Upper Big Cove Creek Watershed Implementation Plan

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Prepared for the Fulton County Conservation District

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ACRONYM & ABBREVIATION DEFINITIONS

Acronym / Abbreviation	Definition
AL	Allowable Load
ASL	Adjusted Source Load
BMP(s)	Best Management Practice(s)
BOD	Biological Oxygen Demand
CAP	Countywide Action Plan
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CWF	Cold Water Fishes
CWP	Center for Watershed Protection, Inc.
FBRSA	Function-Based Rapid Stream Assessment Methodology
FCCD	Fulton County Conservation District
EMPR	Equal Marginal Percent Reduction
eDMR	Electronic Discharge Monitoring Report
EPR	Ecosystem Planning and Restoration, LLC
GIS	Geographic Information System(s)
GWLF-E	Generalized Watershed Loading Function Enhanced
HSG	Hydrologic Soil Group
HQ-CWF	High Quality-Cold Water Fishes
ICE-IS	Instream Comprehensive Evaluation Station
LA	Load Allocation
LNR	Loads Not Reduced
MMW	Model My Watershed
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NFWF	National Fish and Wildlife Foundation
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
NWI	National Wetlands Inventory
PA DCED	Pennsylvania Department of Community and Economic Development
PA DCNR	Pennsylvania Department of Conservation and Natural Resources
PA DEP	Pennsylvania Department of Environmental Protection
PASDA	Pennsylvania Spatial Data Access
PDA	Pennsylvania Department of Agriculture
PENNVEST	Pennsylvania Infrastructure Investment Authority
PFBC	Pennsylvania Fish and Boat Commission
SL	Source Load
SSURGO	Soil Survey Geographic Database
SRMA(s)	State Resource Management Area(s)
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UF	Uncertainty Factor
USDA FSA	U.S. Department of Agriculture Farm Service Agency
USDA NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
US FWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
US EPA	U.S. Environmental Protection Agency
UVM SAL	University of Vermont Spatial Analysis Lab
WIP	Watershed Implementation Plan
WLA	Wasteload Allocation

Executive Summary

A Watershed Implementation Plan (WIP) for the Upper Big Cove Creek watershed was created through coordination with the Fulton County Conservation District (FCCD) and stakeholders to provide an action plan to reduce sediment loads and accompanying nutrient loads. The WIP provides a list of projects that, when installed, will improve the water quality in the watershed to meet Pennsylvania Department of Environmental Protection (PA DEP) estimated reduction needs for sediment. This project was funded by a PA DEP Growing Greener grant that can provide funding for project implementation once the WIP is approved.

This WIP is developed for the Upper Big Cove Creek subwatershed, which drains approximately 17 square miles (sq. mi.). The watershed includes the headwaters of Big Cove Creek that flow through Todd Township and the Borough of McConnellsburg and then join the mainstem to an area just below the confluence with Kendall Run. Figure 1 shows the location of the subwatershed and its relationship to the larger Big Cove Creek watershed. There are two townships in the subwatershed, Ayr and Todd, and the Borough of McConnellsburg which is the county seat.

Watershed Baseline Assessment

The baseline assessment (Sections 1-4) summarizes subwatershed characteristics including geology, land use, stream condition, and pollution sources. Land use is dominated by forest and cropland with impervious cover around six percent and associated primarily with the Borough of McConnellsburg. Dominant crops include no-till corn grain, soybean, and small grain for silage, and livestock operations primarily include swine and chickens.

The streams in the subwatershed are designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). Approximately 8.1 stream miles in the subwatershed are listed as impaired for aquatic life use. The primary cause of aquatic life use impairments as listed in the PA Integrated Water Quality Report is siltation associated with agriculture.

A Total Maximum Daily Load (or TMDL) is an estimate of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. When water bodies are too polluted to meet the established water quality criteria, they are added to an "impaired waters list." In Pennsylvania, the PA DEP develops a TMDL for waterbodies identified as impaired with the goal of "de-listing" or improving the stream so that it can fully support its designated uses. The subwatershed does not currently have any prescribed TMDLs and the development of this WIP will hopefully reduce the chances that will happen in the future.

Field Assessments and Findings

CWP Center for Watershed Protection, Inc (CWP) and Ecosystem Planning and Restoration, LLC (EPR) conducted field assessments in 2023 to identify restoration opportunities within the subwatershed. Field assessments included identification of stormwater retrofit projects, pollutant reduction, and restoration opportunities in neighborhoods and commercial, industrial, institutional, municipal, and transport-related operations, as well as stream restoration assessments conducted following a modified version of the FBRSA Data Sheet to evaluate restoration opportunities at identified reaches. A summary is found in Section 5.

The retrofit inventory identified fourteen total stormwater retrofit opportunities, which cumulatively treat about 30 acres of urban land. Stormwater retrofits identified include ten bioretention practices, two bioswales, and one site for conversion to a dry extended detention pond. In addition, opportunities for slope stabilization and impervious surface removal were also identified. The WIP provides a summary of the estimated pounds of phosphorus, nitrogen, and TSS the retrofits would remove each year, a planning level cost estimate to design and build the retrofit and maintain it for 1 year, and the cost effectiveness for all retrofits identified.

Stream assessments were conducted along agricultural land to provide an understanding of the degree of streambank erosion and potential for stream restoration projects. EPR conducted a comprehensive assessment of stream reaches in the subwatershed, including Big Cove Run, Kendall Run, and their respective tributaries. Utilizing both GIS-based desktop analysis and field verification, EPR classified stream segments into three condition categories—good, fair, and poor—based on criteria such as channel stability, riparian vegetation, and sediment load. These assessments guided the identification and prioritization of 17 restoration project areas, categorized as high, medium, or low priority, to address ecological uplift and cost-efficiency.

The methodology combined GIS data with empirical field assessments to ensure accurate condition scoring. Parameters such as floodplain connectivity, vertical stability, and geomorphology were evaluated, and the data was recalibrated to refine the restoration plan. The restoration recommendations are based on Natural Channel Design (NCD) Priority 2 and 3 approaches, which involve creating stable channels connected to floodplains. These approaches aim to enhance ecological functions, such as increased floodplain access, groundwater recharge, and habitat complexity, while minimizing environmental impacts and supporting long-term ecosystem health.

Financial considerations were integrated into the project prioritization, with estimated costs ranging from $45 to $65 per linear foot for planning and $400 to $600 for construction. The average cost for implementation is approximately $665 per linear foot. These estimates include comprehensive restoration activities, such as in-channel adjustments, new channel creation, bank grading, and the installation of various instream structures like vanes and weirs, as well as bioengineering techniques. The project prioritization emphasizes cost-efficiency, environmental stewardship, and collaboration with landowners and local stakeholders, ensuring that selected sites provide significant ecological benefits while remaining financially viable.

Pollutant Load Reduction Modeling and Evaluation of BMPs

A simple spreadsheet model, Model My Watershed (MMW), was used to estimate the total phosphorus (TP), total nitrogen (TN), and total sediment (TSS) loads for the subwatershed. MMW is a model developed by Stroud Water Research Center to analyze nationally available landscape, climate and other datasets and model stormwater runoff and water quality impacts (Stroud Water Research Center, 2017). The results are provided in Section 6 and include the potential pollutant load reductions from the implementation of Best Management Practices (BMPs) identified from field assessments and information provided by FCCD.

The model results were compared to sediment load reduction estimates calculated by the PA DEP to determine if implementation of the BMPs identified would address stream impairments. A "Reference Watershed Approach" method is used because Pennsylvania does not have numeric water quality criteria for sediment, so an estimate of pollutant loading rates in both an impaired watershed as well as a similar watershed that is not listed as impaired is used to calculate necessary load reductions based on scaling the loading rate in the unimpaired watershed to the similar area of the impaired watershed.

Recommended Watershed Management Actions and Implementation Plan

Nine primary recommendations are provided to achieve the goals of the WIP. These include implementation of agricultural and urban BMPs, stakeholder engagement, agricultural land preservation, water quality monitoring, and increase staff capacity to support BMP implementation. Section 7 provides a summary of the cost for implementation of all identified BMPs at a total of around $17 million dollars and a list of funding opportunities. A public outreach plan that enhances understanding of the BMPs and provides an opportunity for public involvement is provided in Section 8. An implementation table that lists the plan's recommendations, along with a suggested timeframe for implementation, partners, and milestones is found in Section 9. Recommendations include:

1. Document practices in the subwatershed in a centralized database such as Practice Keeper.
2. Implement prioritized Agricultural BMPs for water quality improvement.
3. Continue to engage landowners through outreach to the entire Big Cove watershed.

4. Promote preservation of agricultural lands.
5. Assess the impact of conversion of agricultural lands to solar farms.
6. Implement priority stormwater management BMP retrofits for water quality improvement.
7. Implement priority streambank restoration projects for water quality improvement and conduct a rapid BANCS assessment of stream sites to better determine sediment reductions from stream restoration projects.
8. Conduct chemical and biological stream monitoring in the entire watershed.
9. Hire additional engineers and trained technicians to increase capacity for BMP implementation.

SECTION 1. INTRODUCTION AND PROJECT BACKGROUND

This report serves to both document the existing nonpoint source pollution load conditions and develop a basic Watershed Implementation Plan (WIP) for a specific portion of the Big Cove Creek watershed in Fulton County, Pennsylvania. The Big Cove Creek watershed is a tributary of Licking Creek, which drains to the Potomac River and ultimately the Chesapeake Bay. This report focuses on a subwatershed of the Big Cove Creek watershed called the Upper Big Cove Creek subwatershed (hereafter, “subwatershed”) (Figure 1), which consists of the headwaters of Big Cove Creek that flow through Todd Township and the Borough of McConnellsburg and then join the mainstem to an area just below the confluence with Kendall Run. Figure 1 shows the location of the Upper Big Cove Creek subwatershed and its relationship to the larger Big Cove Creek watershed. There are two townships in the focus watershed, Ayr and Todd, and the Borough of McConnellsburg which is the county seat. Land use in the watershed is primarily agriculture and forest, with some imperviousness associated with the Borough of McConnellsburg.

The subwatershed that is the focus of this WIP drains approximately 17 square miles (sq. mi.) as delineated in Figure 1. The subwatershed has 44.6 miles of streams, and all streams in the Big Cove Creek watershed are designated for Cold Water Fishes (CWF) (PA DEP, 2022b). Approximately 8.1 stream miles in the subwatershed are listed as impaired for aquatic life use. The primary cause of aquatic life use impairments as listed in the 2024 PA Integrated Water Quality Report is siltation associated with agriculture (Table 1). Additional causes of impairment within the subwatershed include excessive nutrients and habitat alterations associated with agriculture, as well as unknown causes associated with non-construction-related highway/road/bridge runoff and non-boating recreation and tourism (PA DEP, 2024) It is believed that these problems may be remedied by the same best management practices used to address siltation problems.

Table 1. Subwatershed stream segments and impairments listed by PA DEP Integrated report (2024)

Stream	Source(s)	Causes Listed In Integrated Report
Big Cove Creek mainstem	Siltation, Nutrients	Grazing in Riparian or Shoreline Zones Link to 2024 Waterbody Report
Kendall Run	Siltation	Grazing in Riparian or Shoreline Zones Link to 2024 Waterbody Report

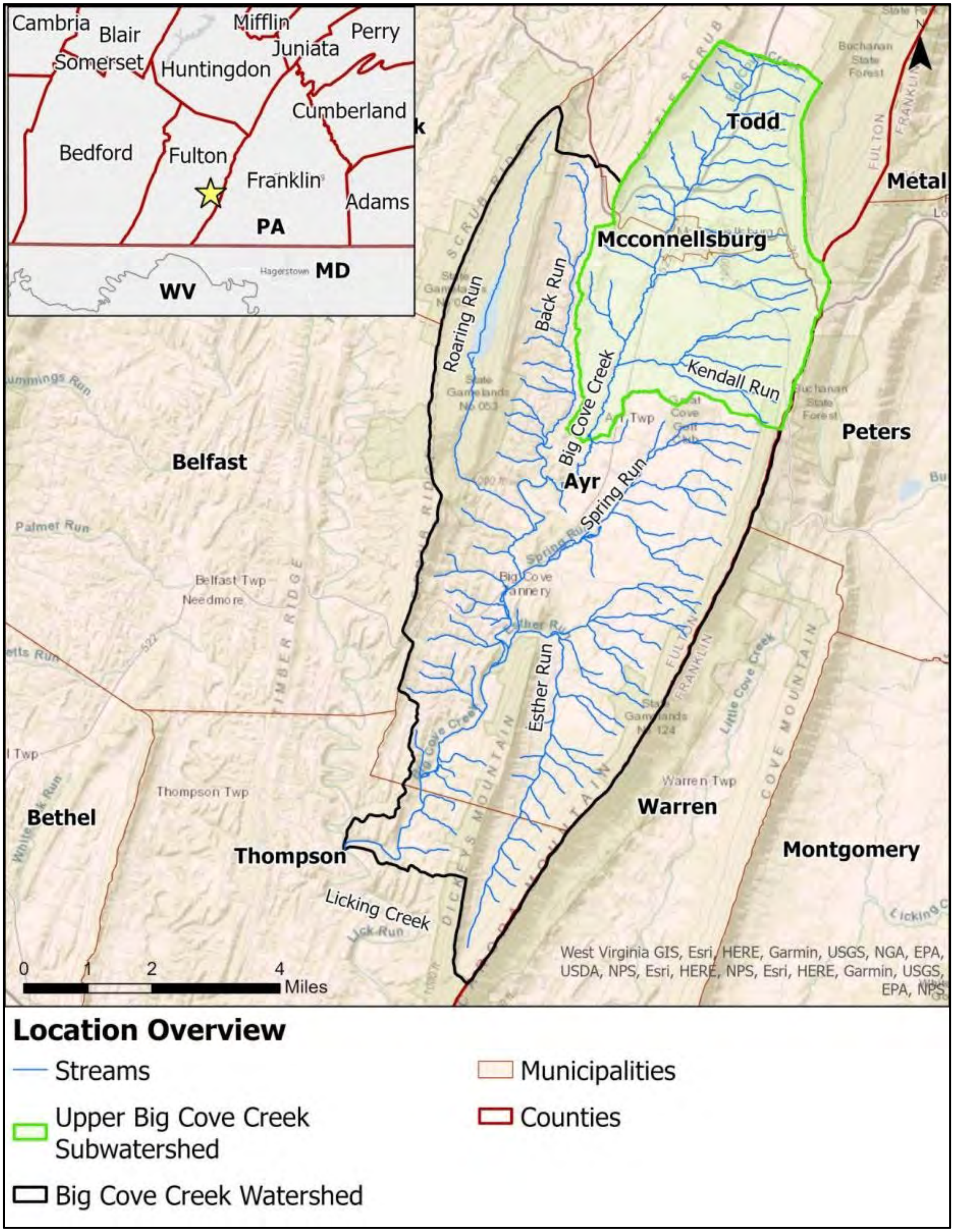

Figure 1. Upper Big Cove Creek subwatershed

SECTION 2. WATERSHED DESCRIPTION

Physical Features

GEOLOGY

The subwatershed lay in the Ridge and Valley physiographic province. The subwatershed is bounded by a hilly topography with mountain ridges to the east (Tuscarora) and to the west (Scrub Ridge). This means that there are steeper slopes that are dominated by tree growth. The geologic formations underlying the watershed are illustrated in Figure 2. There are 11 different geologic formations within the subwatershed and 19 different geologic formations within the Big Cove Creek watershed. The dominant geology is the Reedsville Formation along with the Nittany and Stonehenge/Larke Formations and Coburn Formation through Loysburg Formations. The Reedsville Formation, Nittany and Stonehenge/Larke Formations, and Catskill Formation are dominant in the larger Big Cove Creek watershed. The watershed also has several limestone and dolomite formations.

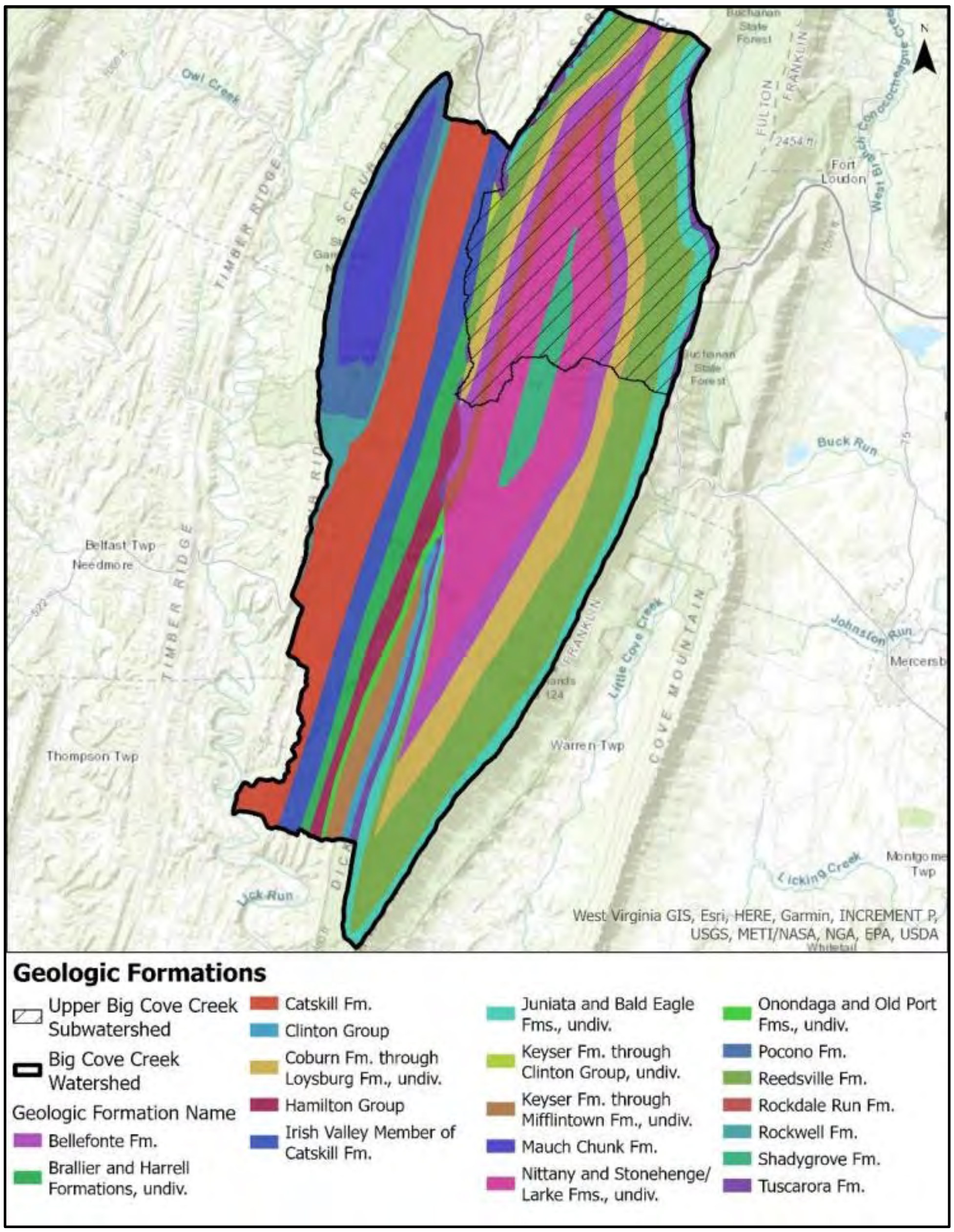

Figure 2. Geology of Upper Big Cove Creek subwatershed and the Big Cove Creek watershed

Table 2 includes the area of geologic formations present and percentage for both the subwatershed and the Big Cove Creek watershed.

Table 2. Geologic formations underlying the Upper Big Cove Creek watershed and Big Cove Creek watershed

Geologic Formation Name	Big Cove Creek Watershed		Upper Big Cove Creek Subwatershed	
	Area (ac)	Percentage of Watershed	Area (ac)	Percentage of Watershed
Bellefonte Formation	2,704.8	7.4%	1,539.4	14.3%
Brallier and Harrell Formations, undivided	1,237.5	3.4%	9.7	0.1%
Catskill Formation	4,499.8	12.3%	–	–
Clinton Group	329.4	0.9%	–	–
Coburn Formation through Loysburg Formation, undivided	3,409.4	9.3%	1,564.2	14.6%
Hamilton Group	968.4	2.6%	–	–
Irish Valley Member of Catskill Formation	2,208.5	6.0%	192.5	1.8%
Juniata and Bald Eagle Formations, undivided	2,239.2	6.1%	896.8	8.4%
Keyser Formation through Clinton Group, undivided	46.3	0.1%	41.0	0.4%
Keyser Formation through Mifflintown Formation, undivided	677.1	1.8%	–	–
Mauch Chunk Formation	1,594.8	4.4%	–	–
Nittany and Stonehenge/Larke Formations, undivided	4,758.9	13.0%	1,965.8	18.3%
Onondaga and Old Port Formations, undivided	309.9	0.8%	–	–
Pocono Formation	1,418.2	3.9%	–	–
Reedsville Formation	6,801.4	18.6%	2,934.7	27.4%
Rockdale Run Formation	936.7	2.6%	756.6	7.1%
Rockwell Formation	668.3	1.8%	–	–
Shadygrove Formation	875.6	2.4%	371.9	3.5%
Tuscarora Formation	975.2	2.7%	455.1	4.2%

Karst Features

The subwatershed is in an area with karst topography. The karst landscape type is characterized by sinkholes, caves, and underground drainage of water. This is due to the interaction of the carbonate bedrock (limestone and dolomite) with water which creates a weak, natural acid that more easily dissolves the underlying rock creating karst features. This has implications not only for human safety and land use considerations due to sinkhole formation, but it can also affect water quality since contaminants may move more quickly into streams and groundwater and compromise drinking water sources as well as aquatic habitat. There are 622 surface depressions, five sinkholes, and one surface mine within the Big Cove Creek watershed. There are 628 total karst features in the Big Cove Creek watershed, with 64% of the features located in the subwatershed (Figure 3). Karst information came from the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) through the PASDA portal.

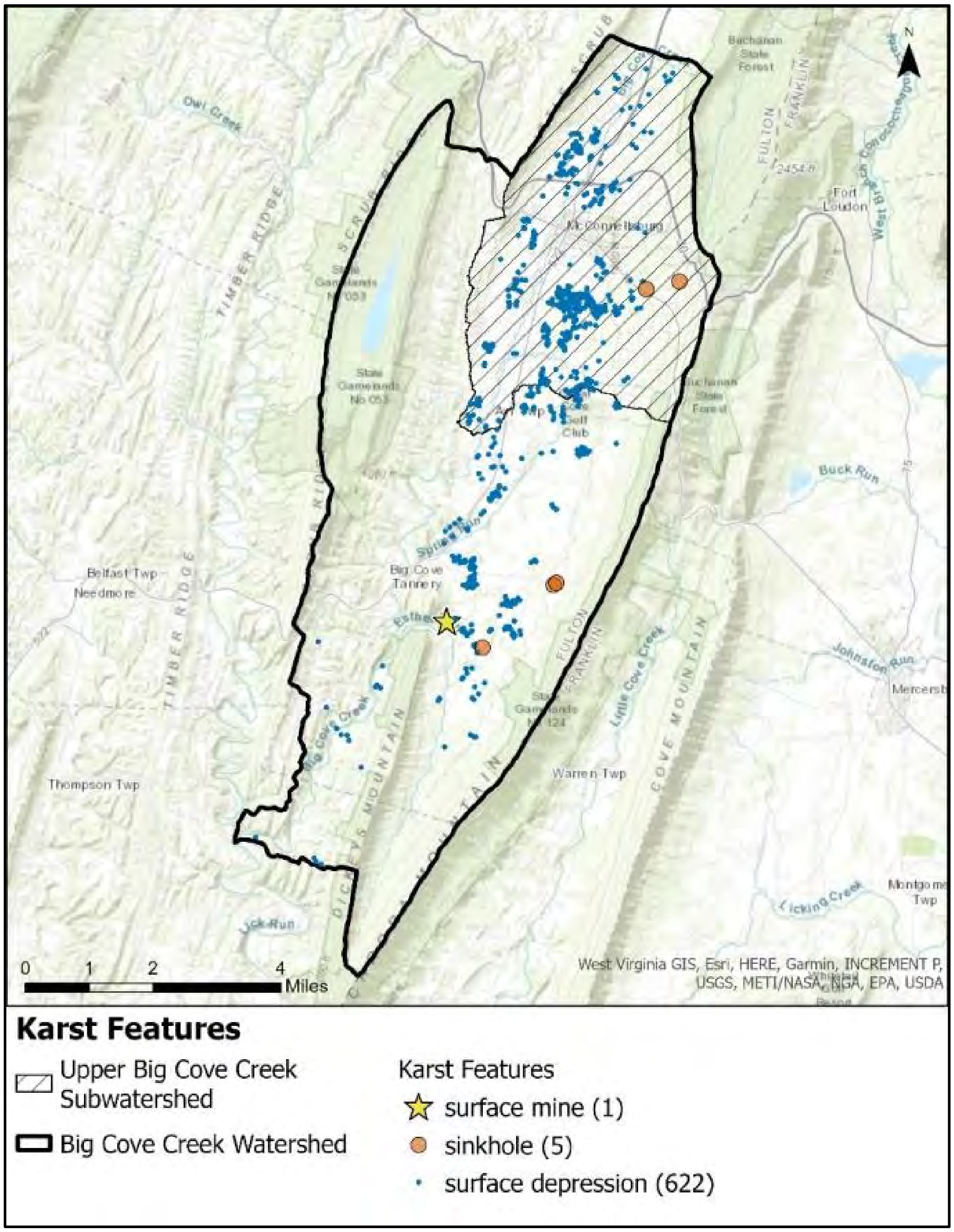

Figure 3. Karst features in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

HYDROLOGIC SOIL GROUPS (HSGS)

When rain falls over land, a portion runs into streams and the piped stormwater system while the remaining rainfall infiltrates into the soil or evaporates into the atmosphere. The hydrologic soil group (HSG) is a soil property that represents the rate that water infiltrates soil. Soils are classified into seven soil groups, including four HSGs (A, B, C, and D) based on the soil's infiltration capacity, and three "dual classifications" (A/D, B/D, and C/D) where a soil's infiltration capacity is influenced by a perched water table (Table 3). Data was obtained from the Soil Survey Geographic Database (SSURGO), which is developed and maintained by the U.S. Department of Agriculture's Natural Resource Conservation Service (USDA NRCS).

Table 3. Overview of Hydrologic Soil Groups (HSGs)[1] found in the Big Cove Creek watershed	
Hydrologic Soil Group (HSG)	**Description**
HSG-A	HSG-A soils consist of deep, well-drained sands or gravelly sands with high infiltration and low runoff rates.
HSG-B	HSG-B soils consist of deep, well-drained soils with a moderately fine to moderately coarse texture and a moderate rate of infiltration and runoff.
HSG-C	HSG-C consists of soils with a layer that impedes the downward movement of water or fine-textured soils and a slow rate of infiltration.
HSG-D	HSG-D consists of soils with a very slow infiltration rate and high runoff potential. This group is composed of clays that have a high shrink-swell potential, soils with a high-water table, soils that have a clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material.
HSG-B/D	HSG-B/D soils naturally have a very slow infiltration rate due to a high-water table, but they will have a moderate rate of infiltration and runoff if drained.
HSG-C/D	HSG-C/D soils naturally have a very slow infiltration rate due to a high-water table, but they will have a slow rate of infiltration if drained.
No HSG Assigned[2]	Data not available in SSURGO.

[1] Source: NRCS, 2007 https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba
[2] Indicates HSG data was not available within a particular soil boundary.

Figure 4 shows the HSG distribution for the subwatershed and Big Cove Creek watershed. Table 4 provides more detail on the different HSG types by area and percentage for the subwatershed and the larger Big Cove watershed.

Within the Big Cove Creek watershed, HSG-B soils—which are well-drained and moderately coarse—are dominant at 38.4%. The second-most dominant soils are HSG-C, which comprise 22.9% of the watershed and typically infiltrate slowly. In the subwatershed, the dominant hydrologic soil groups are by HSG-B and HSG-C soils, at 49.1% and 22.8% respectively.

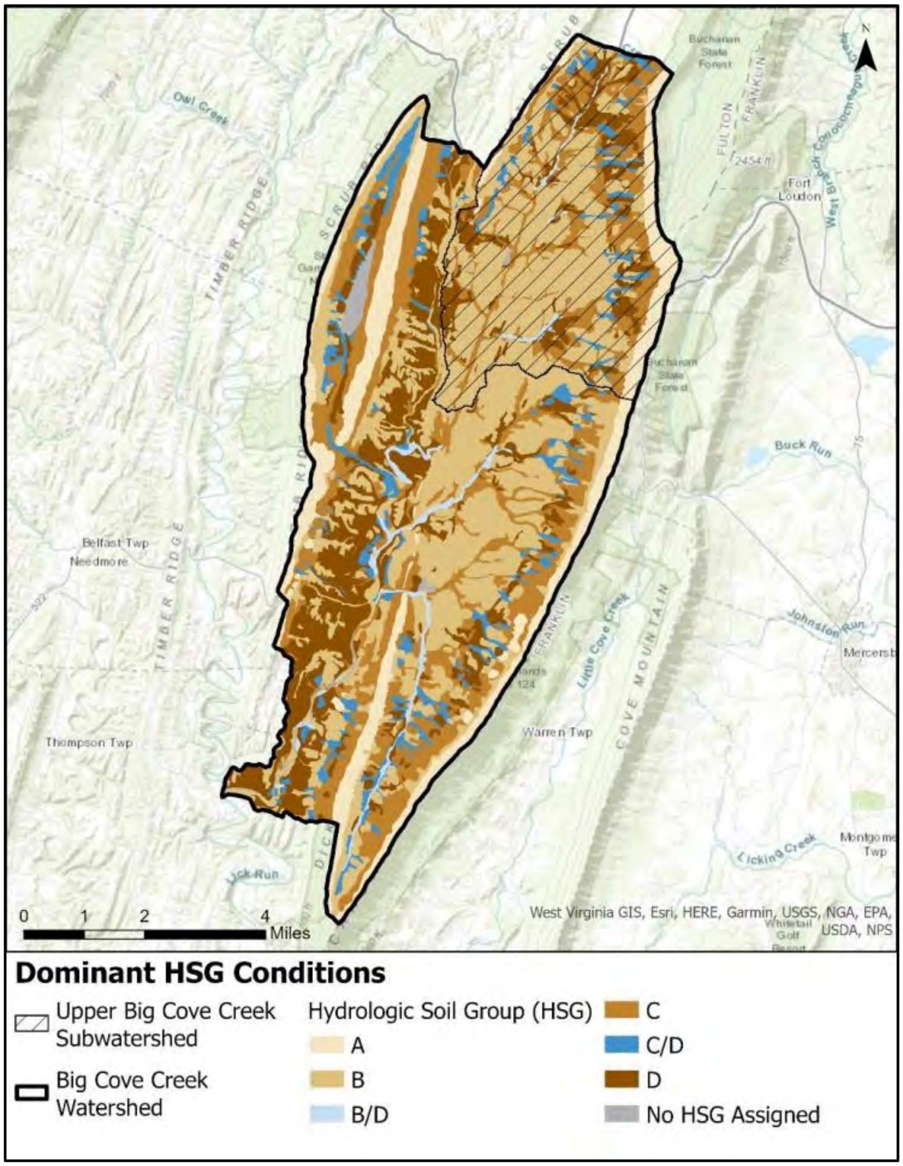

Figure 4. Dominant Hydrologic Soil Group (HSG) conditions in the Big Cove Creek watershed

Table 4. Distribution of dominant hydrologic soil group (HSG) conditions in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Hydrologic Soil Group (HSG)	Big Cove Creek Watershed		Upper Big Cove Creek Subwatershed	
	Area (ac)	Percentage of Watershed	Area (ac)	Percentage of Watershed
HSG-A	4,454.0	12.2%	958.0	8.9%
HSG-B	14,074.3	38.4%	5,266.0	49.1%
HSG-B/D	610.9	1.7%	142.6	1.3%
HSG-C	8,373.5	22.9%	2,446.8	22.8%
HSG-C/D	2,144.1	5.9%	481.1	4.5%
HSG-D	6,683.1	18.3%	1,413.5	13.2%
No HSG Assigned	273.5	0.7%	13.9	0.1%

Hydrology

Annual Precipitation

The townships and borough in the subwatershed average approximately 40 inches of rain and an annual average temperature of 51 degrees Fahrenheit (Stroud Water Research Center, Model My Watershed, 2022).

Flood Zones

Flood zones in the Big Cove Creek watershed are characterized by the impact associated with the 100-year and 500-year flood events (Table 5). Nearly all of the mapped flood zone is in the "X" zone, which is associated with minimal to moderate flood hazard, except for some of the areas surrounding Big Cove Creek and its tributaries (Figure 5; Table 6). No data is available for the 10-, 25-, or 50-year flood events.

Table 5. Definitions of flood zones

Flood Zone	Definition*
A	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event where no hydraulic analyses have been performed.
AE	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event where hydraulic analyses have been performed.
AO	Areas subject to inundation by the 1-percent-annual-chance (100-year) shallow flooding where average depths are between one and three feet.
VE	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event with additional hazards due to storm-induced velocity wave action.
X	An area of minimal to moderate flood hazard that is outside of the Special Flood Hazard Area and either 1) between the limits of the base flood and the 0.2-percent-annual-chance (500-year) flood, or 2) above the elevation of the 0.2-percent-annual-chance (500-year) flood.

* Definitions adapted from https://floodpartners.com/flood-zones/

Table 6. Flood zones in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Flood Zone	Big Cove Creek Watershed		Upper Big Cove Creek Subwatershed	
	Area (ac)	Percentage of Watershed	Area (ac)	Percentage of Watershed
A	1,415.4	3.9%	206.5	1.9%
AE	38.4	0.1%	38.4	0.4%
X	35,081.8	96.0%	10,487.9	97.7%

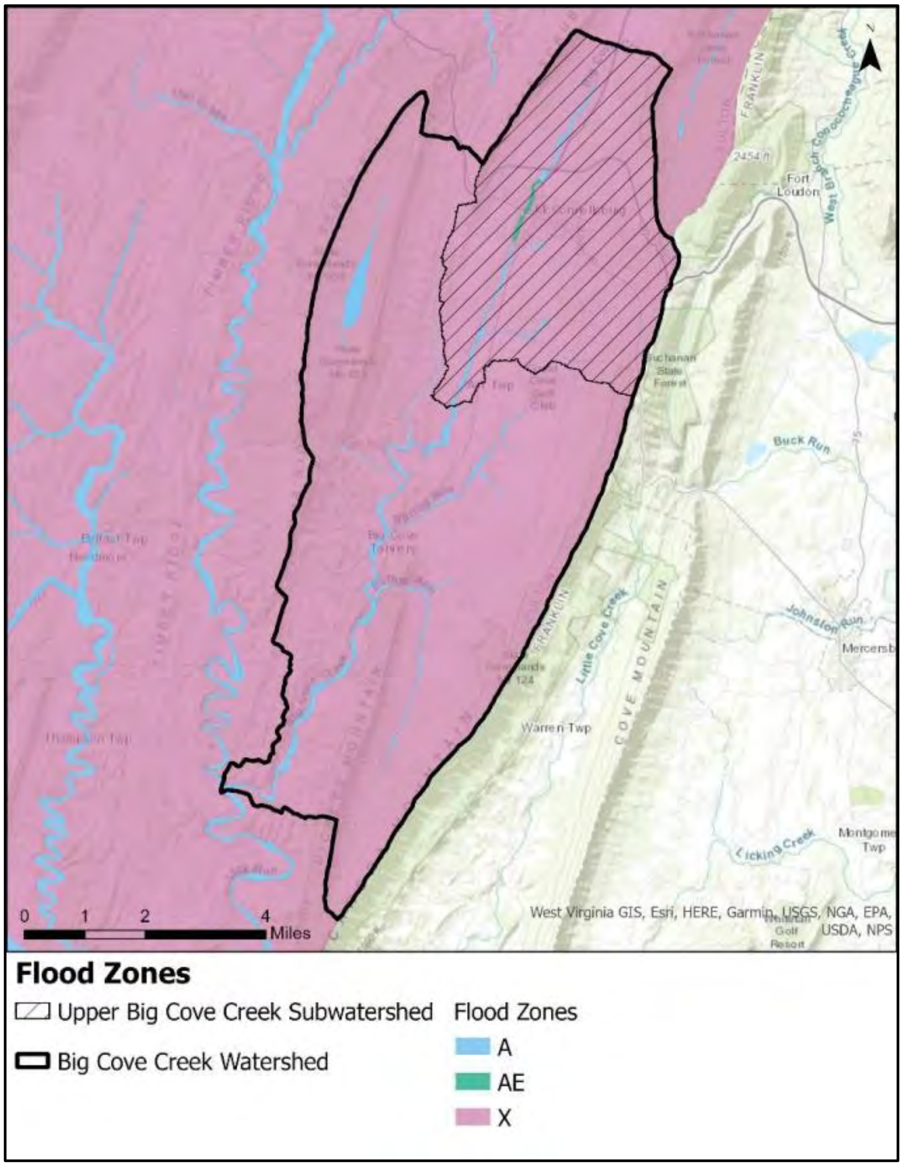

Figure 5. Flood zones in the Big Cove Creek watershed

Surface Water Features

Surface water features (streams, freshwater ponds, lakes) are illustrated in Figure 6 using 2023 Chapter 93 Designated Use streams from the Pennsylvania Department of Environmental Protection (PA DEP), PA DEP's Integrated List of Lakes, and wetland/waterbody data from the U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI). There are 145.1 miles of streams in the Big Cove Creek watershed, 30.7% of which (44.6 miles) are within the subwatershed. The majority of the stream miles within the subwatershed are first-order streams (58.2%). First-order streams are typically dominated by overland flow and are typically most susceptible to the impacts of non-point source pollution. Stream orders within the subwatershed are included in Table 7. Meadow Grounds Lake, which has a footprint of just over 195 acres, is the only lake in the larger Big Cove Creek watershed.

There are also 23.3 acres of freshwater ponds in the Big Cove Creek watershed (46.2% of which are within the subwatershed), which correspond to "Freshwater Pond" wetland types in the NWI dataset. Areas of each of the types of wetlands are illustrated in Figure 7 and summarized in Table 8. The majority of wetlands in the Big Cove Creek watershed (43.8%) are classified as riverine and are located along the streams, and 23% of all types of wetlands are located in the subwatershed.

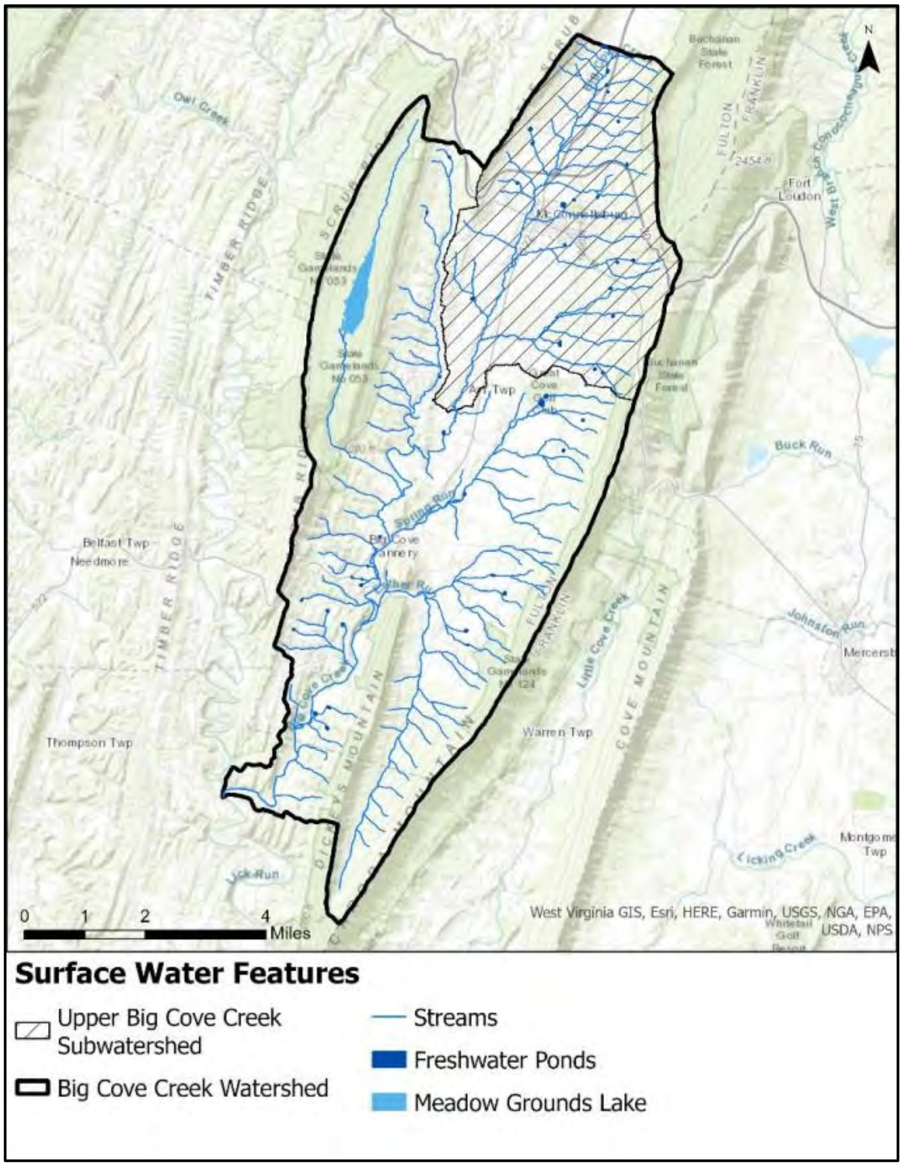

Figure 6. Surface water features within the Big Cove Creek watershed

Table 7. Summary of stream orders in the Upper Big Cove Creek subwatershed from Model My Watershed[1]		
Stream Order	**Total Length (miles)**	**Percentage of Total Length**
1st	13.3	58.2%
2nd	4.4	19.3%
3rd	1.4	6.2%
Other	3.7	16.4%

[1] Note that the above stream order summary from Model My Watershed results from analyzing the National Hydrography Dataset (NHD), which is less detailed and contains fewer tributaries than the PA DEP datasets used in this report. As such, stream miles from this table will be notably less than those tabulated in the Surface Water Conditions section.

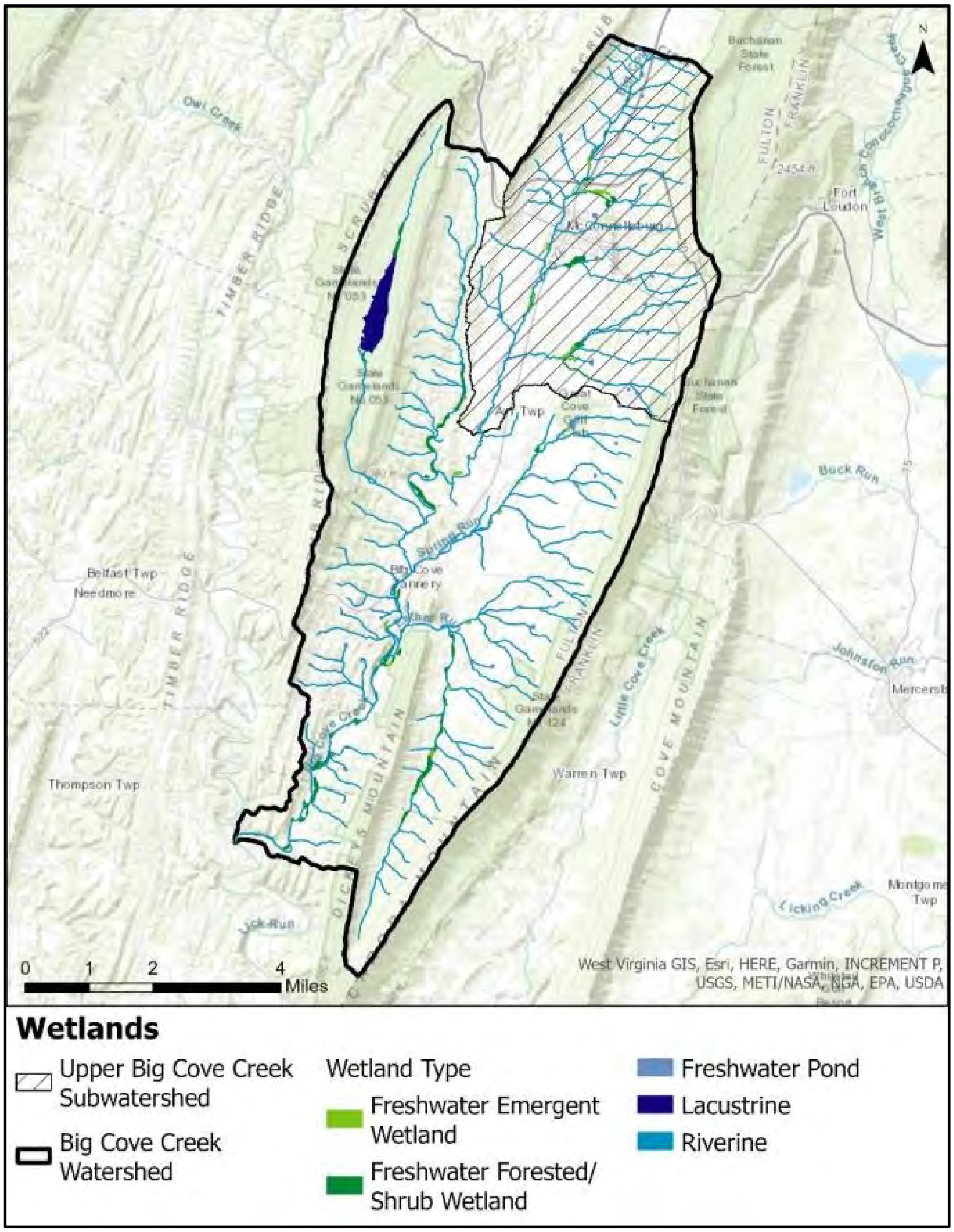

Figure 7. Wetlands within the Big Cove Creek watershed

Table 8. Wetland areas in the Big Cove Creek watershed and Upper Big Cove Creek subwatershed

Wetland Type	Big Cove Creek Watershed		Upper Big Cove Creek Subwatershed	
	Area (ac)	Percentage of Watershed	Area (ac)	Percentage of Watershed
Freshwater Emergent Wetland	53.6	6.7%	35.1	19.0%
Freshwater Forested/ Shrub Wetland	179.5	22.3%	32.0	17.3%
Freshwater Pond	23.3	2.9%	10.8	5.8%
Lacustrine	195.2	24.3%	0.0	0.0%
Riverine	352.5	43.8%	107.1	57.9%

Surface Water Conditions

Within the Big Cove Creek watershed, approximately 18.8% of stream miles are impaired for aquatic life uses, and all streams have a designated use for cold-water fishes (PA DEP, 2022b). Additionally, 7.8 miles—5.4% of all streams—are designated for High Quality-Cold Water Fishes (HQ-CWF); however, none of these HQ-CWF streams are within the subwatershed. For the subwatershed, approximately 18.3% of stream miles are impaired for aquatic life uses. The primary causes of aquatic life use impairments are siltation (from agriculture and grazing in riparian or shoreline zones), nutrients (from grazing in riparian or shoreline zones), habitat alterations (from agriculture), non-construction-related runoff from highways/roads/bridges (from unknown causes), and non-boating recreation and tourism (from unknown causes). In the Big Cove Creek watershed, the majority of aquatic life use impairments (70.1%) are caused by agriculture-related siltation, and the same is true for the subwatershed. The Meadow Grounds Lake, illustrated in Figure 6, is impaired for aquatic life use as well. There are no stream segments that are impaired for fish consumption.

According to Pennsylvania Fish and Boat Commission (PFBC) data, there are no stream sections that support natural trout reproduction in the Big Cove Creek watershed; however, there are 16.1 miles of stocked trout waters in the watershed, 2.0 miles (12.5%) of which are within the subwatershed. Most of these are on the mainstem of Big Cove Creek, starting in the lower reaches of the subwatershed and extending downstream to near its mouth with Licking Creek (Figure 8). This stocked area includes nearly a mile of "Keystone Select" waters, which is a designation where certain streams are stocked with larger trout and managed to enhance recreational angling opportunities (PFBC, 2022).

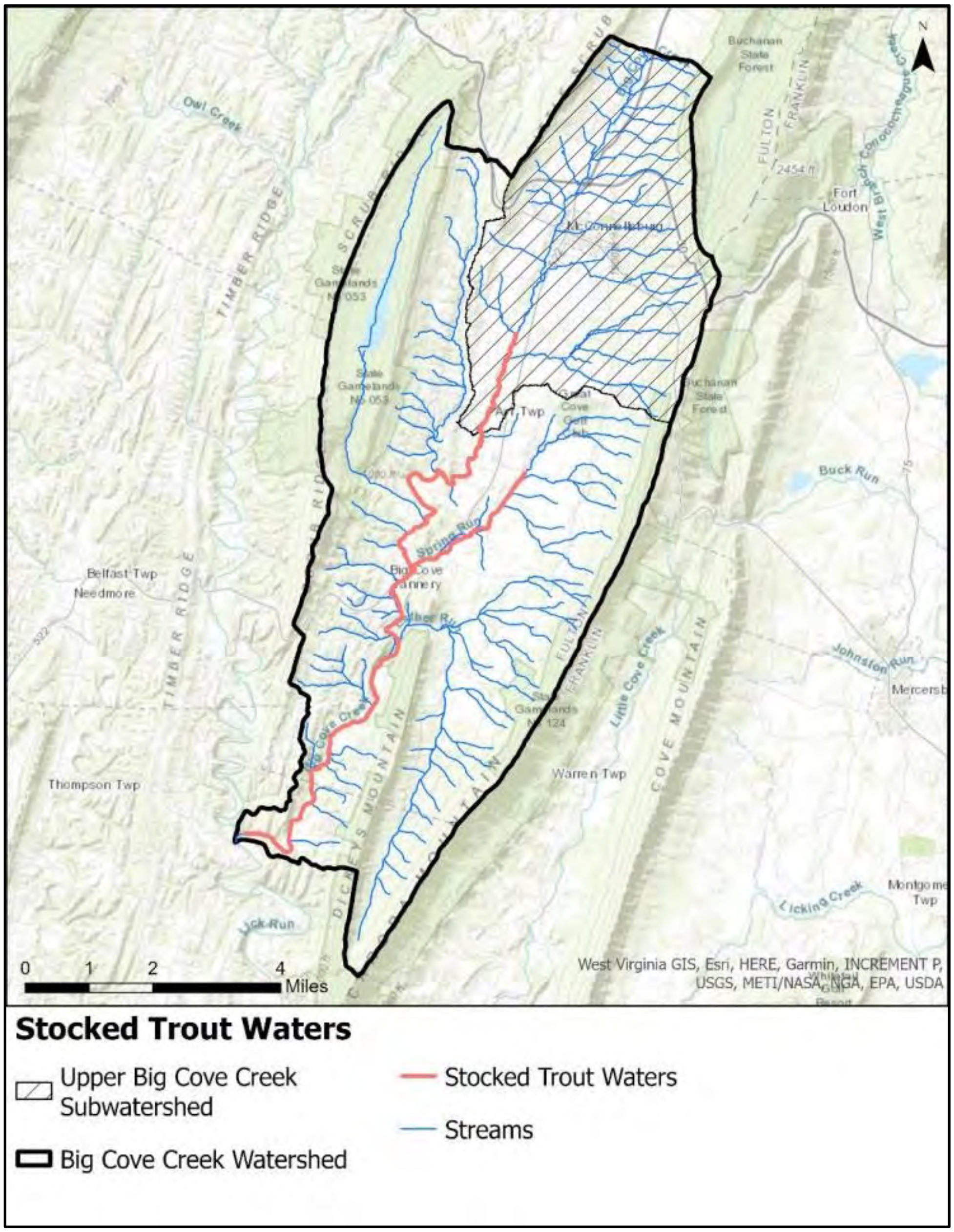

Figure 8. Stocked trout waters in the Big Cove Creek watershed

Figure 9 shows the streams in the Big Cove Creek watershed that are designated as impaired. Figure 10 shows the streams that are supporting and impaired for aquatic life use in the subwatershed. Figure 11 shows streams that are supporting fish consumption use, as well as those that are not designated/assessed for fish consumption use. Because these streams are not designated for fish consumption, they are not assessed for potential impairments for this use. Table 9 and Table 10 summarize the lengths of streams that are supporting and impaired for each use within the Big Cove Creek watershed and subwatershed, respectively.

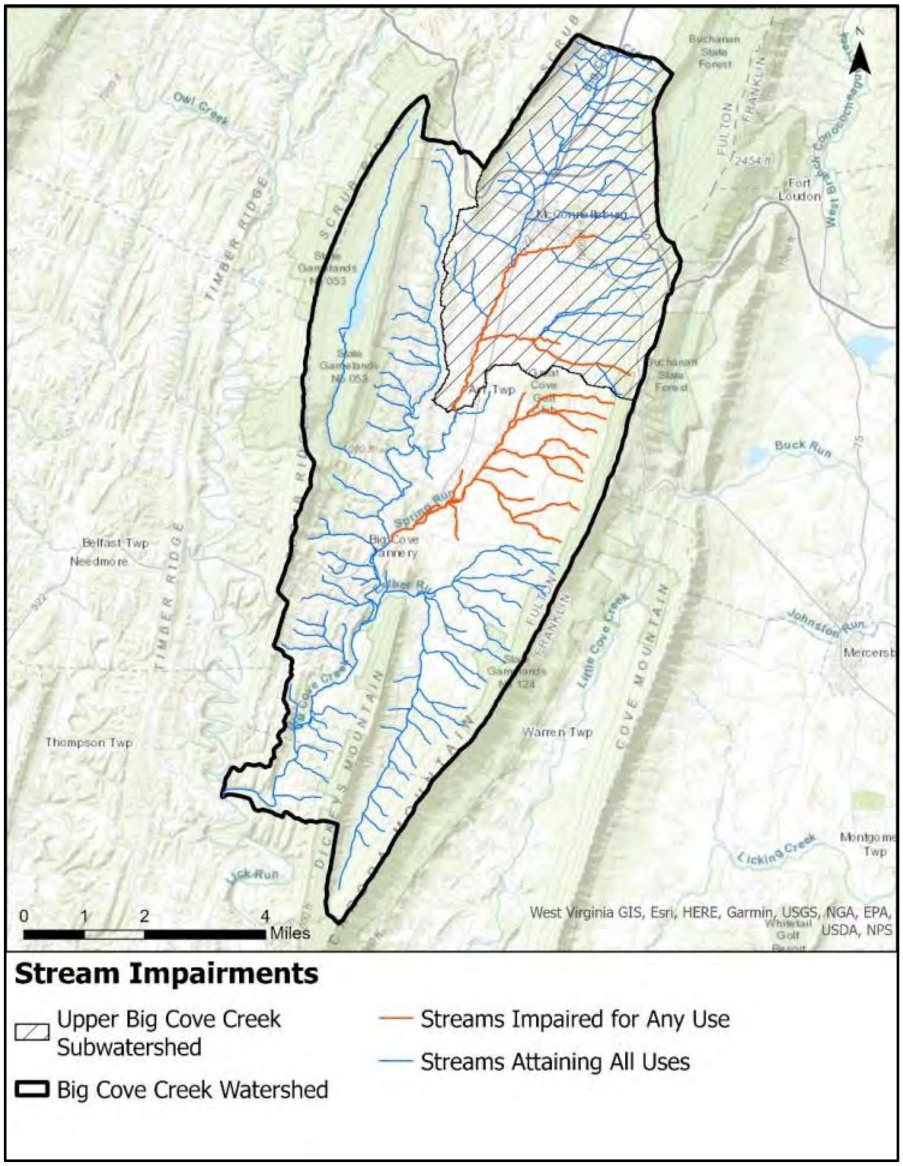

Figure 9. Overall stream impairments in the Big Cove Creek watershed

Table 9. Summary of stream impairments in the Big Cove Creek watershed[1]

Designated Use	Supporting Length (mi)	Impaired Length (mi)	Percentage of Total Length of Streams that are Impaired
Aquatic Life	117.9	27.2	18.8%
Fish Consumption	139.9	0.0	0.0%

[1] The sum of the supporting and impaired stream lengths is greater than the total length of streams in the watershed because there is known overlap between the stream segments and between/within uses in the Integrated List GIS datasets.

Table 10. Summary of stream impairments in the Upper Big Cove Creek subwatershed[1]

Designated Use	Supporting Length (mi)	Impaired Length (mi)	Percentage of Total Length of Streams that are Impaired
Aquatic Life	36.5	8.1	18.3%
Fish Consumption	43.0	0.0	0.0%

[1] The sum of the supporting and impaired stream lengths is greater than the total length of streams in the watershed because there is known overlap between the stream segments and between/within uses in the Integrated List GIS datasets.

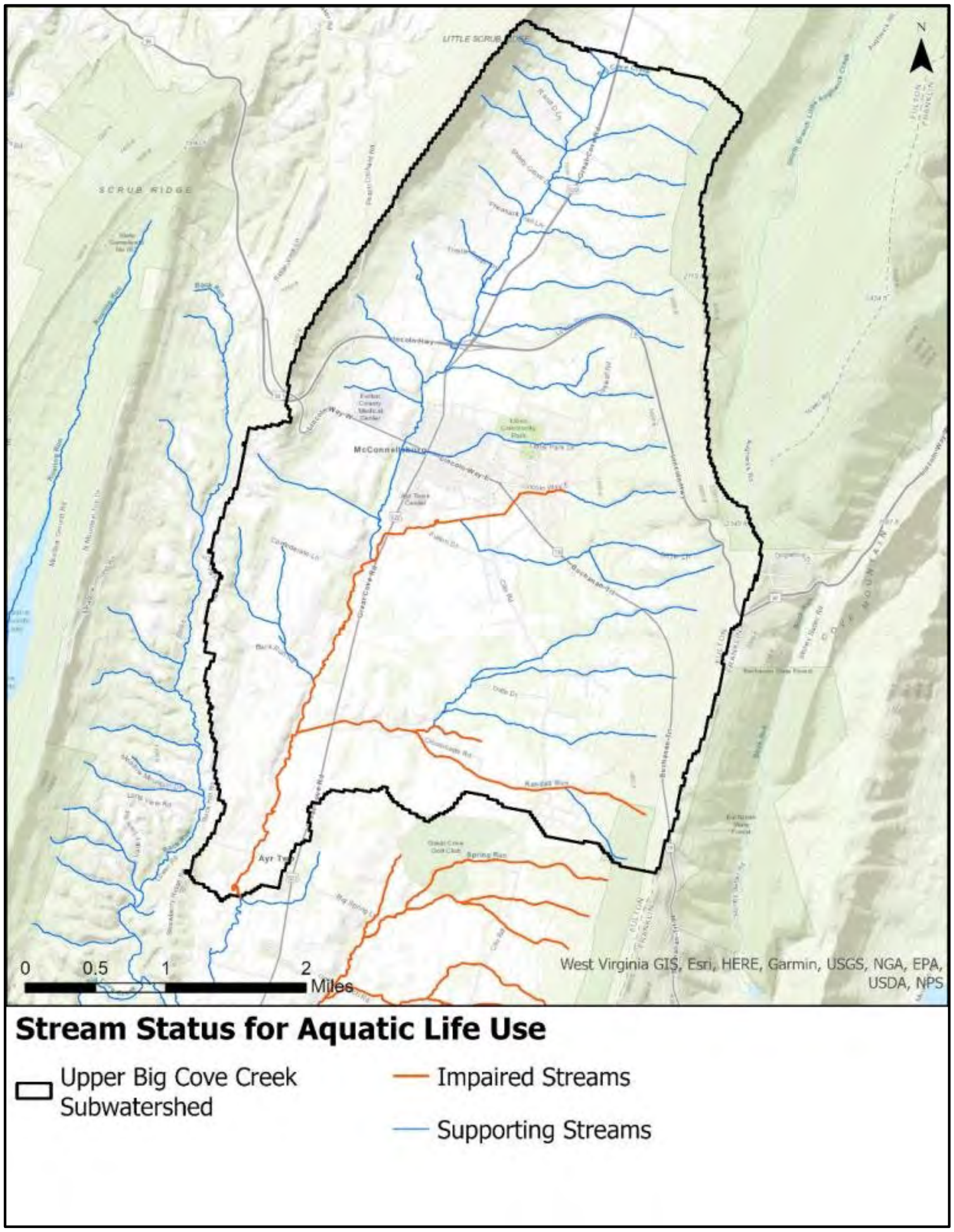

Figure 10. Streams supporting and impaired for aquatic life use in the Upper Big Cove Creek subwatershed

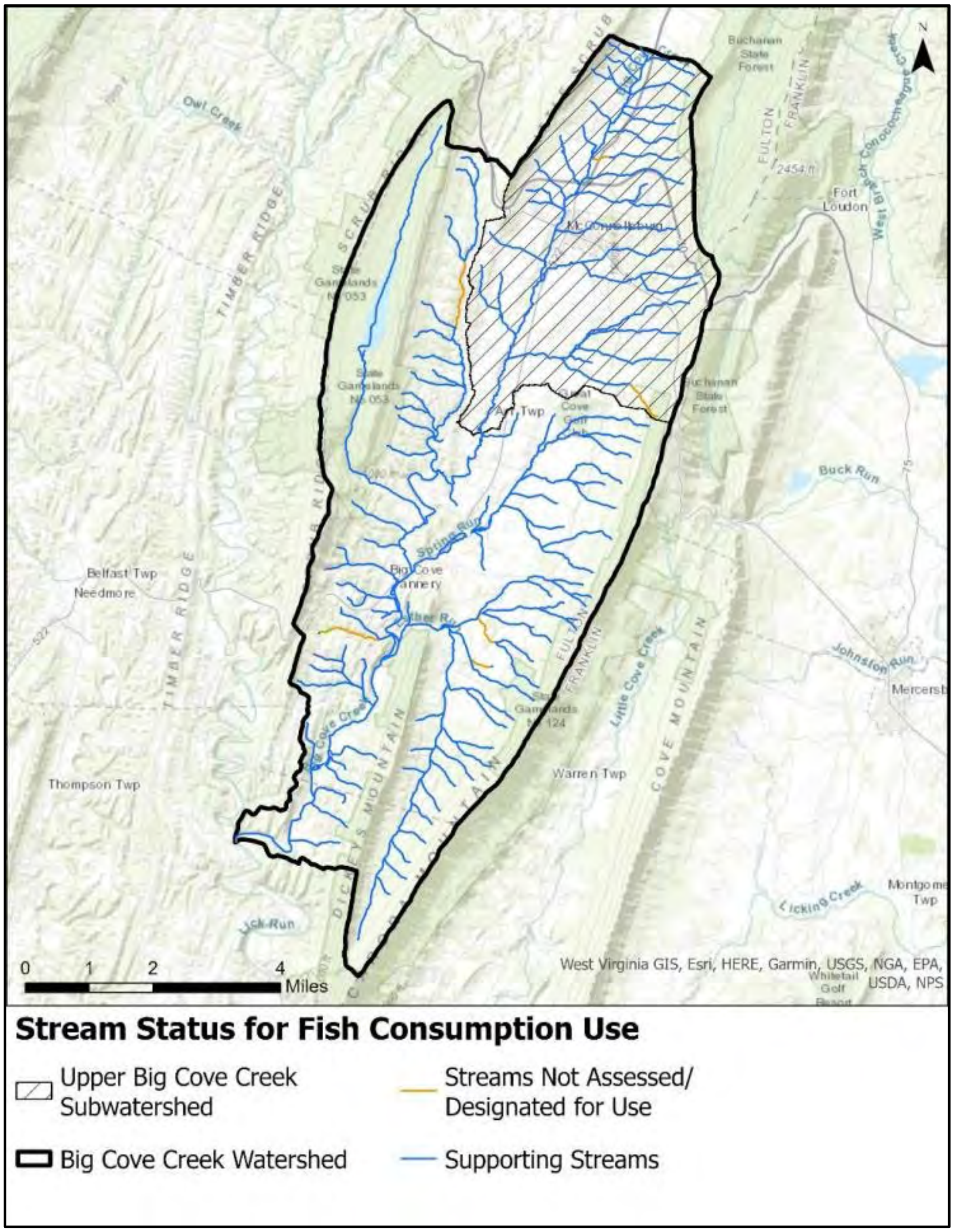

Figure 11. Streams supporting and not assessed/designated for fish consumption use in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Land Use Land Cover

Land cover and land use were summarized using 2017/2018 data from the Chesapeake Bay Program Office's "One-Meter Resolution Land Use/Land Cover Dataset for the Chesapeake Bay Watershed."[1] These datasets were developed in collaboration between Chesapeake Conservancy, the U.S. Geological Survey (USGS), and the University of Vermont Spatial Analysis Lab (UVM SAL) with funding from the Chesapeake Bay Program (CBP).

While both the land cover and land use datasets are one-meter resolution, the land use dataset has the most detailed classification with 37 more unique classes than the land cover dataset. Land cover within the Big Cove Creek watershed and subwatershed is illustrated in Figure 12 and summarized in Table 11. General land use within the Big Cove Creek watershed and subwatershed is in Figure 13 and Table 12.

[1] https://www.chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/lulc-data-project-2022/

Land cover information from the land cover dataset indicates that the Big Cove Creek watershed is primarily tree canopy (62.4%), followed by herbaceous cover (33.4%). Most of this herbaceous cover corresponds to cropland (14.0%) and pasture/hay (13.3%) land uses. The land cover breakdown within the subwatershed is similar, but tree canopy and herbaceous cover percentages are closer (45.8% and 46.5%, respectively).

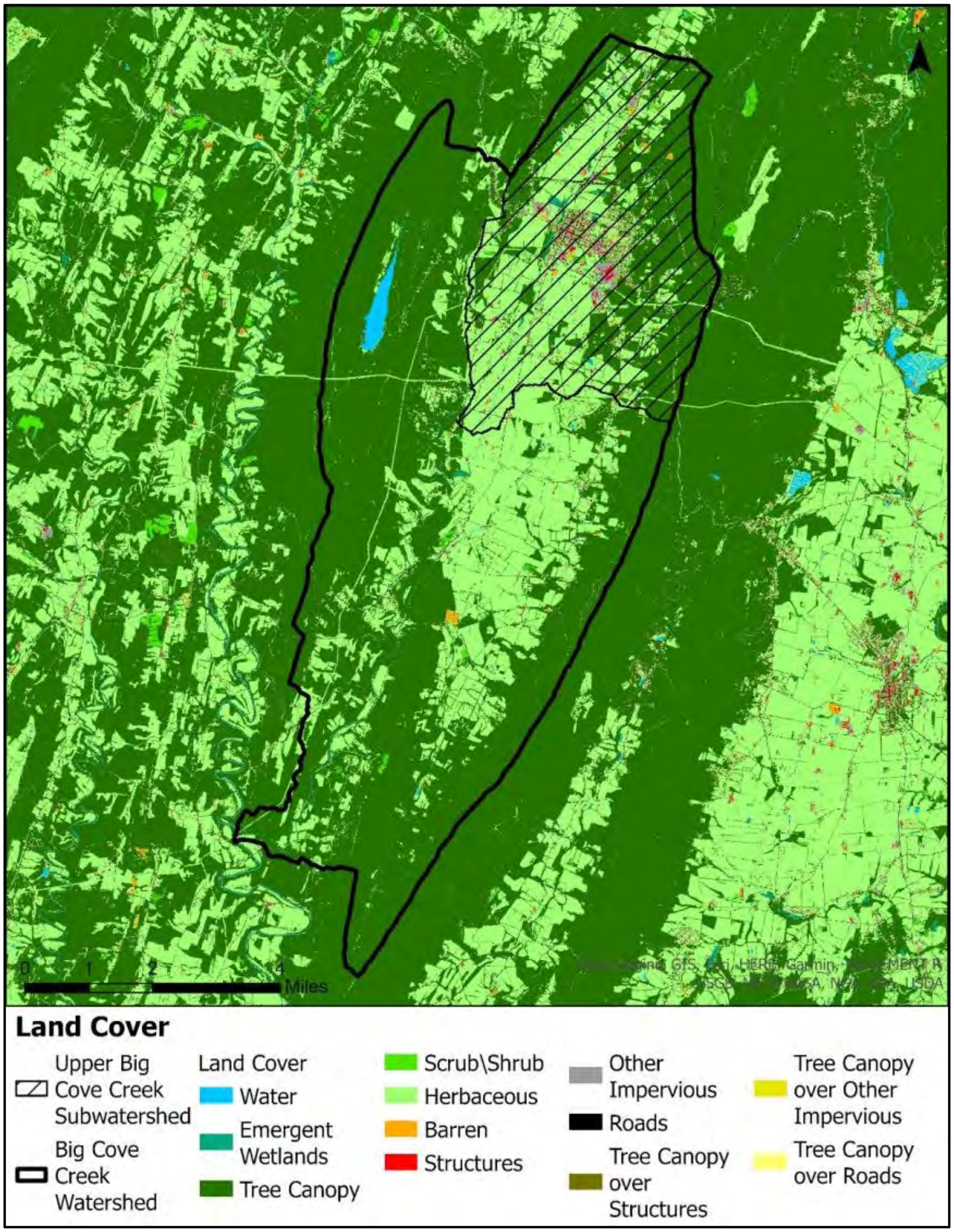

Figure 12. Land cover within the Big Cove Creek watershed

Table 11. Summary of land cover within the Upper Big Cove Creek subwatershed and Big Cove Creek watershed				
Land Cover Category	**Big Cove Creek Watershed**		**Upper Big Cove Creek Subwatershed**	
	Area (ac)	**Percentage of Watershed**	**Area (ac)**	**Percentage of Watershed**
Water	262.4	0.7%	21.5	0.2%
Emergent Wetlands	62.4	0.2%	46.5	0.4%
Tree Canopy	22,842.8	62.4%	4,914.5	45.8%
Scrub/Shrub	92.9	0.3%	31.5	0.3%
Herbaceous	12,227.8	33.4%	4,991.8	46.5%
Barren	115.4	0.3%	68.1	0.6%
Structures	173.3	0.5%	129.0	1.2%
Other Impervious	405.9	1.1%	323.5	3.0%
Roads	320.0	0.9%	176.6	1.6%
Tree Canopy over Structures	3.4	< 0.1%	1.9	< 0.1%
Tree Canopy over Other Impervious	19.2	0.1%	12.8	0.1%
Tree Canopy over Roads	64.0	0.2%	17.4	0.2%
Total	**36,589.5**		**10,735.1**	

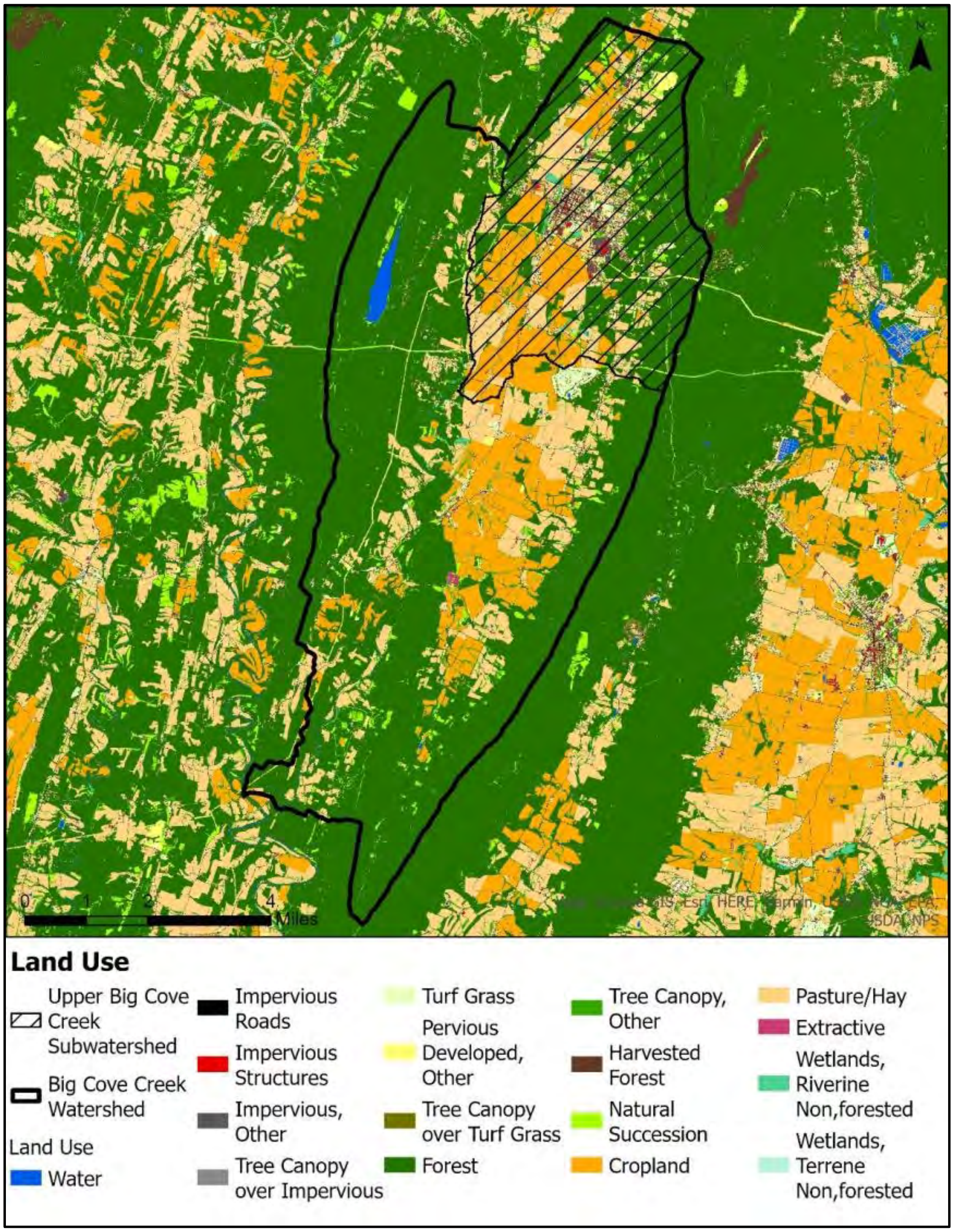

Figure 13. Land use within the Big Cove Creek watershed

Table 12. Summary of land uses within the Upper Big Cove Creek subwatershed and Big Cove Creek watershed				
Land Use Category	**Big Cove Creek**		**Upper Big Cove Creek**	
	Area (ac)	**Percentage of Watershed**	**Area (ac)**	**Percentage of Watershed**
Water	262.4	0.7%	21.5	0.2%
Impervious Roads	320.0	0.9%	176.6	1.6%
Impervious Structures	173.3	0.5%	129.0	1.2%
Impervious, Other	405.9	1.1%	323.5	3.0%
Tree Canopy over Impervious	86.5	0.2%	32.1	0.3%
Turf Grass	977.4	2.7%	516.1	4.8%
Pervious Developed, Other	509.6	1.4%	264.1	2.5%
Tree Canopy over Turf Grass	436.5	1.2%	218.2	2.0%
Forest	21,797.7	59.6%	4,451.3	41.5%
Tree Canopy, Other	608.6	1.7%	245.0	2.3%
Natural Succession	883.4	2.4%	285.4	2.7%
Cropland	5,139.7	14.0%	2,173.6	20.2%
Pasture/Hay	4,856.2	13.3%	1,822.6	17.0%
Extractive	18.7	0.1%	74.6	0.7%
Wetlands, Riverine Non-forested	111.8	0.3%	1.4	< 0.01%
Wetlands, Terrene Non-forested	1.5	< 0.01%	0.0	0.0%

A potential issue of concern in the Big Cove Creek watershed is the increasing use of agricultural land for the placement of solar farms (Figure 14). The construction associated with solar farms is subject to the same NPDES permit coverage requirements for earth disturbance of one acre or greater as outlined in 25 Pa. Code § 102.5(a). This includes erosion and sediment control practices as well as post construction stormwater controls to mitigate runoff. The primary goal to address stormwater runoff is mitigation through the preservation or restoration of perennial vegetative cover to infiltrate runoff and avoid concentrated flows beneath the installed panels. PA DEP has a frequently asked questions (FAQ) document that details the criteria to meet post construction requirements for solar farms (PA DEP, 2021).

Figure 14. Solar farm site Big Cove Creek watershed (Source: Fulton County Conservation District)

Impervious Cover

Approximately 985.7 acres (2.7%) of the Big Cove Creek watershed is categorized as impervious cover, while the subwatershed is approximately 6.2% impervious with 661.2 acres of impervious cover. There are approximately 167.8 miles of roads in the Big Cove Creek watershed, 50.0% of which are within the subwatershed (Figure 15).[2] Impervious cover was calculated as the sum of the following classes from the land cover dataset (Table 11): structures, roads, other impervious, tree canopy over structures, tree canopy over roads, and tree canopy over other impervious. Fulton County also maintains a dataset with points for all built structures in the County. There are 2,232 structures in the Big Cove Creek watershed, and 72.5% (1,619 structures) are within the study subwatershed (Table 13).

Based on the Impervious Cover Model, the subwatershed is in the "sensitive" category defined as impervious cover less than 10%. Within this range, streams are expected to maintain their structure and function with adequate protection. Examples of potential management approaches for protecting sensitive streams include keeping watershed impervious cover below 10%; retaining existing forest, meadow, and wetland cover; implementing best practices on all croplands; and preventing livestock from entering streams (Schueler et al., 2009).

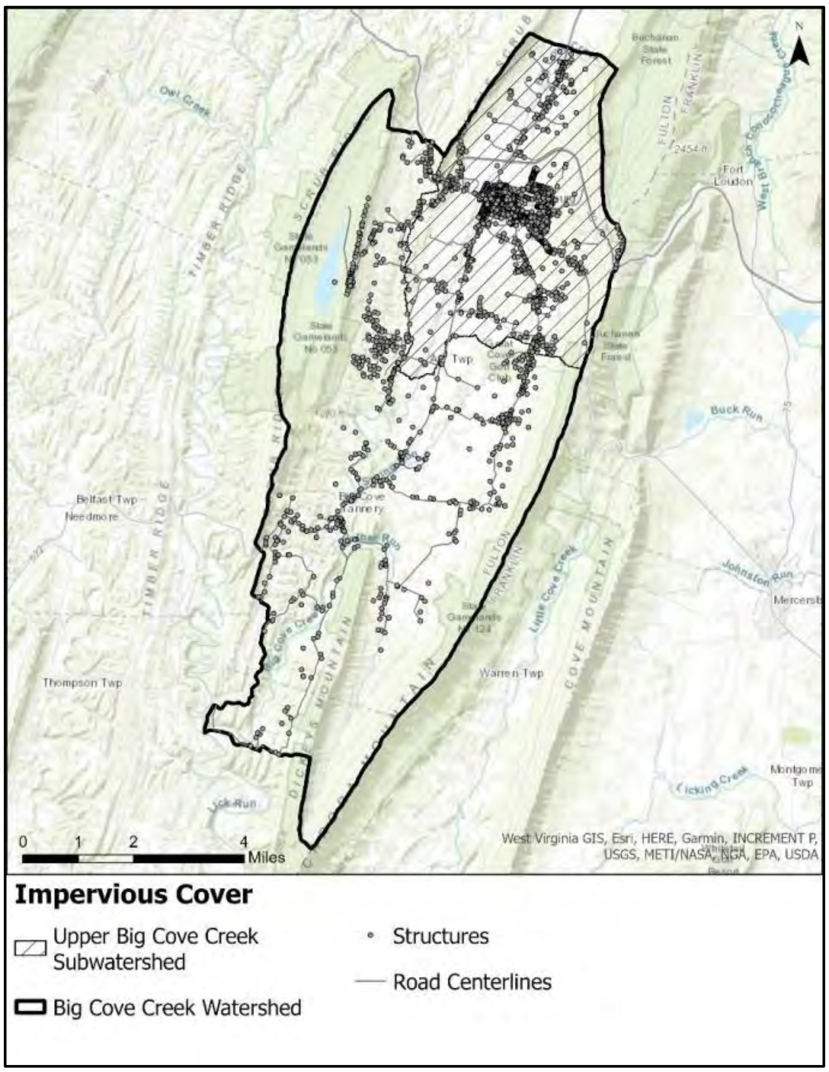

Figure 15. Road centerlines and structures in the Upper Big Cover Creek subwatershed and Big Cove Creek watershed

[2] Note impervious surfaces in Figure 15 are not comprehensive. Buildings, parking lots, and other impervious surfaces may not be displayed due to unavailable data.

Table 13. Counts of structures and lengths of road centerlines in in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed				
Geography	**Structures**		**Road Centerlines**	
	Count	**Percentage of Total Structures in the Watershed**	**Length (mi)**	**Percentage of Total Road Centerlines in the Watershed**
Upper Big Cove Creek Subwatershed	1,619	72.5%	84.0	50.0%
Big Cove Creek Watershed	2,232	100%	167.8	100%

EASEMENTS & OTHER PROTECTED AREAS

Several protected areas are either fully or partially within the Big Cove Creek watershed, including four agricultural easements, three state resource management areas, and one local park (Figure 16 and Table 14).

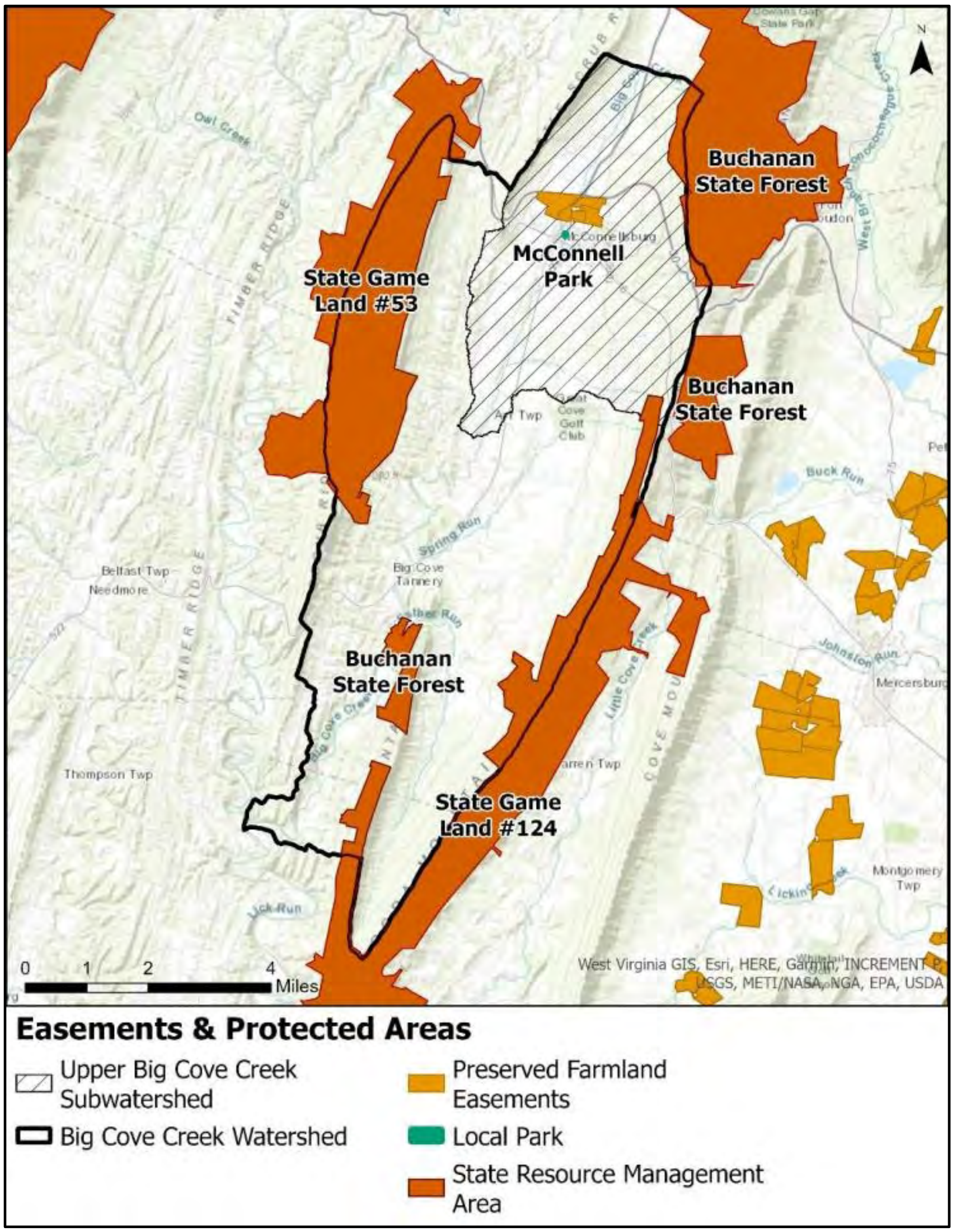

Figure 16. Easements and protected areas in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Table 14. Summary of easements and protected areas within the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Type of Easement or Protected Area	Big Cove Creek		Upper Big Cove Creek	
	Area (ac)	Percentage of Watershed	Area (ac)	Percentage of Watershed
Preserved Farmland Easement	249.1	0.7%	249.1	2.3%
Local Park	0.12	< 0.01%	0.12	< 0.01%
State Resource Management Area	6,016.8	16.4%	347.8	3.2%
Total	**6,267.0**	**17.1%**	**596.9**	**5.6%**

The protected areas in the preceding figure are from the U.S. Geological Survey (USGS) Protected Area Database of the United States (PAD-US). The preserved farmland easements information is from WeConservePA (PASDA, 2023). Within the subwatershed, a local park of 0.1 acres, McConnel Park, is identified as a protected area. Portions of State Resource Management Areas (SRMAs) that include State Game Land areas #124 and #53 and the multipart Buchanan State Forest are also protected. The SRMA's include a total of 6,017.8 acres within the Big Cove Creek watershed, 5.8% (347.8 acres) of which are within the Upper Big Cove Creek subwatershed. The state game lands are primarily used for the management of habitat for wildlife, opportunities for lawful hunting and trapping, and recreational uses (PGC, no date).

In the Big Cove Creek watershed, there are four unique Farmland Preservation Easement acquisitions covering a total of 0.7% (249.1 acres). All four are located within the subwatershed and owned by Fulton County with closed access to the public.

The Pennsylvania Bureau of Farmland Preservation administers Preserved Farmland Easements through the Pennsylvania Agricultural Conservation Easement Purchase Program. Since its approval in 1988, this program has purchased easements for over 5,300 farms covering a total of over 550,000 acres throughout the state of Pennsylvania. In the Big Cove Creek watershed, this program is administered by the Fulton County Commissioners Office.

Land protected by an agricultural conservation easement can only be used for agricultural production or other specified activities and cannot be developed. The goal of the program is to purchase agricultural conservation easements in perpetuity to keep land in agricultural production and help ensure the future of agriculture in Fulton County. Protecting groups or clusters of farms helps maintain the local agricultural industry. Agricultural conservation easements are purchased or donated voluntarily by a landowner to protect farms for agriculture in perpetuity (Land Conservation Assistance Network, n.d.).

SECTION 3. WATER QUALITY

Total Maximum Daily Loads (TMDLs)

Under the Clean Water Act, each state is required to designate uses for each waterbody and to establish water quality criteria that must be met to support those uses. States regularly assess whether water quality criteria are being met through the collection and analysis of surface water monitoring data. There are 40 Instream Comprehensive Evaluation (ICE-IS) water sampling stations within the Big Cove Creek watershed (Figure 17), 12 of which are within the subwatershed. These stations mark where surface water has been sampled to determine whether surface waters are attaining their designated use(s). The ICE-IS evaluation includes water properties such as pH, temperature, alkalinity, conductivity, and dissolved oxygen. It also includes macroinvertebrate collection. All sampling is done following DEP data collection protocols as highlighted in Water Quality Monitoring Protocols for Streams and Rivers (Lookenbill & Whiteash, 2021).

Where water bodies are too polluted to meet the designated uses, they are added to an "impaired waters list." In Pennsylvania, the PA DEP develops a Total Maximum Daily Load (TMDL) for waterbodies identified as impaired with the goal of "de-listing" or improving the stream so that it can fully support its designated uses. There are 19.1 miles of streams with TMDLs in the Big Cove Creek watershed, none of which are within the subwatershed.

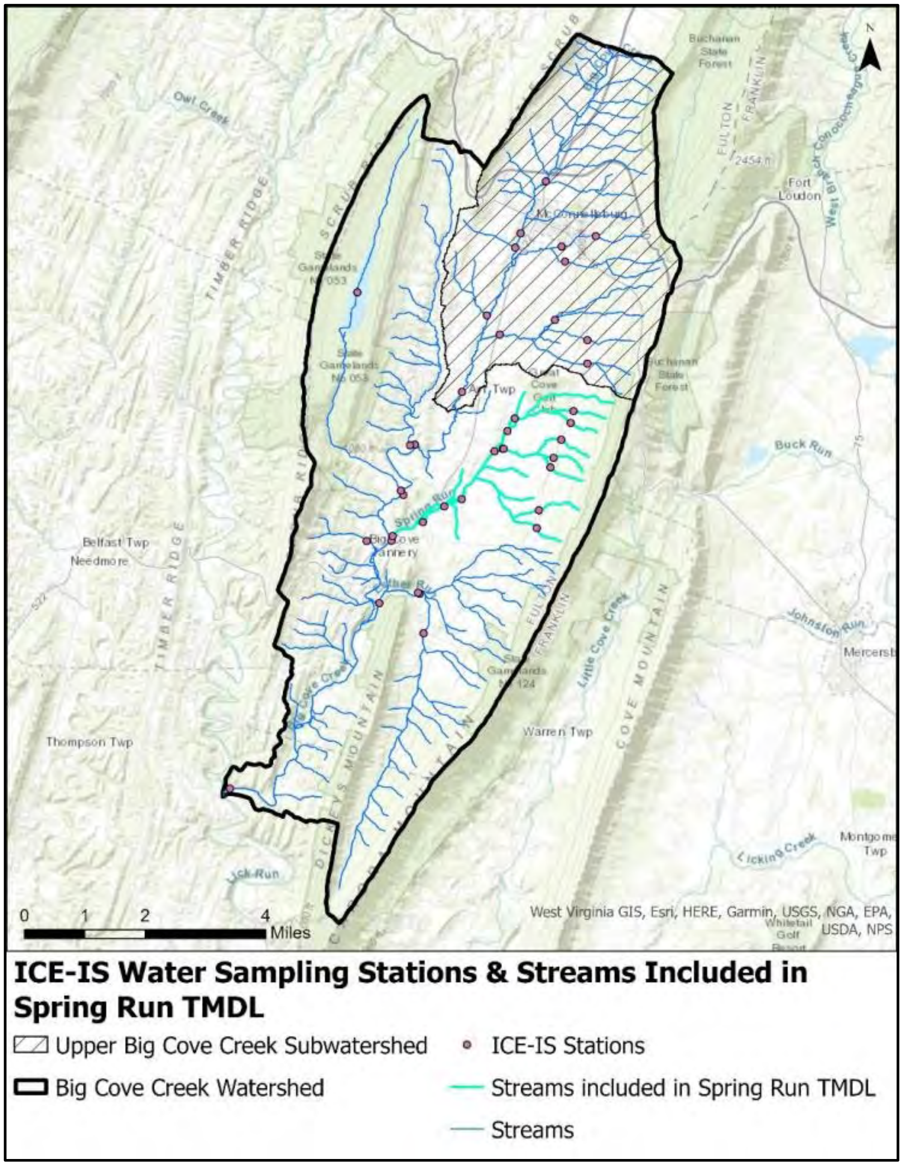

Figure 17. ICE-IS water sampling stations and streams included in Spring Run TMDL in the Big Cove Creek watershed

WATER RESOURCE FACILITIES

A Water Resource Facility is a primary facility type of PA DEP related to the Water Use Planning Program. These facilities are categorized by use (e.g., agricultural, commercial, industrial, sewage treatment) and by subtype (e.g., discharge, interconnection, surface water withdrawal, groundwater withdrawal). There are 10 active Water Resource facilities in the Big Cove Creek watershed, illustrated in Figure 18 and summarized by use and subtype in Table 15. Five of these facilities are within the subwatershed. Note that a number of the points representing individual facilities overlap one another in the spatial dataset, which is why there are only five visible points in Figure 18; however, there is no overlap of facilities across different use categories.

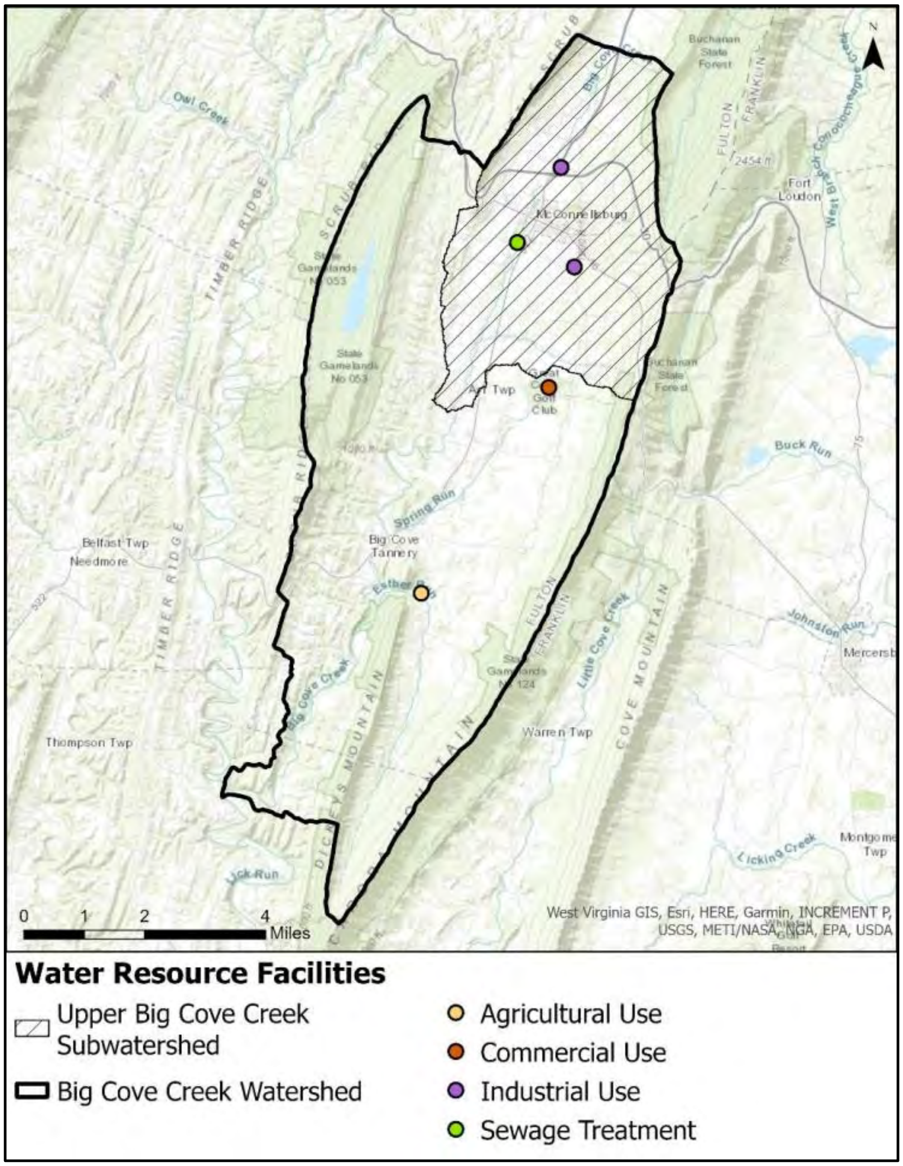

Figure 18. Water resource facilities in the Big Cove Creek watershed

Table 15. Water Resource Facilities by use and subtype in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Facility Subtype[1]	Count	
	Big Cove Creek Watershed	Upper Big Cove Creek Subwatershed
Agricultural Use		
Groundwater Withdrawal	1	0
Total Agricultural	1	0
Commercial Use		
Discharge	1	0
Groundwater Withdrawal	3	0
Total Commercial	4	0
Industrial Use		
Discharge	1	1
Interconnection	1	1
Groundwater Withdrawal	2	2
Total Industrial	4	4

Table 15. Water Resource Facilities by use and subtype in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed		
Facility Subtype[1]	**Count**	
	Big Cove Creek Watershed	**Upper Big Cove Creek Subwatershed**
Sewage Treatment Use		
Discharge	1	1
Total Sewage Treatment	1	1
Total of All Uses/Subtypes	10	5
[1] Definitions of the facility subtypes can be found at: https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=289		

Habitat & Water Quality Monitoring

There is no recent or consistent habitat or water quality monitoring data available within the Big Cove Creek watershed.

Section 4. Possible Pollutant Sources

Pollutant sources are summarized using data on biosolid sites, Captive Hazardous Waste Operations, and data from the PA DEP permitted facility report that provides information on facilities with National Pollutant Discharge Elimination System (NPDES) permits, and other permits related to water quality. Under the Clean Water Act, the NPDES permit program was created to regulate point sources that discharge pollutants to waters of the U.S. In general terms, an NPDES permit is a license for a facility to discharge a specified amount of a pollutant into a receiving waterbody under defined conditions.

NPDES Permits

At the time of this report's preparation, there are five active NPDES permits in the subwatershed, one of which has a Significant/Category I Noncompliance. The locations of these permitted facilities are listed in Table 16 and illustrated in Figure 19.

Table 16. NPDES permits in the Upper Big Cove watershed

Facility Name – Facility ID(s)	Link to Facility Report	Applicable Statute(s)*	Compliance Status	Potential Contribution to Sediment Loading (lbs/yr)
Glazier Pit[1] – PAM415001	https://echo.epa.gov/detailed-facility-report?fid=110070201711	CWA	No Violation Identified	N/A
JLG Industries[2] – PAC290008, PAP120508, PAR113514	https://echo.epa.gov/detailed-facility-report?fid=110055113461	CAA, CWA, and RCRA	No Violation Identified	N/A
JLG Industries-Success Drive[2] – PAP220508	https://echo.epa.gov/detailed-facility-report?fid=110070105438	CWA	N/A	N/A
McConnellsburg STP[3] – PA0020508	https://echo.epa.gov/detailed-facility-report?fid=110010978638	CWA	No Violation Identified	5,769

Table 16. NPDES permits in the Upper Big Cove watershed

Facility Name – Facility ID(s)	Link to Facility Report	Applicable Statute(s)*	Compliance Status	Potential Contribution to Sediment Loading (lbs/yr)
P&W Legion[4] – PAM416008	https://echo.epa.gov/detailed-facility-report?fid=110070054420	CWA	Significant/ Category I Noncompliance	N/A

* Clean Water Act (CWA), Clean Air Act (CAA), Resource Conservation and Recovery Act (RCRA)
[1] Glazier Pit: Small noncoal mining permit. Facility has no outfall (Michael Schirato, PA DEP, personal communication with Michael Morris, PA DEP).
[2] JLG Industries, Inc.: Industrial stormwater permits without loading limits or electronic discharge monitoring report (eDMR) reporting requirements.
[3] McConnellsburg Sewage Treatment Plant (STP). The potential sediment load was based on PA DEP's analysis of electronic discharge monitoring report (eDMR) data. There were eight years (2013-2021, excluding 2015) where total suspended solids (TSS) loads, in lbs/d, were reported as monthly averages. The value for each month was multiplied by the number of days in each month and all the months within the year were summed to produce an annual value. The value reported above is the average of the eight annual values.
[4] P&W Excavating, Inc. Large noncoal mining operation with one permitted stormwater outfall. This outfall only discharges during precipitation events and does not have a TSS limit (Michael Schirato, PA DEP, personal communication with Michael Morris, PA DEP).

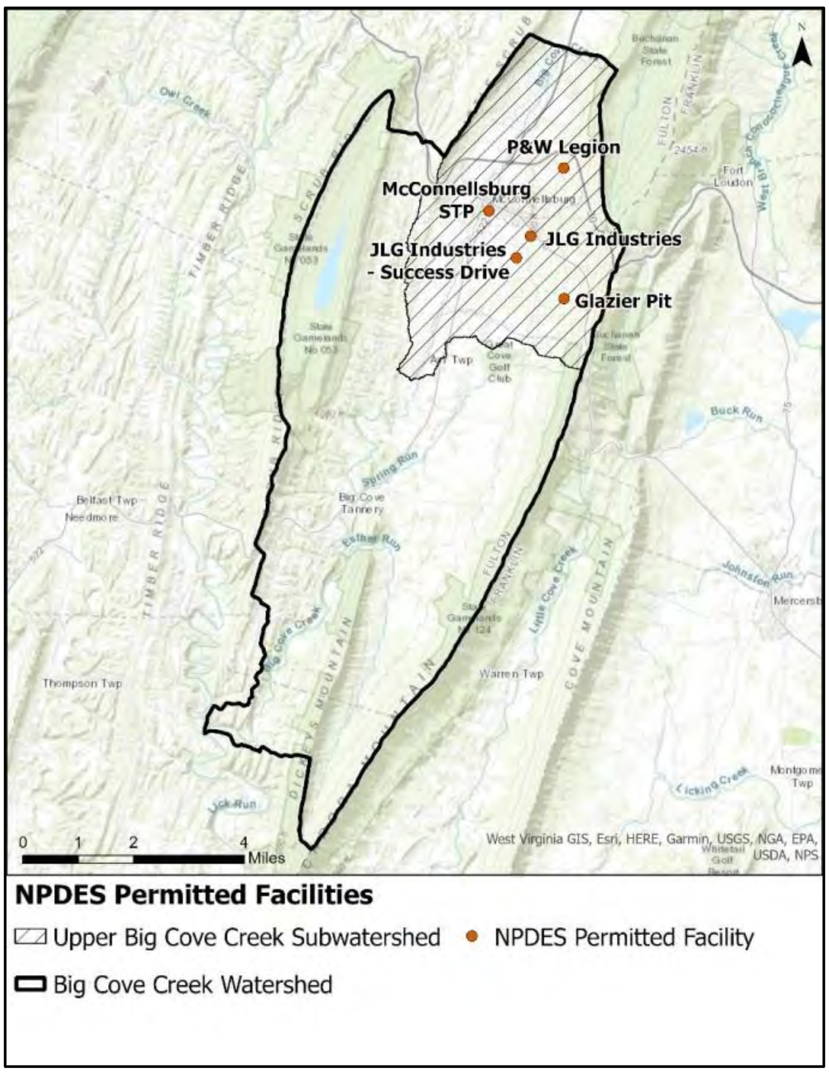

Figure 19. NPDES permits in the Upper Big Cove Creek subwatershed

Biosolids

Biosolids refer to nutrient-rich organic material resulting from the solids produced during the wastewater treatment process and solids and liquids from residential septic tanks, holding tanks, and other treatment units. Once treatment is conducted, the biosolid product has beneficial uses when applied to mine reclamation sites or areas for forestry, gardening and landscaping, and agriculture. The PA DEP regulates biosolids under the Pennsylvania permit PAG-08. There are 11 biosolid sites in the Big Cove Creek watershed that apply fertilizer on agricultural lands, six that are active, three that are inactive, and two that were proposed but never materialized (Figure 20). Two of these active sites and one inactive site are within the subwatershed.

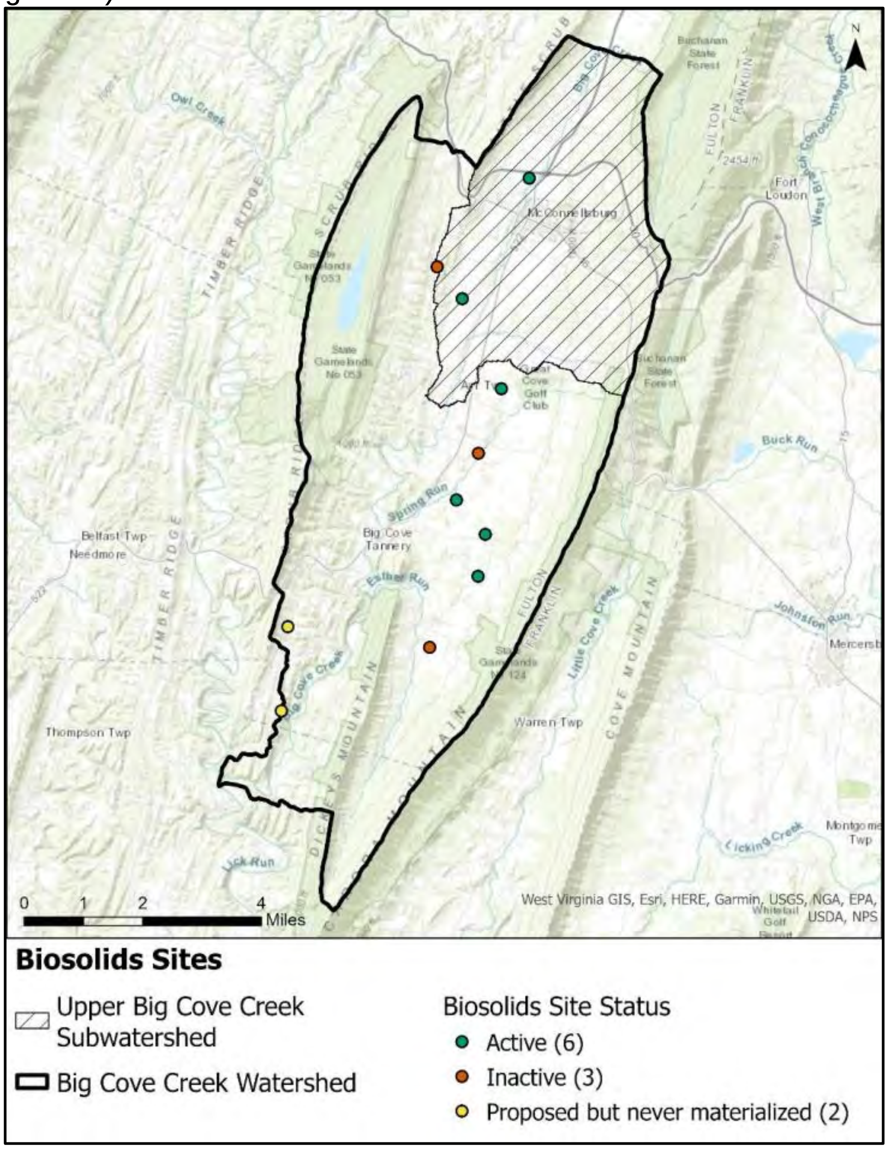

Figure 20. Biosolids sites in the Upper Big Cove Creek subwatershed and Big Cove Creek watershed

Captive Hazardous Waste Operation

A Captive Hazardous Waste Operation is a primary type of PA DEP facility related to the Waste Management Hazardous Waste Program. These operations are categorized as either boilers/industrial furnaces, disposal facilities, hazardous generators, incinerators, or facilities for recycling, storage, or treatment (PA DEP, 2022). There are five active and compliant Captive Hazardous Waste Operations within the subwatershed (Figure 21).

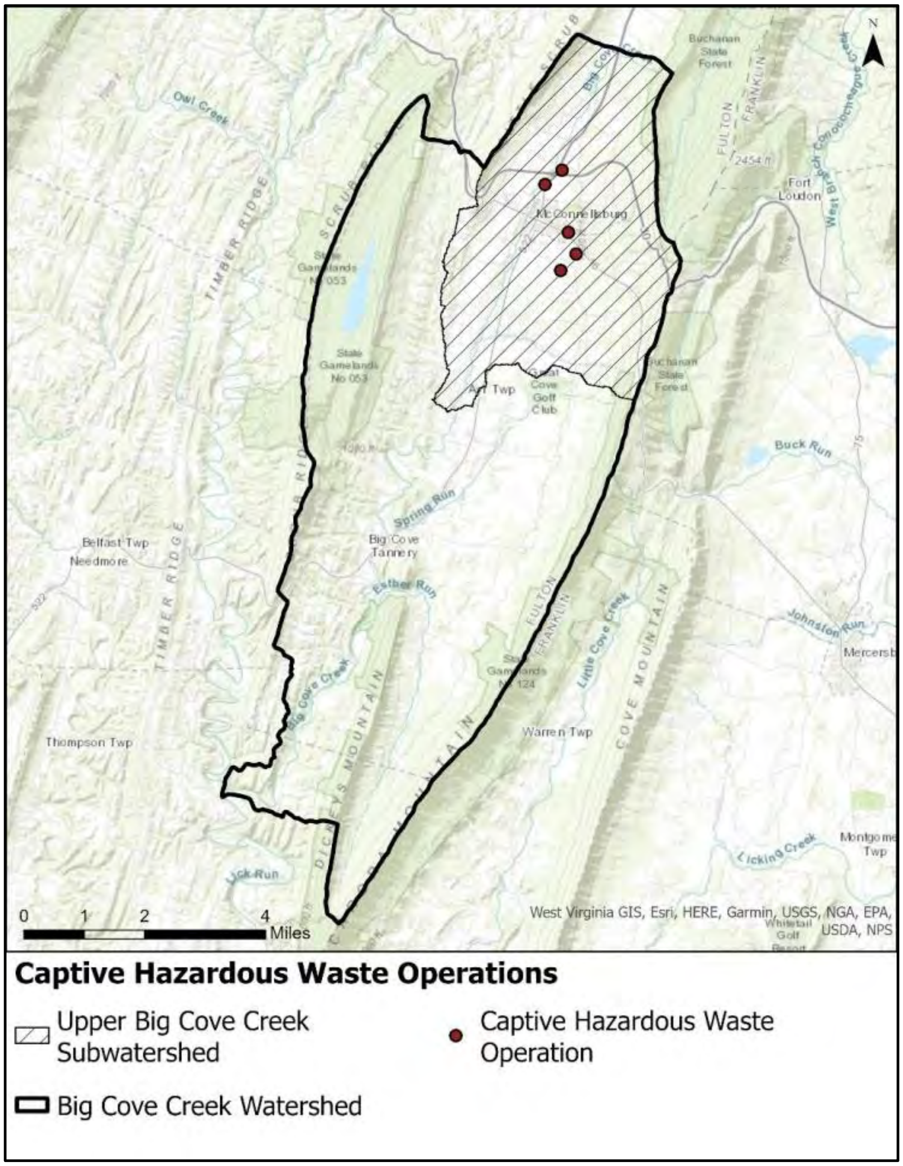

Figure 21. Captive Hazardous Waste Operations in the Big Cove Creek watershed

Livestock Agriculture

Agriculture is a prominent land use in the Big Cove Creek watershed. Livestock agriculture operations can be point sources of pollution since waste is typically collected at a point like a manure lagoon or tank. There are approximately 7,760 animals used for agriculture in the Big Cove Creek watershed, 2,513 of which are in the subwatershed (32.4%). Counts by livestock type in the Big Cove Creek watershed and the subwatershed were obtained from Model My Watershed and are summarized in Table 17.

Table 17. Counts of livestock in the Big Cove Creek watershed and Upper Big Cove Creek subwatershed (Stroud Water Research Center, 2022)

Livestock Type	Count of Animals (#)	
	Big Cove Creek Watershed	Upper Big Cove Creek Subwatershed
Chickens, Broilers	915	400
Cows, Beef	435	127
Cows, Dairy	742	228

Table 17. Counts of livestock in the Big Cove Creek watershed and Upper Big Cove Creek subwatershed (Stroud Water Research Center, 2022)		
Livestock Type	**Count of Animals (#)**	
	Big Cove Creek Watershed	**Upper Big Cove Creek Subwatershed**
Horses	101	29
Pigs/Hogs/Swine	4,595	1,347
Sheep	319	93
Turkeys	653	289
Total	**7,760**	**2,513**

Encroachment Locations

Encroachment locations are a primary facility type of PA DEP related to the Water Resources Management Obstructions Program. There are 36 encroachment locations within the Big Cove Creek watershed, all of which are active and compliant, and 19 of which are within the subwatershed (Figure 22). There are several sub-facility types of encroachment locations, counts of which are included in Table 18.

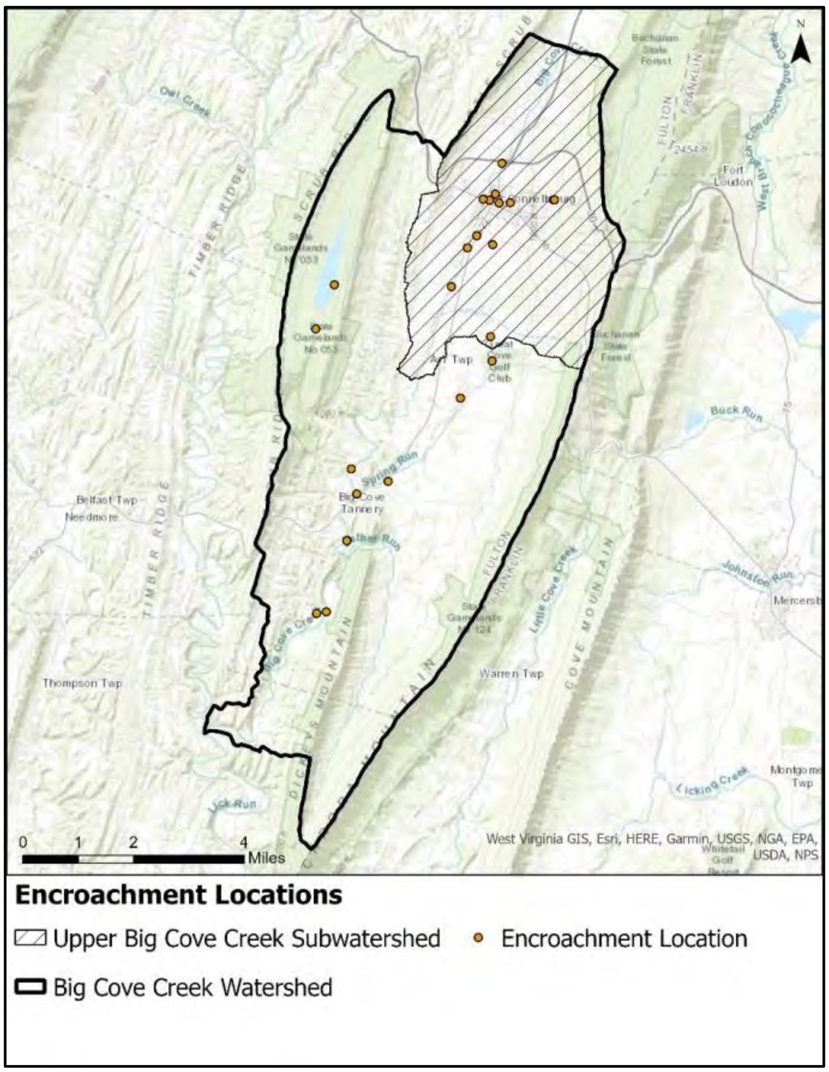

Figure 22. Encroachment locations within the Big Cove Creek watershed

Table 18. Encroachment facilities, by sub-facility type, in the Big Cove Creek watershed and Upper Big Cove Creek subwatershed		
Encroachment Location Type	**Count**	
	Big Cove Creek Watershed	**Upper Big Cove Creek Subwatershed**
Bridge	9	1
Pipeline or Conduit	7	5
Culvert	5	5
Floodway Direct Impact	2	0
Outfall Structure	2	1
Stream Restoration	2	2
Wetland Impact	2	2
Dock	1	0
Floodway Activity	1	1
Other Activities	1	1
Stream Direct Impact	1	0
Stream Enhancement	1	1
Temporary Floodway Impact	1	0
Wetland Direct Impact	1	0
Total	**36**	**19**

Section 5. Field Assessments and Findings

Field assessments were conducted by both Ecosystem Planning & Restoration (EPR) and the Center for Watershed Protection, Inc (CWP) during the summer of 2023. CWP conducted field assessments on August 15th – 16th, 2023, to identify stormwater retrofit opportunities within the subwatershed. The field assessments included identification of stormwater retrofit projects at more than 35 sites to address pollutant reduction and runoff retention opportunities in a variety of settings including neighborhoods, commercial areas, and institutional/municipal operations.

The stream assessments conducted by EPR included a desktop and field assessments. The desktop assessment involved evaluation of 50,534 linear feet of stream across 38 distinct reaches, distributed between two primary watersheds: Kendall Run and Big Cove. Kendall Run encompassed 11 reaches amounting to 15,716 linear feet, while Big Cove, along with its unnamed tributaries, included 27 reaches totaling 34,818 linear feet. EPR field analysis consisted of a modified version of the Function-based Rapid Stream Assessment methodology (FBRSA) (USFWS - Starr et al, 2015) of the same 38 reaches identified in the desktop analysis. Critical functions on two levels of the stream functions pyramid were assessed including Hydraulics and Geomorphology.

This section provides an overview of the field methods for each assessment, field results, and recommendations.

Stormwater Retrofit Reconnaissance Inventory (RRI)

Stormwater retrofits are structural stormwater management practices that can be used to address existing stormwater management problems within a watershed. These practices are installed in upland areas to capture and treat stormwater runoff before it is delivered to the storm drainage system, and ultimately, the streams. They are an essential element of a holistic watershed restoration program because they can help improve water quality, increase groundwater recharge, provide channel protection, and control overbank flooding. Without using stormwater retrofits to address existing problems and to help establish a stable, predictable hydrologic regime by regulating the volume, duration, frequency, and rate of stormwater runoff, the success of many other watershed restoration strategies—such as stream stabilization and aquatic habitat enhancement—will be threatened. In addition to the stormwater management benefits they offer, stormwater retrofits can be used as demonstration projects, forming visual centerpieces that can be used to help educate residents and build additional interest in watershed restoration.

Potential stormwater retrofit opportunities at several candidate project sites in the study watershed were assessed during the retrofit inventory using the methods described in Schueler et al. (2007). A Retrofit Reconnaissance Inventory (RRI) field form was used to evaluate retrofit opportunities at candidate sites. Appendix A includes an example RRI field form that was completed during field work. The RRI forms were incorporated into an ArcGIS Field Maps App for mobile data collection. Field teams used a tablet to complete the retrofit site form and took pictures of the conceptual sketches, so they were associated with the data collection point in the mobile application. Field crews look specifically at drainage patterns, the amount of impervious cover, available space, and other site constraints when developing concepts for a site. Candidate retrofit sites identified for the assessment generally were located on municipal or institutional sites with large areas of impervious cover and could serve as a demonstration project.

Desktop Assessment

In preparation for the field assessment, the Center first conducted a desktop analysis using a combination of data provided by PASDA and aerial imagery from Esri and Google Earth. The goal was to identify potential locations to visit in the subwatershed since data for existing stormwater BMP locations was not available. The aerial imagery and the subwatershed boundary delineated by DEP were used to identify municipal and institutional areas in the Borough of McConnellsburg and Ayr and Todd Townships. Table 19 and Figure 23 shows the sites visited for potential retrofit opportunities.

Table 19. Sites visited for potential stormwater retrofit opportunities

Site ID	Location	Site ID	Location
1	Ayr Township Municipal Building	19	Fulton County Offices
2	Mountain View Christian School	20	Public Parking
3	State Police Barracks	21	Fulton County Prothonotary’s Office
4	Fulton County Food Basket	22	Fulton County Commissioners Offices
5	McConnellsburg High School/Middle School	23	Fulton County Child Services
6	Fulton County Center for Families Childcare	24	Bible Baptist Church
7	Old McConnellsburg High School	25	American Legion Post 561
8	My Father’s House Ministries International	26	Mountain View Mennonite Church
9	McConnellsburg Volunteer Fire Company	27	Fulton County Medical Center/ Hospital
10	St. Stephen Catholic Church	28	Calvary Independent Baptist Church
11	Fulton County Fairgrounds	29	All Things Automotive
12	Fulton House Parklet	30	Fulton County Maintenance Office
13	Water Treatment Plant	31	Hope Christian Academy
14	United Methodist Church	32	Fulton County Library
15	Lions Community Park	33	Fulton Precision Industries
16	United Methodist Church	34	Waring Products
17	United Methodist Church	35	Giant
18	District Justices Office	101	844 Lincoln Way E (Estate Drive)

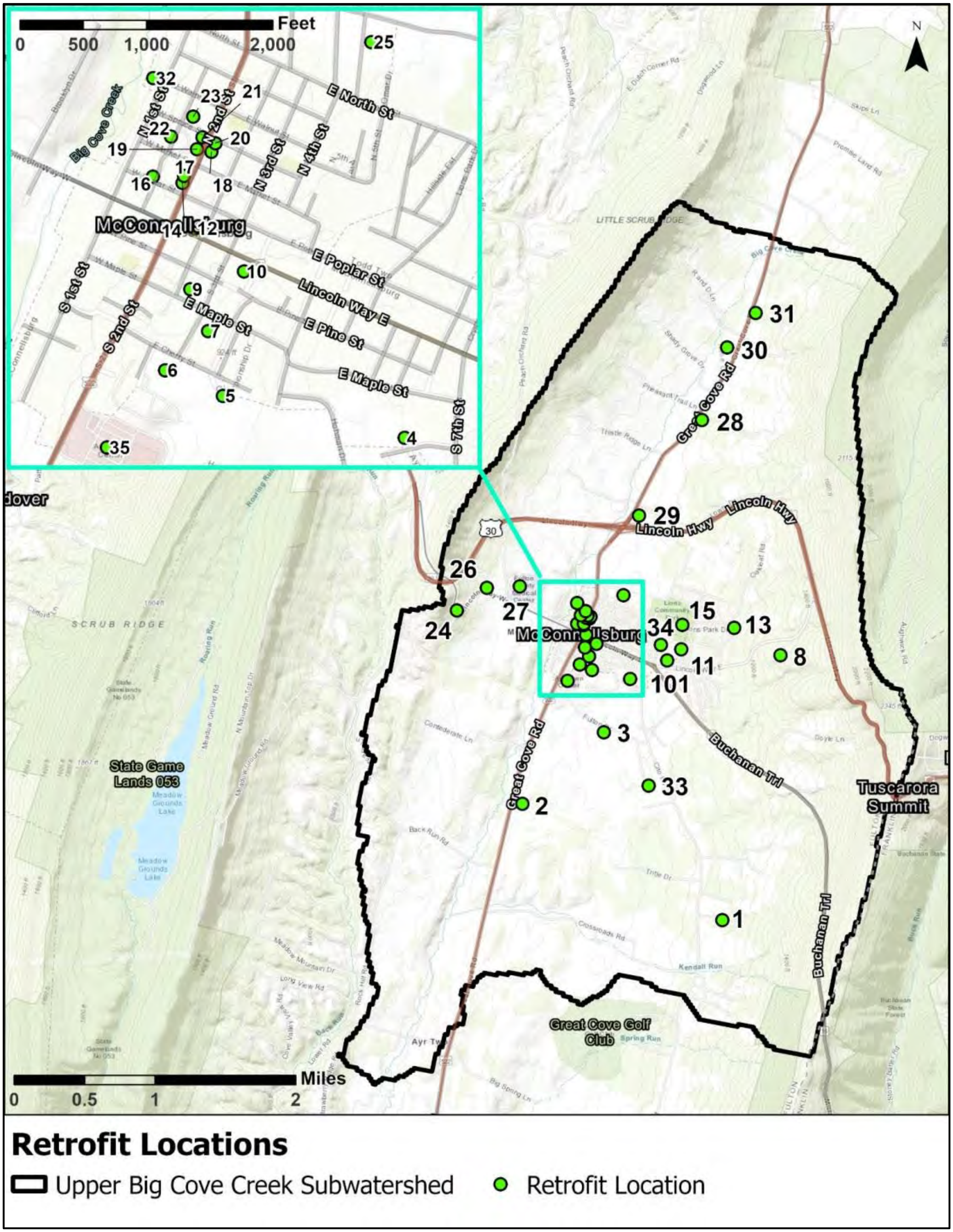

Figure 23. Potential stormwater retrofit sites visited during field assessment

Field Assessment

Thirty-five sites were identified through the desktop analysis. However, during our site visit one additional site (101) was identified for a total of 36 sites. After visiting all 36 potential retrofit locations identified in Figure 23, only 14 of these locations were deemed suitable for retrofits. The remaining 22 sites were not suitable for a retrofit project due to topography, land use, space constraints, or other reasons that would make constructing a stormwater retrofit inherently difficult or expensive.

The majority of retrofit opportunities proposed are bioretention practices. Additional opportunities identified include one bioswale, additional plantings in an existing detention practice, and one site for slope stabilization. Two of the locations identified modifications to exiting site conditions or practices that would provide additional pollutant removal. Approximately 0.27% (29.5 acres) of the subwatershed would be treated if all retrofit opportunities were implemented and about 2% of the impervious cover would be treated.

Table 20 provides a summary of identified retrofits that includes the estimated pounds of phosphorus, nitrogen, and TSS the retrofits would remove each year, a planning level cost estimate to design and build the retrofit and maintain it for 1 year, and the cost effectiveness for all retrofits identified. Appendix B includes pictures of the proposed retrofit locations.

Prioritized Ranking of Recommended Actions

Table 20 lists each proposed practice and the ranking they received based on various criteria, such as pollutant removal, cost, cost effectiveness, maintenance cost, and land ownership. The factors in the rating are based on typical factors found in stormwater grants. This allows the strongest projects to be proposed for grant funding, while still prioritizing the goals of the regional Countywide Action Plan (CAP) plan. The ranking also seeks to balance the primary focus of the plan (sediment load reduction) with other factors such as cost for implementation and maintenance burden to provide a suggested schedule for project implementation. It is assumed that the County will prefer to implement projects on publicly held land before moving on to projects that would require private landowner consent.

<u>Cost of the practice</u>

The cost for each practice was calculated based on estimates in the CAST Cost Profiles for the State of Pennsylvania (Appendix F). Projects that cost less than $25,000 received a 10, projects that cost between $25,000 to $60,000 received a 5, and projects that cost over $60,000 received a 1.

<u>Total Suspended Solids (TSS) Removal</u>

The TSS Removal was rated based on how much suspended sediment would be removed each year by this project. Projects above 0.75 tons/yr received a 10, projects between 0.75 to 0.1 tons/yr received a 5, and projects under 0.1 tons/yr received a 1.

<u>Total Phosphorus (TP) Removal</u>

The TP Removal was rated based on how much total phosphorus would be removed each year by this project. Projects above 0.50 lbs/yr received a 10, projects between 0.50 to 0.10 lbs/yr received a 5, and projects under 0.10 lbs/yr received a 1.

<u>Cost Effectiveness for Total Suspended Solids (TSS) Removal</u>

Rankings are based on the calculated removal efficiencies for sediment and the costs of each practice. Projects with a cost effectiveness of less than $30,000/tons/yr received a 10, projects with a cost effectiveness between $30,000/tons/yr to $80,000/tons/yr received a 5, and projects with a cost effectiveness over $80,000/tons/yr received a 1.

<u>Cost Effectiveness for Total Phosphorus (TP) Removal</u>

Rankings are based on the calculated nutrient removal efficiencies for phosphorus and the costs of each practice. Projects with a cost effectiveness of $40,000/lbs/yr received a 10, projects with a cost effectiveness between $40,000/lbs/yr to $140,000/lbs/yr received a 5, and projects with a cost effectiveness over $140,000/lbs/yr received a 1.

Property Ownership

Publicly owned land is scored higher than privately owned land as the County can install projects easier on land where it has ownership. Practices on privately held land are given a score of 1; and practices on publicly owned land are given a score of 10.

Maintenance Cost

When dealing with rain events, there is rarely any solution that does not involve maintenance. The maintenance needs are based on the cost per year for each practice. Projects that cost less than $300 received a 10, projects that cost between $300 to $1,000 received a 5, and projects that cost over $1,000 received a 1.

Table 20. Stormwater retrofits identified in the Upper Big Cove Creek subwatershed

Location Name	Retrofit ID	BMP Type	Drainage Area (acres)	% IC	% Water Quality Volume	Total TSS Removal (tons/yr)	Total Phosphorus Removal (lbs/yr)	Total Nitrogen Removal (lbs/yr)	Cost $ (Design, Construct) **	Cost Effectiveness ($/ton TSS Removed)	Cost Effectiveness ($/lb TP Removed)	Maintenance Cost Per Year***	Public Land
Fulton County Food Basket	4A	Bioretention/raingardens, A/B soils, underdrain	0.45	88%	40%	0.19	0.12	0.61	$16,272.66	$37,081.12	$56,419.73	$316.79	No
McConnellsburg Middle School	5A	Bioretention/raingardens, A/B soils, underdrain	1.03	83%	59%	0.42	0.29	1.40	$42,997.61	$56,544.07	$83,087.59	$1,067.84	Yes
McConnellsburg High School	5B	Bioretention/raingardens, A/B soils, underdrain	1.09	89%	52%	0.45	0.30	1.48	$40,875.46	$49,827.02	$74,128.97	$1,008.20	Yes
McConnellsburg High School	7A	Bioretention/raingardens, A/B soils, underdrain	0.44	80%	30%	0.18	0.12	0.60	$13,222.53	$28,550.44	$42,089.10	$231.08	Yes
Fulton County Fairgrounds	11A	Bioswale	11.84	16%	48%	1.29	0.89	5.14	$164,148.81	$77,106.98	$112,013.52	$6,964.50	No
United Methodist Church	14A	Bioretention/raingardens, A/B soils, underdrain	0.55	31%	42%	0.15	0.12	0.70	$19,553.63	$60,640.10	$78,753.38	$409.00	No
Fulton County Child Services	23A	Bioretention/raingardens, A/B soils, underdrain	0.26	97%	83%	0.11	0.07	0.35	$18,487.94	$76,636.01	$116,839.38	$379.05	Yes
American Legion Post	25A	Bioretention/raingardens, A/B soils, underdrain	2.19	88%	88%	0.90	0.61	2.97	$126,493.77	$84,370.68	$124,947.32	$3,414.32	No
Mountain View Mennonite Church	26A	Bioretention/raingardens, A/B soils, underdrain	0.27	93%	28%	0.11	0.07	0.37	$9,720.00	$26,818.20	$39,372.73	$132.65	No
Fulton County Medical Center/ Hospital	27A	Slope stabilization/ Conversion to Natural Cover/Tree Planting*	2.63	17%	0%	0.20	0.00	0.00	$3,213.94	$11,478.37	N/A	$52.58	Yes
All Things Automotive	29A	Bioretention/raingardens, A/B soils, underdrain	1.44	77%	77%	0.40	0.30	1.82	$75,147.44	$109,605.37	$144,980.65	$1,971.34	No
Fulton County Library	32A	Bioretention/raingardens, C/D soils, underdrain	0.37	92%	60%	0.10	0.06	0.18	$22,937.75	$112,110.97	$181,983.55	$399.96	Yes
Waring Products	34A	Bioswale and Impervious Cover Removal	3.19	69%	8%	0.88	0.67	4.04	$12,312.94	$5,193.85	$6,828.41	$320.02	No
844 Lincoln Way E (Estate Drive)	101A	Dry Extended detention basin	3.75	57%	191%	0.77	0.21	1.36	$31,109.68	$21,192.93	$77,713.75	$287.56	No
		TOTAL	**29.5**	**N/A**	**N/A**	**6.2**	**3.8**	**21.0**	**$596,494.16**	**N/A**	**N/A**	**$16,954.89**	**N/A**

* While slope stabilization is proposed, Model My Watershed does not include this practice. The Filter Strip – Stormwater Treatment practice was used since it was determined this was the closest practice to slope stabilization.

**The construction estimates are based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania, and the percent of water quality volume per BMP, the costs have been increased by 30% to account for the recent inflation. The cost also includes design cost which is based on engineering guideline of about 30% of the construction cost and an additional $5,000 for survey and geotechnical report. These do not include the permit fee cost

***The maintenance estimates are based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania, and the percent of water quality volume per BMP.

Table 21. Priority ranking of stormwater retrofits in the Upper Big Cove Creek subwatershed												
Location Name	**Retrofit ID**	**BMP Type**	**Cost Ranking**	**Cost Effectiveness Ranking TSS**	**Cost Effectiveness Ranking TP**	**TSS Removal Ranking**	**TP Ranking**	**Public Land**	**Maintenance Ranking**	**Total Points**	**Ranking**
Waring Products	34A	Bioswale/Impervious Surface Reduction	10	10	10	10	10	1	5	56	1
McConnellsburg High School/Middle School	7A	Bioretention/raingardens - A/B soils, underdrain	10	10	5	5	5	10	10	55	2
Mountain View Mennonite Church	26A	Bioretention/raingardens - A/B soils, underdrain	10	10	10	5	1	1	10	48	3
844 Lincoln Way E (Estate Drive)	101A	Dry Extended Detention Pond	5	10	5	10	5	1	10	46	4
Fulton County Medical Center/ Hospital	27A	Filter Strip	10	10	0	5	1	10	10	46	5
Fulton County Child Services	23A	Bioretention/raingardens - A/B soils, underdrain	10	5	5	5	1	10	5	41	6
McConnellsburg High School/Middle School	5A	Bioretention/raingardens - A/B soils, underdrain	5	5	5	5	5	10	1	36	7
McConnellsburg High School/Middle School	5B	Bioretention/raingardens - A/B soils, underdrain	5	5	5	5	5	10	1	36	8
Fulton County Food Basket	4A	Bioretention/raingardens - A/B soils, underdrain	10	5	5	5	5	1	5	36	9
United Methodist Church	14A	Bioretention/raingardens - A/B soils, underdrain	10	5	5	5	5	1	5	36	10
Fulton County Fairgrounds	11A	Bioswale	1	5	5	10	10	1	1	33	11
Fulton County Library	32A	Bioretention/raingardens - C/D soils, underdrain	10	1	1	5	1	10	5	33	12
American Legion Post 561	25A	Bioretention/raingardens - A/B soils, underdrain	1	1	5	10	10	1	1	29	13
All Things Automotive	29A	Bioretention/raingardens - A/B soils, underdrain	1	1	1	5	5	1	1	15	14

Stream Assessments

A standardized stream assessment process was used to evaluate existing stream conditions and restoration potential of a diverse selection of stream sites in the subwatershed located in Fulton County, PA.

Desktop Assessment

Potential stream restoration opportunities were first assessed using a desktop process. This approach used relevant data on key environmental parameters such as stream lengths, soils, sinuosity, vegetative cover, slope, and various forms of land use/land cover types. The selection of these specific parameters was driven by their potential impact on stream stability and watershed hydrology. Stream reaches/segments defined by GIS hydrology lines were segmented in the main stem for analysis based on 2,000 linear feet of stream length unless intersected by a confluence of a tributary. Next, tributaries were segmented based on 1,000 linear feet of stream length unless intersected by a confluence of a lesser tributary. The following categories were taken into equally weighted consideration to develop condition scores: sinuosity, riparian vegetation, agriculture encroachment, development encroachment, road presence, and soil erodibility. Each category was scored with ratings of 1 – 3, except for Sinuosity (ratings of only 0 or 1), with three (3) being the category for instability, and one (1) being the most stable. Refer to Appendix C for EPR's full stream assessment report for more information.

The scores for each reach were summed to yield the overall stream segment condition score. The worst overall score possible is theoretically a 16, but no reach scored worse than a rating of 14. Given this distribution, scores were then sorted into three equal sub-ranges for stream stability: 6 – 8 is good condition, 9 – 11 is fair condition, and 12 – 14 is poor condition.

The desktop assessment results for the subwatershed show 13 reaches (34%) were classified as Good with a combined length of 14,831 linear feet. Fifteen reaches (40%) were marked as Fair, covering another 14,831 linear feet, and ten reaches (26%) fell into the Poor category, spanning 15,660 linear feet.

Breaking down the results further for Upper Big Cove main stem and its tributaries, 30% of the stream reaches (8) and 25% of the stream length (8,831 LF) were rated as Good. In contrast, 41% of the reaches (11) and stream length (14,327 LF) were deemed Fair, and 30% (8) of the reaches along with 33% of the stream length (11,660 LF) were categorized as Poor.

For Kendall Run and its tributaries, the evaluation showed that 45% of the stream reaches (5) and 38% of the stream length (6,000 LF) were considered Good. Meanwhile, 36% of both the reaches (8) and stream length (5716 LF) were rated as Fair, and 18% of the reaches (2) with 25% of the stream length (4000 LF) were classified as Poor.

Refer to Appendix C for locations of each delineated reach and Appendix A that contained the report entitled "Big Cove Existing Stream Condition Ratings Map."

Field Assessment

A total of thirty-eight (38) representative sites in the subwatershed were selected, in coordination with the FCCD. Representative field sites were chosen for field assessment verification based on equal representation of existing stream segment conditions, varied locations within the watershed, and stream segment access. At these sites, EPR conducted a modified Functional-Based Rapid Stream Assessment (FBRSA) to evaluate critical functions on two levels of the stream functions pyramid. This assessment allowed for the analysis of the current field conditions and the potential changes in defined stream functions, aiding in the selection of priority sites.

The following assessment parameters, by function pyramid level, were evaluated:

- Level 2 - Hydraulics – floodplain connectivity, floodplain drainage, and vertical stability extent.
- Level 3 - Geomorphology – lateral stability, riparian vegetation, and bedform diversity.

The FBRSA used the assessment ratings of Functioning, Functioning-at-Risk, and Not-Functioning to parallel the overall rating conditions of good, fair, and poor.

Among the Big Cove and its tributaries field sites, one (1) site was dry, and two (2) sites were not channels and, therefore, not rated. Of the remaining sites, four (4) were rated as being in "Good condition," sixteen (16) were rated as being in "Fair condition," and four (4) segments were rated as being in "Poor condition."

For Kendall Run and its tributaries, the assessment rated three (3) sites as being in "Good condition" and eight (8) sites as being in "Fair condition." No segments were rated as being in "Poor condition."

Good Sites:
A "good" site is characterized by optimal performance in Level 2 (Hydraulics) and Level 3 (Geomorphology) of the Stream Functions Pyramid. Hydraulics at this level involves effective transport of water and sediment, assessed through floodplain connectivity, drainage complexity, and vertical stability. Key metrics include a low Bank Height Ratio (BHR), indicating frequent floodplain access, a high Entrenchment Ratio (ER), signifying extensive floodplain availability, and stable vertical conditions with minimal aggradation or degradation. In geomorphology, good sites exhibit diverse riparian vegetation over 100 feet wide, minimal bank erosion, and high-quality fish habitats with substantial stable substrate.

Fair Sites:
"Fair" sites demonstrate moderate performance in both Hydraulics and Geomorphology. These sites have a BHR that allows occasional floodplain access and an ER that provides limited floodplain availability. Vertical stability shows potential for localized aggradation or degradation. Geomorphologically, fair sites have riparian vegetation between 25 – 100 feet wide, a moderate rate of bank erosion (less than 50%), and in-stream habitats with 20% – 70% stable substrate. These conditions indicate a moderate connection and dynamic equilibrium yet show signs of disturbance or limited diversity.

Poor Sites:
"Poor" sites perform inadequately across the assessed criteria. Hydraulically, they exhibit high BHR, hindering floodplain access, and low ER, indicating minimal floodplain availability. Vertical stability in these sites shows high potential for widespread aggradation or degradation. In terms of geomorphology, poor sites have riparian vegetation less than 25 feet wide, often dominated by invasive species or significantly impacted by human activity. Over 50% of the banks in these sites are actively eroding, and fish habitats contain less than 20% stable substrate, leading to poor in-stream conditions and habitat quality.

Appendix C includes an example FBRSA Data Sheet that was completed during field work. Detailed desktop and field assessment results are presented in Table 22 and a map is provided in Figure 24.

Table 22. Desktop and field stream assessment summary scores

Label	STREAM LENGTH (FT)	Field Score	Desktop Score	Vegetation		Floodplain Connectivity		Lateral Stability		Bedform Diversity	
				Field	Desktop	Field	Desktop	Field	Desktop	Field	Desktop
BC-RUT1-2	766	Fair	Poor	3	3	2	3	2	3	3	2
BC-RUT1-1	573	Fair	Fair	2	3	2	2	2	2	3	2
BC-23	540	Poor	Good	3	3	3	3	2	2	2	2
BC-7	291	Fair	Good	1	1	2	2	2	1	2	2
BC-3	1950	Fair	Poor	3	3	2	2	2	2	3	2
BC-1	2000	Good	Good	1	1	1	1	1	1	2	2
BC-29	2000	Fair	Good	2	1	3	2	3	2	2	1
BC-14	253	Fair	Fair	2	3	2	3	2	2	2	2
BC-8	1024	Fair	Fair	2	1	1	3	2	2	2	3
BC-25	2000	Fair	Fair	2	3	3	2	2	2	2	2
BC-28	2000	Fair	Fair	2	3	1	2	2	2	1	2
BC-19	944	Fair	Poor	2	3	1	3	2	2	2	2
BC-26	1024	Poor	Fair	3	3	2	2	2	2	2	2
BC-LUT7-9	1000	Fair	Good	2	1	1	3	2	2	3	2
BC-RUT9-LUT1-1	1000	DRY	Good	N/A	2	N/A	2	N/A	2	N/A	2
BC-LUT4-4	1000	Good	Good	1	1	1	1	1	1	2	2
BC-RUT4-2	1000	Good	Good	1	1	1	1	1	1	2	2
BC-RUT9-4	1000	Good	Fair	2	3	1	3	1	2	2	2
BC-LUT8-8	1000	NOT A CHANNEL	Fair	N/A	3	N/A	2	N/A	3	N/A	2
BC-LUT5-8	1000	Poor	Poor	3	3	3	3	3	3	2	2
KR-3	2000	Fair	Good	3	1	3	3	2	1	2	2
KR-10	716	Fair	Fair	3	3	2	2	2	2	2	2
KR-4	2000	Fair	Fair	3	3	2	2	2	2	2	2
KR-5	2000	Good	Fair	2	3	1	2	2	2	2	2
KR-8	2000	Fair	Poor	3	3	2	3	2	2	3	2
KR-9	2000	Fair	Poor	3	3	2	3	2	2	2	2
KR-RUT1-2	1000	Fair	Good	2	1	2	2	2	1	2	2

Table 22. Desktop and field stream assessment summary scores

Label	STREAM LENGTH (FT)	Field Score	Desktop Score	Vegetation		Floodplain Connectivity		Lateral Stability		Bedform Diversity	
				Field	Desktop	Field	Desktop	Field	Desktop	Field	Desktop
BC-RUT1-2	766	Fair	Poor	3	3	2	3	2	3	3	2
BC-RUT1-1	573	Fair	Fair	2	3	2	2	2	2	3	2
KR-RUT1-7	1000	Good	Good	2	1	2	3	1	1	2	2
KR-RUT1-LUT1-6	1000	Fair	Good	2	1	2	3	2	1	2	2
KR-RUT1-LUT2-7	1000	Good	Good	2	1	1	3	1	1	2	1
KR-RUT1-LUT3-2	1000	Fair	Fair	2	3	1	2	1	2	2	2
BC-32	2000	Fair	Poor	3	3	2	2	2	2	2	2
BC-34	2000	Fair	Fair	3	3	2	3	2	2	2	2
BC-12	2000	Fair	Fair	2	3	2	3	2	2	2	2
BC-15	1453	Fair	Fair	2	3	2	3	2	2	2	2
BC-36	2000	Fair	Poor	3	3	2	3	2	2	2	2
BC-LUT10-4	1000	NOT A CHANNEL	Poor	N/A	3	N/A	3	N/A	3	N/A	3
BC-37	2000	Poor	Poor	3	3	3	2	2	3	2	2

Figure 24. Map of existing stream condition ratings from Appendix B to EPR's Upper Big Cove Creek Alternative Restoration Plan Stream Assessment Report (Appendix C)

PROPOSED RESTORATION DESIGN APPROACH

Proposed stream restoration recommendations are based on the Natural Channel Design (NCD) Priority 2 and 3 restoration approaches (Rosgen, 2006). The NCD Priority 1 design approach was considered during the initial assessment phase. However, this restoration approach involves reconnecting the stream to its original floodplain by raising the stream bed elevation which creates an increase in the100-year flood elevation. The increase in the 100-year flood elevation infringes upon private property and infrastructure, which is unacceptable. Therefore, the NCD Priority 1 restoration approach was not recommended to be used for any of the proposed restoration sites. The NCD Priority 2 and 3 restoration approaches call for different levels of effort in adjusting channel and floodplain conditions to provide ecological uplift, while meeting design objectives.

A Priority Level 2 restoration creates a new stable channel that is connected to the floodplain, but the floodplain is excavated at the existing bankfull elevation, i.e., the bed elevation of the stream remains nearly the same. The formerly channelized and incised stream is re-meandered through the excavated floodplain. This approach is typically used if there is not a knickpoint or other abrupt change in grade upstream of the project, in larger streams, or in cases where flooding cannot be increased on adjacent property. A plan view and cross section example of priority level 2 restoration is shown in Figure 25.

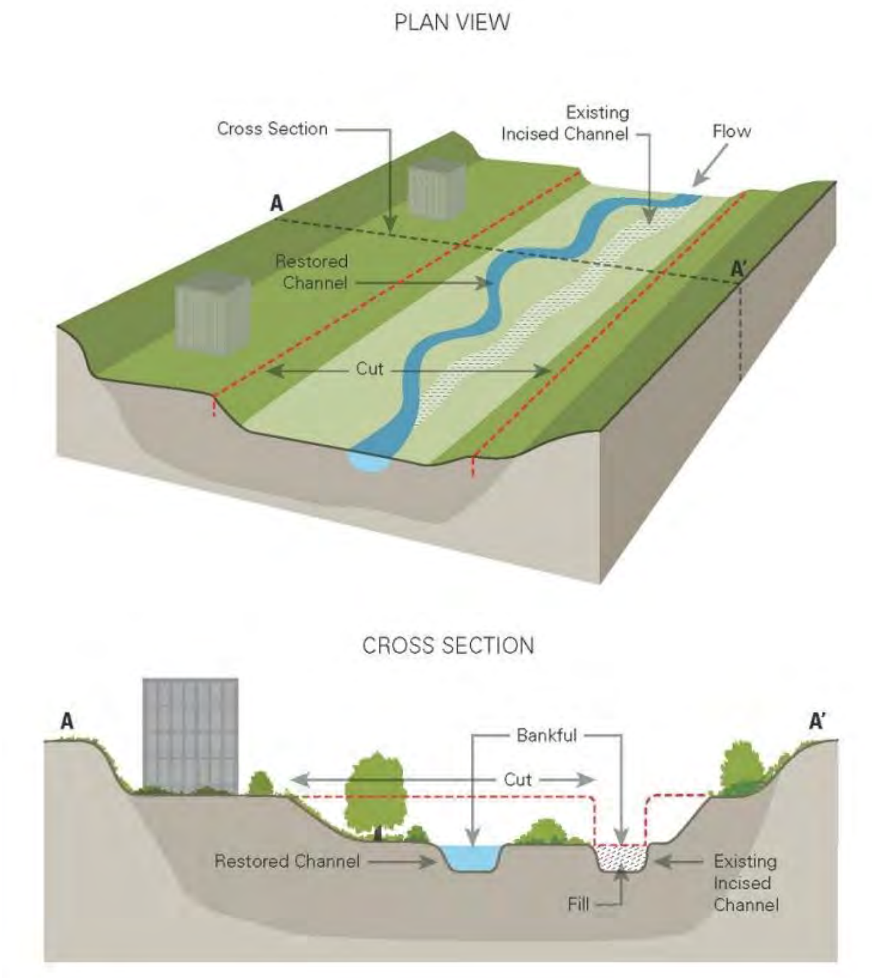

Figure 25. Plan view and cross section for priority level 2 restoration

NCD Priority Level 3 restoration also creates a new stable channel that is connected to the existing bankfull elevation, i.e., the bed elevation of the stream remains nearly the same. However, the newly excavated floodplain is much narrower than a floodplain associated with a Priority Level 2 and is commonly referred to as a floodplain bench. This approach is typically used if the floodplain has been encroached upon by development and there is limited space for a floodplain area. A plan view and cross section example of Priority Level 3 Restoration is shown in Figure 26 –.

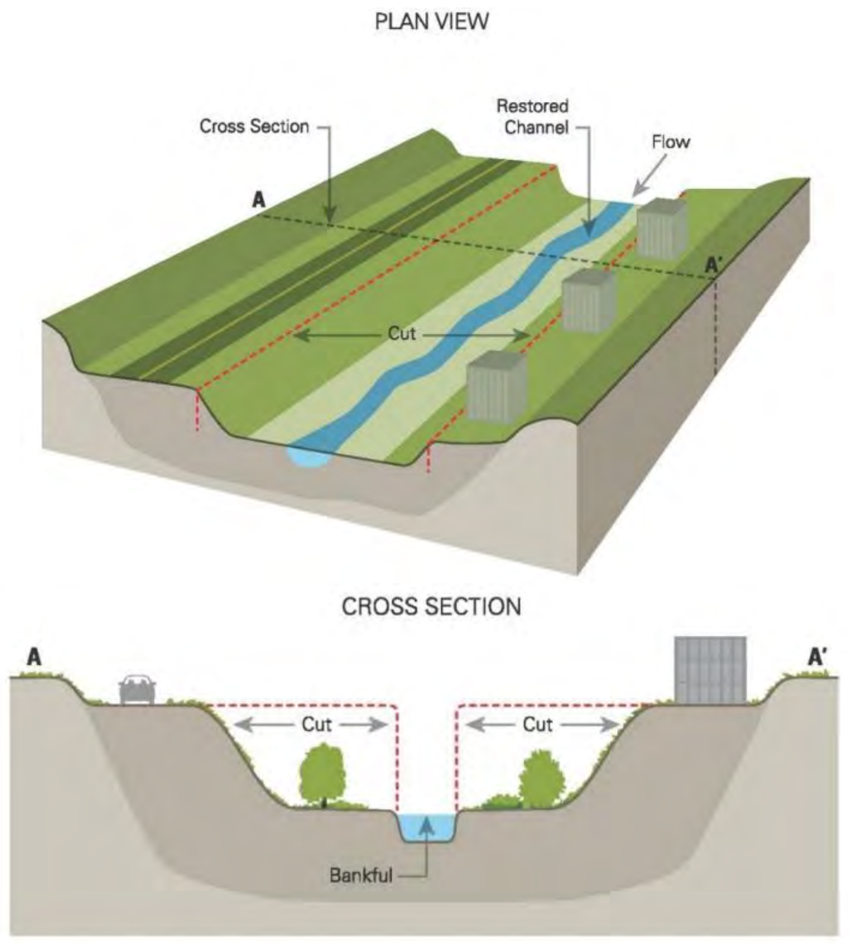

Figure 26. Plan view and cross section for priority level 3 restoration

Prioritized Ranking of Recommended Actions

The process of identifying potential stream restoration sites was driven by a comprehensive set of criteria designed to balance ecological objectives with logistical feasibility. A critical factor was the willingness of property owners to participate in the projects, which is essential for accessing the streams and ensuring their long-term upkeep and success. The majority of streams chosen for restoration were between 1,000 to 4,000 feet in length—manageable sizes that still allow for significant ecological impact. In addition, site ownership is included in the criteria for site prioritization, favoring publicly accessible or pre-approved sites, construction feasibility, and input from local government stakeholders. This approach ensures that selected sites are technically and financially viable, leading to measurable improvements and higher implementation success rates.

Additional key factors include cost-efficiency and potential for significant load reductions, along with minimizing impacts on adjacent utilities and natural resources. Stream restoration project costs are influenced by various factors, including existing stream conditions such as channel stability, sediment load, and vegetation cover, which determine the necessary interventions. Projects in unstable or degraded streams require more intensive and costly efforts like channel reshaping and bank stabilization. Restoration objectives—ranging from water quality improvement to flood risk management—influence the project's scope and cost. Natural channel design approaches, which aim to mimic natural fluvial processes, add complexity and cost due to detailed geomorphological assessments and design solutions. Typically, costs for assessment, design, permitting, and construction range from $45 to $65 per linear foot for planning and $400 to $600 per linear foot for construction, including activities like in-channel adjustments, bank grading, and bioengineering techniques. A cost estimate of $665 per linear foot is recommended for budgeting purposes, acknowledging that actual costs vary based on project-specific conditions and requirements. This represents a top end cost for project implementation tasks associated with legacy sediment removal and accounts for potential changes in project cost. These approximate costs are specifically associated with Legacy Sediment Removal style projects that involve reconnecting the stream to the floodplain by removing significant amounts of accumulated sediments from the floodplain. The selection of each design approach and the amount of floodplain connection achieved through restoration efforts will influence pollutant load reduction calculations for each individual project.

Table 23 lists each proposed restoration site and the planning level cost estimate. A map of the potential stream restoration locations is provided in Figure 27, which is extracted from Appendix B to EPR's Upper Big Cove Creek Alternative Restoration Plan Stream Assessment Report (provided as Appendix C to this report).

Table 23. Proposed Project Area Prioritization

Proposed Project Area	Project Area Priority	Project Reach Length (LF)	Sediment Reduction (tons/yr)	Planning Level Cost	Proposed NCD Stream Restoration Recommendations
1	Medium	2,551	146.68	$1,696,478	Priority 3
2	Medium	1,779	102.29	$1,183,105	Main Stem- Priority 2 Tributary- Priority 3
3	Low	2,357	135.53	$1,567,425	Priority 2
4	Medium	4,014	230.81	$2,669,068	Priority 2
5	High	2,898	166.64	$1,927,071	Priority 2
6	High	1,468	84.41	$976,050	Priority 3
7a	Medium	2,250	129.38	$1,496,555	Priority 2
7b		3,668	210.91	$2,439,138	Priority 2
8	High	2,821	162.21	$1,876,049	Priority 2
9	Medium	956	54.97	$635,794	Priority 3
10	Medium	1,423	81.82	$946,405	Priority 3
11	Medium	2,202	126.62	$1,464,645	Priority 2
12	High	978	56.24	$650,498	Priority 3
13	High	1,320	75.90	$878,091	Priority 3
14	Medium	2,043	117.47	$1,358,265	Priority 3
15	Low	1,571	90.33	$1,044,849	Priority 3
16	High	12,411	713.63	$8,253,485	Priority 2
17	High	2,422	139.27	$1,610,350	Priority 2

Figure 27. Map of potential stream restoration projects from Appendix B to EPR's Upper Big Cove Creek Alternative Restoration Plan Stream Assessment Report (Appendix C)

SECTION 6. POLLUTANT LOADING

Reference Watershed

The PA DEP TMDL section graciously assisted in development of this plan and calculated an estimate of the sediment reductions needed to achieve water quality standards and address stream impairments. The full document created by the DEP can be accessed in Appendix E. Prescribed reductions were made for the subwatershed using a Reference Watershed Approach. Because Pennsylvania does not have numeric water quality criteria for sediment, the "Reference Watershed Approach" method is used to estimate pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. The loading rate in the unimpaired watershed is then scaled to the area of the impaired watershed to calculate necessary load reductions. The assumption is that reducing loading rates in the impaired watershed to the levels found in the reference watershed will result in progress toward eliminating siltation impairments.

To find a reference, DEP used GIS data layers largely consistent with the stream impairments noted in Pennsylvania's Integrated Report (DEP 2022b) to search for nearby watersheds that were similar to the Big Cove Creek subwatershed but lacked stream segments listed as impaired for Aquatic Life Use. Factors such as landscape position, topography, hydrology, soil drainage types, and land cover were used to screen for comparable watersheds. Benthic macroinvertebrate and physical habitat assessment scores were also reviewed to confirm that a reference was acceptable, and preliminary modelling was conducted to make sure that use of a particular reference would result in reasonable pollution reductions. Special emphasis was given to searching for watersheds within the Appalachian Mountain section of the Ridge and Valley Physiographic Province just like the Big Cove Creek watershed. The two reference watersheds selected were Cove Creek in Bedford County and Wooden Bridge Creek in Fulton County (Figure 28). Both subwatersheds lacked stream segments listed as Aquatic Life Use impaired per the 2022 Integrated Report (DEP 2022b), despite having substantial, though lesser agricultural land cover versus the Big Cove Creek subwatershed (Table 24). There

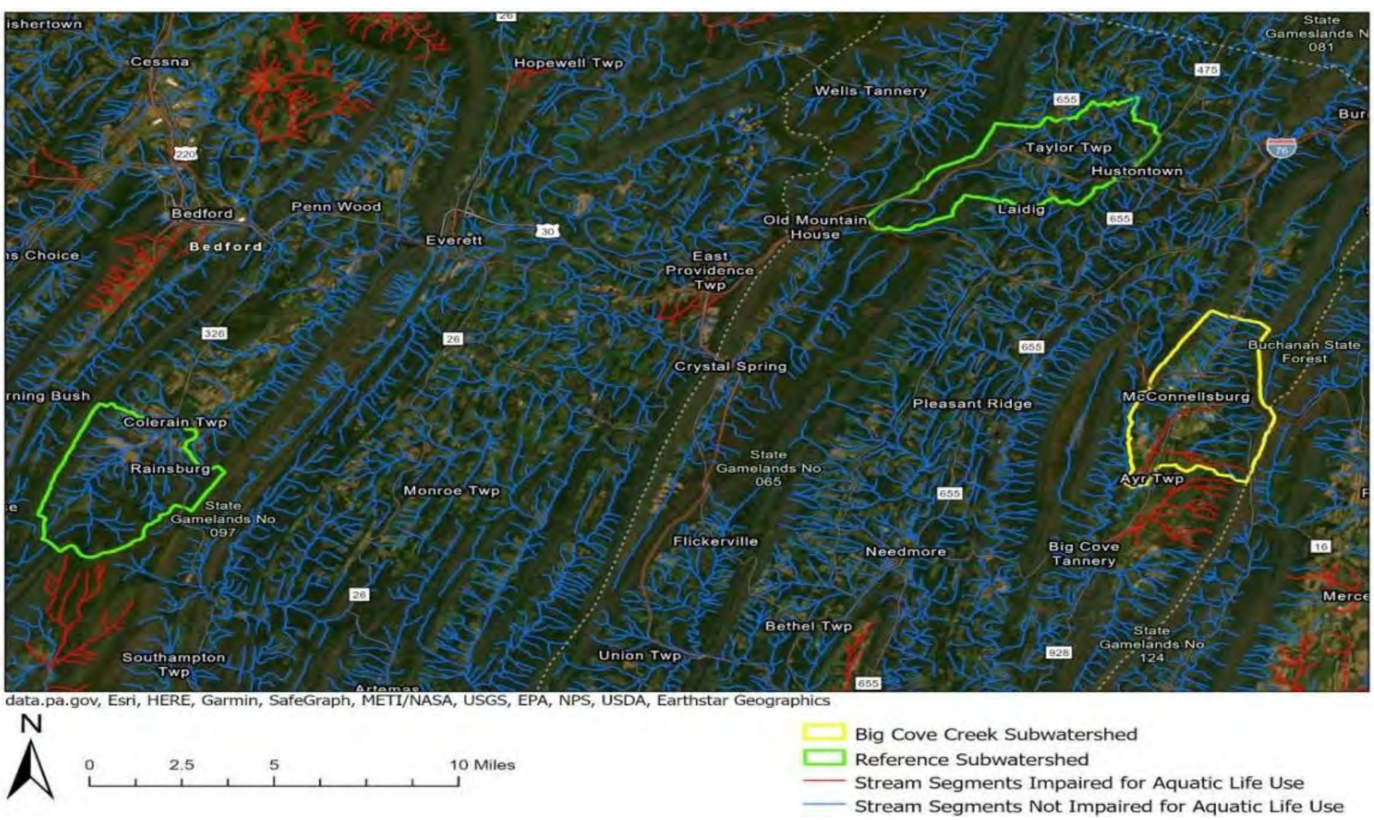

Figure 28. Big Cove Creek watershed and location of reference watersheds

was also significant development in the reference subwatersheds, though again, the amount was less relative to the Big Cove Creek subwatershed (Table 24).

Table 24. Big Cove Creek and potential reference subwatersheds comparison

Watershed	**Big Cove Creek**	**Cove Creek**	**Wooden Bridge Creek**
Physiographic Province[1]	Appalachian Mountain Section of the Ridge and Valley Physiographic Province		
Land Area (ac)	10,712	10,388	10,544
Landuse[2] (%)			
Agriculture	40	31	27
Forest/Natural Vegetation	46	64	64
Developed	14	5	8
Soil Infiltration[3] (%)			
A	9	13	15
B	49	42	34
B/D	1	3	4
C	27	30	12
C/D	0	6	<1
D	13	6	36
Dominant Bedrock[4] (%)			
Argillaceous Sandstone	-	-	10
Dolomite	33	4	-
Limestone	25	23	-
Quartzite	4	0	-
Sandstone	8	33	90
Shale	27	39	-
Siltstone	2	-	-
Average Precipitation[5] (in/yr)	40.4	42.5	40.4
Average Surface Runoff[5] (in/yr)	2.8	1.5	2.2
Average Elevation[5] (ft)	1,132	1,712	1,267
Average Slope[5] (%)	12	15	13
Average Stream Channel Slope[5] (%)			
1st order	7.3	5.1	4.2
2nd order	2.7	1.5	2.8
3rd order	0.8	0.3	0.6
4th order	0.3		0.4

1. Per pags_physsections2008 GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
2. Based on MMW output utilizing NLCD 2019
3. Based on MMW output utilizing USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils.
4. Per Bedrock_V GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources.
5. Hydrologic and terrain variables were generated by MMW

When comparing the Big Cove watershed to the reference watersheds several differences were noted including a greater amount of naturally vegetated lands, primarily forests, in both reference watersheds (Table 4). All three watersheds exhibited similar distributions of soil drainage classes with weighting towards moderate infiltration soils, though the Wooden Bridge Creek subwatershed had more very slow infiltration soils Estimated surface runoff rates were highest in the Big Cove Creek subwatershed, at least in part due to its greater urbanized area. The average slope in all three watersheds was approximately the same (12-15%) and the slope of the highest order stream segments among the subwatersheds was similarly low (0.3 to 0.4%) Finally, NPDES permitted point sources appeared to be either negligible or nonexistent in the potential references similar to the situation in the Big Cove watershed.

One major distinguishing factor among the subwatersheds was bedrock geology. The Big Cove and Cove Creek subwatersheds both had substantial karst (limestone and dolomite) formations, though the amount was greater in the Big Cove Creek subwatershed. In contrast, the Wooden Bridge Creek subwatershed was dominated by sandstone and lacked karst geology. Karst geology has such a strong influence on a watershed's hydrogeologic characteristics, use of a karst reference is ideal but finding large, low-gradient karst references in Pennsylvania is often problematic because Aquatic Life Use impairments typify such areas, as karst geology produces some of the state's best agricultural soils.

Whereas stream segments within the Big Cove Creek subwatershed were designated Cold Water Fishes at 25 Pa. Code § 93, stream segments were designated High Quality – Cold Water Fishes within the Wooden Bridge Creek subwatershed and Exceptional Value within the Cove Creek subwatershed. Using a special protection watershed as a reference for a non-special protection watershed is concerning in that overly stringent prescribed pollution reductions may result. However, this concern was dismissed because, as will be explained later, assessment data and site observations suggested that neither one of these potential reference watersheds appeared to be atypically healthy.

The limited assessment data available indicates that the Big Cove Creek subwatershed appears to have a severe siltation problem within the lower watershed (south of McConnellsburg) which has resulted in the Aquatic Life Impairments (Figure 10). The sediment deposition plus embeddedness couplet score at the site sampled within this area was only a 13 out of 40 possible points, which scores below the impairment threshold (≤24) (Walters 2017). Benthic macroinvertebrates were not sampled in this area. The lower mainstem of the largest tributary in the lower watershed also exhibited heavy siltation, with a sediment deposition plus embeddedness couplet score of only 6. Not surprisingly, the benthic macroinvertebrate community was impaired at this site. In contrast, sediment deposition plus embeddedness couplet scores did not indicate impairment further upstream, though the macroinvertebrate community was determined to be impaired at one other site.

PA DEP Prescribed Overall Sediment Reductions Needed

The existing annual average sediment loading in the subwatershed was estimated to be 7,066,754 pounds per year (3,533 tons per year). To meet water quality objectives, it was determined that annual average sediment loading should be reduced by 60% to 2,814,779 pounds per year (1,407 tons per year). Allocation of annual average sediment loading among the restoration plan variables is summarized in Table 25. All values are annual averages in lbs/yr.

Table 25. Summary of variables for the Upper Big Cove Creek subwatershed

Subwatershed	AL (lbs/yr)	UF (lbs/yr)	SL (lbs/yr)	LNR	ASL
Upper Big Cove	2,814,779	281,478	2,533,301	18,817	2,514,484

AL=Allowable Load
UF = Uncertainty Factor
SL = Source Load; the SL is further divided into LNR = Loads Not Reduced and ASL= Adjusted Source Load

DEP Calculation of Allowable Loading

The estimated mean annual sediment loading rates were 308 lbs/(ac*yr) and 218 lbs/(ac*yr) in the Cove and Wooden Bridge Creek reference subwatersheds, respectively (Table 26). These were substantially lower than the estimated mean annual loading rate in the Big Cove Creek subwatershed 660 lbs/(ac*yr). As mentioned previously, the Cove Creek subwatershed appears to be the best match for the Big Cove Creek subwatershed based on physical characteristics, but there was concern over its lack of assessment data and possible impairment. And, while the Wooden Bridge Creek subwatershed has been assessed much more rigorously and has been found to be supporting its Aquatic Life Use, there was concern over its dissimilar topography and geology, and whether its use would result in prescribed reductions that were too stringent. Thus, for the sake of defining the acceptable loading rate, it was decided to use the average loading rate of these two reference subwatersheds, or 263 lbs/(ac*yr). Thus, to achieve the average loading rate of the unimpaired subwatersheds, sediment loading in the Big Cove Creek subwatershed should be reduced by 60% to 2,814,779 lbs/yr (Table 27).

Table 26. Existing annual average loading values for the Big Cove Creek and potential reference subwatersheds

	Big Cove Creek			**Cove Creek**			**Wooden Bridge Creek**		
Land Cover	*acres*	*Sediment (lbs/yr)*	*Sediment (lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment (lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment (lbs/(ac*yr)*
Hay/Pasture	2,160	1,218,897	564	1,146	174,835	153	2,096	763,970	364
Cropland	2,089	4,189,991	2,006	2,101	2,211,747	1,053	798	825,175	1,035
Forest	4,928	11,412	2	6,590	9,974	2	6,731	7,277	1
Wetland	15	21	1	0	2	0	5	13	3
Open Land	22	1,601	72	37	3,064	83	37	3,211	87
Bare Rock	10	14	1	25	76	3	22	18	1
Low Density Mix Dev	1,086	13,784	13	457	5,254	12	649	7,873	12
Med Density Mix Dev	272	17,597	65	17	1,420	82	151	10,001	66
High Density Mix Dev	119	7,697	65	5	335	68	49	3,236	66
Stream Bank		1,599,972			788,168			941,804	
Riparian Buffer Discount					0			-263,410	
Point Sources		5,769			0			375	
Totals	10,701	7,066,754	660	10,378	3,194,876	308	10,538	2,299,544	218

Table 27. Annual average allowable loading in the Big Cove Creek subwatershed.

Subwatershed	**Ref. Loading Rate** (lbs/(ac*yr))	**Land Area**(ac)	**Target AL** (lbs/yr)
Big Cove Creek	263	10,701	2,814,779

The reference loading rate was derived from the average of the Cove Creek and Wooden Bridge Creek reference subwatersheds.

Calculation of the Uncertainty Factor and Source Load

In the ARP equation, the Allowable Load (AL) is comprised of the Source Load (SL), which accounts for all significant natural and anthropogenic sources of the pollutant, plus an Uncertainty Factor (UF). Thus:

AL = SL + UF

Reserving a portion of the load as a UF requires further load reductions from targeted sectors to achieve the AL. For this analysis, the UF was explicitly designated as ten-percent of the AL based on professional judgment. Thus:

2,814,779 lbs/yr AL * 0.1 = 281,478 lbs/yr UF Then, the SL is calculated as:
2,814,779 lbs/yr AL – 281,478 lbs/yr UF = 2,533,301 lbs/yr SL

Calculation of the Adjusted Source Load

In the ARP equation the SL is further divided into the Adjusted Source Load (ASL), which is comprised of the sources causing the impairment and targeted for reduction, as well as the loads not reduced (LNR), which is comprised of the natural and anthropogenic sources that are not considered responsible for the impairment nor targeted for reduction. Thus:

SL =ASL + LNR

Therefore, before calculating the allowable loading from the targeted sectors, the LNR must also be defined.

Since the impairments addressed by this WIP were for sedimentation due to agriculture, but development is also suspected to be of concern (Table 25), croplands, hay/pasture lands, developed lands, and streambanks will be considered the targeted sectors. Therefore, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands, bare rock, and point sources within the Big Cove Creek subwatershed were considered LNR. LNR was calculated to be 18,817 lbs/yr (Table 28).

Table 28. Source load loads not reduced and adjusted source loads. All values were expressed as annual average lbs/yr.

	Big Cove Creek
Source Load (SL)	2,533,301
Loads Not Reduced (LNR)	
Forest	11,412
Wetland	21
Open Land	1,601
Bare Rock	14
Point Sources	5,769
Total LNR	18,817
Adjusted Source Load (ASL)	2,514,484

Then, the ASL is calculated as:
2,533,301 lbs/yr SL – 18,817 lbs/yr LNR = 2,514,484 lbs/yr ASL

Calculation of Sediment Load Reductions by Source Sector

To calculate prescribed load reductions by source, the ASLs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although the Upper Big Cove Creek subwatershed WIP was developed to address impairments caused by agriculture and development, streambanks were also significant contributors to the sediment load, and bank erosion rates are influenced by agriculture and development. Thus, streambanks were included in the ASLs and targeted for reduction.

In the Big Cove Creek subwatershed, croplands exceeded the ASL by itself. Thus, croplands received a greater percent reduction (72%) than hay/pasture lands, streambanks, or developed lands (53% each) (Table 29). Note however, the prescribed reductions by source sector are simply suggested targets and not rigid goals that must be met. During implementation, greater or lesser reductions can be made for each source sector, so long as the overall ASL is achieved.

Table 29. Annual average sediment load allocations for source sectors in the Big Cove Creek subwatershed.

Source	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal %
Cropland	1,176,866	4,189,991	72%
Hay/Pasture Land	570,486	1,218,897	53%
Streambank	748,843	1,599,972	53%
Developed Lands	18,290	39,077	53%
Sum	*2,514,484*	*7,047,937*	*64%*

Pollutant Modeling and Cost Estimates

Model My Watershed (MMW) was used to estimate the total phosphorus (TP), total nitrogen (TN), and total sediment loads for the subwatershed. MMW is a model developed by Stroud Water Research Center to analyze nationally available landscape, climate and other datasets and model stormwater runoff and water quality impacts (Stroud Water Research Center, 2017). MMW estimates loads for three different conditions, representing three different points in time:

- *Baseline* represents loads exported by MMW, without BMPs entered into the model. In this watershed plan, there are currently no TMDL loading baselines.
- *Existing* reflects loads with BMPs implemented prior to 2023.
- *Future* represents conditions with all of the BMPs implemented in the Existing condition, in addition to BMPs that were or identified as a part of this project.

Pollutant modeling was done using the Model My Watershed BMP spreadsheet tool.[3] The information required to characterize the watershed (land cover breakdown, count of animals, and stream length) and associated pollutant load estimates was generated using the online version of the model. That data was input into the spreadsheet tool to develop the pollutant removal estimates for stormwater retrofits and agricultural practices. The data tables can be found in Appendix D.

Cost estimates for stormwater retrofits and agricultural practices were developed using the construction estimates based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania. CAST bases the implementation cost and maintenance cost using the drainage area treated by the BMP practice. Stormwater retrofit estimates capped the drainage area treated at the 1-inch storm for water quality to ensure the cost

[3] https://github.com/WikiWatershed/MMW-BMP-spreadsheet-tool

estimates were more accurate to the size of the BMP practice. The implementation cost also includes design cost which is based on an engineering guideline of about 30% of the construction cost and an additional $5,000 for survey and geotechnical report. These costs do not include the permit fee cost. Please note these are planning-level costs, and more in depth and site specifics cost estimates should be developed if/when these projects are designed and constructed.

Model Input Data

Drainage Area Boundaries

The MMW model platform requires a drainage area boundary or point of interest from which to delineate the watershed. This boundary is then used to summarize both land cover (using data from the 2019 National Land Cover Classification Dataset, NLCD) and hydrologic soils group (HSG; from the SSURGO database) present in the watershed. For this plan, the watershed delineation was provided by PA DEP using MMW (DEP, 2023 draft).

Urban BMP Data

Existing Conditions

Existing urban stormwater BMP data was not available from local sources and was created using anecdotal information and field observations. The difficulty in securing data for existing practices resulted in the use of geospatial information to calculate both the size and drainage areas for existing BMPs. This means additional BMPs may be present, and a more thorough accounting of the watershed is recommended. Table 30 lists the stormwater BMPs identified and the estimated pollutant removal numbers.

Table 30. Existing Stormwater BMPs in Upper Big Cove Watershed

Location	BMP Type	Total TSS Removal (tons/yr)	Total Phosphorus Removal (lbs/yr)	Total Nitrogen Removal (lbs/yr)
State Police Barracks	Dry Detention Pond	0.08	0.07	0.21
McConnellsburg High School/Middle School	Dry Detention Pond	0.04	0.03	0.09
My Father's House Ministries International	Dry Detention Pond	0.02	0.02	0.05
Lions Community Park	Dry Detention Pond	0.03	0.02	0.07
Fulton County Medical Center/ Hospital	Permeable Pavement w/o Sand, Veg	0.05	0.03	0.16
	Permeable Pavement w/o Sand, Veg	0.04	0.02	0.13
	Permeable Pavement w/o Sand, Veg	0.03	0.02	0.10
	Permeable Pavement w/o Sand, Veg	0.03	0.02	0.09
	Permeable Pavement w/o Sand, Veg	0.07	0.04	0.24
	Permeable Pavement w/o Sand, Veg	0.07	0.04	0.25
	Bioretention/raingarden	0.11	0.08	0.51
	Dry Detention Pond	0.07	0.06	0.19
	Dry Detention Pond	0.03	0.03	0.09
	Dry Detention Pond	0.01	0.01	0.04
	Dry Detention Pond	0.01	0.01	0.03
	Dry Detention Pond	0.01	0.01	0.02
	Dry Detention Pond	0.01	0.01	0.02
	Dry Detention Pond	0.01	0.01	0.02
	Dry Detention Pond	0.01	0.01	0.02

	Dry Detention Pond	0.01	0.01	0.02
	Dry Detention Pond	0.01	0.01	0.03
	Dry Detention Pond	0.02	0.01	0.04
	Dry Detention Pond	0.03	0.02	0.07
All Things Automotive	Dry Detention Pond	0.05	0.04	0.13
Giant	Dry Extended Detention Pond	3.28	0.89	5.76
	Total	4.13	1.52	8.38

The equation used to estimate the drainage area or volume treated was slightly different for each BMP, and the calculations used the MMW defaults of Low-Density Mixed (15% impervious cover) Medium-Density Mixed (52% impervious cover) or High-Density Mixed (87% impervious cover).

Since MMW is based on curves that assume by default a 1” treatment depth, the area treated for structural stormwater BMPs assumed this treatment depth to normalize the drainage area. The area treated is calculated in Equation 1.

Equation 1. Calculation for drainage area treated by stormwater BMPs

$$DA_{SW-BMP} = \frac{V}{d \times I \times 3630}$$

where:

$DA_{SW\text{-}BMP}$ = Drainage Area (acres)
V = Treatment Volume (cf)
d = Assumed Treatment Depth (1 inch)
I = Assumed Impervious Cover Fraction (0.87)
3,630 = Conversion factor from (ac-in) to cf

Future Conditions

Future urban BMP data was provided from stormwater BMP opportunities identified during stormwater retrofit field work (see “Stormwater Retrofit Reconnaissance Inventory (RRI)” section). These practices included design information regarding the practice area, design storm and drainage area, and all practice details were entered into the spreadsheets to reflect future urban BMPs (Table 20).

Agricultural BMP Data

Existing agricultural BMP information was provided by Fulton County Conservation District (FCCD) using information from the Practice Keeper database. Specific locations were not included with the data for privacy reasons, and as a result Agricultural BMPs in the subwatershed are provided in more general acres of practice implemented (Table 31). The amount of implementation was quantified by relating the NRCS Name in Practice Keeper to the equivalent name in MMW.

Table 31. Existing agricultural BMPs with estimated pollutant reductions

Proposed BMP	Unit	Amount	Sediment Reduction (tons/yr)	Nitrogen Reduction (lbs/yr)	Phosphorus Reduction (lbs/yr)
Cover Crops	Acres	118	11.8	222.2	9.6
Nutrient Management	Acres	1000	0.00	634.1	105.4
Conservation Tillage, >60	Acres	158	125.2	189.3	176.1
Forest Buffer-Streamside with Exclusion Fencing	Acres	7	3.9	48.85	8.7
Ag E&S/Soil and Water Conservation Plan	Acres	1400	351	958.4	425.7

Future BMPs were credited using both data provided by FCCD and future agricultural implementation practices identified as a part of the CAP (DEP, 2020) and are presented in Table 32.

Table 32. Proposed agricultural BMPs with estimated costs and pollutant reductions

Proposed BMP	Unit	Amount	Sediment Reduction (tons/yr)	Nitrogen Reduction (lbs/yr)	Phosphorus Reduction (lbs/yr)	Cost ($)
Cover Crops	Acres	164	16.45	308.76	13.3	$12,382.40
Nutrient Management	Acres	790	0.00	500.94	83.23	$6,999.40
Conservation Tillage, >60	Acres	248	196.49	297.1	276.5	$0
Pasture and Grazing Management Practices	Acres	250	21.16	56.82	43.51	$20,317.50
Riparian Forest Buffers	Acres	40	79.39	954.75	139.20	$162,496.80
Riparian Grass Buffers	Acres	60	116.99	1,088.23	204.43	$53,949.00
Forest Buffer-Streamside with Exclusion Fencing	Acres	18	10.03	125.61	22.33	$13,625.28
Grass Buffer-Streamside with Exclusion Fencing	Acres	30	15.68	181.16	35.04	$17,669.10
	Total	1600	456.18	3,513.37	817.54	$287,439.08

MMW does not allow double counting of certain BMPs on the same land and recommends reducing BMP acreage to ensure that total land covered by BMPs does not exceed the land area in that category. In order to account for potential overestimation of BMP implementation and correct for double counting restrictions, a conservative approach was used where the reduction efficiency of a practice in MMW determined the number of acres entered. Practices where double counting is not allowed (cover crops and conservation tillage) were adjusted so the maximum amount of the practice with a higher reduction coefficient was entered and a corresponding reduction in the other practices was made to keep the model from entering negative territory when error checking was done.

Stream Restoration

Several existing stream restoration projects were identified as being implemented in the Upper Big Cove watershed. Table 33 shows the information for the four projects identified as being within the delinested watershed area. MMW defines stream restoration as 'streambank stabilization' and applies a pollutant reduction (lb/ft) based on the feet of stream stabilized.

Table 33. Existing stream restoration projects with estimated costs and pollutant reductions

Project	Unit	Amount	Sediment Reduction (tons/yr)	Nitrogen Reduction (lbs/yr)	Phosphorus Reduction (lbs/yr)
Lincoln Way West Stream Restoration	LF	1800	103.50	313.20	345.60
Confederate Road	LF	800	46.00	153.60	139.20
Back Run Road	LF	1350	77.63	259.20	234.90
Rock Hill Road	LF	950	54.63	182.40	165.30
		Total	281.76	908.4	885

EPR identified 17 potential stream restoration areas, with a total of 24,318 linear feet of stream ranked as High priority at 7 sites. Another 8 sites were ranked as Medium Priority with a total of 17,218 linear feet and 2 sites were ranked as Low priority equating to 3,668 linear feet of stream. The majority of streams chosen for restoration were between 1,000 to 4,000 feet in length—manageable sizes that still allow for significant ecological impact. These segments received Poor to Fair ratings in desktop and field assessments. For the modeling effort, only those streams rated as a high priority were assessed to calculate future load reductions for sediment. Table 34 includes information on the estimated load reductions and potential costs for the seven high priority sites.

Table 34. Proposed high priority stream restoration sites with cost and pollutant reduction estimates

Proposed Project Area	Unit	Amount	Sediment Reduction (tons/yr)	Nitrogen Reduction (lbs/yr)	Phosphorus Reduction (lbs/yr)	Cost ($)
5	Linear Feet	2,898	166.64	504.25	556.42	$1,927,071
6	Linear Feet	1,468	84.41	255.43	281.86	$976,050
8	Linear Feet	2,821	162.21	490.85	541.63	$1,876,049
12	Linear Feet	978	56.24	170.17	187.78	$650,498
13	Linear Feet	1,320	75.90	229.68	253.44	$878,091
16	Linear Feet	12,411	713.63	2,159.51	2,382.91	$8,253,485
17	Linear Feet	2,422	139.27	421.43	465.02	$1,610,350
	Totals	**24,318**	**1,398.3**	**4,231.32**	**4,669.06**	**$16,171,594**

Results

The sediment reduction targets for subwatershed were expressed as a percent reduction from the baseline load. Agricultural areas contributed to the highest sediment loads, followed by stream bank erosion. Loads from other land uses accounted for about 1% of the sediment loading. Based on the MMW modeling runs, the pollutant load reduction targets for sediment are achievable. The MMW results provide achievable overall reductions of approximately 75% for sediment from the initial model load estimates if all the proposed BMPS are implemented (Table 35).

Table 35. Estimated Sediment load reductions (tons/year)

Current	
Calculated Baseline Load No BMPs	3,533
Load Reduction with Existing BMPs	778
MMW % reduction from baseline	22.0%
Remaining Baseline Load[1]	2,755
Future	
Load Reduction with Proposed BMPs	1,861
MMW % reduction from baseline	52.7%
Remaining Baseline Load[2]	894
Targets	
DEP Allowable Load	1,407
Required Load Reduction[3]	2,126
Reduction Target (%)	60.0%
Load Reduction with Existing and Future BMPs Implemented	2,639
Overall load reductions achieved	74.7%

[1] This is the adjusted load with existing BMPs
[2] This is the adjusted load with proposed BMPs
[3] From DEP document (Appendix E)

The analysis shows that to completely meet the sediment load reduction assigned by DEP (60% or 2,126 tons/year) almost all the proposed BMPs need to be implemented. There may also be an overestimation of available agricultural lands in the modelling since the conversion of agricultural lands to solar panel farms may not be reflected in the 2019 NLCD database used. If solar farm conversion continues and begins to take a significant amount of land out of production, sediment load levels will likely decrease.

While the focus of this plan is primarily on sediment reduction, the same BMPs used to address siltation problems also help with nutrient load reductions. The baseline and expected reductions for nitrogen and phosphorus are in Table 36.

Table 36. Phosphorus and nitrogen loading from Model My Watershed (MMW)

	TN (lbs/yr)	TP (lbs/yr)
Baseline	115,670	9,220
Loads Removed w/Existing BMPs	3,002	1,580
Loads Removed w/Proposed BMPs	8,204	5052
Total Load Reduction	11,206	6,632
Percent reduction from baseline	9.7%	71.9%

SECTION 7. COSTS AND FUNDING RESOURCES

Estimated Costs

Estimated costs for implementation of all recommended BMPs in the entire watershed are $16,913,718.37 (Table 37). The bulk of the costs were from the seven highest priority stream restoration projects with a total cost of $16,171,594. Estimated costs for applied agriculture and stormwater practices were determined using capital costs per unit provided in the CAST Cost Profiles for the State of Pennsylvania (Appendix F).

Table 37. Estimated costs for BMP implementation in the Upper Big Cove Creek subwatershed

BMP Type	Number of Practices	Unit Cost (per acre treated)	Total Cost
Urban BMPs			
Bioswale	2	$17,420.79	$34,841.58
Bioretention/raingardens – A/B soils, underdrain	9	$39,377.89	$354,401.01
Bioretention/rain gardens – C/D soils, underdrain	1	$49,630.78	$49,630.78
Filter Strip – Stormwater Treatment	1	$11,459.95	$11,459.95
Dry Extended Detention Pond	1	$4,351.97	$4,351.97
Total Urban BMP Costs			**$454,685.29**
Agricultural BMPs			
BMP Type	**Area treated (acres)**	**Unit Cost (per acre treated)**	**Total Cost**
Cover Crops	164	$75.50/acre	$12,382.40
Nutrient Management	790	$8.86/acre	$1,8875.00
Conservation Tillage, >60	248	$0.00/acre	$0
Pasture and Grazing Management Practices	250	$81.27/acre	$2,0317.50
Riparian Forest Buffers	40	$4,062.42/acre	$162,496.80
Riparian Grass Buffers	60	$899.15/acre	$5,3949.00
Forest Buffer-Streamside with Exclusion Fencing	18	$756.96/acre	$13,625.28

Table 37. Estimated costs for BMP implementation in the Upper Big Cove Creek subwatershed			
Grass Buffer-Streamside with Exclusion Fencing	30	$588.97/acre	$17,669.10
Total Agricultural BMP Costs			**$287,439.08**
Stream Restoration Practices			
BMP Type	**Area treated (linear feet)**	**Unit Cost (per linear foot)**	**Total Cost**
Streambank Restoration		$665.00/foot	$16,171,594
		Total Costs	$16,913,718.37

It should be noted that based on professional experience, CAST costs values are found to be low, and a 30% cost increase should be added to account for inflation, maintenance, etc. All costs are estimates and it is recommended that a detailed cost analysis is provided prior to requesting funding for a proposed BMP.

Funding

There are many financial assistance programs which may provide funding for project implementation activities within the subwatershed. This includes both federal and state funding, as well as some nonprofits that may provide monetary assistance. Many of the programs involve cost sharing, and some may allow the local contribution of materials, land, and in-kind services (such as construction and staff assistance) to cover a portion or the entire local share of the project. These programs are presented in Table 38.

Table 38. Funding sources for BMP implementation

Grant Name (Linked)	Agency	Activities Funded
319 Nonpoint Source Management Program	US EPA thru PA DEP	Watershed plan development; implementation of projects in approved watershed plans. The 319 program will primarily fund BMP implementation in priority 1 sites first, however, priority 2 or lower projects could be funded if there is significant justification for a new/unforeseen opportunity or environmental benefit.
Agricultural Management Assistance	USDA NRCS	A program that helps agricultural producers manage financial risk through diversification, marketing or natural resource conservation practices.
Agriculture Conservation Assistance Program	PDA	The Agriculture Conservation Assistance Program (ACAP) was created through the Clean Streams Fund established by the FY2022-2023 Pennsylvania State Budge. ACAP provides financial and technical assistance for the implementation of best management practices (BMPs) on agricultural operations within the Commonwealth.
Chesapeake Bay Stewardship Fund: Small Watershed Grants	NFWF	Water quality and habitat restoration project implementation
Chesapeake Watershed Investments for Landscape Defense Grants (WILD) Program	NFWF	Implementation and planning and technical assistance grants with a focus on climate change, public access, clean water, and community partnerships.
Clean Water State Revolving Fund (CWSRF)	PENNVEST	Provides low interest financing for projects related to wastewater collection, treatment or disposal facilities, stormwater management, and nonpoint source pollution controls. Projects involving the installation of agricultural BMPs and watershed management also qualify.

Table 38. Funding sources for BMP implementation		
Grant Name (Linked)	**Agency**	**Activities Funded**
Climate Smart Commodities – Farmers for Soil Health Coalition	NFWF	This effort will expand markets for America's climate-smart commodities, leverage the greenhouse gas benefits of climate-smart commodity production, and provide direct, meaningful benefits to production agriculture, including for small and underserved producers.
Conservation Innovation Grants	USDA NRCS	Competitive program that supports the development of new tools, approaches, practices, and technologies to further natural resource conservation on private lands.
Conservation Reserve Enhancement Program (CREP)	USDA FSA	The USDA provides a yearly payment to farmers who remove erodible and flood-prone land from agricultural production and covers costs for reforesting and replanting to control erosion and provide wildlife habitat.
Conservation Stewardship Program	USDA NRCS	Works one-on-one with producers to develop a conservation plan that outlines and enhances existing efforts, using new conservation practices or activities, based on management objectives for your operation. Annual costs are offered for these practices.
County Action Plan (CAP) Implementation Grant	PA DEP	The purpose of this program is to provide a mechanism to fund the implementation of CAPs developed at the county level to maximize specified nutrient and sediment reduction goals established as part of Pennsylvania's Phase 3 WIP.
Environmental Quality Incentives Program (EQIP)	USDA NRCS	Works one-on-one with producers to develop a conservation plan that outlines conservation practices and activities to help solve on-farm resource issues.
Growing Greener	PA DEP	Growing Greener provides funding for farmland-preservation projects; protecting open space; eliminating the maintenance backlog in watersheds; helping communities address land use; and provide for new and upgraded water and sewer systems.
PA Most Effective Basins	NFWF	Projects that accelerate implementation of cost-effective agricultural best management practices ("practices") in selected basins of the Chesapeake Bay watershed of Pennsylvania
Regional Conservation Partnership Program (RCPP)	USDA NRCS	RCPP provides funds for producers to install and maintain conservation activities. The program is not a grant program, but partners can leverage RCPP funding in their programs.
Resource Enhancement and Protection Program (REAP)	PDA	REAP is a program that enables farmers, businesses, and landowners to earn PA income tax credits to offset the cost of implementing conservation practices that reduce nitrogen, phosphorus, and sediment pollution.
Watershed Restoration and Protection Program (WRPP)	PA DCED	PA Department of Community and Economic Development WRPP grants provide funds to restore and maintain stream reaches impaired by the uncontrolled discharge of nonpoint source polluted runoff and ultimately to remove these streams from the Department of Environmental Protection's Impaired Waters list.

Section 8. Education and Outreach

The Upper Big Cove WIP is the first plan developed for a Fulton County watershed. Engagement with the residents in the watershed and across the County is important in developing stakeholder buy-in for potential projects. Education and outreach activities are a vital component to building community support for projects to help reach Upper Big Cove Creek WIP target reduction goals. Partners from state, regional, and local entities need to be involved in the education and outreach efforts in the watershed, and outreach activities need to focus on the impact of individual actions on watershed habitat. Everyone who lives within the watershed is a stakeholder, especially the landowners who have property directly impacted by flooding, and the people and businesses who benefit from recreational tourism in the watershed.

Existing Education and Outreach

There are a number of organizations that can assist with education and outreach associated with the plan. The watershed currently lacks active watershed associations such that the education effort will initially be supported by the FCCD. Other possible partners include the County government, Penn State Extension, and local youth programs. FCCD is already active in the watershed, both working directly with the agricultural community and applying for grants for implementation. The Fulton County government offices are also located within the subwatershed so they may be willing partners in educational efforts.

The FCCD is the local agency that provides conservation-based programs and services to the residents of Fulton County and the lead organization for this WIP. The FCCD acts as a clearinghouse for natural resource information, community conservation concerns and local environmental efforts. The goal of FCCD is to promote the protection, management, improvement and wise use of Fulton County’s soil, water and other natural resources. The FCCD carries out these responsibilities through four major program areas: agricultural conservation, environmental education, erosion and sediment pollution control, and watershed conservation.

Several programs through the Penn State Extension office are active in Fulton County and in the watershed. One program is the Penn State Master Gardener Program, designed to educate and empower volunteers to protect environmental resources. Training and volunteer service are coordinated at the county level by extension staff, partners, or trained volunteers.

Local youth programs are also available through Penn State Extension. The Fulton County 4-H has a unique program to educate youth aged 5-18 on a variety of topics including environmental science. The local 4-H clubs are led by an experienced volunteer to provide the best hands-on experience in the county. One club that may be closest aligned with watershed planning is the Fulton County Licking Creek Little Critters 4-H Club.

As part of this project, a stakeholder meeting was held prior to field assessments. The goal was to help identify potential locations for project implementation. The meeting was not well attended, which was not unexpected as direct one to one communication seems to be a more effective outreach technique in this watershed. We were able to have supervisors from Ayr and Todd townships attend and walk them through the WIP process and how having an approved WIP might benefit the County in securing funding.

Additional Education and Outreach Needs

Education efforts in the subwatershed need to identify common themes and campaigns that can then be tailored to target audiences. The general public, area businesses and landowners, farmers, and municipal officials are all target audiences. Target audiences often have preferred methods for receiving and acting on information, so the use of multiple avenues of message distribution is recommended. Table 39 provides an overview of possible target audiences in the watershed, their potential water quality related interests and concerns, and communication channels to best engage with each audience.

Table 39. Example targets for education efforts in the Upper Big Cove Subwatershed		
Target Audience	**Potential Audience Concerns**	**Communication Channels**
General public	• Livability for current and future generations • Quality of habitat • Recreation opportunities • Flooding	• Newspapers • Websites • Social media • Community/civic groups and events • Local media • Local government • Conservation Districts
Landowners	• Property values • Flooding	
Local businesses	• Property values • Promoting tourism • Flooding	
Agricultural (livestock and crop) community	• Manure and nutrient management • Fertilizer use and regulations • Tillage practices • Funding/cost share opportunities • Flooding	• Crop Advisors • 4-H groups • Conservation District • Word of mouth • Demonstration projects • Newspapers • FCCD training events
Elected officials and County staff	• Compliance with current regulations • Potential additional programmatic and regulatory requirements • Technical and financial support • Property values and revenue	• State agencies • Other local governments • County Commissioners Association of Pennsylvania • Pennsylvania State Association of Elected County Officials • Conservation Districts

Table 40 provides some recommended outreach and education activities to be conducted in the target watershed. Currently, FCCD maintains a website that provides primarily agriculture related information for the public on things like soil testing (and provides soil test kits) as well as links to sources of information on farm related topics like developing E&S plans. Expansion of the website to include watershed specific information is a recommendation for future outreach.

The measures of success for the outreach efforts are fairly straightforward as this plan will help lay the groundwork for future WIP plans in the County and help better understand the most effective engagement techniques. Outreach would be successful if the following indicators were documented:

- Strong attendance in project-related meetings and community events. Measures could include the number of meetings with landowners, and the number of interactions with the public at the Fair.
- Increased number of landowners implementing recommended practices on their property.
- Positive feedback through surveys and coverage in public media outlets, including news articles, social media, website visits, and presentations to community groups.

Table 40. Outreach Metrics for Upper Big Cove subwatershed			
Outreach Approach	**Partners**	**Outreach Methods**	**Number of Contacts/ Possible Venues**
One-on-One Farmer Engagement – Education and technical assistance to advance water quality BMPs on working Agriculture Lands. This is part of FCCD core mission and happens on a regular basis	FCCD, NRCS, Penn State Agricultural Extension	Demonstration Projects, In person meetings	Meet with 5 farmers annually, install 2-3 projects in first 5 years after official WIP approval

Table 40. Outreach Metrics for Upper Big Cove subwatershed			
Outreach Approach	**Partners**	**Outreach Methods**	**Number of Contacts/ Possible Venues**
One-on-one municipal engagement – Onsite or offsite education to enhance knowledge of water quality BMPs on agriculture and urban land uses.	FCCD, Local chapter of Trout Unlimited, Penn State Agricultural Extension	Presentations at meetings In person meetings	Quarterly presentations on plan progress at Fulton County Commissioner Meetings
Specific or Broad Audience Engagement – Targeted or stakeholder outreach on water quality concerns in the watershed	NRCS, Fulton County Recycling Coordinator, Municipalities and School Districts	Websites Social media Community/civic groups and events	Fulton County Fair (annual event), Presentations to school classrooms (2 per year), FCCD website 2 pages dedicated to watershed information
Regional Partnerships – Development of cross watershed and cross county partnerships.	Fulton County Planning & Mapping	Meeting participation	Participation in the regional CAP planning effort
Adaptive Management Practices – Stakeholders will be involved in evaluating the WIP to make changes and adapt the plan over time.	Interested Stakeholders from the groups identified in Table 31	Newspapers, Websites, Social media	One annual meeting

Section 9. Schedule and Milestones

A key part of Watershed Implementation Plans (WIPs) are interim milestones that provide evaluation points and demonstrate progress over time. Milestones may not only be documented changes in water quality, but also measurable program implementation steps that help direct resources in an effective way. A multi-year implementation schedule is assumed and divided into three phases: short term, medium term, and long term. For this plan, short-term is considered 1 – 2 years, medium-term is 3 – 5 years, and long-term is > 5 years. Each phase will rely on an adaptive management approach and will build upon previous phases. The overall plan recommendations are summarized below, and Table 41 lists the recommendations with a suggested timeframe for implementation, partners, and milestones.

Overall Plan Recommendations

1. Document practices in the watershed in a centralized database such as Practice Keeper. This will help with tracking implementation progress and evaluating sediment reduction values in the future. This should include any stormwater structural treatment practices implemented to keep a permanent record moving forward.
2. Implement prioritized Agricultural BMPs for water quality improvement.
   The priority agricultural BMPs throughout the watershed include stream side buffers, Tillage Management (High Residue), and cover crops. The acres of implementation and estimated sediment reduction associated with these practices are provided in Section 6. Pollutant Loading. The increase in agricultural practice implementation will be the only way to reasonably achieve the required sediment reductions.
3. Continue to engage landowners through outreach to the entire watershed.

FCCD along with the NRCS are the lead organizations working with agricultural operators on agricultural resource conservation. Since agriculture is the largest land use in the entire watershed, watershed restoration practices are focused on implementation of agricultural BMPs as discussed in recommendation #2. Section 8.3. Information, Education, and Public Participation provides additional information on outreach.

4. Promote preservation of agricultural lands.
   FCCD can promote agricultural conservation easements while conducting outreach to landowners. These efforts will further promote the protection of agricultural lands from development.
5. Assess the impact of conversion of agricultural lands to solar farms.
   The impact of implementation of large-scale solar projects is currently being examined and Pennsylvania has developed guidance on some of the issues regarding this topic[4]. The primary impact is during the actual construction as clearing of lands may contribute to sediment loads if proper erosion and sediment control is not employed. Additional information on solar panel research is found in the references section of this plan.
6. Implement priority stormwater management BMP retrofits for water quality improvement.
   While the developed lands in the watershed are a minimal source of sediment in comparison to agricultural areas, they do provide an opportunity for public engagement as several are in high visibility locations where they can act as demonstration projects. Retrofit ID 7A located at the McConnellsburg High School site provides this type of opportunity as well as the possibility of functioning as a learning lab site for the school science classes.
7. Implement priority streambank restoration projects for water quality improvement and conduct a rapid BANCS assessment of stream sites to better determine sediment reductions from stream restoration projects. Pollutant reduction credits are available based on the Chesapeake Bay Program Expert Panel to Define Removal Rates for Individual Stream Restoration Projects (Schueler and Stack, 2014) and Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Stream Restoration Projects Built for Pollutant Removal Credit (Wood, 2020). Results from the rapid BANCS assessment and planning level estimates of bulk density and soil nutrient concentrations can be used to estimate the potential sediment and nutrient load reductions due to prevented streambank sediment (Protocol 1 in the crediting guidance) if stream restoration projects were implemented at assessed sites.
8. Conduct chemical and biological stream monitoring in the entire watershed. The lack of recent monitoring information can make the goal of demonstrating habitat improvements difficult. As FCCD implements additional agricultural BMPs, it is anticipated that annual stream monitoring will show improvements. The Watershed Implementation Plan is intended to be an adaptive and integrated management strategy that is evaluated and updated over time. It will be measured by progress benchmarks (Section 10) to track and evaluate progress towards attaining implementation goals.
9. Hire additional engineers and trained technicians to increase capacity for BMP implementation. To increase capacity and accelerate implementation of recommended BMPs, increased staffing of engineers and trained technicians at FCCD and NRCS is recommended. Along with this recommendation is to continue to identify new sources of funding to support staff and BMP implementation as highlighted in Section 7.

Table 41 lists the plan's recommendations, along with a suggested timeframe for implementation, partners, and milestones. For this plan, short-term is considered 1 – 2 years, medium-term is 3 – 5 years, and long-term is > 5 years.

[4] https://files.dep.state.pa.us/Water/BPNPSM/StormwaterManagement/ConstructionStormwater/Solar_Panel_Farms_FAQ.pdf

Table 41. Implementation schedule and milestones

Recommendation	Timeframe for Implementation	Partners	Milestones
1. Comprehensive documentation of practice implementation.	Short-term	FCCD	Add records for existing stormwater practices
	Medium- to long-term	FCCD	Add new records for implemented practices
2. Implement prioritized Agricultural BMPs for water quality improvement.	Short-term	FCCD/Farmers	Implement Ag field practice BMPs on 10% of the proposed additional acres as funding becomes available.
	Medium- to long-term	FCCD/Farmers	Implement at least 50% of proposed Ag BMPs as funding becomes available.
3. Continue to engage landowners through outreach to the entire watershed.	Short-term	FCCD, Ayr and Todd Townships, Private Property Owners	Outreach events that result in 5-8 farmers willing to implement proposed Ag BMPs Achieve at least one retrofit on private property.
	Medium- to long-term	FCCD, Ayr and Todd Townships, Private Property Owners	Achieve an average of one retrofit per year Farmer participation is sufficient to meet implementation goals.
4. Continue to promote preservation of agricultural lands	Medium- to long-term	FCCD, PDA, Pennsylvania Farmland Preservation Association	Conserve an additional 10% of agricultural land
5. Assess the impact of conversion of agricultural lands to solar farms.	Medium- to long-term	FCCD	Results from monitoring show increase in IBI downstream of converted areas
6. Implement priority stormwater management BMP retrofits for water quality improvement.	Short- to medium- term	Municipalities, County	Concepts developed and implemented for 1 high priority urban BMP
	Medium- to long-term	Municipalities, County	Concepts developed and implemented for 3-5 high priority urban BMP
7. Implement priority streambank restoration projects for water quality improvement and conduct a rapid BANCS assessment for sediment load calculations and crediting	Short- to medium- term	FCCD,	Concepts developed and implemented for 1 high priority restoration project
	Medium- to long-term		Concepts developed and implemented for 3 high priority restoration projects
8. Conduct chemical and biological stream monitoring in the entire watershed	Short-term	FCCD	Secure PA DEP 319 Funding to perform chemical and biological stream monitoring
	Medium- to long-term	FCCD	Confirm reductions in siltation through IBI scores and water quality monitoring
9. Hire additional engineers and trained technicians to increase capacity for BMP implementation	Short-term	FCCD, NRCS	Hire 1-2 new staff
	Medium- to long-term	FCCD, NRCS	Continue to additional staff as needed

SECTION 10. EVALUATING PROGRESS AND ADAPTIVE MANAGEMENT

Adaptive management is a strategy to address natural resource management efforts that use the state of a managed system to determine the best action at each decision point, The iterative nature of adaptive management offers flexibility for responsible parties to monitor implementation actions, determine success and base future management decisions upon the results of completed implementation actions. The implementation milestones and benchmarks from section nine will guide the adaptive management process, helping to determine the type of monitoring and implementation tracking that will be necessary to gauge progress over time. There are a number of partners that can assist with the implementation of the plan. The FCCD is already active in the watershed, both working directly with the agricultural community and applying for grants for implementation. The Fulton County government offices are also located within the subwatershed so they may be willing partners in both educational and project implementation efforts.

The Watershed Implementation Plan is intended to be an adaptive and integrated management strategy that is evaluated and updated over time. It will be measured by progress benchmarks to track and evaluate progress towards attaining implementation goals. Project implementation will be tracked by FCCD through Practice Keeper and other tools. Table 42 identifies watershed benchmarks that include water quality indicators, outreach efforts, and BMP implementation. It is recommended that BCCD continue project tracking as well as water quality data and public engagement to monitor progress in reaching milestones (Table 41) and progress benchmarks (Table 42).

Table 42. Progress benchmarks

Benchmark	Year 5	Year 10	Year 15
IBI scores	Establish IBI baseline through approved DEP assessment methodology	10% improvement from IBI baseline scores	20% additional improvement toward attaining aquatic life use
General public engagement	Development of website page on WIP plan for watershed Development of presentation materials for school	Participation in 4 County fairs 6-8 annual presentations to local community groups	Survey of residents to demonstrate increased knowledge of watershed restoration 4 articles in local paper on plan progress
Agricultural BMPs	10% implementation of future agricultural practices	40% of additional implementation target	80% additional implementation target
Urban BMPs	Implementation of 1-2 practices on public land as demonstration projects	Implementation of all 5 practices on public land	Implementation of additional 2 practices on private lands
Load Reduction Achieved	10% reduction in sediment loads	30% reduction in sediment loads	60% reduction in total sediment loads

Ultimately, the most important benchmark is improvement in the IBI score as it directly reflects water quality improvement in the streams. The IBI score should improve as the other benchmarks of outreach and BMP implementation progress. The plan should be evaluated annually for progress made and if milestones are being met, especially at 2, 5 and 10 years. If there is less progress being made than expected, the reasons should be explored, and strategies adjusted.

SECTION 11. MONITORING PLAN

The FCCD is interested in submitting a funding application for a long-term water quality monitoring plan (the monitoring plan) in the Big Cove Creek Watershed. The goal of the monitoring plan is to collect chemical water quality data and annual biological sampling (i.e., macroinvertebrates) to monitor stream improvement trends and ultimately support the delisting of aquatic life use impaired streams in the watershed. The FCCD has selected this watershed as the County has an implementation goal it has set as part of a Regional Countywide Action Plan (CAP) designed to help meet the Chesapeake Bay Total Maximum Daily Load (TMDL) requirements. The proposed monitoring plan would follow the suite of monitoring and data collection protocols currently used by the Pennsylvania Department of Environmental Protection (DEP) to meet multiple surface water characterization objectives in flowing waterbodies. The monitoring protocols can be found on DEP's website[5] and is entitled "Water Quality Monitoring Protocols for Streams and Rivers" (Pennsylvania Department of Environmental Protection, 2021). DEP uses macroinvertebrate IBI scores to determine if a water body is impaired or attaining its use. Sampling macroinvertebrates will allow the improvements to the watershed to be tracked as BMPs are implemented.

There is no recent or consistent habitat or water quality monitoring currently within the Big Cove Creek watershed as noted by DEP in the document Prescribed Sediment Reductions for Big Cove Creek (Appendix E). The most recent monitoring has occurred primarily in the Spring Run watershed which is not part of this plan. Systematic water quality monitoring is important to measure implementation progress toward sediment reduction goals. The lack of consistent monitoring data for the Upper Big Cove watershed means that a baseline will need to be established. The baseline IBI scores for the watershed would be established in the first 5 years of the progress benchmark cycle to allow for the future demonstration of water quality improvements based on project implementation. The baseline would be determined using the assessment methodology found in "Assessment Methodology for Streams and Rivers" (Pennsylvania Department of Environmental Protection, 2021b). The Upper Big Cove monitoring plan would establish a minimum of 4 monitoring sites located along the main stem to measure the health of the watershed while also accounting for the challenges of minimal staffing. A fifth site is also recommended (funding permitting) along the Kendall Run tributary at the intersection with Great Cove Road to monitor this impaired waterway for attainment. Water chemistry would be measured once per year and include total suspended solids, total nitrogen, and total phosphorus. Since the primary impairment in the watershed is sediment, field sampling for aquatic macroinvertebrates would be sampled at each site at least every other year but preferably on an annual basis. The final sites for monitoring would be selected in cooperation with a PA DEP biologist to establish the optimal locations. Figure 29 identifies five potential sampling locations for the Upper Big Cove based on accessibility (public land or roadway crossing) or future project locations.

The FCCD will require additional funding for staff to help coordinate the monitoring effort if they assume responsibility for the program. The water quality data collected will provide a baseline for future comparisons to determine incremental success of project implementation at reducing sediment loads. The ultimate goal is to use the data to justify the removal of the stream segments currently considered impaired for aquatic life use according to the PA DEP Integrated Water Quality Report.

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5 https://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Technical%20Documentation/MONITORING_BOOK.pdf

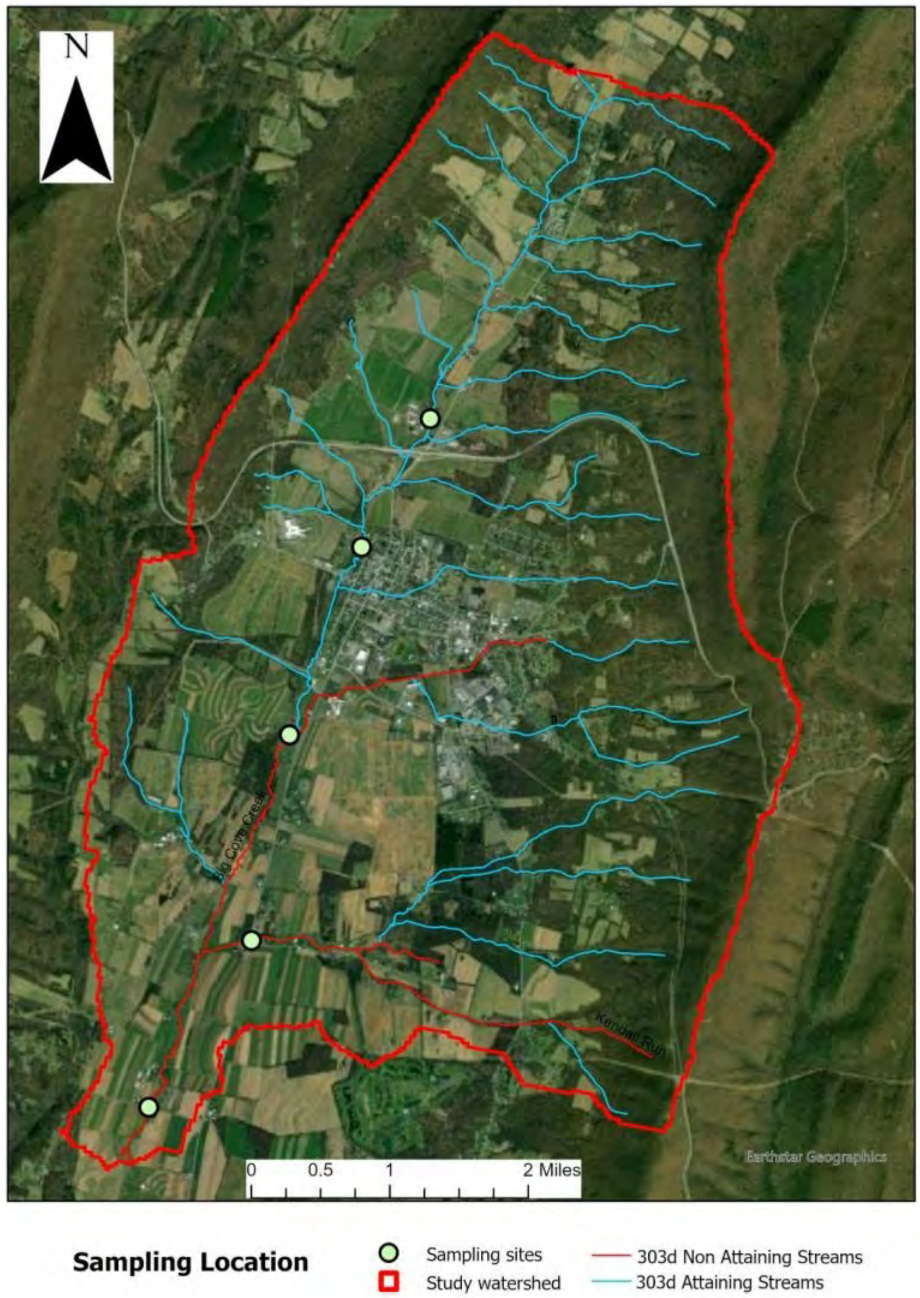

Figure 29. Proposed IBI monitoring locations

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APPENDICES

Appendix A. Example Retrofit Reconnaissance Investigation (RRI) Form

WATERSHED:	**SUBWATERSHED:**	**UNIQUE SITE ID:**	
DATE:	**ASSESSED BY:**	**CAMERA ID:**	**PICTURES:**
GPS ID:	**LMK ID:**	**LAT:**	**LONG:**

SITE DESCRIPTION

Name:____
Address:____

Ownership: ☐ Public ☐ Private ☐ Unknown
If Public, Government Jurisdiction: ☐ Local ☐ State ☐ DOT ☐ Other:_______________________

Corresponding USSR/USA Field Sheet? ☐ Yes ☐ No If yes, Unique Site ID:_________________

Proposed Retrofit Location:

Storage
- ☐ Existing Pond
- ☐ Below Outfall
- ☐ In Road ROW
- ☐ Above Roadway Culvert
- ☐ In Conveyance System
- ☐ Near Large Parking Lot
- ☐ Other:______________________________

On-Site
- ☐ Hotspot Operation
- ☐ Small Parking Lot
- ☐ Individual Street
- ☐ Underground
- ☐ Individual Rooftop
- ☐ Small Impervious Area
- ☐ Landscape / Hardscape
- ☐ Other:_____________

DRAINAGE AREA TO PROPOSED RETROFIT

Drainage Area ≈ _________________
Imperviousness ≈ ________________%
Impervious Area ≈ _______________

Notes:

Drainage Area Land Use:
- ☐ Residential
  - ☐ SFH (< 1 ac lots)
  - ☐ SFH (> 1 ac lots)
  - ☐ Townhouses
  - ☐ Multi-Family
- ☐ Commercial
- ☐ Institutional
- ☐ Industrial
- ☐ Transport-Related
- ☐ Park
- ☐ Undeveloped
- ☐ Other:_____________

EXISTING STORMWATER MANAGEMENT

Existing Stormwater Practice: ☐ Yes ☐ No ☐ Possible
If Yes, Describe:

Describe Existing Site Conditions, Including Existing Site Drainage and Conveyance:
Existing Street Width:__________

Existing Head Available:	**Note where points are measured from: (i.e. street elevation to catch basin invert, manhole rim to catch basin invert, other)**

PROPOSED RETROFIT

Purpose of Retrofit:

☐ Water Quality ☐ Recharge ☐ Channel Protection ☐ Flood Control
☐ Demonstration / Education ☐ Repair ☐ Other:____________________

Retrofit Volume Computations - Target Storage:	**Retrofit Volume Computations - Available Storage:**

Proposed Treatment Option:

☐ Extended Detention ☐ Wet Pond ☐ Created Wetland ☐ Bioretention
☐ Filtering Practice ☐ Infiltration ☐ Swale ☐ Other:____________________

Describe Elements of Proposed Retrofit, Including Surface Area, Maximum Depth of Treatment, and Conveyance:

Available Width:	________
Available Length:	________
Available Area:	________
Ponding Depth:	________
Soil Depth:	________

SITE CONSTRAINTS

Adjacent Land Use:

☐ Residential ☐ Commercial ☐ Institutional
☐ Industrial ☐ Transport-Related ☐ Park
☐ Undeveloped ☐ Other:____________________

Possible Conflicts Due to Adjacent Land Use? ☐ Yes ☐ No

If Yes, Describe:

Access:

☐ No Constraints

Constrained due to

☐ Slope ☐ Space
☐ Utilities ☐ Tree Impacts
☐ Structures ☐ Property

Ownership

☐ Other:____________________

Conflicts with Existing Utilities:

	Yes	Possible/ Modifiable	No	Unknown
Sewer:	☐	☐	☐	☐
Water:	☐	☐	☐	☐
Gas:	☐	☐	☐	☐
Electric to Streetlights:	☐	☐	☐	☐
Other:	☐	☐	☐	☐

____
____

Potential Permitting Factors:

Dam Safety Permits Necessary	☐ Probable	☐ Not Probable
Impacts to Wetlands	☐ Probable	☐ Not Probable
Impacts to a Stream	☐ Probable	☐ Not Probable
Floodplain Fill	☐ Probable	☐ Not Probable
Impacts to Forests	☐ Probable	☐ Not Probable
Impacts to Specimen Trees	☐ Probable	☐ Not Probable

How many?______________

Approx. DBH______________

Other factors:____________________________________
____
______

Soils:

Soil auger test holes:	☐ Yes	☐ No
Evidence of poor infiltration (clays, fines):	☐ Yes	☐ No
Evidence of shallow bedrock:	☐ Yes	☐ No
Evidence of high water table (gleying, saturation):	☐ Yes	☐ No

SKETCH

DESIGN OR DELIVERY NOTES

FOLLOW-UP NEEDED TO COMPLETE FIELD CONCEPT

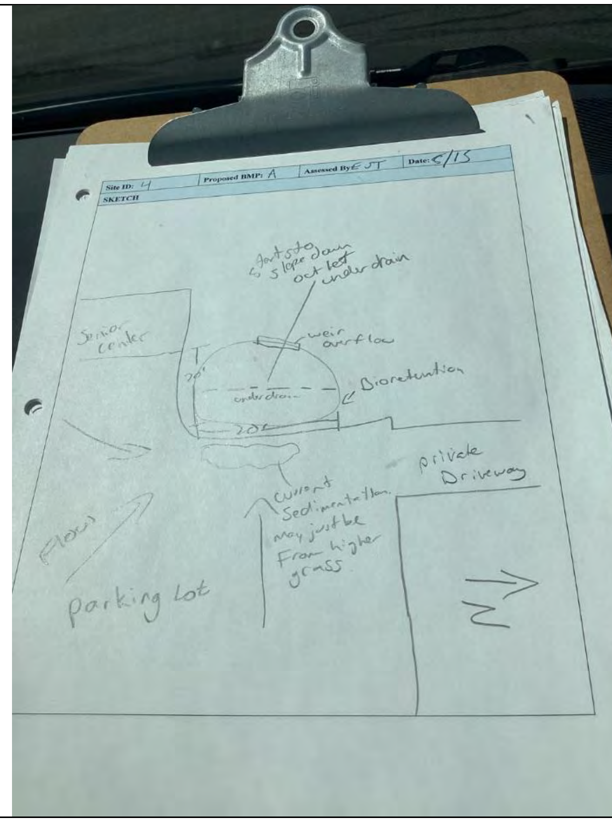
- ☐ Confirm property ownership
- ☐ Confirm drainage area
- ☐ Confirm drainage area impervious cover
- ☐ Confirm volume computations
- ☐ Complete concept sketch
- ☐ Obtain existing stormwater practice as-builts
- ☐ Obtain site as-builts
- ☐ Obtain detailed topography
- ☐ Obtain utility mapping
- ☐ Confirm storm drain invert elevations
- ☐ Confirm soil types
- ☐ Other:____

INITIAL FEASIBILITY AND CONSTRUCTION CONSIDERATIONS

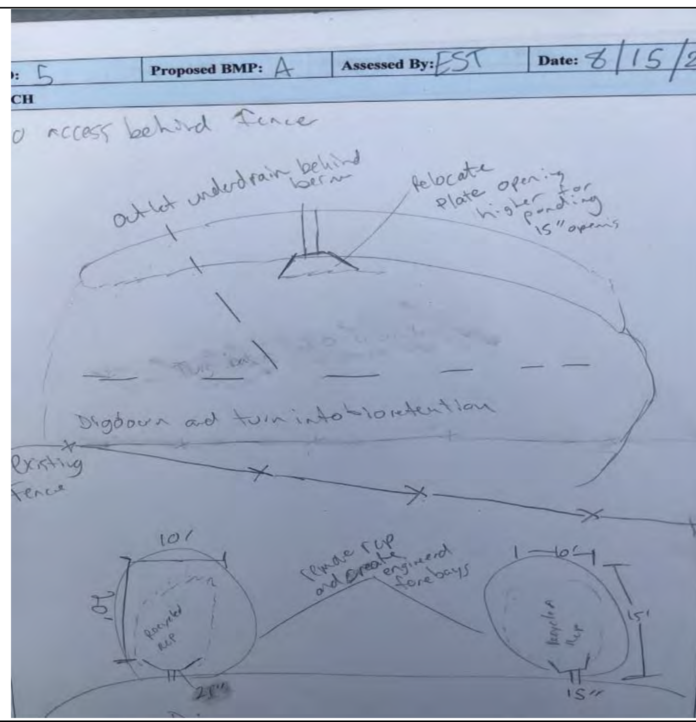
SITE CANDIDATE FOR FURTHER INVESTIGATION:	☐ YES	☐ NO	☐ MAYBE
IS SITE CANDIDATE FOR EARLY ACTION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE
IF NO, SITE CANDIDATE FOR OTHER RESTORATION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE

IF YES, TYPE(S):____

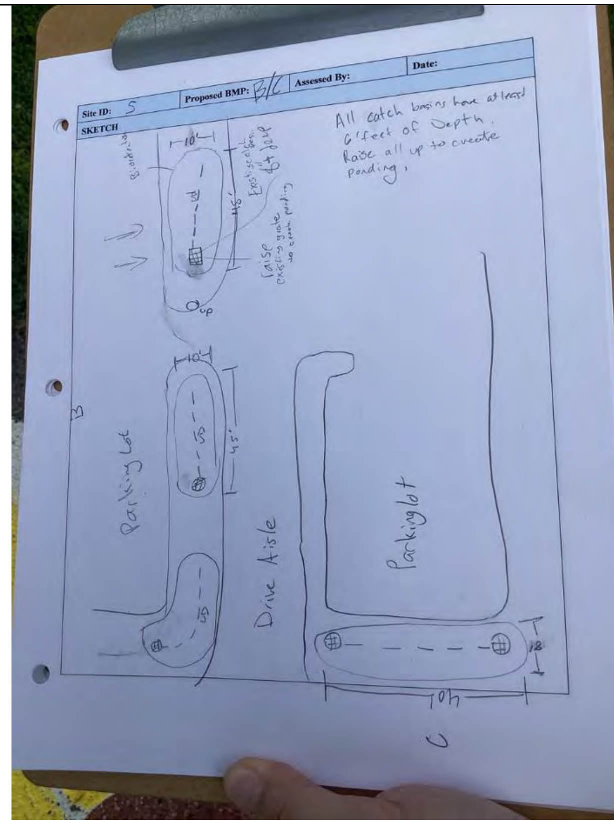
APPENDIX B. PHOTOS OF RETROFIT LOCATIONS



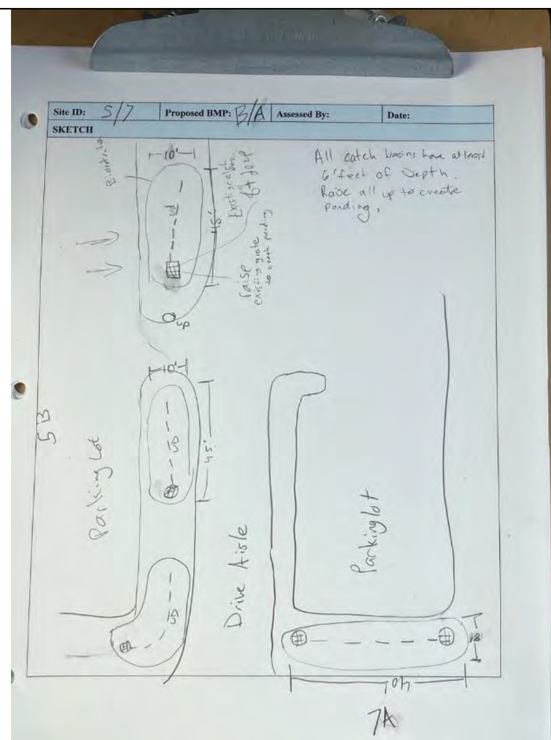
Site 4A. Fulton County Food Basket



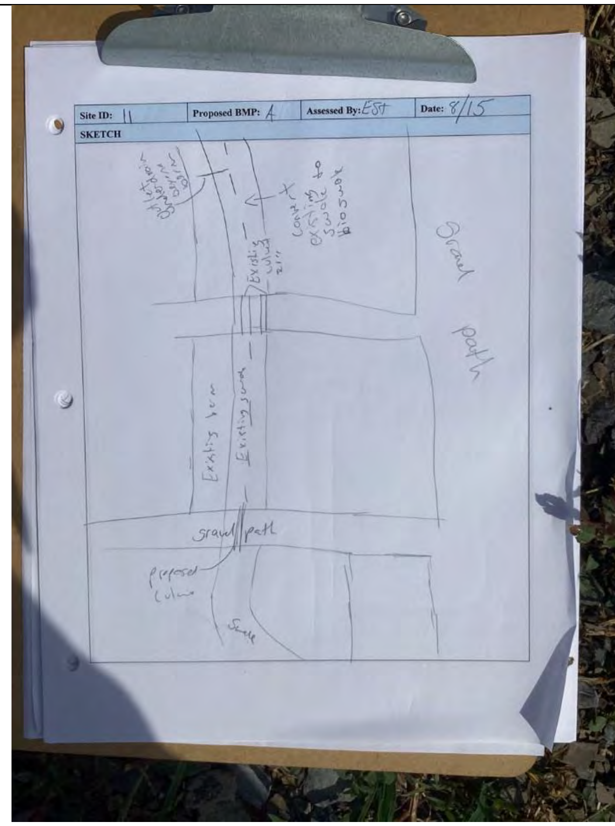
Site 5A. McConnellsburg High School



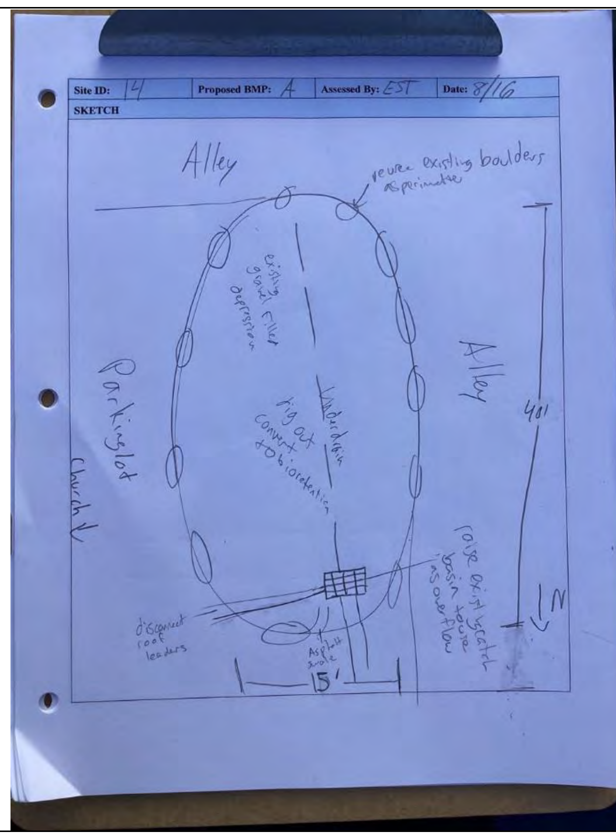
Site 5B. McConnellsburg High School



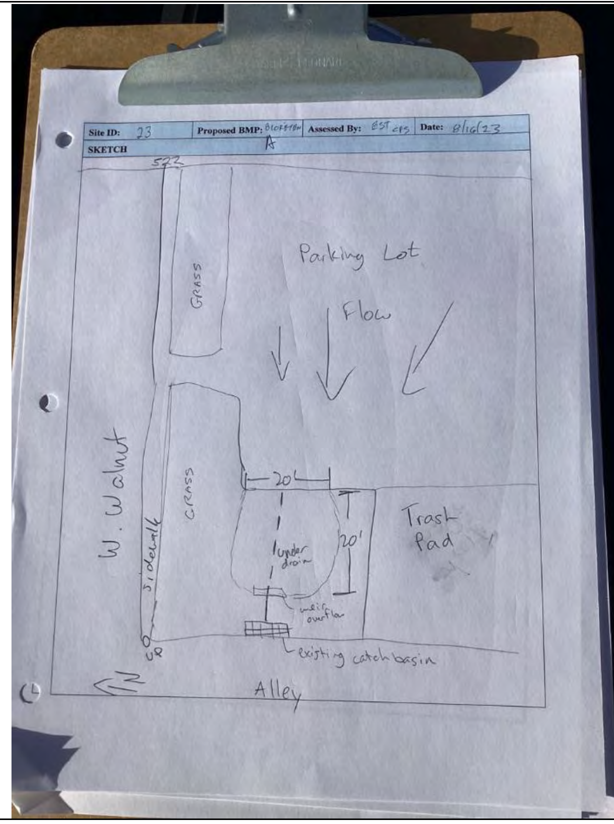
Site 7A. McConnellsburg High School



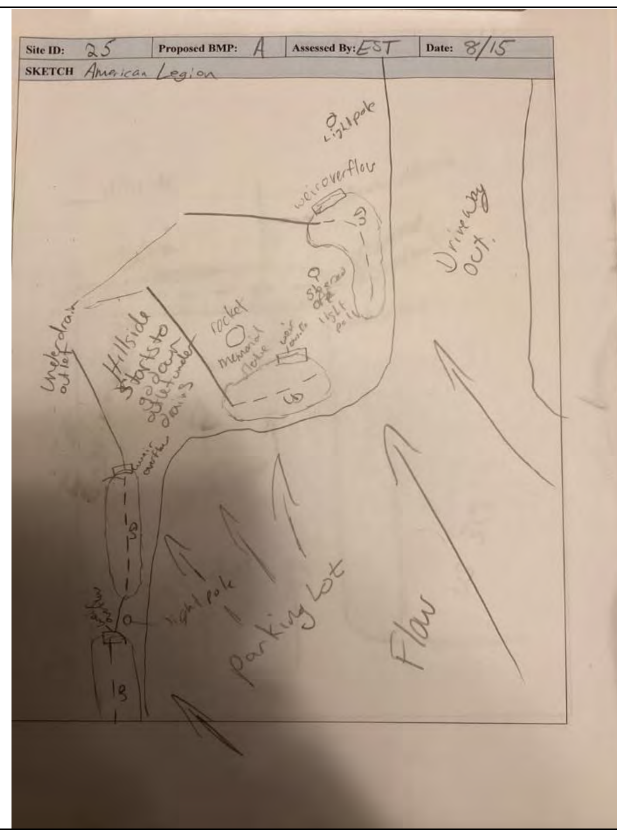
Site 11A. Fulton County Fairgrounds



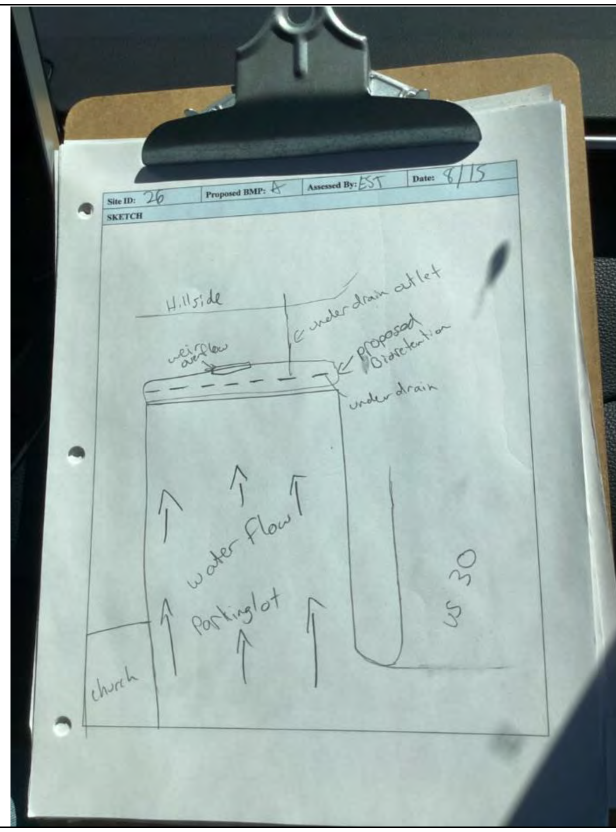
Site 14A. United Methodist Church



Site 23A. Fulton County Child Services

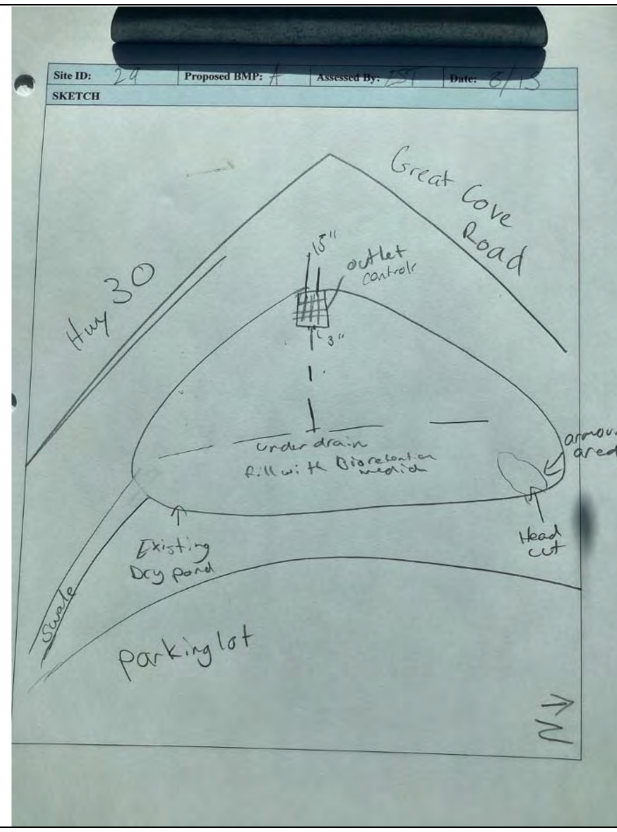


Site 25A. American Legion Post

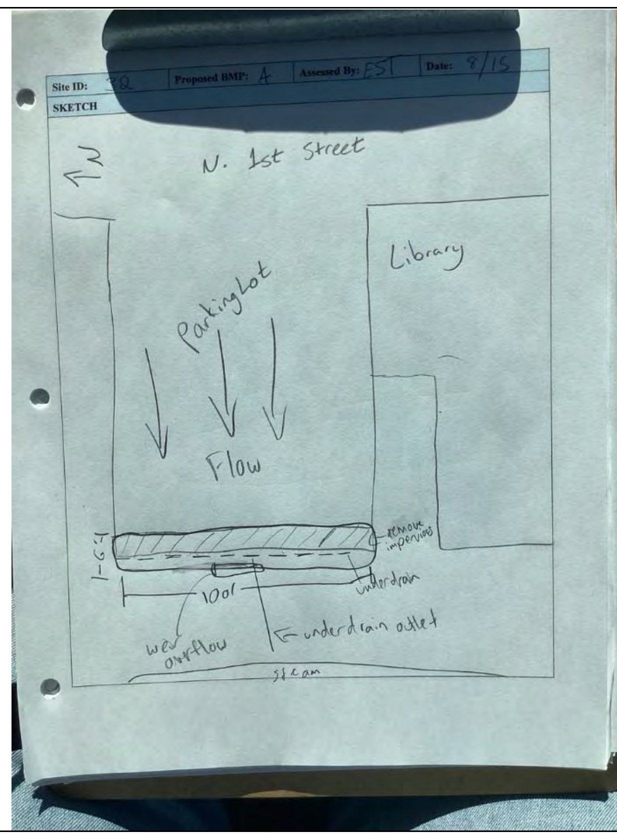


Site 26A. Mountain View Mennonite Church

Site 27A. Fulton County Medical Center/ Hospital



Site 29A. All Things Automotive



Site 32A. Fulton County Library

Site 34A. Waring Products

Site 101A. 844 Lincoln Way E (Estate Drive)

Appendix C. Upper Big Cove Creek Alternative Restoration Plan Stream Assessment Report

UPPER BIG COVE CREEK ALTERNATIVE RESTORATION PLAN
STREAM ASSESSMENT REPORT
FULTON COUNTY, PENNSYLVANIA

Prepared for:

Center for Watershed Protection
11711 E Market Pl
Fulton, MD 20759

Prepared by:

Ecosystem Planning and Restoration, LLC
8808 Centre Park Drive, Suite 205
Columbia, MD 21045

May 2024

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APPENDICES

1 Purpose

Ecosystem Planning and Restoration, LLC (EPR) has prepared the Stream Assessment Report as the Task 5 "Field Assessment Writeup" component of the Center for Watershed Protection's (CWP) Upper Big Cove Alternative Restoration Plan report. It specifically addresses the evaluation of stream existing conditions and restoration potential of a diverse selection of stream sites in the Upper Big Cove watershed and identifies specific locations for stream restoration as a part of Fulton County Soil Conservation District's (FCCD) Best Management Practices (BMP's) that will become part of Fulton County's watershed implementation plan. Upper Big Cove watershed is defined here as the Big Cove Creek watershed delineated downstream of the Kendal Run confluence in CWP's Upper Big Cove Watershed Characterization Report (May 2023).

The assessment for potential restoration includes Big Cove Creek, Kendall Run, and other associated tributaries upstream of Kendall Run located in Fulton County, PA, all of which drain into the Potomac River and eventually into Chesapeake Bay. The drainage area of the Upper Big Cove Creek Watershed is approximately 17 sq. miles and is 49% forest, 36.5% agriculture, 14% developed, and less than 1% herbaceous cover.

This report documents the findings of EPR's GIS-based desktop stream segment analysis, desktop stream segments field-verification, stream restoration site prioritization, and preliminary implementation costs of the priority stream restoration sites.

2 Assessment Methodology

This section documents the methodology of EPR's G.I.S.-based desktop analysis, field validation, recalibration of desktop and field data, and identification of priority stream restoration sites. It is noted that the additional collection of detailed desktop and field data over an extended time period would provide a greater understanding of existing conditions, the causes of stream functional impairments, and the ability to assess the stream conditions to determine the need for restoration.

2.1 GIS-Based Desktop Analysis Methodology

EPR categorized the baseline condition of every stream reach in the Upper Big Cove Watershed with a condition score based on GIS data and aerials. Stream reaches/segments defined by GIS hydrology lines (shapefiles) were segmented in the main stem for analysis based on 2,000 linear feet of stream length unless intersected by a confluence of a tributary. Tributaries were segmented based on 1,000 linear feet of stream length unless intersected by a confluence of a lesser tributary. EPR gathered relevant data on key environmental parameters such as stream lengths, soils, sinuosity, vegetative cover, slope, and various forms of land use/land cover types. The selection of these specific parameters was driven by their potential impact on stream stability and watershed hydrology. This data was then analyzed to rate the existing conditions. The results were summarized into desktop condition scores. The following categories were taken into equally weighted consideration to develop condition scores: sinuosity, riparian vegetation, agriculture encroachment, development encroachment, road presence, and soil erodibility. Every category was scored with ratings of 1-3, except for Sinuosity (ratings of only 0 or 1), with three (3) being the category for instability, and one (1) being the most stable. A further explanation of the scoring technique is below:

1. **Sinuosity**: The sinuosity of a stream's flow path is a crucial parameter in analyzing potential stream bank erosion. When a stream exhibits an overly low or high sinuous pattern, it often signifies heightened vulnerability to erosion. Similarly stream slope significantly influences stream energy, the higher the stream slope the higher the stream energy which can lead to stream erosion. To evaluate sinuosity, we compare the elevations at the start and end of a reach along the stream's course, calculating the slope over the length of that reach. This analysis focused on reaches with slopes ranging from 0 to 3%, which are typically characterized as alluvial. Within this range, if the sinuosity falls between 1.2 to 1.4, indicating a stable flow pattern, a sinuosity score of 0 was assigned. However, if the sinuosity deviates from this stable range, suggesting instability, the reach receives a score of 1. It's important to note that slopes exceeding 3% are excluded from sinuosity categorization since streams with such steep gradients typically do not exhibit significant sinuosity.
2. **Riparian Vegetation**: The presence absence and composition of riparian vegetation can significantly impact stream stability by impacting both mechanical stability through root systems that reinforce soil and prevent erosion, and hydrological dynamics by moderating soil moisture and reducing erosion risks. Furthermore, riparian vegetation is vital for maintaining ecological balance, moderating stream temperatures, influencing biodiversity and protecting water quality. To evaluate riparian vegetation the areas within 25 feet of the stream were assessed. If the stream segment buffer is more than 75% forested, the stream segment receives a score of 1; if 50-75% forested, the segment receives a score of 2, and less than 50% forested receives a rating of 3.
3. **Agriculture Encroachment**: Area Agricultural practices often cause soil compaction and erosion, increasing runoff and negatively impacting water quality and aquatic habitats by destabilizing streambanks. Chemical runoff from fertilizers and pesticides contributes to eutrophication in nearby streams, leading to oxygen depletion and harm to aquatic life. Additionally, water diversion for irrigation and stream channel alteration to optimize land use further disrupt natural water flows and stream health, increasing flood risks and affecting biodiversity. To evaluate agriculture encroachment the areas within 100 feet of the stream were assessed. If land use adjacent to the stream segment is estimated more than 50% agriculture, the stream segment receives a rating of 3; if the land use is 25- 50% agriculture, the segment receives a score of 2, and if less than 25% agriculture, the segment receives a rating of 1.
4. **Development Encroachment**: Development encroachment on stream corridors can lead to several adverse effects on stream stability. Increased impervious surfaces result in higher stormwater runoff, causing erosion, sedimentation, and altered stream flows, which degrade aquatic habitats and ecosystem health. Additionally, urban runoff introduces pollutants like oils and heavy metals into streams, disrupting ecological balance, while development-related channel modifications and the loss of riparian buffers

exacerbates erosion and destabilizes natural stream dynamics. To evaluate development encroachment the areas within 100 feet of the stream were assessed. If the stream segment is estimated to be more than 50% developed (e.g., graded, built upon, cleared for non-agricultural use) the stream segment receives a rating score of 3; if the segment is estimated as 25- 50% developed, the segment receives a score of 2, and if less than 25% developed receives a score of 1.

5. **Road Presence**: Area Similar to development encroachment, the presence of roads in the riparian areas and their crossings over streams significantly impacts stream stability through various mechanisms. Roads alter natural water flow patterns and increase runoff, leading to exacerbated streambank erosion, channel incision, and sediment buildup that disrupt the stream's natural equilibrium and morphological health. Furthermore, crossings, if improperly designed or in a state of disrepair, can obstruct the movement of aquatic organisms and lead to the degradation or removal of crucial riparian vegetation, carrying pollutants like heavy metals and oils into streams, which harms water quality, aquatic habitats, and biodiversity. To evaluate the amount of impact from roads on stream stability areas within 25 feet of the stream were assessed. If the stream segment intersects with more than 5,000 feet of paved road the segment receives a rating score of 3; if intersecting between 0-5000 feet, the segment receives a rating of 2, and if 0 feet of road presence receives a score of 1.
6. **Soil Erodibility**: The soil erodibility factor (K factor) is essential for predicting soil's response to erosive forces like rain and runoff, crucial for stream stability. To assess soil erodibility areas within 25 feet of the stream. were assessed. If the K factor (i.e., erodibility factor provided in US NRCS' on-line soil survey) of the stream segment is more than a factor of 0.4, the stream segment receives a rating score of 3; if the K factor is between 0.2-0.4, the segment receives a score of 2, and if the factor is under 0.2, it receives a score of 1.

Scores are then added up to yield the overall stream segment condition score. The worst overall score possible is theoretically a 16, but no reach scored worse than a rating of 14. Given this distribution, scores were then sorted into three equal sub-ranges for stream stability: 6-8 is good condition, 9-11 is fair condition, and 12-14 is poor condition.

A total of thirty-eight (38) representative sites were selected, in coordination with the FCCD. Representative field sites were chosen for field assessment verification based on equal representation of existing stream segment conditions, varied locations within the watershed, and stream segment access.

2.2 Field Verification Methodology

EPR conducted a modified version of the Function-based Rapid Stream Assessment methodology (FBRSA) (USFWS - Starr et al, 2015) of the 38 representative sites identified from the desktop Critical functions on two levels of the stream functions pyramid were assessed so that the observed field existing conditions for these levels and potential changes in defined stream functions could be evaluated for the selection of priority sites.

The following assessment parameters, by function pyramid level, were evaluated:

Level 2 - Hydraulics – floodplain connectivity, floodplain drainage, and vertical stability extent.
Level 3 - Geomorphology – lateral stability, riparian vegetation, and bedform diversity.

The FBRSA used the assessment ratings of Functioning, Functioning-at-Risk, and Not-Functioning to parallel the overall rating conditions of good, fair, and poor presented at the end of Section 2.1. A description of the rating of the RSFBA is presented in Section 3. A reach section of each representative site was conducted; full stream segment lengths were not assessed due to project time constraints to assess the entire stream length and accessibility issues (e.g., change in landowner or fencing, for example).

2.3 Desktop Analysis Recalibration Methodology

After the field assessment, EPR calibrated the GIS based desktop analysis of every stream reach that was field assessed with a condition score that more closely resembled the empirical field data. EPR evaluated the calibration of the Desktop Analysis to ensure that it matched or closely matched the field data. EPR found that as individual sites were inspected on the desktop, much of the channel sinuosity did not match the GIS basemap imagery. Given that the FEMA hydrology layer was a decade old, it was expected that the stream planform would exhibit alterations from the configurations previously recorded in the hydrology layer. Thus, EPR decided that the inaccurate GIS hydrology data layer was not relevant in the desktop analysis, and sinuosity as an analysis parameter was removed from the condition score final calculations. The final scoring metrics are described in **Section 3.1 GIS Based Desktop Results**.

Revised scores are then added up to yield the overall condition score. The worst score possible is theoretically a 15, but no reach segment scored worse than a rating of 13. Given this distribution, scores were then sorted into three sub-ranges of stream condition: 6-8 is good condition, 9-11 is fair condition, and 12-13 is poor condition.

3 Assessment Results

3.1 Desktop Assessment Results

The desktop assessment involved a detailed evaluation of 50,534 linear feet of stream across 38 distinct reaches, as illustrated in Appendix C - Detailed desktop and field assessment results. These reaches were distributed between two primary watersheds: Kendall Run and Big Cove. Kendall Run encompassed 11 reaches amounting to 15,716 linear feet, while Big Cove, along with its unnamed tributaries, included 27 reaches totaling 34,818 linear feet.

The analysis was structured around the methodology outlined in section **2.1 GIS-Based Desktop Analysis Methodology**. Streams were assessed and assigned lengths and scores, categorizing them into three conditions: Good, Fair, and Poor. Specifically, 13 reaches were classified as Good with a combined length of 14,831 linear feet. Fifteen reaches were marked as Fair, covering another 14,831 linear feet, and ten reaches fell into the Poor category, spanning 15,660 linear feet.

Breaking down the results further for Big Cove and its tributaries, 30% of the stream reaches (8) and 25% of the stream length (8831 LF) were rated as Good. In contrast, 41% of the reaches (11) and stream length (14,327 LF) were deemed Fair, and 30% (8) of the reaches along with 33% of the stream length (11,660 LF) were categorized as Poor.

For Kendall Run and its tributaries, the evaluation showed that 45% of the stream reaches (5) and 38% of the stream length (6000 LF) were considered Good. Meanwhile, 36% of both the reaches (8) and stream length (5716 LF) were rated as Fair, and 18% of the reaches (2) with 25% of the stream length (4000 LF) were classified as Poor**.**

Reference Appendix A – Big Cove Existing Stream Condition Ratings Map for locations of each delineated reach.

3.2 Field Assessment Results

The EPR field assessment encompassed the reaches identified and rated in the Desktop Assessment. Among the Big Cove and its tributaries field sites, one (1) site was dry, and two (2) sites were not channels and, therefore, not rated. Of the remaining sites, four (4) were rated as being in "Good condition," sixteen (16) were rated as being in "Fair condition," and four (4) segments were rated as being in "Poor condition."

For Kendall Run and its tributaries, the assessment rated three (3) sites as being in "Good condition" and eight (8) sites as being in "Fair condition." No segments were rated as being in "Poor condition."
The characterization of a “good” site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
    a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A good BHR signifies that flood flows can frequently access the floodplain relative to the bankfull elevation, and as such the floodplain is well-connected to the stream.
    b. Entrenchment Ratio: ER is calculated as flood prone area width divided by bankfull width. A good ER is a high ER, as this indicates much of the floodplain is available for flood flows once stream flows have overtopped the banks.
    c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed

adjustments and is best described as either local or system wide. A good vertical stability rating does not currently have high potential to aggrade or degrade.

2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.
    a. Riparian vegetation: Riparian vegetation primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality, density, diversity and composition. A good riparian corridor extends over 100 feet wide, with diversity and density in its vegetation community, no adverse human impacts, and none/sparse invasive species presence.
    b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A good Dominant Bank Erosion Rate Potential occurs when very few of the banks are actively eroding.
    c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Good shelter for fish contains greater than 70% of substrate favorable for colonization and fish cover, in which a mix of snags, submerged logs, undercut banks, rubble, gravel, cobble, large rocks, and other stable habitat aspects allow for full colonization potential.

The characterization of a “fair**”** site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
    a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A fair BHR signifies that flood flows can sometimes access the floodplain relative to the bankfull elevation, and as such the floodplain is moderately connected to the stream.
    b. Entrenchment Ratio: ER is calculated as flood prone area width divided by bankfull width. A fair ER indicates some, but not much, floodplain is available for flood flows once stream flows have overtopped the banks.
    c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed adjustments and is best described as either local or system wide. A fair Vertical Stability has potential to aggrade or degrade and has a magnitude of streambed adjustments contained only to instances of local instability.
2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This

pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.

   a. Riparian vegetation: Riparian vegetation primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality, density, diversity and composition. A fair riparian corridor extends to a width of 25-100 feet, where composition is dominated by two or three species, human activities have caused great negative impact, and invasive species have altered the vegetation community.
   b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A fair Dominant Bank Erosion Rate Potential occurs when a moderate amount—yet less than 50%—of the banks are actively eroding.
   c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Fair shelter for fish contains a mix of 20-70% stable habitat with a potential for full colonization, but not yet prepared for colonization. Habitat aspects may be suited for maintenance of fish population, but are in the form of new fall, and are not well-integrated into the in-stream ecosystem.

The characterization of a "poor" site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
   a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A poor BHR signifies that flood flows can barely access the floodplain relative to the bankfull elevation, and as such the floodplain is not well connected to the stream.
   b. Entrenchment Ratio: ER is calculated as flood prone area width divided by bankfull width. A fair ER indicates very little floodplain is available for flood flows once stream flows have overtopped the banks.
   c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed adjustments and is best described as either local or system wide. A poor Vertical Stability has high potential to aggrade or degrade and has a high magnitude of streambed adjustments to yield widespread instability.
2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.
   a. Riparian vegetation: Riparian vegetation primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality,

density, diversity and composition. A poor riparian corridor extends to a width less than 25 feet, with little to no vegetation due to human impact, and/or a majority of the vegetation is invasive.

b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A poor Dominant Bank Erosion Rate Potential occurs when over 50% of the banks are actively eroding.
c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Poor shelter for fish contains less than 20% of stable habitat in the mix, in which lack of available habitat visually and obviously undesirable, and substate is unstable or lacking.

Detailed field assessment results are presented in Appendix C.

4 Stream Restoration Recommendations

4.1 Restoration Site Selection and Prioritization

The process of identifying potential stream restoration sites was driven by a comprehensive set of criteria designed to balance ecological objectives with logistical feasibility. A critical factor was the willingness of property owners to participate in the projects, which is essential for accessing the streams and ensuring their long-term upkeep and success. The majority of streams chosen for restoration were between 1,000 to 4,000 feet in length—manageable sizes that still allow for significant ecological impact. These segments had previously received Poor to Fair ratings in desktop assessments, highlighting a substantial potential for ecological improvement. Reference Appendix B – Big Cove Potential Stream Restoration Project Area Map for locations of recommended restoration reaches.

Financial considerations were equally important; restoration efforts were limited to streams where the costs per linear foot were reasonable, ensuring that the projects could deliver the greatest ecological benefits without financial overreach. The streams selected typically ranged from the 2nd to 4th order, a factor that affects both project costs and the potential ecological benefits. Cost-efficiency and the potential for significant load reductions influenced the prioritization process. Additionally, the strategy included an assessment of environmental considerations and potential impacts on adjacent utilities and natural resources. The approach aimed to minimize these impacts as much as possible, demonstrating a commitment to environmental stewardship and the preservation of local ecosystems.

The prioritization of sites for the project was determined by a set of criteria designed to meet load reduction goals efficiently and effectively. The ranking structure considered ownership, giving priority to sites that are either publicly accessible or have already received approval and support from their owners. The feasibility of construction was also a key consideration, focusing on the accessibility of each site for construction equipment and staging areas to ensure smooth project execution. Additionally input from local government stakeholders provided significant weighting to the final prioritization.

This prioritization approach ensures that site selections are technically and financially sound resulting in measurable improvement while also considering the likelihood of implementation.

Altogether, the stream assessment led to the development of 17 proposed project areas that span the assessment reaches across Big Cove and Kendall Run. Some assessment reaches were combined into one proposed project area to maximize potential TMDL credits and ecological uplift. These 17 reaches were categorized into High, Medium, and Low Priority sites. In total, there were 7 High Priority sites, 8 Medium Priority sites, and 2 Low Priority sites. (Table 1 – Proposed Stream Restoration Project Area Ranking).

Proposed Project Area	Ranking	Length	Reach ID
1	Medium	2551	BC-RUT1-1, BC-RUT1-2, BC-3, BC-4
2	Medium	1779	BC-RUT3-3, BC-RUT3-4, BC-6
3	Low	2357	BC-7, BC-8, BC-9, BC-10
4	Medium	4014	BC-10, BC-11, BC-RUT5-2, BC-RUT5-3
5	High	2898	BC-12, BC-13, BC-14
6	High	1468	BC-LUT6-8, BC-LUT6-9
7a	Medium	2250	BC-14, BC-15, BC-16, BC-17
7b		3668	BC-RUT7-2, BC-RUT7-3, BC-RUT7-4, BC-RUT7-5, BC-RUT7-6, BC-RUT7-7
8	High	2821	BC-19, BC-20, BC-21, BC-22
9	Medium	956	BC-26
10	Medium	1423	BC-LUT9-16, BC-LUT9-17, BC-LUT9-18
11	Medium	2202	BC-27, BC-28
12	High	978	BC-29, BC-30
13	High	1320	BC-31, BC-32
14	Medium	2043	KR-RUT1-13, KR-RUT1-14, KR-RUT1-15, KR-8
15	Low	1571	KR-8, KR-9
16	High	12411	BC-32, BC-33, BC-34, BC-35, BC-36, KR-9, KR-10
17	High	2422	BC-36, BC-37, BC-38

Table 1: Big Cove Proposed Stream Restoration Project Area Ranking

4.2 Proposed Restoration Design Approach

Proposed stream restoration recommendations are based on the Natural Channel Design (NCD) Priority 2 and 3 restoration approaches (Rosgen 2006). The NCD Priority 1 design approach was considered during the initial assessment phase. However, this restoration approach involves reconnecting the stream to its original floodplain by raising the stream bed elevation. By so doing, this creates a 100-year flood elevation increase. The increase in the 100-year flood elevation, infringes upon private property and infrastructure, which is unacceptable. Therefore, the NCD

Priority 1 restoration approach was not recommended to be used for any of the proposed restoration sites. The NCD Priority 2 and 3 restoration approaches call for different levels of effort in adjusting channel and floodplain conditions to provide ecological uplift, while meeting design objectives.

A Priority Level 2 restoration creates a new stable channel that is connected to the floodplain, but the floodplain is excavated at the existing bankfull elevation, i.e. the bed elevation of the stream remains nearly the same. The formerly channelized and incised stream is re-meandered through the excavated floodplain. This approach is typically used if there is not a knickpoint or other abrupt change in grade upstream of the project, in larger streams, or in cases where flooding cannot be increased on adjacent property. A plan view and cross section example is shown below in Figure 1 – Priority Level 2 Restoration.

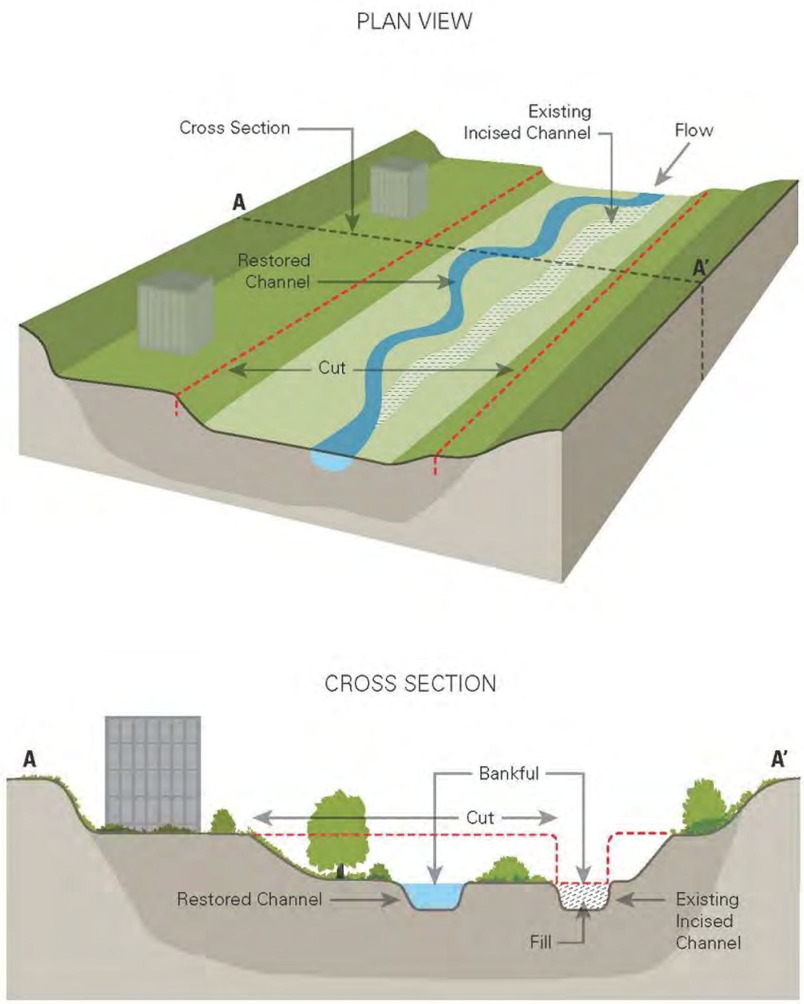


Figure 1: NCD Priority Level 2 Restoration

NCD Priority Level 3 restoration also creates a new stable channel that is connected to the existing bankfull elevation, i.e. the bed elevation of the stream remains nearly the same. However, the newly excavated floodplain is much narrower than a floodplain associated with a Priority Level 2 and is commonly referred to as a floodplain bench. This approach is typically used if the floodplain has been encroached upon by development and there is limited space for a floodplain area. A plan view and cross section example is shown below in Figure 2 – Priority Level 3 Restoration.

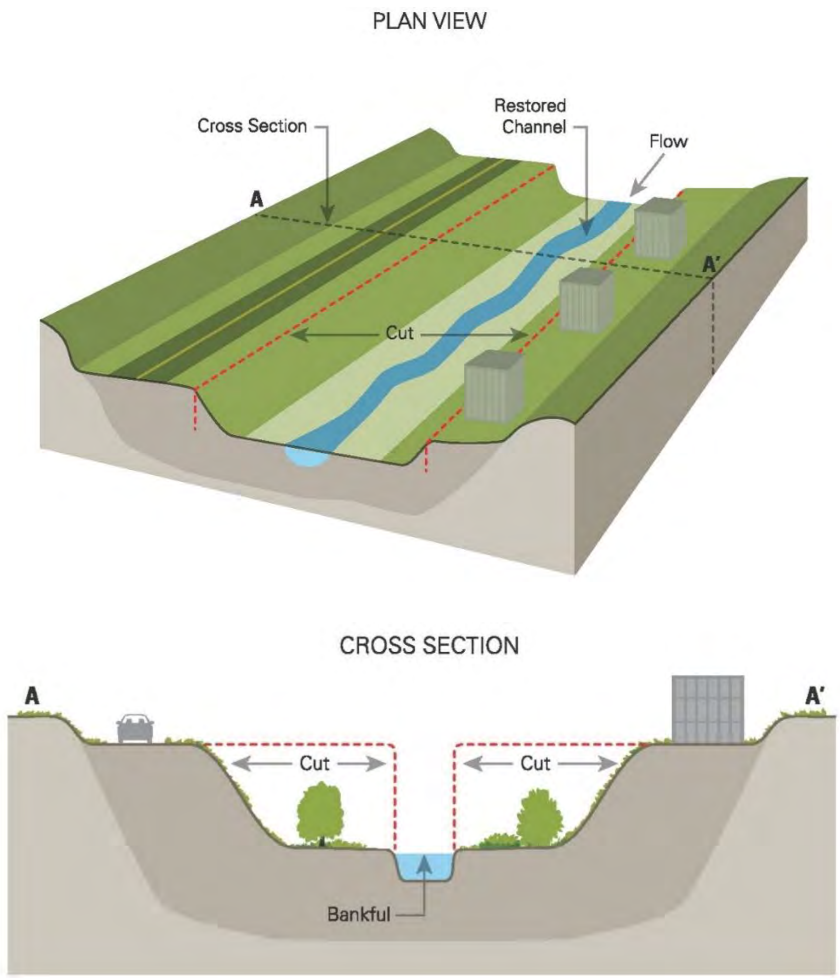


Figure 2: NCD Priority Level 3 Restoration

5 Ecological Uplift

The enhanced ecological functions outlined below could be achieved by implementing the stream restoration recommendations for the priority sites within the watershed. These projects aim to enhance ecological uplift and resilience through strategic interventions focused on restoring natural floodplain dynamics and stream functions. The comprehensive approach will facilitate the following outcomes:

1. *Increased Floodplain Access Frequency*: Restoration will enable regular access to the floodplain during flood events, allowing for natural water distribution across the landscape.
2. *Enhanced Storm Flow Storage and Attenuation:* The floodplain will act as a natural buffer, absorbing peak storm flows, reducing water velocity and volume during storm events, and mitigating downstream flooding risks.
3. *Groundwater Recharge Enhancement:* Increased floodplain inundation will enhance water percolation through soil layers, recharging groundwater reserves.
4. *Development of Stream/Wetland Complex Systems:* The interaction between the stream and its floodplain will evolve into integrated wetland systems, bolstering biodiversity and ecosystem stability.
5. *Extension of the Hyporheic Zone:* The hyporheic zone, critical for nutrient cycling and supporting unique aquatic communities, will extend into the floodplain.
6. *Raising of Groundwater Levels:* Enhanced groundwater recharge will raise groundwater levels, essential for sustaining vegetation during dry periods.
7. *Improved Groundwater and Riparian Vegetation Interaction:* Higher groundwater levels will enhance the interaction between groundwater and the root zones of riparian vegetation, promoting plant growth and stability.
8. *Increased Denitrification:* Enhanced microbial activity within the floodplain will reduce nitrate levels, improving water quality.
9. *Augmented Floodplain Habitat Complexity:* The project will increase the complexity of habitats available for various species including amphibians, reptiles, mammals, and birds, providing food, cover, and nesting sites.
10. *Reduced Sediment Inputs from Bank Erosion:* Stabilizing stream banks will decrease sediment entering the stream, maintaining clearer waterways and supporting aquatic life.
11. *Enhanced Sediment Trapping:* Floodplain restoration will serve as a natural sediment filter, preventing sedimentation impacts downstream.
12. *Restoration of Riparian Buffers:* Riparian buffers will be restored and enhanced to filter pollutants, provide wildlife corridors, and stabilize stream banks.
13. *Reduction in Invasive Plant Species:* Targeted management practices will reduce invasive species, promoting native biodiversity.
14. *Increased Wood and Detritus:* The presence of large wood and detritus will increase, essential for organic matter processing and habitat provision.
15. *Improved Bedform Diversity:* Enhanced bedform diversity in the stream will provide varied habitats for macroinvertebrates and fish.
16. *Water Quality Improvements*: Bank stabilization and improved groundwater connections will decrease nutrient and sediment loads entering the stream.
17. *Optimized Water Temperature:* Connections between the hyporheic zone and floodplain, along with enhanced riparian buffers, will help regulate water temperature.
18. *Biological Benefits:* Wildlife species diversity and density are expected to increase due to improved stream and floodplain habitats.

6 Stream Restoration Costs

Stream restoration project costs are influenced by a variety of factors that can significantly affect their overall costs. Primarily, the existing conditions of the stream—such as channel stability, sediment load, and vegetation cover—play a crucial role in determining the initial assessment and intervention strategies required. Streams that exhibit high levels of instability or degradation often demand more intensive restoration efforts, which in turn, increase project costs. These interventions may include extensive channel reshaping, bank stabilization, and the installation of structures to manage water flow and sediment transport.

Furthermore, the objectives of the restoration project directly impact the scope and, therefore, the cost. Objectives can range from improving water quality and increasing biodiversity to providing flood risk management and enhancing recreational opportunities. Each goal requires specific interventions and technologies, influencing both the complexity and extent of the necessary work. For instance, projects aimed at habitat restoration may involve detailed designs that include the creation of specific features like riffles, pools, and meanders to support diverse aquatic life, which can be costly to implement correctly.

The selection of a natural channel design prioritization level approach also significantly influences the restoration costs. This approach, which emphasizes restoring or mimicking the natural fluvial processes of the stream, requires thorough geomorphological assessments and often complex design solutions to achieve a self-sustaining system. The complexity of these designs, combined with the need for specialized equipment and expertise, can lead to higher costs, particularly in cases where the pre-restoration conditions of the stream are far removed from their natural state. By carefully considering these factors—existing conditions, project objectives, and design approach—planners and engineers can better estimate the costs and necessary resources for effective stream restoration.

All proposed projects align with either Priority 2 (P2) or Priority 3 (P3) restoration approaches. Despite varying design strategies, costs for assessment, design, permitting, and construction are similar, ranging from $45 to $65 per linear foot as a planning level estimate and $400 to $600 per linear foot for construction.

The construction phase includes several assumed restoration activities, including in-channel adjustments, new channel creation, bank grading, and the installation of various instream structures such as vanes and weirs. Additionally, reach-wide plantings and bioengineering techniques for enhance ecological uplift and to stabilize river banks. This cost also assumes some activities associated with protecting and repairing existing infrastructure to ensure the resilience of the restoration work. These costs reflect the total expenses associated with the initial project design, construction, and any necessary environmental compliance measures except for operations and maintenance (O&M) and long-term monitoring.

For implementation planning, it is recommended to use an average cost of approximately $665.00 per linear foot (LF). This estimate serves as a practical planning level estimate for budgeting, enabling program managers to develop initial prioritization and direct resources to appropriate projects. It’s important to note that this figure is a planning level estimate; actual costs can vary significantly based on the specific conditions and requirements of each project, including the complexity of the natural channel design and the extent of necessary ecological enhancements.

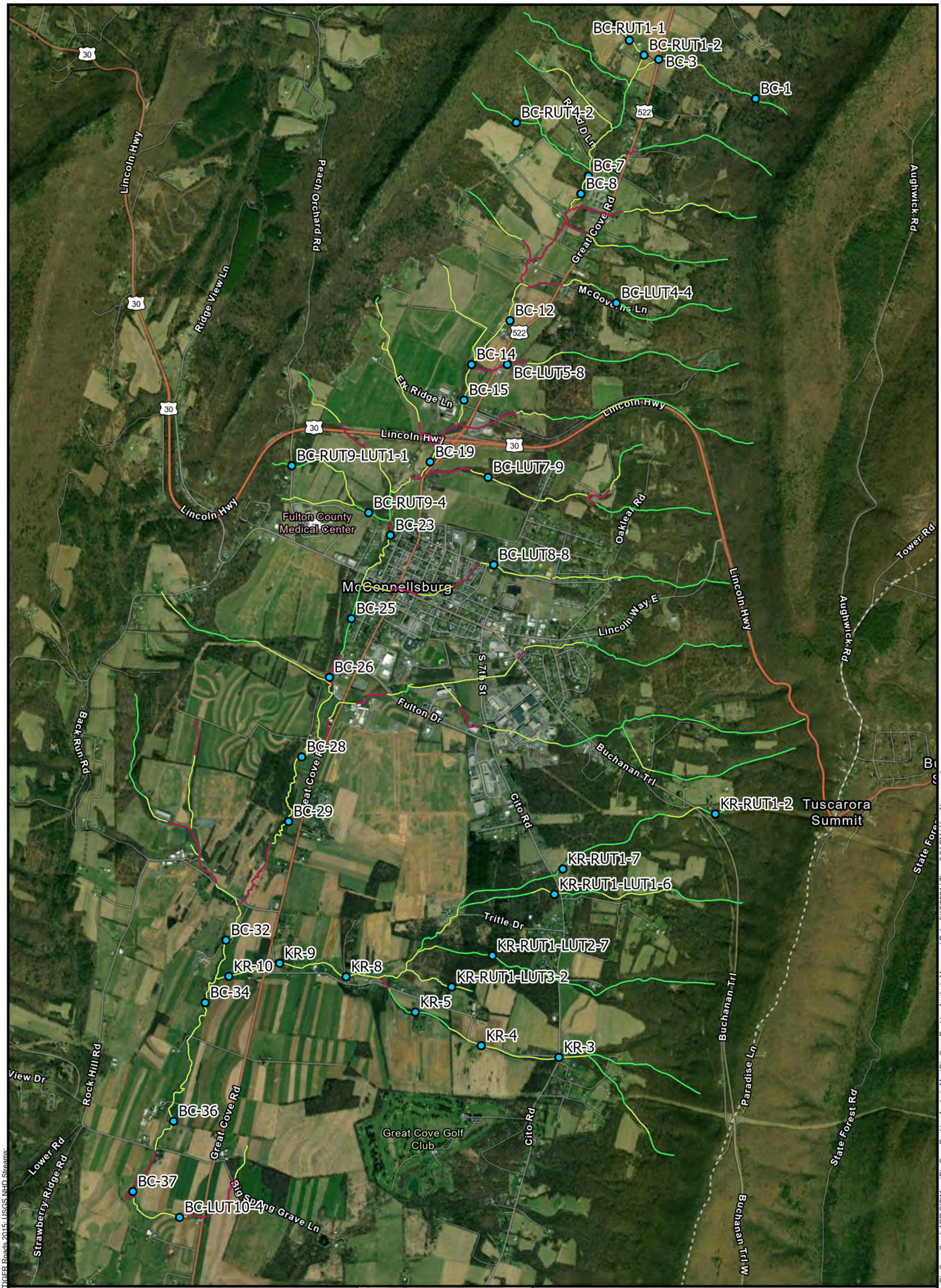
Table 2 shows each prioritized reach its reach length, recommended restoration approach and planning level cost estimate using these assumptions.

Proposed Project Area	Project Area Priority	Project Reach Length (LF)	Proposed NCD Stream Restoration Recommendations	Planning Level Cost
1	Medium	2551	Priority 3	$ 1,696,478
2	Medium	1779	Main Stem- Priority 2 Tributary- Priority 3	$ 1,183,105
3	Low	2357	Priority 2	$ 1,567,425
4	Medium	4014	Priority 2	$ 2,669,068
5	High	2898	Priority 2	$ 1,927,071
6	High	1468	Priority 3	$ 976,050
7a	Medium	2250	Priority 2	$ 1,496,555
7b		3668	Priority 2	$ 2,439,138
8	High	2821	Priority 2	$ 1,876,049
9	Medium	956	Priority 3	$ 635,794
10	Medium	1423	Priority 3	$ 946,405
11	Medium	2202	Priority 2	$ 1,464,645
12	High	978	Priority 3	$ 650,498
13	High	1320	Priority 3	$ 878,091
14	Medium	2043	Priority 3	$ 1,358,265
15	Low	1571	Priority 3	$ 1,044,849
16	High	12411	Priority 2	$ 8,253,485
17	High	2422	Priority 2	$ 1,610,350

Table 2: Recommended Restoration Design Approach and Planning Level Cost

7 References

1. Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C. EPA 843-K-12-006.
2. Fox, J., Swann, C. May 2023. *Upper Big Cove Watershed Characterization Report (for Fulton County Conservation District)*. Center for Watershed Protection. Fulton, MD.
3. Starr, R., Harman, W. and Davis, S., 2015. *Final Draft Function-Based Rapid Stream Assessment Methodology*. U.S. Fish and Wildlife Service. Annapolis, MD. CBFO-S15-06.



Legend

Stream Assessment Reach ID Points

Stream Condition Rating

- Good
- Fair
- Poor

Big Cove Existing Stream Conditions Rating Map

Fulton County, PA

Prepared For

N

0 1,000 2,000 Feet

Appendix A

Date: May 2024

Sources: ESRI Aerial Imagery 2017; Open Street Map; TIGER Roads 2015; USGS NHD Streams;

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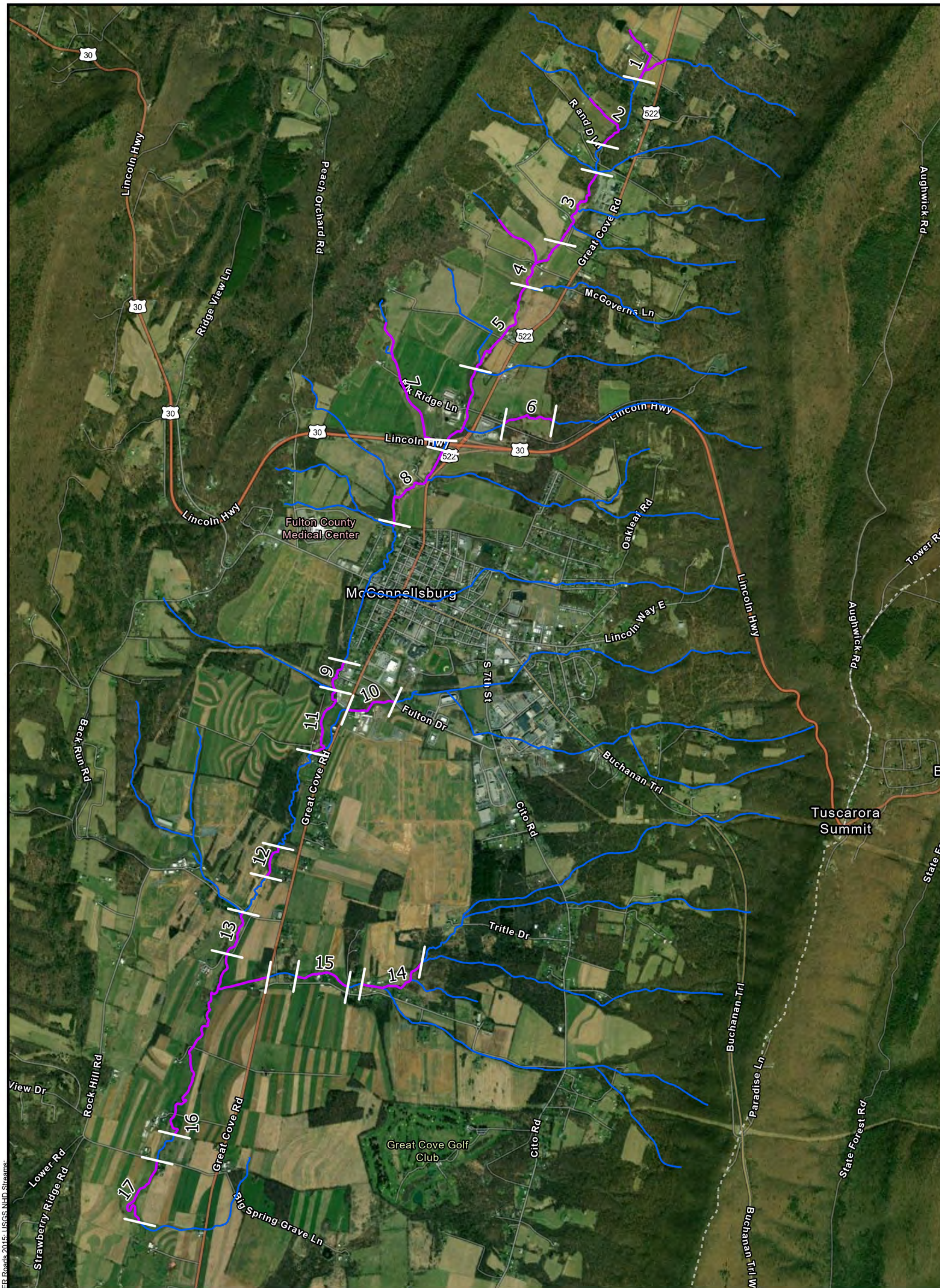

Legend

- Big Cove Hydrology
- Potential Stream Restoration Reach Separator

Big Cove Potential Stream Restoration Project Areas

Fulton County, PA

Prepared For

N

0 1,000 2,000 Feet

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Appendix B

Date:
May 2024

Sources: ESRI Aerial Imagery 2017; Open Street Map; TIGER Roads 2015; USGS NHD Streams

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Appendix C: Desktop and Field Assessment Summary

Label	STREAM LENGTH (FT)	Field Score	Desktop Score	Vegetation		Floodplain Connectivity		Lateral Stability		Bedform Diversity	
				Field	Desktop	Field	Desktop	Field	Desktop	Field	Desktop
BC-RUT1-2	766	Fair	Poor	3	3	2	3	2	3	3	2
BC-RUT1-1	573	Fair	Fair	2	3	2	2	2	2	3	2
BC-23	540	Poor	Good	3	3	3	3	2	2	2	2
BC-7	291	Fair	Good	1	1	2	2	2	1	2	2
BC-3	1950	Fair	Poor	3	3	2	2	2	2	3	2
BC-1	2000	Good	Good	1	1	1	1	1	1	2	2
BC-29	2000	Fair	Good	2	1	3	2	3	2	2	1
BC-14	253	Fair	Fair	2	3	2	3	2	2	2	2
BC-8	1024	Fair	Fair	2	1	1	3	2	2	2	3
BC-25	2000	Fair	Fair	2	3	3	2	2	2	2	2
BC-28	2000	Fair	Fair	2	3	1	2	2	2	1	2
BC-19	944	Fair	Poor	2	3	1	3	2	2	2	2
BC-26	1024	Poor	Fair	3	3	2	2	2	2	2	2
BC-LUT7-9	1000	Fair	Good	2	1	1	3	2	2	3	2
BC-RUT9-LUT1-1	1000	DRY	Good	N/A	2	N/A	2	N/A	2	N/A	2
BC-LUT4-4	1000	Good	Good	1	1	1	1	1	1	2	2
BC-RUT4-2	1000	Good	Good	1	1	1	1	1	1	2	2
BC-RUT9-4	1000	Good	Fair	2	3	1	3	1	2	2	2
BC-LUT8-8	1000	NOT A CHANNEL	Fair	N/A	3	N/A	2	N/A	3	N/A	2
BC-LUT5-8	1000	Poor	Poor	3	3	3	3	3	3	2	2
KR-3	2000	Fair	Good	3	1	3	3	2	1	2	2
KR-10	716	Fair	Fair	3	3	2	2	2	2	2	2
KR-4	2000	Fair	Fair	3	3	2	2	2	2	2	2
KR-5	2000	Good	Fair	2	3	1	2	2	2	2	2
KR-8	2000	Fair	Poor	3	3	2	3	2	2	3	2
KR-9	2000	Fair	Poor	3	3	2	3	2	2	2	2
KR-RUT1-2	1000	Fair	Good	2	1	2	2	2	1	2	2
KR-RUT1-7	1000	Good	Good	2	1	2	3	1	1	2	2
KR-RUT1-LUT1-6	1000	Fair	Good	2	1	2	3	2	1	2	2
KR-RUT1-LUT2-7	1000	Good	Good	2	1	1	3	1	1	2	1
KR-RUT1-LUT3-2	1000	Fair	Fair	2	3	1	2	1	2	2	2
BC-32	2000	Fair	Poor	3	3	2	2	2	2	2	2
BC-34	2000	Fair	Fair	3	3	2	3	2	2	2	2
BC-12	2000	Fair	Fair	2	3	2	3	2	2	2	2
BC-15	1453	Fair	Fair	2	3	2	3	2	2	2	2
BC-36	2000	Fair	Poor	3	3	2	3	2	2	2	2
BC-LUT10-4	1000	NOT A CHANNEL	Poor	N/A	3	N/A	3	N/A	3	N/A	3
BC-37	2000	Poor	Poor	3	3	3	2	2	3	2	2
	50534										

EXISTING and PROPOSED REACH LEVEL RAPID FUNCTION-BASED STREAM ASSESSMENT FIELD DATA SHEET

Watershed: ______________________ Rater(s):______________________
Stream: ______________________ Date: ______________________
Reach Length: ______________________ Latitude:______________________
Photo(s): ______________________ Longitude:______________________

Reach ID:	

Floodplain Connectivity (Vertical Stability)

Stream Function Pyramid Level 2 Hydraulics

1. Bank Height Ratio (BHR)	<1.20			1.21 - 1.50				>1.50		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
2a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, E, DA Streams)	>2.2			2.1 - 1.4				<1.4		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
2b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4			1.3 - 1.1				<1.1		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
3. Vertical Stability Extent	Stable			Localized Instability				Widespread Instability		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
If existing floodplain connectivity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason										

Floodplain Connectivity Overall EXISTING Condition F FAR NF Score:
Floodplain Connectivity Overall PROPOSED Condition F FAR NF Score:

Stream Function Pyramid Level 2 Hydraulics Overall EXISTING Condition F FAR NF Score:

Stream Function Pyramid Level 2 Hydraulics Overall PROPOSED Condition F FAR NF Score:

Riparian Vegetation

Stream Function Pyramid Level 3 Geomorphology

4. Riparian Vegetation Zone (EPA, 1999, modified)	Riparian zone extends to a width of >100 feet; good vegetation community diversity and density; human activities do not impact zone; invasive species not present or sparse			Riparian zone extends to a width of 25-100 feet; species composition is dominated by 2 or 3 species; human activities greatly impact zone; invasive species well represented and alter the community				Riparian zone extends to a width of <25 feet; little or no riparian vegetation due to human activities; majority of vegetation is invasive		
Left Bank Existing	10	9	8	7	6	5	4	3	2	1
Left Bank Proposed	10	9	8	7	6	5	4	3	2	1
Right Bank Existing	10	9	8	7	6	5	4	3	2	1
Right Bank Proposed	10	9	8	7	6	5	4	3	2	1
If existing riparian vegetation is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason										

Riparian Vegetation Overall EXISTING Condition F FAR NF Score:
Riparian Vegetation Overall PROPOSED Condition F FAR NF Score:

Lateral Stability

5. Dominant Bank Erosion Rate Potential	Dominate bank erosion rate potential is low or BEHI/NBS Rating: L/VL, L/L, L/M, L/H, L/VH, M/VL			Dominate bank erosion rate potential is moderate or BEHI/NBS Rating: M/L, M/M, M/H, L/Ex, H/L, M/VH, M/Ex, H/L, H/M, VH/VL, Ex/VL				Dominate bank erosion rate potential is high or BEHI/NBS Rating: H/H, H/Ex, VH/H, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex		
Existing Condition (Right bank)	10	9	8	7	6	5	4	3	2	1
Proposed Condition (Right Bank)	10	9	8	7	6	5	4	3	2	1
Existing Condition (Left bank)	10	9	8	7	6	5	4	3	2	1
Proposed Condition (Left Bank)	10	9	8	7	6	5	4	3	2	1
69. Lateral Stability Extent	Stable			Localized Instability				Widespread Instability		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
If existing lateral stability is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason										

Lateral Stability Overall EXISTING Condition F FAR NF Score:
Lateral Stability Overall PROPOSED Condition F FAR NF Score:

Bedform Diversity (Do not complete if stream is ephemeral)

7. Shelter for Fish and Macroinvertebrates (EPA 1999)	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, rubble, gravel, cobble and large rocks, or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)			20-70% mix of stable habitat; suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale)				Less than 20% mix of stable habitat; lack of habitat availability less than desirables obvious; substrate unstable or lacking		
Existing Condition	10	9	8	7	6	5	4	3	2	1
Proposed Condition	10	9	8	7	6	5	4	3	2	1
If existing bedform diversity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason										

Bedform Diversity Overall EXISTING Condition F FAR NF Score:
Bedform Diversity Overall PROPOSED Condition F FAR NF Score:

Stream Function Pyramid Level 3 Geomorphology Overall EXISTING Condition F FAR NF Score:

Stream Function Pyramid Level 3 Geomorphology Overall PROPOSED Condition F FAR NF Score:

Reach ID:	

Bankfull Determination and Rosgen Stream Classification

Rosgen Stream Type (Observation)					
Regional Curve (circle one):	Piedmont	Coastal Plain	Allegheny Plateau/Ridge and Valley	Urban	Karst
DA (sqmi)				Rosgen Valley Type	
BF Width (ft)				BF Area (sqft)	
BF Depth (ft)				Percent Impervious (%)	

Field Measurements

Parameter	Measurements and Ratios			
Water surface to geomorphic feature elevation difference				
Riffle Mean Depth at Bankfull Stage (dbkf)				
Riffle Width at Bankfull Stage (Wbkf)				
Riffle XS Area at Bankfull Stage (Abkf = dbkf*Wbkf)				
Floodprone Area Width (Wfpa) (Wfpa=Width at elevation determined by 2xDmax)				
Entrenchment Ratio (ER) (ER=Wfpa/Wbkf)				
Low Bank Height (LBH)				
Riffle Maximum Depth at Bankfull Stage (Dmax)				
Bank Height Ratio (BHR) (BHR=LBH/Dmax)				
BEHI/NBS Ratings and Lengths				

Restoration Potential Solution Approach Description	

RESTORATION ESTIMATED COST

Parameter	Category and cost			
Project difficulty	Minor localized bank grading (< 50% of reach), localized bank plantings (< 50% of reach), low cost bio-engineering (i.e.,…….),	Moderate localized bank grading (> 50% of reach), localized bank plantings (> 50% of reach), moderate cost bio-engineering, instream structures to address localized instability problem (i.e.,…….),	In-channel adjustments, bank grading, instream structures (i.e., vanes, cross vanes, W weirs, sills, etc.) reach-wide plantings and/or bio-engineering, repair of infrastructure,	In-channel adjustments and new channel construction, bank grading, instream structures (i.e., vanes, cross vanes, W weirs, sills, etc.) reach-wide plantings and/or bio-engineering, protections and repair of infrastructure
Cost Per Linear Foot	$100 - $200	$200 - $300	$300 - $400	$400 - $600

Cost/foot: $___________ Area to be treated: ___________ feet Total cost: $___________

Reach ID:	

Rapid Assessment Summary

Overall Watershed Condition   Good   Fair   Poor

Overall EXISTING Reach Level Stream Condition   F   FAR   NF   Score:

LEVEL 1 - F FAR NF Score: LEVEL 2 - F FAR NF Score: LEVEL 3 - F FAR NF Score: LEVEL 4 - F FAR NF Score: LEVEL 5 - F FAR NF Score:

If existing overall condition is FAR or NF, provide description of cause(s)	

	Functioning	Functioning-at-Risk: Trending Towards Functioning	Functioning-at-Risk: Trending Towards Not Functioning	Not Functioning
Channel Evolution Trend (Rosgen, 1996)	Little or no presence of active vertical or lateral stream adjustment; floodplain and/or flood prone area well developed, vegetated, and hydrologically connected to stream. Simon Stage 1 & 6. Rosgen Stream type E, C, B, A, & DA	Presence of localized vertical or lateral stream adjustment; floodplain well developed, vegetated and hydrologically connected to stream (floodplain can be newly formed within a channel that shows past active vertical or lateral stream adjustments). Simon Stage 5. Rosgen Stream type F→C, D→C, F→Bc, & G→B	Channel shows past evidence of active vertical downcutting and lateral widening but is currently rebuilding a new floodplain; presence of moderately defined riffles and pools; moderate aggradation occurring; width/depth ratio 12-40. Rosgen Stream type C→F, C→D, Bc→F, E→Gc, B→G & C→Gc	Channel has widespread active vertical downcutting and lateral widening; floodplain not hydrologically connected (abandoned floodplain); lack of well defined riffles and pools; incision ratio > 2.1; and for laterally meandering stream a sinuosity ratio < 1.2; entrenchment < 1.4. Simon Stage 2, 3, 4, & 5. Rosgen Stream type F, D, Gc, & G
	10 9	8 7 6	5 4 3	2 1

If existing channel evolution is FAR or NF, provide description of cause(s)	

Constraints

List all man-made features that have the potential to limit design solutions	

Restoration POTENTIAL Level

	5	4	3	2	1
	10 9	8 7	6 5	4 3	2 1
Provide reason(s) for restoration potential prediction					

Overall PROPOSED Reach Level Stream Condition and Uplift

LEVEL 1 - F FAR NF   LEVEL 2 - F FAR NF   LEVEL 3 - F FAR NF   LEVEL 4 - F FAR NF   LEVEL 5 - F FAR NF

Existing Condition - All parameters in Pyramid Levels 2 and 3 have Not Functioning scores. Parameters in Levels 4 and 5 are Not Functioning or Functioning-at-Risk. **Potential Condition** - Functioning scores for Levels 1-5.	**Existing Condition** -Mix of Not-Functioning and Functioning-at-Risk scores for parameter Levels 2 through 5. **Potential Condition** - Functioning scores for Levels 1-5. **or** **Existing Condition** All parameters in Pyramid Levels 2 and 3 have Not Functioning scores. **Potential Condition** - Functioning scores for Levels 1-3.	**Existing Condition** -Mix of Not-Functioning, Functioning-at-Risk and Functioning scores for parameter Levels 2 through 5. **Potential Condition** - Functioning scores for Levels 1-5. **or** **Existing Condition** Mostly Functioning-at-Risk and Functioning scores for parameter Levels 2 through 3. May include some Not-Functioning scores. **Potential Condition** - Functioning scores for Levels 1-3.
10 9 8	7 6 5 4	3 2 1

If any Pyramid Level proposed condition cannot potentially achieve F, provide reason(s)	

APPENDIX D. MODEL MY WATERSHED (MMW) DATA

Animal	Count
Chickens, Broilers	400
Chickens, Layers	0
Cows, Beef	127
Cows, Dairy	228
Horses	29
Pigs/Hogs/Swine	1,347
Sheep	93
Turkeys	289

Type	NLCD Code	Area (km^2)	Coverage (%)	Active River Area (km^2)
Open Water	11	0.01	0.02	0
Perennial Ice/Snow	12	0	0	0
Developed, Open Space	21	2.3	5.31	0.58
Developed, Low Intensity	22	2.1	4.84	0.56
Developed, Medium Intensity	23	1.1	2.53	0.3
Developed, High Intensity	24	0.48	1.11	0.16
Barren Land (Rock/Sand/Clay)	31	0.04	0.1	0
Deciduous Forest	41	17.25	39.79	3.15
Evergreen Forest	42	0.17	0.4	0.06
Mixed Forest	43	2.42	5.58	0.71
Shrub/Scrub	52	0.12	0.27	0.03
Grassland/Herbaceous	71	0.09	0.21	0.02
Pasture/Hay	81	8.75	20.19	2.91
Cultivated Crops	82	8.46	19.51	1.54
Woody Wetlands	90	0.06	0.13	0.06
Emergent Herbaceous Wetlands	95	0	0.01	0
Total		43.35	100	10.07

Stream Order	Total Length (km)	Mean Channel Slope (%)
1st	21.45	4.78%
2nd	7.11	0.75%
3rd	2.27	0.29%
4th	0	No Data
5th	0	No Data
6th	0	No Data
7th	0	No Data
8th	0	No Data
9th	0	No Data
10th	0	No Data
Other	6.03	No Data
Combined	36.86	2.95%

Length in agricultural areas = 14.35 km

Length in non-agricultural areas = 22.51 km

Sources	Sediment (kg)	Total Nitrogen (kg)	Total Phosphorus (kg)
Hay/Pasture	552,787.70	2,474.30	710.5
Cropland	1,900,222.70	8,107.00	1,920.30
Wooded Areas	5,175.50	207	14.7
Wetlands	9.5	2	0.1
Open Land	726	10.4	0.8
Barren Areas	6.3	2.2	0.1
Low-Density Mixed	2,978.30	79.2	8.4
Medium-Density Mixed	7,980.30	172.9	17.7
High-Density Mixed	3,490.50	75.6	7.8
Low-Density Open Space	3,273.00	87.1	9.3
Farm Animals	0	3,364.20	894
Stream Bank Erosion	725,611.00	611	164
Subsurface Flow	0	35,402.70	388.5
Point Sources	0	1,477.00	45
Septic Systems	0	385.4	0

Entire Watershed

	Sediment (lbs/yr)	TN (lbs/yr)	TP (lbs/yr)
Initial MMW Loads	7,066,754	115,670	9,220
Loads Removed w/Existing Urban BMPs	215,245	354	315
Loads Removed w/Proposed Urban BMPs	838,813	1,401	1,254
Loads Removed w/Existing Agricultural BMPs	1,340,388	2,648	1,265
Loads Removed w/Proposed Agricultural BMPs	2,882,419	6,857	3,798
Loads Removed w/Existing Floodplain Restoration BMPs	-	-	-
Loads Removed w/Proposed Floodplain Restoration BMPs	-	-	-
Total Loads Removed	5,276,865	11,206	6,632
New Reduced Load	1,789,889	104,410	2,681
Percent Reduction (0-100)	*74.7%*	*9.7%*	*71.9%*
Total Baseline Load (1)	5,511,121	112,668	7,640
Total Loads Removed from Baseline (2)	3,721,232	8,258	5,053
Percent Reduction from Baseline Load	*67.5%*	*7.3%*	*66.1%*

(1) After existing BMPs have been accounted for

(2) After proposed BMPs have been accounted for

Appendix E. PA DEP Load Calculations

BUREAU OF CLEAN WATER
PRESCRIBED SEDIMENT REDUCTIONS FOR BIG COVE CREEK
FULTON COUNTY
DRAFT FOR STAKEHOLDERS, APRIL 14, 2023

Prepared by:
Michael Morris
PA Department of Environmental Protection
Office of Water Programs
Bureau of Clean Water
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Harrisburg, PA 17105

2023

Photo/Image Credit:
Aside from the imagery used in mapping, all photographs by Michael Morris, DEP

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EXECUTIVE SUMMARY

Portions of the Big Cove Creek watershed in Fulton County were listed as Aquatic Life Use impaired per the 2022 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. These impairments were partially attributed to excessive siltation from agriculture. The purpose of this study is to prescribe sediment reduction goals as a basis for the development of a watershed restoration plan. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from similar unimpaired watersheds were used to calculate the reduction goals.

Existing annual average sediment loading within the Big Cove Creek subwatershed was estimated to be 7,066,754 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 60% to 2,814,779 pounds per year. To achieve this reduction while maintaining a 10% margin of safety, annual average loading from croplands should be reduced by 72%, while loading from streambanks, hay/pasture lands, and developed lands should each be reduced by 53%. Allocation of annual average sediment loading among the restoration plan variables is summarized in Table 1.

Table 1. Summary of ARP variables for the Big Cove Creek subwatershed. All values are annual averages in lbs/yr.

AL	UF	SL	LNR	ASL
2,814,779	281,478	2,533,301	18,817	2,514,484

AL=Allowable Load; UF = Uncertainty Factor; SL = Source Load. The SL is further divided into LNR = Loads Not Reduced and ASL=Adjusted Source Load.

INTRODUCTION

Big Cove Creek is a tributary of Licking Creek in Fulton County (Figure 1). The purpose of this study is to establish sediment reduction goals to address siltation impairments occurring downstream of McConnellsburg (Figure 2). Because the mainstem was not considered impaired further downstream of what is shown in Figures 1 and 2, only the headwaters area, henceforth referred to as the “Big Cove Creek subwatershed” will be considered in this study. While another major tributary to Big Cove Creek, Spring Run, was also listed as impaired for siltation, reduction goals for it were prescribed in a 2018 TMDL developed by the Pennsylvania Department of Environmental Protection (DEP).

The Big Cove Creek subwatershed, as delineated in Figure 1, was approximately 17 square miles, and all its stream segments were designated Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93. Big Cove Creek is notable for its trout fishing opportunities. According to the Pennsylvania Fish and Boat Commission (PFBC), there are nearly 16 miles of stocked trout waters in the greater Big Cove Creek watershed. Most of these are on the mainstem of Big Cove Creek, starting in the lower reaches of the present study subwatershed and extending downstream to near its mouth with Licking Creek (PFBC 2022). This stocked area includes nearly a mile of “Keystone Select” “Delayed Harvest

Artificial Lures Only" waters that are stocked with larger trout and managed to enhance recreational angling opportunities.

The recreational value of the Big Cove Creek watershed could be enhanced through the establishment of robust wild trout populations. According to PFBC, no stream reaches within the entire Big Cove Creek watershed were identified as harboring naturally reproducing trout populations (PFBC 2022), likely at least in part due to the aforementioned water quality impairments. It is hoped that by restoring water quality in the headwaters area, aquatic health will improve both within the study subwatershed and further downstream.

According to the 2022 Final Integrated Report (DEP 2022b), the mainstem below McConnellsburg and some reaches within a tributary system were listed as impaired for siltation (Figure 2). Additional causes of impairment within the subwatershed included excessive nutrients and habitat alterations associated with agriculture, as well as unknown causes associated with development (Figure 1 and Table 2). Such impairments are consistent with expectations since over half of the land area within the subwatershed was devoted to anthropogenic landuses, and most of the forested lands were relegated to the margins of the subwatershed (Figure 1). Consequently, valley stream segments tended to be bordered by agricultural and developed lands which may result in both poor habitat and direct nonpoint source pollution runoff to streams. National Pollution Discharge Elimination System (NPDES) permitted point sources however appeared to be a minor source of sediment on a watershed scale (Table 3).

The removal of natural vegetation and soil disturbance associated with agriculture and land development increases erosion leading to sediment deposition in streams. Excessive fine sediment deposition may destroy the coarse-substrate habitats required by many stream organisms. While Pennsylvania does not have numeric water quality criteria for sediment, it does have applicable narrative criteria:

> *Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. (25 PA Code § 93.6 (a))*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code, § 93.6 (b))*.

The Fulton County Conservation District, in cooperation with the Center for Watershed Protection, are seeking to develop a Watershed Implementation Plan that would qualify projects within the study subwatershed (Figure 1) for funding under Section 319 of the Clean Water Act. However, since there are currently no Total Maximum Daily Loads (TMDLs) or other prescribed pollution reductions for this subwatershed, DEP's TMDL section has developed this document to estimate the sediment reductions needed to achieve water quality standards. While other sources of impairment such as habitat alterations and excessive nutrients may also exist, it is believed that these problems may be remedied by the same best management practices that will be used to address siltation problems. Thus for simplicity, along with the fact that the nutrient impairments were diagnosed with outdated methodology, it is proposed to focus on one pollutant, siltation.

Table 2. Aquatic Life Use impaired stream segments in the Big Cove Creek subwatershed per the 2022 final Pennsylvania Integrated Report (DEP 2022b). See Appendix A for more information on the listing process and Appendix C for a listing of each segment.

Source	USEPA 305(b) Cause Code	Miles
Agriculture	Siltation	0.5
Grazing in Riparian or Shoreline Zones	Siltation	5.9
Grazing in Riparian or Shoreline Zones	Nutrients	3.2
Agriculture	Habitat Alterations	0.5
Highway/Road/Bridge Runoff (Non-Construction Related)	Cause Unknown	1.1
Recreation and Tourism (Non-Boating)	Cause Unknown	0.5

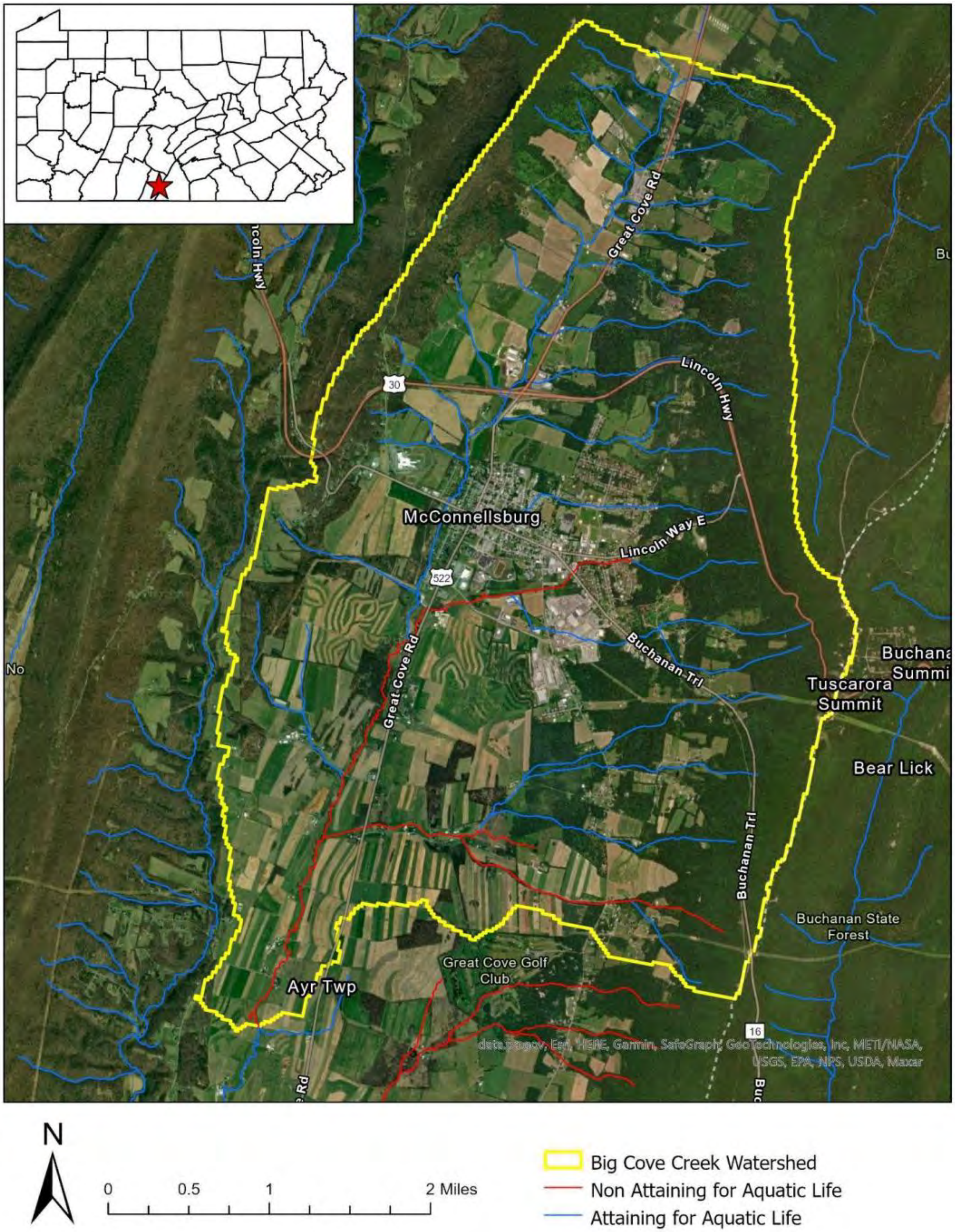

Figure 1. Big Cove Creek subwatershed. Aquatic Life Use impairments per the 2022 Integrated Report (DEP 2022b) are shown in red.

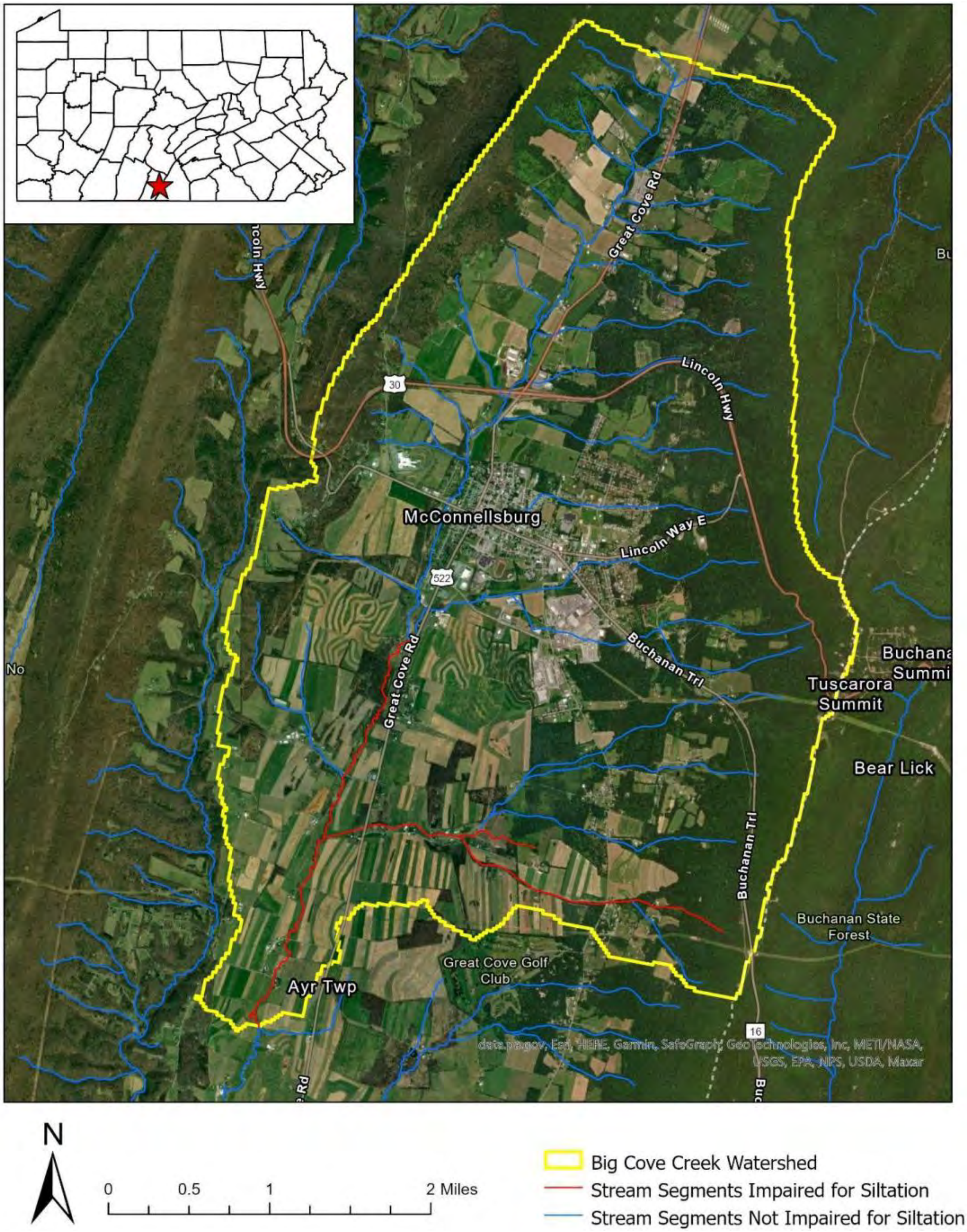

Figure 2. Big Cove Creek subwatershed. Siltation impairments per the 2022 Integrated Report (DEP 2022b) are shown in red.

Table 3. Existing NPDES-permitted discharges in the Big Cove Creek subwatershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Mean, lbs/yr
PA0020508	McConnellsburg STP[1]	5,769
PAR113553	JLG IND INC[2]	N/A
PAR113514	JLG IND INC[2]	N/A
PAM418012	RC Mellott Estate Shale Pit[3]	N/A
PAM415001	Glazier Pit[3]	N/A
PAM416008	P&W Excavating, Inc.[4]	N/A

Permits within the delineated watershed were based on DEP's eMapPA (DEP 2022a) and USEPA's Watershed Resources Registry (USEPA 2022).

[1]**McConnsellsburg Sewage Treatment Plant**. The above load was based on an analysis of electronic discharge monitoring report (eDMR) data. There were eight years (2013-2021, excluding 2015) where total suspended solids (TSS) loads, in lbs/d, were reported as monthly averages. The value for each month was multiplied by the number of days in each month and all the months within the year were summed to produce an annual value. The value reported above is the average of the eight annual values.

[2]**JLG Industries Inc**. Industrial stormwater permits without loading limits or eDMR reporting requirements.

[3]Small noncoal mining permit. Facility has no outfall (Michael Schirato, DEP, personal communication).

[4]Large noncoal mining operation with one permitted stormwater outfall. This outfall only discharges during precipitation events and does not have a TSS limit (Michael Schirato, DEP, personal communication).

SELECTION OF THE REFERENCE WATERSHED

Because Pennsylvania does not have numeric water quality criteria for sediment, the "Reference Watershed Approach" was used. This method estimates pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. Then, the loading rate in the unimpaired watershed is scaled to the area of the impaired watershed so that necessary load reductions may be calculated. It is assumed that reducing loading rates in the impaired watershed to the levels found in the reference watershed will result in the amelioration of the siltation impairments.

In addition to anthropogenic influences, there are many other natural factors affecting sediment loading and accumulation rates in a watershed. Thus, selection of a reference watershed with similar natural characteristics as the impaired watershed is crucial. Failure to use an appropriate reference watershed could result in problems such as the setting of sediment reduction goals that are unachievable, or nonsensical calculations that suggest that sediment loading in the impaired watershed should be increased.

To find a reference, GIS data layers largely consistent with the stream impairments noted in Pennsylvania's Integrated Report (DEP 2022b) were used to search for nearby watersheds that were similar to the Big Cove Creek subwatershed but lacked stream segments listed as impaired for Aquatic Life Use. Once potential references were identified, they were screened to determine which ones were most like the impaired subwatershed with regard to factors such as landscape position, topography, hydrology, soil drainage types, land cover etc. Furthermore, benthic macroinvertebrate and physical habitat assessment scores were reviewed to confirm that a reference was acceptable. Preliminary modelling was conducted to make sure that use of a particular reference would result in reasonable pollution reductions.

To increase the likelihood of finding similar references, special emphasis was given to searching for subwatersheds that, like the Big Cove Creek subwatershed, were within the Appalachian Mountain section of the Ridge and Valley Physiographic Province. Numerous potential candidates from this area were explored, but this list was narrowed down to two subwatersheds, Cove Creek in Bedford County (Figure 3) and Wooden Bridge Creek in Fulton County (Figure 4). Both were near the Big Cove Creek subwatershed; the Cove Creek subwatershed was about thirty miles due west while the Wooden Bridge Creek subwatershed was only about eight miles to the northwest (Figure 5). Furthermore, both subwatersheds lacked stream segments listed as Aquatic Life Use impaired per the 2022 Integrated Report (DEP 2022b), despite having substantial, though lesser agricultural land cover versus the Big Cove Creek subwatershed (Table 4). There was also significant development in the reference subwatersheds, though again, the amount was less relative to the Big Cove Creek subwatershed (Table 4).

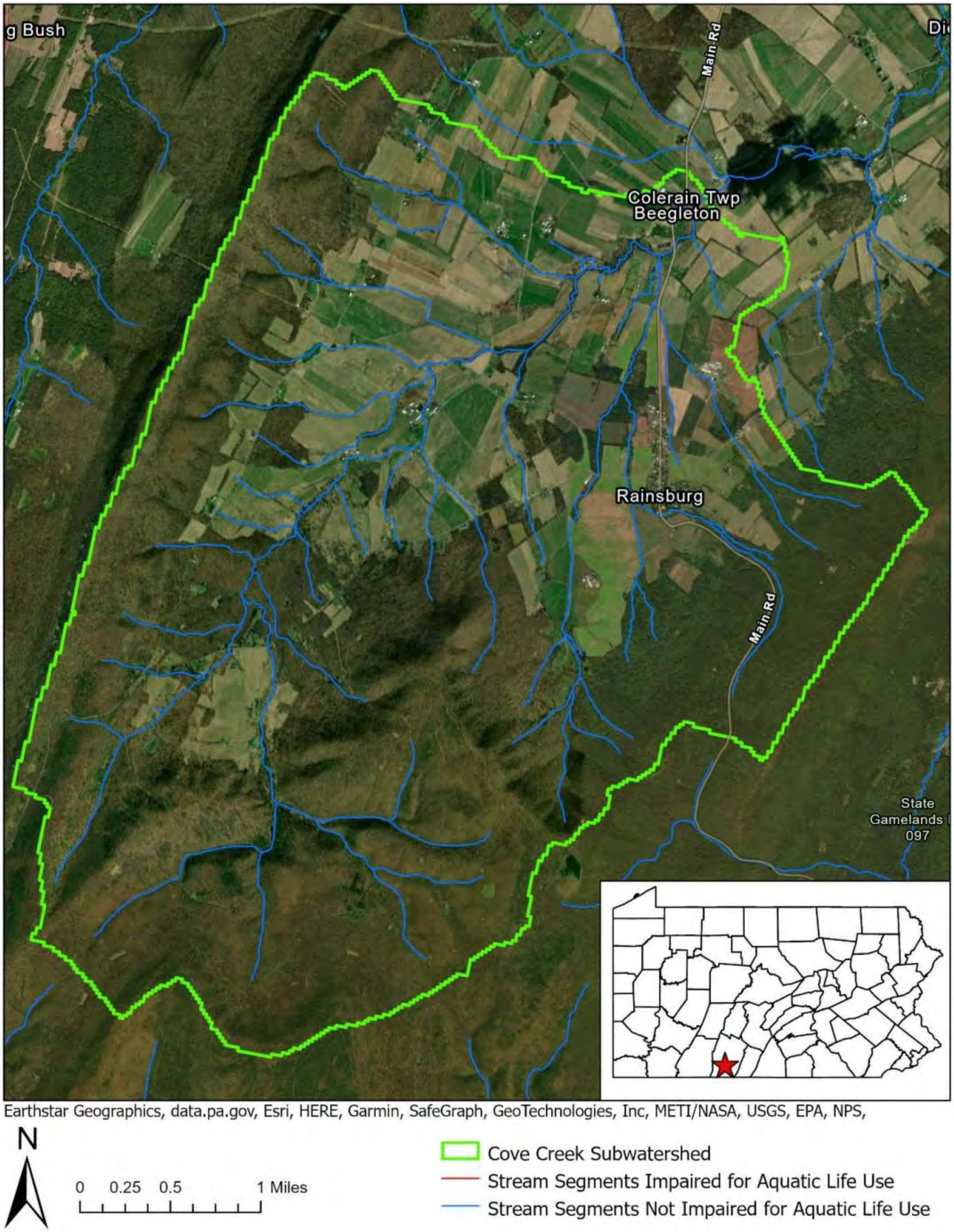

Figure 3. Cove Creek subwatershed. All stream segments were listed as supporting their Aquatic Life Use per the 2022 Integrated Report (DEP 2022b).

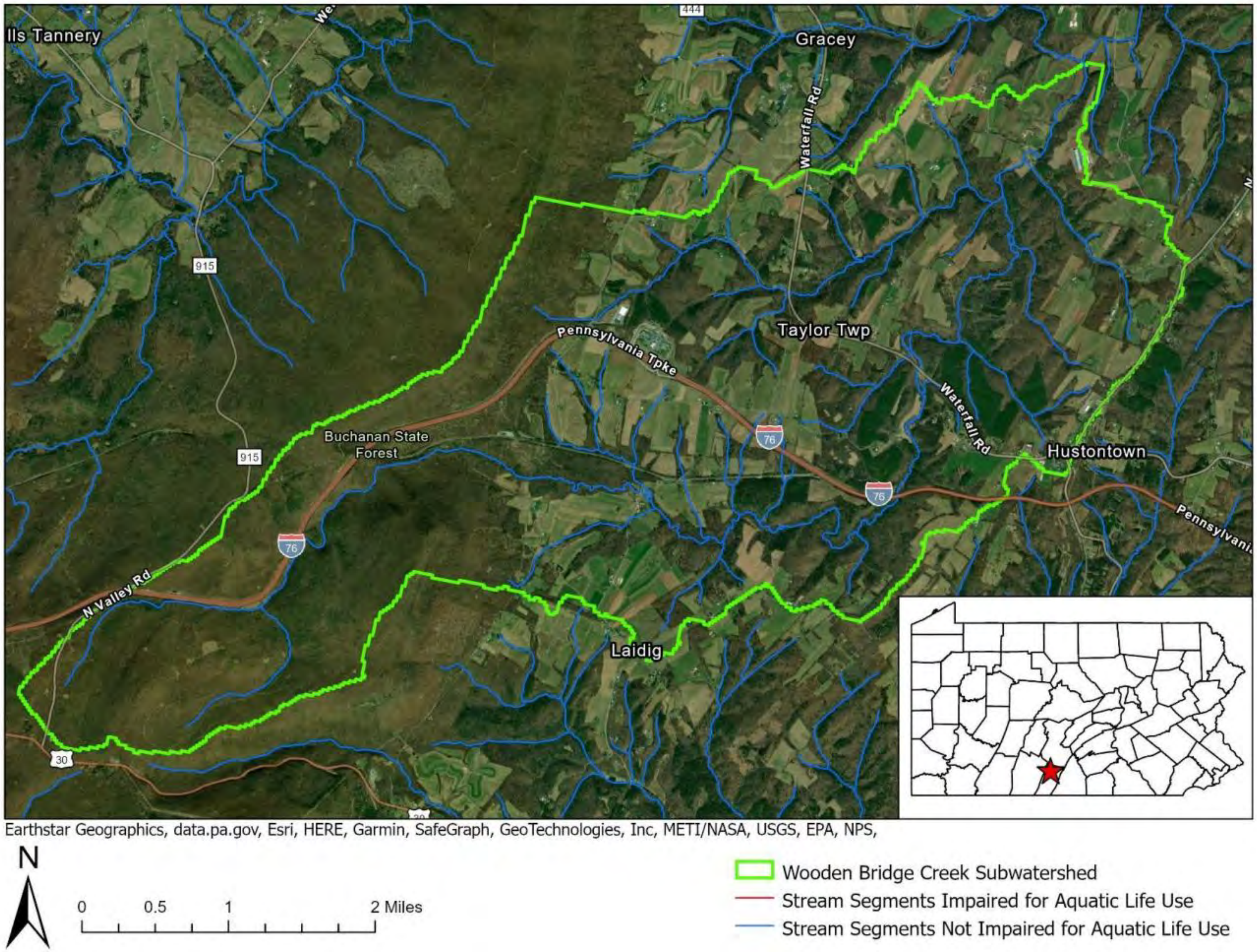

Figure 4. Wooden Bridge Creek subwatershed. All stream segments were listed as supporting their Aquatic Life Use per the 2022 Integrated Report (DEP 2022b).

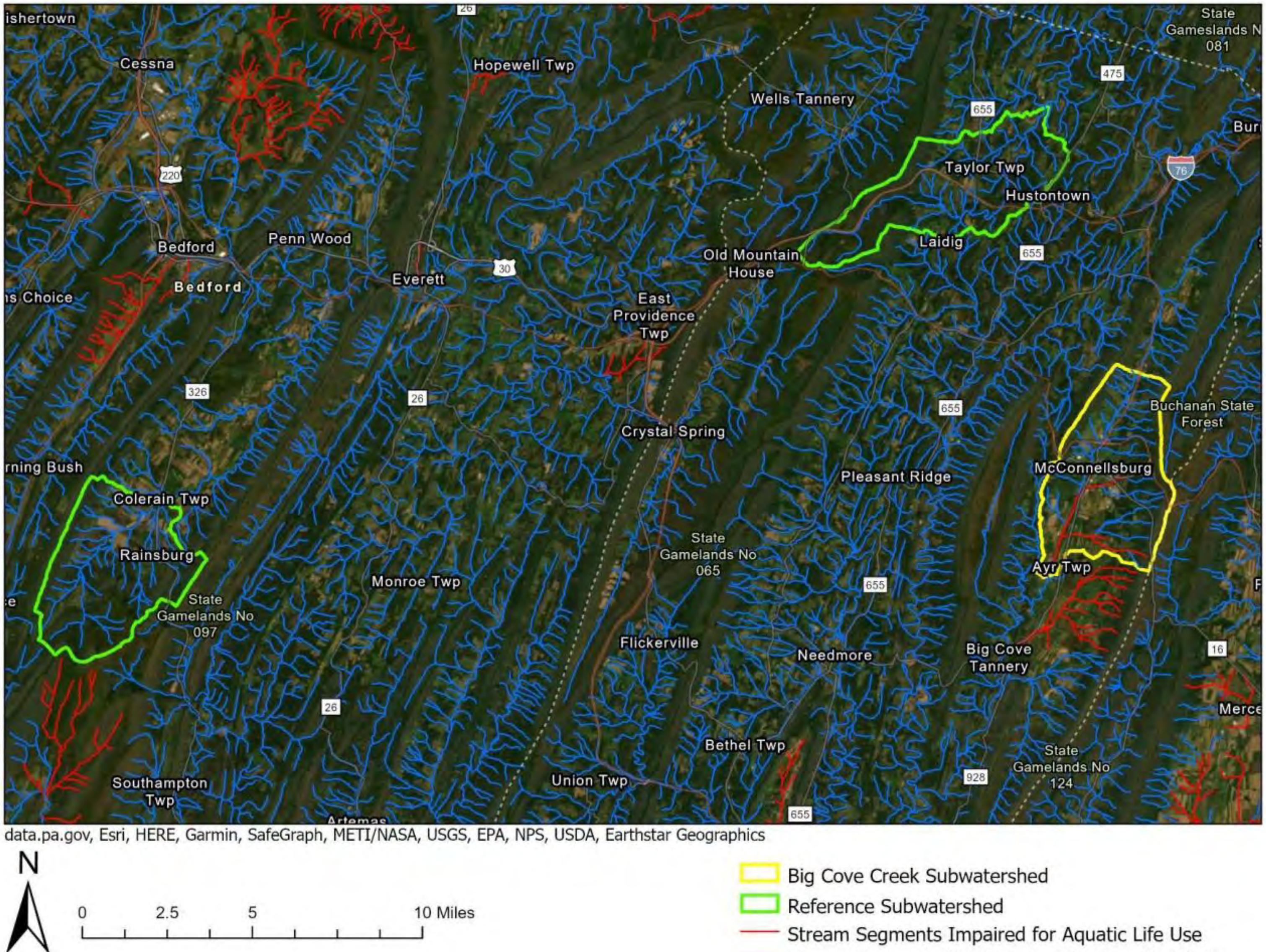

Figure 5. Big Cove Creek and potential reference subwatersheds. Aquatic Life Use impairments were based on the 2022 Integrated Report (DEP 2022b).

Table 4. Comparison of the Big Cove Creek and potential reference subwatersheds.

Watershed	Big Cove Creek	Cove Creek	Wooden Bridge Creek
Physiographic Province[1]	Appalachian Mountain Section of the Ridge and Valley Physiographic Province		
Land Area (ac)	10,712	10,388	10,544
Landuse[2] **(%)**			
Agriculture	40	31	27
Forest/Natural Vegetation	46	64	64
Developed	14	5	8
Soil Infiltration[3] **(%)**			
A	9	13	15
B	49	42	34
B/D	1	3	4
C	27	30	12
C/D	0	6	<1
D	13	6	36
Dominant Bedrock[4] **(%)**			
Argillaceous Sandstone	-	-	10
Dolomite	33	4	-
Limestone	25	23	-
Quartzite	4	0	-
Sandstone	8	33	90
Shale	27	39	-
Siltstone	2	-	-
Average Precipitation[5] **(in/yr)**	40.4	42.5	40.4
Average Surface Runoff[5] **(in/yr)**	2.8	1.5	2.2
Average Elevation[5] **(ft)**	1,132	1,712	1,267
Average Slope[5] **(%)**	12	15	13
Average Stream Channel Slope[5] **(%)**			
1st order	7.3	5.1	4.2
2nd order	2.7	1.5	2.8
3rd order	0.8	0.3	0.6
4th order	0.3		0.4

[1]Per pags_physsections2008 GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources

[2]Based on MMW output utilizing NLCD 2019

[3]Based on MMW output utilizing USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils.

[4]Per Bedrock_V GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources.

[5]Hydrologic and terrain variables were generated by MMW.

As would be expected given their lesser anthropogenic lands, the amount of naturally vegetated lands, primarily forests, was greater in both reference watersheds (Table 4) versus the Big Cove Creek subwatershed. Like the Big Cove Creek subwatershed, much of the forested land within the Cove Creek subwatershed was relegated to the margins of the watershed (Figure 3). One difference however was that the uppermost portion of the Cove Creek subwatershed was forested while the uppermost portion of the Big Cove Creek subwatershed was within the agricultural valley (Figures 3 and 1). The Wooden Bridge Creek subwatershed differed in that large forested tracts tended to occur along stream segments within the middle and lower subwatershed, which may protect these stream segments from surrounding agriculture.

All three watersheds exhibited similar distributions of soil drainage classes with weighting towards moderate infiltration soils, though the Wooden Bridge Creek subwatershed had more very slow infiltration soils (Table 4). Even so, estimated surface runoff rates were highest in the Big Cove Creek subwatershed, at least in part due to its greater urbanized area (Table 4). The average slope in all three watersheds was approximately the same (12-15%) and the slope of the highest order stream segments among the subwatersheds was similarly low (0.3 to 0.4%) (Table 4).

A major distinguishing factor among the subwatersheds was bedrock geology. The Big Cove and Cove Creek subwatersheds both had substantial karst (limestone and dolomite) formations, though the amount was greater in the Big Cove Creek subwatershed (Table 4). In contrast, the Wooden Bridge Creek subwatershed was dominated by sandstone and lacked karst geology (Table 4). Because karst geology has such a strong influence on a watershed's hydrogeologic characteristics, use of a karst reference would be ideal. However, finding large, low-gradient karst references in Pennsylvania is often problematic because Aquatic Life Use impairments typify such areas, as karst geology produces some of the state's best agricultural soils.

Whereas stream segments within the Big Cove Creek subwatershed were designated Cold Water Fishes at 25 Pa. Code § 93, stream segments were designated High Quality – Cold Water Fishes within the Wooden Bridge Creek subwatershed and Exceptional Value within the Cove Creek subwatershed. Using a special protection watershed as a reference for a non-special protection watershed is concerning in that overly stringent prescribed pollution reductions may result. However, this concern was dismissed because, as will be explained later, assessment data and site observations suggested that neither one of these potential reference watersheds appeared to be atypically healthy. Finally, like the impaired subwatershed, NPDES permitted point sources appeared to be either negligible or nonexistent in the potential references (Tables 3, 5 and 6).

Table 5. Existing NPDES permitted discharges in the Cove Creek reference subwatershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Load, mean lbs/yr
None	None	NA

Permits within the delineated watershed were based on eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

Table 6. Existing NPDES permitted discharges in the Wooden Bridge Creek subwatershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Load, mean lbs/yr
PA0088242	Country View Farms LLC[1]	NA
PA0248029	Hustontown STP[2]	178
PA0083186	HMS Host Sideling Hill TPK Plaza[3]	197

Permits within the delineated watershed were based on eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

[1]In Pennsylvania, routine, dry-weather discharges from concentrated animal feeding operations (CAFOs) are not allowed. Wet weather discharges are controlled through best management practices, which result in infrequent discharges from production areas and reduced sediment loadings from lands under the control of CAFOs owner or operators, such as croplands where manure is applied. Although not quantified in this table, pollutant loading from CAFOs is accounted for in the modeling of land covers within the watershed, with the assumption of no additional CAFO-related best management practices.

[2]**Hustontown Joint Sewer Authority-** The average annual load reported above was based on an analysis of eDMR data. Monthly reported average monthly TSS loads, in lbs/d, from years 2020 and 2021 were analyzed. These reported loads were multiplied by the number of days in the month, and all months within each year were summed to produce average annual loads. The two annual loads were then averaged. Note that where eDMR data included ”<” signs, the numeric value without the “<” sign was used in calculations.

[3]**HMS Host Sideling Hill TPK Plaza-** The average annual load reported above was based on an analysis of eDMR data. Monthly reported average monthly flows, in MGD, along with monthly reported average monthly TSS concentrations, in mg/l, were used to calculate average monthly TSS loads, in lbs/d, for each month for years 2019, 2020, and 2021. These values were multiplied by the number of days in each month, and then all months were summed within a year to calculate a yearly load. The three yearly total loads were then averaged. Note that where eDMR data included “<” signs, the numeric value without the “<” sign was used in the calculations.

Based on limited assessment data, the Big Cove Creek subwatershed appeared to have a severe siltation problem within the lower watershed (south of McConnellsburg, Figure 6 and Table 7). The sediment deposition plus embeddedness couplet score at the site sampled within this area was only a 13 out of 40 possible points, which scores below the impairment threshold (≤24) (Walters 2017). Benthic macroinvertebrates were not sampled in this area. Similarly, the lower mainstem of the largest tributary in the lower watershed (Figure 6, Table 7) also exhibited heavy siltation, with a sediment deposition plus embeddedness couplet score of only 6. Not surprisingly, the benthic macroinvertebrate community was impaired at this site. In contrast, sediment deposition plus embeddedness couplet scores did not indicate impairment further upstream, though the macroinvertebrate community was determined to be impaired at one other site (Table 7, Figure 6).

This however does not necessarily indicate that landuse conditions are not problematic in the upper watershed, as erosion from these areas may be sources of the siltation that settles out further downstream.

Sample coverage was poor and the samples that did exist were decades old in the Cove Creek subwatershed. However, this limited information suggests a lack of impairments for siltation, at least within the two sites that were sampled (Table 7, Figure 7). When considered against more modern criteria relative to what was used at the time, the site within the upper watershed appeared to harbor a very healthy benthic macroinvertebrate community. However, the site near the subwatershed outlet appeared to be slightly impaired (per non-special protection standards), not because of its “Index of Biotic Integrity” score, but rather due to a lack of stoneflies in the subsample. In contrast, the Wooden Bridge Creek subwatershed has been sampled extensively and more recently (Table 7, Figure 8), and these data suggest healthy macroinvertebrate communities. With regard to sediment deposition plus embeddedness scores couplet scores, the majority of samples, including all of the more recent sampling, exceeded the impairment threshold (Table 7). However, interspersed amongst these samples were poorer scores that suggested localized siltation problems, though perhaps not rising to the level of widespread impairment.

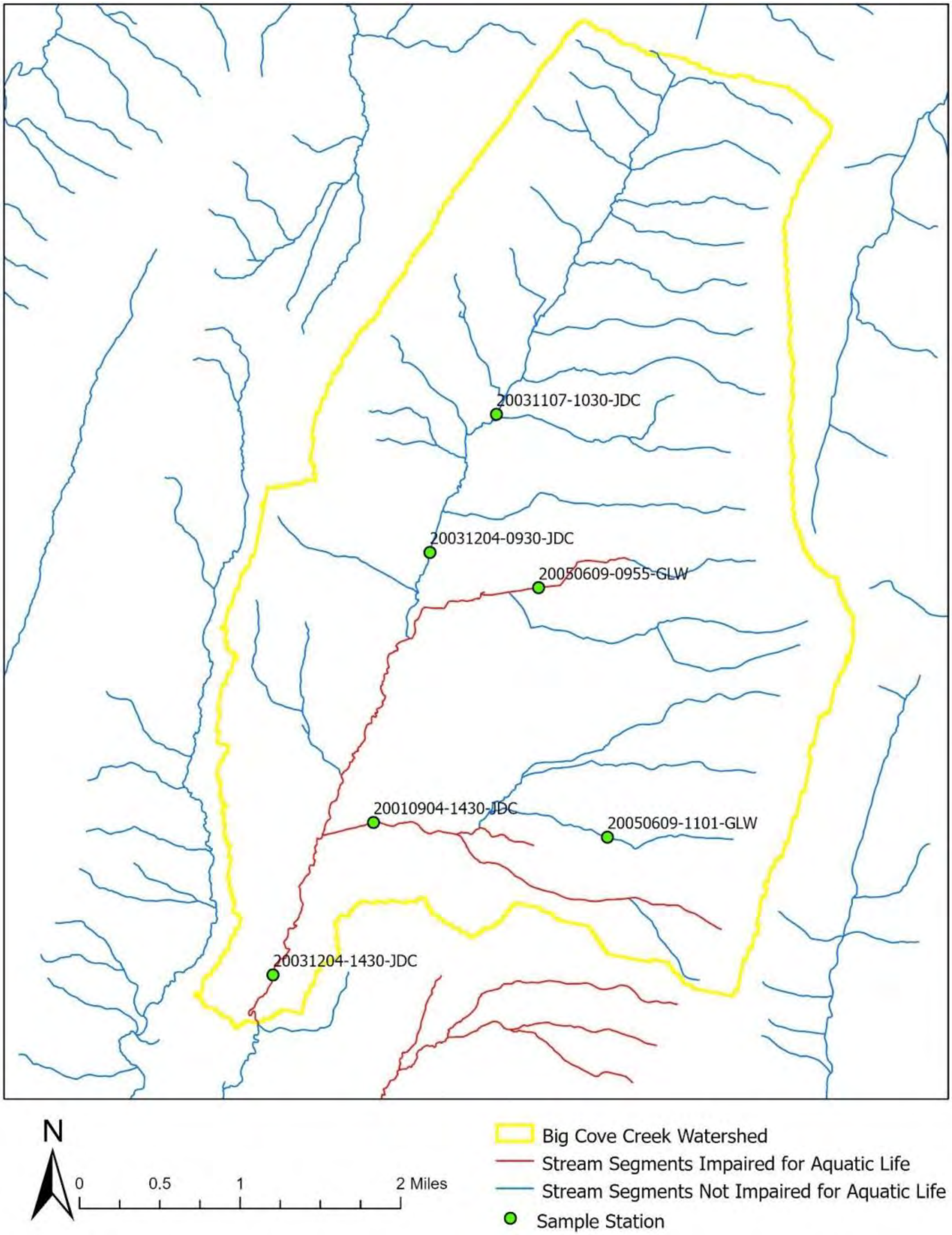

Figure 6. DEP assessment sites within the Big Cove Creek subwatershed. The labels correspond to those used in Table 7.

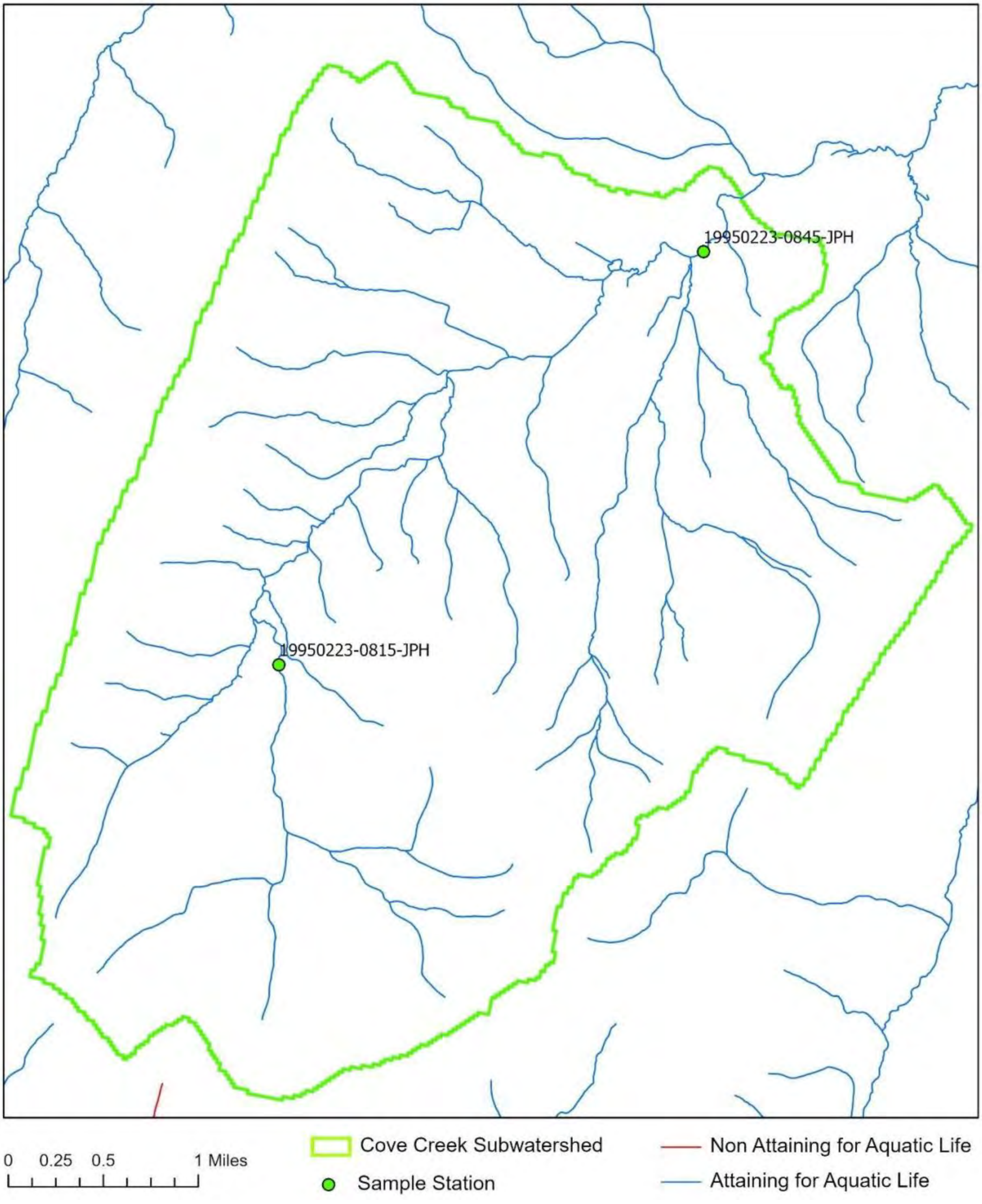

Figure 7. DEP assessment sites within the Cove Creek subwatershed. The labels correspond to those used in Table 7.

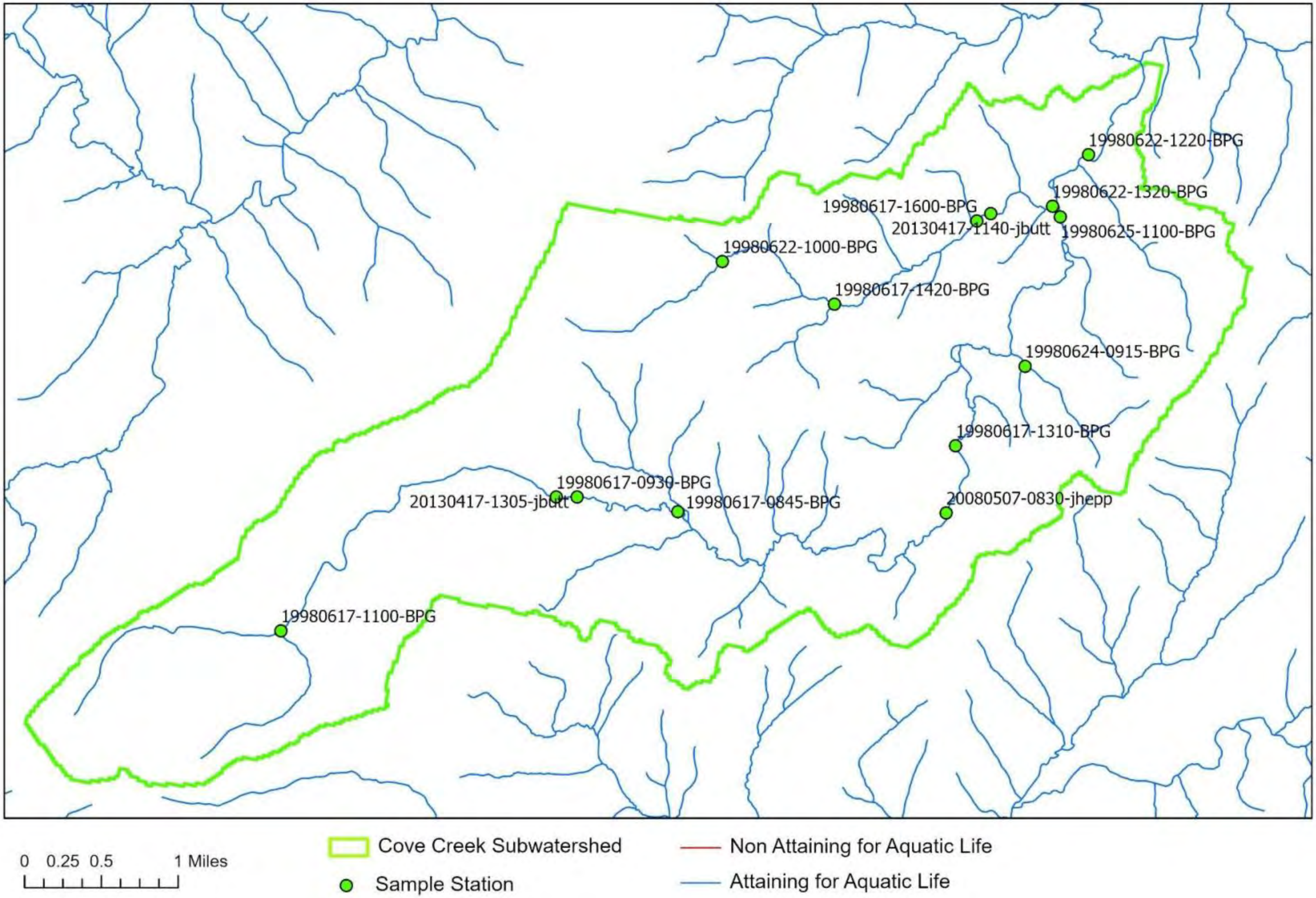

Figure 8. DEP assessment sites within the Wooden Bridge Creek subwatershed. The labels correspond to those used in Table 7.

Table 7. Summary of DEP assessment data in the Big Cove Creek and potential reference subwatersheds. The following describes how to interpret this data in reference to non-special protection impairment thresholds. SSWAP samples were evaluated based on a series of questions from which the biologist drew conclusions about impairment status. More recent Stream MI samples utilize an Index of Biotic Integrity (IBI) score. For October-May 6d-200 samples, IBI scores <50 suggest impairment (Shull and Whiteash 2021). This value is relevant for all stream MI samples in the Wooden Bridge Creek subwatershed. For the Cove Creek 2d-100 samples, IBI scores <50 would suggest impairment (Gary Walters, DEP personal communication). Even though 19950223-0845-JPH is above this threshold, impairment is suggested due to a lack of stoneflies. Sediment deposition plus embeddedness couplet scores ≤24 suggest impairment for siltation.

Assessment ID	Station Type	IBI Score	SSWAP Bugs Impaired?	Sample Type	Sed Dep. + Embed.	Select Assessment Sheet Comments
Big Cove Creek						
20010904-1430-JDC	SSWAP		Yes		6	There is a raw looking cattle/cow pound about 500 meters upstream from the site, with eroded banks…However, the general land use in the watershed did not look that bad…
20031107-1030-JDC	SSWAP		No		32	Upstream…recent riparian reforestation…upstream recent fencing has been installed
20031204-1430-JDC	No biological sample				13	Most of the Big Cove stream riparian conditions, from this point upstream to the McConnellsburg WWTP, are poor tdue to livestock access...
20031204-0930-JDC	SSWAP		No		29	Much of the riparian corridor on the west side has recently planted with trees
20050609-0955-GLW	SSWAP		Yes		25	Station is impaired based on taxa collected….Likely source of impairment is road runnoff.
20050609-1101-GLW	SSWAP		No		27	Station is attaining based on taxa colleted. …In mid to late summer the stream is likely to be dry or have subsurface flow at this station…The souce of impairment was agriculture
Cove Creek						
19950223-0815-JPH	Stream MI	96.3		2d-100	32	
19950223-0845-JPH	Stream MI	57.5		2d-100	31	
Wooden Bridge Creek						
20080507-0830-jhepp	Stream MI	63.4		6d-200	28	
20130417-1140-jbutt	Stream MI	67.7		6d-200	32	
20130417-1305-jbutt	Stream MI	82.7		6d-200	32	
19980617-0845-BPG	SSWAP		No		21	Mainly pasture some cattle in stream directly upstream of site
19980617-0930-BPG	SSWAP		No		32	
19980617-1100-BPG	SSWAP		No		29	
19980617-1310-BPG	SSWAP		No		17	
19980617-1420-BPG	SSWAP		No		23	Stream situated in cow pasture, cattle in stream throughout reach
19980617-1600-BPG	SSWAP		No		24	
19980622-1000-BPG	SSWAP		No		24	
19980622-1220-BPG	SSWAP		No		28	Predomiatntly agriculture, little forest along stream reach
19980622-1320-BPG	SSWAP		No		28	
19980624-0915-BPG	SSWAP		No		25	
19980625-1100-BPG	SSWAP		No		23	

EXPLORATION OF EXISTING CONDITIONS

The Big Cove Creek subwatershed was visited during the fall of 2022 to observe watershed conditions as well as the causes and severity of impairments. To explore its suitability for use as a reference, the Cove Creek reference watershed was visited a few days later. The Wooden Bridge Creek watershed however was not visited specifically for this study as it was visited during December 2021 and August 2020 as part of prior TMDL studies. Observations from those prior visits are included herein.

Observations of the Big Cove Creek watershed were consistent with a significant siltation problem within the study area but improved conditions further downstream. At approximately three miles downstream from the outlet of the present study area, the mainstem appeared to be clear and rocky (Figure 9). The lack of obvious impairments in this area may be in large part due to: more forested land cover, increased topographic relief resulting in a higher gradient stream channel, and increased flow volumes especially from two largely forested tributary systems. Higher stream gradient and greater flow volume may make the stream better able to flush rather than accumulate its fine sediment load. Further upstream within the study subwatershed the mainchannel passes through a broader and flatter valley resulting in a more sluggish stream channel surrounded by intensive agriculture (Figures 10 and 11). Signs of degradation, including silt deposits and increased turbidity, were apparent in the mainstem of the study subwatershed (Figures 10 and 11). Conditions within smaller tributaries were variable and dependent on the conditions of their surrounding landscape (Figure 12). While mapping indicated a high density of first order streams (Figure 1), many were dry during the site visit (Figure 12) likely due to both recent dry weather and infiltration into karst geology.

Figure 13 illustrates typical landscapes within the Big Cove Run study subwatershed. As is also evident in mapping (Figure 1), there was a broad central valley with very intensive agriculture, while the eastern and western margins of the subwatershed were bounded by forested ridges. Given the intensity of agriculture in the central valley, impairments within the mainstem would be expected. Furthermore, much of this land was large expanses of croplands, which tend to have the highest sediment loading rates among the land covers typically found in Pennsylvania. Some croplands with bare soils were observed during the late October site visit. Also, livestock had direct access to some stream segments which may result in the lack of riparian buffers, bank trampling, and direct animal waste inputs.

While the total percentage of developed lands in the subwatershed, 14%, was not especially high, the borough of McConnellsburg, which had substantial impervious land cover, was situated immediately along the mainchannel of Big Cove Run and some of its tributaries (Figures 1 and 14). Such impervious cover may lead to larger flood pulses and resultant bank erosion, and this along with pollutant runoff and poor habitat associated with developed lands may contribute to water quality impairments.

On the other hand, positive factors that may be protective against siltation pollution were observed in some cases as well, including the use of contour tillage, the allowance for crop residues following harvest, and the presence of forested and wetland riparian buffers (Figure 15).

Similarly to what was observed in the Big Cove Creek watershed, the mainstem of the Cove Creek watershed in Bedford County improved further downstream from the upper subwatershed. The downstream-most observations, which were taken about four miles below the outlet of the delineated subwatershed shown in Figure 16, suggested a healthy stream. The water was clear and the substrate was largely rocky, though some minor siltation occurred in slackwater areas (Figure 16). This may be in large part due to the mainstem running along the base of a mountain in this area, which results in more forested land cover and a higher gradient stream. Further upstream near the outlet of the delineated subwatershed, the mainstem passed through a broad, low-relief agricultural valley (Figure 3). This area exhibited greater signs of siltation (Figures 17 and 18). While the substrate was dominated by gravel or small cobbles, a coating of siltation was often observed especially in slackwater areas. Progressing further upstream towards the mountainous headwaters, the mainstem appeared healthier, higher gradient and typically rocky and clear, though some turbidity and minor fines deposition was apparent in some slow-moving pools (Figure 19). As was the case with the Big Cove Creek subwatershed, many valley tributaries appeared dry during the site visit, likely due to recent dry weather and infiltration into karst geology (Figure 20). Conditions within smaller tributaries appeared to be variable; those flowing from more mountainous areas appearing high gradient, rocky and clear while tributaries in the agricultural valley sometimes exhibiting signs of minor to moderate siltation (Figure 21). In general, stream conditions within the Cove Creek subwatershed appeared healthier versus the Big Cove Creek subwatershed.

Figure 22 illustrates typical landscapes within the Cove Creek sbwatershed. Like the Big Cove Creek subwatershed, much of the Cove Creek subwatershed was a low relief agricultural valley bordered by forested mountain ridges (Figure 3). One difference however was that while the uppermost reaches of the Big Cove Creek subwatershed originated in an agricultural valley, the uppermost reaches of the Cove Creek subwatershed originated in forested uplands (Figures 1 and 3) thus contributing to its greater forested land cover (Table 4). Another factor that may improve water quality within the Cove Creek subwatershed was the use of forested and herbaceous buffers along streams and drainageways (Figures 23 and 24). However, while common, they tended to be narrow. Still, it was less common to see agriculture occurring right up to the streambanks in the Cove Creek subwatershed. Also, crop fields appeared to have high levels of crop residues following harvest, which may be important in protecting their soils from erosion (Figure 25).

Observations of the Wooden Bridge Creek reference subwatershed suggested that, while all stream segments were currently listed as supporting their Aquatic Life Use, some stream segments may be on the cusp of experiencing impairments. While riffle areas and higher gradient reaches were often rocky in the lower mainstem, substantial fine sediment deposition was apparent in some pools, particularly during sluggish summer low flows (Figures 26 and 27). Also, while many tributaries appeared to be healthy, some apparently localized fine sediment pollution was observed (Figures 28 and 29). Finding a reference that may be nearly impaired may actually be an asset in preventing the prescription of reductions that may be too stringent. Conversely, the Department's use of a 10% margin of safety factor (described later) helps guard against the prescription of reductions that may not be stringent enough due to a reference's borderline impairment.

Like the Big Cove Creek subwatershed, the valley areas of the Wooden Bridge Creek subwatershed had substantial agricultural land cover while the mountainous headwaters areas were dominated by forest. However, expansive forested riparian buffers appeared to be much more common along the lower reaches of the Wooden Bridge Creek subwatershed, likely at least in part due in part due to its greater channel incision (Figures 4, 30 and 31). It is speculated that this, along with a lesser amount of agricultural lands, may be key factors in explaining the better water quality of the Wooden Bridge Creek subwatershed. As was the case with the Big Cove Creek subwatershed, there were obvious opportunities for improved best management practice (BMP) implementation in the Wooden Bridge Creek subwatershed, especially with regard to fencing cattle from streams (Figure 32). However, such problem areas were apparently neither severe nor common enough to result in widespread impairment.

In light of these observations, the review of the assessment data, and preliminary modeling, it is proposed to use both the Cove Creek and Wooden Bridge Creek subwatersheds as references. Cove Creek appears to be more topographically and geologically similar to Big Cove Creek, though there has been little prior sampling in the subwatershed and there is some evidence of borderline impairment. While the Wooden Bridge Creek subwatershed has much more robust sampling data, there is concern that it is geologically and topographically dissimilar and that it would produce prescribed reductions that are so low that they may be difficult to achieve. Thus, to balance these concerns, it was decided to use both as reference watersheds, as described below.

Figure 9. Big Cove Creek approximately three miles downstream of the impaired area. Note the clear water and largely rocky substrate.

Figure 10. Stream conditions within the lower mainstem of the impaired area within the Big Cove Creek subwatershed. Note the obvious turbidity and signs of siltation pollution.

Figure 11. Mainstem conditions upstream of McConnellsburg within the Big Cove Creek subwatershed. Siltation was obvious, likely due in part to agricultural landuses but also low gradient wetland conditions. Photograph D shows obvious wetlands near the mainstem's origins.

Figure 12. Condition within small tributaries of the Big Cove Creek subwatershed. Many tributaries were dry as in A during the October 2022 site visit, likely in part due to karst geology as well as recent dry weather. Photographs B through D show that tributary conditions ranged from murky and with obvious siltation to clear and rocky.

Figure 13. Landscapes within the Big Cove Creek subwatershed. The eastern and western watershed margins consisted largely of forested mountain ridges while the valley lowlands were dominated by agriculture.

Figure 14. Factors promoting siltation within the Big Cove Creek subwatershed. Photographs A and B show large expanses of crop fields with seasonally bare soils. Photograph C shows a pasture where livestock had direct access to the stream. Photograph D shows urbanized lands within McConnellsburg.

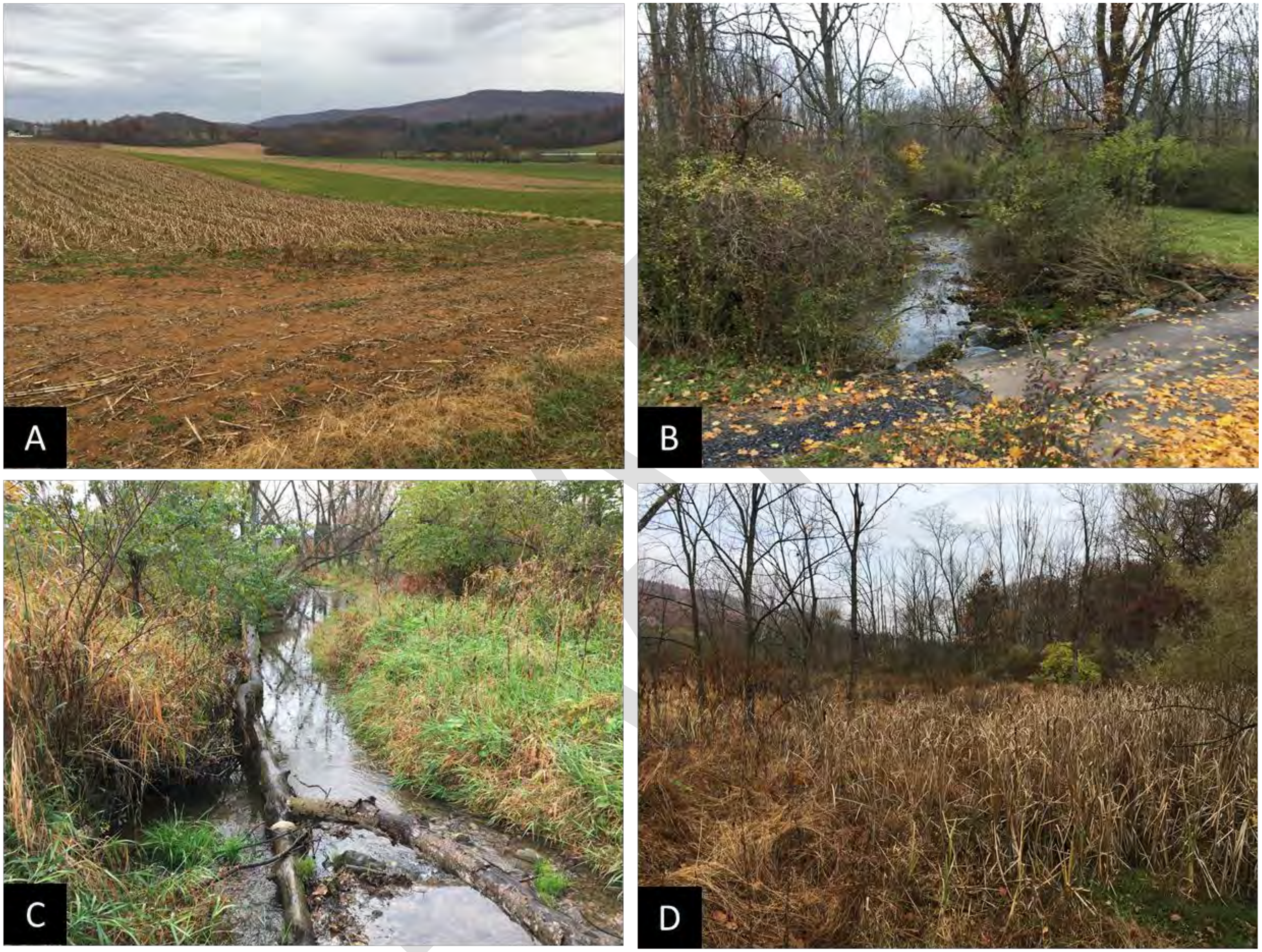

Figure 15. Factors that may protect against sediment pollution in the Big Cove Creek subwatershed. Note the high levels of crop residues and use of contour tillage in A. Photographs B through D show the use of forested riparian and wetland buffers.

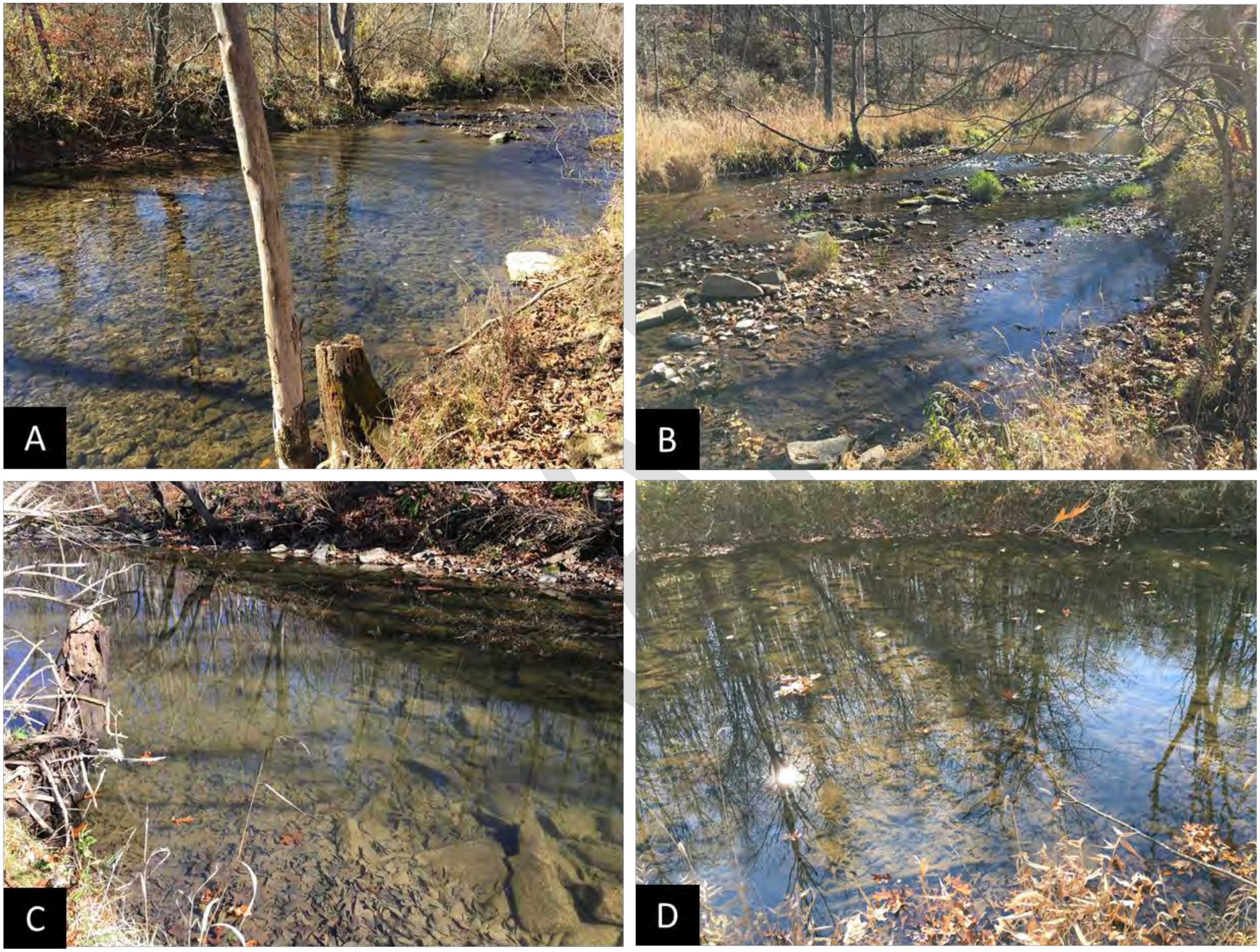

Figure 16. Conditions within the downstream mainstem of Cove Creek, approximately four miles below the reference subwatershed outlet. Note the clear water and largely rocky substrate, though some minor siltation was apparent in slackwater areas.

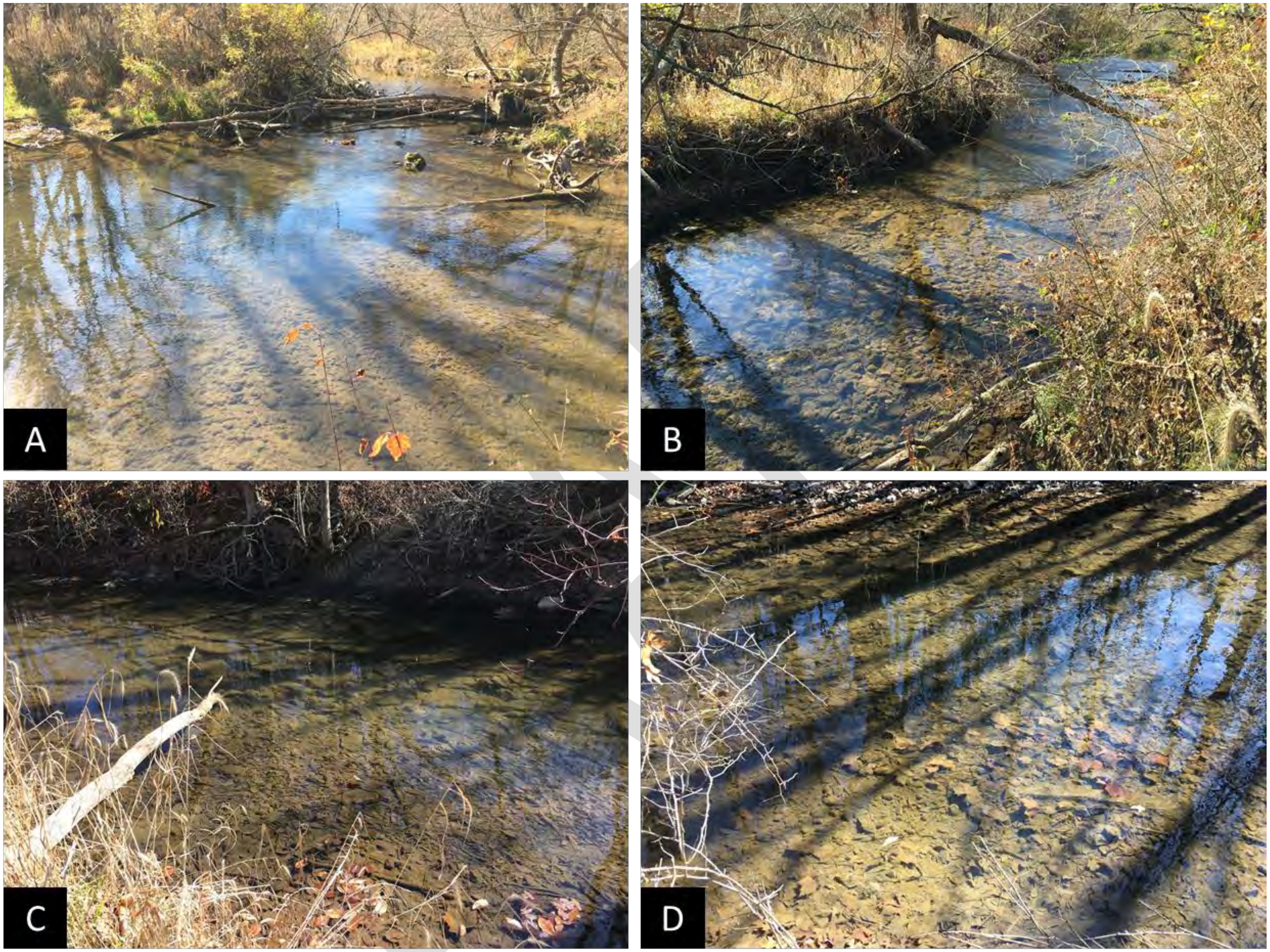

Figure 17. Conditions within the Cove Creek mainstem just below the outlet of the delineated reference subwatershed. While the water was largely clear and the substrate was gravelly, there was some obvious siltation coating the substate of slower reaches. The fine sediment deposition is likely attributable to both the high amounts of agriculture and sluggish flows of the low gradient mainstem.

Figure 18. Condition of the mainstem near the outlet of the Cove Creek reference subwatershed. While the water was largely clear and the substrate was gravelly, there was some obvious siltation coating the substate of slower reaches. This fine sediment deposition is likely attributable to both the high amounts of agriculture within the watershed and the sluggish flows of the low gradient mainstem.

Figure 19. Upper mainstem within the Big Cove Creek subwatershed. The substrate was largely clear and rocky, though some turbidity and siltation can be seen in the pools shown in C and D.

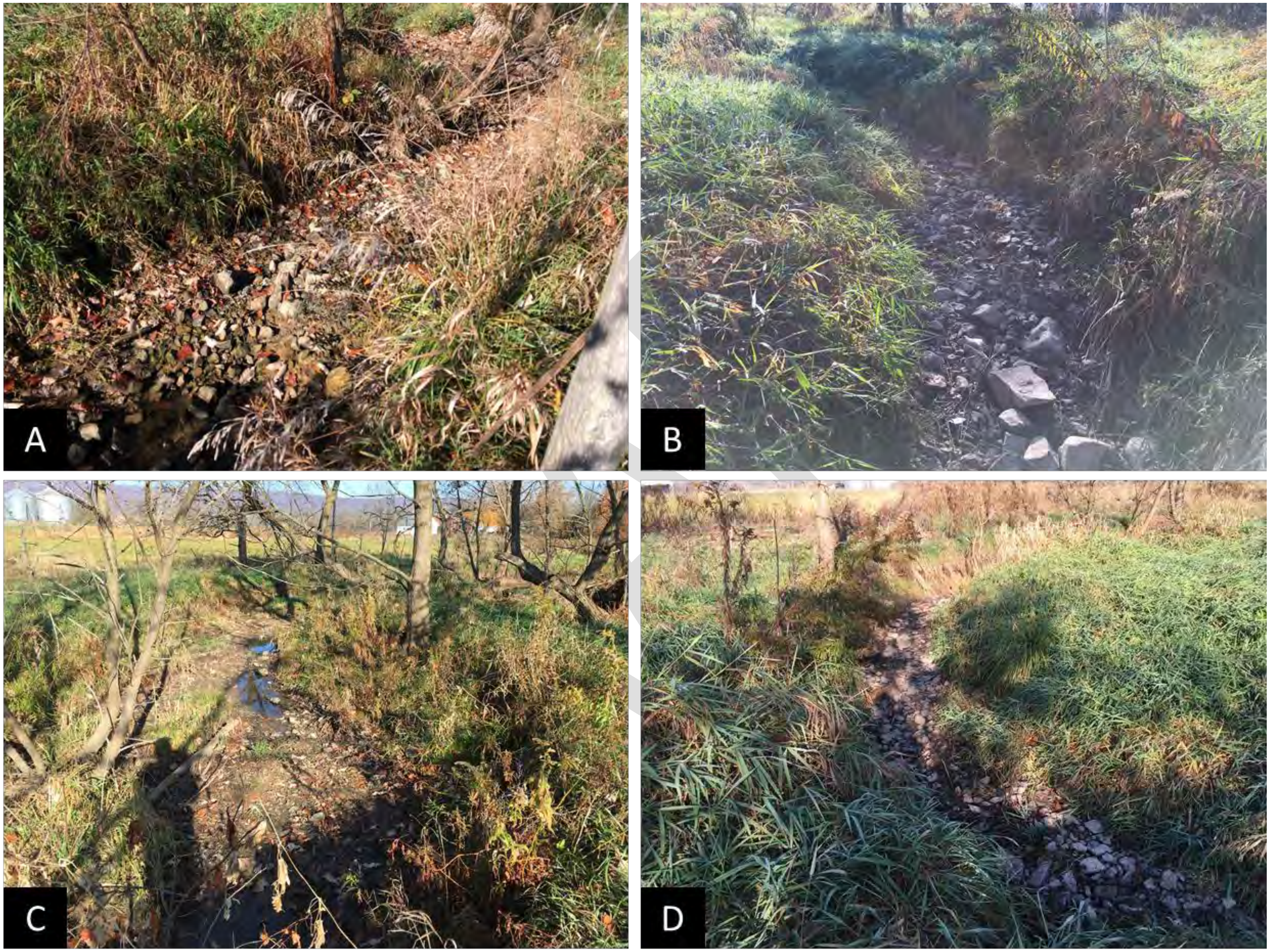

Figure 20. Intermittent and dry channels within valley areas of the Cove Creek subwatershed. Lack of flow was likely due to infiltration into karst geology and recent dry conditions during the November 2022 site visit.

Figure 21. Small flowing channels within the Cove Creek subwatershed. Such streams tended to be rocky and clear, though siltation was obvious in some areas.

Figure 22. Landscapes within the Cove Creek reference subwatershed. The watershed was bounded by forested mountain ridges in its southern, western and eastern margins, while the central valley area was dominated by agriculture.

Figure 23. Forested riparian buffers within the Cove Creek subwatershed. The watershed began in a forested mountain area (Photograph A). Forested riparian buffers were common in valley areas further downstream, though they were often narrow.

Figure 24. Other factors contributing to water quality protection in the Cove Creek subwatershed. Drainageways/small streams were protected by herbaceous wetland buffers in some cases. Also note the crop residues protecting agricultural soils following harvest in A and D.

Figure 25. Factors contributing to water quality degradation within the Cove Creek subwatershed. Vast areas of croplands, such as those shown in A, occurred in some areas. While buffers were common, they were often very narrow as in B. Photograph C shows a small stream segment where it appears that livestock had direct access to the stream, though grazing appeared to be light. Photograph D shows an area with obvious bank erosion.

Figure 26. Stream conditions within the lower mainstem of the Wooden Bridge Creek subwatershed during summer low flows. Higher gradient riffle areas appeared to be rocky, while significant sediment deposition was observed in some pools.

Figure 27. Stream conditions within the lower mainstem of the Wooden Bridge Creek subwatershed during higher spring flows. The substrate tended to be primarily rocky in flowing reaches. However, a bar of fine sediments can be observed in photograph C, and some embeddedness was apparent in D.

Figure 28. Example small tributaries of the Wooden Bridge Creek subwatershed during low summer flows. In many cases stream segments appeared to be healthy and have rocky substrate. However, some apparently localized areas exhibited substantial fine sediment deposition (D).

Figure 29. Example small tributaries of the Wooden Bridge Creek subwatershed during higher spring flows. Again, many stream segments appeared to be healthy and with rocky substrate, though, some apparently localized heavy fine sediment deposits were observed (D).

Figure 30. Example landscapes within the Wooden Bridge Creek subwatershed. The uppermost area of the watershed descended from a forested mountainous area (above). There was significant agricultural lands in the valley area of the lower watershed, though streamside areas were often forested (below).

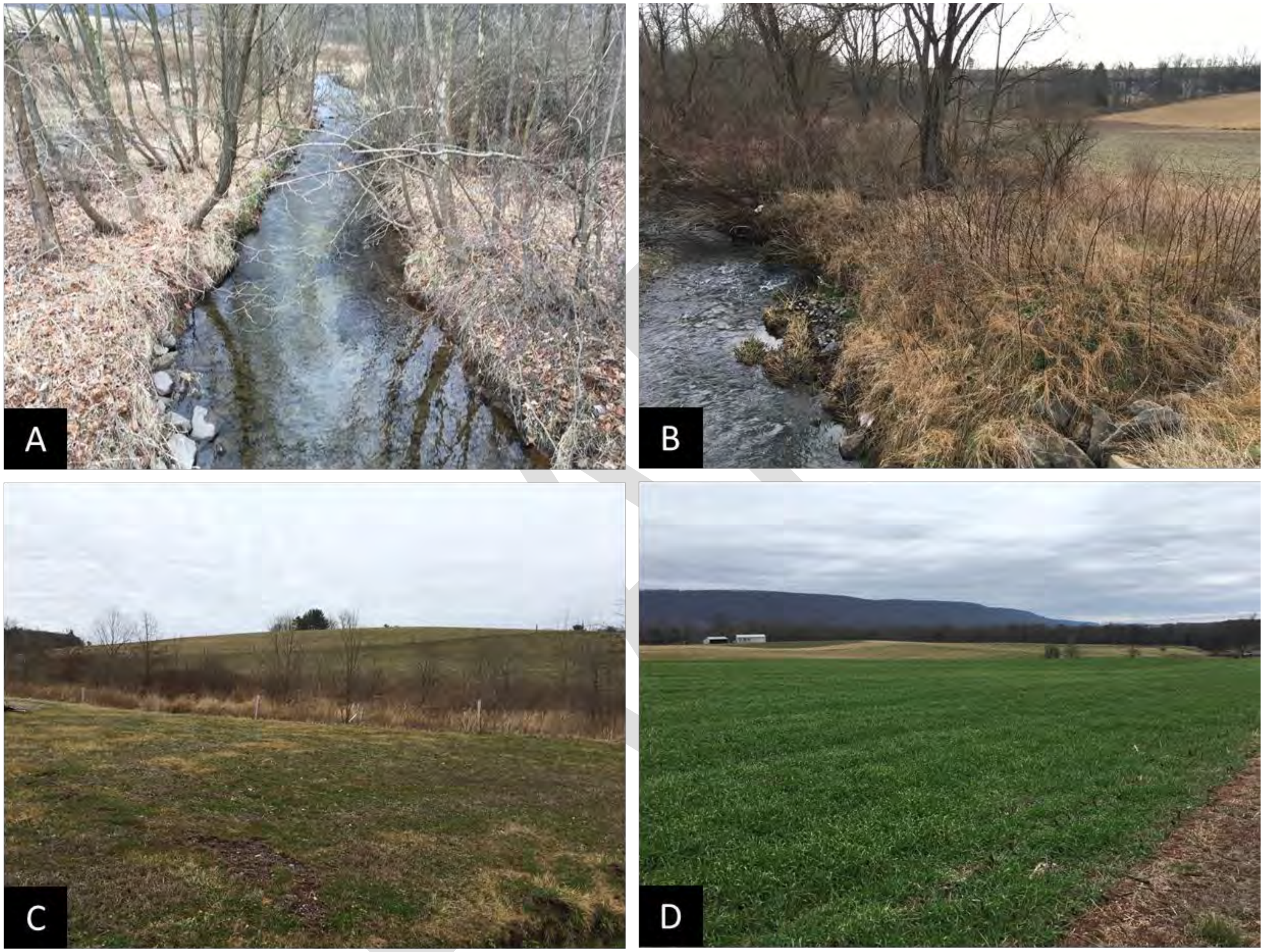

Figure 31. Factors that may be protective against sediment pollution in the Wooden Bridge Creek subwatershed. Some streams flowed through large forested tracts (A) or had forested buffers (B). Photograph C shows an area where either a drainageway or small stream segment has been buffered. Photograph D shows the use of what appears to be a cover crop.

Figure 32. Factors that may promote sediment pollution in the Wooden Bridge Creek subwatershed. The stream segments shown in A and B appear to flow through highly degraded pasture areas. Photograph C shows what appears to be a largely unbuffered drainageway flowing through croplands. Photograph D show a stream area with erosive banks.

HYDROLOGIC / WATER QUALITY MODELING

Estimates of sediment loading for the impaired and reference watersheds were calculated using the “Model My Watershed” application (MMW-Version 1.33.8, Stroud Water Research Center 2022). MMW is a replacement for the MapShed desktop modelling application. Both programs calculate sediment and nutrient fluxes using the “Generalized Watershed Loading Function Enhanced” (GWLF-E) model. However, MapShed was built using a MapWindow GIS package that is no longer supported, whereas MMW operates with GeoTrellis, an open-source geographic data processing engine and framework. The MMW application is freely available for use at https://wikiwatershed.org/model/. In addition to the changes to the GIS framework, the MMW application continues to be updated and improved relative to its predecessor.

In the present study, watershed areas were defined using MMW’s Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 28-years of daily water, nitrogen, phosphorus and sediment fluxes. To provide a general understanding of how the model functions, the following excerpts are quoted from MMW’s technical documentation.

> *The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values.*
>
> *GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios, but each area is assumed to be homogenous in regard to various “landscape” attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but simply aggregates the loads from each source area into a watershed total; in other words there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.*
>
> *With respect to major processes, GWLF simulates surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs from the United States Environmental Protection Agency (USEPA) Center for Exposure Assessment Modeling (CEAM) meteorological data distribution. Erosion and sediment yield are estimated using monthly*

erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly KLSCP values for each source area (i.e., land cover/soil type combination). A sediment delivery ratio based on watershed size and transport capacity, which is based on average daily runoff, is then applied to the calculated erosion to determine sediment yield for each source sector. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area.

Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

Streambank erosion is calculated as a function of factors such as the length of streams, the monthly stream flow, the percent developed land in the watershed, animal density in the watershed, the watersheds curve number and soil k factor, and mean topographic slope.

For a detailed discussion of this modelling program, including a description of the data input sources, see Evans and Corradini (2016) and Stroud Research Center (2022).

MMW allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the present study except that estimated average daily flows from the wastewater treatment plants located in the Wooden Bridge Creek subwatershed, 90.0 m^3/d, were added as in input. This flow value was calculated from an analysis of electronic discharge monitoring report (eDMR) data during another recent TMDL study. The flows from the wastewater treatment plant in the Big Cove Creek subwatershed were already considered by MMW.

The sediment load of the Wooden Bridge Creek reference subwatershed was further reduced to account for a greater amount of riparian buffering. Riparian buffer coverage for all three subwatersheds was estimated via a GIS analysis in ArcGIS Pro. Briefly, land cover per a high-resolution land cover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of USGS high-resolution NHD flowlines. Then the sum of raster pixels that were classified as either "Emergent Wetlands", "Tree Canopy" or "Shrub/Scrub" was divided by the total number of non-water pixels to determine percent riparian buffer. Using this methodology, percent riparian buffer was determined to be 49% in the agricultural area of the impaired Big Cove Creek subwatershed versus 78% in the agricultural area of the Wooden Bridge Creek reference subwatershed. The rate of riparian buffering was estimated to be only 38% in the Cove Creek reference subwatershed, in part because buffers, while common, tended to be narrow. Since this value was less than the percent riparian buffer estimated for the Big Cove Creek subwatershed, no additional reduction credit was given for the Cove Creek reference subwatershed.

An additional reduction credit was given to the Wooden Bridge Creek reference subwatershed to account for its greater riparian buffering versus the impaired subwatershed. Applying a reduction credit solely to the reference watershed to account for its extra buffering was chosen as more appropriate than taking a reduction from both watersheds because the model has been calibrated at a number of actual sites (see https://wikiwatershed.org/help/model-help/mmw-tech/) with varying amounts of existing riparian buffers. If a reduction were taken from all sites to account for existing buffers, the datapoints would likely have a poorer fit to the calibration curve versus simply providing an additional credit to a reference site.

When accounting for the buffering of croplands using the BMP Spreadsheet Tool (Version 2020-01-09, Evans et al. 2020), provided by a prior version of MMW, the user enters the length of buffer on both sides of the stream. To estimate the extra length of buffers in the reference subwatershed over the amount found in the impaired subwatershed, the approximate length of USGS high-resolution NHD flowlines within the reference subwatershed was multiplied by the proportion of riparian pixels that were within the agricultural area selection polygon (Figures 33, 34, 35) and then by the difference in the proportion buffering between the agricultural areas of the reference subwatershed and the impaired subwatershed, and then by two since both sides of the stream are considered. The BMP spreadsheet tool then calculates sediment reduction using a similar methodology as the Chesapeake Assessment Scenario Tool (CAST) (Belt et al. 2014). The length of riparian buffers is converted to acres, assuming that the buffers are 100 feet wide. For sediment loading, the spreadsheet tool assumes that 2 acres of croplands are treated per acre of buffer. Thus, twice the acreage of buffer was multiplied by the sediment loading rate calculated for croplands and then by a reduction coefficient of 0.54. The BMP spreadsheet tool is designed to account for the area of lost cropland and gained forest when riparian buffers are created. However, this part of the reduction equation was deleted for the present study since historic rather than proposed buffers were being accounted for.

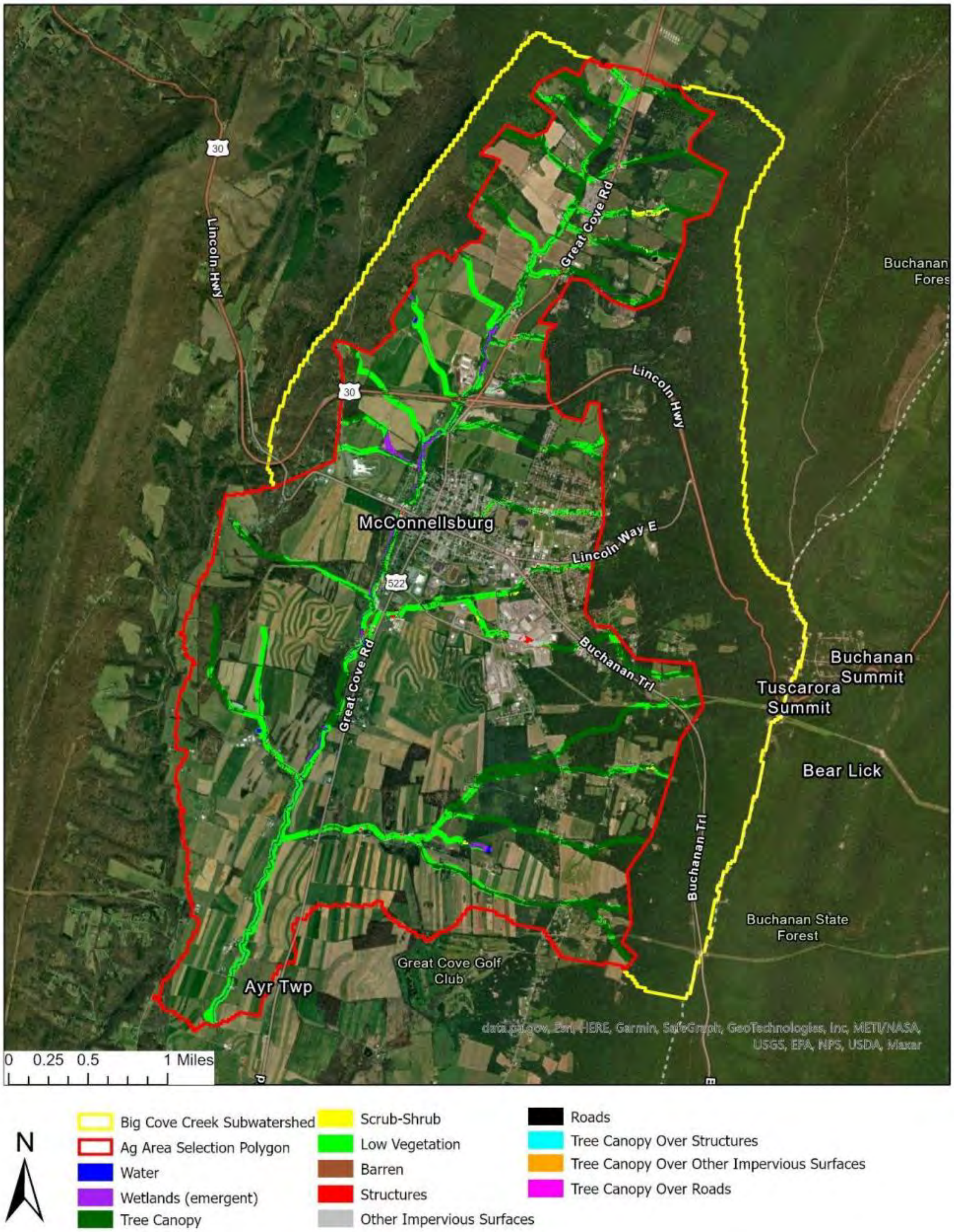

Figure 33. Riparian buffer analysis for the Big Cove Creek subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. The rate of riparian buffering (comprised of tree canopy, scrub-shrub and wetlands) was estimated to be about 49% in the agricultural area.

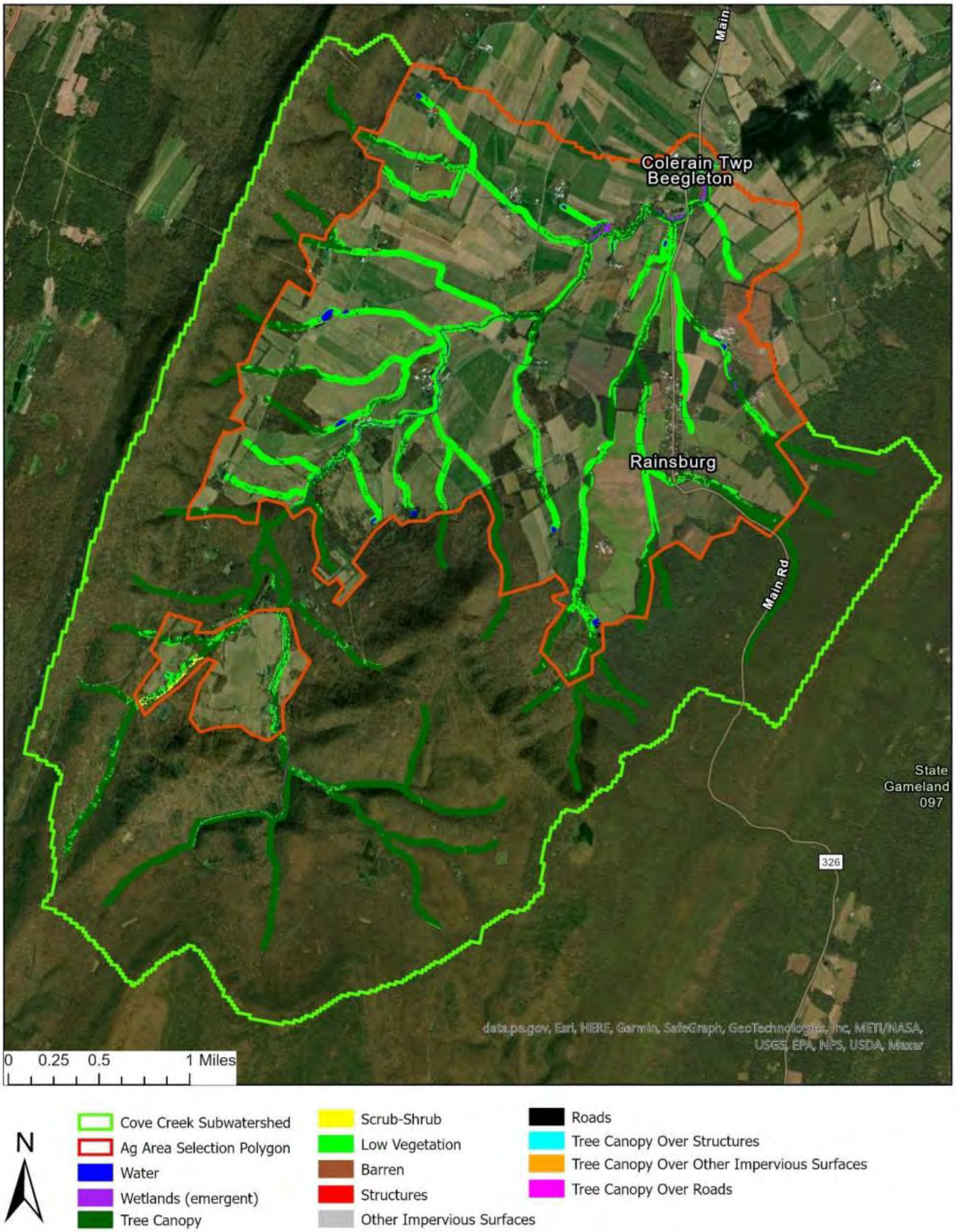

Figure 34. Riparian buffer analysis for the Cove Creek subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. The rate of riparian buffering (comprised of tree canopy, scrub-shrub and wetlands) was estimated to be about 38% in the agricultural area.

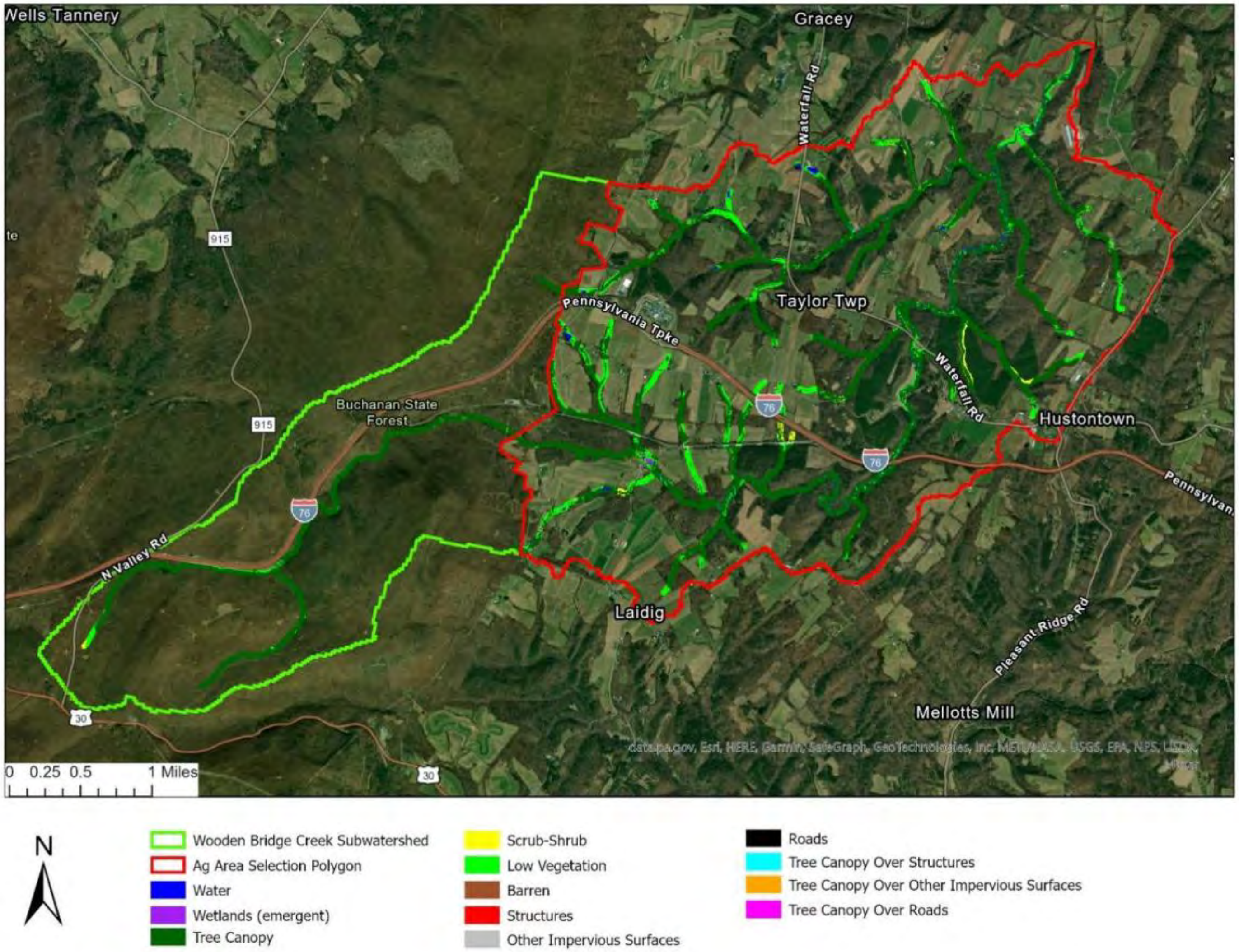

Figure 35. Riparian buffer analysis for the Wooden Bridge Creek subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. The rate of riparian buffering (comprised of tree canopy, scrub-shrub and wetlands) in the agricultural area was estimated to be about 78%.

CALCULATION OF ALLOWABLE LOADING

The estimated mean annual sediment loading rates were 308 lbs/(ac*yr) and 218 lbs/(ac*yr) in the Cove and Wooden Bridge Creek reference subwatersheds, respectively (Table 8). These were substantially lower than the estimated mean annual loading rate in the Big Cove Creek subwatershed 660 lbs/(ac*yr). As mentioned previously, the Cove Creek subwatershed appears to be the best match for the Big Cove Creek subwatershed based on physical characteristics, but there was concern over its lack of assessment data and possible impairment. And, while the Wooden Bridge Creek subwatershed has been assessed much more rigorously and has been found to be supporting its Aquatic Life Use, there was concern over its dissimilar topography and geology, and whether its use would result in prescribed reductions that were too stringent. Thus, for the sake of defining the acceptable loading rate, it was decided to use the average loading rate of these two reference subwatersheds, or 263 lbs/(ac*yr). Thus, to achieve the average loading rate of the unimpaired subwatersheds, sediment loading in the Big Cove Creek subwatershed should be reduced by 60% to 2,814,779 lbs/yr (Table 9).

Table 8. Existing annual average loading values for the Big Cove Creek and potential reference subwatersheds.

	Big Cove Creek			Cove Creek			Wooden Bridge Creek		
Land Cover	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	2,160	1,218,897	564	1,146	174,835	153	2,096	763,970	364
Cropland	2,089	4,189,991	2,006	2,101	2,211,747	1,053	798	825,175	1,035
Forest	4,928	11,412	2	6,590	9,974	2	6,731	7,277	1
Wetland	15	21	1	0	2	0	5	13	3
Open Land	22	1,601	72	37	3,064	83	37	3,211	87
Bare Rock	10	14	1	25	76	3	22	18	1
Low Density Mix Dev	1,086	13,784	13	457	5,254	12	649	7,873	12
Med Density Mix Dev	272	17,597	65	17	1,420	82	151	10,001	66
High Density Mix Dev	119	7,697	65	5	335	68	49	3,236	66
Stream Bank		1,599,972			788,168			941,804	
Riparian Buffer Discount					0			-263,410	
Point Sources		5,769			0			375	
Total	**10,701**	**7,066,754**	**660**	**10,378**	**3,194,876**	**308**	**10,538**	**2,299,544**	**218**

Table 9. Annual average allowable loading in the Big Cove Creek subwatershed. The reference loading rate was derived from the average of the Cove Creek and Wooden Bridge Creek reference subwatersheds.

Subwatershed	**Ref. Loading Rate** (lbs/(ac*yr))	**Land Area** (ac)	**Target AL** (lbs/yr)
Big Cove Creek	263	10,701	2,814,779

CALCULATION OF THE SOURCE LOAD ALLOCATIONS

Calculation of the Uncertainty Factor and Source Load

In the ARP equation, the Allowable Load (AL) is comprised of the Source Load (SL), which accounts for all significant natural and anthropogenic sources of the pollutant, plus an Uncertainty Factor (UF). Thus:

AL = SL + UF

Reserving a portion of the load as a UF requires further load reductions from targeted sectors to achieve the AL. For this analysis, the UF was explicitly designated as ten-percent of the AL based on professional judgment. Thus:

2,814,779 lbs/yr AL * 0.1 = 281,478 lbs/yr UF

Then, the SL is calculated as:

2,814,779 lbs/yr AL – 281,478 lbs/yr UF = 2,533,301 lbs/yr SL

Calculation of the Adjusted Source Load

In the ARP equation the SL is further divided into the Adjusted Source Load (ASL), which is comprised of the sources causing the impairment and targeted for reduction, as well as the loads not reduced (LNR), which is comprised of the natural and anthropogenic sources that are not considered responsible for the impairment nor targeted for reduction. Thus:

SL =ASL + LNR

Therefore, before calculating the allowable loading from the targeted sectors, the LNR must also be defined.

Since the impairments addressed by this ARP were for sedimentation due to agriculture, but development is also suspected to be of concern (Table 2), croplands, hay/pasture lands, developed lands, and streambanks will be considered the targeted sectors. Therefore, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands, bare rock, and point sources within the Big Cove Creek subwatershed were considered LNR. LNR was calculated to be 18,817 lbs/yr (Table 10).

Table 10. Source load, loads not reduced and adjusted source loads. All values were expressed as annual average lbs/yr.

	Big Cove Creek
Source Load (SL)	2,533,301
Loads Not Reduced (LNR)	
Forest	11,412
Wetland	21
Open Land	1,601
Bare Rock	14
Point Sources	5,769
Total LNR	18,817
Adjusted Source Load (ASL)	2,514,484

Then, the ASL is calculated as:

2,533,301 lbs/yr SL – 18,817 lbs/yr LNR = 2,514,484 lbs/yr ASL

CALCULATION OF SEDIMENT LOAD REDUCTIONS BY SOURCE SECTOR

To calculate prescribed load reductions by source, the ASLs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although the Big Cove Creek subwatershed ARP was developed to address impairments caused by agriculture and development, streambanks were also significant contributors to the sediment load, and bank erosion rates are influenced by agriculture and development. Thus, streambanks were included in the ASLs and targeted for reduction.

In the Big Cove Creek subwatershed, croplands exceeded the ASL by itself. Thus, croplands received a greater percent reduction (72%) than hay/pasture lands, streambanks, or developed lands (53% each) (Table 11). Note however, the prescribed reductions by source sector are simply suggested targets and not rigid goals that must be met. During implementation, greater or lesser reductions can be made for each source sector, so long as the overall ASL is achieved.

Table 11. Annual average sediment load allocations for source sectors in the Big Cove Creek subwatershed.

Source	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal %
Cropland	1,176,866	4,189,991	72%
Hay/Pasture Land	570,486	1,218,897	53%
Streambank	748,843	1,599,972	53%
Developed Lands	18,290	39,077	53%
Sum	*2,514,484*	*7,047,937*	*64%*

RECOMMENDATIONS

As the foundation for the development of a Watershed Implementation Plan for the Big Cove Creek subwatershed, DEP has prepared this document to prescribe sediment reductions needed to meet water quality standards. It was estimated that a 60% sediment reduction was needed.

Sediment loading from agricultural activities can be achieved via the implementation of required Erosion and Sediment Control Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, § 102.4, see also Appendix E) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, livestock exclusion fencing, and riparian buffers.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. Furthermore, riparian buffers are also beneficial for many other reasons beyond just protecting from sedimentation and nutrients. For instance, riparian buffers may: filter out other pollutants such as pesticides; provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; and moderate stream temperature. Thus, use of forested riparian buffers should be encouraged wherever possible.

Development of a more detailed Watershed Implementation Plan is encouraged. Further ground truthing should be performed to assess both the extent of existing BMPs and to determine the most cost effective and environmentally protective combination of BMPs required for meeting the prescribed sediment reductions.

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APPENDIX A: BACKGROUND ON STREAM ASSESSMENT METHODOLOGY

Note that the following contains generalizations about DEP's most commonly used aquatic life assessment methods, but doesn't seek to describe all of the current and historic variations of such methodology. For more information, see DEP's *Assessment Methodology for Streams and Rivers* (Shull and Whiteash 2021).
Documentation of other historic methodologies is available upon request.

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be listed as such in the Integrated Water Quality Monitoring and Assessment Report. Prior to 2004, the impaired waters were found on the 303(d) List; from 2004 to present, the 303(d) List was incorporated into the Integrated Water Quality Monitoring and Assessment Report (IR) and found on List 5. Table A1. summarizes the changes to listing documents and assessment methods over time.

With guidance from USEPA, the states have developed methods for assessing the waters within their respective jurisdictions. From 1996-2006, the primary method adopted by DEP for evaluating waters found on the 303(d) lists (1998-2002) or in the IR (2004-2006) was the Statewide Surface Waters Assessment Protocol (SSWAP). SSWAP was a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II) and provided a more consistent approach to assessing Pennsylvania's streams.

The assessment method called for selecting representative stream segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates were typically identified to the family level in the field.

The listings found in the Integrated Water Quality Monitoring and Assessment Reports from 2008 to 2018 were derived based on the Instream Comprehensive Evaluation protocol (ICE). Like the superseded SSWAP protocol, the ICE protocol called for selecting representative segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include D-frame kicknet sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Collected samples were returned to the laboratory where the samples were typically to be subsampled for a target benthic macroinvertebrate sample of 200 ± 20% (N = 160-240). The benthic macroinvertebrates in this subsample were typically identified to the generic level. The ICE protocol is a modification of the USEPA Rapid Bioassessment Protocol III (RPB-III) and provides a more rigorous and consistent approach to assessing Pennsylvania's streams than the SSWAP. More recent listings from 2020 to present were based on updated data collection protocols and Aquatic Life Use (ALU) assessment methods that are specific to the use(s) being assessed.

After these surveys (SSWAP, 1998-2006 lists; or ICE, 2008-2018 lists; ALU 2020-present lists) are completed, biologists are to determine the status of the stream segment. Decisions are to be based on the performance of the segment using a series of biological metrics. If the stream segment is classified as impaired, it is to be listed on the state's 303(d) List, or presently, the IR with the source and cause documented.

Once a stream segment is listed as impaired, a TMDL typically must be developed for it. A TMDL addresses only one pollutant. If a stream segment is impaired by multiple pollutants, each pollutant generally receives a separate and specific TMDL within that stream segment. Adjoining stream segments with the same source and cause listings may be addressed collectively on a watershed basis.

Table A1. Impairment Documentation and Assessment Chronology

Listing Date:	**Listing Document:**	**Assessment Method:**
1998	303(d) List	SSWAP
2002	303(d) List	SSWAP
2004	Integrated List	SSWAP
2006	Integrated List	SSWAP
2008-2018	Integrated List	ICE
2020-present	Integrated List	ALU

APPENDIX B: MODEL MY WATERSHED DATA TABLES

Table B1. “Model My Watershed” land cover outputs for the Big Cove Creek subwatershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.01	0.02
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	2.3	5.31
Developed, Low Intensity	22	2.1	4.84
Developed, Medium Intensity	23	1.1	2.53
Developed, High Intensity	24	0.48	1.11
Barren Land (Rock/Sand/Clay	31	0.04	0.1
Deciduous Forest	41	17.25	39.79
Evergreen Forest	42	0.17	0.4
Mixed Forest	43	2.42	5.58
Shrub/Scrub	52	0.12	0.27
Grassland/Herbaceous	71	0.09	0.21
Pasture/Hay	81	8.75	20.19
Cultivated Crops	82	8.46	19.51
Woody Wetlands	90	0.06	0.13
Emergent Herbaceous Wetlar	95	0	0.01
Total		43.35	100

Table B2. "Model My Watershed" land cover outputs for the Cove Creek subwatershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.01	0.02
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	1.51	3.6
Developed, Low Intensity	22	0.34	0.82
Developed, Medium Intensity	23	0.07	0.17
Developed, High Intensity	24	0.02	0.04
Barren Land (Rock/Sand/Clay)	31	0.1	0.24
Deciduous Forest	41	25.97	61.77
Evergreen Forest	42	0.05	0.12
Mixed Forest	43	0.55	1.3
Shrub/Scrub	52	0.12	0.29
Grassland/Herbaceous	71	0.15	0.35
Pasture/Hay	81	4.64	11.04
Cultivated Crops	82	8.51	20.23
Woody Wetlands	90	0	0.01
Emergent Herbaceous Wetlands	95	0	0
Total		42.04	100

Table B3. “Model My Watershed” land cover outputs for the Wooden Bridge Creek subwatershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.01	0.01
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	1.64	3.84
Developed, Low Intensity	22	0.99	2.32
Developed, Medium Intensity	23	0.61	1.43
Developed, High Intensity	24	0.2	0.46
Barren Land (Rock/Sand/Clay	31	0.09	0.21
Deciduous Forest	41	22.42	52.55
Evergreen Forest	42	1.83	4.28
Mixed Forest	43	2.58	6.05
Shrub/Scrub	52	0.43	1.02
Grassland/Herbaceous	71	0.15	0.34
Pasture/Hay	81	8.49	19.89
Cultivated Crops	82	3.23	7.56
Woody Wetlands	90	0.02	0.04
Emergent Herbaceous Wetlar	95	0	0
Total		42.67	100

Table B4. "Model My Watershed" hydrology outputs for the Big Cove Creek subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.17	1	4.09	0.08	0.5	6.99
Feb	6.03	0.96	5	0.07	0.76	7.05
Mar	6.39	0.47	5.83	0.08	2.34	8.11
Apr	5.3	0.09	5.14	0.08	5.34	7.97
May	3.61	0.29	3.24	0.08	9.93	10.69
Jun	2.75	1.01	1.67	0.08	13.19	9.93
Jul	0.95	0.28	0.58	0.08	11.3	9
Aug	0.49	0.29	0.12	0.08	8.96	9.19
Sep	0.97	0.84	0.06	0.08	5.92	8.94
Oct	1.27	0.67	0.52	0.08	3.94	7.94
Nov	1.37	0.46	0.83	0.08	2.11	8.57
Dec	3.67	0.77	2.82	0.08	0.99	8.2
Total	37.97	7.13	29.9	0.95	65.28	102.58

Table B5. "Model My Watershed" hydrology outputs for the Cove Creek subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.88	0.44	5.45	0	0.49	7.3
Feb	6.19	0.48	5.7	0	0.72	7.1
Mar	7.15	0.47	6.68	0	2.19	8.76
Apr	6.08	0.19	5.89	0	4.15	8.7
May	4.35	0.08	4.27	0	8.59	10.42
Jun	2.71	0.33	2.39	0	12.64	10.61
Jul	1.02	0.1	0.92	0	13.55	10.25
Aug	0.42	0.26	0.17	0	10.3	10.77
Sep	0.31	0.2	0.11	0	6.78	9.17
Oct	1.07	0.39	0.68	0	3.93	7.97
Nov	1.53	0.34	1.2	0	1.93	8.4
Dec	4.65	0.48	4.17	0	0.94	8.46
Total	41.36	3.76	37.63	0	66.21	107.91

Table B6. "Model My Watershed" hydrology outputs for the Wooden Bridge Creek subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.93	0.76	5.16	0.01	0.51	6.99
Feb	6.3	0.73	5.56	0.01	0.77	7.05
Mar	6.46	0.34	6.11	0.01	2.38	8.11
Apr	5.26	0.06	5.19	0.01	5.37	7.97
May	3.44	0.22	3.21	0.01	9.7	10.69
Jun	2.57	0.89	1.68	0.01	10.99	9.93
Jul	0.86	0.23	0.62	0.01	9.21	9
Aug	0.41	0.23	0.17	0.01	8.62	9.19
Sep	1.12	0.69	0.42	0.01	5.94	8.94
Oct	1.74	0.54	1.2	0.01	3.95	7.94
Nov	2.44	0.34	2.1	0.01	2.13	8.57
Dec	5.45	0.59	4.85	0.01	1.01	8.2
Total	41.98	5.62	36.27	0.12	60.58	102.58

Table B7. "Model My Watershed" outputs for sediment in the Big Cove Creek subwatershed.

Sources	Sediment (kg)
Hay/Pasture	552,787.70
Cropland	1,900,222.70
Wooded Areas	5,175.50
Wetlands	9.5
Open Land	726
Barren Areas	6.3
Low-Density Mixed	2,978.30
Medium-Density Mixed	7,980.30
High-Density Mixed	3,490.50
Low-Density Open Spa	3,273.00
Farm Animals	0
Stream Bank Erosion	725,611.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B8. "Model My Watershed" outputs for sediment in the Cove Creek subwatershed.

Sources	Sediment (kg)
Hay/Pasture	79,290.30
Cropland	1,003,059.70
Wooded Areas	4,523.30
Wetlands	1
Open Land	1,389.50
Barren Areas	34.3
Low-Density Mixed	440.7
Medium-Density Mixed	644.2
High-Density Mixed	152.1
Low-Density Open Space	1,942.10
Farm Animals	0
Stream Bank Erosion	357,446.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B9. “Model My Watershed” outputs for sediment in the Wooden Bridge Creek subwatershed.

Sources	Sediment (kg)
Hay/Pasture	346,471.80
Cropland	374,229.20
Wooded Areas	3,300.10
Wetlands	5.7
Open Land	1,456.30
Barren Areas	8.3
Low-Density Mixed	1,342.40
Medium-Density Mixed	4,535.70
High-Density Mixed	1,467.40
Low-Density Open Space	2,228.30
Farm Animals	0
Stream Bank Erosion	427,122.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

APPENDIX C: STREAM SEGMENTS IN THE SPRING CREEK WATERSHED WITH AQUATIC LIFE USE IMPAIRMENTS DUE TO SILTATION

ATTAINS ID:	Stream Name:	Length (miles):	Impairment Source:	Impairment Cause:	Impairment Cause Context:
PA-SCR-49478484	Unnamed Tributary to Kendall Run	0.11	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-49478486	Unnamed Tributary to Kendall Run	0.06	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-49485870	Unnamed Tributary to Kendall Run	0.01	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-49485872	Unnamed Tributary to Kendall Run	0.37	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-49482238	Kendall Run	0.89	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49482240	Kendall Run	0.62	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49482242	Kendall Run	1.14	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49482244	Kendall Run	0.08	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49470392	Big Cove Creek	1.58	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49470412	Big Cove Creek	0.42	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-49470428	Big Cove Creek	1.17	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT

APPENDIX D: EQUAL MARGINAL PERCENT REDUCTION METHOD

Note that the following is based on a calculator that was developed using terminology that is used for Pennsylvania's TMDL documents. Since the present document does not constitute a TMDL, different terminology was used. However, the terms used in this study are essentially analogous to TMDL terms, as follows:

Allowable Load (AL) ≈ Total Maximum Daily Load (TMDL)
Uncertainty Factor (UF) ≈ Margin of Safety (MOS)
Source Load (SL) ≈ Load Allocation (LA)
Adjusted Source Load (ASL) ≈ Adjusted Load Allocation (ALA)

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute the ALA between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using a MS Excel spreadsheet. The 5 major steps identified in the spreadsheet are summarized below:

Step 1: Calculation of the TMDL based on impaired watershed size and unit area loading rate of reference watershed.

Step 2: Calculation of ALA based on TMDL, MOS, WLA and existing LNR.

Step 3: Actual EMPR Process:

a. Each landuse/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of EMPR.

b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

Step 4: Calculation of total loading rate of all sources receiving reductions.

Step 5: Summary of existing loads, final load allocations, and percent reduction for each pollutant source

Table D1. Equal Marginal Percent Reduction calculations for the Big Cove Creek subwatershed.

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to	How much does sum exceed	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	4,189,991	yes	2,514,484		0.47	1,337,618	1,176,866	0.72
Hay/Pasture	1,218,897	no	1,218,897	2,857,946	0.23	648,411	570,486	0.53
Streambank	1,599,972	no	1,599,972		0.30	851,130	748,843	0.53
Developed	39,077	no	39,077		0.01	20,788	18,290	0.53
sum	**7,047,937**		**5,372,431**		**1.00**	**2,857,946**	**2,514,484**	**0.64**

Appendix F. Chesapeake Assessment Scenario Tool (CAST) Cost Profiles for the State of Pennsylvania

Land BMP Costs

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Monitored P removal system for animal production area	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Soil Conservation and Water Quality Plans	1	24.91	$/acre	0	$/acre/year	0	$/acre	26.16
Agriculture	Grass Buffer-Narrow with Exclusion Fencing	19	10366.19	$/acre	509.32	$/acre/year	971.31	$/acre	1415.64
Agriculture	Forest Buffer-Narrow with Exclusion Fencing	25	13529.46	$/acre	554.6	$/acre/year	971.31	$/acre	1563.11
Agriculture	Forest Buffer	40	4062.42	$/acre	81.25	$/acre/year	1770.23	$/acre	406.51
Agriculture	Agricultural Stormwater Management	10	7187.4	$/acre	287.5	$/acre/year	0	$/acre	1218.3
Agriculture	Tree Planting	40	1433.84	$/acre	21.51	$/acre/year	1770.23	$/acre	193.58
Agriculture	Land Retirement to Ag Open Space	10	601.86	$/acre	18.06	$/acre/year	1770.23	$/acre	184.52
Agriculture	Grass Buffer	10	899.15	$/acre	35.97	$/acre/year	1770.23	$/acre	240.93
Agriculture	Land Retirement to Pasture	10	173.85	$/acre	5.22	$/acre/year	798.92	$/acre	67.68
Agriculture	Drainage Water Management	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Alternative Crops	10	344.49	$/acre	10.33	$/acre/year	1085.03	$/acre	109.19
Agriculture	Forest Buffer-Streamside with Exclusion Fencing	30	7216.47	$/acre	238.95	$/acre/year	971.31	$/acre	756.96
Agriculture	Off Stream Watering Without Fencing	20	5.29	$/acre	0.08	$/acre/year	0	$/acre	0.5
Agriculture	Precision Intensive Rotational/Prescribed Grazing	1	81.27	$/acre	0	$/acre/year	0	$/acre	85.33
Agriculture	Horse Pasture Management	5	359.82	$/acre	3.6	$/acre/year	0	$/acre	86.71
Agriculture	Water Control Structures	10	1265.55	$/acre	37.97	$/acre/year	0	$/acre	201.86

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Monitored denitrifying bioreactor for spring or seep	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Rye Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Brassica Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Grass Buffer - Narrow	10	899.15	$/acre	35.97	$/acre/year	1770.23	$/acre	240.93
Agriculture	Forest Buffer - Narrow	40	4062.42	$/acre	81.25	$/acre/year	1770.23	$/acre	406.51
Agriculture	Barnyard Runoff Control	15	6013.28	$/acre	0.6	$/acre/year	0	$/acre	579.93
Agriculture	Loafing Lot Management	10	154966.64	$/acre	25	$/acre/year	0	$/acre	20093.89
Agriculture	Denitrifying Ditch Bioreactors	20	388.91	$/acre	0.93	$/acre/year	0	$/acre	32.14
Agriculture	Cover Crop Traditional Wheat Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Wheat Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Injection	1	0	$/acre	85.28	$/acre/year	0	$/acre	85.28
Agriculture	Cover Crop Traditional Wheat Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Incorporation Low Disturbance Early	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Manure Incorporation High Disturbance Early	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Cover Crop Traditional Wheat Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Incorporation Low Disturbance Late	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Manure Incorporation High Disturbance Late	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Cover Crop Traditional Barley Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Forage Radish Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Irrigation Water Capture Reuse	15	530.25	$/acre	15.91	$/acre/year	0	$/acre	67
Agriculture	Cover Crop Commodity Early	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Commodity Normal	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Commodity Late	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Forage Radish Plus Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	P removal systems	7	13.89	$/acre treated	9.32	$/acre treated/year	0	$/acre treated	11.72
Agriculture	Saturated Buffer	20	5439.76	$/acre	91.11	$/acre/year	1565.01	$/acre	605.86
Agriculture	Cover Crop Traditional Forage Radish Plus Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Tillage Management-Low Residue	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Tillage Management-Conservation	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional with Fall Nutrients Brassica Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Nutrient Management Core N	5	8.86	$/acre	4.1	$/acre/year	0	$/acre	6.15
Agriculture	Nutrient Management Core P	5	8.86	$/acre	4.71	$/acre/year	0	$/acre	6.76
Agriculture	Cropland Irrigation Management	1	38.42	$/acre	0	$/acre/year	0	$/acre	40.34
Agriculture	Nutrient Management N Rate	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management P Rate	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management N Placement	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Grass Buffer-Streamside with Exclusion Fencing	18	4053.2	$/acre	193.67	$/acre/year	971.31	$/acre	588.97
Agriculture	Nutrient Management P Placement	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management N Timing	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management P Timing	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Blind inlets with P-sorbing materials	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Tillage Management-Continuous High Residue	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Blind inlets	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Oats, Winter Hardy Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
	Forage Radish Plus Normal Drilled								
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Wetland Restoration - Floodplain	15	544.56	$/acre	52.11	$/acre/year	1770.23	$/acre	193.09

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Wetland Restoration - Headwater	15	3246.67	$/acre	52.11	$/acre/year	1770.23	$/acre	453.41
Agriculture	Wetland Creation - Floodplain	15	3240.84	$/acre	52.11	$/acre/year	1565.01	$/acre	442.59
Agriculture	Wetland Creation - Headwater	15	3393.93	$/acre	52.11	$/acre/year	1770.23	$/acre	467.6
Developed	Advanced Grey Infrastructure Nutrient Discovery Program (IDDE)	5	5.37	$/acre treated	9.91	$/acre treated/year	0	$/acre treated	11.15
Developed	Forest Conservation	1	0	$/acre	0	$/acre/year	0	$/acre	0
Developed	Impervious Surface Reduction	21	711456.42	$/acre	1968.74	$/acre/year	0	$/acre	57459.57
Developed	Conservation Landscaping Practices	10	206.9	$/acre	-329.69	$/acre/year	0	$/acre	-302.9
Developed	Forest Buffer	40	4062.42	$/acre	0	$/acre/year	0	$/acre	236.75
Developed	Grass Buffers	10	899.15	$/acre	35.97	$/acre/year	0	$/acre	152.41
Developed	Dirt & Gravel Road Erosion & Sediment Control - Driving Surface Aggregate + Raising the Roadbed	25	14.98	$/foot	0.3	$/foot/year	0	$/foot	1.36
Developed	Wet Ponds and Wetlands	32	11504.51	$/acre treated	361.51	$/acre treated/year	780.79	$/acre treated	1128.56
Developed	Dry Detention Ponds and Hydrodynamic Structures	30	10008.07	$/acre treated	155.54	$/acre treated/year	380.78	$/acre treated	825.62
Developed	Dry Extended Detention Ponds	23	4351.97	$/acre treated	76.69	$/acre treated/year	761.56	$/acre treated	437.41
Developed	Infiltration Practices w/o Sand, Veg. - A/B soils, no underdrain	35	21810.28	$/acre treated	1032.04	$/acre treated/year	1951.97	$/acre treated	2461.63
Developed	Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	35	23481.02	$/acre treated	1070.44	$/acre treated/year	1951.97	$/acre treated	2602.06

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Filtering Practices	22	25767.52	$/acre treated	763.45	$/acre treated/year	487.99	$/acre treated	2745.42
Developed	Stormwater Performance Standard-Runoff Reduction	25	33195.59	$/acre	1709.24	$/acre/year	1951.97	$/acre	4162.15
Developed	Stormwater Performance Standard-Stormwater Treatment	21	16243.99	$/acre	462.48	$/acre/year	1724.24	$/acre	1815.66
Developed	Impervious Disconnection to amended soils	5	0	$/impervious acre	0	$/impervious acre/year	217046.1	$/impervious acre	10852.31
Developed	Filter Strip Runoff Reduction	10	11459.95	$/acre	262.46	$/acre/year	7807.87	$/acre	2136.97
Developed	Filter Strip Stormwater Treatment	10	11459.95	$/acre	262.46	$/acre/year	3903.93	$/acre	1941.77
Developed	Forest Planting	28	470.95	$/acre	7.06	$/acre/year	0	$/acre	38.67
Developed	Tree Planting - Canopy	40	1433.84	$/acre	21.51	$/acre/year	0	$/acre	105.07
Developed	Dirt & Gravel Road Erosion & Sediment Control - Driving Surface Aggregate with Outlets	25	15.87	$/foot	0.44	$/foot/year	0	$/foot	1.57
Developed	Dirt & Gravel Road Erosion & Sediment Control - Outlets only	10	0.89	$/foot	0.14	$/foot/year	0	$/foot	0.26
Developed	Bioretention/raingardens - A/B soils, underdrain	22	39377.89	$/acre treated	2856.03	$/acre treated/year	1171.18	$/acre treated	5906.15
Developed	Bioswale	35	17420.79	$/acre treated	1219.76	$/acre treated/year	780.79	$/acre treated	2322.72
Developed	Permeable Pavement w/ Sand, Veg. - A/B soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Vegetated Open Channels - A/B soils, no underdrain	20	44589.14	$/acre treated	2271.82	$/acre treated/year	780.79	$/acre treated	5888.81
Developed	Floating Treatment Wetland 10% Coverage of Pond	3	3819.5	$/acre	190.97	$/acre/year	0	$/acre	1593.52
Developed	Floating Treatment Wetland 20% Coverage of Pond	3	7638.99	$/acre	381.95	$/acre/year	0	$/acre	3187.05
Developed	Floating Treatment Wetland 30% Coverage of Pond	3	11458.49	$/acre	572.92	$/acre/year	0	$/acre	4780.58
Developed	Floating Treatment Wetland 40% Coverage of Pond	3	15277.98	$/acre	763.9	$/acre/year	0	$/acre	6374.11
Developed	Floating Treatment Wetland 50% Coverage of Pond	3	19097.48	$/acre	954.87	$/acre/year	0	$/acre	7967.63
Developed	Nutrient Management Plan	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Plan High Risk Lawn	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Plan Low Risk Lawn	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Maryland Commercial Applicators	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Maryland Do It Yourself	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Vegetated Open Channels - C/D soils, no underdrain	20	73270.44	$/acre treated	3614.74	$/acre treated/year	780.79	$/acre treated	9533.19
Developed	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	22	125057.41	$/acre treated	8881.67	$/acre treated/year	19519.67	$/acre treated	19358.33

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Permeable Pavement w/ Sand, Veg. - A/B soils, no underdrain	22	125057.41	$/acre treated	8881.67	$/acre treated/year	19519.67	$/acre treated	19358.33
Developed	Permeable Pavement w/ Sand, Veg. - C/D soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Bioretention/raingardens - A/B soils, no underdrain	22	17720.05	$/acre treated	1285.21	$/acre treated/year	1171.18	$/acre treated	2689.97
Developed	Bioretention/raingardens - C/D soils, underdrain	23	49630.78	$/acre treated	1770.61	$/acre treated/year	1171.18	$/acre treated	5508.64
Developed	Advanced Sweeping Technology - 2 pass/week	8	3788.19	$/acre	3091.16	$/acre/year	0	$/acre	3677.28
Developed	Advanced Sweeping Technology - 1 pass/week	8	1894.1	$/acre	1545.58	$/acre/year	0	$/acre	1838.64
Developed	Advanced Sweeping Technology - 1 pass/2 weeks	8	947.05	$/acre	772.79	$/acre/year	0	$/acre	919.32
Developed	Advanced Sweeping Technology - 1 pass/4 weeks	8	473.52	$/acre	386.4	$/acre/year	0	$/acre	459.66
Developed	Advanced Sweeping Technology - 1 pass/8 weeks	8	236.76	$/acre	193.2	$/acre/year	0	$/acre	229.83
Developed	Advanced Sweeping Technology - 1 pass/12 weeks	8	156.63	$/acre	127.81	$/acre/year	0	$/acre	152.04
Developed	Advanced Sweeping Technology - spring 1 pass/1-2 weeks else monthly	8	655.65	$/acre	535.01	$/acre/year	0	$/acre	636.45

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Advanced Sweeping Technology - fall 1 pass/1-2 weeks else monthly	8	874.2	$/acre	713.35	$/acre/year	0	$/acre	848.61
Developed	Mechanical Broom Technology - 2 pass/week	5	1894.1	$/acre	6182.33	$/acre/year	0	$/acre	6619.82
Developed	Mechanical Broom Technology - 1 pass/week	5	947.05	$/acre	3091.16	$/acre/year	0	$/acre	3309.9
Developed	Mechanical Broom Technology - 1 pass/4 weeks	5	236.76	$/acre	772.79	$/acre/year	0	$/acre	827.48
Developed	Storm Drain Cleaning	1	0.77	$/lb of TSS	0	$/lb of TSS/year	0	$/lb of TSS	0.81
Developed	Erosion and Sediment Control Level 1	1	1439.26	$/acre	0	$/acre/year	0	$/acre	1511.22
Developed	Erosion and Sediment Control Level 2	1	6040.36	$/acre	0	$/acre/year	0	$/acre	6342.38
Developed	Erosion and Sediment Control Level 3	1	7550.45	$/acre	0	$/acre/year	0	$/acre	7927.97
Natural	Abandoned Mine Reclamation	20	18986.21	$/acre	113.67	$/acre/year	0	$/acre	1637.17
Natural	Urban Stream Restoration Protocol	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Non Urban Stream Restoration Protocol	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Urban Stream Restoration	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Non Urban Stream Restoration	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Urban Shoreline Management	20	590.18	$/foot	29.51	$/foot/year	0	$/foot	76.87
Natural	Oyster reef restoration – nutrient assimilation	50	18036.15	$/acre	179.31	$/acre/year	0	$/acre	1167.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Natural	Oyster reef restoration – enhanced denitrification	50	18036.15	$/acre	179.31	$/acre/year	0	$/acre	1167.27
Natural	Non Urban Shoreline Management	20	100.72	$/foot	5.04	$/foot/year	0	$/foot	13.12
Natural	Forest Harvesting Practices	1	56.45	$/acre	0	$/acre/year	0	$/acre	59.27
Natural	Non Urban Shoreline Erosion Control Non-Vegetated	20	163	$/foot	8.15	$/foot/year	0	$/foot	21.23
Natural	Non Urban Shoreline Erosion Control Vegetated	20	45.19	$/foot	2.26	$/foot/year	0	$/foot	5.89
Natural	Urban Shoreline Erosion Control Non-Vegetated	20	1076.21	$/foot	53.81	$/foot/year	0	$/foot	140.17
Natural	Urban Shoreline Erosion Control Vegetated	20	104.15	$/foot	5.21	$/foot/year	0	$/foot	13.57
Natural	Algal Flow-way Tidal	50	701953.68	$/acre	29043.49	$/acre/year	0	$/acre	67494.22
Natural	Algal Flow-way Tidal Monitored	50	0	$/acre	39.13	$/acre/year	0	$/acre	39.13
Natural	Algal Flow-way Non-Tidal	50	701953.68	$/acre	29043.49	$/acre/year	0	$/acre	67494.22
Natural	Algal Flow-way Non-Tidal Monitored	50	0	$/acre	39.13	$/acre/year	0	$/acre	39.13
Natural	Wetland Enhancement	15	1336.9	$/acre	52.11	$/acre/year	1770.23	$/acre	269.42
Natural	Wetland Rehabilitation	15	3246.67	$/acre	52.11	$/acre/year	1770.23	$/acre	453.41
Natural	Diploid Oyster Aquaculture 2.25 Inches	2	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Diploid Oyster Aquaculture 3.0 Inches	3	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Natural	Diploid Oyster Aquaculture 4.0 Inches	4	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Diploid Oyster Aquaculture 5.0 Inches	5	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Natural	Diploid Oyster Aquaculture Greater 6.0 Inches	6	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Natural	Triploid Oyster Aquaculture 2.25 Inches	2	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 3.0 Inches	2	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 4.0 Inches	3	-0.03	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 5.0 Inches	4	-0.04	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture Greater than 6.0 Inches	5	-0.05	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Site-Specific Monitored Oyster Aquaculture	4	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Septic	Septic Effluent - Advanced	30	23296.95	$/system	1457.49	$/system/year	0	$/system	2972.99
Septic	Septic Secondary Treatment - Advanced	30	34067.99	$/system	1753.65	$/system/year	0	$/system	3969.82
Septic	Septic Denitrification - Advanced	30	46249.61	$/system	2972.37	$/system/year	0	$/system	5980.97
Septic	Septic Denitrification - Enhanced	30	57396.87	$/system	2612.92	$/system/year	0	$/system	6346.67
Septic	Septic Secondary Treatment - Enhanced	30	30296.02	$/system	1164.67	$/system/year	0	$/system	3135.47
Septic	Septic Denitrification - Conventional	30	37871.89	$/system	1744.4	$/system/year	0	$/system	4208.02
Septic	Septic Effluent - Enhanced	30	19524.98	$/system	868.52	$/system/year	0	$/system	2138.65
Septic	Septic Secondary Treatment - Conventional	30	10771.04	$/system	1753.65	$/system/year	0	$/system	2454.32
Septic	Septic Connection	25	14457.83	$/system	234.4	$/system/year	0	$/system	1260.22
Septic	Septic Pumping	1	0	$/system	114	$/system/year	0	$/system	114

Animal BMP Costs

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Transport	pullets	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	turkeys	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	hogs and pigs for breeding	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	beef	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	broilers	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	dairy	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	hogs for slaughter	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	horses	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	layers	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	other cattle	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	sheep and lambs	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	goats	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Mortality Composters	pullets	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	turkeys	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	hogs and pigs for breeding	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	beef	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	broilers	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	dairy	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	hogs for slaughter	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	horses	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	layers	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	other cattle	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	sheep and lambs	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	goats	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Poultry Nutrient Reduction	pullets	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Poultry Nutrient Reduction	turkeys	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Poultry Nutrient Reduction	broilers	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Poultry Nutrient Reduction	layers	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Dairy Precision Feeding and/or Forage Management	dairy	1	0	$/animal unit	-43.99	$/animal unit/year	0	$/animal unit	-43.99
Poultry Litter Amendments (alum, for example)	pullets	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	turkeys	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	broilers	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	layers	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Biofilters	pullets	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	turkeys	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	broilers	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	layers	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Lagoon Covers	hogs and pigs for breeding	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	beef	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	dairy	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	hogs for slaughter	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	other cattle	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Animal Waste Management System	pullets	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	turkeys	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Animal Waste Management System	hogs and pigs for breeding	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	beef	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	broilers	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	dairy	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	hogs for slaughter	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	horses	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	layers	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	other cattle	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	sheep and lambs	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	goats	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Manure Treatment Slow Pyrolysis	pullets	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	turkeys	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	hogs and pigs for breeding	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	beef	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	broilers	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	dairy	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	hogs for slaughter	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Slow Pyrolysis	horses	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	layers	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	other cattle	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	sheep and lambs	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	goats	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Fast Pyrolysis	pullets	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	turkeys	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	hogs and pigs for breeding	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	beef	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	broilers	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	dairy	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	hogs for slaughter	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	horses	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	layers	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	other cattle	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	sheep and lambs	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	goats	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Low Heat Gasification	pullets	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	turkeys	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	hogs and pigs for breeding	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	beef	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	broilers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	dairy	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	hogs for slaughter	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	horses	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	layers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	other cattle	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	sheep and lambs	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	goats	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	pullets	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	turkeys	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	hogs and pigs for breeding	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	beef	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	broilers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment High Heat Gasification	dairy	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	hogs for slaughter	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	horses	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	layers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	other cattle	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	sheep and lambs	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	goats	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Combustion	pullets	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	turkeys	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	hogs and pigs for breeding	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	beef	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	broilers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	dairy	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	hogs for slaughter	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	horses	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	layers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	other cattle	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Combustion	sheep and lambs	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	goats	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	pullets	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	turkeys	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	hogs and pigs for breeding	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	beef	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	broilers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	dairy	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	hogs for slaughter	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	horses	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	layers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	other cattle	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	sheep and lambs	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	goats	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Rotating Bin	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Rotating Bin	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Rotating Bin High CN	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Forced Aeration	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Forced Aeration	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Forced Aeration High CN	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Forced Aeration Low CN	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Turned Pile Windrow	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow High CN	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow Low CN	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Static Pile Windrow	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow High CN	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow Low CN	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Treatment Direct Monitor	pullets	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	turkeys	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	hogs and pigs for breeding	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	beef	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	broilers	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	dairy	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	hogs for slaughter	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	horses	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	layers	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	other cattle	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Direct Monitor	sheep and lambs	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	goats	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Broiler Mortality Freezers	broilers	15	7836.06	$/ton of carcasses	1751.84	$/ton of carcasses/year	0	$/ton of carcasses	2506.78