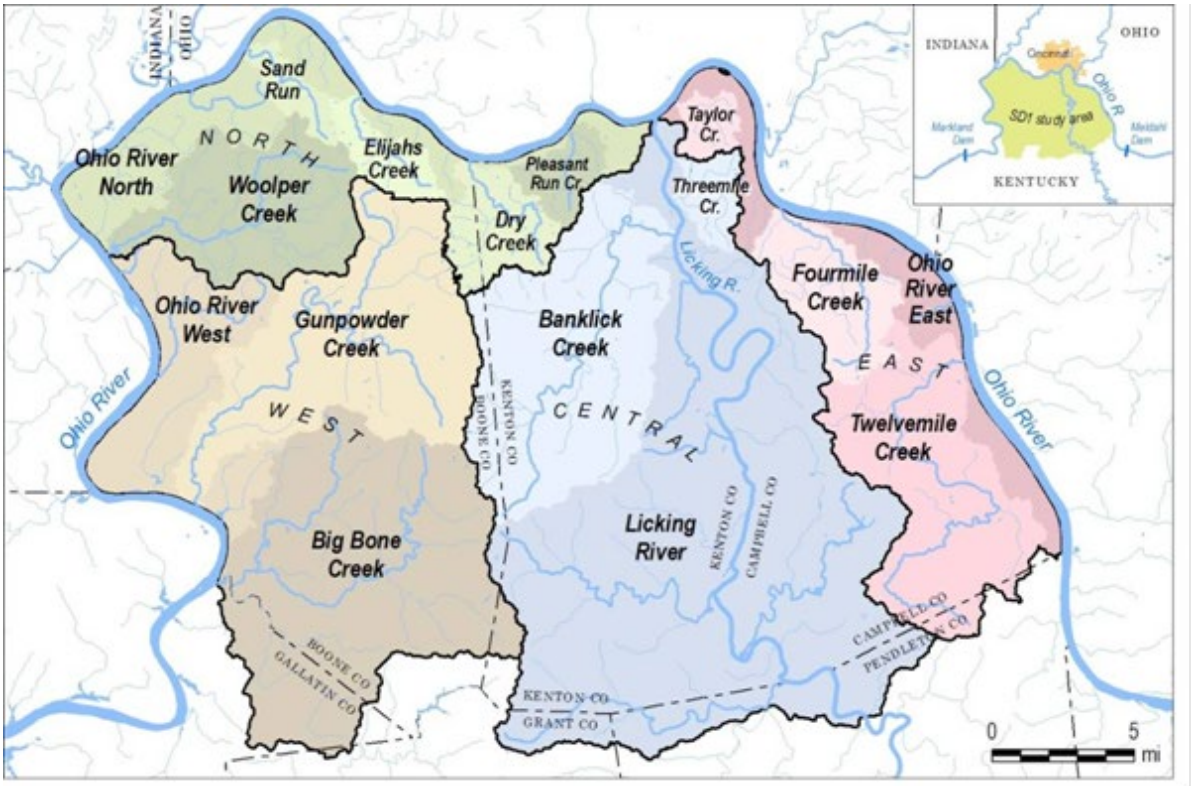


Figure 1. Study Basins and Watersheds

[1] SD1 entered into a Consent Decree with state and federal environmental regulators in 2007.

Background

The watersheds depicted in Figure 1 represent varying conditions with respect to the amount of development, as well as sources of stream pollution. The variation in the stream conditions can range from undeveloped watersheds that have been categorized as "exceptional" waters by the State, while other watersheds are more highly developed and are identified as "impaired" by the State.

As a result of the vast differences between these watersheds, SD1 initiated a comprehensive monitoring program in 2006 to collect instream water quality, biology, physical habitat, and stream stability data to establish current conditions and long-term datasets for model development and trend analysis.

This monitoring program is being implemented in a phased approach which is designed to achieve the following objectives:

- Characterize watershed conditions during baseflow/dry weather and storm flow/wet weather;
- Provide datasets for calibrating detailed watershed and water quality models;
- Provide datasets for assessment tools, such as a Stream Condition Index;
- Meet regulatory requirements for the Nine Minimum Controls as defined within the Long-term Control Plan requirements of the CSO Policy;
- Meet regulatory requirements for the Six Minimum Control Measures as defined within the Storm Water Quality Management Plan requirements of the Phase II MS4 Program;
- Characterize physical stream channel responses from urbanized storm water runoff (i.e., hydromodification);
- Establish a baseline for evaluating improvements from implementing controls; and,
- Respond to regulatory initiatives such as 305(b) assessments, 303(d) listings, TMDLs, etc.

Prior to 2006, limited water quality monitoring and biological assessments had been conducted in the watersheds of Northern Kentucky, thus the monitoring program has evolved over time based on the relative timetable associated with the objectives identified above. SD1 initiated a watershed wide monitoring program in 2006 to establish baseline conditions (base flow and storm flow) and datasets for model development - Period 1 (2006-2011). Period 2 spanned from 2012-2015 which established the basin rotation approach (e.g., 2012 - East Basin; 2013 - Central Basin; 2014 - North Basin; 2015 - West Basin). Period 3 spanned from 2016-2019 and was a continuation of the Period 2 basin rotation approach and established the ambient water quality monitoring approach to focus on spatial and temporal changes within the watersheds. After a temporary suspension of monitoring and assessment activities in 2020, Period 4 (2021-2024) data collection activities are in progress.

This report will focus on the West Basin watersheds and each of the four monitoring components of SD1's monitoring program to assess stream condition trends for Periods 2 and 3.

Ambient Water Quality Monitoring

Water Quality Sampling

The objective of the ambient monitoring program is to characterize instream water quality under a wide range of environmental conditions in Northern Kentucky streams. By monitoring instream water quality, the condition of watersheds can be assessed along with the impact of land-based activities on the local waterways. Specific or emerging water quality issues may also be identified by monitoring and gathering information on the various waterbodies.

Although watershed wide water quality monitoring was initiated in 2006, the development of an ambient monitoring program component began in 2015 (i.e., the last year of Period 2). During Period 3, the ambient monitoring was further enhanced to meet program objectives. In 2021 (the beginning of Period 4), additional sites will be added to each watershed's rotational basin schedule to increase spatial resolution of the monitoring.

Biological Assessments

Biological Assessment

The objective of the biological assessment program is to characterize the biological diversity and habitat quality in Northern Kentucky streams. By assessing the biological community to determine pollutant tolerant and pollutant intolerant species, the overall integrity of a waterbody can be determined along with both present and past effects of stressors of the biological integrity on the aquatic ecosystem.

Watershed wide biological assessments were conducted from 2006 through 2011 (Period 1) in order to record baseline data on the current condition of the streams and to develop subsequent monitoring and assessment strategies. With respect to the Basin Trend Reports, results and analysis of biological assessments began with the Period 2 datasets.

Stream Stability Assessments

Stream Stability Assessment

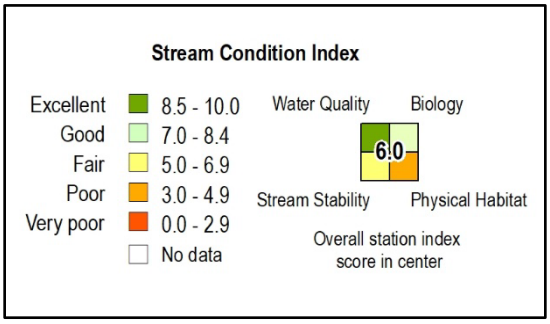
The objective of the stream stability assessment program is to characterize the rate of streambed and streambank movement in Northern Kentucky streams. By measuring physical stream channel responses over time, that are primarily attributable to land-use conversion from undeveloped to developed, a stream site can be designated as stable or unstable. The altered flow regime associated with conventional urban development leads to hydromodification – flashier streams, larger flow, excessive stream erosion and overall channel instability. Accelerated bank erosion,

channel deepening/widening, and overall enlargement pose risks to adjacent public infrastructure (i.e., sewers, roads and bridges), as well as private property losses. These same actions also cause water quality impairments (i.e., high TSS and sedimentation/siltation) and have adverse effects on aquatic biota, such as fish and macroinvertebrate populations.

Limited stream stability assessments began in 2008 after sampling crews documented significant stream erosion while conducting water quality monitoring and biological assessments. Throughout Periods 1 and 2, additional sites were added to meet program objectives. Beginning in 2019, rapid stream stability assessments were conducted at all biological assessment sites.

Stream Condition Index

To better evaluate, summarize, and communicate the results of the monitoring program, SD1 has utilized data collected from local streams and watersheds to develop a regionally based Stream Condition Index (SCI)[2]. Appropriate indicators of stream condition were researched and selected in four key categories: water quality, biology, physical habitat, and stream stability. A scoring system for each indicator and a method to aggregate indicator scores at each site was established, creating a sub-index score for each of the four categories. At each site, the four sub-index scores are averaged to create a single Stream Condition Index (SCI) score. The SCI scores allow for a general comparison of stream conditions across the Northern Kentucky area.



Stream Condition Index

These types of environmental indices are commonly used by resource managers and scientists to summarize large amounts of complex data but are rarely calibrated to reflect conditions of such a localized area. The local focus of the SCI will allow its use in resource monitoring, potentially diagnosing problem areas, predicting relative resource condition, setting benchmarks for management targets, and (perhaps most importantly) streamlining complex data in terms that can be understood by a non-technical audience.[3]

The objectives for the SD1's SCI were to:

- Summarize large amounts of complex data from Northern Kentucky streams;
- Use existing monitoring programs and indices to the extent possible;
- Incorporate and reflect broader conditions beyond water quality;
- Balance scientific rigor with the timely development of an index; and,
- Communicate information on monitoring data to a lay audience.

[2] *A Stream Condition Index for Water Utility Resource Management in Northern Kentucky*, 2015.
[3] *A Manager's Guide to Indicator Selection*. U.S. EPA, 2006.

West Basin

The West Basin study area is located mainly in Boone Counties, KY (Figure 2). This basin includes (from north to south): Gunpowder Creek and Big Bone Creek, along with smaller tributaries that discharge directly to the Ohio River (collectively depicted as Ohio River West).

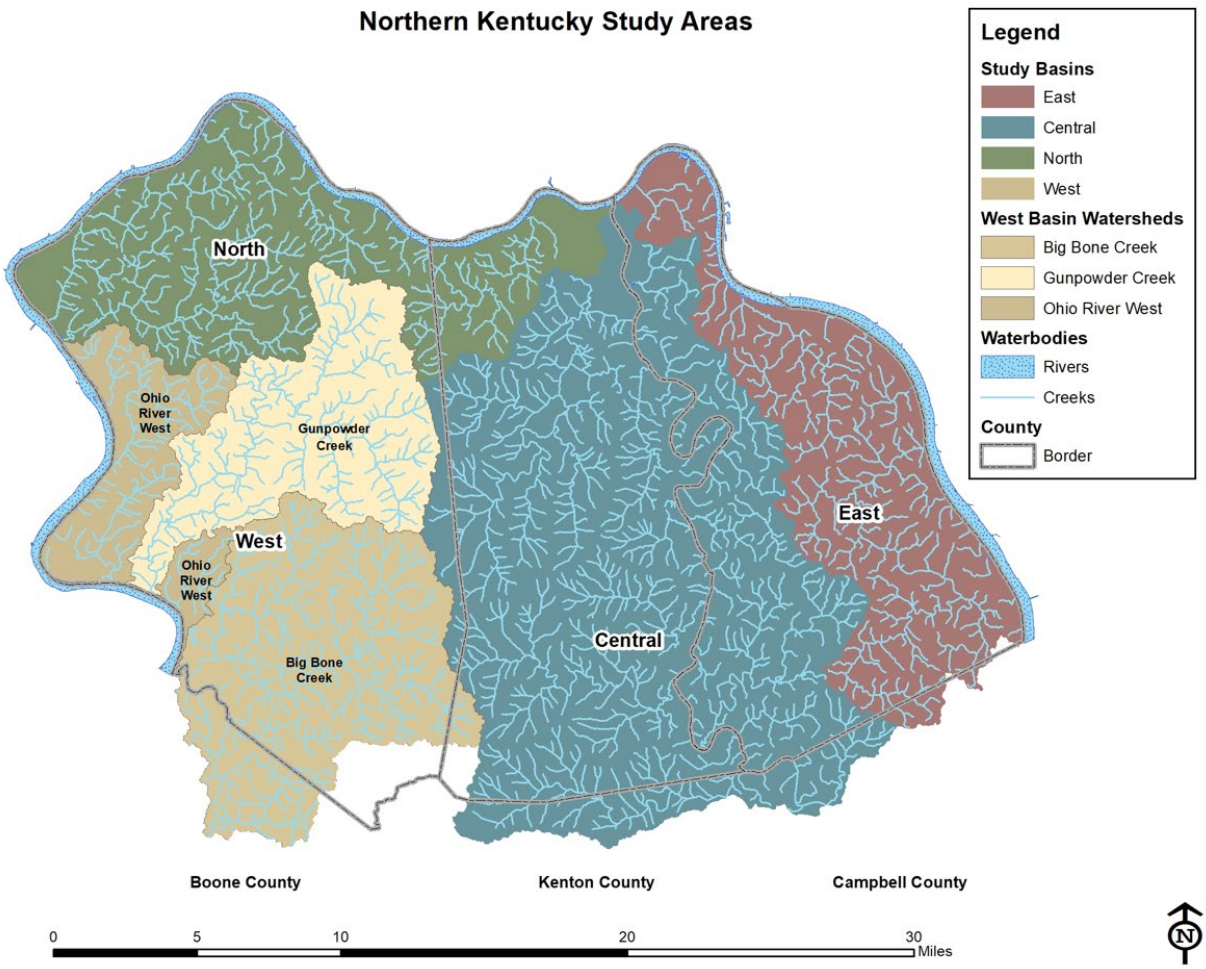


Figure 2. West Basin Study Area Map

The Basin Trend monitoring and assessment sites within the West Basin are located in two primary watersheds: Big Bone Creek and Gunpowder Creek. Each watershed has multiple sites located throughout its drainage area, representing varying conditions with respect to the amount of development (i.e., impervious surface), as well as potential sources of stream pollution. Table 1 identifies the individual sites contained in each watershed.

Table 1. West Basin Site Locations

Big Bone Creek	Gunpowder Creek
BBC3.9	GPC4.6
MLC3.0	GPC14.7
MLC12.0	GPC17.9
	SFG5.3

Sampling site locations were selected using several criteria including, but not limited to, drainage area, accessibility, stream heterogeneity, adjacent land use, past studies, and available resources.

Land cover and sewer system areas each play an important role in the quantity and quality of runoff into receiving waters. Each watershed overview section includes a series of maps that depict watershed conditions, as follows:

1) General watershed characteristics displayed as follows:
    a. Waterbodies include rivers and creeks that are designated as perennial, intermittent or piped, as well as reservoirs and impoundments, such as lakes and ponds.
    b. Constructed features include buildings, pavement, such as roads, parking lots, etc., as well as other impervious surfaces.

2) National Land Cover Database (NLCD) modified and displayed as follows:
    a. Initial dataset included agriculture, barren land, developed, forest, grassland, shrubland, water and wetlands categories representing 2019 conditions.
    b. Modified dataset to Circa 2023 with local GIS and imagery data including parcel information, buildings, pavement surfaces and waterbodies to correct and refine the agriculture, developed, grassland and water land cover categories.

3) SD1 service area boundaries and the active sewer overflow locations displayed as follows:
    a. Storm Water and Wastewater Service Area boundaries depicted as of December 2019.
    b. Modeled Sewer Overflow Locations[4] include model predicted sanitary sewer overflows[5] and combined sewer overflows[6], based on 2020 sewer system conditions.

[4] Refer to SD1's Amended Consent Decree, Appendix A, filed 3/17/09.
[5] Design storm modeling based on a 2-year, 6-hour rainfall event (2.29") for the Eastern Region of KY.
[6] Typical year modeling based on 1970 rainfall events recorded at the Cincinnati-NKY International Airport.

Big Bone Creek

Located mostly in Boone County, the Big Bone Creek watershed originates west of Union, KY and flows approximately 11.9 miles in a southwesterly direction to the Ohio River (Figure 3). Mud Lick Creek (headwaters to the west in Kenton County) and Big South Fork (headwaters to the south in Gallatin County) are two significant tributaries that contribute drainage to Big Bone Creek. The overall watershed mainly provides drainage to portions of unincorporated Boone County, as well as portions of the cities of Union and Walton and portions of unincorporated Kenton County and Gallatin County. The Big Bone Creek watershed has a drainage area of approximately 82.6 square miles with 4.7% estimated as impervious surface. Monitoring is conducted at one site on the main-stem of Big Bone Creek, as well as two sites within the Mud Lick Creek sub-watershed.

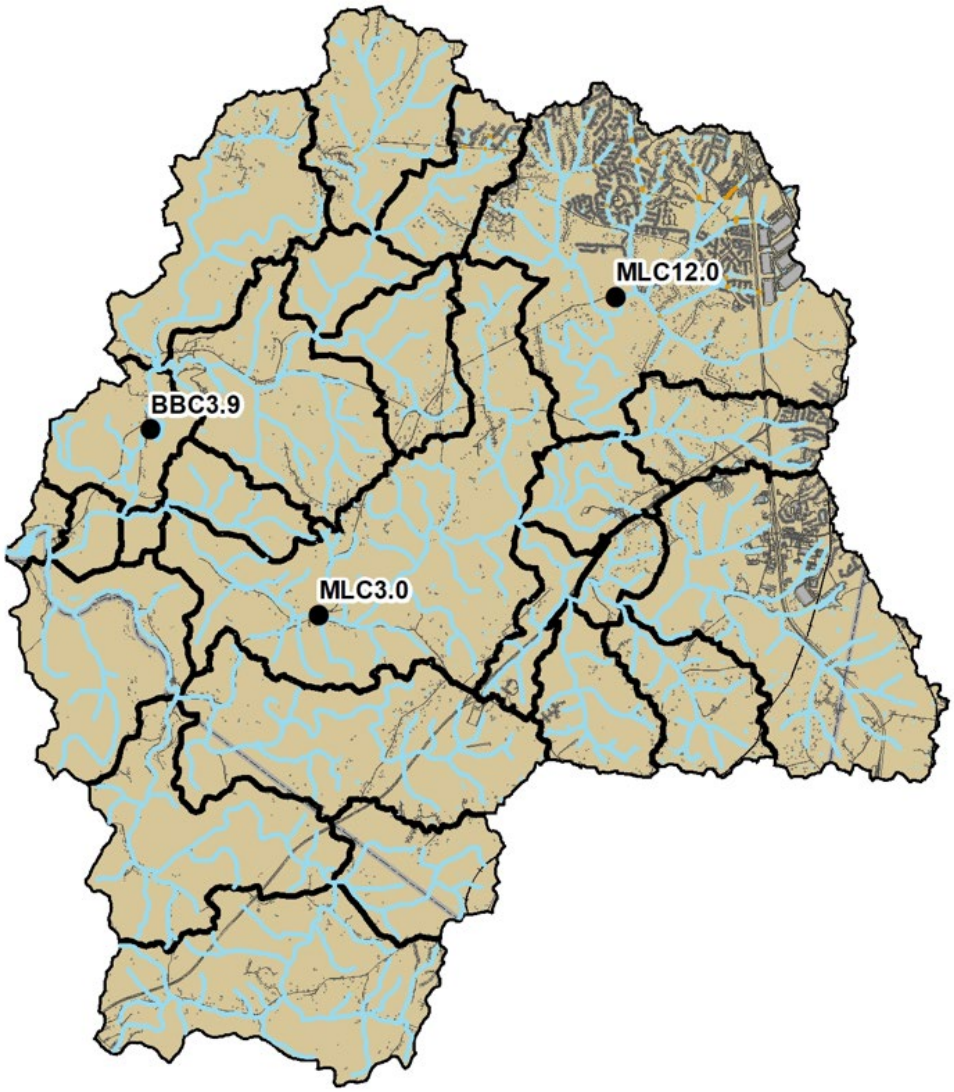


Figure 3. Big Bone Creek Watershed

Big Bone Creek watershed is mostly rural with suburban and urban areas in the upper portions of the Mud Lick sub-watershed (Figure 4). Land cover consists of predominately forested land (~48%), with lesser amounts of pastureland (~28%) and developed land (~20%). Interstate highways I-71 and I-75, significant transportation routes, traverse the upper portions of the watershed.

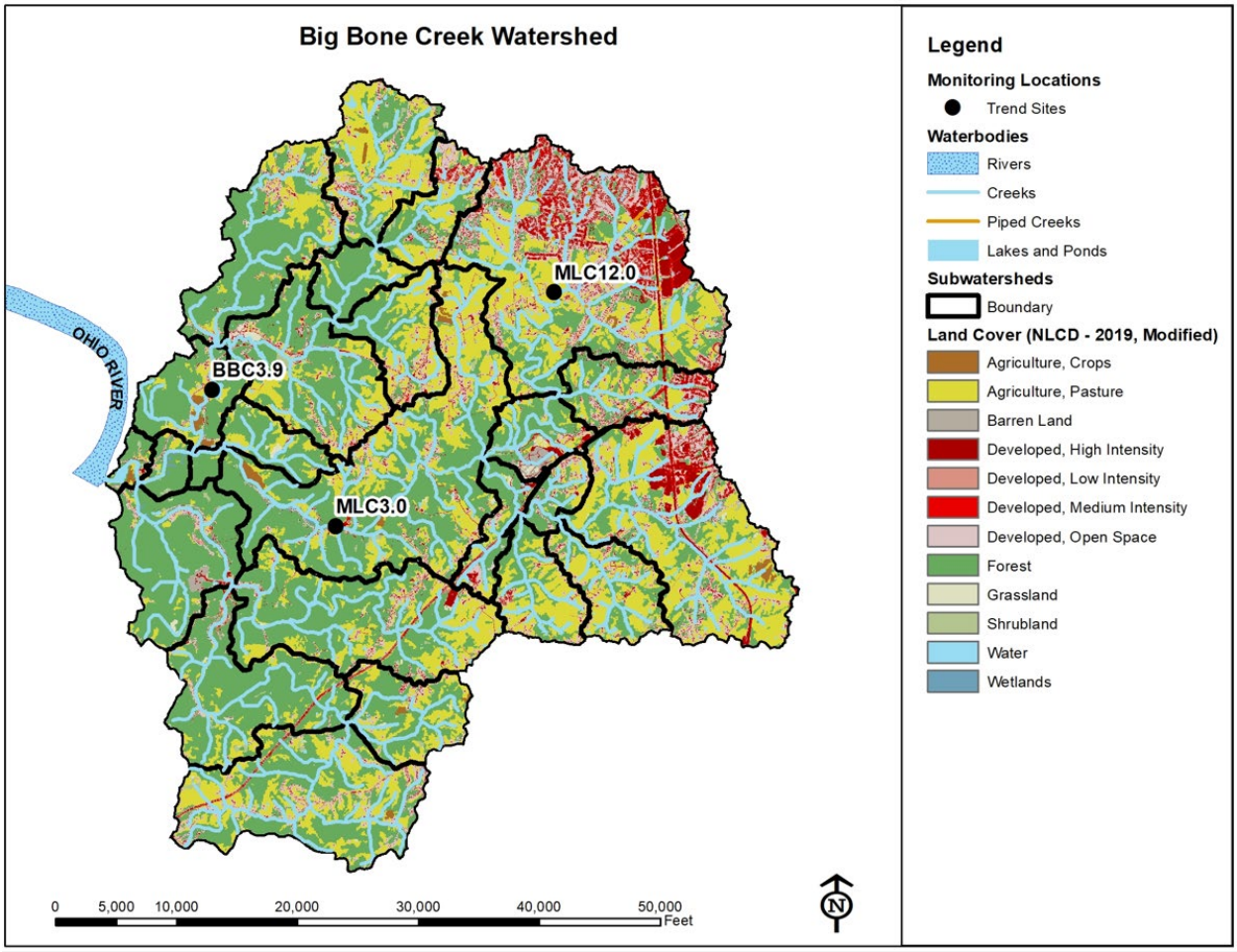


Figure 4. Big Bone Creek Land Cover

Areas within the Big Bone Creek watershed that are managed by SD1 with respect to centralized sanitary sewers and regional storm water systems are depicted in Figure 5. There are no modeled overflow locations within the watershed, which is mostly outside of the wastewater service area. Only a small portion of the watershed is subject to Kentucky's Phase II MS4 program and is encompassed within SD1's storm water service area, representing the NKY Regional Storm Water Program. KYTC rights-of-way within the MS4 program area are subject to the Transportation Cabinet's storm water program.

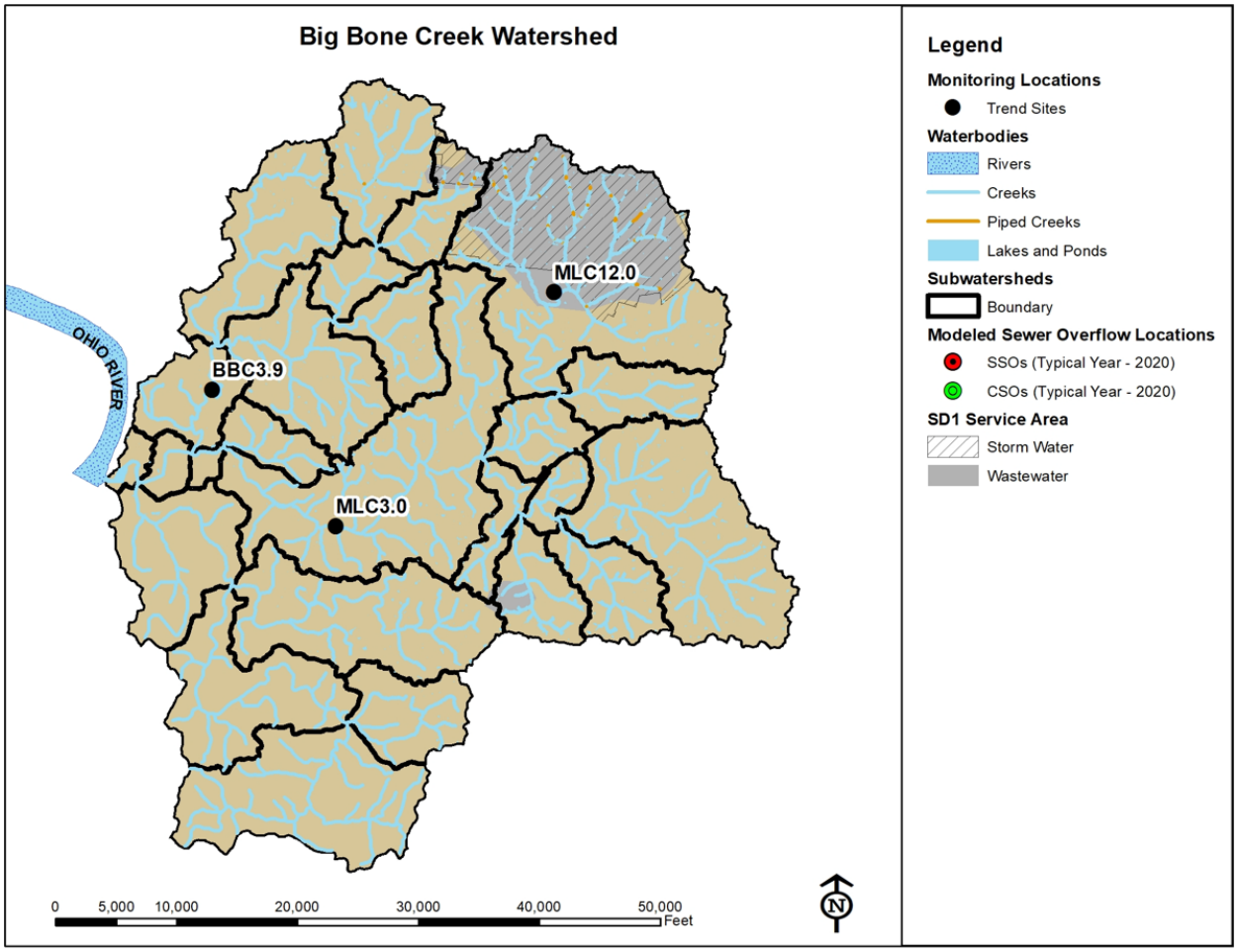


Figure 5. Big Bone Creek Modeled Sewer Overflows and Service Areas

Gunpowder Creek

Located entirely in Boone County, the Gunpowder Creek watershed originates on the south end of the Cincinnati/Northern Kentucky International Airport and flows approximately 22.5 miles in a southwesterly direction to the Ohio River (Figure 6). Long Branch (south central), Riddles Run (southwest) and South Fork Gunpowder Creek (southeast) are three significant tributaries that contribute drainage to Gunpowder Creek. The overall watershed mainly provides drainage to portions of unincorporated Boone County, as well as most of the cities of Florence and Union. The Gunpowder Creek watershed has a drainage area of approximately 58.3 square miles with 18.7% estimated as impervious surface. Monitoring is conducted at three sites on the main-stem of Gunpowder Creek, as well as one site within the South Fork Gunpowder Creek sub-watershed.

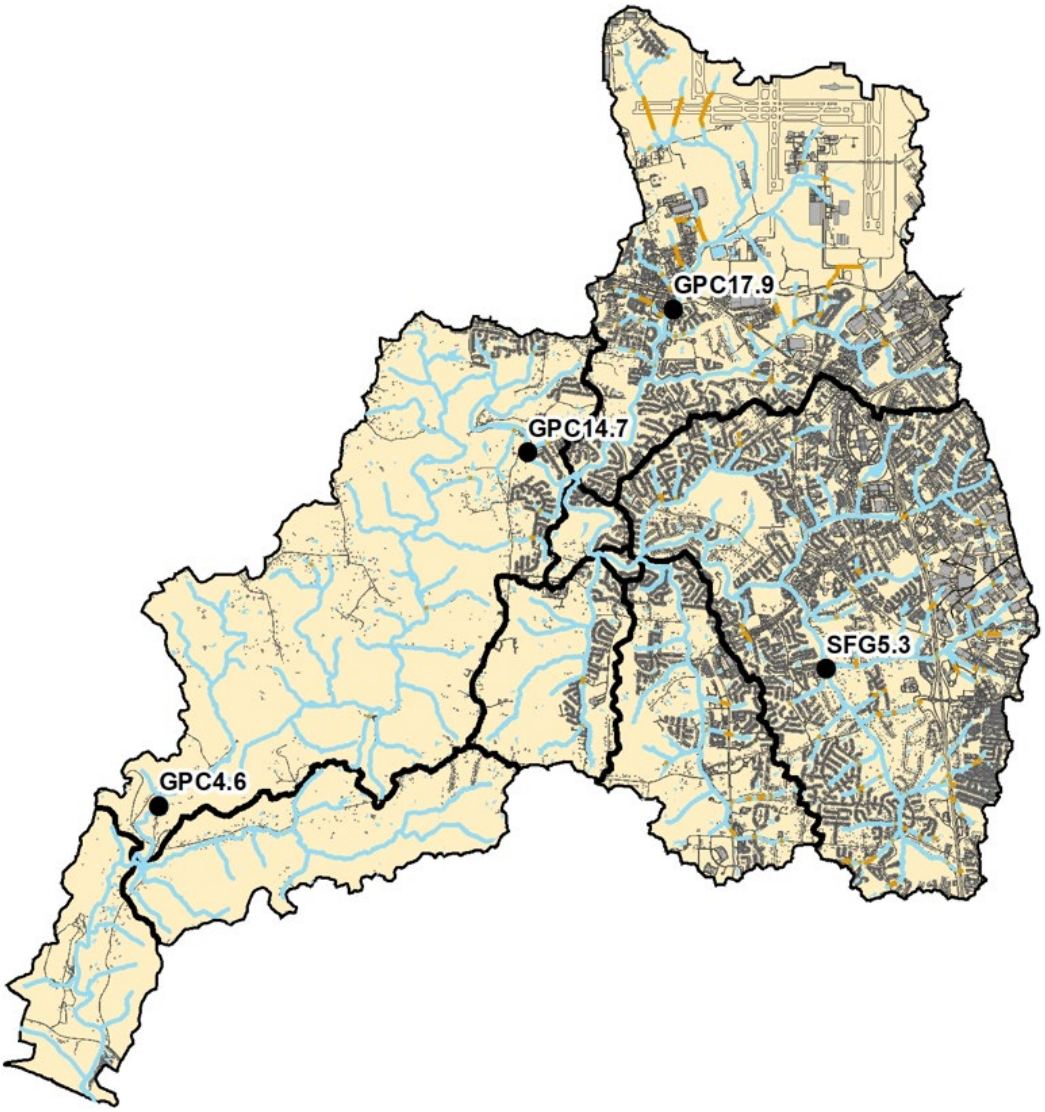


Figure 6. Gunpowder Creek Watershed

Gunpowder Creek watershed is mostly rural in the lower portions of the watershed and highly urbanized in the upper portions of the watershed, which includes the Cincinnati/Northern Kentucky International Airport (Figure 7). Land cover consists of predominately developed land (~51%), with lesser amounts of forested land (~32%) and pastureland (~12%). Interstate highway I-71/75, a significant transportation route, traverses the upper portions of the watershed.

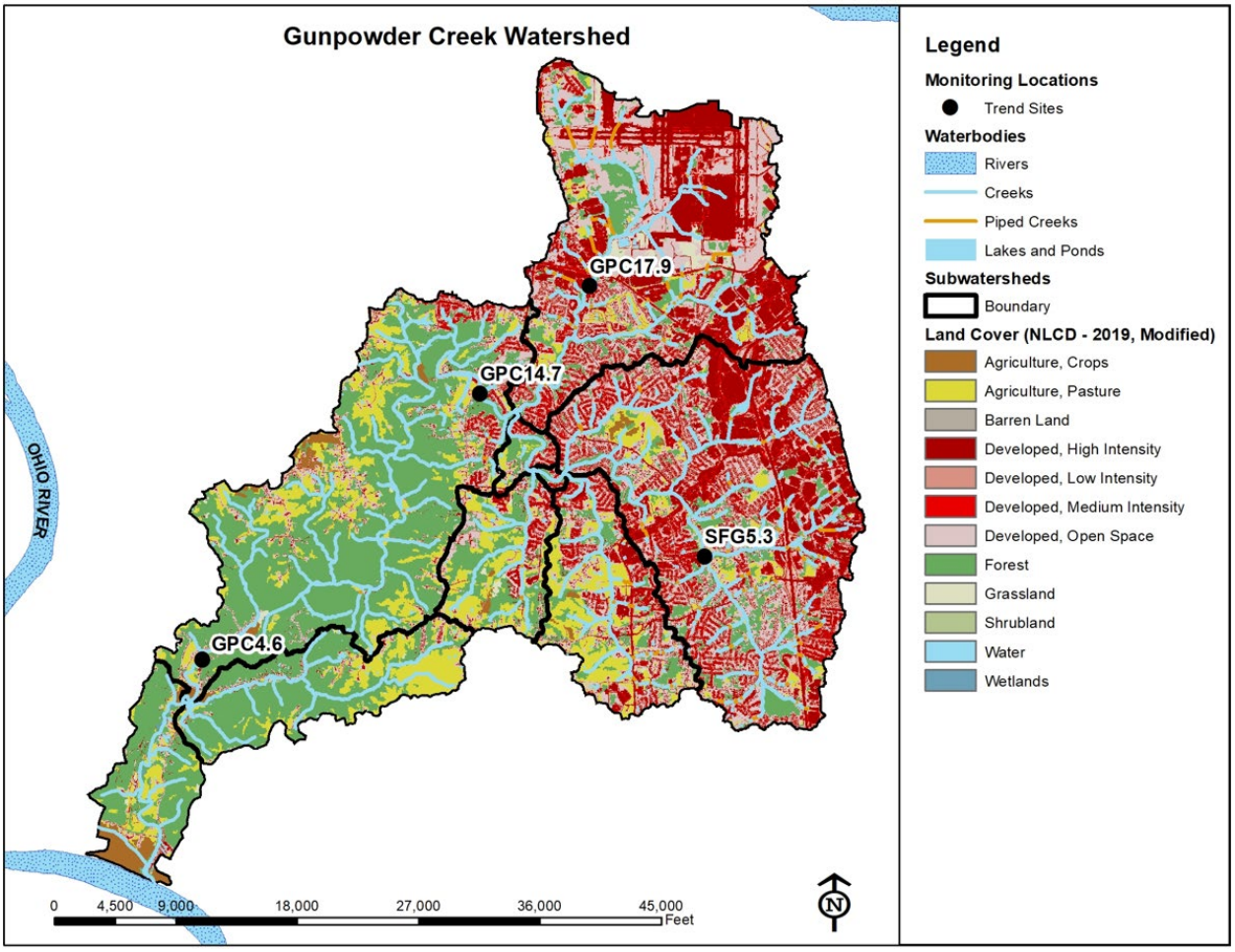


Figure 7. Gunpowder Creek Land Cover

Areas within the Gunpowder Creek watershed that are managed by SD1 with respect to centralized sanitary sewers and regional storm water systems, are depicted in Figure 8. Currently within the wastewater system two modeled overflow locations, consisting of only sanitary sewer overflows (SSOs), discharge during various wet weather conditions. Both overflow locations occur in the upper portion of Gunpowder Creek. Approximately half of the watershed is subject to Kentucky's Phase II MS4 program. The majority of the MS4 program area is encompassed within SD1's storm water service area, representing the NKY Regional Storm Water Program, while area within the city limits of Florence is subject to the city's storm water program. KYTC rights-of-way within the MS4 program area are subject to the Transportation Cabinet's storm water program.

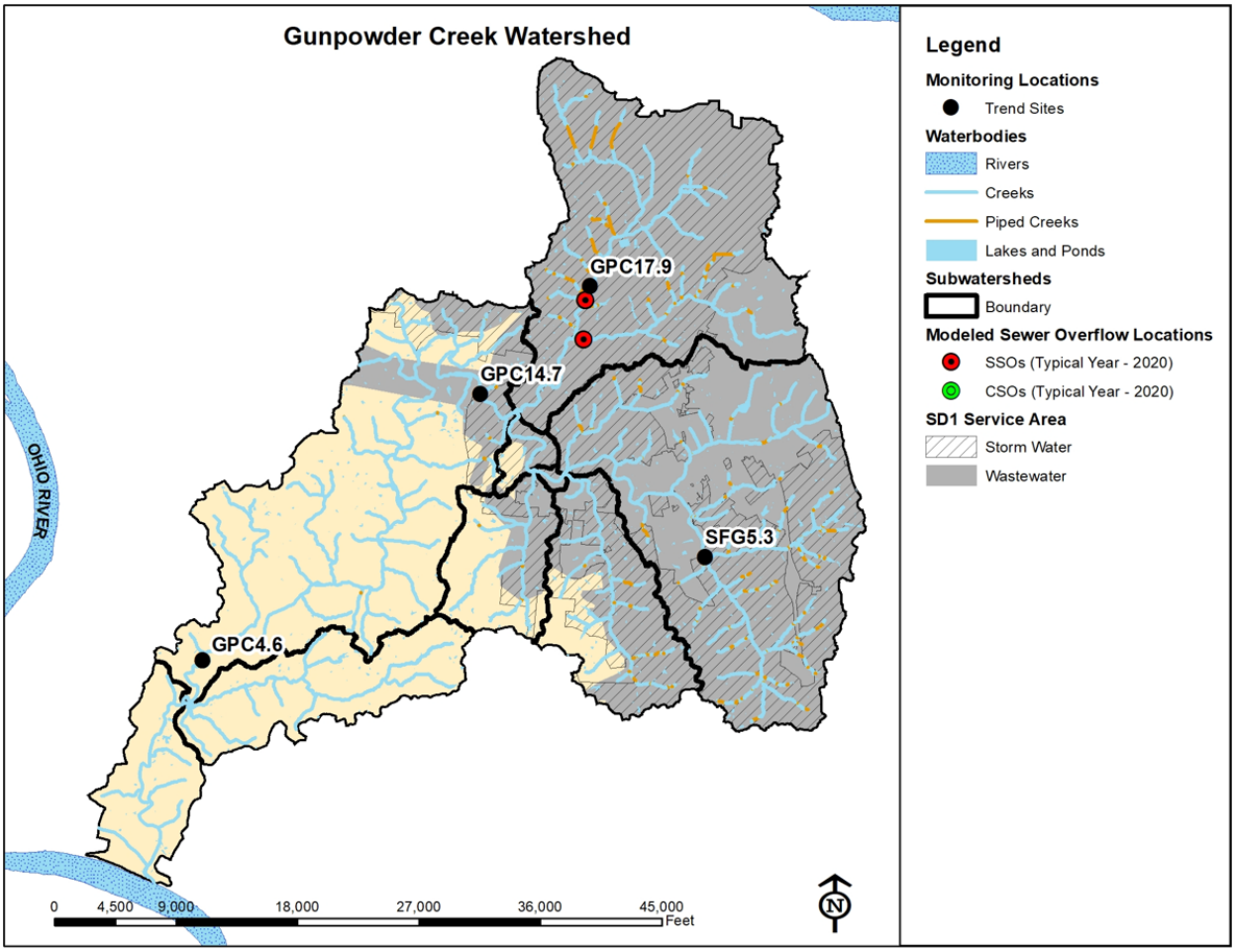


Figure 8. Gunpowder Creek Modeled Sewer Overflows and Service Areas

Further detailed characteristics of each watershed can be found on the SD1 website, https://www.sd1.org/233/Watershed-Characterization-Reports.

Ambient Water Quality Monitoring Results

SD1's ambient water quality monitoring consists of surface water grab samples collected from March through November on a set schedule (10 – 16 events per year) to "capture" varying flow regimes during the spring, summer and fall seasons. All sampling events were conducted following the appropriate Field Monitoring and Sampling Plan (FMSP) and the associated Quality Assurance Program Plan (QAPP) utilizing approved sampling protocols[7]. The FMSP and QAPP were designed to ensure that all monitoring activities undertaken result in representative data necessary to support the characterization of the watershed being sampled. Samples collected were analyzed in a laboratory for bacteria (*Escherichia coli* - *E. coli*), solids (total suspended solids - TSS), and nutrients (total phosphorus - TP and total nitrogen - TN) per the associated QAPP following approved analytical protocols[8].

- Bacteria are utilized as pathogen indicators and can range widely based on failing or undersized infrastructure and host source (e.g., human, livestock, pets, wildlife).
- TSS can rise significantly during and immediately after rainfall events due to land surface erosion and/or streambank erosion caused by runoff.
- Background phosphorus is typically higher in NKY area watersheds, primarily due to creek beds composed of limestone bedrock, however excess values are often attributed to point source and nonpoint source pollution.
- Nitrogen is found naturally in the environment; however excess values are often attributed to point source and nonpoint source pollution.

Ambient results for each site were compiled by parameter and represented in Box-and-Whisker plots. The whiskers for each plot represent the minimum and maximum values, while the box represents the 25th and 75th percentile range of the data. The "heavy" short black line represents the median value of the data. These plots are used to compare time periods within the watershed by site for each parameter. Additionally, either the water quality criteria or benchmark values are also shown in the figures. The water quality standard was derived from Section 401 of the Kentucky Administrative Regulations *401 KAR 10:031. Surface water standards*. The benchmarks were developed by Kentucky Division of Water as a guideline since there are no current standards developed for those parameters yet.

Table 2. Water Quality Criteria Type

Parameter	Water Quality Criteria Type	Value	Units	Applies
E. coli	KDOW Standard - Max	240	mpn/100 mL	May-Oct
TSS	KDOW Benchmark	7.25	mg/L	Apr-Oct
TP	KDOW Benchmark	0.08	mg/L	Jan-Dec
TN	KDOW Benchmark	0.6	mg/L	Jan-Dec

Refer to Appendix A for results from individual sites within the West Basin study area.

[7]EPA Guidance for Quality Assurance Project Plans, 2002.
[8] Standard Methods for the Examination of Water and Wastewater, 2017.

Big Bone Creek

Big Bone Creek watershed monitoring site MLC 3.0 was sampled during Period 2 and all four years of Period 3. Monitoring sites BBC3.9 and MLC12.0 were added to the ambient monitoring program in 2021, with all three sites scheduled for sampling during the Period 4 per the basin rotation cycle.

Table 3. Big Bone Creek Number of Samples Collected

Big Bone Creek	Period 2 No. of Samples	Period 3 No. of Samples			
Site	**2015**	**2016**	**2017**	**2018**	**2019**
BBC3.9	NS	NS	NS	NS	NS
MLC3.0	10	16	13	12	12
MLC12.0	NS	NS	NS	NS	NS

Columns displaying "NS" do not currently have results available but will in subsequent years (i.e., Period 4).

Photo 1. Mud Lick Creek 3.0

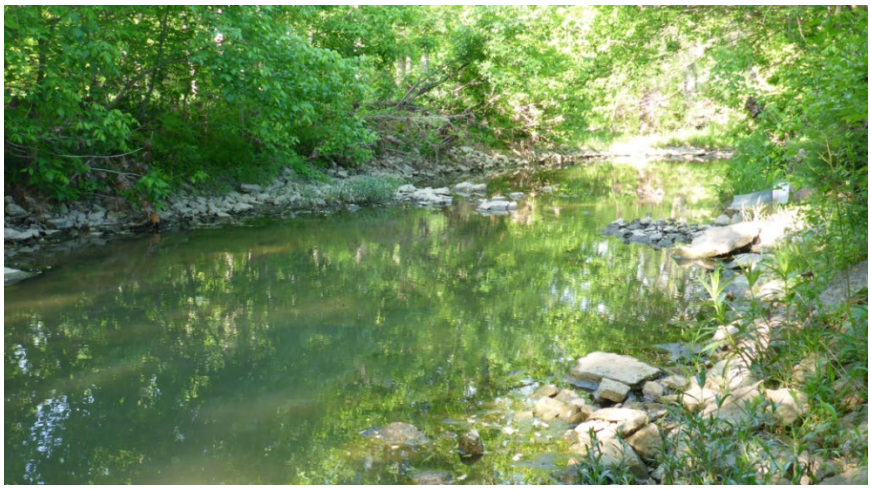


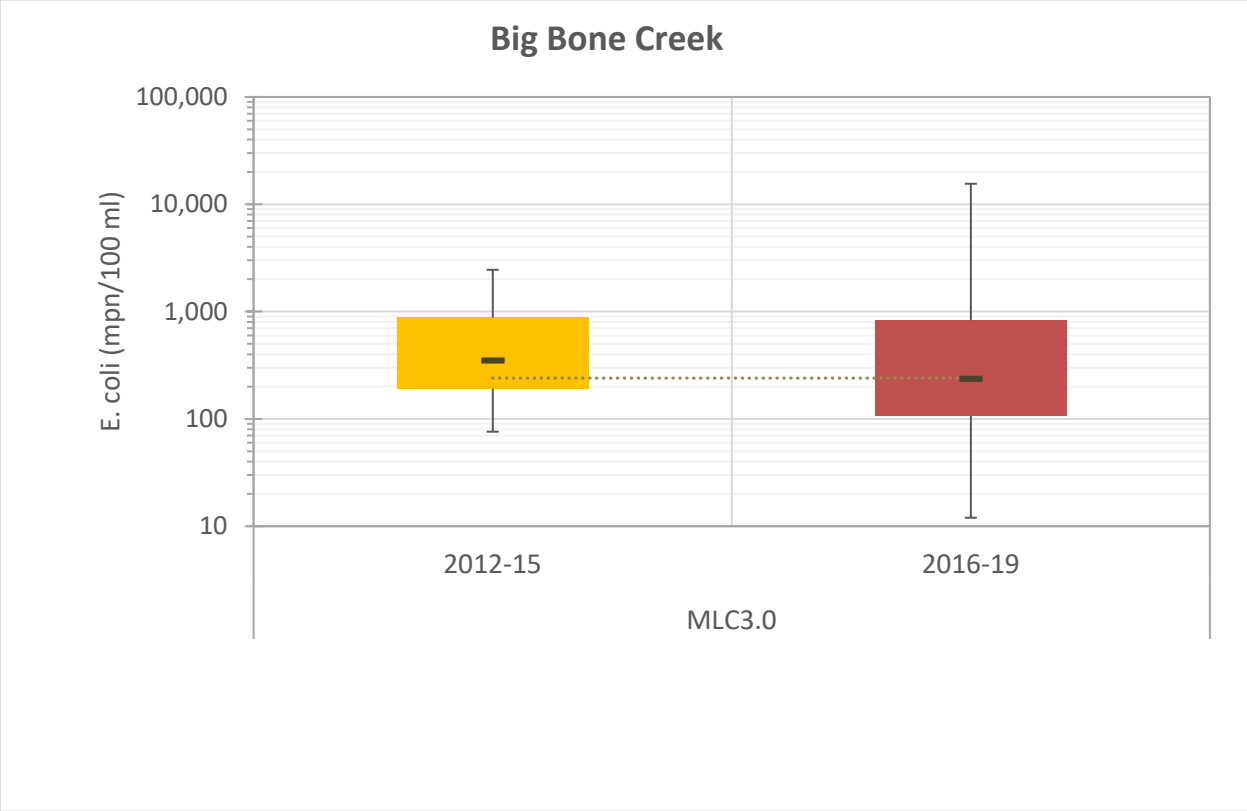
Photo 2. Mud Lick Creek 12.0

Big Bone Creek *E. coli*

E. coli values ranged from 76 mpn/100ml to 2,452 mpn/100ml during Period 2 and ranged from 12 mpn/100ml to 15,530 mpn/100ml during Period 3 at MLC3.0. The median value during Period 2 was above the 240 mpn/100ml criteria (348 mpn/100ml) and the median value during Period 3 was just below the criteria (236 mpn/100ml).

Suspected sources of elevated *E. coli* values within Big Bone Creek waterhsed primarliy includes failing septic systems and storm water runoff.

Photo 3. Big Bone Creek 3.9



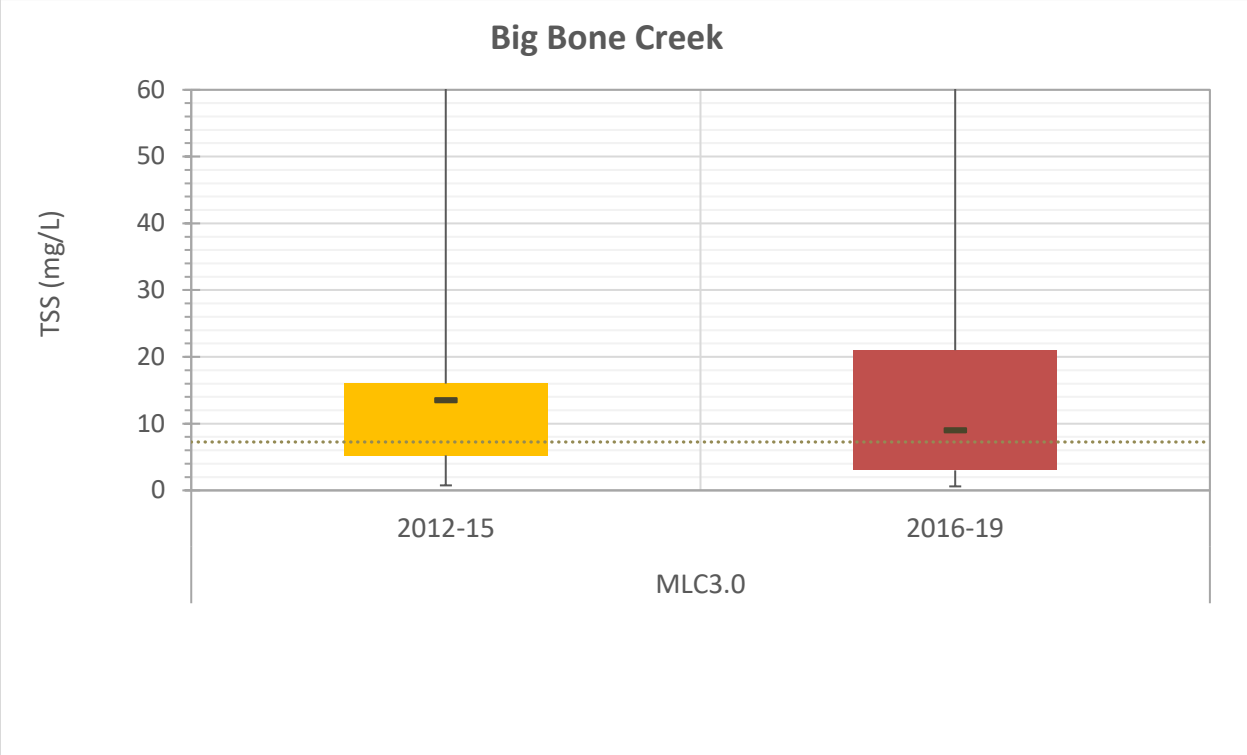
The dashed line in the graph represents the single sample maximum criteria of 240 mpn/100ml.

Figure 9. Big Bone Creek E. coli Results

Big Bone Creek Total Suspended Solids

TSS values ranged from <1.2 mg/L to 65 mg/L during Period 2 and ranged from <1.2 mg/L to 168 mg/L during Period 3 at MLC3.0. The median values during both periods were above the 7.25 mg/L benchmark, 14 mg/L and 9 mg/L.

Suspected sources of elevated TSS values within the Big Bone Creek watershed primarily includes storm water runoff and streambank erosion due to hydromodification.



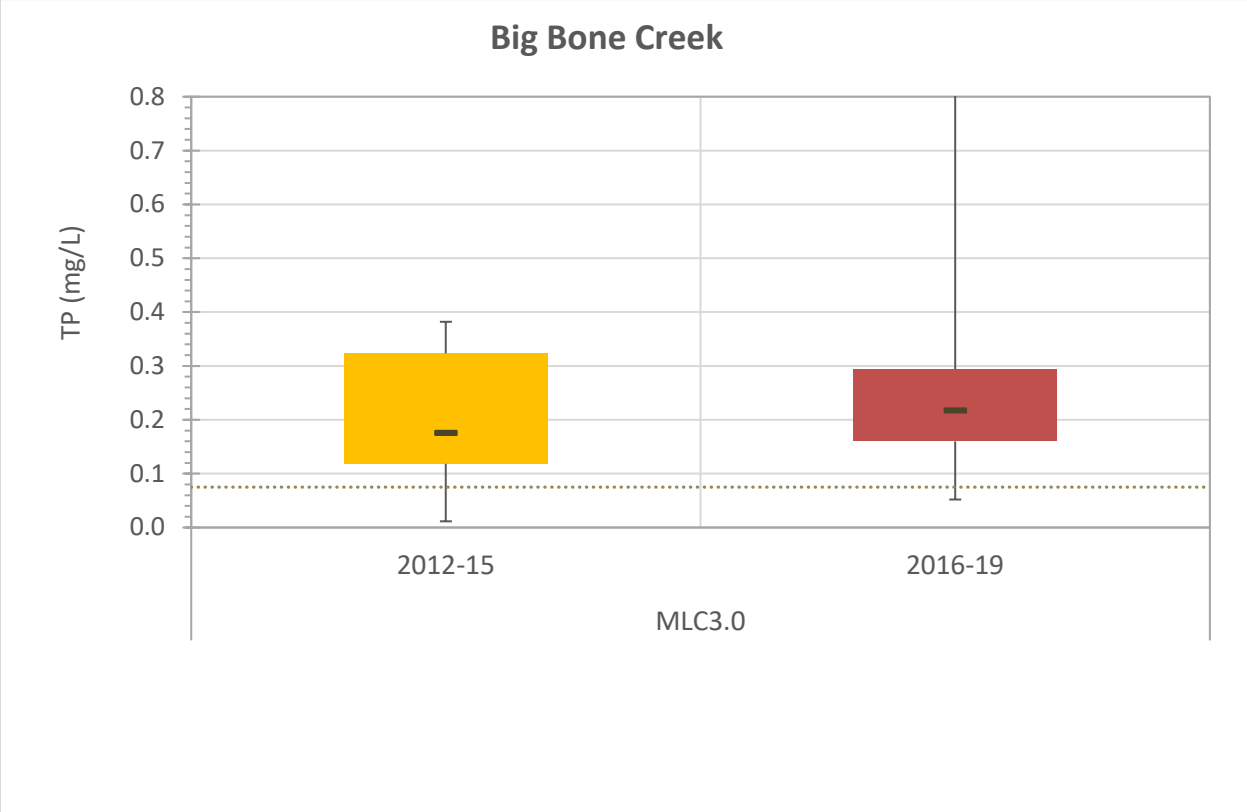
The dashed line in the graph represents the benchmark value established by KDOW of 7.25 mg/L.

Figure 10. Big Bone Creek TSS Results

Big Bone Creek Total Phosphorous

TP values ranged from <0.023 mg/L to 0.382 mg/L during Period 2 and ranged from 0.052 mg/L to 1.01 mg/L during Period 3 at MLC3.0. The median value during Periods 2 and 3 was above the 0.08 mg/L benchmark, 0.176 mg/L and 0.217 mg/L.

The median TP values for each reporting period was highest within the Big Bone Creek watershed when compared to the other West Basin watershed. Suspected sources of elevated phosphorus values within the Big Bone Creek watershed primarily includes point source discharges and storm water runoff.



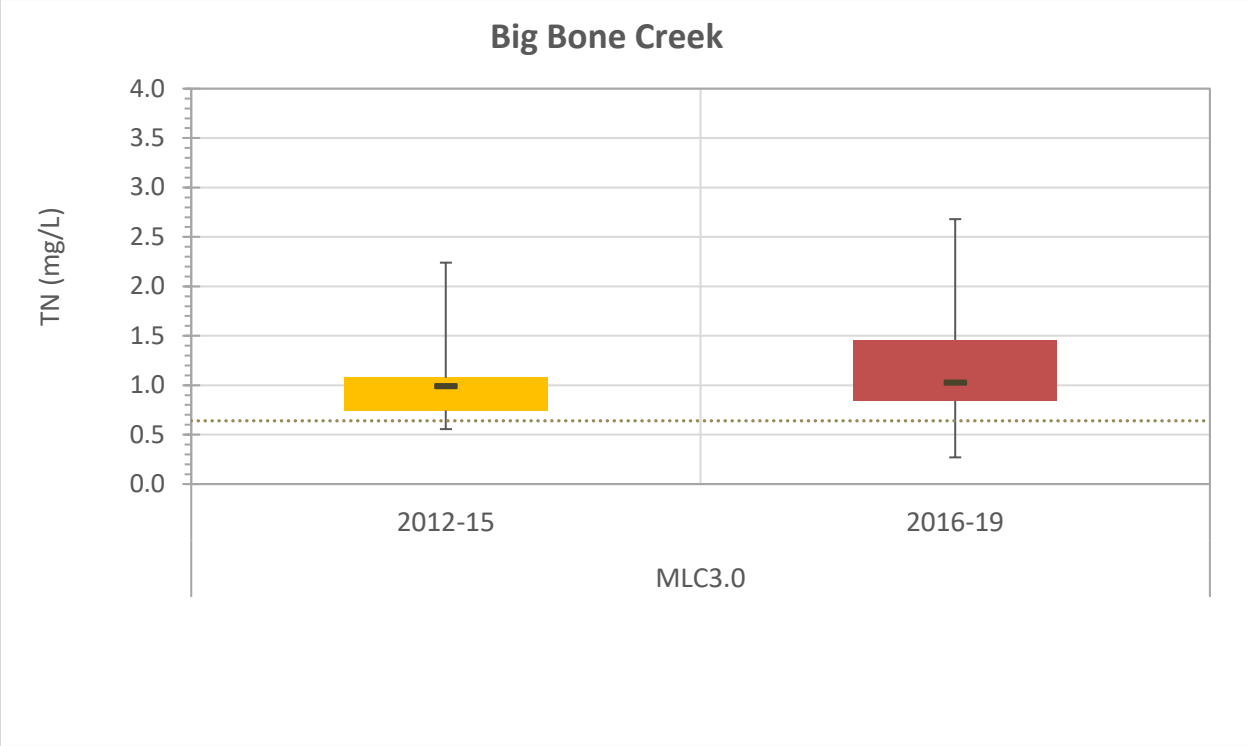
The dashed line in the graph represents the benchmark value established by KDOW of 0.08 mg/L.

Figure 11. Big Bone Creek TP Results

Big Bone Creek Total Nitrogen

TN values ranged from 0.56 mg/L to 2.24 mg/L during Period 2 and 0.27 mg/L to 2.68 mg/L during Period 3 at MLC3.0. The median values during both periods were above the 0.6 mg/L benchmark, 0.99 mg/L and 1.03 mg/L.

Suspected sources of excess nitrogen values within the Big Bone Creek watershed primarily include point source discharges and storm water runoff.



The dashed line in the graph represents the benchmark value established by KDOW of 0.6 mg/L.

Figure 12. Big Bone Creek TN Results

Gunpowder Creek

The Gunpowder Creek watershed monitoring site GPC14.7 was sampled during Period 2 and all four years of Period 3, monitoring site GPC4.6 was only sampled during Period 2 and the first two years of Period 3. Monitoring sites GPC17.9 and SFG5.3 were added to the ambient monitoring program in 2021, with all four sites scheduled for sampling during Period 4 per the basin rotation cycle.

Table 4. Gunpowder Creek Number of Samples Collected

Gunpowder Creek	Period 2 No. of Samples	Period 3 No. of Samples			
Site	**2015**	**2016**	**2017**	**2018**	**2019**
GPC4.6	10	16	6	NS	NS
GPC14.7	10	16	13	12	12
GPC17.9	NS	NS	NS	NS	NS
SFG5.3	NS	NS	NS	NS	NS

Columns displaying "NS" do not currently have results available but will in subsequent years (i.e., Period 4).

Photo 4. Gunpowder Creek 4.6

Photo 5. South Fork Gunpowder Creek 5.3

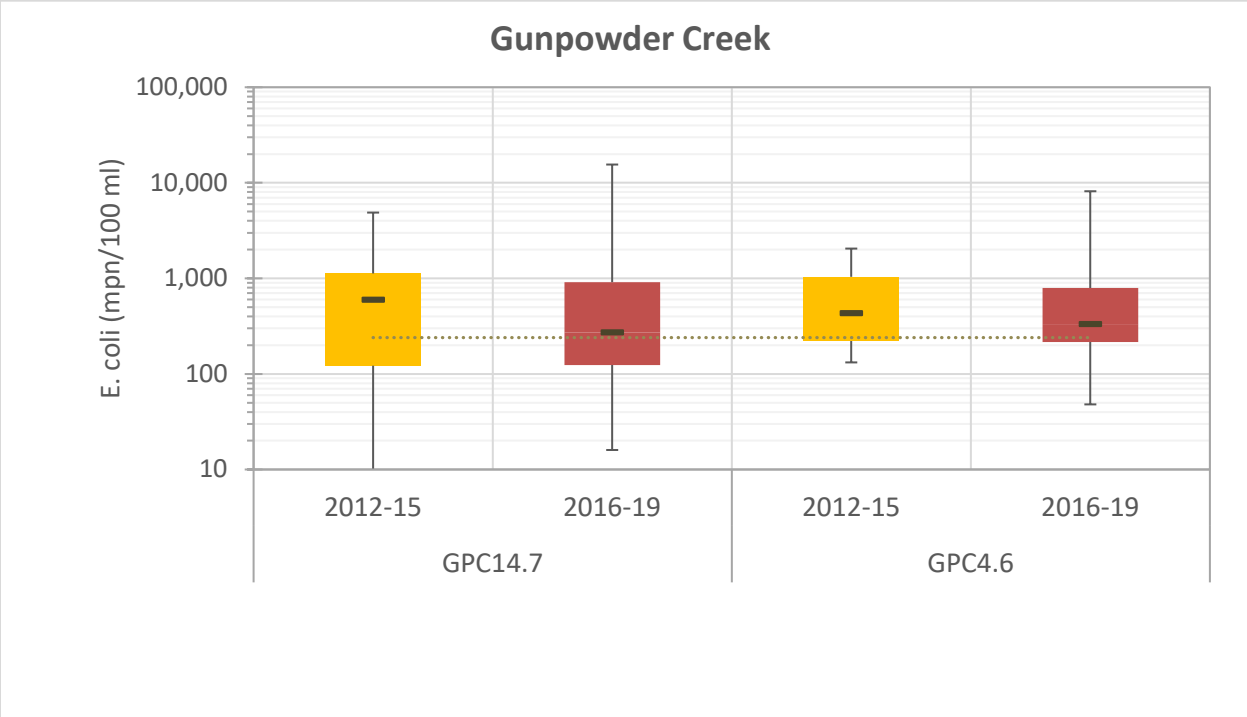
Gunpowder Creek *E. coli*

E. coli values ranged from 132 mpn/100ml to 2,050 mpn/100ml during Period 2 and ranged from 48 mpn/100ml to 8,160 mpn/100ml during Period 3 at GPC4.6. The median value during both periods was above the 240 mpn/100ml criteria, 430 mpn/100 ml and 332 mpn/100ml.

E. coli values ranged from 8 mpn/100ml to 4,880 mpn/100ml during Period 2 and ranged from 16 mpn/100ml to 15,530 mpn/100ml during Period 3 at GPC14.7. The median value during both periods was above 240 mpn/100ml, 596 mpn/100ml and 272 mpn/100ml.

The median bacteria value for each reporting period was highest within the Gunpowder Creek watershed when compared to the other West Basin watershed. Suspected sources of elevated *E. coli* values within the Gunpowder Creek watershed primarily includes failing septic systems and storm water runoff.

Photo 6. Gunpowder Creek 14.7



The dashed line in the graph represents the single sample maximum criteria of 240 mpn/100ml.

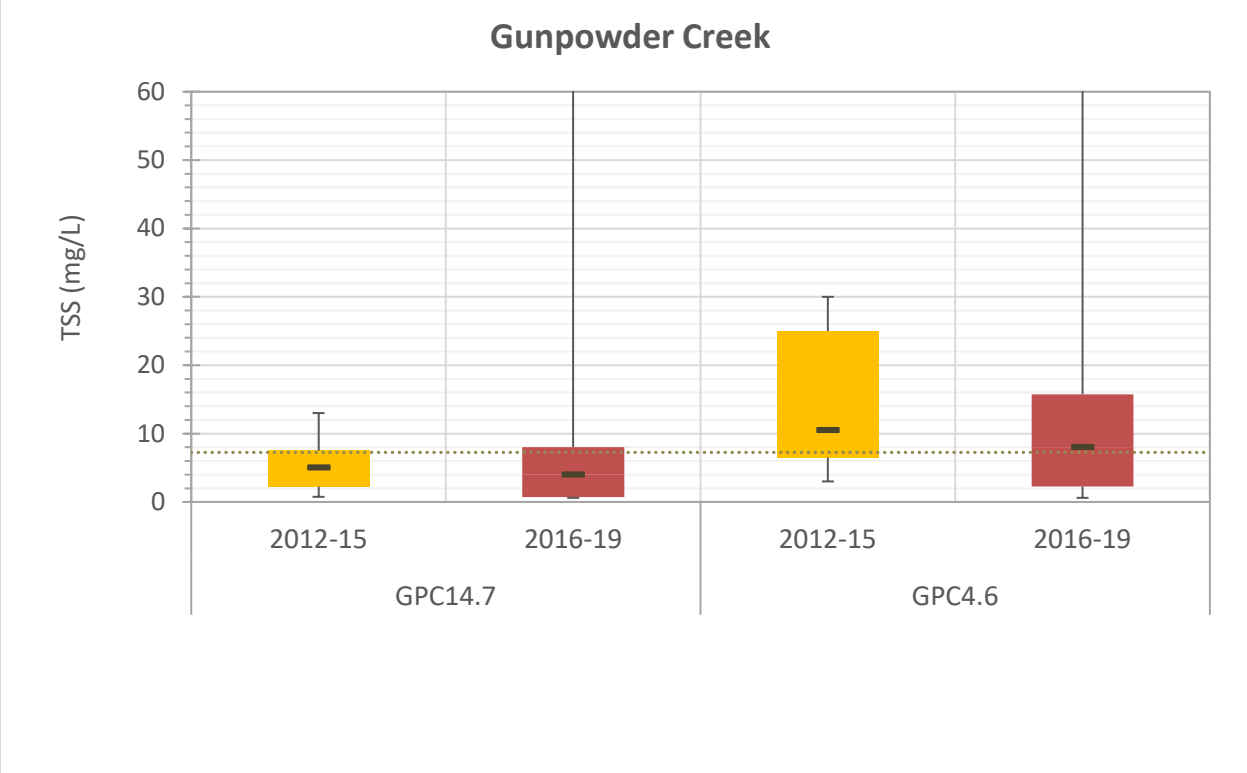
Figure 13. Gunpowder Creek E. coli Results

Gunpowder Creek Total Suspended Solids

TSS values ranged from 3 mg/L to 30 mg/L during Period 2 and ranged from <1.2 mg/L to 146 mg/L during Period 3 at GPC4.6. The median values during both periods were above the 7.25 mg/L benchmark, 11 mg/L and 8 mg/L.

TSS values ranged from <1.5 mg/L to 13 mg/L during Period 2 and ranged from <1.2 mg/L to 150 mg/L during Period 3 at GPC14.7. The median values during both periods were below the 7.25 mg/L benchmark, 5 mg/L and 4 mg/L.

Suspected sources of elevated TSS values within the Gunpowder Creek watershed primarily includes storm water runoff and streambank erosion due to hydromodification.



The dashed line in the graph represents the benchmark value established by KDOW of 7.25 mg/L.

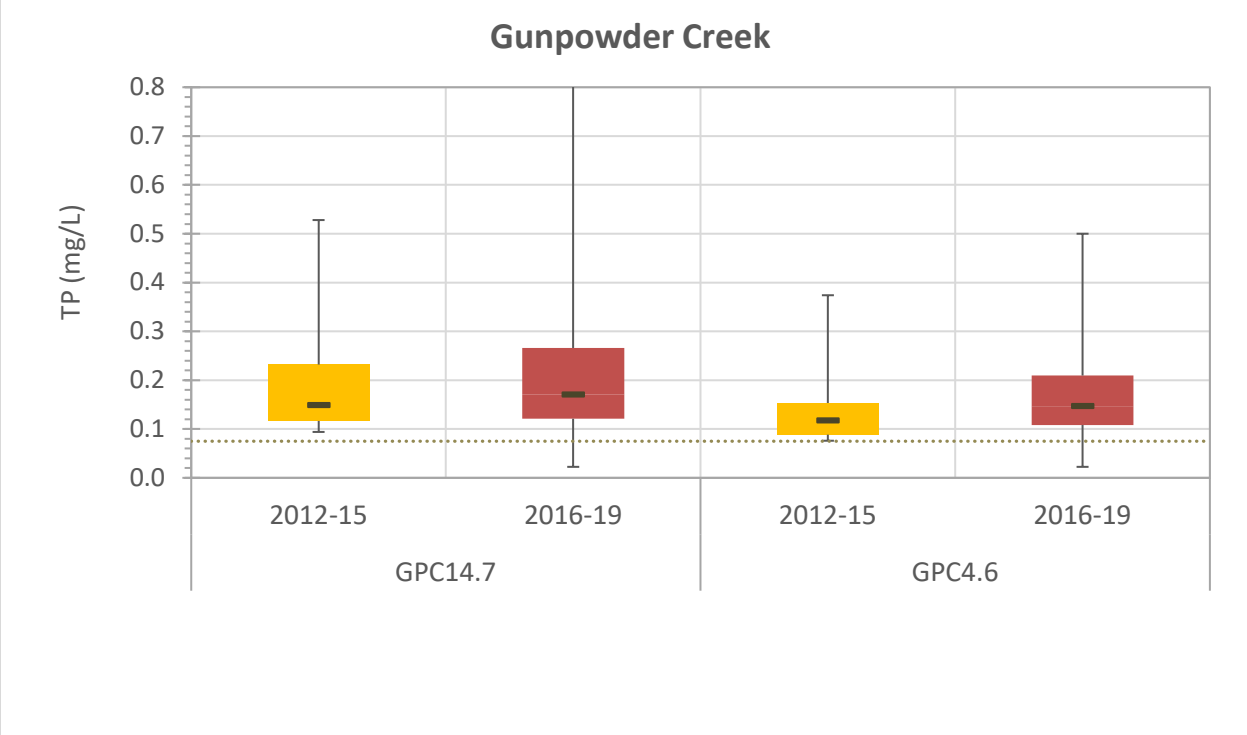
Figure 14. Gunpowder Creek TSS Results

Gunpowder Creek Total Phosphorous

TP values ranged from 0.076 mg/L to 0.374 mg/L during Period 2 and ranged from <0.045 mg/L to 0.500 mg/L during Period 3 at GPC4.6. The median values during both periods were above the 0.08 mg/L benchmark, 0.118 mg/L and 0.147 mg/L.

TP values ranged from 0.094 mg/L to 0.528 mg/L during Period 2 and ranged from <0.045 mg/L to 2.01 mg/L during Period 3 at GPC14.7. The median values during both periods were above the 0.08 mg/L benchmark, 0.149 mg/L and 0.17 mg/L.

Suspected sources of elevated phosphorus values within the Gunpowder Creek watershed primarily include storm water runoff.



The dashed line in the graph represents the benchmark value established by KDOW of 0.08 mg/L.

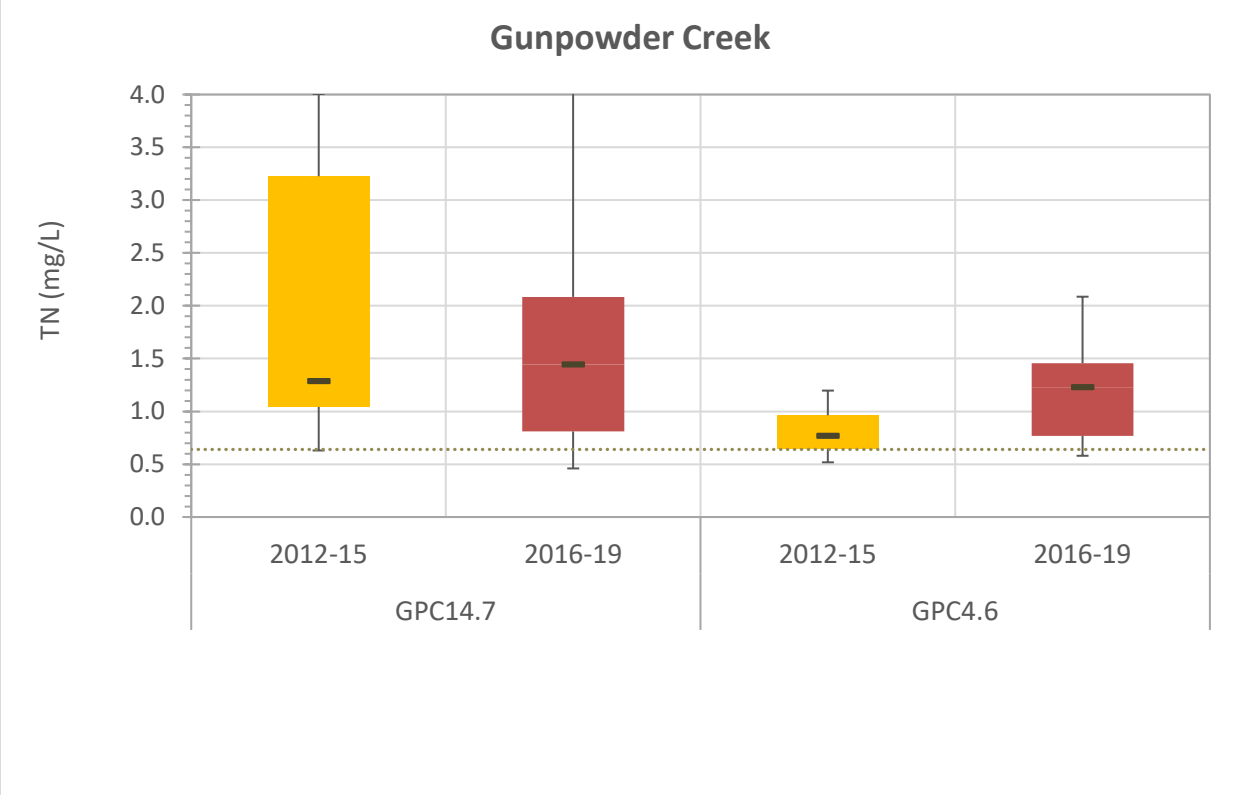
Figure 15. Gunpowder Creek TP Results

Gunpowder Creek Total Nitrogen

TN values ranged from 0.52 mg/L to 1.20 mg/L during Period 2 and 0.58 mg/L to 2.09 mg/L during Period 3 at GPC4.6. The median values during both periods were above the 0.6 mg/L benchmark, 0.77 mg/L and 1.23 mg/L.

TN values ranged from 0.63 mg/L to 4.01 mg/L during Period 2 and 0.46 mg/L to 13.41 mg/L during Period 3 at GPC14.7. The median values during both periods were above the 0.6 mg/L benchmark, 1.29 mg/L and 1.44 mg/L.

The median TN value for each reporting period except for Period 2 at GPC4.6, was highest within the Gunpowder Creek watershed when compared to the other West Basin watershed. Suspected sources of elevated nitrogen values within the Gunpowder Creek watershed primarily include storm water runoff.



The dashed line in the graph represents the benchmark value established by KDOW of 0.6 mg/L.

Figure 16. Gunpowder Creek TN Results

Biological Assessment Results

SD1's biological assessments consist of macroinvertebrate specimen collection and habitat characterization conducted at multiple sites in each watershed. During the Period 2 basin rotation, West Basin sites were collected in 2015; during the Period 3 basin rotation, West Basin sites were collected in 2019. All assessments were conducted following the appropriate Field Monitoring and Sampling Plan (FMSP) and the associated Quality Assurance Program Plan (QAPP) utilizing approved bioassessment protocols[9].

Macroinvertebrate specimen samples were analyzed using the Kentucky Division of Water Macroinvertebrate Biologic Index (MBI), as well as statistical analyses that examine community structure. The MBI is a multi-metric index that uses various attributes to assign a score (0-100, scaled temporally and spatially) and a rating (Excellent, Good, Fair, Poor, Very Poor) to a given stream reach, with higher scores corresponding to higher quality streams. Key metrics that affect overall index scores (refer to Appendix B1 for additional details) are as follows:

- Abundance of genera (i.e., taxa richness) - increasing total number of genera generally indicates improving water quality and habitat conditions (see example photos below).

Photo 7. Hellgrammite Larvae (Megaloptera)

Photo 8. Crane Fly Larvae (Diptera)

- Abundance of pollution sensitive organisms (specifically insect orders of Ephemeroptera, Plecoptera and Trichoptera) - increasing total pollutant sensitive organisms generally indicate improving water quality and habitat conditions (see example photos below).

Photo 9. Mayfly Nymph (Ephemeroptera)

Photo 10. Stonefly (Plecoptera)

[9] Kentucky Division of Water/U.S. Environmental Protection Agency criteria (Barbour et al. 1999, KDOW 2001)

- Abundance of pollution tolerant organisms - increasing total pollutant tolerant organisms generally indicate declining water quality conditions (see example photos below).

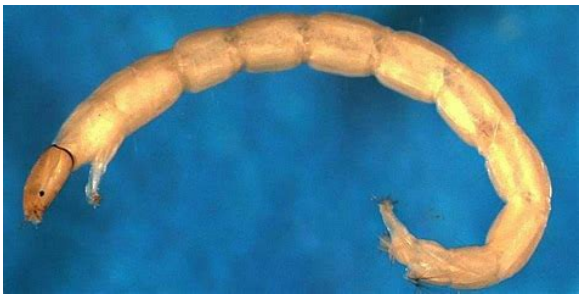


Photo 11. Chironomid Larvae (Chironomidae) [10]

Photo 12. Aquatic Worm (Oligochaete)

Habitat assessments were determined using Rapid Bioassessment Protocols (RBP). This protocol evaluates instream metrics – such as embeddedness, and velocity, as well as the surrounding riparian buffer metrics – such as bank stability, vegetative protection, and channel alteration. In combination, these metrics give an overall evaluation of the stream reach. In total there are ten metrics that are evaluated (refer to Appendix B2 for additional details). Each metric is assigned a score (0-20) by the field crew for each site. A final score is calculated, and a rating (Good, Fair, Poor) is given to the stream reach, with higher scores corresponding to higher quality streams.

Habitat and macroinvertebrate data were collected at sampling sites as defined in the FMSP. Sites were separated into two types and categorized as either headwater or wadeable. Headwater sites have 5 miles^2 or less drainage area, while wadeable sites have greater than 5 miles^2 of drainage area.

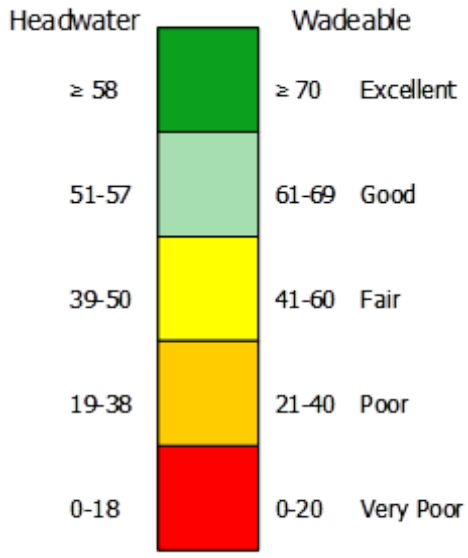


Figure 17. MBI Ratings

Table 5. RBP Ratings

Headwater		Wadeable	
Good	>156	Good	>130
Fair	142-155	Fair	114-129
Poor	<141	Poor	<113

Refer to Appendices B1 and B2 for results from individual sites within the West Basin study area.

[10] Photo taken from the North Carolina Department of Environmental Quality website.

Big Bone Creek

Big Bone Creek streams within the watershed are typically steep to moderate gradient, with streambeds usually dominated by a mixture of bedrock/cobble substrate in the lower portions of the watershed and reduced stream substrate in the upper portions of the watershed. Riparian zone habitat varies throughout the stream length, dependent primarily on the surrounding land use. The current state of development has resulted in a watershed total impervious surface area of 4.7%. Assessments were performed at all three monitoring sites during Period 2 and Period 3.

Table 6. Big Bone Creek MBI Scores

Big Bone Creek	Site Type	Period 2 MBI Scores	Period 3 MBI Scores
Site	**Category**	**2015**	**2019**
BBC3.9	Wadeable	68.98 (Good)*	61.21 (Good)
MLC3.0	Wadeable	69.18 (Good)	62.92 (Good)
MLC12.0	Wadeable	52.32 (Fair)*	55.65 (Fair)

*Sites BBC3.9 and MLC12.0 were assessed in 2016.

The Big Bone Creek MBI scores ranged from fair to good at all three sites. Scores decreased at sites BBC3.9 and MLC3.0 from 2015 to 2019 but remained with a good rating. The score increased at site MLC12.0 from 2015 to 2019 most likely due to changes in the percentages of pollutant sensitive and pollutant tolerant organisms.

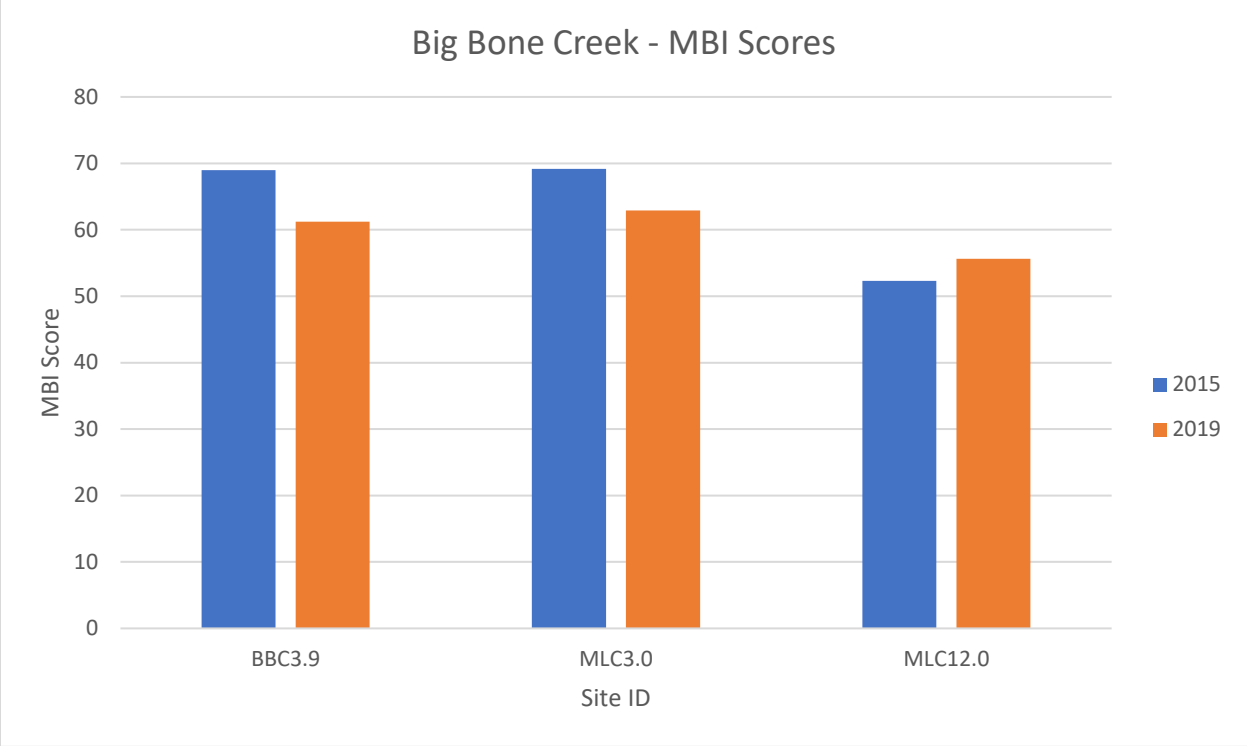


Figure 18. Big Bone Creek MBI Scores

Table 7. Big Bone Creek RBP Scores

Big Bone Creek	Site Type	Period 2 RBP Scores	Period 3 RBP Scores
Site	**Category**	**2015**	**2019**
BBC3.9	Wadeable	121 (Fair)*	139 (Good)
MLC3.0	Wadeable	132 (Good)	130 (Good)
MLC12.0	Wadeable	97(Poor)*	124 (Fair)

*Sites BBC3.9 and MLC12.0 were assessed in 2016.

The Big Bone Creek habitat scores ranged from poor to good at all three sites. Scores increased at both BBC3.9 and MLC12.0, while MLC3.0 remained almost the same. Site MLC12.0 had the greatest increase in score (27 points) moving from poor in 2015 (i.e., 2016) to fair in 2019, which was mainly due to increases in channel flow status, riffle frequency and epifaunal substrate metrics.

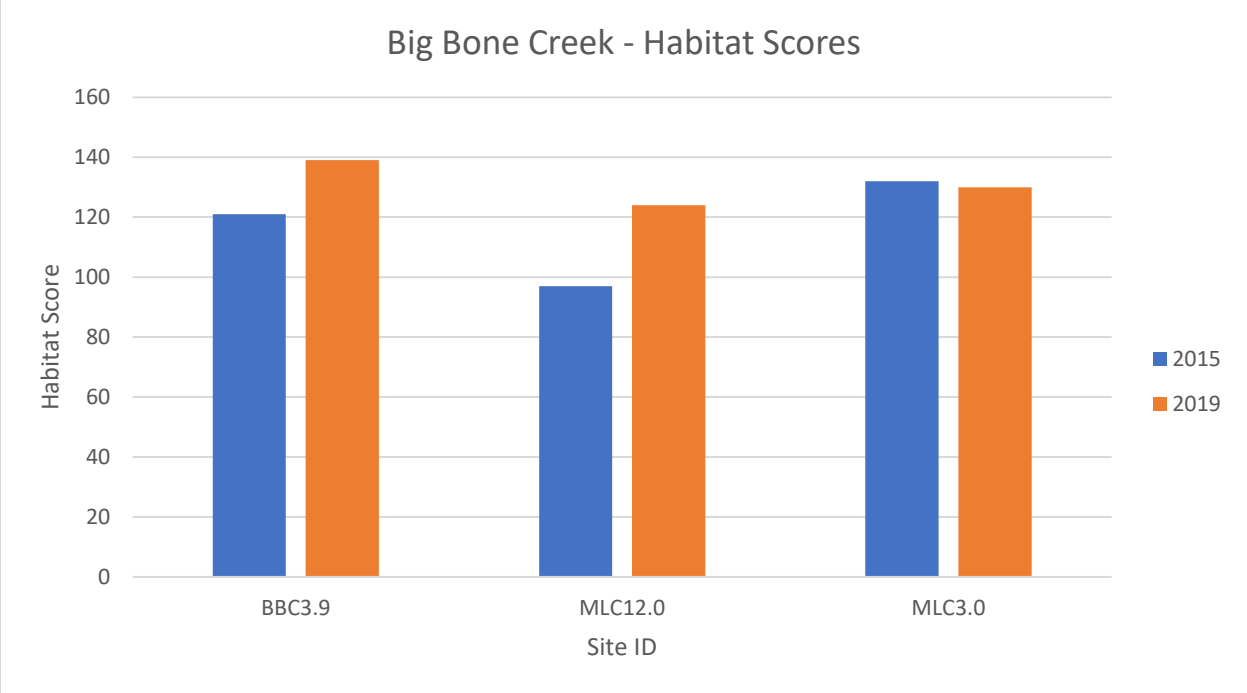


Figure 19. Big Bone Creek Habitat Scores

Gunpowder Creek

Gunpowder Creek streams within the watershed are typically of moderate gradient, with streambeds usually dominated by cobble/boulder substrates. Riparian zone habitat varies throughout the stream length, dependent primarily on the surrounding land use. The current state of development has resulted in a watershed total impervious surface area of 18.7%. Assessments were performed at three monitoring sites during Period 2 and Period 3. Biological monitoring will be added to site GPC4.6 for assessment during Period 4 per the basin rotation cycle.

Table 8. Gunpowder Creek MBI Scores

Gunpowder Creek	Site Type	Period 2 MBI Scores	Period 3 MBI Scores
Site	**Category**	**2015**	**2019**
GPC4.6	Wadeable	NA	NA
GPC14.7	Wadeable	50.42 (Fair)	59.73 (Fair)
GPC17.9	Wadeable	49.00 (Fair)	53.68 (Fair)
SFG5.3	Wadeable	43.73 (Fair)	41.53 (Fair)

Columns displaying "NA" do not currently have results available but will in subsequent years (i.e., Period 4).

The Gunpowder Creek MBI scores remained in the fair range at all three sites. At sites GPC14.7 and GPC17.9 the scores increased from 2015 to 2019, due mainly to increase in taxa richness and abundance of percent primary clinger organisms. Site SFG5.3 decreased slightly due to an increase in abundance of pollutant tolerant organisms.

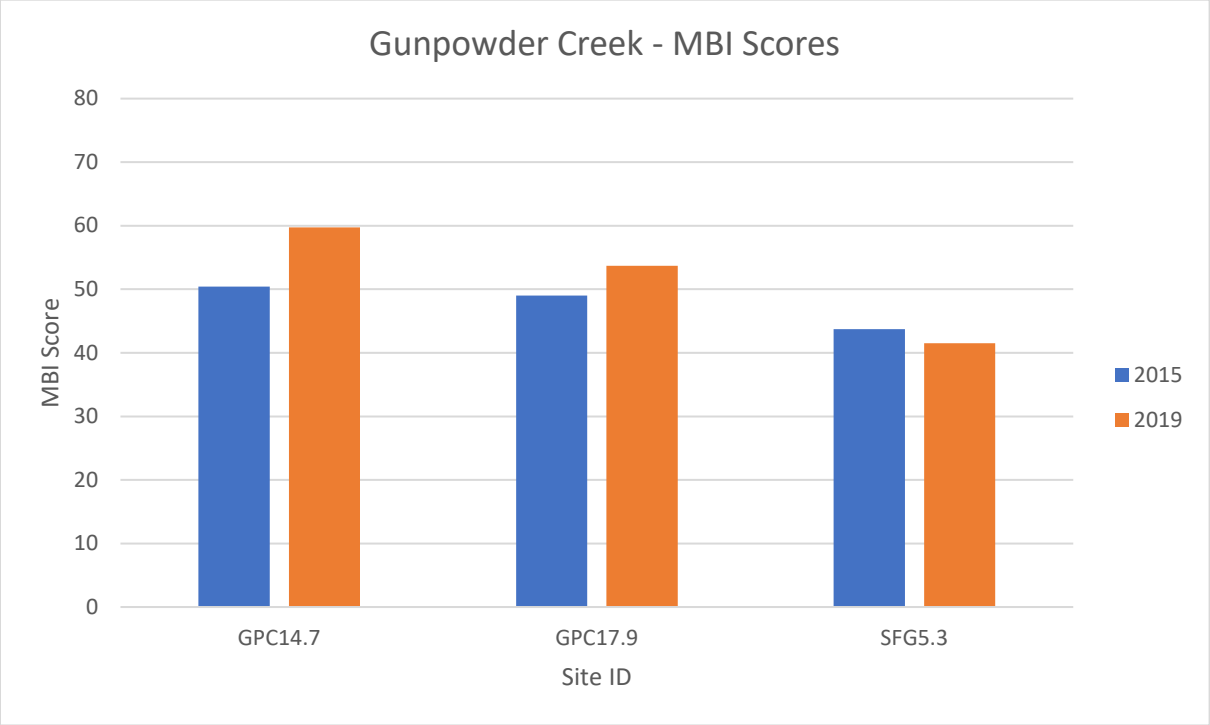


Figure 20. Gunpowder Creek MBI Scores

Table 9. Gunpowder Creek RBP Scores

Gunpowder Creek	Site Type	Period 2 RBP Scores	Period 3 RBP Scores
Site	**Category**	**2015**	**2019**
GPC4.6	Wadeable	NA	NA
GPC14.7	Wadeable	126 (Fair)	143 (Good)
GPC17.9	Wadeable	104 (Poor)	134 (Good)
SFG5.3	Wadeable	60 (Poor)	102 (Poor)

Columns displaying "NA" do not currently have results available but will in subsequent years (i.e., Period 4).

The Gunpowder Creek habitat scores ranged from poor to good at all three sites with significant improvements from 2015 to 2019. Site GPC14.7 and Site GPC17.9 scores increased from both fair and poor respectively to good, while the Site SFG5.3 score increased by 42 points, remaining with a poor rating. Main improvements were in channel flow status and embeddedness scores.

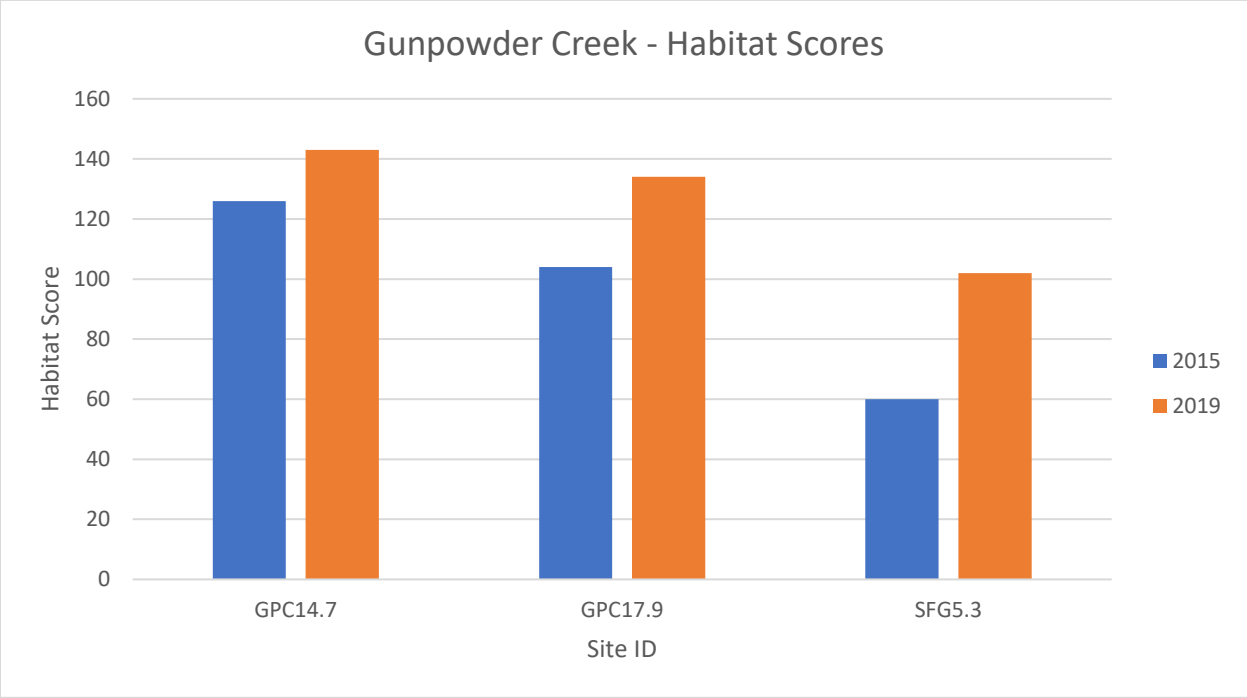


Figure 21. Gunpowder Creek Habitat Scores

Stream Stability Assessment Results

The stream stability monitoring program collects dimensions of stream geomorphology across NKY to develop a regional stream stability index, which consists of full surveys (i.e., channel cross-sections and longitudinal profiles, along with bed material particle counts), as well as rapid stability assessments[11] (i.e., bank height/angle, channel shape, bedrock, and pool depth indexes). The rapid stability assessment was developed to supplement the labor-intensive data collection of full surveys to enable the generation of a numerical score immediately upon data collection. For efficient data collection, rapid stream stability assessments were conducted during the biological assessments.

Rapid Stability Scores measure rates of channel change, as seen in Figure 22 (figure shows the channel evolution model – illustration of how a stream can deepen, then widen, and reestablish new banks, over time), in conjunction with field indicators, failure mechanisms, and sediment transport analyses to develop a regionally calibrated channel stability index. The index scale (i.e., 0 – 10 scale) is designed to have built-in flexibility to score sites without detailed stream stability surveys on the same scale as those with multiple years of data using simple but significant metrics. There is not a definitive separation between scores, as in the MBI, however, as a guideline, Table 10 shows stability rankings (i.e., Stable, Transition and Unstable) with respect to assessment scores.

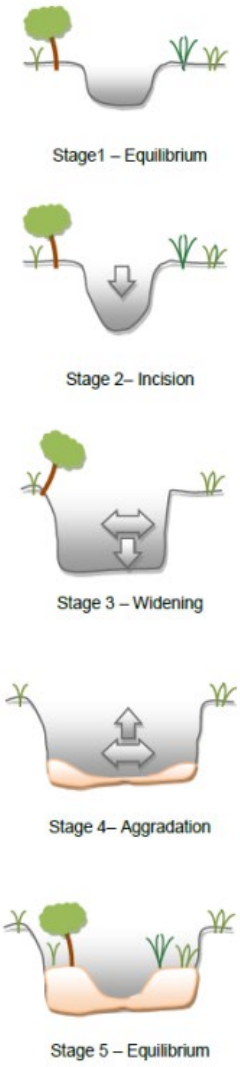


Figure 22. Channel Evolution Model[12]

Table 10. Rapid Stability Scores

Rapid Stability Scores	
Stable (relative equilibrium)	>7
Transition (intermediate)	>4 to <7
Unstable (actively adjusting in multiple dimensions)	<4

Refer to Appendix C for results from individual sites within the West Basin study area.

[11] *Regionally-Calibrated Channel Stability Index for Northern Kentucky Streams*, July 2012 Memorandum
[12] *Incised Channels: Morphology Dynamics and Control*, Schumm et al. 1984

Big Bone Creek

Big Bone Creek watershed monitoring sites were assessed in 2015 during Period 2 (BBC3.9 and MLC3.0) and 2019 during Period 3 (BBC3.9, MLC3.0 and MLC12.0). All three sites are scheduled for assessment during Period 4, per the basin rotation cycle.

Table 11. Big Bone Creek Rapid Stability Scores

Big Bone Creek	Period 2	Period 3
Site	**2015**	**2019**
BBC3.9	3.35	5.60
MLC3.0	6.05	3.60
MLC12.0	NA	6.00

Columns displaying "NA" do not currently have results available but will in subsequent years (i.e., Period 4).

The monitoring sites in the Big Bone Creek watershed were all below the stable threshold score of 7, with two sites (BBC3.9 and MLC12.0) currently within the transition zone, as represented by the area between the solid and dashed blue lines in Figure 23. Site BBC3.9 went from an unstable score to a transitional phase score, with an increase in pool shape and embeddedness, while site MLC3.0 went from a transitional score to an unstable score due to an increase in bedrock and substrate embeddedness.

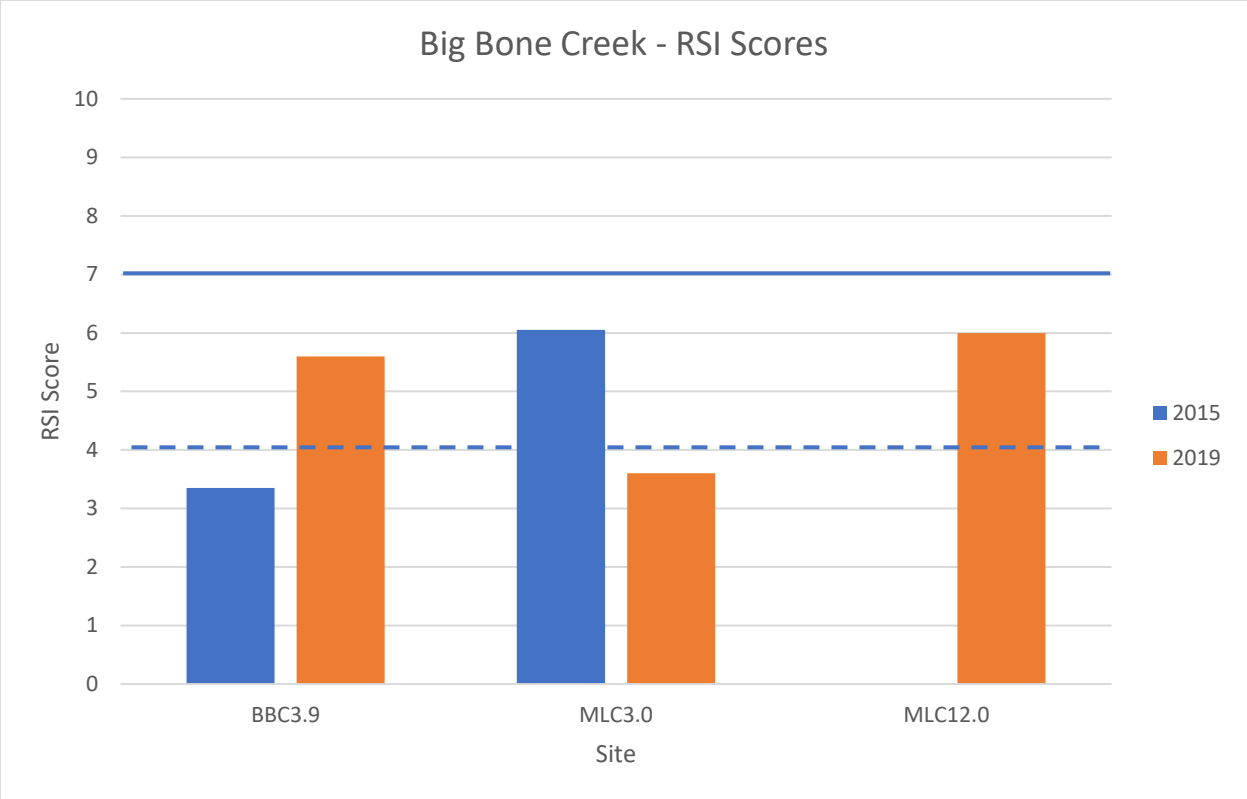


Figure 23. Big Bone Creek Rapid Stability Scores

Photo 13. Big Bone Creek 3.9

Photo 14. Mud Lick Creek 3.0

Gunpowder Creek

Gunpowder Creek watershed monitoring sites were assessed in 2015 during Period 2 (GPC14.7) and 2019 during Period 3 (GPC14.7, GPC17.9 and SFG5.3). Site GPC4.6 has been added and scheduled for assessment during Period 4, per the basin rotation cycle.

Table 12. Gunpowder Creek Rapid Stability Scores

Gunpowder Creek	Period 2	Period 3
Site	**2015**	**2019**
GPC4.6	NA	NA
GPC14.7	7.75*	5.10
GPC17.9	NA	2.40
SFG5.3	NA	1.85

Columns displaying "NA" do not currently have results available but will in subsequent years (i.e., Period 4).
*GPC14.7 was assessed on 12/16/2014.

The monitoring sites in the Gunpowder Creek watershed depicted a variety of stability scores. Site GPC14.7 had a stable score in 2015 and showed a decrease in 2019. Whereas sites GPC17.9 and SFG5.3 had unstable scores in 2019.

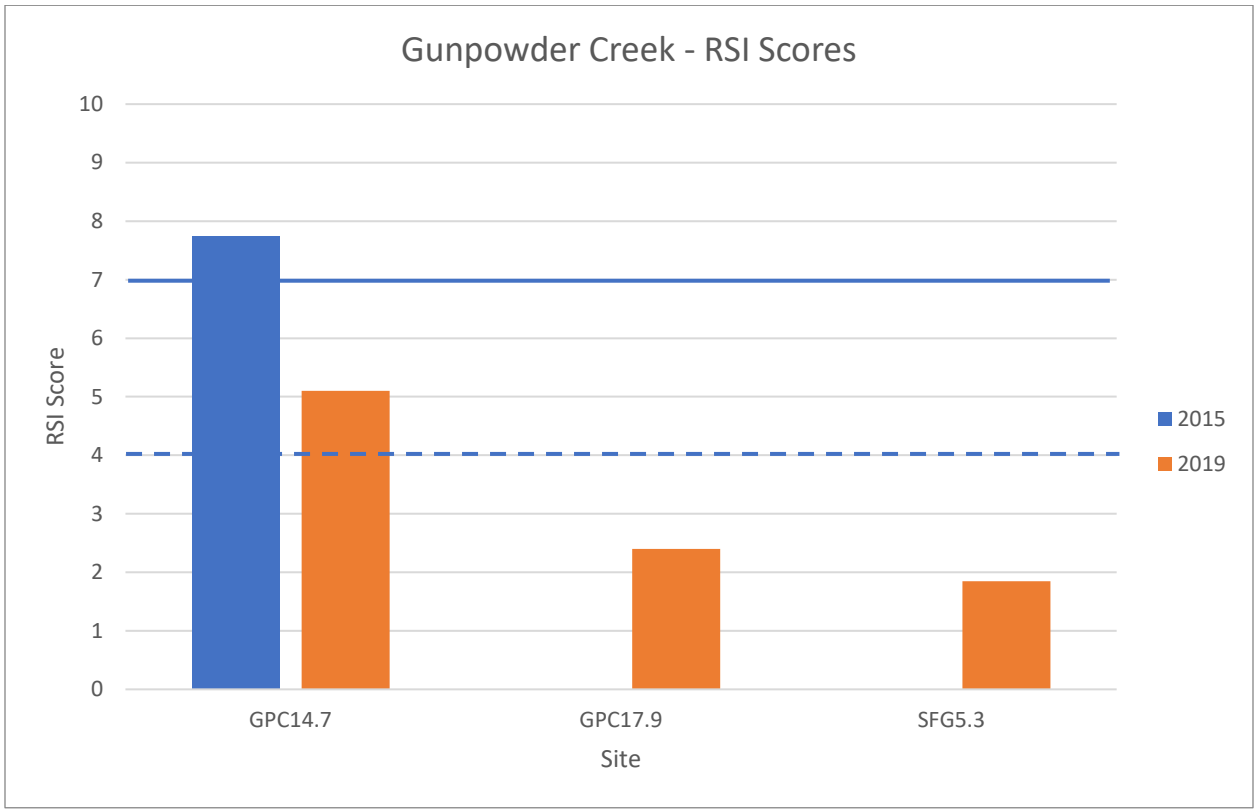


Figure 24. Gunpowder Creek Rapid Stability Scores

Photo 15. Gunpowder Creek 14.7

Photo 16. South Fork Gunpowder Creek 5.3

Stream Condition Index Basin Trends

The Stream Condition Index (SCI) is a visual representation (Figure 25) of four key components of SD1's watershed assessment program: water quality, biology, physical habitat, and stream stability[13]. Originally developed for a tool to summarize large amounts of complex information that can be easily understood by the general public, the SCI was updated in 2020 for trend analysis[14]. Each of these four components is essential to fully understand the ecological functions and relative health of the individual streams. Relying on a single parameter could be problematic since some streams may rate well in one category, but poor in others. Each of the four indicators used in the Stream Condition Index are given sub-scores. The four sub-scores are then averaged to generate a single overall Stream Condition Index score. These scores are updated as additional data is collected and as the characterization of the watersheds are refined. The overall score for a monitoring site is only calculated if 3 out of the 4 indicators are populated with a sub-score.

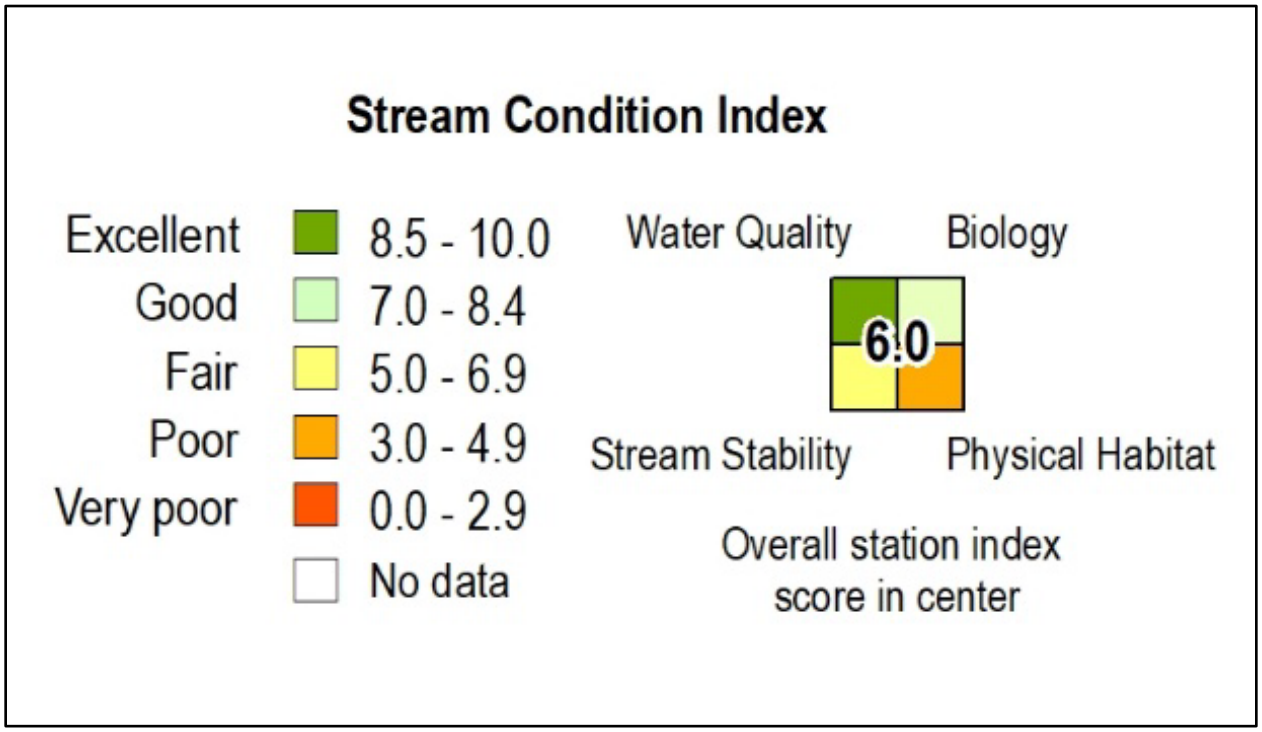


Figure 25. Stream Condition Index Visual Representation

An overall watershed SCI score is calculated if at least 50% of the monitoring sites within the watershed contain data and, if at minimum, sub-scores are calculated for water quality, biology, and physical habitat. Watershed scores for Periods 2 and 3 are displayed in the preceding graphs and tables. These scores are out of a total rating of 10, which would be the highest score possible. Appendix D contains tables for Individual site scores for Periods 2 and 3.

[13] A Stream Condition Index for Water Utility Resource Management in Northern Kentucky Document, June 2013
[14] Basin Trend Stream Condition Index Water Quality Sub-Indice Development, October 2020 Memorandum

The overall SCI scores for the West Basin watersheds from 2012 - 2015 range from 6.43 to 6.66. Big Bone Creek had the higher score of 6.66 (Fair), while Gunpowder Creek had the lower score of 6.43 (Fair) (Table 13 and Figure 26).

Table 13. Stream Condition Index Basin Trend Scores by Watershed for Period 2 (2012 - 2015)

Watershed	Water Quality Score	Biology Score	Habitat Score	Stream Stability Score	Score
Big Bone Creek	6.33	8.69	7.15	4.47	6.66
Gunpowder Creek	6.68	5.96	5.31	7.75	6.43

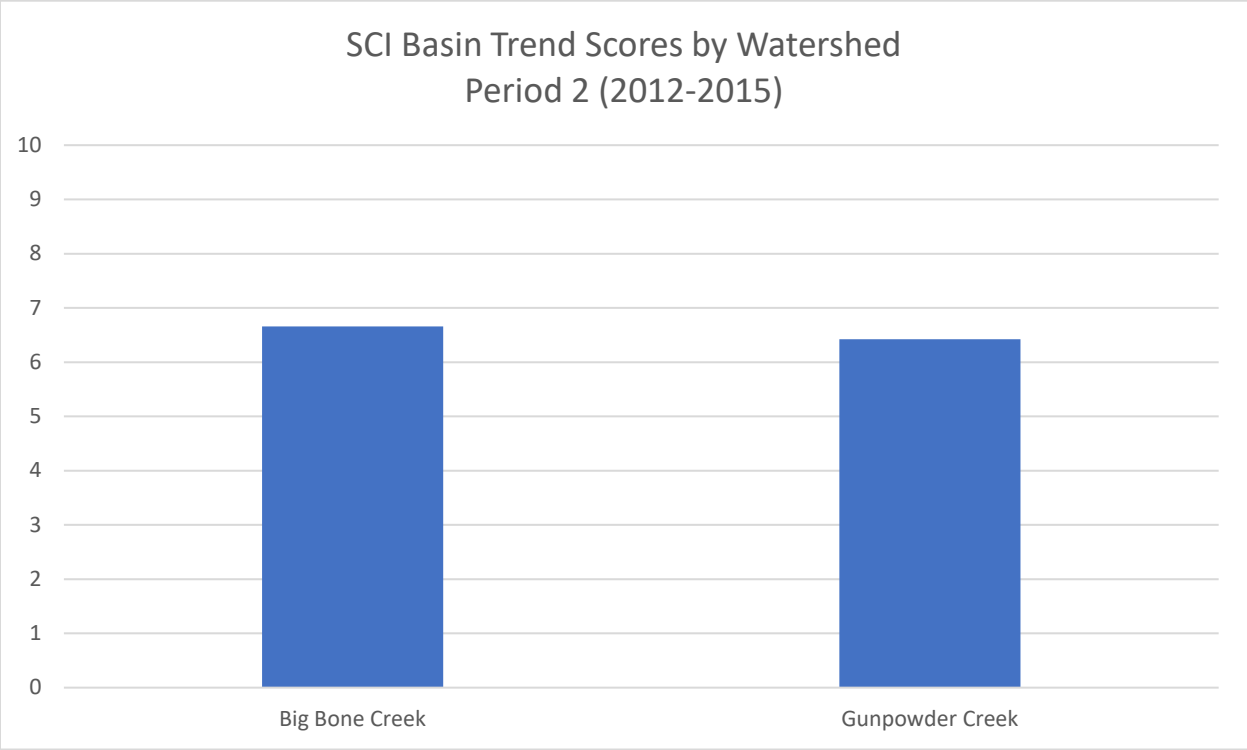


Figure 26. Stream Condition Index Basin Trend Scores by Watershed for Period 2

The overall SCI scores for the West Basin watersheds from 2016 - 2019 range from 6.12 to 7.32. Big Bone Creek had the higher score of 7.32 (Good), while Gunpowder Creek had the lower score of 6.12 (Fair) (Table 14 and Figure 27).

Table 14. Stream Condition Index Basin Trend Scores by Watershed for Period 3 (2016 - 2019)

Watershed	Water Quality Score	Biology Score	Habitat Score	Stream Stability Score	Score
Big Bone Creek	7.18	7.66	9.38	5.07	7.32
Gunpowder Creek	6.75	6.46	8.16	3.12	6.12

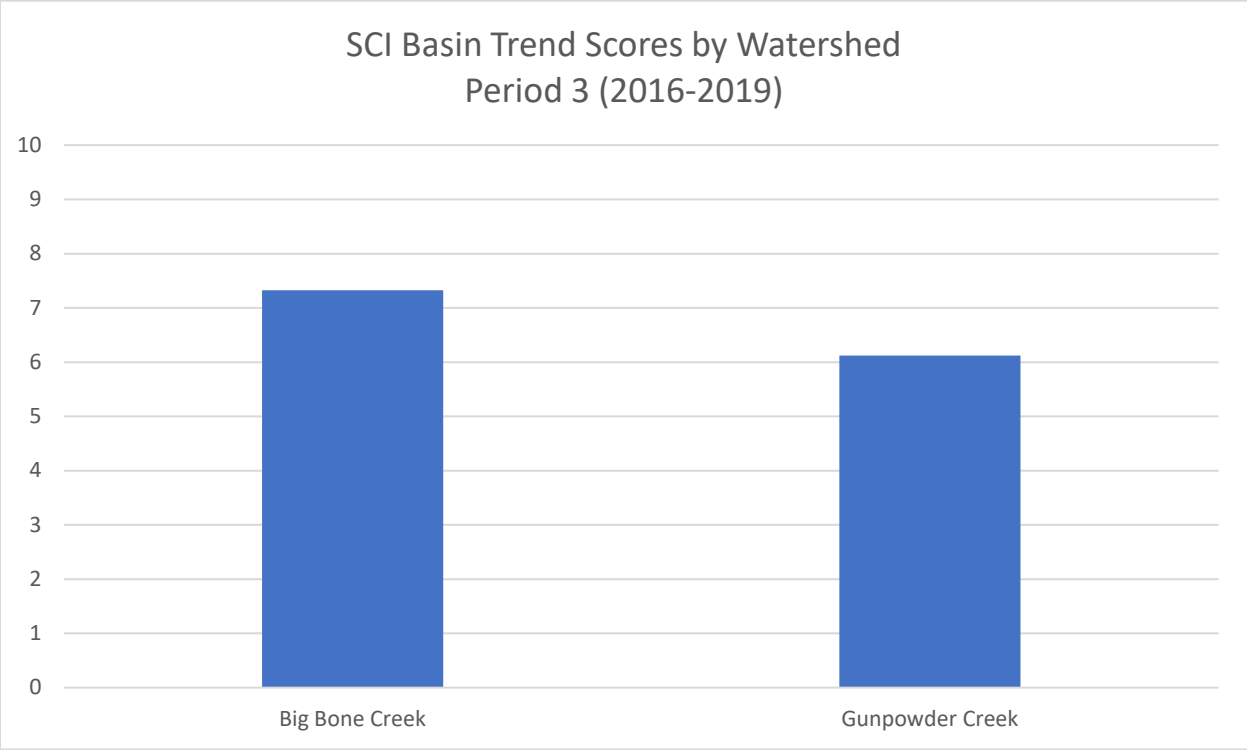


Figure 27. Stream Condition Index Basin Trend Scores by Watershed for Period 3

Conclusion

Table 15 and Figure 28 depict the initial points of a trend line representing SD1's Stream Condition Index for the two watersheds in the West Basin. Although data was limited as some monitoring sites within the watersheds during Periods 2 and 3, a more complete dataset starting with Period 4 will increase the accuracy of the analysis.

Over time as the watersheds are sampled and assessed, the trend line representing each watersheds rating will extend. Currently, the line between periods for Big Bone Creek is trending upward (i.e., positive improvement) and the line between periods for Gunpowder Creek and is trending down slightly (i.e., not improving).

Table 15. Stream Condition Index Basin Trend Scores

Watershed	Period 2 (2012-2015)	Period 3 (2016-2019)
Big Bone Creek	6.66	7.32
Gunpowder Creek	6.43	6.12

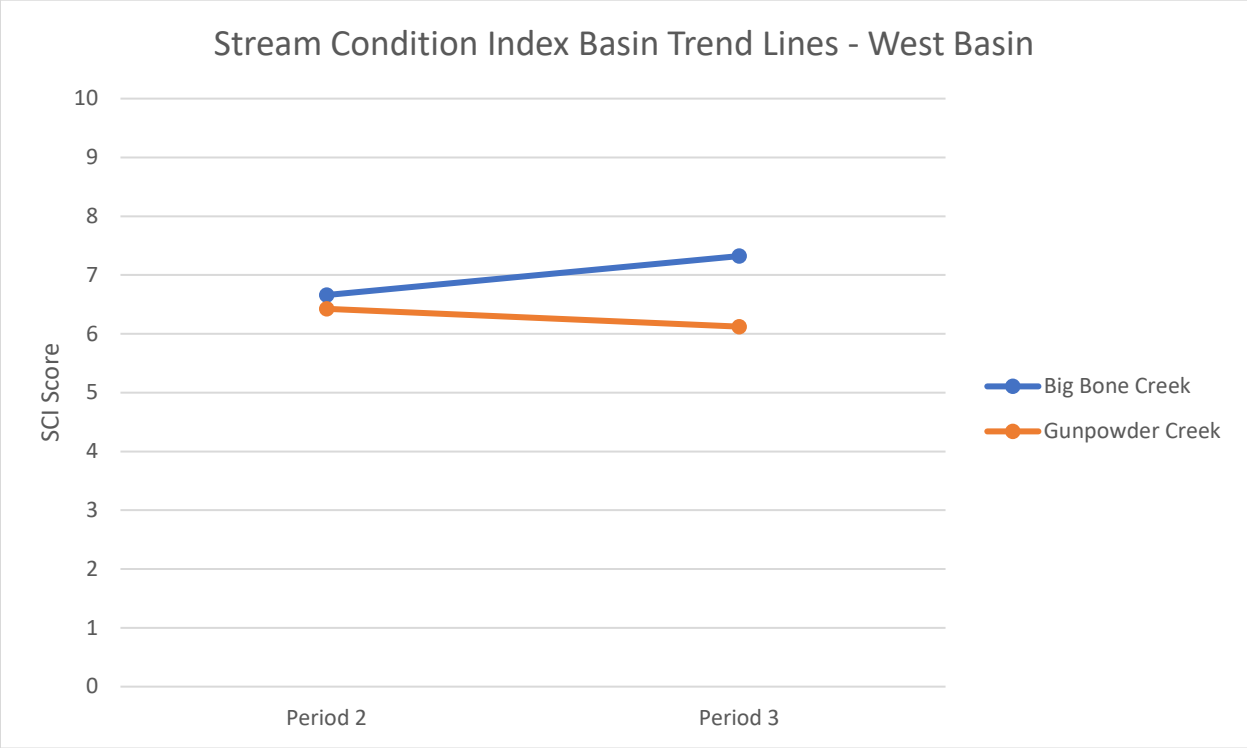


Figure 28. Stream Condition Index Basin Trend Scores

As stated in the beginning objectives, there are numerous reasons why SD1 continues to collect instream water quality, biology, physical habitat, and stream stability data. These monitoring program components together not only characterize the state of Northern Kentucky watersheds, but they also provide locally relevant data as to how to better manage the impacts to the watersheds by implementing effective regulatory requirements and improvement projects.

This data has been used to inform local storm water management policies and regulations that are effective in protecting the region's water quality. Additionally, the monitoring data collected by SD1 has been used by local partners (e.g., conservation districts and citizen watershed groups) to obtain 319 (h) grants from Kentucky to inform additional watershed plans and implementation projects that compliment SD1 initiatives.

SD1 is committed to balance the need to keep local waterways clean and safe with the need to provide affordable wastewater and storm water services in Northern Kentucky. Clean H_2O40 is SD1's commitment to increasing our capacity to better manage the flow of wastewater and storm water in Northern Kentucky. Through a number of strategic projects specifically designed to address sewer overflows, SD1 will meet the requirements of Northern Kentucky's consent decree and improve the quality of life in our community. By the year 2040, SD1 will completely eliminate typical-year sanitary sewer overflows and recapture at least 85 percent of all typical-year combined sewer overflows.

Additional information on SD1's monitoring programs and Clean H_2O40 initiative can be found at https://www.sd1.org.

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Appendix A – Water Quality Data

Instream water quality results are listed in tables beginning with the Big Bone Creek watershed, followed by the Gunpowder Creek watershed. Along with the individual parameter results, the precipitation condition in which the samples were collected is also included in the tables as follows:

- Baseflow (Dry) – flow in the stream is comprised primarily of groundwater and/or the hydrograph is stable (typical example: no precipitation within 72 hours prior to sampling).
- Storm Flow (Wet) – flow in the stream is dominated by runoff and/or the hydrograph is rising or falling (typical example: greater than 0.25" of precipitation within 24 hours prior to sampling).

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Big Bone Creek Water Quality Data

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	7/7/15 8:45	480	14	0.208	1.086	0.395	0.691
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	7/21/15 9:05	944	16	0.109	0.762	0.248	0.514
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	8/4/15 8:05	2,452	65	0.376	1.413	0.798	0.615
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	8/18/15 8:38	168	13	0.140	0.990	0.472	0.518
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	9/1/15 9:15	188	16	0.111	0.665	0.600	0.065
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Dry	9/15/15 9:00	76	9	0.382	2.240	0.610	1.630
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Wet	9/29/15 8:50	216	4	<0.023	0.991	0.938	0.053
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Wet	10/13/15 8:40	1,140	30	0.354	0.740	0.687	0.053
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Wet	10/27/15 9:45	204	<1.5	0.143	0.556	0.375	0.181
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	2	Wet	11/10/15 8:40	688	3	0.231	1.046	0.529	0.517
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	5/24/16 9:10	188	2	0.176	0.920	0.710	0.210
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	6/7/16 8:25	344	11	0.203	0.954	0.669	0.285
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	6/21/16 9:00	128	9	0.203	0.958	0.953	<0.01
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/19/16 9:10	228	13	0.217	1.066	0.831	0.235
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	8/30/16 9:05	372	24	0.052	1.491	1.140	0.351
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/13/16 9:20	944	27	0.182	1.715	0.993	0.722

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/27/16 9:10	60	10	0.168	1.051	1.020	0.031
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	10/11/16 9:05	64	2	0.243	0.912	0.898	0.014
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	10/25/16 9:30	324	3	0.302	1.665	0.905	0.760
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	11/8/16 9:20	60	4	0.358	1.363	0.825	0.538
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	4/25/17 9:15	64	2	0.216	0.735	0.680	0.055
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	5/23/17 9:30	1,304	24	0.128	1.365	0.580	0.785
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	6/6/17 9:15	600	14	0.217	0.675	<0.097	0.626
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	6/20/17 9:00	1,548	25	0.274	1.513	1.050	0.463
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/25/17 9:15	600	8	0.238	1.261	0.821	0.440
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	8/15/17 9:15	52	5	0.155	0.729	0.683	0.046
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/5/17 9:20	192	6	0.220	1.036	0.629	0.407
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	10/17/17 9:33	116	<1.4	0.281	0.459	0.436	0.023
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	11/14/17 10:05	172	<1.4	0.232	1.025	0.398	0.627
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	4/17/18 9:05	840	6	0.119	0.790	0.432	0.358
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	5/8/18 9:16	184	<1.4	0.182	0.709	0.672	0.037
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/10/18 9:00	460	9	0.163	0.874	0.840	0.034
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/24/18 9:10	736	17	0.279	1.680	0.875	0.805

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/11/18 9:30	1,460	19	0.226	1.824	0.584	1.240
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	10/16/18 9:30	148	<1.4	0.363	0.270	<0.102	0.219
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	11/13/18 9:10	92	<1.4	0.163	1.141	0.159	0.982
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	3/19/19 8:55	48	4	0.080	0.903	0.471	0.432
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	4/23/19 9:20	216	2	0.097	0.843	0.551	0.292
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	5/7/19 9:15	416	11	0.147	0.827	0.249	0.578
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	5/21/19 9:10	420	10	0.258	1.900	1.430	0.470
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	6/11/19 9:20	1,844	33	0.304	1.458	0.991	0.467
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/9/19 9:30	260	8	0.133	0.498	0.442	0.056
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	7/23/19 9:15	5,480	44	0.294	1.282	0.715	0.567
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	8/13/19 9:20	96	21	0.133	0.939	0.882	0.057
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/10/19 8:50	136	5	0.151	0.716	0.668	0.048
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	9/24/19 9:10	16	6	0.154	0.797	0.789	<0.016
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	10/22/19 9:30	12	2	0.522	0.974	0.780	0.194
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Dry	11/12/19 9:40	64	3	0.400	1.037	0.667	0.370
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	4/12/16 9:12	3,264	49	0.742	1.542	1.110	0.432
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	4/26/16 9:10	44	<1.2	0.185	0.628	0.599	0.029

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	5/10/16 9:05	180	6	0.194	0.781	0.610	0.171
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	7/5/16 8:55	1,304	28	0.341	1.753	1.130	0.623
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	8/2/16 9:30	1,548	43	0.517	1.579	0.955	0.624
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	8/16/16 9:00	3,264	66	0.589	1.523	1.090	0.433
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	4/11/17 9:40	552	21	0.210	0.853	0.785	0.068
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	5/9/17 9:15	236	4	0.147	1.139	0.674	0.465
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	7/11/17 9:15	144	43	0.253	1.046	0.927	0.119
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	9/19/17 9:20	36	2	0.250	0.893	0.851	0.042
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	3/27/18 9:00	108	2	0.123	0.868	0.583	0.285
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	5/22/18 8:50	15,530	168	1.010	1.937	1.490	0.447
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	6/12/18 9:05	820	14	0.160	0.987	0.872	0.115
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	8/21/18 9:12	560	21	0.298	1.025	0.526	0.499
Big Bone Creek	Mud Lick Creek	3.0	MLC3.0	3	Wet	9/25/18 9:00	5,480	42	0.333	2.680	1.360	1.320

Gunpowder Creek Water Quality Data

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	7/7/15 9:45	1,644	6	0.241	1.325	0.384	0.941
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	7/21/15 10:05	1,232	13	0.160	1.250	0.190	1.060
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	8/4/15 9:45	804	10	0.528	3.957	0.497	3.460
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	8/18/15 9:40	8	6	0.205	2.208	0.548	1.660
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	9/1/15 10:20	76	<1.5	0.283	3.566	0.896	2.670
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Dry	9/15/15 10:10	88	<1.5	0.102	0.630	0.450	0.180
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Wet	9/29/15 9:45	784	3	0.124	0.666	0.473	0.193
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Wet	10/13/15 9:30	4,880	8	0.138	1.131	0.732	0.399
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Wet	10/27/15 10:40	408	4	0.114	4.005	0.385	3.620
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2	Wet	11/10/15 9:40	224	2	0.094	1.013	0.387	0.626
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	5/24/16 10:15	48	<1.2	0.103	0.810	0.673	0.137
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	6/7/16 9:20	192	2	0.142	1.899	0.699	1.200
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	6/21/16 10:00	52	<1.2	0.194	2.617	0.597	2.020
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/19/16 10:05	272	<1.2	0.311	3.812	0.652	3.160
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	8/30/16 10:05	612	7	<0.045	1.592	0.996	0.596
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/13/16 10:45	136	2	0.153	3.741	0.871	2.870
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/27/16 10:05	1,104	<1.2	0.366	3.747	0.857	2.890
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	10/11/16 0:00	144	<1.2	0.263	2.737	0.607	2.130
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	10/25/16 10:30	224	<1.2	0.279	1.560	0.857	0.703
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	11/8/16 10:55	24	3	0.237	0.775	0.730	0.045
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	4/25/17 10:15	64	<1.4	0.198	0.615	0.586	0.029
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	5/23/17 10:35	540	5	0.100	1.444	0.715	0.729
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	6/6/17 10:15	1,740	6	0.142	1.496	0.966	0.530
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	6/20/17 10:05	796	9	0.215	1.977	0.747	1.230

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/25/17 9:50	292	4	0.170	1.334	0.722	0.612
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	8/15/17 9:50	56	2	0.108	0.593	0.497	0.096
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/5/17 10:05	148	<1.4	0.121	0.787	0.541	0.246
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	10/17/17 10:10	84	2	0.280	0.460	0.418	0.042
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	11/14/17 11:05	216	<1.4	0.138	1.476	0.745	0.731
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	4/17/18 9:40	664	4	0.081	0.657	0.509	0.148
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	5/8/18 10:05	588	2	0.081	0.537	0.517	0.020
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/10/18 9:40	124	4	0.171	1.224	0.653	0.571
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/24/18 9:40	284	9	0.151	1.041	0.654	0.387
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/11/18 10:05	716	6	0.189	1.542	0.550	0.992
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	10/16/18 10:00	128	<1.4	0.457	2.479	0.319	2.160
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	11/13/18 9:50	172	<1.4	0.120	1.205	0.396	0.809
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	3/19/19 9:25	64	4	0.051	0.739	0.504	0.235
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	4/23/19 9:55	396	<1.4	0.074	0.843	0.583	0.260
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	5/7/19 9:55	104	2	0.103	1.269	0.318	0.951
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	5/21/19 9:40	1,104	7	0.303	2.527	0.147	2.380
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	6/11/19 10:20	612	5	0.209	1.613	0.613	1.000
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/9/19 10:05	260	3	0.075	0.682	0.509	0.173
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	7/23/19 9:45	2,068	31	0.203	1.075	0.586	0.489
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	8/13/19 9:55	11,200	56	0.227	1.462	1.120	0.342
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/10/19 9:25	148	5	0.121	0.609	0.533	0.076
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	9/24/19 9:50	124	8	0.132	0.805	0.660	0.145
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	10/22/19 10:15	32	2	0.111	0.586	0.554	0.032
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Dry	11/12/19 10:15	608	8	0.177	1.042	0.633	0.409
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	4/12/16 10:30	912	25	0.737	1.555	1.020	0.535
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	4/26/16 10:25	16	<1.2	0.142	1.109	0.702	0.407

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	5/10/16 10:15	196	3	0.121	1.007	0.602	0.405
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	7/5/16 10:00	15,530	113	0.572	2.253	1.320	0.933
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	8/2/16 10:45	2,192	24	0.266	2.260	1.040	1.220
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	8/16/16 10:10	2,748	91	2.010	13.410	13.000	0.410
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	4/11/17 10:46	2,908	72	0.296	1.521	1.260	0.261
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	5/9/17 10:20	3,870	150	0.380	2.097	1.530	0.567
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	7/11/17 10:00	188	5	0.187	1.259	0.658	0.601
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	9/19/17 10:10	104	<1.4	0.156	2.155	0.785	1.370
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	3/27/18 9:35	100	2	0.076	0.717	0.694	0.023
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	5/22/18 9:30	14,140	62	0.446	2.084	1.280	0.804
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	6/12/18 9:45	548	5	0.151	2.169	0.539	1.630
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	8/21/18 9:45	1,460	5	0.128	0.932	0.464	0.468
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	3	Wet	9/25/18 9:35	2,068	10	0.276	1.737	0.717	1.020
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	7/7/15 9:20	1,847	10	0.199	1.063	0.376	0.687
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	7/21/15 9:40	882	22	0.133	0.984	0.259	0.725
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	8/4/15 9:20	822	19	0.328	2.556	0.539	2.017
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	8/18/15 9:12	110	6	0.175	1.703	0.486	1.217
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	9/1/15 9:50	150	4	0.183	2.080	0.677	1.403
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Dry	9/15/15 9:45	154	2	0.089	0.628	0.449	0.179
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Wet	9/29/15 9:20	458	11	0.104	0.592	0.462	0.130
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Wet	10/13/15 9:10	2,992	18	0.163	0.935	0.696	0.239
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Wet	10/27/15 10:15	856	6	0.244	2.418	0.388	2.030
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	2	Wet	11/10/15 9:10	276	4	0.101	1.010	0.386	0.624
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	5/24/16 9:45	180	<1.2	0.082	0.881	0.802	0.080
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	6/7/16 9:00	182	5	0.127	1.487	0.674	0.814

Watershed	Stream	RM	LocID	Period	Precip Condition	Date	E. coli (mpn/100 ml)	TSS (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	N/N (mg/L)
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	6/21/16 9:35	370	2	0.176	1.612	0.599	<0.01
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	7/19/16 9:40	384	3	0.244	2.587	0.679	1.908
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	8/30/16 9:40	704	12	0.037	1.597	1.013	0.584
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	9/13/16 10:15	204	2	0.145	2.530	0.826	1.704
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	9/27/16 9:40	944	1	<0.045	2.569	0.887	1.682
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	10/11/16 0:00	188	<1.2	0.185	1.939	0.595	1.345
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	10/25/16 10:00	248	<1.2	0.272	1.499	0.817	0.683
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	11/8/16 10:30	57	3	0.182	0.731	0.706	<0.01
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	4/25/17 9:50	74	2	0.186	0.662	0.636	0.026
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	5/23/17 10:05	540	10	0.112	1.414	0.720	0.695
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	6/6/17 9:50	1,046	6	0.111	1.267	0.976	0.292
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Dry	6/20/17 9:35	1,050	14	0.217	1.720	0.792	0.928
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	4/12/16 9:50	1,614	41	0.486	1.519	1.015	0.504
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	4/26/16 9:50	76	4	0.140	0.845	0.623	0.222
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	5/10/16 9:45	204	7	0.107	0.817	0.588	0.229
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	7/5/16 9:30	8,861	70	0.441	2.170	0.978	1.192
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	8/2/16 10:10	2,018	66	0.354	2.008	1.105	0.903
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	8/16/16 9:40	5,454	119	1.255	7.563	7.165	0.398
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	4/11/17 10:15	1,478	41	0.240	1.066	0.927	0.139
Gunpowder Creek	Gunpowder Creek	4.6	GPC4.6	3	Wet	5/9/17 9:50	2,049	81	0.268	1.544	1.035	0.509

Appendix B1 – Biological Data

Macroinvertebrate assessment results are listed in tables beginning with the Big Bone Creek watershed, followed by the Gunpowder Creek watershed. The MBI metrics included in the tables are as follows:

- Percent Chironomidae+Oligochaeta (%Chir+%Olig) – calculates the relative abundance of pollution tolerant organisms; increasing metric values generally indicate declining water quality conditions.

- Percent Primary Clingers (%ClngP) – calculates the relative abundance of organisms that require hard/silt-free substrates; increasing metric values generally indicate improving substrate stability.

- Percent Ephemeroptera (%Ephem) – calculates the abundance of mayfly species (insect order Ephemeroptera), which are pollution sensitive; metric is only utilized for assessing headwater streams.

- Modified Percent EPT Abundance (m%EPT) – calculates the abundance of pollution sensitive organisms (specifically insect orders of Ephemeroptera, Plecoptera and Trichoptera); increasing metric values generally indicate improving water quality and habitat conditions.

- Genus Ephemeroptera, Plecoptera, Trichoptera Richness (G-EPT) – calculates the total number of distinct genera of pollution sensitive organisms in a composite sample; increasing metric values generally indicate improving water quality and habitat conditions.

- Genus Taxa Richness (G-TR) – calculates the total number of genera in a composite sample; increasing metric values generally indicate improving water quality and habitat conditions.

- Modified Hilsenhoff Biotic Index (mHBI) – calculates the overall pollution tolerance of the benthic macroinvertebrate community (including arthropods) (Lenat 1993); increasing metric values generally indicate decreasing water quality conditions.

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Big Bone Creek Macroinvertebrate Index Scores

Watershed	Stream	RM	LocID	Year	Site Type	%Chir+%Olig	%ClngP	G-EPT	G-TR	m%EPT	mHBI	MBI_Genus	MBI_Genus Rating
Big Bone Creek	Mud Lick Creek	12	MLC12.0	2016	W	26.69	66.22	5	43	6.08	5.76	52.32	Fair
Big Bone Creek	Mud Lick Creek	12	MLC12.0	2019	W	21.57	57.19	6	42	24.51	5.77	55.65	Fair
Big Bone Creek	Mud Lick Creek	3	MLC3.0	2015	W	9.80	86.10	10	39	38.30	4.51	69.18	Good
Big Bone Creek	Mud Lick Creek	3	MLC3.0	2019	W	28.43	59.11	13	46	29.71	5.03	62.92	Good
Big Bone Creek	Big Bone Creek	3.9	BBC3.9	2016	W	7.52	78.10	14	48	24.84	5.35	68.98	Good
Big Bone Creek	Big Bone Creek	3.9	BBC3.9	2019	W	33.77	61.26	12	47	26.16	5.09	61.21	Good

Gunpowder Creek Macroinvertebrate Index Scores

Watershed	Stream	RM	LocID	Year	Site Type	%Chir+%Olig	%ClngP	G-EPT	G-TR	m%EPT	mHBI	MBI_Genus	MBI_Genus Rating
Gunpowder Creek	Gunpowder Creek	17.9	GPC17.9	2015	W	27.10	49.20	6	32	21.70	6.11	49.00	Fair
Gunpowder Creek	Gunpowder Creek	17.9	GPC17.9	2019	W	27.27	21.75	7	38	58.12	5.90	53.68	Fair
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2015	W	41.60	38.50	9	29	34.30	5.12	50.42	Fair
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2019	W	34.10	55.08	11	36	39.67	5.03	59.73	Fair
Gunpowder Creek	South Fork Gunpowder Creek	5.3	SFG5.3	2015	W	48.50	52.50	6	33	10.20	6.12	43.73	Fair
Gunpowder Creek	South Fork Gunpowder Creek	5.3	SFG5.3	2019	W	63.91	35.76	8	36	18.54	5.97	41.53	Fair

Appendix B2 – Biological Data

Habitat assessment results are listed in tables beginning with the Big Bone Creek watershed, followed by the Gunpowder Creek watershed. The RBP metrics included in the tables are as follows:

- Bank Stability (BankSta) – estimates actual or potential streambank erosion; eroded banks indicate sediment movement and deposition issues.
- Bank Vegetative Protection (BankVegP) – estimates the vegetative protection adjacent to the stream; differing vegetative types provide various abilities to resist erosion.
- Channel Flow Status (ChaFlowS) – estimates the degree to which the stream channel is filled with water; relates to the amount of substrate that is suitable for aquatic organisms.
- Channel Alteration (ChanAlter) – characterizes large scale or direct changes to the shape of the stream channel; relates to the amount of natural habitat with meandering streams having greater potential and straightened or deepened channels have less potential and subject to scouring.
- Embeddedness – estimates the extent of stream bottom substrate covered by silt, sand, or mud due to sedimentation; greater embeddedness decreases habitat diversity.
- Epifaunal Substrate/Available Cover (EpiFauSub) – estimates the relative quantity and variety of natural structures (e.g., boulders, logs, aquatic vegetation, etc.) in the stream that provide habitat; greater habitat opportunities provide greater potential for aquatic organism colonization.
- Frequency of Riffles (FreqOfRiffles) – determines the sequence of riffles occurring in the stream system; higher frequencies typically provide better habitat opportunities.
- Riparian Vegetative Zone Width (RipVegZW) – estimates the width of the vegetation from the edge of the streambank to the edge of the riparian zone; larger undisturbed riparian zones support more robust stream systems.
- Sediment Deposition (SedDep) – estimates the amount of stream bed sediment accumulation in pools; deposition signifies an unstable regime that is not suitable from many organisms.
- Velocity/Depth Regime (Vel/Dep Regime) – determines the occurrence pattern of stream velocity and stream depth regimes (i.e., slow-deep, slow-shallow, fast-deep and fast-shallow); the number of patterns present relates to the stability of the aquatic environment.

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Big Bone Creek Habitat Scores

Watershed	Stream	RM	LocID	Year	Site Type	BankSta-LB	BankSta-RB	BankVegP-LB	BankVegP-RB	ChaFlowS	ChanAlter	Embeddedness	EpiFauSub	FreqOfRiffles	RipVegZW-LB	RipVegZW-RB	SedDep	Vel/Dep Regime	RBP_HA	RBP_HA Rating
Big Bone Creek	Mud Lick Creek	12	MLC12.0	2016	W	6	4	6	4	14	10	11	7	7	5	2	9	12	97	Poor
Big Bone Creek	Mud Lick Creek	12	MLC12.0	2019	W	7	6	6	5	18	11	13	12	11	6	6	11	12	124	Fair
Big Bone Creek	Mud Lick Creek	3	MLC3.0	2015	W	7	7	7	7	17	12	19	13	11	5	5	11	11	132	Good
Big Bone Creek	Mud Lick Creek	3	MLC3.0	2019	W	7	8	7	7	13	15	10	14	15	5	6	10	13	130	Good
Big Bone Creek	Big Bone Creek	3.9	BBC3.9	2016	W	9	7	9	9	8	13	16	14	10	3	2	10	11	121	Fair
Big Bone Creek	Big Bone Creek	3.9	BBC3.9	2019	W	9	8	7	7	11	17	15	14	15	7	6	11	12	139	Good

Gunpowder Creek Habitat Scores

Watershed	Stream	RM	LocID	Year	Site Type	BankSta-LB	BankSta-RB	BankVegP-LB	BankVegP-RB	ChaFlowS	ChanAlter	Embeddedness	EpiFauSub	FreqOfRiffles	RipVegZW-LB	RipVegZW-RB	SedDep	Vel/Dep Regime	RBP_HA	RBP_HA Rating
Gunpowder Creek	Gunpowder Creek	17.9	GPC17.9	2015	W	5	6	5	5	12	11	10	10	11	4	5	8	12	104	Poor
Gunpowder Creek	Gunpowder Creek	17.9	GPC17.9	2019	W	8	7	7	7	16	13	12	12	13	5	7	14	13	134	Good
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2015	W	7	8	9	4	9	14	14	10	17	9	2	10	13	126	Fair
Gunpowder Creek	Gunpowder Creek	14.7	GPC14.7	2019	W	8	9	7	6	9	14	17	13	17	8	6	14	15	143	Good
Gunpowder Creek	South Fork Gunpowder Creek	5.3	SFG5.3	2015	W	4	5	1	3	11	2	8	7	2	0	1	8	8	60	Poor
Gunpowder Creek	South Fork Gunpowder Creek	5.3	SFG5.3	2019	W	5	5	4	3	16	10	10	9	10	4	3	11	12	102	Poor

Appendix C – Stream Stability Data

Rapid stability assessment results are listed in tables beginning with the Big Bone Creek watershed, followed by the Gunpowder Creek watershed. The stability metrics included in the tables are as follows:

- Bank (LEFT_BANK and RIGHT_BANK) – Bank height and bank angle are utilized to calculate the risk of bank failure score for each stream bank (i.e., left bank and right bank) based on logistic regression thresholds developed from NKY stream systems. Each stream bank is assessed separately with scores ranging from 0 (stable) to 10 (unstable).

- Shape (SHAPE) – Floodplain connectivity and stream bed irregularity are utilized to determine the channel shape score. Each parameter is assessed separately (a score of 5 is stable and a score of 0 is unstable) and then added together for a total score.

- Bedrock (BEDROCK) – Percent of bedrock is utilized to determine the bedrock score as follows: <2% receives a score of 10 (good), 2-10% receives a score of 4 (fair), and >10% receives a score of 0 (poor).

- Pool Depth (POOL) – Depth of the deepest pool in the assessment reach is used to determine the pool depth score as follows: <2.5' receives a score of 10 (good) and >2.5' receives a score of 0 (poor).

- Embeddedness (EMBEDD) – Percent of embeddedness in the assessment reach is utilized to determine the embeddedness score as follows: 0-25% receives a score between 20 and 16 (Optimal), 25-50% receives a score between 15 and 11 (Suboptimal), 50-75% receives a score between 10 and 6 (Marginal), and >75% receives a score between 5 and 0 (Poor).

- Frequency of Riffles (RIFFLE FREQ) – Number of riffles occurring in the assessment reach is used to determine the riffle frequency score as follows: "relatively frequent" receives a score between 20 and 16 (Optimal), "infrequent" receives a score between 15 and 11 (Suboptimal), "occasional" receives a score between 10 and 6 (Marginal), and "generally all flat water" receives a score between 5 and 0 (Poor).

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Big Bone Creek Stream Stability Index Scores

DATE	SITE	LEFT_BANK	RIGHT_BANK	SHAPE	BEDROCK	EMBEDD	POOL	RIFFLE FREQ	SITE SCORE
12/21/2015	BBC3.9	10	10	5	4	14	0	13	***3.35***
7/9/2019	BBC3.9	10	10	10	4	15	0	15	***5.60***
12/21/2015	MLC3.0	4	9	10	4	15	10	11	***6.05***
7/29/2019	MLC3.0	9	10	10	0	10	0	15	***3.60***
6/12/2019	MLC12.0	10	10	10	0	13	10	11	***6.00***

Gunpowder Creek Stream Stability Index Scores

DATE	SITE	LEFT_BANK	RIGHT_BANK	SHAPE	BEDROCK	EMBEDD	POOL	RIFFLE FREQ	SITE SCORE
12/16/2014	GPC14.7	6	10	10	4	14	10	17	***7.75***
8/7/2019	GPC 14.7	4	10	10	0	17	0	17	***5.10***
6/13/2019	GPC 17.9	1	10	10	0	12	0	13	***2.40***
8/7/2019	SFG 5.3	5	4	5	0	10	10	10	***1.85***

Appendix D – Stream Condition Index Scores

Stream Condition Index Basin Trend Scores by Site – Period 2 (2012 - 2015)

Watershed	Site	Water Quality Score	Biology Score	Habitat Score	Stream Stability Score	Score
Big Bone Creek	**3.9**	NA	9.75	7.19	3.35	6.76
	MLC3.0	6.33	9.80	10.00	6.05	8.04
	MLC12.0	NA	6.54	4.25	4.00	4.93
Gunpowder Creek	**4.6**	6.60	NA	NA	NA	NA
	14.7	6.75	6.30	8.75	7.75	7.39
	17.9	NA	6.13	4.56	NA	NA
	SFG5.3	NA	5.47	2.63	NA	NA

Note: An overall monitoring site score is only calculated if 3 out of the 4 categories are populated.

Stream Condition Index Basin Trend Scores by Site – Period 3 (2016 - 2019)

Watershed	Site	Water Quality Score	Biology Score	Habitat Score	Stream Stability Score	Score
Big Bone Creek	**3.9**	NA	7.80	10.00	5.60	7.80
	MLC3.0	7.18	8.23	10.00	3.60	7.25
	MLC12.0	NA	6.96	8.13	6.00	7.03
Gunpowder Creek	**4.6**	6.66	NA	NA	NA	NA
	14.7	6.85	7.47	10.00	5.10	7.35
	17.9	NA	6.71	10.00	2.40	6.37
	SFG5.3	NA	5.19	4.47	1.85	3.84

Note: An overall monitoring site score is only calculated if 3 out of the 4 categories are populated.

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