pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF CLEAN WATER
FISHING CREEK ADVANCE RESTORATION PLAN
LANCASTER COUNTY
SUBMISSION FOR USEPA ACCEPTANCE, MARCH 26, 2025

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EXECUTIVE SUMMARY

An Advance Restoration Plan (ARP) was developed for the Fishing Creek watershed to address siltation impairments. This study was intended as a more comprehensive follow up to a prior restoration effort that only targeted areas within the middle watershed.

Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from similar unimpaired watersheds were used to calculate allowable loading. It was concluded that sediment loading within seven study subwatersheds of Fishing Creek should be reduced by the following percentages: 61% in Head, 46% in A; 53% in B; 58% in C; 21% in D; 20% in F and 33% in G. Subwatershed E was prescribed no additional reductions. Allocation of sediment loading among the ARP variables is summarized in Table 1.

Table 1. Summary of sediment ARP variables for the Fishing Creek subwatersheds. All values are annual averages in lbs/yr.

Subwatershed	AL	UF	SL	LNR	ASL
Head	1,365,923	136,592	1,229,331	8,689	1,220,642
A	433,480	43,348	390,132	1,543	388,588
B	469,553	46,955	422,597	1,257	421,341
C	432,370	43,237	389,133	1,032	388,101
D	415,363	41,536	373,827	1,338	372,489
E	282,807	28,281	254,527	679	253,847
F	274,170	27,417	246,753	676	246,077
G	410,849	41,085	369,764	870	368,894

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

An analysis of best management practice (BMP) opportunities suggests that sediment loading could be reduced beyond what is necessary to achieve water quality standards within each of these seven target subwatersheds. Therefore, an analysis was made to preferentially select more cost effective BMPs. While all of the identified opportunities had a total capital cost of about $3 million, it was estimated that sediment reduction goals could be met for about $229,000, if more cost effective BMPs such as agricultural erosion and sedimentation plan implementation, conservation tillage and precision located grass filter strips were preferentially utilized. However, because of the importance of forested buffers for other aspects of stream habitat, a third “cheapest BMPs plus half the forested buffer opportunities” option was also presented, and its capital cost was about $800,000. In addition to these costs, the plan proposes an additional $110,000 to support the use of agricultural consultants and for the installation of educational signage.

This plan is to be implemented over a nine-year period primarily by The Donegal Chapter of Trout Unlimited in cooperation with landowners and other key partners, such as the Lancaster County Conservation District and the Pennsylvania Department of Environmental Protection (DEP). The primary goal of this plan is the reversal of Aquatic Life Use impairments. Secondary goals include the improvement of wild trout populations and recreational value of the watershed, as well as the protection of the Chesapeake Logperch, a state threatened species.

INTRODUCTION

Fishing Creek (Figure 1) is a second order tributary of the Susquehanna River in southwestern Lancaster County. Its mouth is approximately one mile southeast of Susquehannock State Park and its total watershed area is about 14 square miles. The Fishing Creek watershed contained approximately 21 stream miles; 7 miles were designated Exceptional Value Waters, Migratory Fishes while the remaining were designated High Quality Waters – Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93 (Figure 1).

According to the 2022 Integrated Report (IR) (DEP 2022b), reaches upstream of the Furniss Road area were listed as impaired for siltation due to agriculture (Figure 2, Table 2). Some of these reaches were impaired for habitat as well. Such impairments are consistent with expectations given that approximately 62% of the land cover in the Fishing Creek watershed was agriculture (based Model My Watershed output, Stroud water Research Center 2023). Aside from concentrated animal feeding operations (CAFOs), which will be treated as nonpoint sources in this study, there were no National Pollutant Discharge Elimination System (NPDES) permitted point sources within the watershed (Table 3).

The removal of natural vegetation and soil disturbance associated with agriculture increases soil 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)); and,*
>
> *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 purpose of this study was to develop a watershed restoration plan for Fishing Creek. While many streams within Pennsylvania suffer similar impairments, the Fishing Creek watershed is of special interest due to its recreational value and the presence of wild trout and Chesapeake Logperch *(Percina bimaculata)* populations. These attributes may be partially a consequence of the watershed's topography. As is common for piedmont streams draining to the Susquehanna River in southern Lancaster and York counties, headwater streams originate in low relief agricultural uplands while the lower mainstem rapidly descends through a deeply incised and largely forested valley (Figures 3 and 4). Thus, the headwater streams were the most degraded while the middle and lower mainstem was comparatively well-buffered, as their steep valley walls were not conducive to agriculture (Figures 2, 3 and 4). Furthermore, the high gradient lower mainstem may be less vulnerable to siltation pollution as its powerful flows may better flush, rather than accumulate, silt deposits. Even so, the mainstem's health suffers from the high sediment loads that it transports.

The Fishing Creek watershed offers exceptional recreational opportunities given the hundreds of streamside acres that have been preserved by the Lancaster Conservancy. While Fishing Creek is stocked with hatchery-raised trout, there is also a significant wild trout population, though biomass is presently not high enough for the stream to be considered "Class A". Such wild trout streams are uncommon in Lancaster County, and the fact that they are able to persist at all in this agricultural-dominated watershed may be due to the presence of large forested tracts along a high gradient mainstem.

Of greater conservation concern however is the presence of Chesapeake Logperch within Fishing Creek's lower mainstem. Until recently, Chesapeake Logperch was not recognized as a distinct species apart from Common Logperch *(Percina caprodes)*. However, research published in 2008 indicated that it was a separate species, as confirmed by both genetics and morphology (Pennsylvania Fish and Boat Commission (PFBC) 2015). Historic records suggest that it has been extirpated from much of its native range, including all populations within the Potomac River basin (PFBC 2015). And, as of 2015, this species was only found in about thirty combined stream miles in Pennsylvania (PFBC 2015). Given these losses and its limited native range, the Chesapeake Logperch is now classified as "Threatened" in Pennsylvania (58 Pa. Code § 75.2) and is being considered for listing under the Federal Endangered Species Act. Since pollution is thought to be a major factor contributing to Chesapeake Logperch's decline (PFBC 2015), its persistence within lower Fishing Creek may also be encouraged by the presence of large forested tracts along the lower mainstem. The abundance of Chesapeake Logperch within Lower Fishing Creek watershed was the basis for its "Exceptional Value" designations, as shown in Figure 1 (DEP 2010).

The present study follows a prior restoration effort that lasted from 2016 to 2021 known as the "Pennsylvania Adaptive Toolbox for Conservation Saturation" project (Adaptive Toolbox Project). This project utilized National Fish and Wildlife Foundation funding and was led by the Pennsylvania Department of Agriculture and major cooperating partners such as the Donegal Chapter of Trout Unlimited, the Lancaster County Conservation District, Lancaster Farmland Trust, and the United States Fish and Wildlife Service. Major accomplishments included the development or updating of 32 agricultural erosion and sedimentation plans, the installation of over 3.8 miles of livestock exclusion fencing, restoring 2.0 miles of stream habitat, and establishing more than 7.0 acres of forested riparian buffers and 820 feet of grassed waterways. This work was limited to one study area that included three tributaries and part of the mainstem within the middle watershed (Figure 1). (Berger 2021)

The present study hopes to expand upon these successes by more comprehensively addressing siltation pollution within the larger Fishing Creek watershed. Since observations suggest that much of the problems within the middle and lower mainstem have already been corrected, this study will focus on the headwaters area and smaller tributaries that now appear to be the major sources of pollutant loading (Figure 2). Valuable projects may be found outside of these target subwatersheds, and the present plan does not mean to prevent work in other areas. But, such outside work will not considered a target for the present study. Funding will be sought from DEP's nonpoint source program per Section 319 of the Clean Water Act. It is ultimately hoped that this restoration plan will restore impaired reaches of the Fishing Creek watershed, thus bolstering existing wild trout and Chesapeake Logperch populations and improving its recreational value, while maintaining sustainable agriculture.

Table 2. Aquatic Life Use impaired stream segments in the Fishing Creek watershed 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
Habitat Modification-Other than Hydromodification	Habitat Alterations	12.3
Agriculture	Siltation	21.8

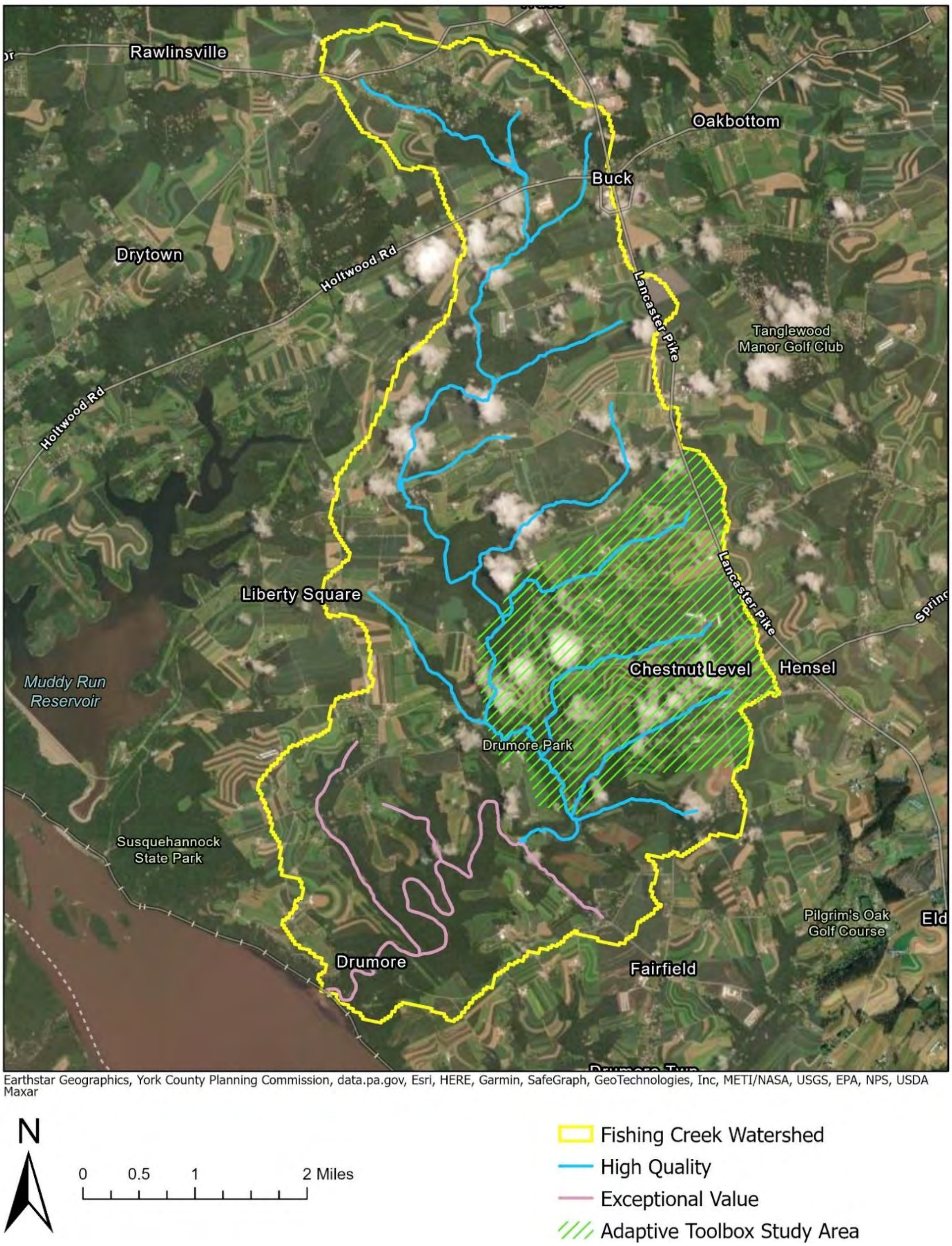


Figure 1. Fishing Creek watershed. Stream segments are identified by their designated use at 25 Pa. Code § 93. The green hash marks show the approximate area of the prior "Adaptive Toolbox" project.

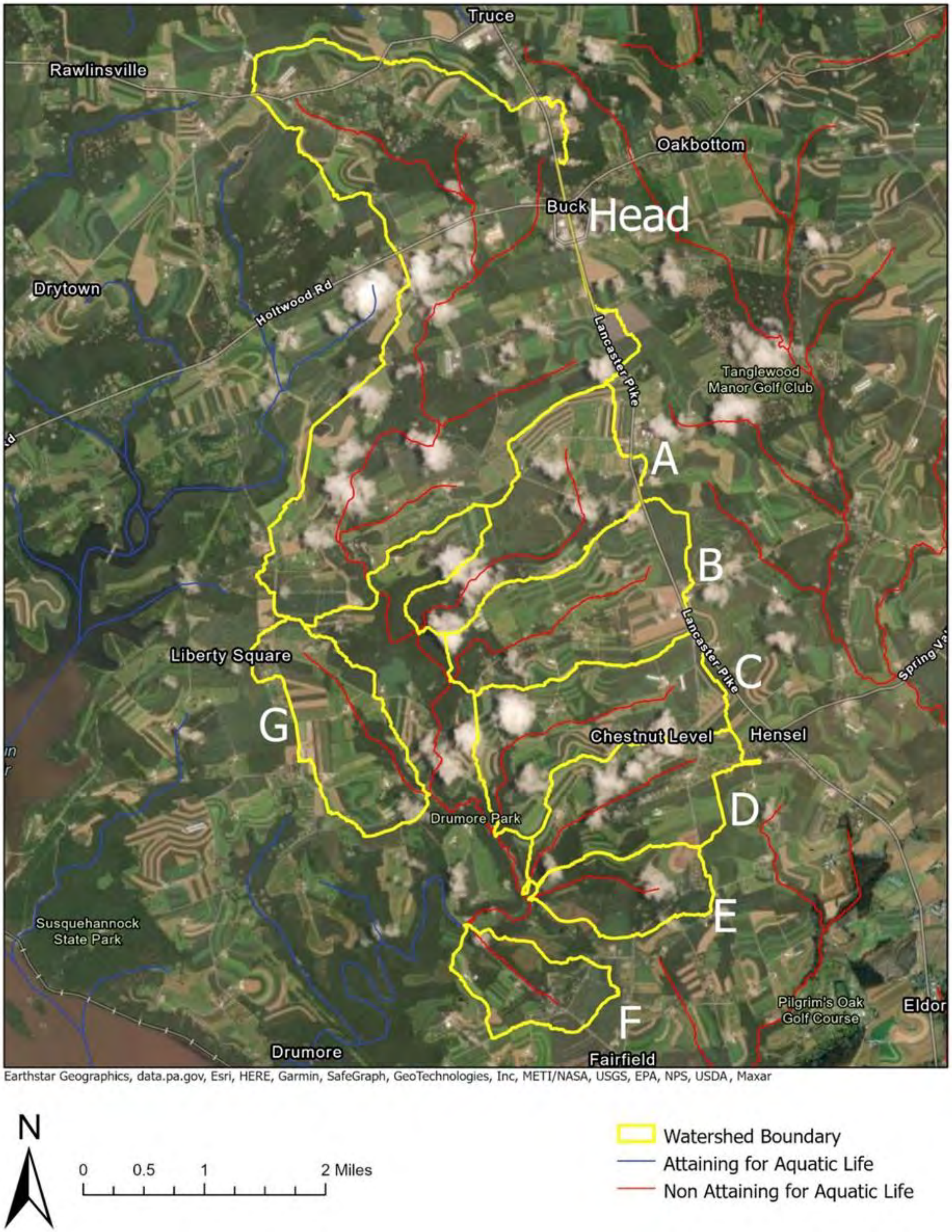


Figure 2. Fishing Creek watershed broken up into impaired subwatersheds. All red stream segments within the Fishing Creek watershed were listed as impaired for siltation due to agriculture per the 2022 Integrated Report. The various subwatersheds will be referred to per the above labels (in large white text).

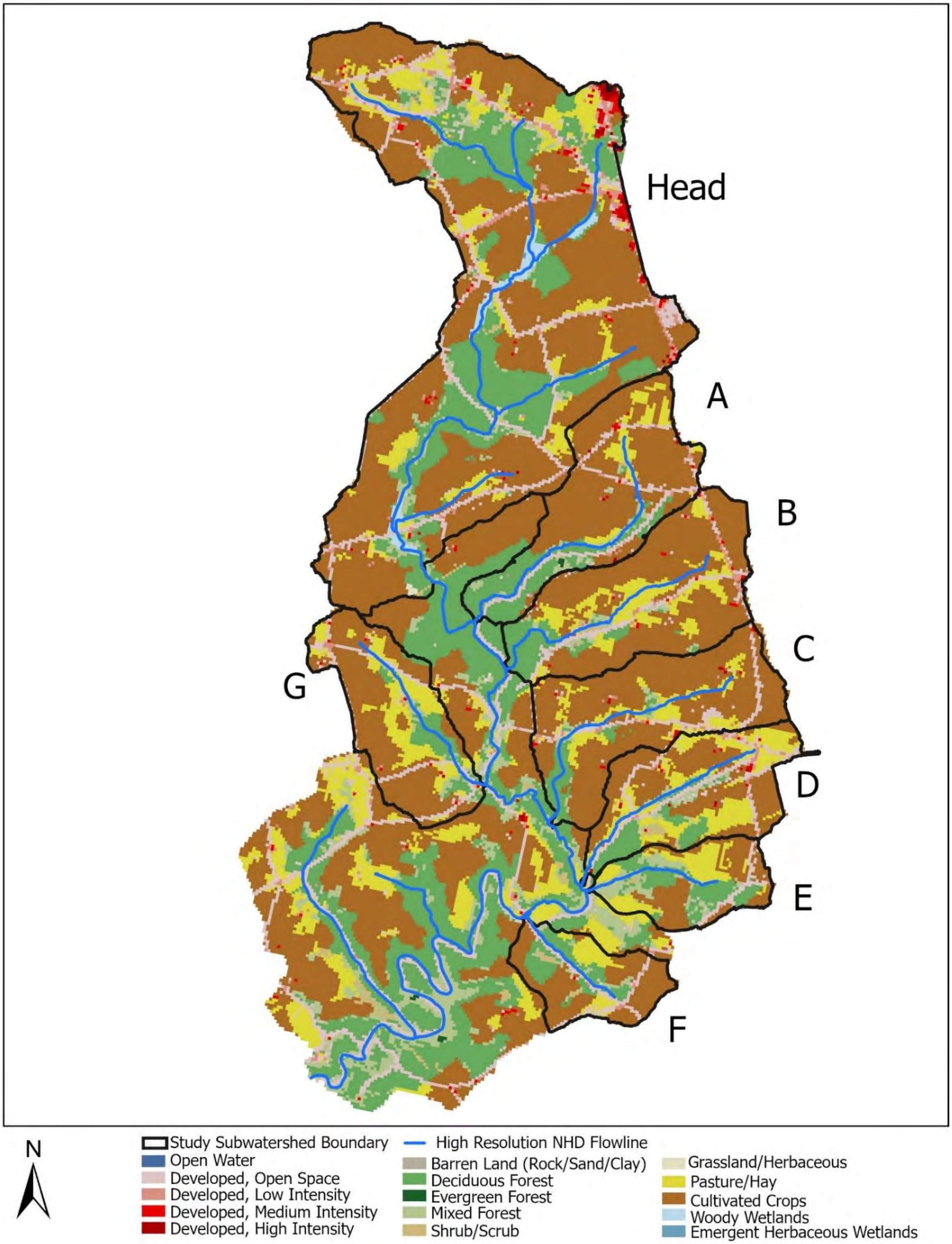


Figure 3. Land cover in the Fishing Creek watershed per NLCD 2019 (Dewitz and U.S. Geological Survey 2021).

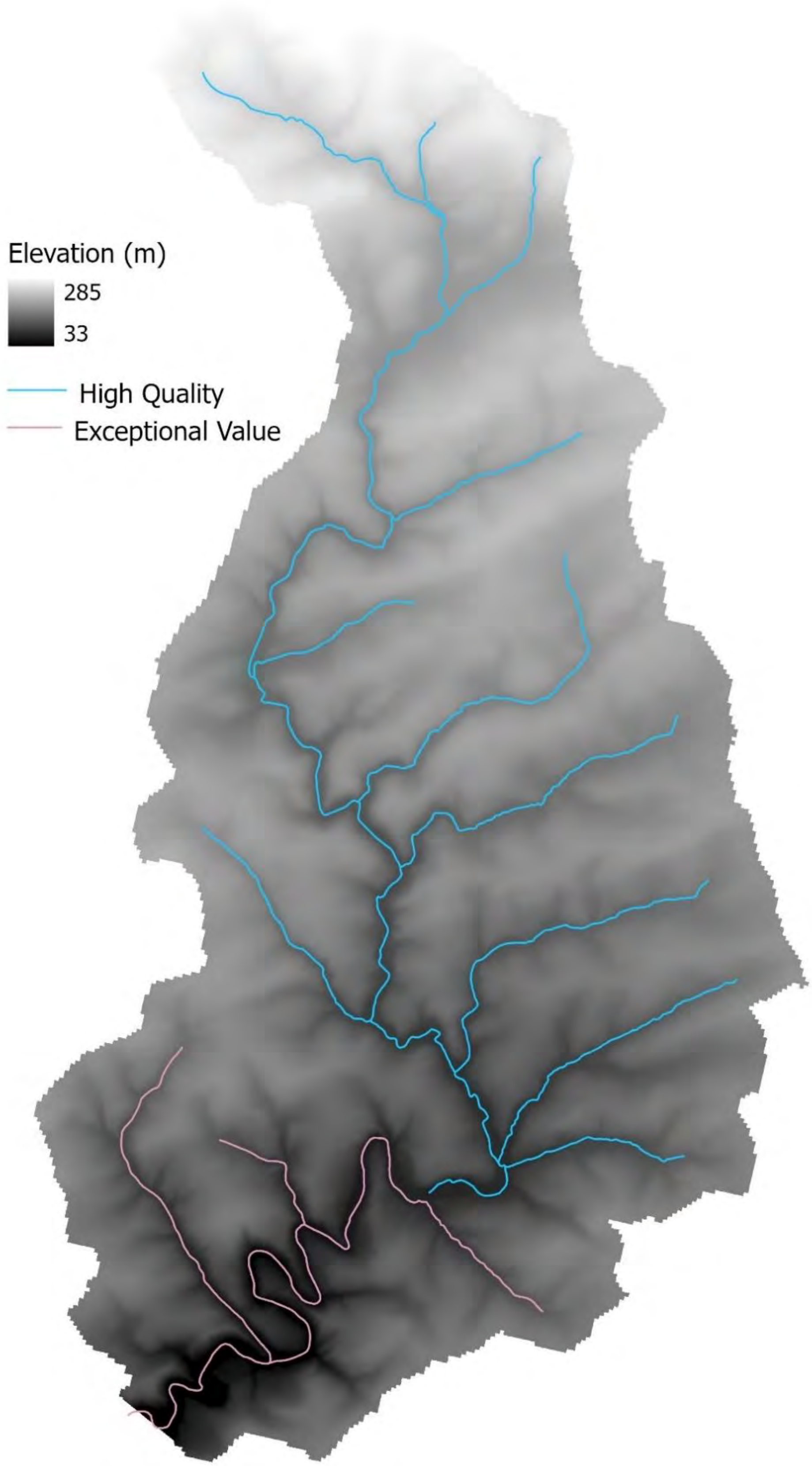


Figure 4. Elevation within the Fishing Creek watershed per a one-meter resolution digital elevation model (USGS 2022). This figure was made in ArcGIS Pro by Esri.

Table 3. Existing NPDES permitted discharges in the Fishing Creek watershed and their potential contribution to sediment Loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Mean, lbs/yr
PA0259969	Silver Crest Acres CAFO[1]	NA
PA0266574	John Lefever CAFO[1]	NA

Permits within the delineated watershed were based on DEP's 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 BMPs.

ARP APPROACH FOR ESTABLISHING POLLUTANT REDUCTION GOALS

Per the Federal Clean Water Act, waters with pollutant impairments typically require the establishment of "Total Maximum Daily Loads" (TMDLs) that set allowable pollutant loading limits. The TMDL is then allocated among point source dischargers, nonpoint sources, natural and anthropogenic background sources not considered responsible for the impairments, as well as a margin of safety factor. TMDLs can then be used to set appropriate loading limits for NPDES permitted dischargers. However, where the pollution problem is due primarily to unpermitted nonpoint sources, there may be no effective mechanism to force pollution reductions. Thus, historically there have been many nonpoint source TMDLs developed that have led to little actual stream improvements.

In recognition of this, the United States Environmental Protection Agency (USEPA) has allowed an alternative or advance restoration plan (ARP) approach, which is essentially a short-term restoration plan that is to be implemented to address the pollution impairments. If it can be shown that the plan can be implemented and could result in the reversal of the impairments, the development of a TMDL may be postponed. If, however, the ARP fails to reverse impairments then a TMDL would be required.

The same basic TMDL process can also be utilized when developing ARPs. These steps include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of a TMDL, or in the case of the ARP, an allowable loading value that appropriately accounts for critical conditions and seasonal variations;
3. Allocation of pollutant loads to various sources;
4. Submission of draft reports for public review and comments; and
5. USEPA approval of the TMDL, or recognition of the ARP.

Because Pennsylvania does not have numeric water quality criteria for sediment, the "reference watershed approach" was used. This method estimates sediment loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for sediment. 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 attaining watershed will result in the impaired stream segments attaining their designated uses.

SELECTION OF THE REFERENCE WATERSHED

In addition to anthropogenic influences, there are many other natural factors affecting sediment loading rates and accumulation. 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 unattainable, 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 DEP's Integrated Report (DEP 2022b) were used to search for other comparably sized watersheds that were within similar topography but lacked stream segments impaired for Aquatic Life Use. To increase the likelihood that the reference would be similar with regard to many important characteristics, emphasis was given to finding a reference that, like the impaired watershed, was also primarily within the Piedmont Upland section of the Piedmont Physiographic Province (Table 4). Once potential references were identified, they were screened to determine which ones were most like the impaired watershed with regard to factors such as landscape position, topography, hydrology, soil drainage types, landuse 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 a reasonable pollution reduction.

Two obvious potential choices were the Huber and Trout Run watersheds, as they share their northern border with the Fishing Creek watershed. Finding such close references greatly improves the likelihood that a wide range of watershed characteristics will be similar. And, while both were too small to be used as a reference for the entire impaired area of the Fishing Creek watershed, they were of suitable size when the Fishing Creek watershed was broken up into a headwaters area and individual tributary subwatersheds, as in Figure 5. Because of similarities in stream slope, the Huber Run watershed was chosen for further evaluation as a reference for the headwaters of Fishing Creek. The unnamed tributary to (UNT) Trout Run-west watershed, broken up into different sizes as in Figure 7, was considered further as a reference for the smaller tributaries, in part, since it provided more modest pollution reductions than either the Huber Run or Trout Run-east subwatersheds. See Table 4 for a summary comparing key characteristics of each impaired watershed to its potential reference.

Similarly to the Fishing Creek watershed, uplands consisted of rolling agricultural hills while streams often occurred in forested valleys in both the Huber and Trout Run watersheds. One difference however was that the potential references had far more forested landcover and less agricultural lands (Table 4). All impaired and reference watersheds were dominated by Class B-moderate infiltration soils, and modelled surface runoff rates were similar (Table 4). Furthermore, all impaired and reference watersheds were nearly exclusively dominated by schist bedrocks, and terrain and stream slopes were generally comparable (Table 4). Also like the Fishing Creek watershed (Table 6), NPDES-permitted point source discharges appeared to be either minor or irrelevant as point sources of sediment in the proposed reference watersheds. Taken together, these data suggest that differences in impairment status among the impaired and reference watersheds may be in large part driven by greater agricultural and lesser forested land covers in the Fishing Creek watershed (Figures 2,6, 7 and Tables 4 and 5).

Like the impaired areas of Fishing Creek, Trout Run was designated High Quality-Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93. In contrast, Huber Run was only designated Cold Water Fishes, Migratory Fishes, though recent assessment data suggests that much of the watershed may not be impaired even if evaluated according to High Quality standards (Figure 9, Table 5).

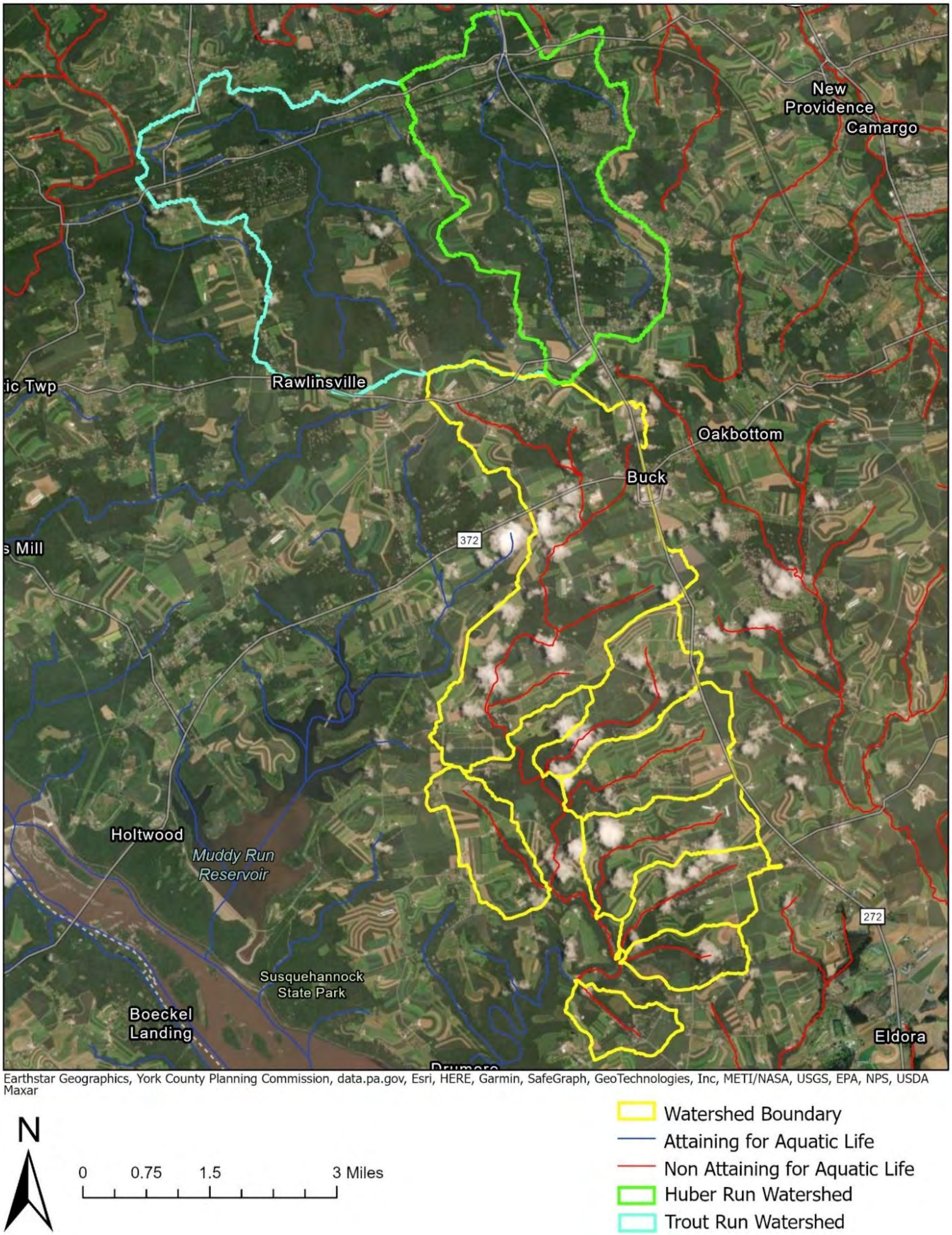


Figure 5. Fishing Creek, Huber Run and Trout Run watersheds.

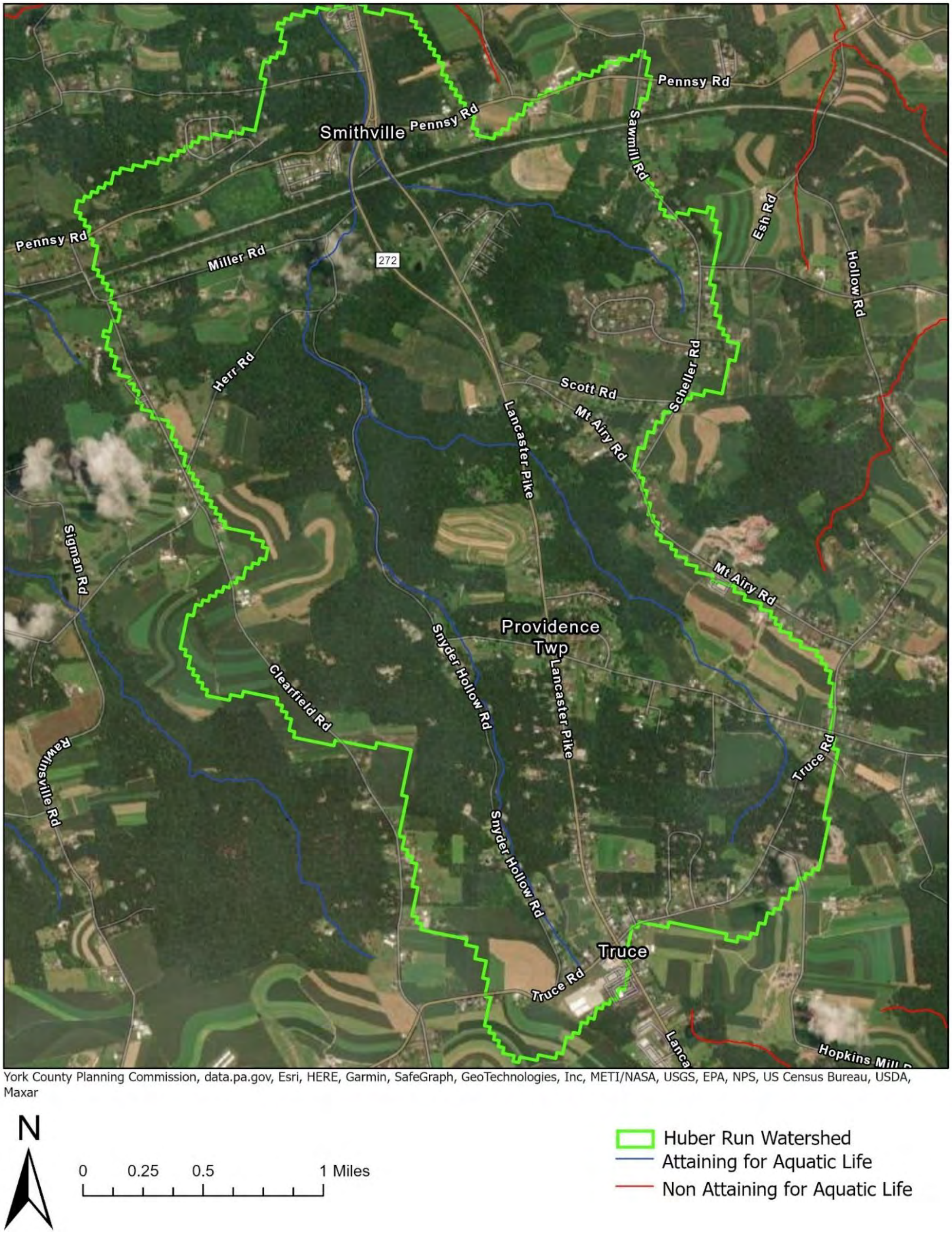


Figure 6. Huber Run reference watershed.

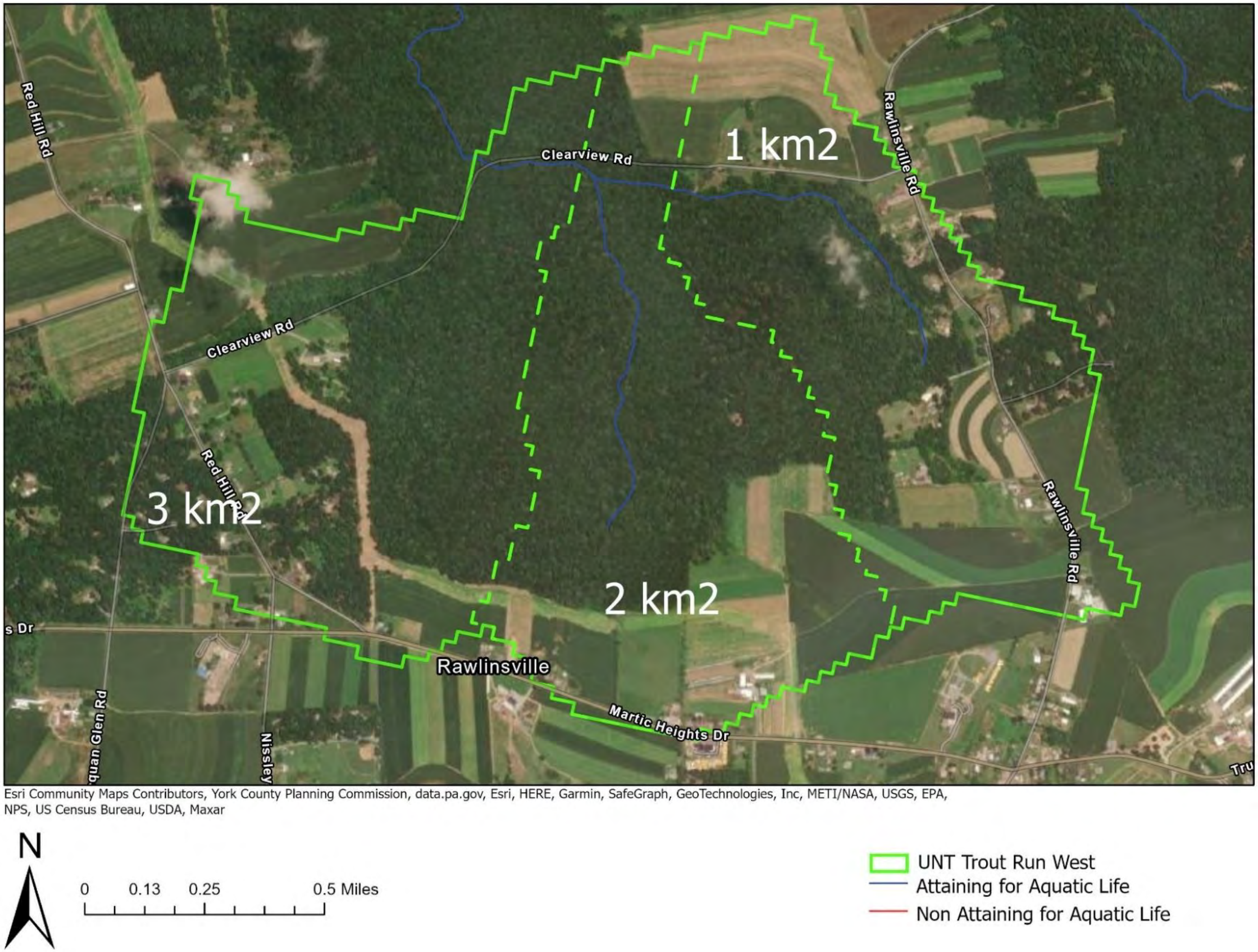


Figure 7. UNT Trout Run-west reference subwatershed. The reference watershed was delineated at different sizes (1 km^2, 2 km^2 or 3km^2) to match various Fishing Creek impaired subwatersheds.

Table 4. Comparison of the impaired Fishing Creek subwatersheds to the potential reference watersheds (Huber Run and UNT Trout Run-west, 1, 2 and 3km^2)

Watershed	**Fishing Cr. Head**	**Huber Run**	**Fishing Cr.** A	**Fishing Cr.** B	**Fishing Cr.** C	**Trout Run,** 3km^2	**Fishing Creek** D	**Fishing Creek** G	**Trout Run,** 2km^2	**Fishing Cr.** E	**Fishing Cr.** F	**Trout Run,** 1km^2
Land Area (ac)	2,904	2,921	612	701	644	751	500	484	487	298	280	235
Landuse[1] (%)												
Agriculture	62	32	66	79	83	34	69	75	40	56	62	45
Forest/Natural Vegetation	26	50	24	13	9	57	16	15	52	38	25	44
Developed	12	18	10	8	8	9	14	11	8	6	12	12
Soil Infiltration[2] (%)												
A	0	<1	0	0	0	0	0	0	0	0	0	0
B	91	92	99	94	94	98	91	97	99	94	96	99
B/D	6	3	0	0	0	2	0	0	<1	0	0	0
C	<1	<1	<1	<1	<1	0	<1	0	<1	0	0	0
C/D	3	4	<1	6	6	<1	9	3	<1	6	4	1
D	0	0	0	0	0	0	0	0	0	0	0	0
Dominant Bedrock[3] (%)												
Albite-Chlorite Schist	100	93	100	100	83	100	<1	100	100	0	0	100
Chlorite-Sericite Schist	0	0	0	0	17	0	>99	0	0	98	98	0
Metabasalt	0	0	0	0	0	0	0	0	0	2	2	0
Limestone	0	7	0	0	0	0	0	0	0	0	0	0
Average Precipitation[4] (in/yr)	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7
Average Surface Runoff[4] (in/yr)	2.3	1.7	2.1	2.2	2.3	1.6	2.0	2.0	1.7	1.6	2.0	1.9
Average Elevation[4] (ft)	704	589	626	571	517	788	489	567	803	479	467	800
Average Slope[4] (%)	6.9	11.0	7.4	7.1	8.3	10.3	10	8.0	9.6	9.8	9.8	8.9
Average Channel Slope[5] (%)												
1st order	2.9	2.8	1.9	1.7	2.1	4.7	2.5	3.6	4.7	3.0	3.9	4.4
2nd order	1.0	1.4			0.8	2.2			2.2		0.7	

[1]based on MMW output utilizing NLCD 2019

[2]Soil Infiltration 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

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

[4]per MMW output

[5]per MMW output based on USGS high-resolution NHD flowlines

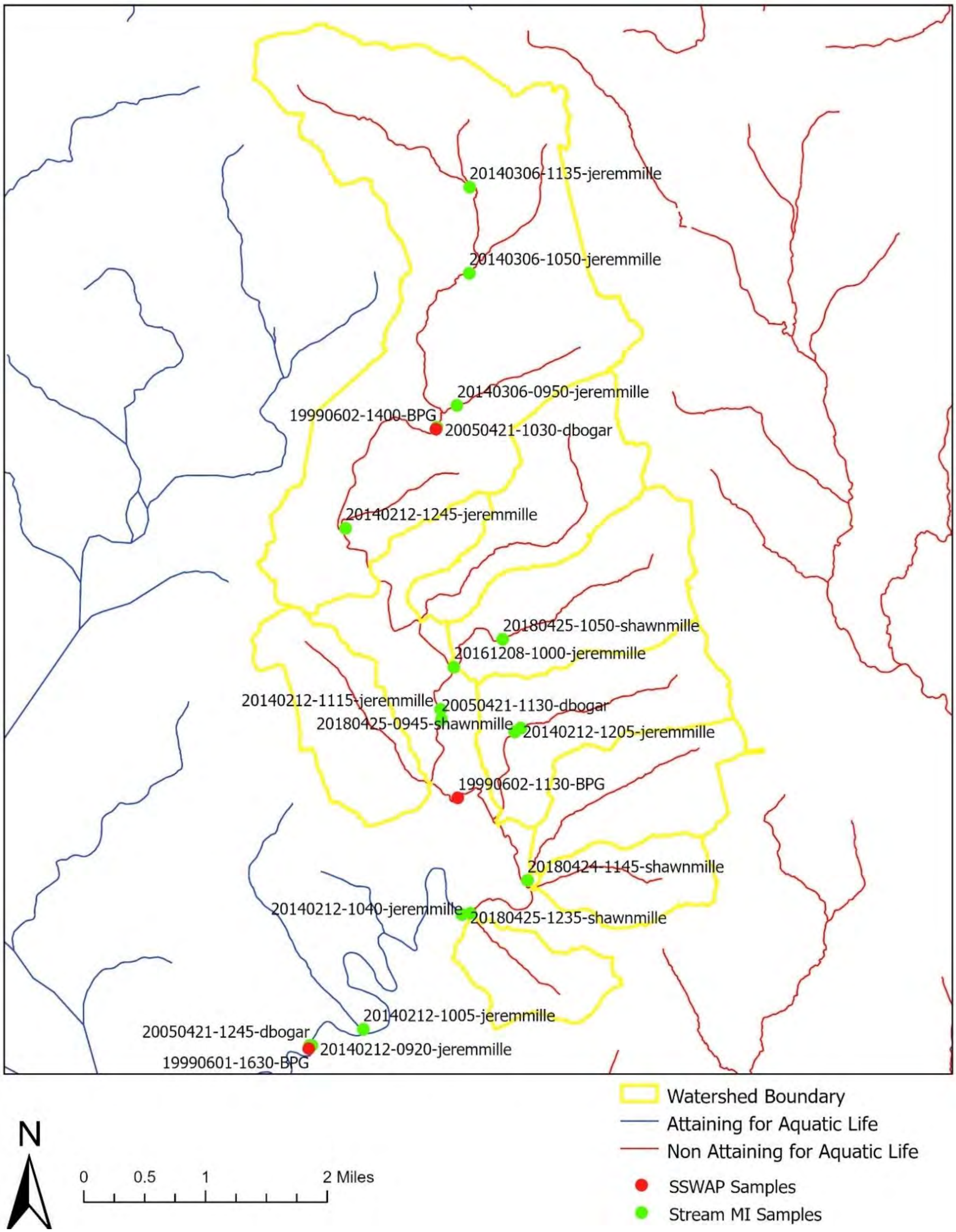


Figure 8. DEP assessment sites within the Fishing Creek watershed. The labels correspond to the labels used in Table 5.

Table 5. Summary of DEP assessment data in Fishing Creek and reference watersheds. Index of Biotic Integrity (IBI) scores below the impairment threshold suggest impairment. Sediment deposition + embeddedness couplet scores ≤24 suggest impairment for siltation. See Figures 8-10 for sample locations.

Watershed	Sample ID	Sample Type	IBI Score	Impairment Threshold HQ/EV	Impairment Threshold Regular	Passes Questions ?	Macro-invertebrates Impaired?	Sediment Deposition + Embedednes
Fishing Cr.								
Head	20140306-1135-jeremmille	Stream MI, 6d-200	36.7	63	50	No	Yes	24
	20140306-1050-jeremmille	Stream MI, 6d-200	37.2	63	50	No	Yes	25
	20140306-0950-jeremmille	Stream MI, 6d-200	57.7	63	50	Yes	Yes	29
	19990602-1400-BPG	SSWAP					No	26
	20050421-1030-dbogar	Stream MI, 6d-200	74.9		63 or 50	Yes	No	30
	20140212-1245-jeremmille	Stream MI, 6d-200	45.8	63	50	Yes	Yes	33
A	None							
B	20180425-1050-shawnmille	Stream MI, 6d-200	26.7	63	50	No	Yes	20
	20161208-1000-jeremmille	Stream MI, 6d-200	69.3	63	50	Yes	No	13
C	20180425-0945-shawnmille	Stream MI, 6d-200	29.4	63	50	No	Yes	14
	20140212-1205-jeremmille	Stream MI, 6d-200	27	63	50	No	Yes	24
D	20180424-1145-shawnmille	Stream MI, 6d-200	38.8	63	50	No	Yes	22
E,F,G	None							
Mainstem	20140212-1115-jeremmille	Stream MI, 6d-200	57.2	63	50	Yes	Yes	30
	20050421-1130-dbogar	Stream MI, 6d-200	73.1		63 or 50	Yes	No	33
	19990602-1130-BPG	SSWAP					No	28
	20140212-1040-jeremmille	Stream MI, 6d-200	40.2*	63	50	No	Yes	30
	20180425-1235-shawnmille	Stream MI, 6d-200	36.6	63	50	No	Yes	28
	20140212-1005-jeremmille	Stream MI, 6d-200	64.8*	63	50	Yes	No	24
	20140212-0920-jeremmille	Stream MI, 6d-200	65.1*	63	50	Yes	No	32
	20050421-1245-dbogar	Stream MI, 6d-200	70.8		63 or 50	Yes	No	28
	19990601-1630-BPG	SSWAP					No	27
Huber R.								
	20151209-1015-jeremmille	Stream MI, 6d-200	63.3	63	50	Yes	No	30
	19990525-1000-BPG	SSWAP					No	22
Trout R. West								
	20141124-0945-jeremmille	Stream MI, 6d-200	89.7	63	50	Yes	No	29
	20150420-1130-jeremmille	Stream MI, 6d-200	86.2	63	50	Yes	No	35

* value may be invalid due to low organism subsample size

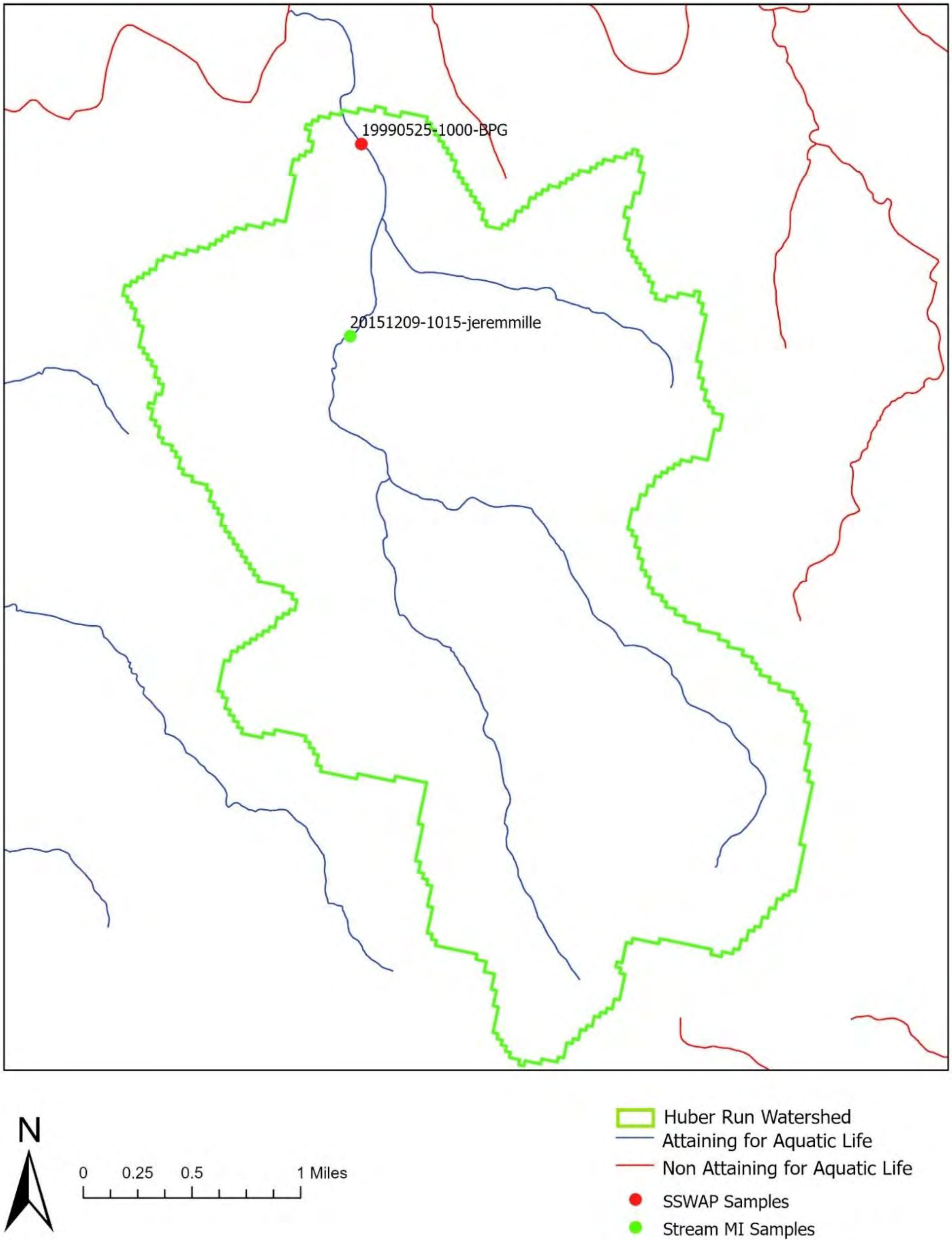


Figure 9. DEP sample sites within the Huber Run watershed. The labels correspond to the labels used in Table 5.

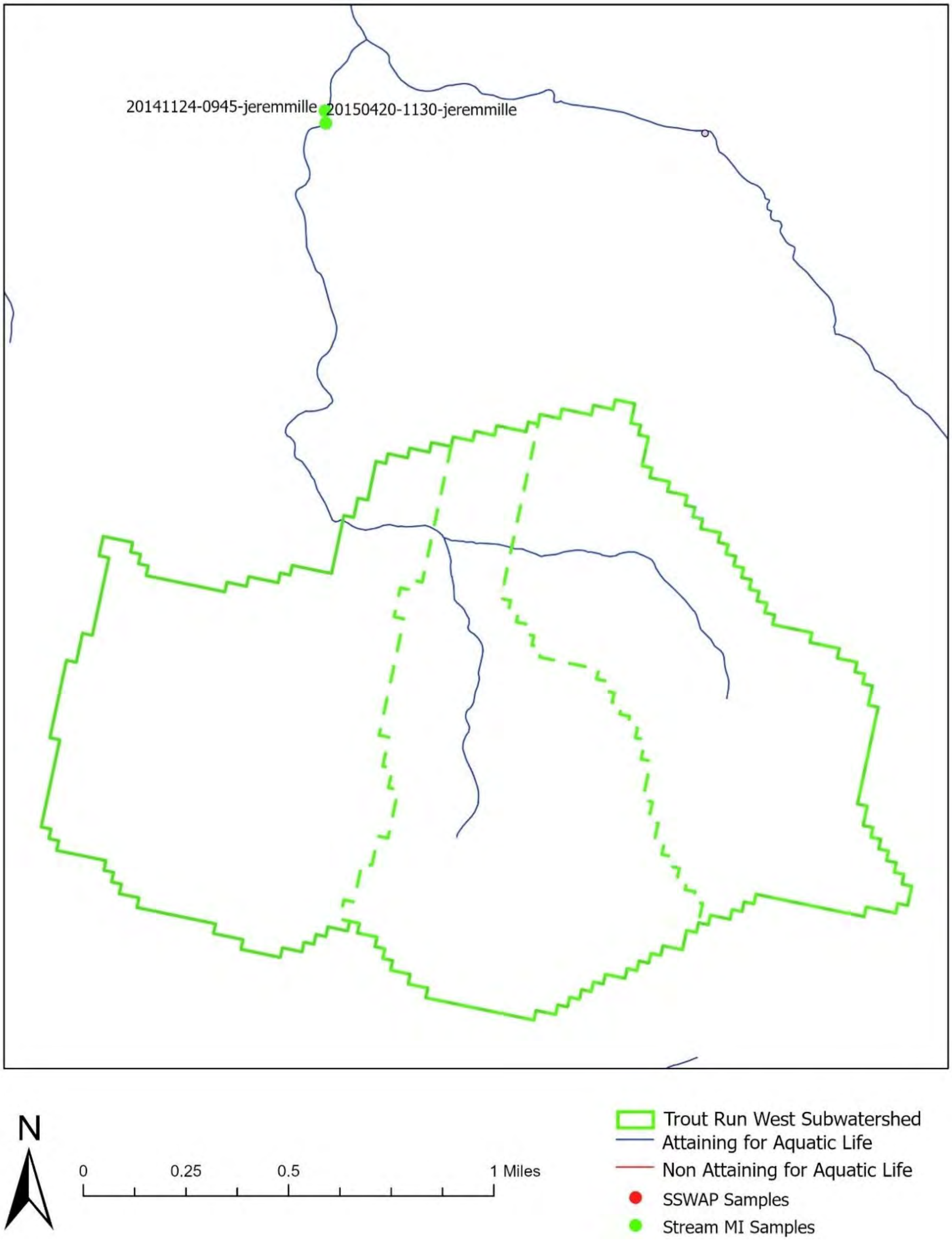


Figure 10. DEP sample sites within the UNT Trout Run-west subwatershed. The labels correspond to the labels used in Table 5.

Table 6. Existing NPDES permitted discharges in the Huber Run and UNT Trout Run-west watersheds and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Mean, lbs/yr
Huber Run		
PA0081981	Smithville Village MHP	152
PA0261131	Tamarack MHP	268
PA0266784	Glenda Perry Residence SFTF	8
PAG043871	Thomas and Rachel Wolf SFTF	8
UNT Trout Run-west		
None	None	0

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

Smithville Village MHP. Mean annual load based on electronic discharge monitoring report (eDMR) data. Reports from four full years (2018-2021) were analyzed. For each month, average monthly total suspended solids (TSS) concentrations along with average monthly flows were used to calculate average monthly pounds per day of sediment. These values were then multiplied by the number of days in each month to calculate pounds per month. All months within each year were then summed to calculated lbs/yr. The value shown above was the average of those four years.
Tamarack MHP. Mean annual load based on eDMR data. Reports from ten full years (2012-2021) were analyzed. For each month, average monthly TSS concentrations along with average monthly flows were used to calculate average monthly pounds per day of sediment. These values were then multiplied by the number of days in each month to calculate pounds per month. All months within each year were then summed to calculated lbs/yr. The value shown above was the average of those ten years.
Perry and Wolf SFTFs. Small flow wastewater treatment facilities serving single-family residences. For each, an average daily flow of 262.5 gpd along with an average monthly TSS concentration of 10 mg/L was assumed. These values were used to estimate annual average loadings. No eDMR data were available.

To explore existing conditions and evaluate the severity and causes of impairment, the Fishing Creek watershed was visited during the summer of 2022. To confirm their suitability, the potential references were visited around the same time.

Observations of the middle to lower mainstem of the Fishing Creek impaired area indicate much recent improvement due to the prior Adaptive Toolbox restoration project. Numerous fish habitat and bank stabilization structures were observed, along with new riparian buffer plantings (Figure 11). Since much of the middle to lower mainstem has been either restored or flows through expansive forested tracts (Figures 1, 11, and 12), much of the work that was needed in this area may have already been completed. This being the case, the obvious siltation that was observed within this area (Figure 11) may have been largely imported from tributaries. The siltation problems appeared to worsen towards the upper mainstem (Figure 12), likely due to both the channel's lower gradient and the greater intensity of agriculture in this region. Tributary conditions were highly variable, ranging from rocky, clear, and apparently healthy, to obviously degraded by siltation (Figure 13).
Figure 14 illustrates typical landscapes within the Fishing Creek watershed. The uplands had intensive agricultural landcover whereas the valley areas were often forested, which supports the hypothesis that siltation problems within the lower mainstem may be largely attributable to import from tributaries. Upland tributary reaches often appeared highly degraded, especially where livestock had direct access to streams and drainageways (Figure 15). Poor buffering along such streams may be especially problematic given large amounts of surrounding croplands, often on hilly terrain. It was

difficult to judge tillage practices during the summer site visit, but instances of bare soils were observed (Figure 16).

A number of other factors that may be protective of water quality were also observed; of prime importance was the presence of large forested tracts within streamside lowlands (Figure 17). Within the upland areas, BMPs such as contour tillage, the retirement of sloping agricultural lands and the protection of drainageways were observed (Figure 18). And, Figure 19 shows some extensive streamside restoration areas associated with the prior Adaptive Toolbox project. While much commendable progress has been made in the Fishing Creek watershed, it was obvious that substantial additional BMP implementation was still needed.

Conditions within the Huber Run potential reference watershed ranged from rocky, clear and apparently healthy, to areas with potentially problematic siltation (Figures 20, 21 and 22). The siltation problems appeared to be primarily associated with pools and sluggish reaches however, in which case they may not be extensive enough to warrant impairment listings. Furthermore, borderline impairment is actually a positive attribute for a reference watershed, in that it helps find the *maximum* load that the impaired watershed may tolerate. Plus, the study will include a margin of safety factor which causes the prescribed reductions to exceed what would be needed for the impaired watershed to simply match the reference watershed. Figure 23 shows typical landscapes within the Huber Run watershed. Like the Fishing Creek watershed, uplands consisted of rolling hills with much agriculture. Also like the Fishing Creek watershed, Huber Run’s incised mainstem caused it to be high gradient and surrounded by forests, which undoubtedly helps to promote stream health (Figure 24). Outside of these areas however, intensive agriculture and significant development, often occurring on rolling hills, may contribute to borderline impairment within some stream reaches (Figures 23, 24 and 25).

Although only a small portion of the watershed was used as the reference (see Figure 7 versus Figure 5), the following discussion will begin with observations of the larger Trout Run watershed but then progress towards observations specific to the chosen UNT Trout Run-west reference area. Much of the middle to lower Trout Run mainstem was very high gradient (Figure 26). As expected, such areas tended to be rocky. However, some fine sediment deposition was apparent within pools, especially within more sluggish reaches (Figure 26). Like both the Fishing Creek and Huber Run watersheds, there was substantial agriculture within Trout Run’s uplands (Figure 27) while large forested tracts dominated the lowlands (Figures 27 and 28). Thus, stream segments within this watershed tended to be very well buffered. The major stressors within this watershed appear to be simply the amount of agricultural lands, though some upland drainageways would clearly benefit from improved buffering (Figures 27 and 28). However, the extensiveness of large forested tracts within the lowlands was so great that it is believed that their benefits greatly outweighed the aforementioned problems. This was especially true of the chosen UNT Trout Run-west reference area (Figures 7 and 30). Not surprisingly, stream segments within this area appeared quite healthy, despite the presence of minor siltation in some pools.

In conclusion, these observations support breaking up the Fishing Creek watershed to focus restoration efforts on the headwaters area and individual tributaries, as in Figure 2. Furthermore, observations suggest that Huber and the UNT Trout Run-west are suitable for use as references.

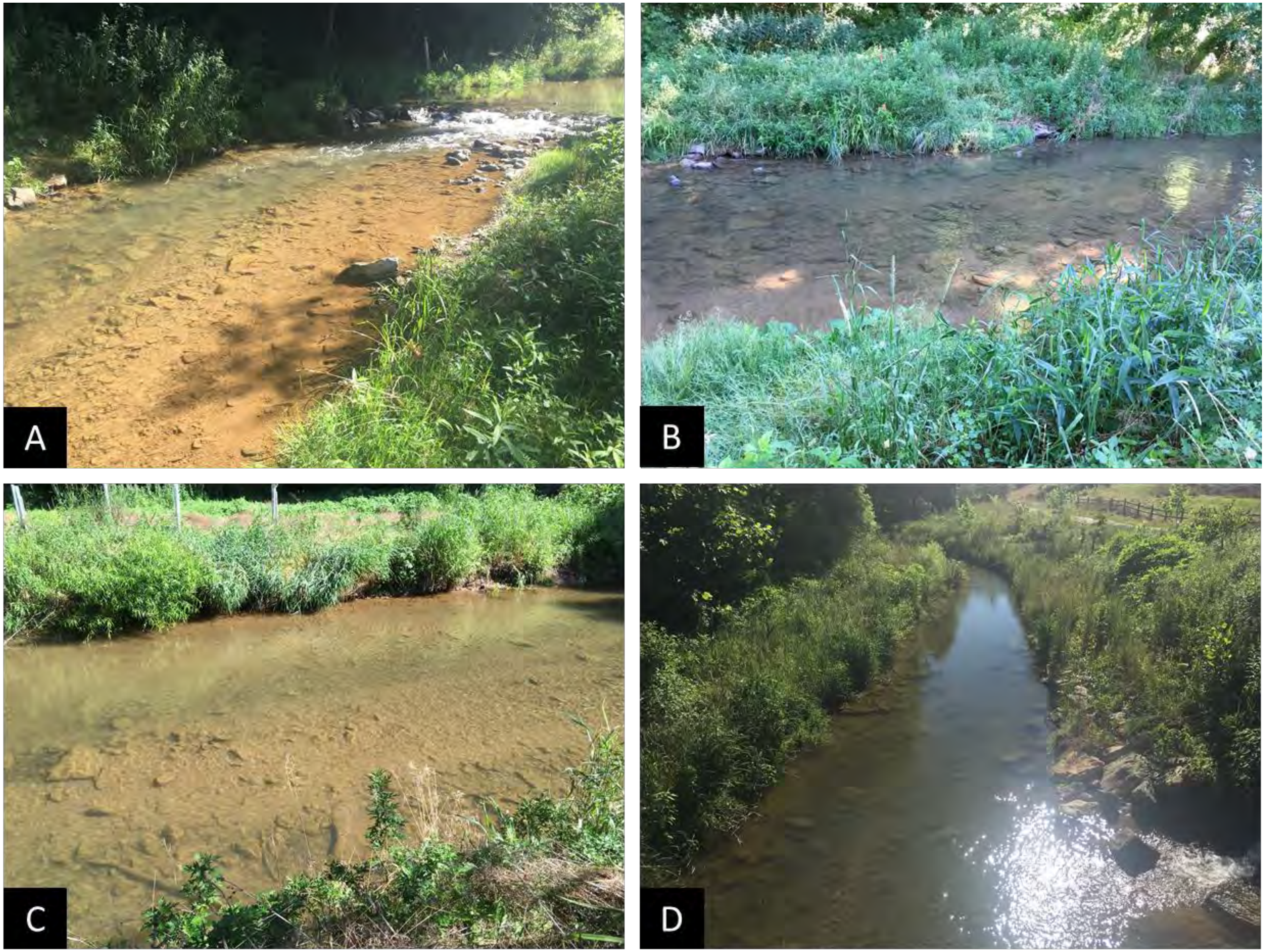


Figure 11. Substrate conditions within the downstream mainstem of Fishing Creek. Note the light to moderate fine sediment deposition, especially in pools. Swifter reaches tended to be rocky however.

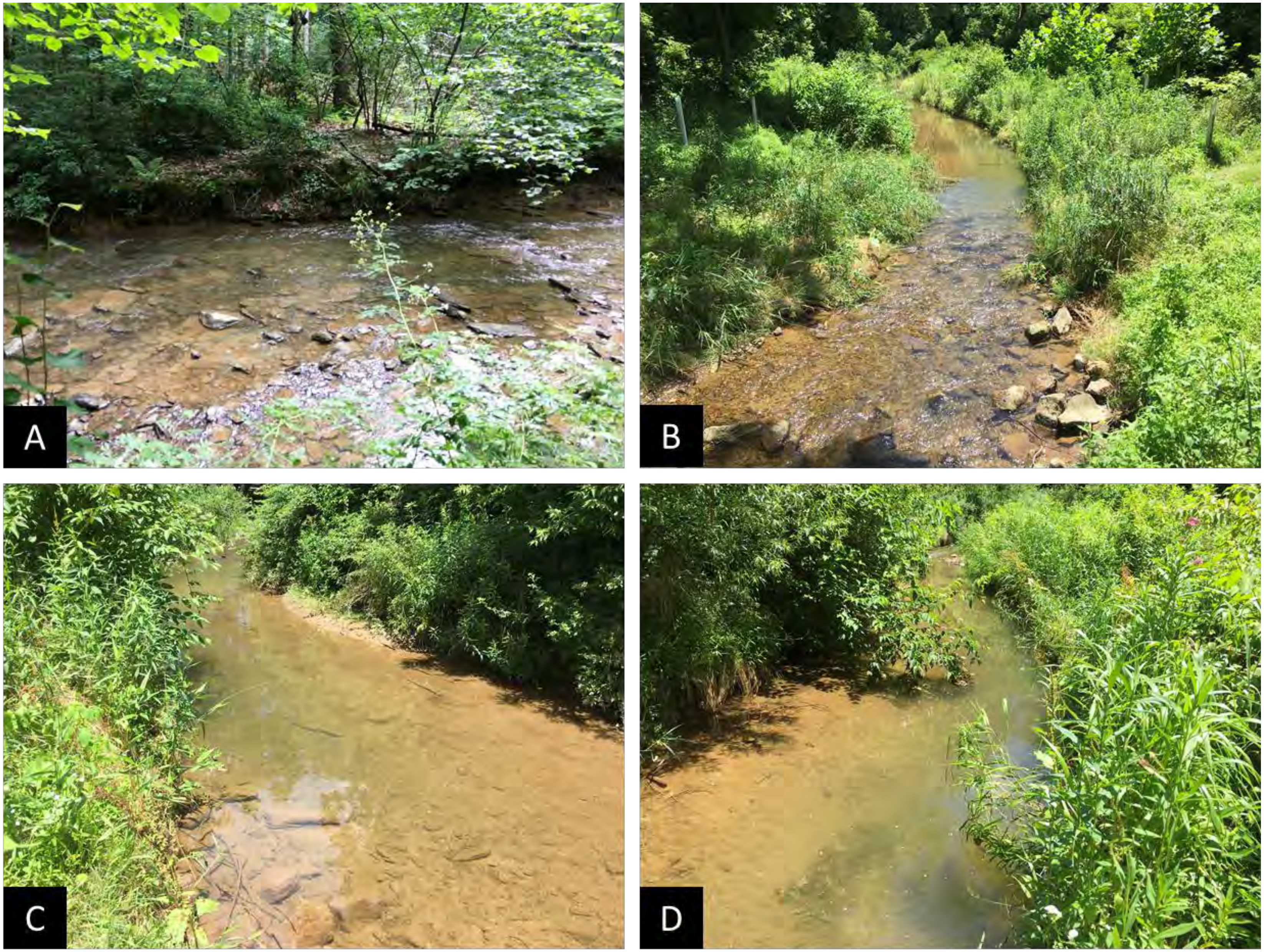


Figure 12. Substrate conditions within the upper mainstem of Fishing Creek. Note that swifter reaches tended to be rocky whereas fine sediment deposition was obvious in some pools.

Figure 13. Stream segments within tributaries of the Fishing Creek watershed. Such streams could either be rocky and clear or exhibit obvious fine sediment deposition.

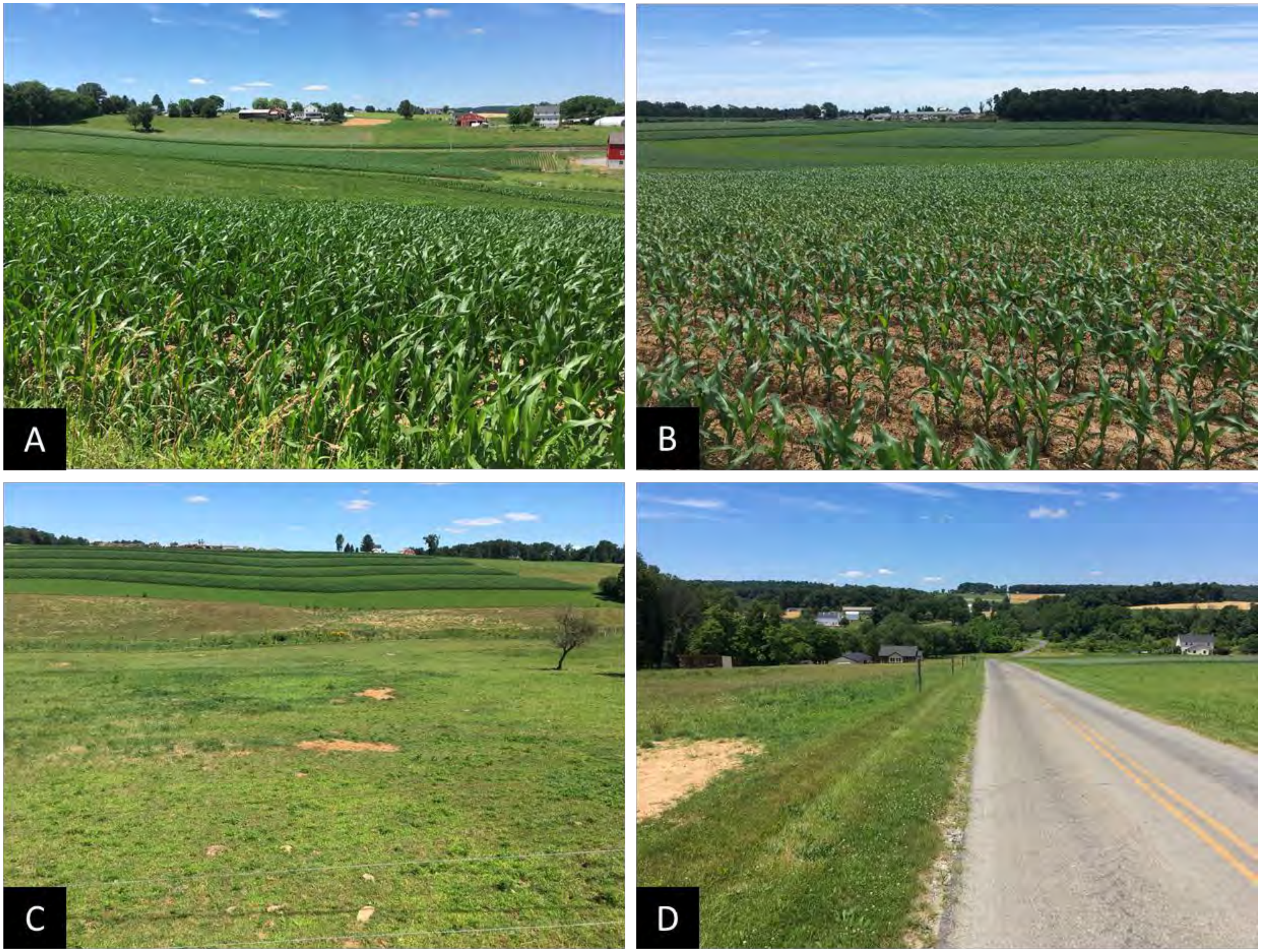


Figure 14. Landscapes within the Fishing Creek watershed. Upland areas were dominated by agriculture while larger stream segments tended to be in incised valleys that were often forested (D).

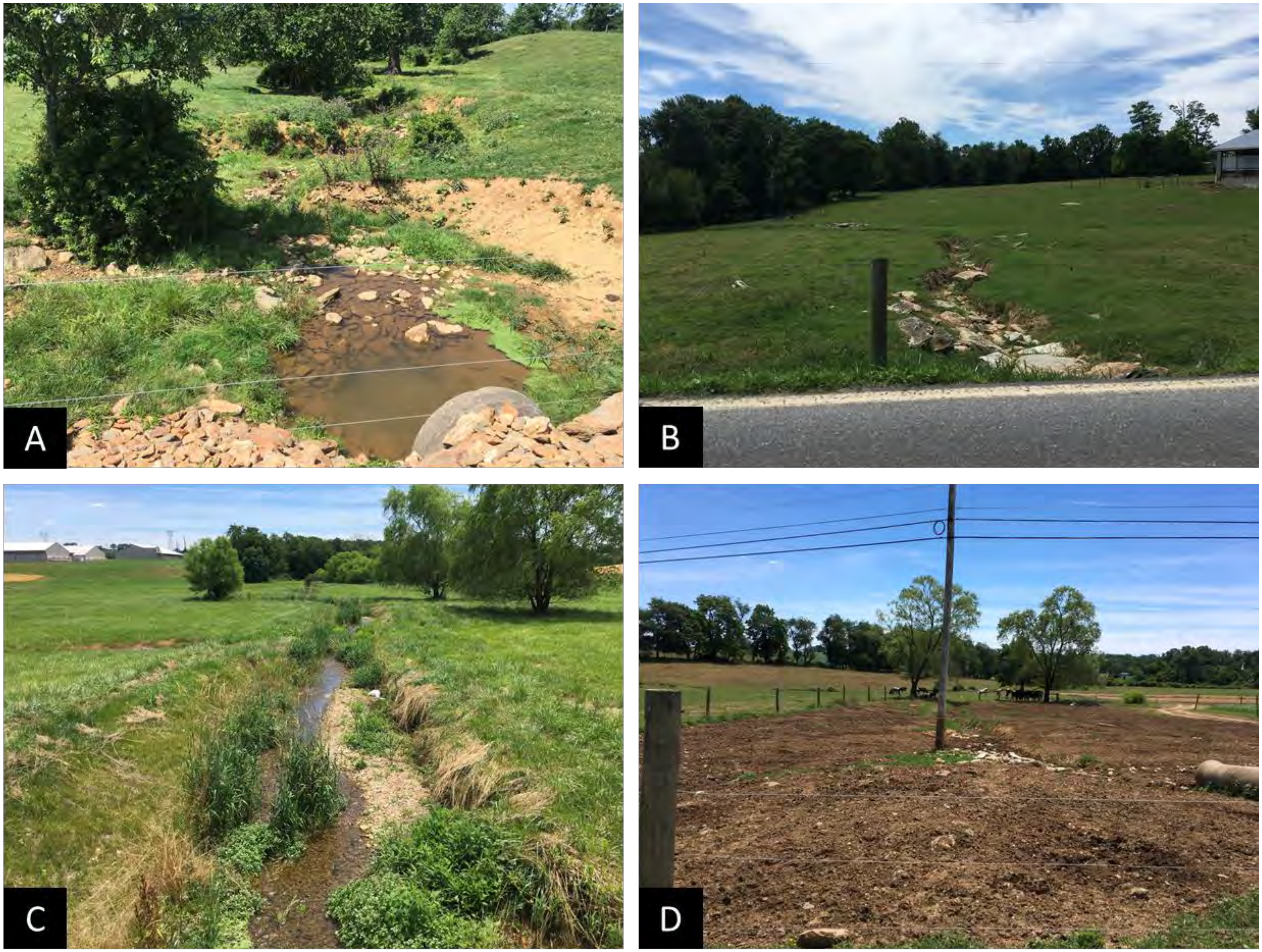


Figure 15. Conditions along stream segments and drainageways that may exacerbate fine sediment pollution within the Fishing Creek watershed. Livestock had direct access to the streams and drainageways shown in A, B and D. Note the erosion and bare soils evident in these areas. Photograph C shows a stream segment that appears to have been straightened to accommodate agriculture along its banks.

Figure 16. Conditions within uplands of the Fishing Creek watershed that may exacerbate fine sediment pollution. Note the large amounts of fields and areas with unbuffered drainageways in A and B. Note the bare soils and steep slopes in C and D.

Figure 17. Photographs of mature forested buffers within the Fishing Creek watershed.

Figure 18. Agricultural practices that may be protective against sediment loading in the Fishing Creek watershed. Note the use of contour farming in A, what appears to be retired agricultural lands on steep slopes in the background of B, and the use of herbaceous buffers along drainageways in C and D.

Figure 19. Examples of recent BMP implementation in the Fishing Creek watershed. A shows a stream restoration project area with structures that prevent bank erosion. Also note the recent establishment of riparian buffers. B, C and D show areas of livestock exclusion streambank fencing that allow for the establishment of riparian buffers.

Figure 20. Stream conditions within the downstream mainstem of the Huber Run watershed. While some stream segments were rocky and apparently healthy, as in A and B, other areas exhibited substantial fine sediment deposition, especially in pools.

Figure 21. Stream conditions within the main eastern tributary of the Huber Run watershed. Conditions could be rocky and clear, as in A and B. However, significant fine sediment deposition was also observed in some pools.

Figure 22. Stream conditions within the main western tributary of the Huber Run watershed. Conditions could be rocky and clear, as in A and B. However, significant fine sediment deposition was also observed in some pools (C and D).

Figure 23. Landscapes within the Huber Run watershed. Upland areas had significant agricultural lands and development, while stream segments often occurred in narrow forested valleys.

Figure 24. Factors that may prevent siltation pollution in the Huber Run watershed. Mature forested buffers were common in many areas of the watershed, particularly in narrow valley areas (A and B). Photograph C shows the use of herbaceous buffers along a drainageway while photograph D shows a stormwater basin serving urbanized development.

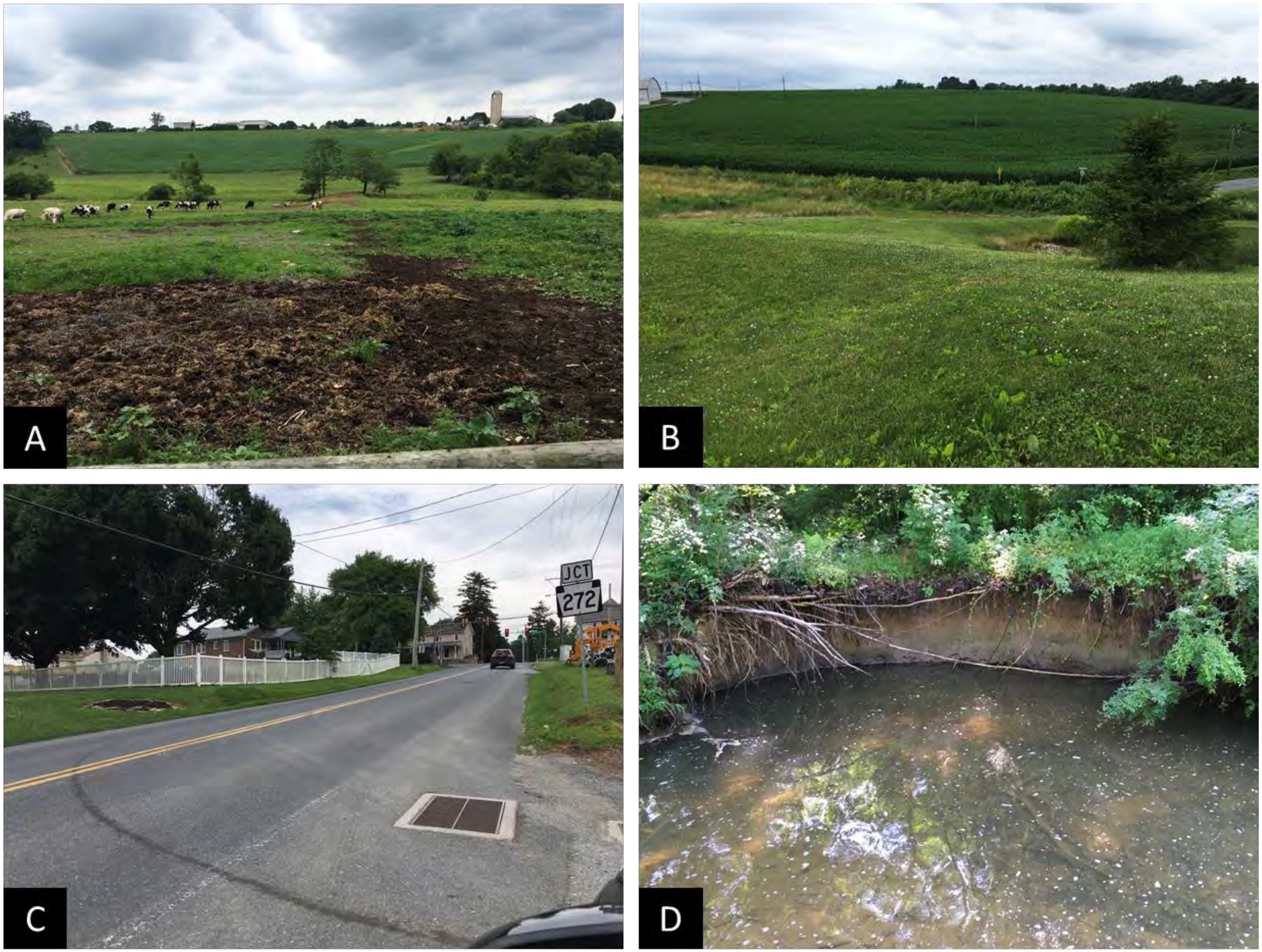


Figure 25. Conditions that may contribute to siltation pollution within the Huber Run watershed. Photographs A and B show significant agricultural lands within the watershed, including some on steep slopes. Photograph C shows and example of the significant urbanized lands within the watershed and photograph D shows an area of extensive streambank erosion.

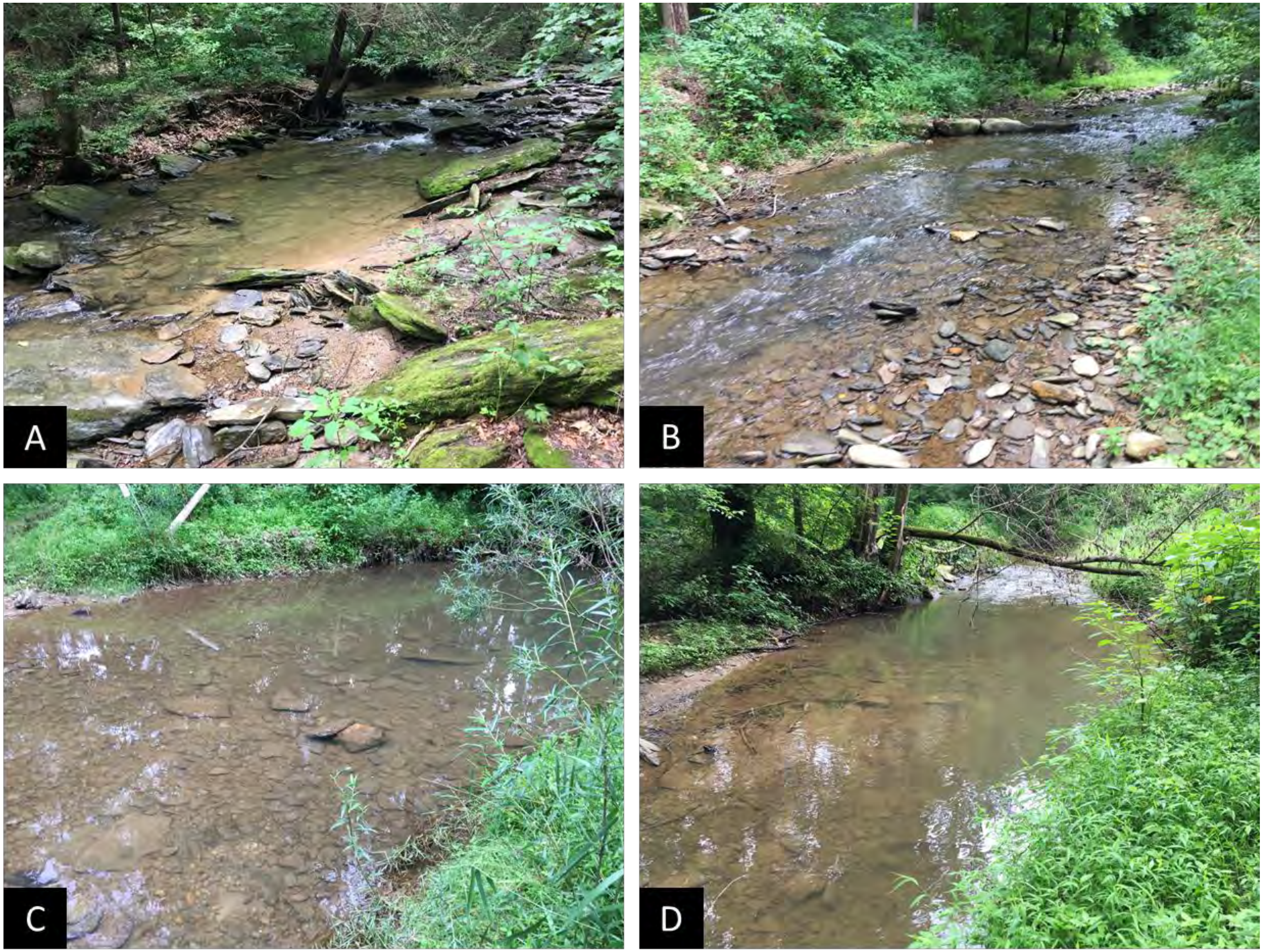


Figure 26. Stream conditions within the lower mainstem of Trout Run (well below the proposed reference watershed). While some stream segments were rocky and clear, some obvious fines deposition was apparent in some pool areas.

Figure 27. Example landscapes within the larger Trout Run watershed. Significant agricultural lands were present, especially in upland areas. However, large forested tracts often occurred along the streams within the valley areas.

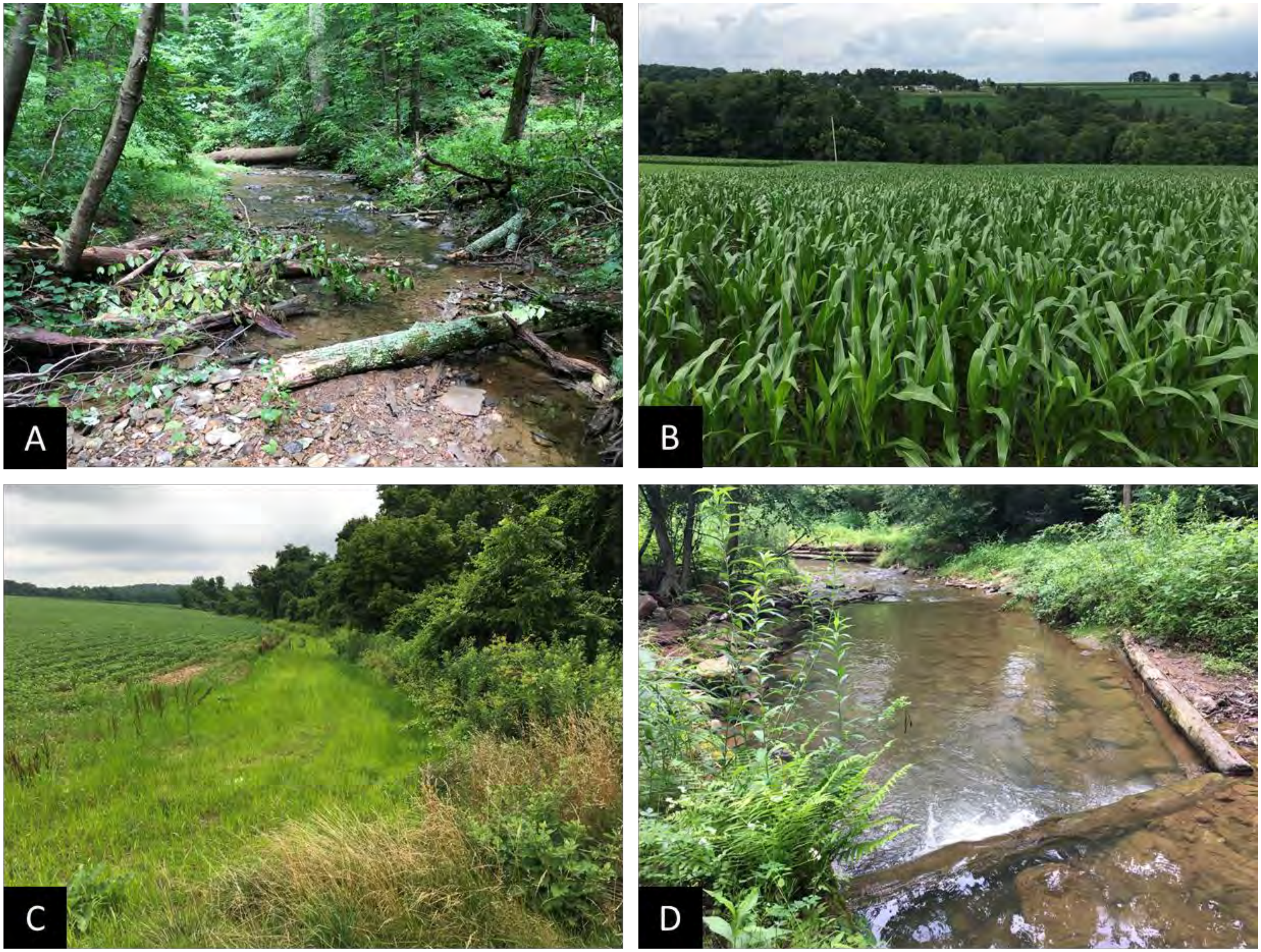


Figure 28. Factors that may contribute to stream health within the larger Trout Run watershed. A, B and C show the presence of mature forested buffers. D shows an area of recent stream restoration work.

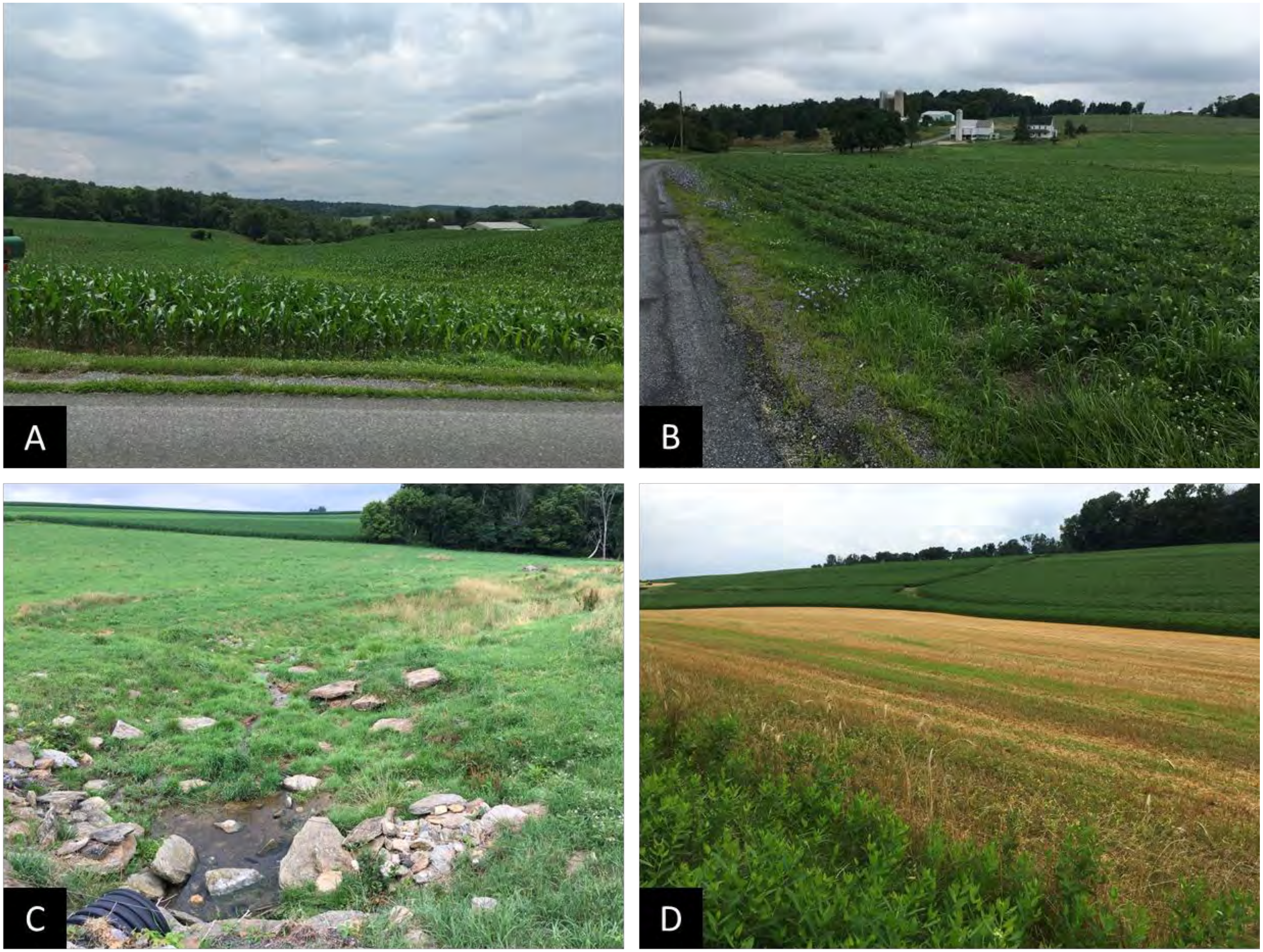


Figure 29. Factors that may exacerbate sediment pollution within the larger Trout Run watershed. Note the presence of vast areas of agricultural lands as well as the presence of unbuffered streams and drainageways in many cases.

Figure 30. Stream conditions within the UNT Trout Run-west watershed either within or near the study watershed area. Note the presence of clear water and rocky substrate, though with some fines deposition within pools.

HYDROLOGIC / WATER QUALITY MODELING

Estimates of sediment loading for the impaired and reference watersheds were calculated using the "Model My Watershed" version 1.34.1 application (MMW), which is part of the WikiWatershed web toolkit developed through an initiative of the Stroud Water Research Center (2023). 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.

Watershed areas were defined using MMW's Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed) for the Fishing Creek watersheds shown in Figures 1 and 4 as well as for all reference watersheds. However, watershed areas for the Fishing Creek head and tributaries (Figures 2 and 3) were based on an analysis of United States Geological Survey (USGS) Digital Elevation Models (USGS 2022) using TauDEM Version 5.3.7. (Tarboton, 2016). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 30-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 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 was 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 watershed's 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, the watershed's sediment delivery ratio, etc. Default values were used for the modelling runs, with the exception that the estimated flow (67.43 m^3/d per an analysis of eDMR data) from the wastewater treatment plants occurring in the Huber Run watershed was added as an input for Huber Run. This has the effect of causing a very minor increase in the streambank sediment load.

Following the model run, corrections for the presence of existing riparian buffers were made using the BMP Spreadsheet Tool (Evans et al. 2020) provided by a prior version of MMW. The following paragraphs describe the riparian buffer correction methodology.

Riparian buffer coverage was estimated via a GIS analysis in ArcGIS Pro. Where necessary to determine riparian buffering within the "agricultural area," a polygon tool was used to clip riparian areas that, based on cursory visible inspection, appeared to have significant, obvious agricultural land on at least one side. This served to exclude riparian buffers that were not buffering agricultural lands, and it was determined to only be necessary for Fishing Creek subwatershed A and the Huber Run watershed (Figures 31-34). Then, to determine riparian buffering, landcover per a high resolution landcover 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 in the agricultural areas. Using this methodology, percent riparian buffer within agricultural areas of the Fishing Creek watershed were determined to be as follows: 72% in Head, 82% in A, 50% in B, 51% in C, 48% in D, 87% in E, 66% in F, and 59% in G. Within the reference watersheds, buffering within the agricultural areas was determined to be 68% in Huber Run and 98% in UNT Trout Run-west-3km^2, 99% in UNT Trout Run-west-2km^2, and 97% in UNT Trout Run-west-1km^2. Since buffering within the Fishing Creek-Head watershed was comparable to the Huber Run reference, no buffer-related pollution reduction was calculated. Otherwise, an additional reduction credit was given to the reference subwatershed to account for the fact it had more riparian buffers than 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, the user enters the length of buffer on both sides of the stream. To estimate the extra length of buffers in the reference watershed over the amount found in the impaired watershed, 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 (if necessary) (Figures 31-34) and then by the difference in the proportion buffering between the agricultural areas of the reference subwatershed and the impaired watershed, 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). 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.

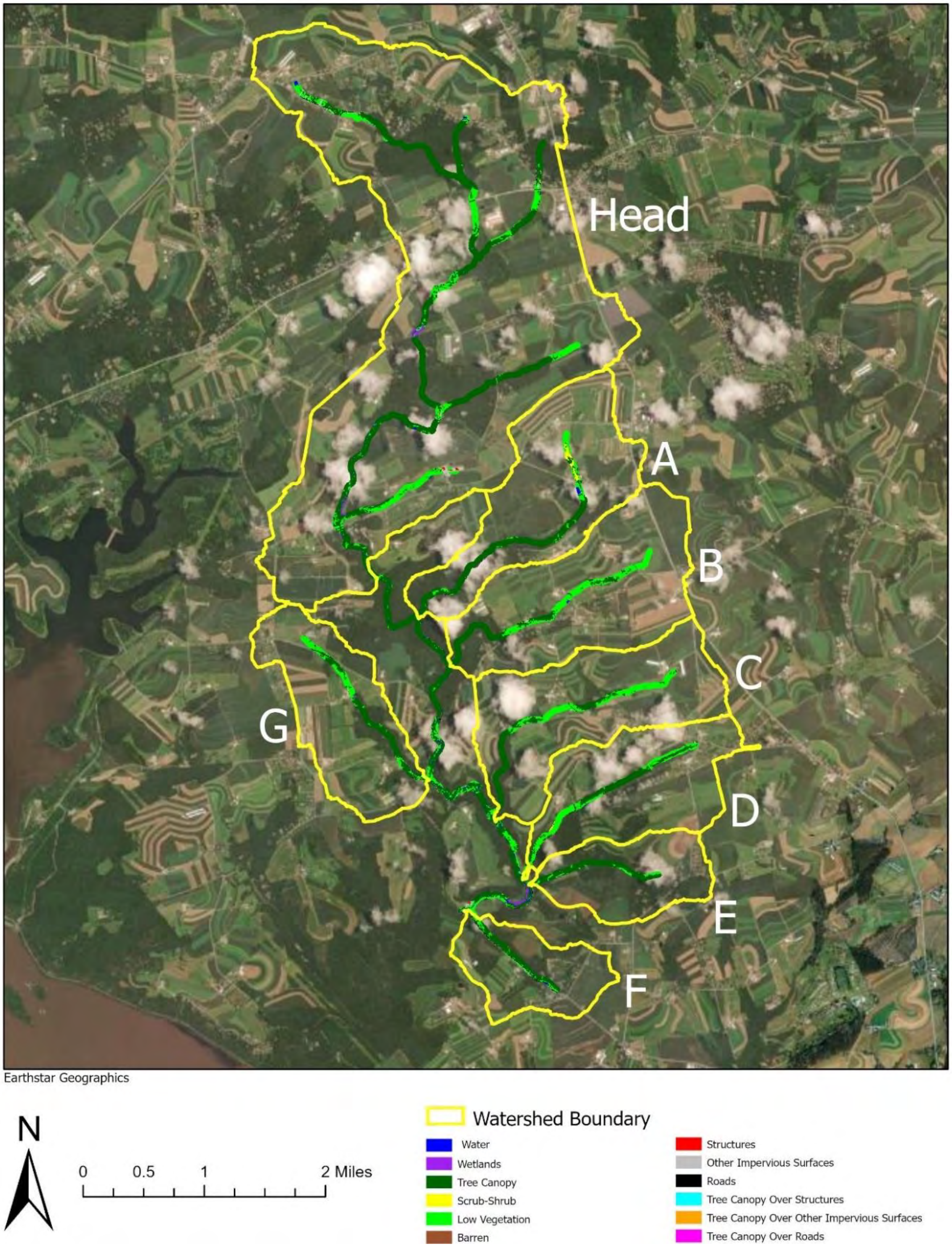


Figure 31. Riparian buffer analysis in the Fishing Creek subwatershed. A raster dataset of high resolution landcover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of tree canopy, shrub/scrub or wetlands.

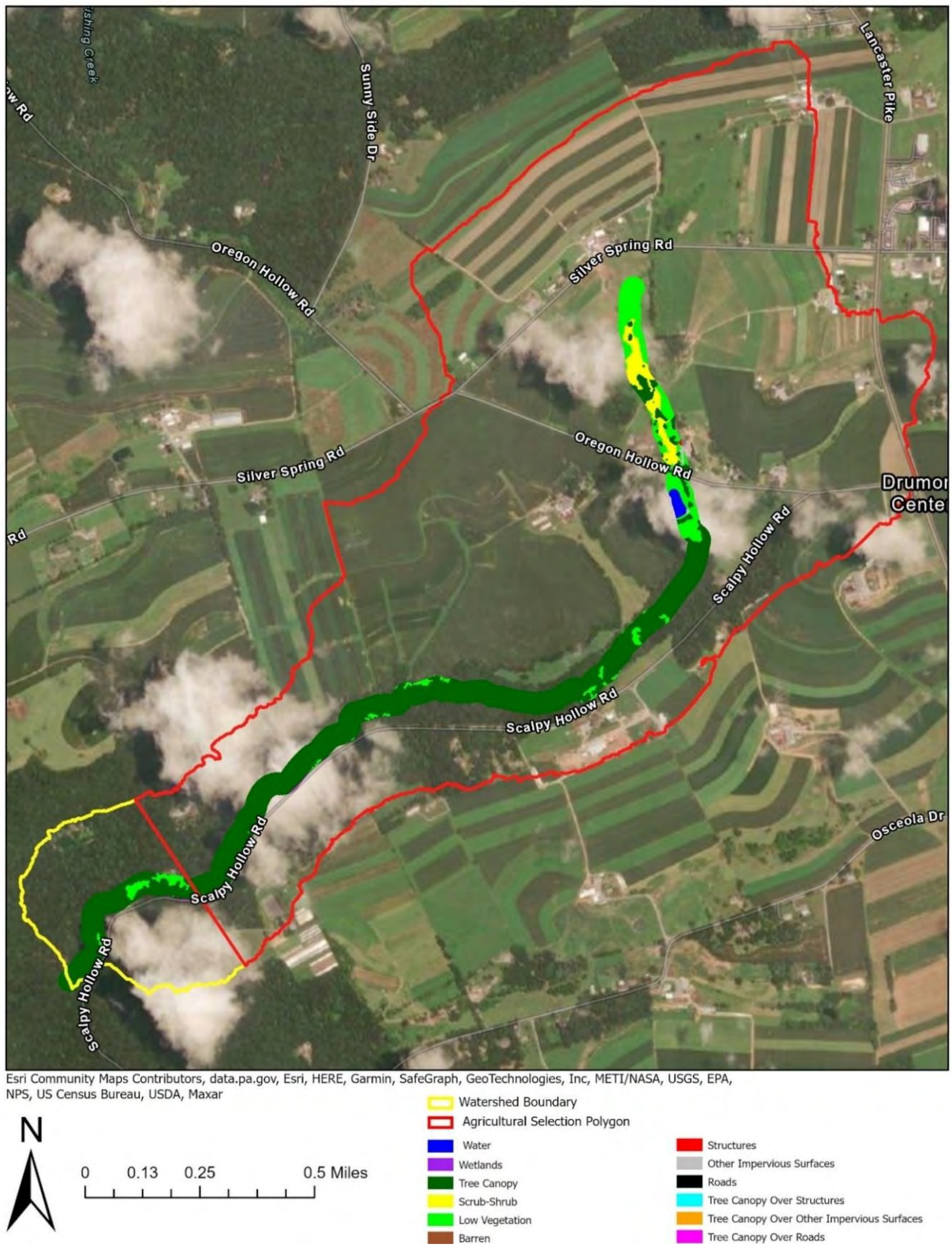


Figure 32. Riparian buffer analysis in Fishing Creek subwatershed A. A raster dataset of high resolution landcover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of tree canopy, shrub/scrub or wetlands.

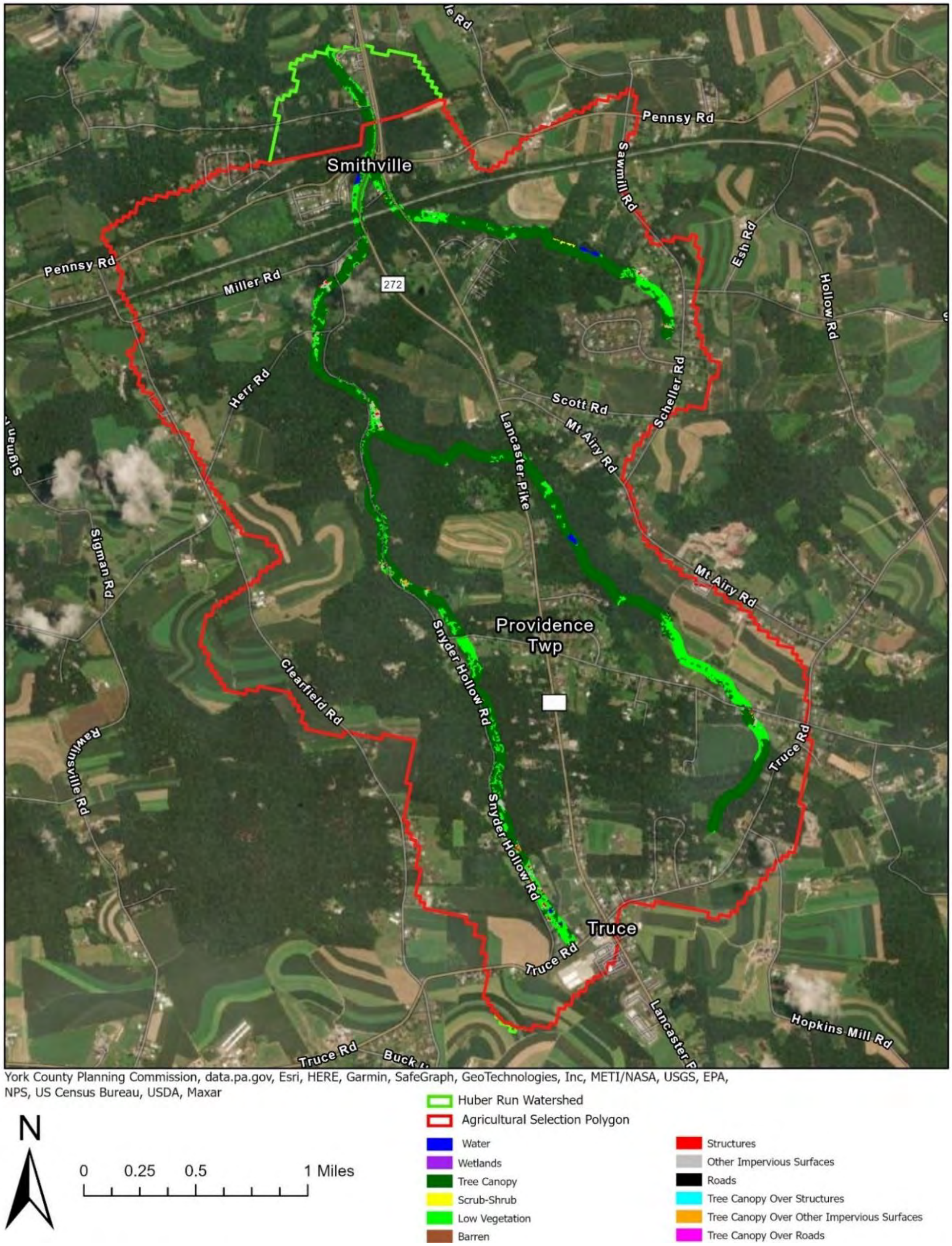


Figure 33. Riparian buffer analysis in the Huber Run subwatershed. A raster dataset of high resolution landcover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of tree canopy, shrub/scrub or wetlands.

Figure 34. Riparian buffer analysis in the UNT Trout Run-west subwatershed. A raster dataset of high resolution landcover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of forest, shrub/scrub or wetlands.

CALCULATION OF THE ALLOWABLE LOADING RATE

The mean watershed-wide sediment loading rate for the unimpaired reference watershed used for Fishing Creek Head (Huber Run) was estimated to be 470 pounds per acre per year (Table 7). This was substantially lower than the estimated loading rate in the impaired Fishing Creek Head watershed (1,199 pounds per acre per year, Table 7). Thus, to achieve the loading rate of the unimpaired subwatershed, sediment loading in the Fishing Creek Head watershed should be reduced by 61% to 1,365,923 pounds per year (Table 11). Similarly, Fishing Creek subwatersheds A through G were estimated to have loading rates ranging from 794 through 1,585 pounds per acre per year (Tables 8-10), while their reference watersheds, subwatersheds of UNT Trout Run-west, were estimated to range from 670 to 980 pounds per acer per year (Tables 8-10). The resultant allowable loads for the Fishing Creek subwatersheds are shown in Table 11. These values represent reductions ranging from 20 to 61%, with subwatershed E excluded, as it had a 0% reduction. The lack of a reduction needed for subwatershed E is not implausible, as this watershed had the highest forested cover of any of the Fishing Creek subwatersheds (Table 4) and its rate of riparian buffering was estimated to be 87%. This being the case, Fishing Creek subwatershed E was removed as a study area.

Table 7. Existing annual average loading values for the Fishing Creek Head (impaired) and Huber Run (reference) watersheds.

	Fishing Creek Head			Huber Run		
Land Use	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	249	39,401	158	380	58,504	154
Cropland	1,553	3,276,631	2,110	543	1,120,140	2,062
Forest	696	1,948	3	1,442	7,148	5
Wetland	52	160	3	12	50	4
Open Land	2	151	61	12	1,333	108
Bare Rock	-	-	-	-	1	-
Low Density Mixed Dev	306	3,353	11	496	5,418	11
Medium Density Mixed Dev	35	2,357	68	25	1,582	64
High Density Mixed Dev	10	720	73	10	553	56
Stream Bank	-	156,985	-	-	178,889	-
Riparian Buffer Discount*	-	-	-	-	-	-
Point Sources	-	-	-	-	436	-
Total	**2,904**	**3,481,706**	**1,199**	**2,921**	**1,374,054**	**470**

* Riparian buffer discount accounts for the greater amount of riparian buffering in the reference watershed versus the impaired watershed.

Table 8. Existing annual average loading values for Fishing Creek subwatersheds A, B and C (impaired) and UNT Trout Run-west 3km^2 (reference) watersheds.

	Fishing Creek A			Fishing Creek B			Fishing Creek C			Trout Run, 3km^2		
Land Use	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	52	8,427	163	116	19,479	168	77	12,766	167	22	3,738	168
Cropland	358	784,701	2,192	437	972,569	2,225	454	996,631	2,194	235	528,726	2,254
Forest	143	540	4	91	294	3	57	149	3	427	1,652	4
Wetland	-	-	-	-	-	-	2	5	2	-	-	-
Open Land	-	-	-	-	-	-	-	-	-	5	492	100
Bare Rock	-	-	-	-	-	-	-	-	-	-	-	-
Low Density Mixed Dev	57	605	11	52	568	11	49	490	10	59	649	11
Medium Density Mixed Dev	2	298	121	5	341	69	5	317	64	2	336	136
High Density Mixed Dev	-	99	-	-	54	-	-	70	-	-	-	-
Stream Bank	-	13,118	-	-	11,197	-	-	10,725	-	-	10,542	-
Riparian Buffer Discount (A)*	-	-	-	-	-	-	-	-	-	-	-14,773	-
Riparian Buffer Discount (B)*	-	-	-	-	-	-	-	-	-	-	-43,516	-
Riparian Buffer Discount (C)*	-	-	-	-	-	-	-	-	-	-	-42,532	-
Point Sources	-	-	-	-	-	-	-	-	-	-	0	-
Total	**612**	**807,789**	**1,319**	**701**	**1,004,502**	**1,432**	**644**	**1,021,154**	**1,585**	**751**	**531,362 (A)**	**708 (A)**
											502,620 (B)	**670 (B)**
											503,603 (C)	**671 (C)**

* Riparian buffer discount accounts for the greater amount of riparian buffering in the reference watershed versus the impaired watershed. Since "Trout Run 3km^2" is being used as a reference for three Fishing Creek subwatersheds, three riparian buffer discounts and totals are shown.

Table 9. Existing annual average loading values for Fishing Creek subwatersheds D and G (impaired) and UNT Trout Run-west 2km^2 (reference) watersheds.

	Fishing Creek D			Fishing Creek G			Trout Run, 2km^2		
Land Use	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	134	25,423	189	104	16,992	163	8	1,233	164
Cropland	213	487,297	2,286	259	585,069	2,257	188	435,858	2,317
Forest	82	355	4	69	215	3	254	866	3
Wetland	-	-	-	-	-	-	-	-	-
Open Land	-	-	-	-	-	-	-	-	-
Bare Rock	-	-	-	-	-	-	-	-	-
Low Density Mixed Dev	66	698	11	49	490	10	34	382	11
Medium Density Mixed Dev	4	225	60	2	148	60	3	291	87
High Density Mixed Dev	1	60	68	-	17	-	-	-	-
Stream Bank	-	10,544	-	-	7,288	-	-	6,844	-
Riparian Buffer Discount (D)*	-	-	-	-	-	-	-	-41,515	-
Riparian Buffer Discount (G)*	-	-	-	-	-	-	-	-32,260	-
Point Sources	-	-	-	-	-	-	-	-	-
Total	**500**	**524,603**	**1,048**	**484**	**610,149**	**1,261**	**487**	**403,959 (D)** **413,215 (G)**	**830 (D)** **849 (G)**

* Riparian buffer discount accounts for the greater amount of riparian buffering in the reference watershed versus the impaired watershed. Since "Trout Run 2km^2" is being used as a reference for two Fishing Creek subwatersheds, two riparian buffer discounts and totals are shown.

Table 10. Existing annual average loading values for Fishing Creek subwatersheds E and F (impaired) and UNT Trout Run-west 1km^2 (reference) watersheds.

	Fishing Creek E			Fishing Creek F			Trout Run, 1km^2		
Land Use	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*Landcover (ac)*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	64	10,665	166	31	5,336	170	4	590	157
Cropland	102	222,823	2,186	143	334,870	2,336	101	237,206	2,338
Forest	114	493	4	71	329	5	102	336	3
Wetland	-	-	-	-	-	-	-	-	-
Open Land	-	-	-	-	-	-	-	-	-
Bare Rock	-	-	-	-	-	-	-	-	-
Low Density Mixed Dev	18	186	10	34	330	10	25	277	11
Medium Density Mixed Dev	-	-	-	-	16	74	2	110	55
High Density Mixed Dev	-	-	-	-	-	-	-	-	-
Stream Bank	-	2,836	-	-	3,550	-	-	2,454	-
Riparian Buffer Discount (E)*	-	-	-	-	-	-	-	-18,426	-
Riparian Buffer Discount (F)*	-	-	-	-	-	-	-	-10,874	-
Point Sources	-	-	-	-	-	-	-	-	-
Total	**298**	**237,003**	**794**	**280**	**344,432**	**1,231**	**235**	**222,548 (E)** **230,100 (F)**	**948 (E)** **980 (F)**

* Riparian buffer discount accounts for the greater amount of riparian buffering in the reference watershed versus the impaired watershed.

Table 11. Annual average allowable sediment loading for Fishing Creek subwatersheds.

Subwatershed	Ref. Loading Rate (lbs/(ac*yr))	Land Area (ac)	Target AL (lbs/yr)
Head	470	2,904	1,365,923
A	708	612	433,480
B	670	701	469,553
C	671	644	432,370
D	830	500	415,363
E	948	298	282,807
F	980	280	274,170
G	849	484	410,849

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, for Fishing Creek Head:

1,365,923 lbs/yr AL * 0.1 = 136,592 lbs/yr UF

Then, the SL for Fishing Creek Head is calculated as:

1,365,923 lbs/yr AL – 136,592 lbs/yr UF = 1,229,331 lbs/yr SL

The SLs for the remainder of the Fishing Creek subwatershds are shown in Table 12.

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 impairment addressed by this ARP is for sedimentation due to agriculture, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands (open land), bare rock, and developed lands within the Fishing Creek watershed were considered LNR. LNR for the Fishing Creek Head watershed was calculated to be 8,689 lbs/yr (Table 12).

Then, the ASL was then calculated as:

1,229,331 lbs/yr SL – 8,689 lbs/yr LNR = 1,220,642 lbs/yr ASL

The ASLs for the remainder of the Fishing Creek subwatersheds are found in Table 12.

Table 12. Source load, loads not reduced and adjusted source load as annual averages. All values are in lbs/yr.

	Fishing Creek Subwatershed							
	Head	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Source Load (SL)	1,229,331	390,132	422,597	389,133	373,827	254,527	246,753	369,764
Loads Not Reduced (LNR)								
Forest	1,948	540	294	149	355	493	329	215
Wetland	160	0	0	5	0	0	0	0
Open Land	151	0	0	0	0	0	0	0
Bare Rock	0	0	0	0	0	0	0	0
Low Density Mixed Dev	3,353	605	568	490	698	186	330	490
Medium Density Mixed Dev	2,357	298	341	317	225	0	16	148
High Density Mixed Dev	720	99	54	70	60	0	0	17
Total LNR	8,689	1,543	1,257	1,032	1,338	679	676	870
Adjusted Source Load (ASL)	1,220,642	388,588	421,341	388,101	372,489	253,847	246,077	368,894

CALCULATION OF SEDIMENT LOAD REDUCTIONS BY SOURCE SECTOR

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

In the Fishing Creek Head watershed, croplands exceeded the ASL by itself. Thus, croplands received a greater percent reduction (68%) than hay/pasture lands and streambanks (14% each) (Table 13). Note however, the prescribed reductions by source sectors 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. Percent reductions by source sector for the other Fishing Creek subwatersheds are shown in Table 13.

Per Table 13, the biggest reductions are needed for the Head, A, B and C subwatersheds; this being the case, they are considered the highest priority subwatersheds, while watersheds D through G would be considered lower priority. Note however, this is not meant to discourage work done in the lower priority watersheds. In fact, since this plan largely relies on the voluntary cooperation of landowners, the degree of landowner willingness in any given area may be the biggest limiting factor for the rate of progress. Thus, implementation partners should not necessarily delay cooperation with willing landowners solely because they are not within one of the high priority subwatersheds.

Table 13. Load allocations and reduction goals for agricultural lands and streambanks.

Subwatershed	Source	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal %
Head	Cropland	1,051,473	3,276,631	68%
	Hay/Pasture Land	33,941	39,401	14%
	Streambank	135,228	156,985	14%
	Sum	*1,220,642*	*3,473,017*	*65%*
A	Cropland	368,176	784,701	53%
	Hay/Pasture Land	7,984	8,427	5%
	Streambank	12,428	13,118	5%
	Sum	*388,588*	*806,245*	*52%*
B	Cropland	392,747	972,569	60%
	Hay/Pasture Land	18,157	19,479	7%
	Streambank	10,437	11,197	7%
	Sum	*421,341*	*1,003,245*	*58%*
C	Cropland	365,951	996,631	63%
	Hay/Pasture Land	12,037	12,766	6%
	Streambank	10,113	10,725	6%
	Sum	*388,101*	*1,020,123*	*62%*
D	Cropland	339,688	487,297	30%
	Hay/Pasture Land	23,185	25,423	9%
	Streambank	9,616	10,544	9%
	Sum	*372,489*	*523,265*	*29%*
E	Cropland	239,346	222,823	-7%
	Hay/Pasture Land	11,456	10,665	-7%
	Streambank	3,046	2,836	-7%
	Sum	*253,847*	*236,323*	*-7%*
F	Cropland	237,500	334,870	29%
	Hay/Pasture Land	5,150	5,336	3%
	Streambank	3,426	3,550	3%
	Sum	*246,077*	*343,756*	*28%*
G	Cropland	346,175	585,069	41%
	Hay/Pasture Land	15,880	16,922	6%
	Streambank	6,839	7,288	6%
	Sum	*368,894*	*609,279*	*39%*

CONSIDERATION OF CRITICAL CONDITIONS AND SEASONAL VARIATIONS

According to MMW's technical documentation (see Stroud Water Research Center 2023), MMW uses 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." The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990 (Stroud Water Research Center 2021). The evapotranspiration calculations also take into account the length of the growing season and changing day length. Monthly calculations are made for sediment loads based on daily water balance accumulated in monthly values. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations.

AN ANALYSIS OF POSSIBLE BEST MANAGEMENT PRACTICES

Based primarily on DEP's observations and analyses, as well as a study conducted by a consulting firm (Rettew), a hypothetical set of Best Management Practices (BMPs) that are calculated to exceed the prescribed sediment loading reductions was generated. Table 14-20 present the proposed BMPs and their calculated sediment reductions. Key locations for the proposed physical BMPs are shown in Figures 35-42. Note that much of the BMP crediting and pricing methodology used herein is based on Chesapeake Bay Program (2018) methods. See Appendix E for more details on crediting.

Where relevant, BMP implementation should follow USDA-NRCS standards from the Field Office Technical Guide for Pennsylvania, unless there is a good reason to deviate from these standards. In cases where there are deviations from these standards, a review should be made of the BMP to determine whether the changes would likely result in substantially diminished sediment pollution prevention. If so, a decision could be made to not credit the BMP. It should be noted that there will likely be other BMP opportunities beyond what is envisioned here, and what is ultimately implemented will largely be dependent on the landowner's preferences. In any case, it will be important to keep careful track of what is implemented so that progress may be documented.

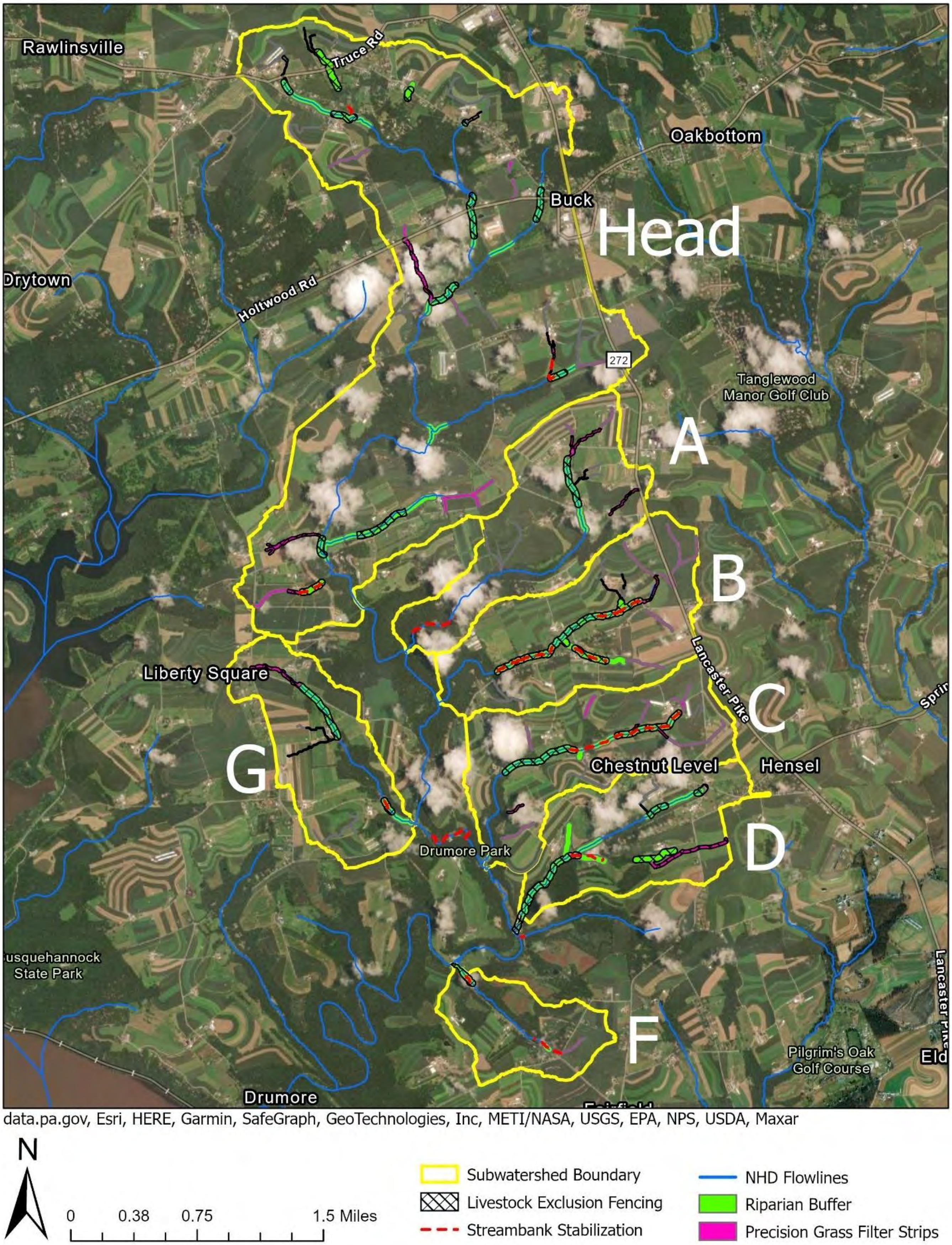


Figure 35. Proposed physical BMP opportunities in the Fishing Creek watershed.

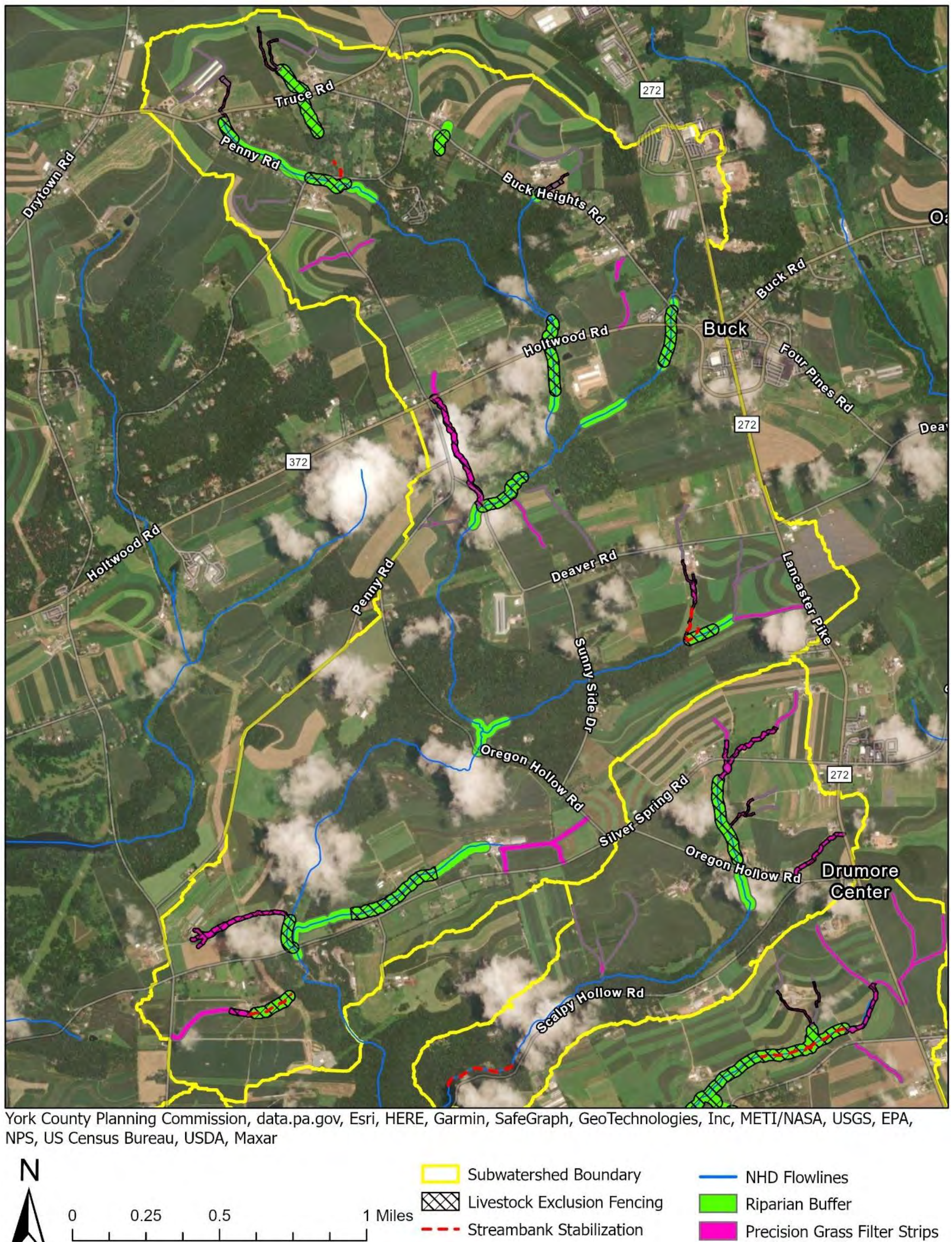


Figure 36. Proposed physical BMP opportunities in the Fishing Creek Head watershed.

Table 14. BMP opportunities and their calculated sediment loading reductions in the Fishing Creek Head watershed. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Head Proposed BMPs	**Sediment reduction** (lbs/yr)
2,237 feet streambank stabilization	53,688
100% ag. erosion and sedimentation plan implementation	822,355
10% more cropland with cover crops (155 acres)	32,768
400 acres conservation tillage-none to medium residue	346,040
224 acres conservation tillage - low to medium residue	108,707
468 acres conservation tillage-medium to high residue	375,242
64 acres forested riparian buffers	126,938
32 acres croplands retired for buffers	67,424
22 acres hay/pasture lands retired for buffers	3,410
47.5 acres precision grass filter strips[1]	973,525
Corrected Subtotal [2]	*2,666,716*
	lbs/yr
current loading for targeted sectors [3]	3,473,017
current loading for targeted sectors - all reductions	806,301
adjusted source load	1,220,642

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

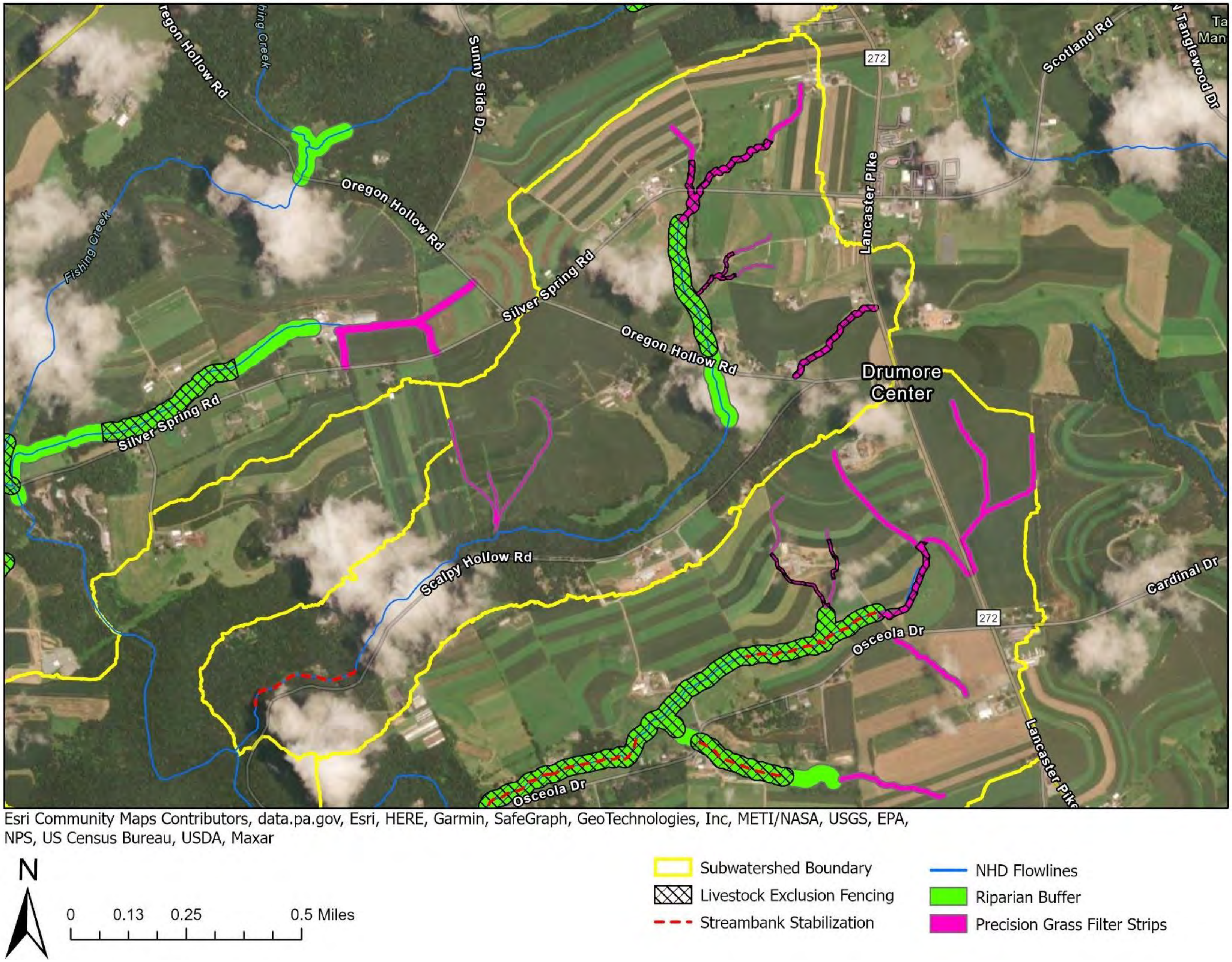


Figure 37. Proposed physical BMP opportunities in the Fishing Creek A subwatershed.

Table 15. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed A. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed A Proposed BMPs	**Sediment reduction** *lbs/yr*
1,344 feet streambank stabilization	7,930
100% ag. erosion and sedimentation plan implementation	196,862
10% more cropland with cover crops (36 acres)	7,847
30% more conservation tillage (107 acres)	96,523
9.5 acres forested riparian buffers	19,575
2.4 acres croplands retired for buffers	5,251
6.5 acres hay/pasture lands retired for buffers	1,034
12.3 acres precision grass filter strips[1]	337,845
Corrected Subtotal [2]	*588,405*
	lbs/yr
current loading for targeted sectors [3]	806,245
current loading for targeted sectors - all reductions	217,840
adjusted source load	388,588

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

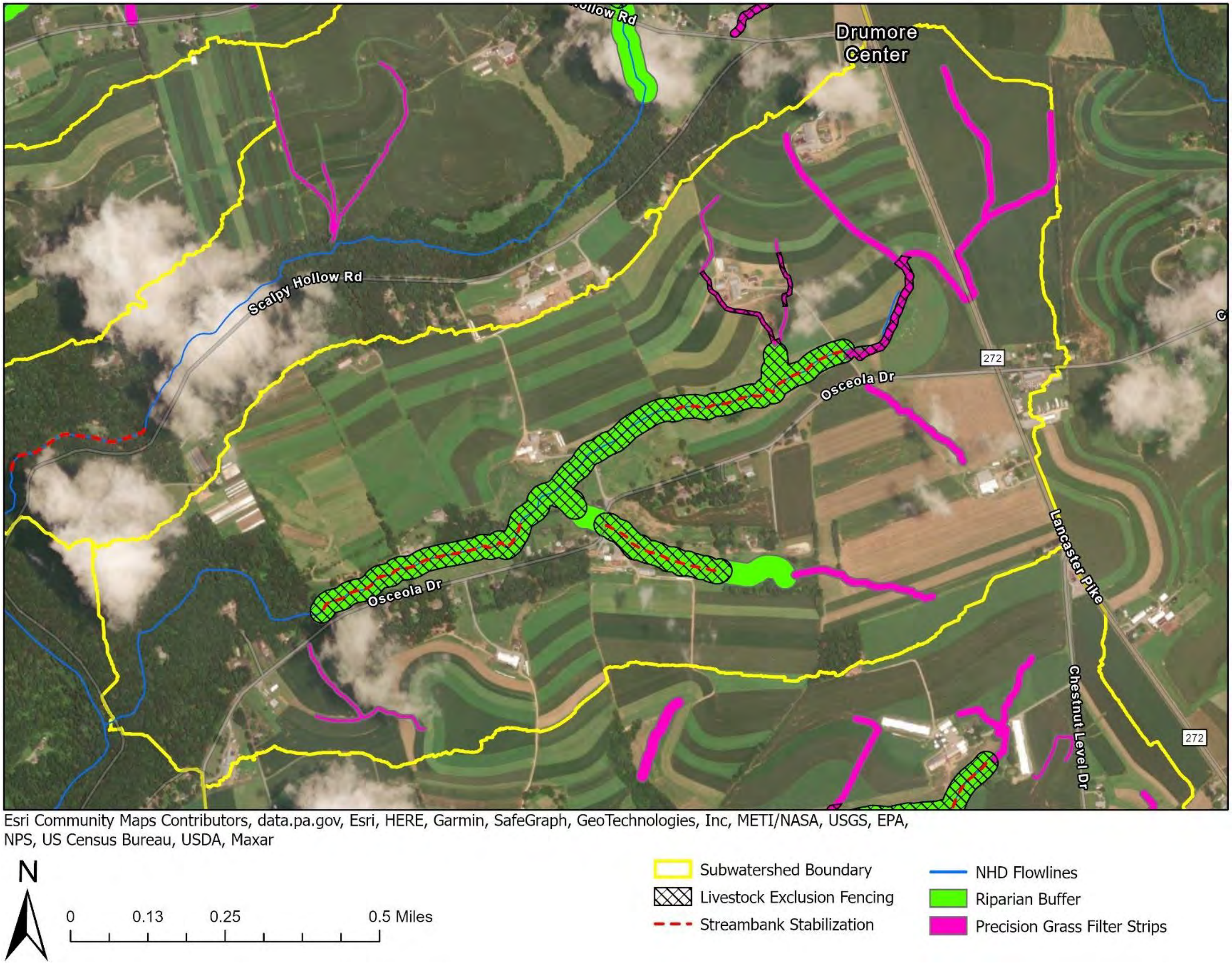


Figure 38. Proposed physical BMP opportunities in the Fishing Creek B subwatershed.

Table 16. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed B. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed B Proposed BMPs	**Sediment reduction** *lbs/yr*
4,724 feet streambank stabilization	10,393
100% ag. erosion and sedimentation plan implementation	244,640
10% more cropland with cover crops (43.7 acres)	9,723
30% more conservation tillage (131 acres)	119,596
29.7 acres forested riparian buffers	62,118
12.4 acres croplands retired for buffers	27,553
16.0 acres hay/pasture lands retired for buffers	2,640
18.5 acres precision grass filter strips[1]	406,828
Corrected Subtotal [2]	781,783
	lbs/yr
current loading for targeted sectors [3]	1,003,245
current loading for targeted sectors - all reductions	221,462
adjusted source load	421,341

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

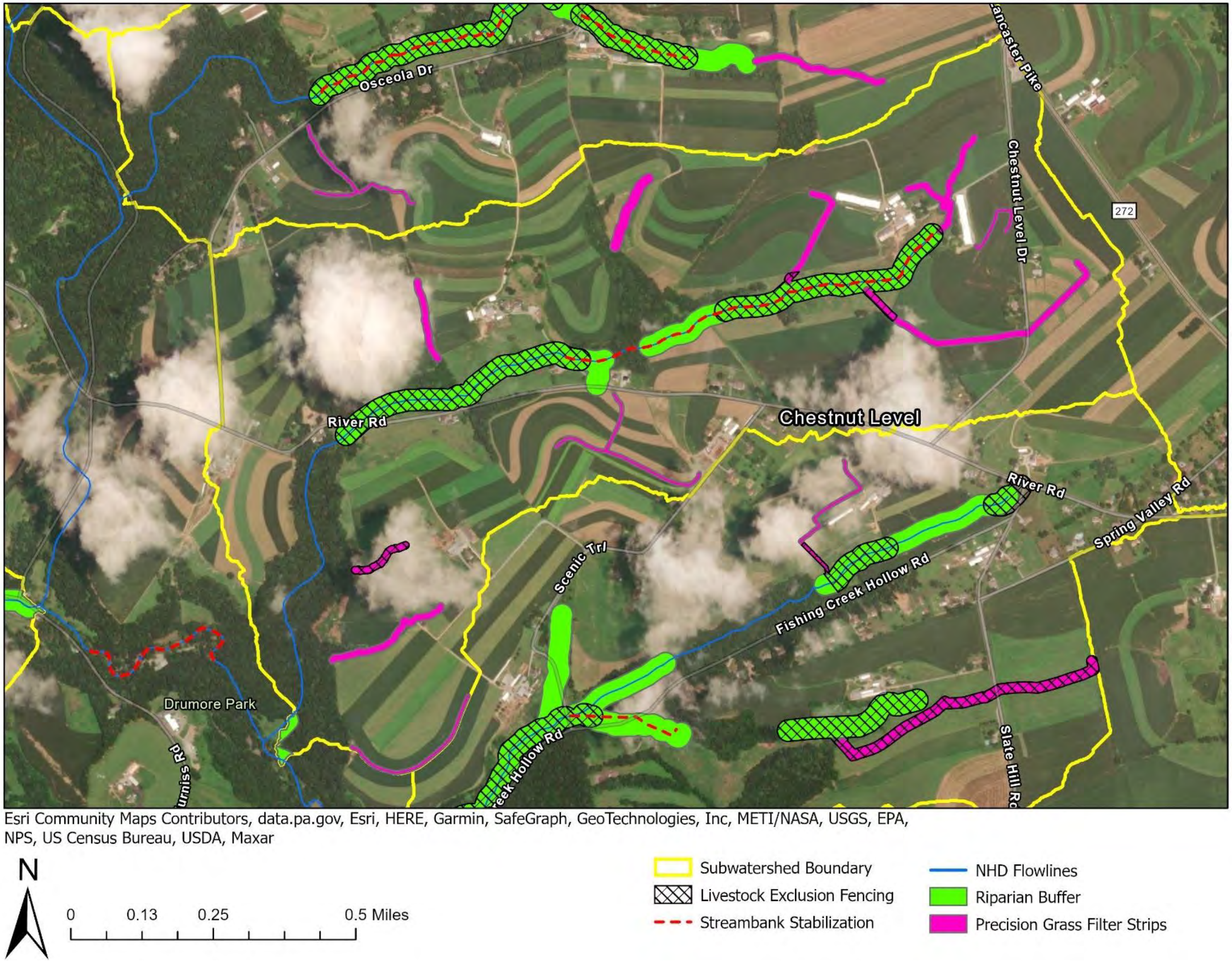


Figure 39. Proposed physical BMP opportunities in the Fishing Creek C subwatershed.

Table 17. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed C. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed C Proposed BMPs	**Sediment reduction** *lbs/yr*
3,795 feet streambank stabilization	9,488
100% ag. erosion and sedimentation plan implementation	250,048
10% more cropland with cover crops (45.4 acres)	9,961
30% more conservation tillage (136 acres)	122,517
28.9 acres forested riparian buffers	59,602
9.3 acres croplands retired for buffers	20,376
12.7 acres hay/pasture lands retired for buffers	2,083
17.6 acres precision grass filter strips[1]	380,097
Corrected Subtotal [2]	*759,148*
	lbs/yr
current loading for targeted sectors [3]	1,020,123
current loading for targeted sectors - all reductions	260,975
adjusted source load	388,101

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

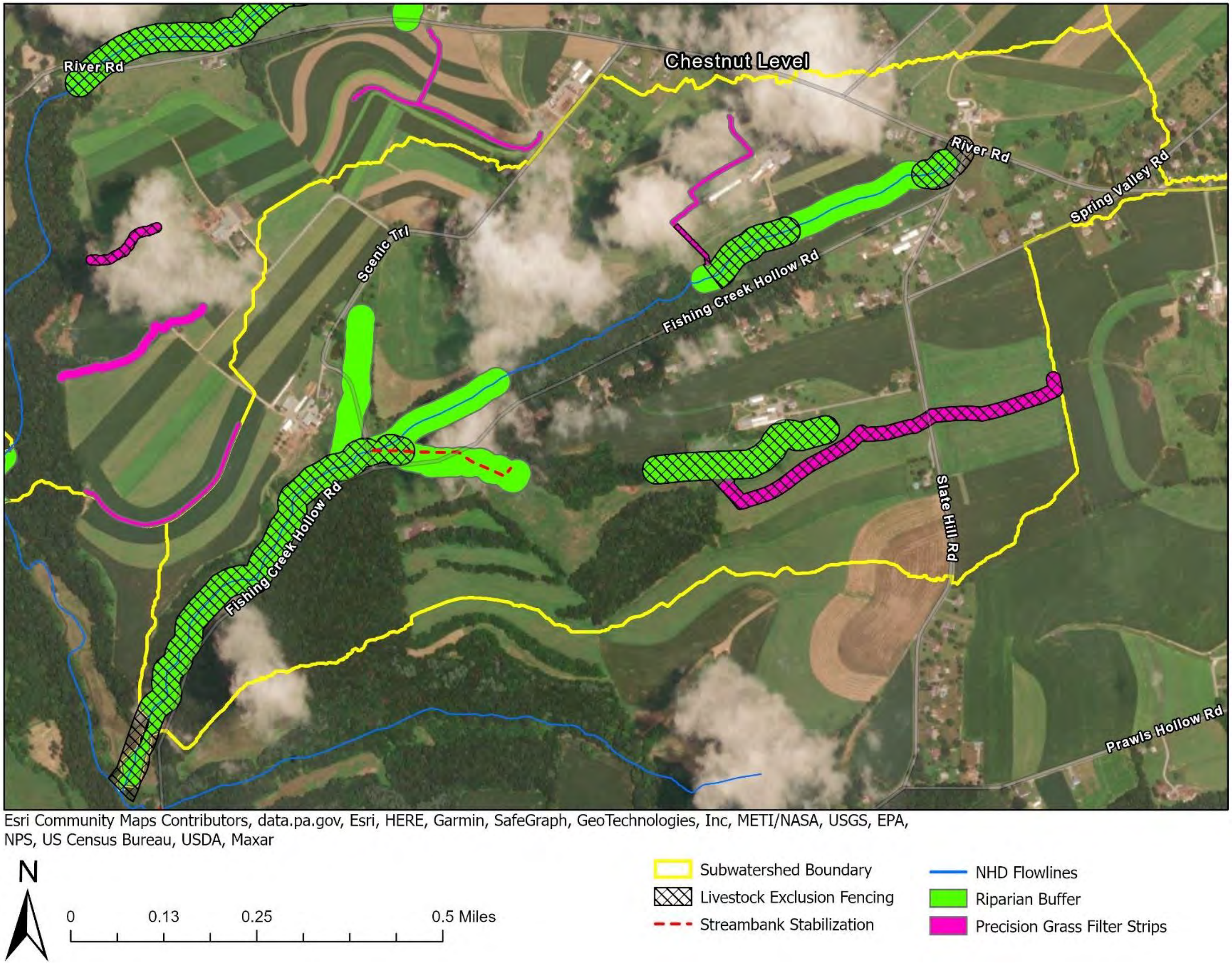


Figure 40. Proposed physical BMP opportunities in the Fishing Creek D subwatershed.

Table 18. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed D. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed D Proposed BMPs	**Sediment reduction** *lbs/yr*
1,055 feet streambank stabilization	6,119
100% ag. erosion and sedimentation plan implementation	123,756
10% more cropland with cover crops (21.3 acres)	4,869
30% more conservation tillage (64 acres)	59,891
34.8 acres forested riparian buffers	74,780
7.7 acres croplands retired for buffers	17,571
21.5 acres hay/pasture lands retired for buffers	3,978
7.7 acres precision grass filter strips[1]	120,564
Corrected Subtotal [2]	*381,386*
	lbs/yr
current loading for targeted sectors [3]	523,265
current loading for targeted sectors - all reductions	141,879
adjusted source load	372,489

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

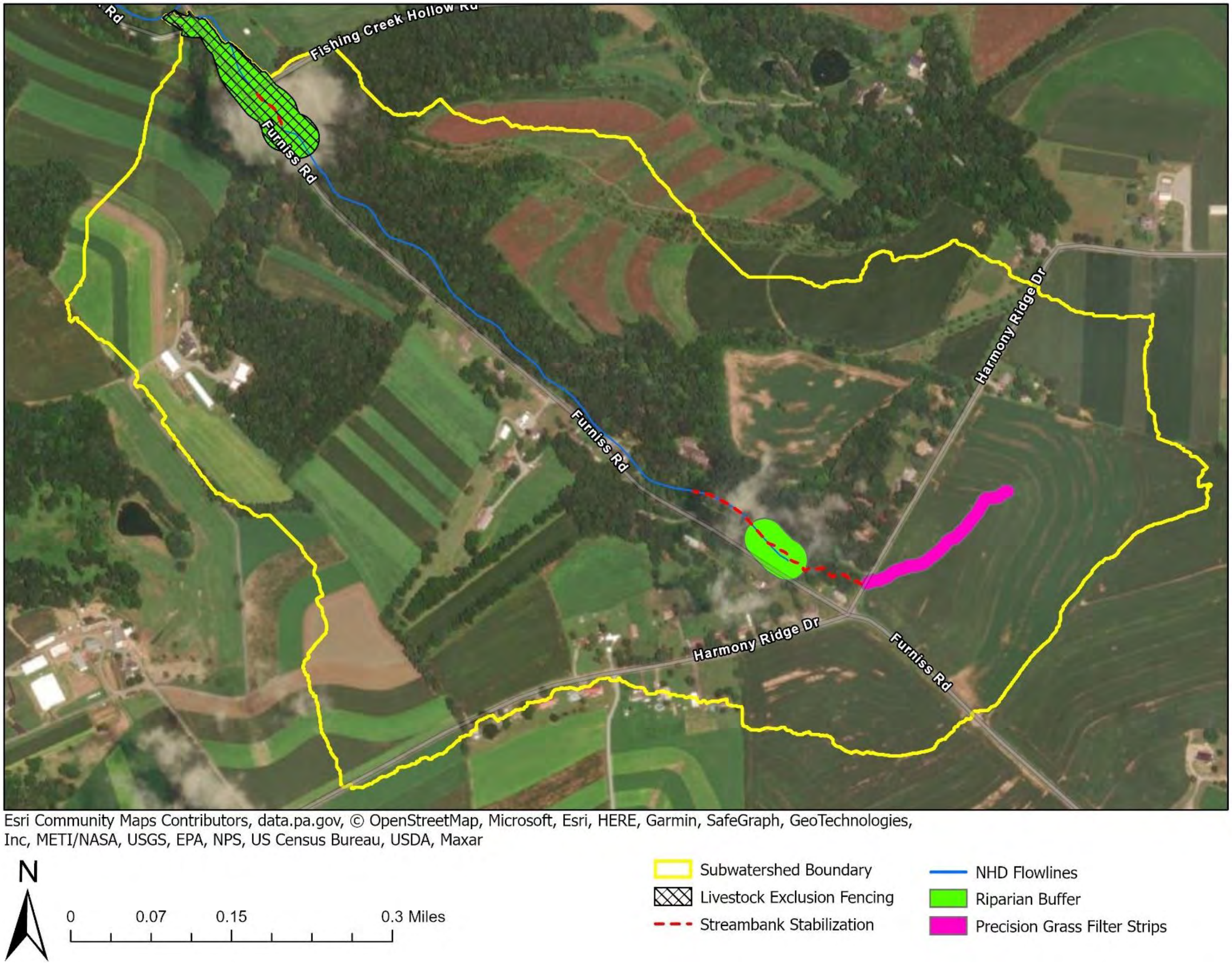


Figure 41. Proposed physical BMP opportunities in the Fishing Creek F subwatershed.

Table 19. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed F. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed F Proposed BMPs	**Sediment reduction** *lbs/yr*
1,267 feet streambank stabilization	2,787
100% ag. erosion and sedimentation plan implementation	83,934
10% more cropland with cover crops (14.3 acres)	3,340
30% more conservation tillage (43 acres)	41,088
4.9 acres forested riparian buffers	10,760
0 acres croplands retired for buffers	0
0.2 acres hay/pasture lands retired for buffers	33
1.4 acres precision grass filter strips[1]	66,458
Corrected Subtotal [2]	*191,786*
	lbs/yr
current loading for targeted sectors [3]	343,756
current loading for targeted sectors - all reductions	151,970
adjusted source load	246,077

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

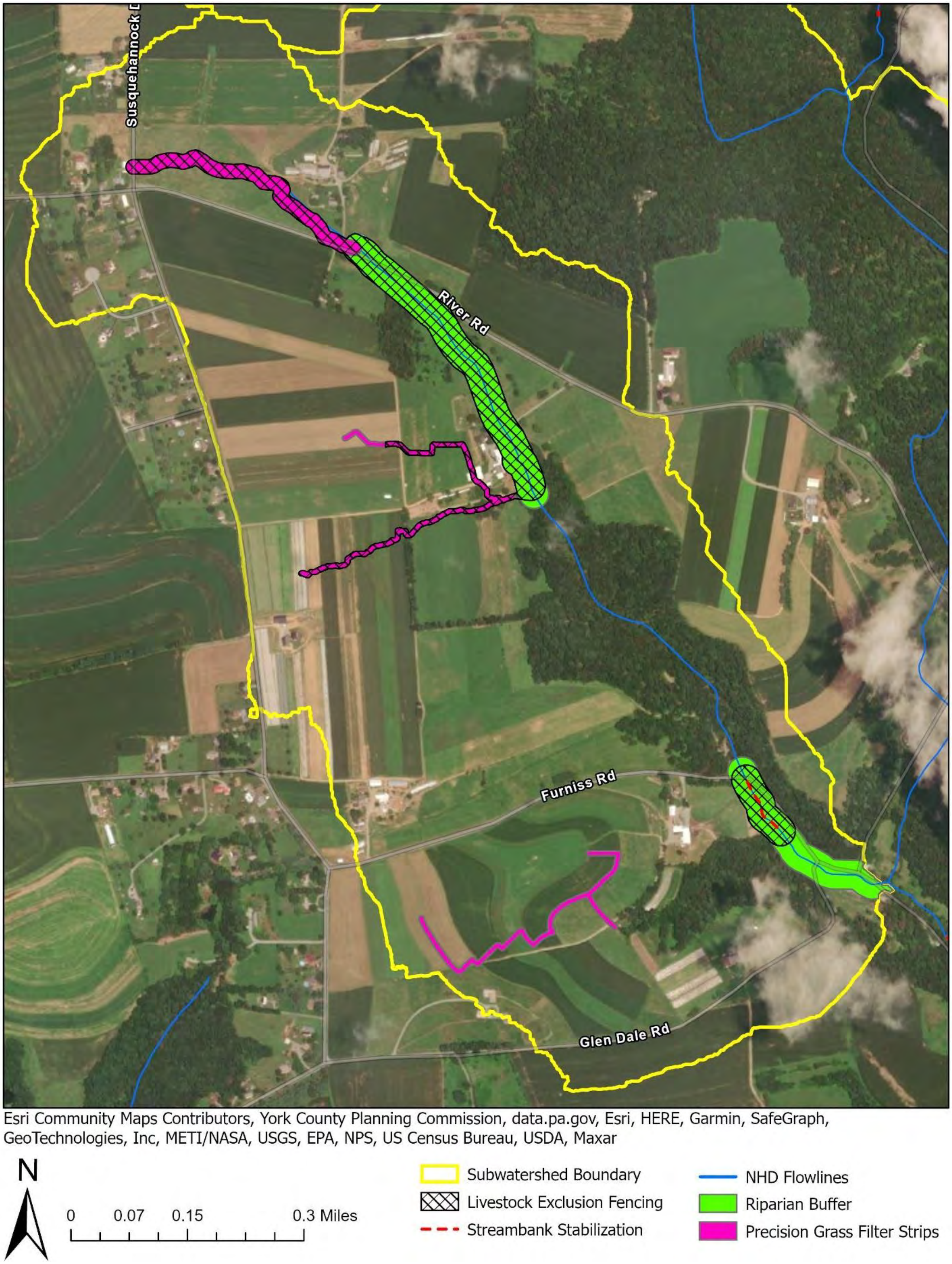


Figure 42. Proposed physical BMP opportunities in the Fishing Creek G subwatershed.

Table 20. BMP opportunities and their calculated sediment loading reductions in Fishing Creek subwatershed G. Note that the following is based on baseline model conditions, and does not take into account recent BMP implementation.

Fishing Creek Subwatershed G Proposed BMPs	**Sediment reduction** *lbs/yr*
426 feet streambank stabilization	2,982
100% ag. erosion and sedimentation plan implementation	147,497
10% more cropland with cover crops (25.9 acres)	5,846
30% more conservation tillage (77.8 acres)	71,901
9.8 acres forested riparian buffers	20,791
0 acres croplands retired for establishing buffers	0
5.1 acres hay/pasture lands retired for establishing buffers	816
8.9 acres precision grass filter strips[1]	239,078
Corrected Subtotal [2]	*429,141*
	lbs/yr
current loading for targeted sectors [3]	609,279
current loading for targeted sectors - all reductions	180,138
adjusted source load	368,894

[1]Need to be installed along specific drainagelines as shown in this document to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.

[2]Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMPs section".

[3]Targeted sectors include croplands, hay/pasture lands, and streambanks.

Table 21. Cost analysis of BMP opportunities in the Fishing Creek Head, A, B, C, D, F and G watersheds. All costs are reported as dollars. Note the table spans this and the following three pages.

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*
Head	Bank Stabilization[1]	ft	20	86	0	0	7	2237	193,366	193,366	15,516	0.289
	E&S Plans[2]	ac	10	15	0	0	2	1802	27,037	27,037	3,501	0.004
	Cover Crops[3]	ac	1	0	76	0	76	155	0	0	11,703	0.357
	Conservation Tillage[3]	ac	1	0	0	0	0	1092	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	22	89,373	128,318	8,943	0.132
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	42	303,092	343,887	31,792	0.245
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	32	28,413	84,352	7,613	0.012
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	16	164,822	180,266	22,509	0.069
								Sum	***806,104***	***957,227***	***101,578***	
A	Bank Stabilization[1]	ft	20	86	0	0	7	1344	116,175	116,175	9,322	1.176
	E&S Plans[2]	ac	10	15	0	0	2	410	6,150	6,150	796	0.004
	Cover Crops[3]	ac	1	0	76	0	76	36	0	0	2,718	0.346
	Conservation Tillage[3]	ac	1	0	0	0	0	107	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	2	7,312	10,499	732	0.141
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	8	55,567	63,046	5,829	0.282
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	6	5,305	15,749	1,421	0.009
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	6	66,344	72,560	9,060	0.051
								Sum	***256,853***	***284,179***	***29,878***	

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*
B	Bank Stabilization[1]	ft	20	86	0	0	7	4724	408,343	408,343	32,766	3.153
	E&S Plans[2]	ac	10	15	0	0	2	553	8,296	8,296	1,073	0.004
	Cover Crops[3]	ac	1	0	76	0	76	44	0	0	3,299	0.339
	Conservation Tillage[3]	ac	1	0	0	0	0	131	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	4	14,386	20,654	1,440	0.117
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	26	188,774	214,183	19,801	0.248
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	15	13,755	40,836	3,686	0.011
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	3	32,852	35,931	4,486	0.064
								Sum	***666,406***	***728,242***	***66,551***	
C	Bank Stabilization[1]	ft	20	86	0	0	7	3795	328,040	328,040	26,323	2.774
	E&S Plans[2]	ac	10	15	0	0	2	531	7,963	7,963	1,030	0.004
	Cover Crops[3]	ac	1	0	76	0	76	45	0	0	3,428	0.344
	Conservation Tillage[3]	ac	1	0	0	0	0	136	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	9	35,140	50,452	3,516	0.138
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	20	146,134	165,803	15,328	0.271
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	16	14,207	42,176	3,807	0.011
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	2	18,659	20,408	2,548	0.065
								Sum	***550,142***	***614,841***	***55,980***	

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*
D	Bank Stabilization[1]	ft	20	86	0	0	7	1055	91,194	91,194	7,318	1.196
	E&S Plans[2]	ac	10	15	0	0	2	348	5,214	5,214	674	0.005
	Cover Crops[3]	ac	1	0	76	0	76	21	0	0	1,608	0.330
	Conservation Tillage[3]	ac	1	0	0	0	0	64	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	12	47,937	68,825	4,797	0.145
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	23	165,979	188,319	17,410	0.275
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	1	899	2,669	241	0.016
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	7	69,453	75,961	9,485	0.090
								Sum	***380,676***	***432,183***	***41,533***	
F	Bank Stabilization[1]	ft	20	86	0	0	7	1267	109,519	109,519	8,788	3.153
	E&S Plans[2]	ac	10	15	0	0	2	175	2,622	2,622	339	0.004
	Cover Crops[3]	ac	1	0	76	0	76	14	0	0	1,080	0.323
	Conservation Tillage[3]	ac	1	0	0	0	0	43	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	2	9,344	13,415	935	0.217
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	3	18,763	21,288	1,968	0.304
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	1	1,259	3,737	337	0.005
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	917	1,416	0	0	0	0	N/A
								sum	***141,507***	***150,582***	***13,447***	

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*
G	Bank Stabilization[1]	ft	20	86	0	0	7	426	36,823	36,823	2,955	0.991
	E&S Plans[2]	ac	10	15	0	0	2	363	5,445	5,445	704	0.005
	Cover Crops[3]	ac	1	0	76	0	76	26	0	0	1,955	0.334
	Conservation Tillage[3]	ac	1	0	0	0	0	78	0	0	0	0.000
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	2	7,312	10,499	732	0.169
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	8	57,732	65,502	6,056	0.350
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	2	2,068	6,140	554	0.009
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	7	67,380	73,694	9,202	0.052
								Sum	***176,761***	***198,103***	***22,158***	
							All Subwatersheds Total Costs		***2,978,449***	***3,365,358***	***331,125***	

Where necessary, costs were annualized using CAST methodology. See https://cast.chesapeakebay.net/Documentation/CostProfiles.

[1] Current CAST methodology reports a much higher cost for "Non Urban Stream Restoration". However, per personal communication with Shaun McAdams formerly of Trout Unlimited, smaller projects using general permit type structures and restoration designs provided by government agencies tend to be much cheaper, approximately $50 per foot. Based on site observations, simpler projects are envisioned for the present study. To be conservative, $63.56 per foot was used in accordance with a prior version of the CAST methodology for Pennsylvania. This value however was multiplied by 1.36 to adjust for inflation from April 2010 to July 2022 per the CPI inflation calculator provided at https://data.bls.gov/cgi-bin/cpicalc.pl.

[2]Based in internal discussions at DEP, the most current CAST estimate of $24.91 per year for "Soil Conservation and Water Quality Plans" does not seem to reflect typical costs and longevity for agricultural erosion and sedimentation plans in Pennsylvania. Thus a prior CAST cost estimate was used.

[3]Based on most recent CAST methodology, except that cover crops were considered annual O&M costs rather than captial costs due to their 1yr lifespans.

*When assigning loads to with and without fenced categories, a simple method was used. The approximate proportion of buffer area with fencing and without fencing was calculated. These proportions were then multiplied by the total load associated with that BMP.

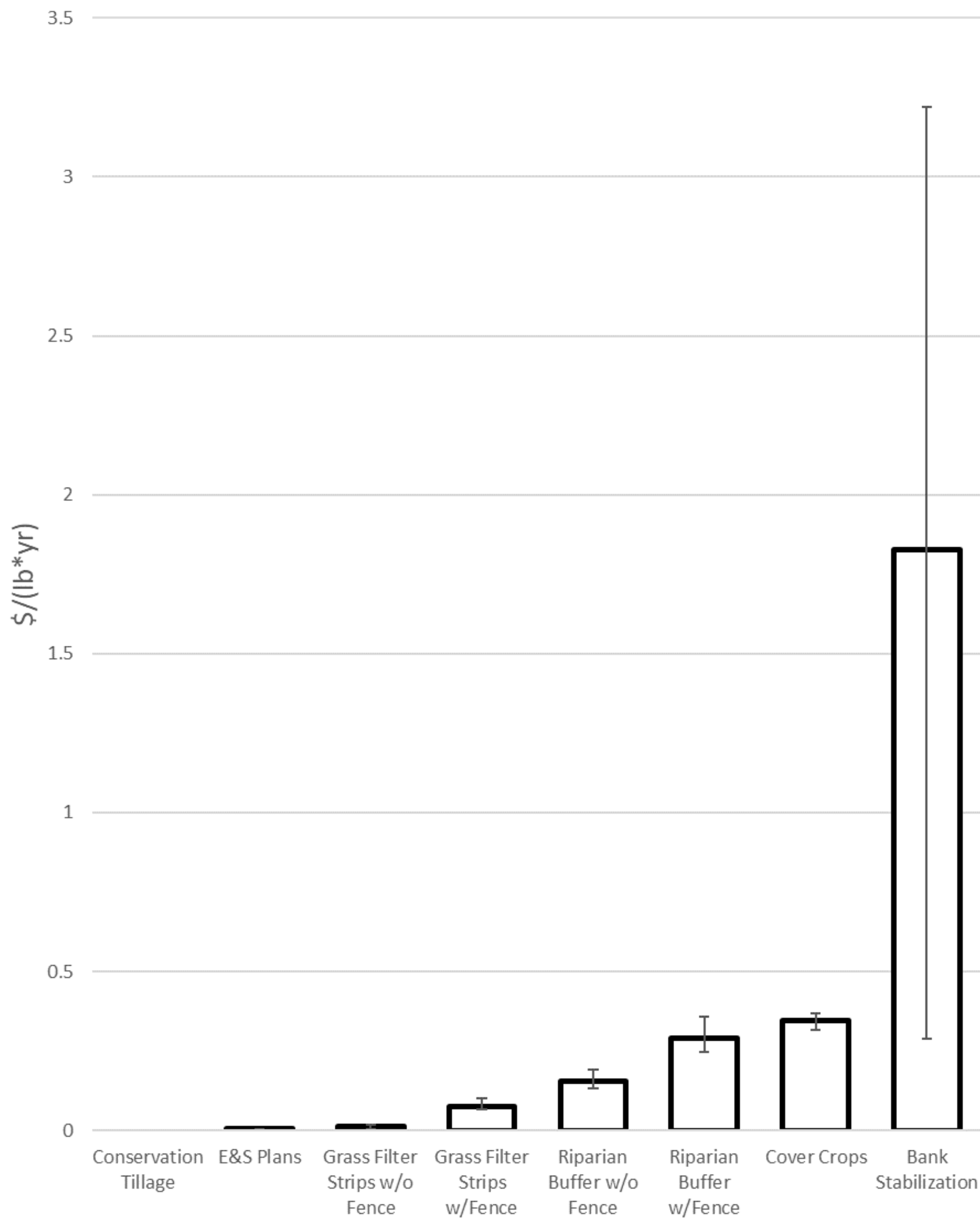


Figure 43. Estimated total annualized cost per pound of sediment removed per year for various BMP types proposed for the Fishing Creek watershed. Bars show the means of the Fishing Creek subwatersheds while error bars show the minimum and maximum values among the subwatersheds. See footnotes in Table 21 for more information.

Agricultural Erosion and Sedimentation Control Plans

Agricultural erosion and sedimentation control plans are a current legal requirement, and thus a 100% implementation rate was assumed. This would result in an estimated 3,417 acres of cropland and 763 acres of hay/pasture lands covered by plans. Based primarily on the Chesapeake Bay Program

(2018) methodology, it was assumed that these plans would reduce sediment loading on croplands by 25% and loading on hay/pasture lands by 8% (See Appendix E). Therefore, an annual sediment reduction of 1,869,092 lbs/yr (totaled from the outlet of each subwatershed) is predicted (Table 14-20).

Based on internal discussions at DEP and prior CAST methodology, these plans were estimated to have a capital cost of about $15 per acre, so, if applied to 100% of the acreage of croplands and hay/pasture lands in the subwatersheds, the total capital cost of these plans would be about $62,727 (Table 21). The average total annualized cost per pound of sediment removed per year was only $0.004 (Table 21, Figure 43), which suggests that this BMP is very cost effective.

For tracking purposes, load reductions associated with agricultural erosion and sedimentation plan implementation may be calculated as:

lb/yr reduction = acres of agricultural lands with implemented plan * agricultural land loading rate * reduction coefficient

where: cropland loading rate (lbs/(ac*yr)) =

- 2,110 in Head
- 2,192 in A
- 2,225 in B
- 2,194 in C
- 2,286 in D
- 2,336 in F
- 2,257 in G

hay/pasture land loading rate (lbs/(ac*yr)) =

- 158 in Head
- 163 in A
- 168 in B
- 167 in C
- 189 in D
- 170 in F
- 163 in G

reduction coefficient for croplands = 0.25
reduction coefficient for hay/pasture lands = 0.08

Note that the loading rates for croplands and hay/pasture lands given above should not be confused with erosion rates reported in agricultural erosion and sediment plans, as the above values reflect loading rates transported to the watershed outlet.

Conservation Tillage

It was assumed that transition from conventional tillage to medium residue conservation tillage could occur on 30% of the current cropland acreage within each Fishing Creek subwatershed, excepting the Head subwatershed, as described below. Based on Chesapeake Bay Program (2018) methodology, it was assumed that such a transition would result in a 41% sediment reduction per acre of cropland that uses this BMP. These simple assumptions were used because both current residue levels and farmers' future plans were unknown. And, on a statewide level, no-till use went from a little over 20% in 2004 to close to 70% by 2014 (USDA-NRCS 2019). This suggests that there may be limited additional room for growth in the adoption of this BMP. When summed from the outlets of the various subwatersheds, it is estimated that this would result in a sediment reduction of 511,516 lbs/yr (Tables 15-20). While this simplified method was used to be conservative about future opportunities, it is encouraged to use the more sophisticated crediting techniques described in the following paragraph if sufficient data is available.

Since the Head subwatershed needed such large sediment reductions, additional detailed analysis was conducted to estimate whether sufficient opportunities existed. According to Chesapeake Bay Program (2018) methodology (See Appendix E), conservation tillage is credited for sediment reduction according to crop residue levels immediately after planting: "low residue tillage" (15-29% residue cover) gets an 18% sediment reduction; "conservation tillage" (30-59% residue cover) gets a 41% sediment reduction; and "high residue" (≥ 60% residue cover) gets a 79% sediment reduction. Based on analysis of Lancaster County tillage data provided by Capital RC&D, it was estimated that in the year 2020, 26% of croplands used conventional tillage, while 14% used low residue, 30% used medium residue, and 30% used high residue conservation tillage. These percentages were then multiplied by the total acres of croplands estimated for the Head subwatershed, to calculate that 400 acres may be using conventional tillage, while 224 acres may be using low residue, 468 acres may be using medium residue, and 461 acres may be using high residue conservation tillage. For the sake of calculating BMP opportunities in Head, it was then assumed that all conventional and low residue tillage could be converted to medium residue tillage, and all medium residue tillage could be converted to high residue tillage. It is estimated that this would result in an 829,990 lb/yr sediment reduction for the Head subwatershed. If added to the totals for the other subwatersheds, the total reductions associated with conservation tillage opportunities was 1,341,505 lbs/yr (see Tables 14-20).

According to CAST documentation, use of conservation tillage is considered to be cost neutral. Thus, with a cost estimate of $0 per pound of sediment removed per year, this is the most cost-effective BMP (Table 21, Figure 43). Given the cost effectiveness and importance of this BMP, not only to preventing siltation but also promoting sustainable agriculture, we suggest that conservation tillage be used to the maximum extent possible.

For tracking purposes, load reductions associated with conservation tillage implementation may be calculated as:

lb/yr reduction = acres croplands with new/recent conservation tillage * cropland loading rate * reduction coefficient

where: cropland loading rate (lbs/(ac*yr)) =

- 2,110 in Head
- 2,192 in A
- 2,225 in B
- 2,194 in C
- 2,286 in D
- 2,336 in F
- 2,257 in G

reduction coefficient = 0.18 for low residue, 0.41 for medium residue and 0.79 for high residue. When crediting transitions from one category to another, the differences in reduction coefficient may be used.

To account for the prior Adaptive Toolbox restoration project, it is proposed to credit all conservation tillage implementation within the past seven years (2017 to present). Very recent implementation progress might not be accounted for by MMW and thus would represent improvements from what is reported by the model. Depending on resources and technological developments, estimates of tillage classes for tracking purposes may be derived from analysis of regional Capital RC&D survey data, remote sensing, information reported by the County Conservation District, or surveys conducted specifically for this study. DEP is presently working with a consultant to develop methodology to estimate tillage classes via remote sensing.

Cover Crops

According to Chesapeake Bay Program (2018) methodology, no additional credit is given for the use of cover crops on croplands that are already managed with low tillage. And, on lands with higher tillage, use of cover crops would provide much less sediment reductions versus converting to conservation tillage. Furthermore, crediting is only applicable when the cover crop is not a commodity crop. Given these limitations, only a small amount of cover crops, 342 acres or 10% of the cropland land area within all the Fishing Creek subwatersheds was presently proposed, to account for areas where landowners are unwilling to implement conservation tillage (Tables 14-20). Based primarily on Chesapeake Bay Program (2018) methodology, this BMP was given a 10% sediment reduction efficiency (See Appendix E). It is estimated that this would reduce sediment loading by a meager 74,354 lbs/yr when added up from each of the subwatershed outlets.

Use of cover crops is estimated to have an annual operation and maintenance cost of $75.50 per acre (Table 21). Thus, if applied to 10% of the acreage of cropland in the subwatersheds, the total annual cost of the proposed cover crops would be about $25,791 (Table 21). The total annualized cost per pound of sediment removed per year averaged among the subwatersheds was $0.34, which indicates that this BMP is expensive (Figure 43).

For tracking purposes, load reductions associated with cover crop implementation may be calculated as:

lb/yr reduction = acres croplands on high tillage lands with new/recent cover crop use * cropland loading rate * reduction coefficient
where: cropland loading rate (lbs/(ac*yr)) =
2,110 in Head
2,192 in A
2,225 in B
2,194 in C
2,286 in D
2,336 in F
2,257 in G
reduction coefficient = 0.1

To account for the prior Adaptive Toolbox restoration project, it is proposed to credit all qualifying cover crop implementation within the past 5 years (2017 to present). Such recent implementation would likely be unaccounted for by MMW and thus may represent improvements from what is reported by the model. Much progress may have already been made in implementing this BMP; for instance, in Berks, Lancaster, Lebanon and York counties (in southcentral PA), use of cover crops after growing corn went from about 40% in 2009 to about 65% in 2012 (USDA-NRCS 2019). Depending on resources and technological developments, estimates of tillage classes for tracking purposes may be derived from analysis of regional Capital RC&D survey data, remote sensing, information reported by the County Conservation District, or surveys conducted specifically for this study.

Conventional Riparian Buffers

It is widely recognized that riparian buffers are highly beneficial to stream communities for many reasons. Not only do they filter out pollutants such as sediment and nutrients, but they also provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; protect streambanks; and moderate stream temperature. Thus, riparian buffers should be encouraged *wherever* possible. Therefore, Figures 35-42 essentially shows proposed 100-foot wide forested buffers for all streamside areas where they were substantially lacking. Relative to the buffer opportunities shown in Figures 35-42, the acreages of buffer opportunities in Tables 14-20 were reduced to reflect only the area with croplands, hay/pasture, or developed open space coverage per NLCD 2019, as some areas may already have some natural vegetative cover and it is unlikely that significant buffers would be established on many developed lands.

While many experimental studies suggest riparian buffers can be very effective at removing upland pollutant loads, recent research suggests that buffer filtration performance may be limited by real-world environmental conditions, especially due to the existence of concentrated flowpaths (Dosskey et al. 2002, Sweeney and Newbold 2014). Furthermore, for any given buffer there may not be much uplands contributing pollutants to it. Or, if there are too much uplands communicating to a unit area of buffer, it is thought that its filtration capacity may be less effective. For such reasons, the CAST expert panel report chose to very conservatively assume that the sediment load from only two acres of uplands are filtered by about half (though variable by region) per acre of buffer created. Credit is also given for the land conversion associated with the creation of the buffer. For more information, see Belt et al. (2014) and Appendix E. Similarly, to Belt et al. (2014) and Chesapeake Bay Program (2018), reductions associated with conventional buffers may be calculated as:

lb/yr reduction = (acres of new streamside buffers created * 2 * cropland loading rate * filtration reduction coefficient) + [acres of new streamside buffers created * (current land cover loading rate – forest land cover loading rate)]

where: cropland loading rate (lbs/(ac*yr)) =

- 2,110 in Head
- 2,192 in A
- 2,225 in B
- 2,194 in C
- 2,286 in D
- 2,336 in F
- 2,257 in G

filtration reduction coefficient = 0.47

current land cover loading rate for hay/pasture lands (if needed) (lbs/(ac*yr)) =

- 158 in Head
- 163 in A
- 168 in B
- 167 in C
- 189 in D
- 170 in F
- 163 in G

current land cover loading rate for developed open space (if needed) (lbs/(ac*yr)) =

- 11 in Head
- 11 in A
- 11 in B
- 10 in C
- 11 in D
- 10 in F
- 10 in G

current land cover loading rate for forest (lbs/(ac*yr)) =

- 3 in Head
- 4 in A
- 3 in B
- 3 in C
- 4 in D
- 5 in F
- 3 in G

One advantage to crediting buffers by the acre rather than by length of stream buffered is that buffer width and configuration will likely vary depending on the landowner's degree of commitment to this BMP. While ≥ 100 foot buffers are preferable, the above formula allows for crediting buffers of varying widths.

Using the above methodology, it is estimated that the proposed buffers shown in Figures 35-42 would remove 526,733 pounds of sediment per year, summed from the outlet of each subwatershed (Tables 14-20).

Note that while forested buffers are preferable for wildlife habitat, grass buffers are thought to provide a similar sediment filtration benefit (see Belt et al. 2014). Reductions associated with streamside grass buffers could be modelled using the above formula, in which case the loading for hay/pasture could be used for the loading rate of the grass buffers when calculating the reductions associated with the change of land cover.

According to CAST's cost estimates for Pennsylvania, the cost of forested riparian buffer is substantially higher if livestock exclusion fencing is necessary. If implemented as proposed in Figures 35-42, exclusion fencing would be necessary most of the time, as streamside areas are commonly used for pasture in this region. Without fencing, riparian buffers are expected to have a capital cost of $4,062.42 per acre, so, for the 53 acres of forested buffers proposed, the capital cost is expected to be $210,804 (Table 21). For forested buffers with exclusion fencing, the capital cost is expected to be $7,216.47 per acre, so for the 130 acres proposed, the total capital cost is expected to be $936,041 (Table 21).

If the cost of the land is included, the total estimated capital + land cost for all the proposed buffers is $1,364,690. With a total annualized cost of $0.15 per pound of sediment removed per year (averaged among each subwatershed), conventional forested buffers without fencing appear to be moderately cost effective (Table 21, Figure 43), even with conservative assumptions of sediment removal. In contrast, buffers where fencing is needed are moderately expensive, at around $0.28 per pound of sediment removed per year (Table 21, Figure 43).

Precision Grass Filter Strips

As mentioned previously, CAST derived methodology for calculating the effectiveness of riparian buffers was purposely very conservative to account for: lack of knowledge of how much sediment communicates to any given buffer and the possibilities of concentrated flowpaths and saturation of filtration effectiveness. Rather than using very conservative crediting to account for these uncertainties, it was sought to directly address these concerns by strategically placing buffers where they would intercept the most agricultural runoff and design them so they would be effective at sediment removal (see Dosskey et al. 2005, Allenby and Burke 2012, Holden et al. 2013).
To determine the locations where buffers may intercept the most storm runoff/sediment loads, USGS Digital Elevation Models (USGS 2022) were analyzed using the TauDEM Version 5.3.7 (Tarboton 2016) toolkit in ArcGISPro. Briefly, the combined DEMs were clipped to the general area of the Fishing Creek watershed, and then the "Pit Remove", "D8 Flow Direction", "D8 Contributing Area",

“Grid Network” and “Stream Definition by Threshold” tools were used to create a drainage network based on an accumulated stream source grid cell threshold value of 10,000. This value was chosen as sufficient for displaying the major drainageways without overwhelming their visualization with too much detail. The “D8 Contributing Area” tool was used to delineate watersheds at various delineation points. The “Stream Reach and Watershed” tool was used to create a shapefile of the watershed’s drainage networks. The “Watershed Grid to Shapefile” tool was used to help create shapefiles of the DEM delineated subwatersheds. The outline of the watersheds were converted to simple polygon shapefiles using ArcGIS Pro.

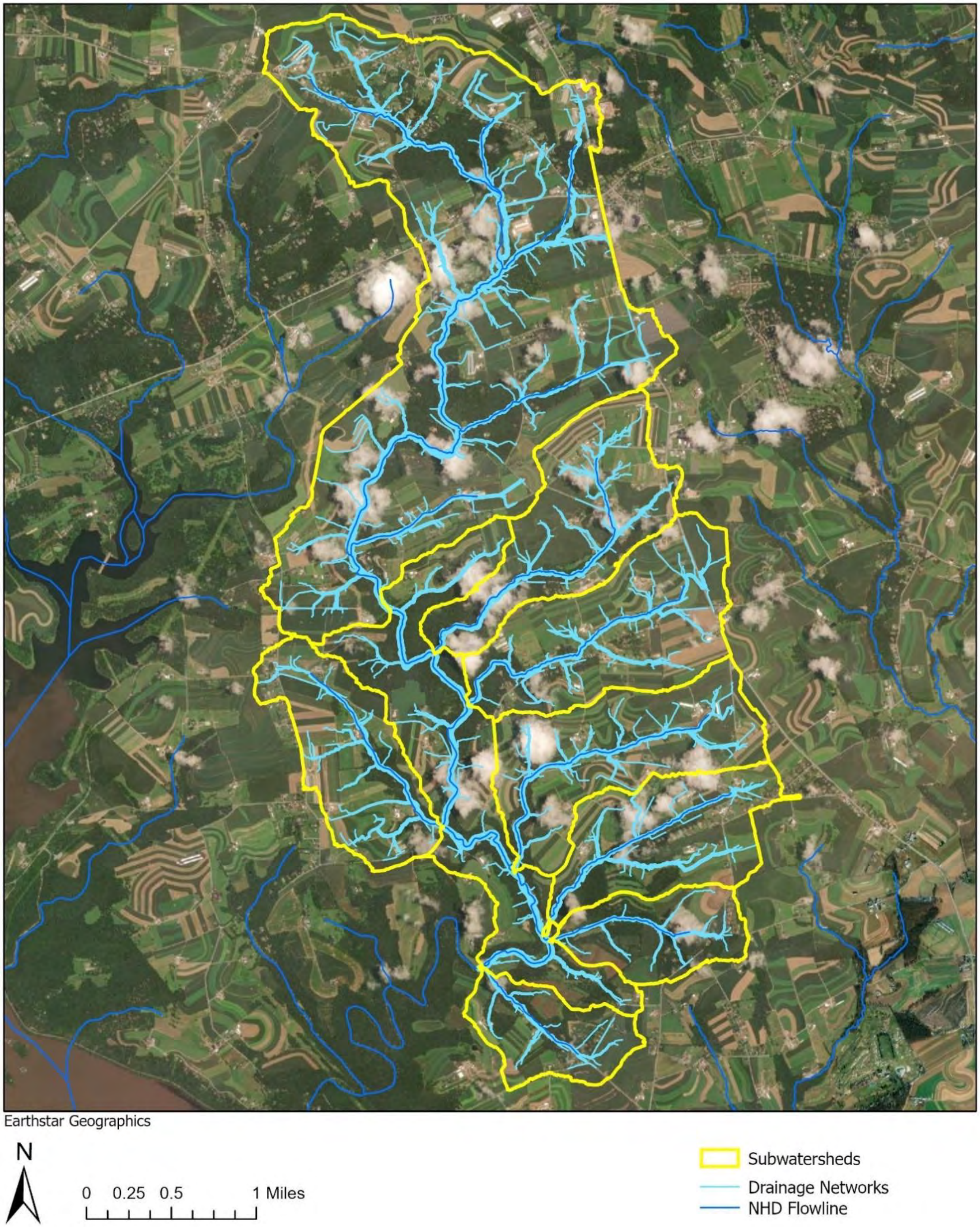


Figure 44. Drainage networks within the Fishing Creek watershed. Drainage networks were mapped using a USGS Digital Elevation Model and the TauDEM toolkit in ArcGIS Pro. The drainage networks are shown in light blue.

As is obvious when comparing the drainageways to the USGS high-resolution NHD flowlines (Figure 44), these results confirm the presence of concentrated overland flowpaths. Therefore, riparian buffers in certain areas would intercept larger amounts of overland flow, whereas buffers established in other areas would filter virtually no upland runoff. To choose the areas that would be most important for buffering, it was sought to define the key overland drainagesheds that drained the greatest amount of agricultural lands. Key drainagesheds were then delineated using the aforementioned TauDEM tools at outlet points, typically near where main drainagelines entered the stream or left a major field area (Figures 45 and 46). The “Watershed Grid to Shapefile” tool was used to help create shapefiles of the DEM delineated drainagesheds. The outline of the drainagesheds were converted to simple polygon shapefiles using ArcGIS Pro (Figures 45 and 46).

To determine the sediment load associated with these drainagesheds, the proportion of NLCD 2019 land cover within each drainageshed were estimated using MMW. These land areas were then multiplied by the landcover loading rates in the BMP spreadsheet tool provided by a prior version of MMW (Evans et al. 2020). Estimated sediment loads for each key drainageshed labeled in Figures 45 and 46 are reported in Table 22.

Simply establishing riparian buffers along the flowing stream at the outlet of the drainagesheds may be ineffective because large amounts of sediment and flow could overwhelm very small areas of buffers (Dosskey et al. 2002 and personal observations). Thus, to provide adequate area to buffer these drainagesheds, it was proposed to extend buffers up the main flowline(s) of each key drainageway (Figures 45 and 46).

Because these drainage lines pass through agricultural fields, establishing forested buffers, though preferable for wildlife habitat, would likely be unacceptable to farmers. Thus, it was proposed to use tall grass buffers instead. Such grass lined waterways or simple grass buffers are commonly used BMPs, and the CAST Expert Panel Report (See Belt et al. 2014) indicates that grass buffers may be as effective as forested buffers for sediment removal.

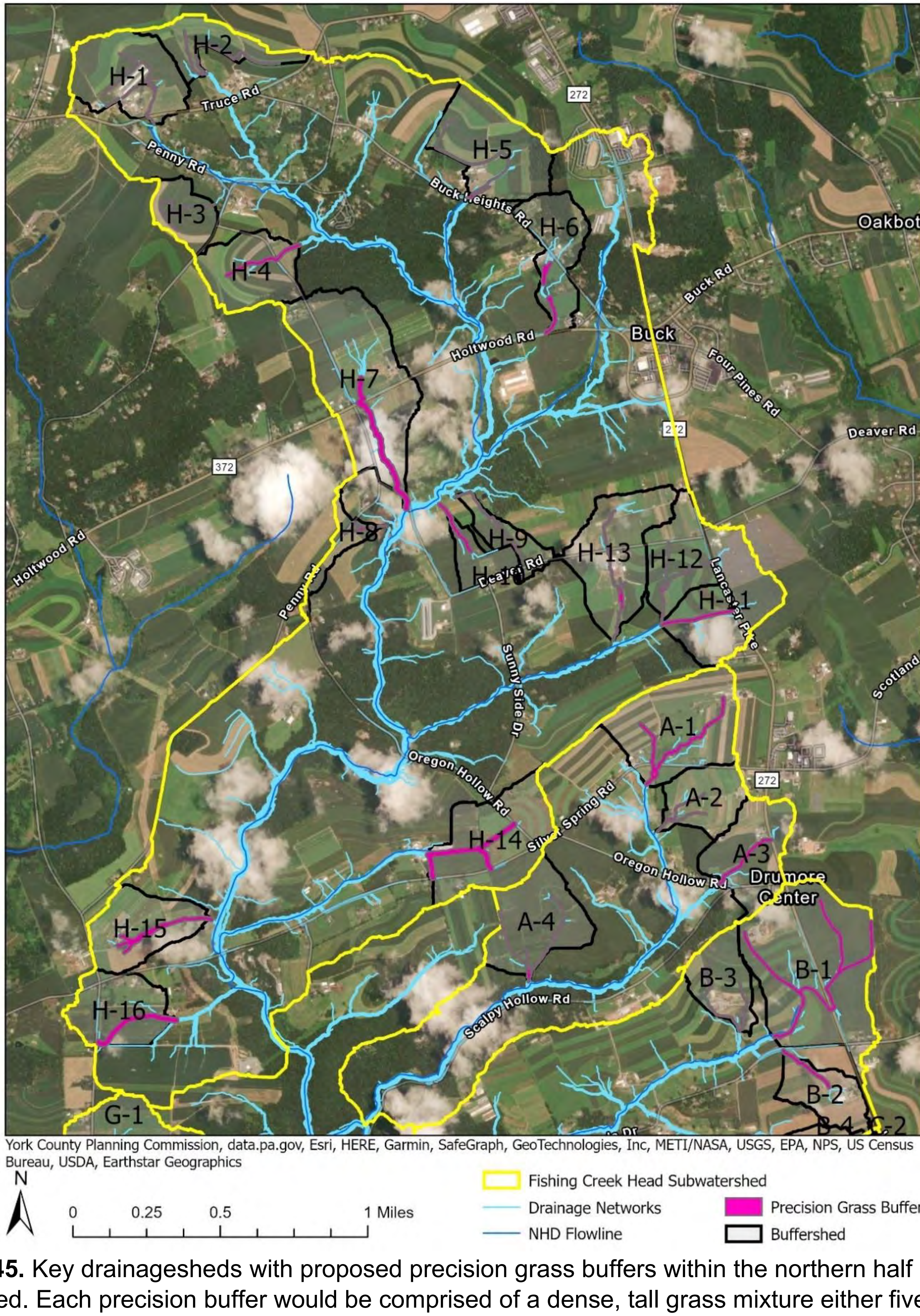


Figure 45. Key drainagesheds with proposed precision grass buffers within the northern half of the watershed. Each precision buffer would be comprised of a dense, tall grass mixture either five, ten for fifteen meters of either side of the main drainage flowline. The letter labels correspond to the labels in Table 22.

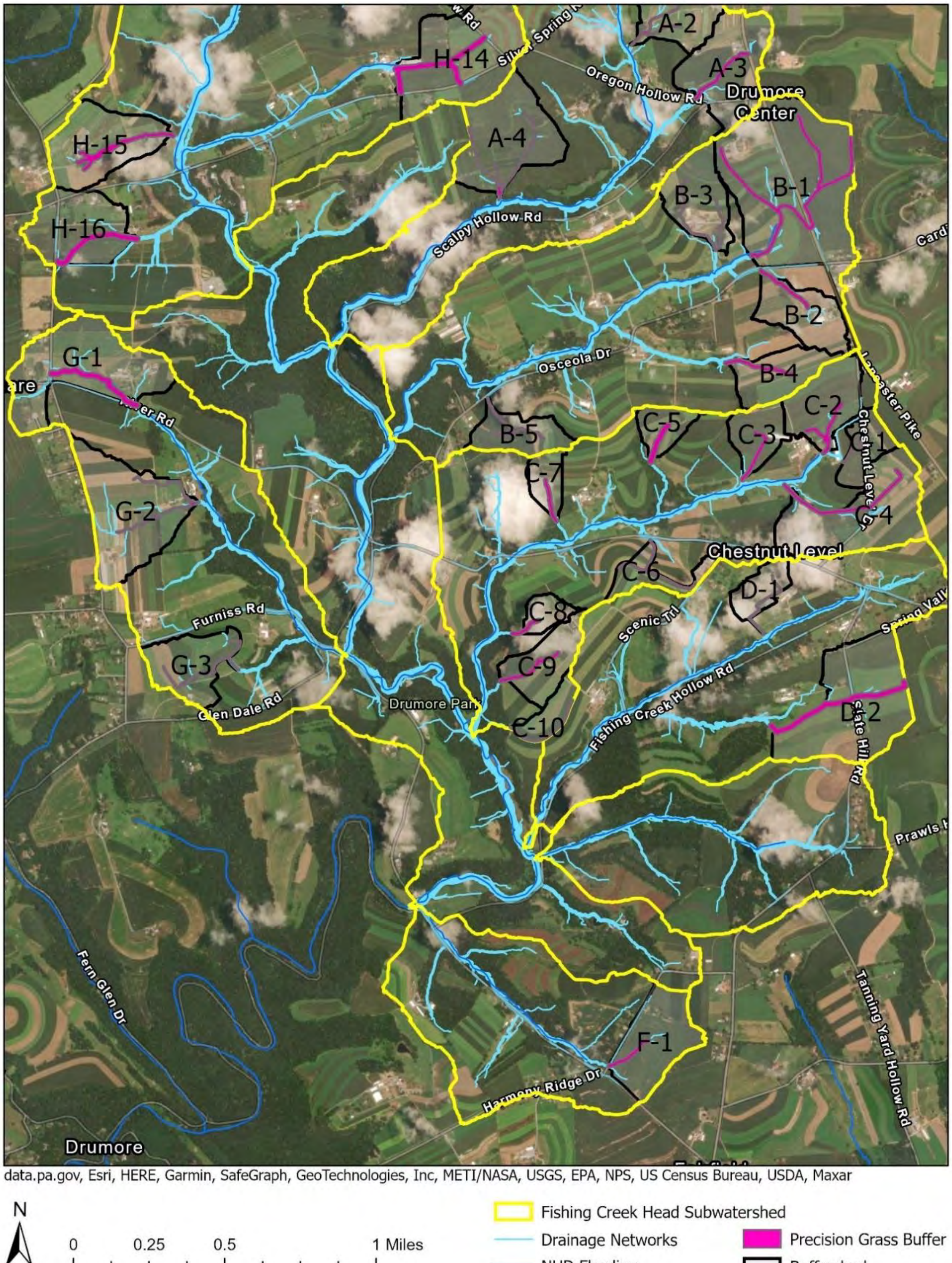


Figure 46. Key drainagesheds with proposed precision grass buffers within the southern half of the watershed. Each precision buffer would be comprised of a dense, tall grass mixture either five, ten for fifteen meters of either side of the main drainage flowline. The letter labels correspond to the labels in Table 22.

Table 22. Contribution of sediment from each drainageshed to the subwatershed total and predicted % sediment removal by the precision buffers for the 5-yr storm. Note: drainageshed labels correspond to labels in Figures 45 and 46.

Drainageshed	Acres	Buffer Width	Drainageshed load (lbs/yr)	Reductions for the 5yr storm %	Reductions for the 5yr storm (lbs/yr)
H-1	59.6	5	107,691	87%	93,368
H-2	31.6	5	65,905	98%	64,323
H-3	24.3	5	45,891	86%	39,328
H-4	46.3	10	75,201	85%	63,996
H-5	65.6	5	102,842	80%	82,479
H-6	43.0	10	28,310	87%	24,686
H-7	111.7	15	119,768	63%	75,813
H-8	14.2	5	19,273	91%	17,461
H-9	18.9	5	30,519	87%	26,521
H-10	19.3	10	34,620	81%	28,146
H-11	66.5	10	83,180	78%	65,213
H-12	41.4	5	73,041	92%	66,832
H-13	68.7	5	107,664	83%	89,145
H-14	73.6	15	112,397	85%	95,537
H-15	47.7	10	97,716	85%	82,668
H-16	45.6	15	77,446	75%	58,007
A-1	79.4	10	115,073	94%	108,168
A-2	34.4	5	70,038	88%	61,564
A-3	50.7	10	86,104	78%	67,161
A-4	56.6	5	122,366	83%	100,952
B-1	133.2	10	224,534	93%	207,919
B-2	31.1	10	53,139	95%	50,217
B-3	33.9	5	74,024	78%	57,665
B-4	27.4	10	51,689	93%	47,812
B-5	23.4	5	50,782	85%	43,215
C-1	17.1	5	33,559	83%	27,753
C-2	34.2	10	59,219	82%	48,441
C-3	20.3	10	43,256	79%	34,258
C-4	66.5	10	107,307	90%	96,361
C-5	14.5	15	30,618	78%	23,760
C-6	15.4	5	28,393	99%	28,138
C-7	13.0	10	26,878	91%	24,486
C-8	10.1	10	21,872	94%	20,626
C-9	27.4	10	55,436	87%	48,174
C-10	12.6	5	28,674	98%	28,101
D-1	14.9	5	28,827	90%	25,829
D-2	79.6	15	120,374	79%	94,735
F-1	41.3	10	86,987	76%	66,458
G-1	72.4	15	105,208	77%	80,905
G-2	67.1	5	114,102	80%	90,711
G-3	32.9	5	71,998	94%	67,462

In order to design and credit these buffers for sediment removal, a rigorous, scientifically-justifiable approach was sought. Ultimately the VFSMOD program was chosen because it was a freely-available mechanistic model designed to estimate sediment and other pollutant removal from grass buffers based on site-specific conditions. Further, this model has been the subject of numerous peer-reviewed scientific publications and it has been validated under experimental conditions.

Using user defined parameters, VFSMOD simulates storm events, generates landscape runoff and sediment loads, and estimates sediment retention versus export in grass filter strips. Since the model cannot accommodate complex site geometry, the total non-buffer land area of the drainageshed was assumed to be a uniform rectangle that drained to a rectangular 5, 10 or 15m wide grass buffer that was twice as long (to account for two sides) as the buffer strips shown in Figures 45 and 46. To be conservative, simulations were conducted using the five-year storms for this region of Pennsylvania: 99.4 mm in 24 hours (PENNDOT 2010). The buffer was assumed to have uniform slope and be comprised of a dense grass mixture. Initial model runs were made assuming a 5m wide buffer. If the model run indicated that the proposed buffer would remove less than 75% of the sediment input during the 5-year storm, model was rerun with a 10m wide buffer. If still not at least 75% effective, modelling was conducted using a 15m wide buffer. See Appendix F for VFSMOD parameter inputs and further details on how site geometry was simplified.

According to the VFSMOD output, the proposed vegetated filter strips were predicted to remove most of the sediment during the 5-year storm in all cases (Table 22). While they would perform even better during the 1-yr storm, it was decided to be conservative and base claimed reductions on the 5-yr storm. Thus, % reductions during the 5-year storm were multiplied by the drainageshed's contribution to the overall annual average sediment load (Table 22). Another reason to believe these results are conservative is that the estimated amount of sediment getting through these buffers is really just sediment reaching the center-line of the drainageway. To actually get to the stream this sediment would have to flow down through the buffer and reach the drainageshed outlet. Filtration in this flow direction was not even accounted for. This likely at least partially compensates for one reason the buffers might not perform as well as expected: the fact that additional concentrated flowpaths feed into the main drainageline and perhaps overwhelm the buffers at certain points. Note that if this is the case, the buffer would be underwhelmed at other points.

Using strategically placed buffers and crediting them with realistic methodology suggests they may be among the most effective BMP opportunities for sediment removal (Tables 14-20). If implemented as proposed, these filter strips would only occupy 114 acres, or about 2.7% of current agricultural lands within the seven study subwatersheds. Yet these buffers would be conservatively estimated to remove 2,524,395 pounds of sediment per year (Tables 14-20), which is more than thirty percent of the combined load emanating from these subwatersheds.

According to CAST's cost estimates for Pennsylvania, grass buffers/filter strips are expected to have a capital cost of $899.15 per acre. However, the cost increases considerably to $10,366 per acre in cases where livestock exclusion fencing is needed to establish such buffers. Based on estimates of how much of each type of grass buffer is proposed, the total capital cost for the grass buffer opportunities is expected to be $485,416 (Table 21). If the cost of the land is also included, the total cost would be about $654,479 (Table 21). There was also an annual operation and maintenance cost of $35.97 per acre if unfenced, or $509.32 per acre if fenced. Given the high amount of predicted sediment removal, these filter strips are predicted to be the most cost effective physical (as opposed to practice) BMP, with a total annualized cost of about either 1 or 7 cents per pound of sediment removed per year, depending on whether fencing is needed (Table 21, Figure 43).

For tracking purposes, the following credit can be claimed for fully implementing the precision grass filter strips as shown in Figures 28 and 29:

Sediment reduction credit for installing tall grass buffers along the drainagelines as shown in Figures 45 and 46.

Drainageshed	**Buffer Length** (ft)	**Buffer Width per side** (m)	**Reduction w/o E&S Plan** (lbs/yr)	**Reduction w/ E&S Plan** (lbs/yr)
H-1	3,940	5	93,368	70,026
H-2	3,449	5	64,323	48,242
H-3	1,998	5	39,328	29,496
H-4	1,585	10	63,996	47,997
H-5	3,964	5	82,479	61,859
H-6	1,555	10	24,686	18,515
H-7	3,099	15	75,813	56,860
H-8	1,080	5	17,461	13,096
H-9	1,989	5	26,521	19,891
H-10	1,123	10	28,146	21,109
H-11	1,385	10	65,213	48,910
H-12	2,750	5	66,832	50,124
H-13	3,796	5	89,145	66,859
H-14	2,696	15	95,537	71,653
H-15	3,171	10	82,668	62,001
H-16	1,681	15	58,007	43,505
A-1	3,714	10	108,168	81,126
A-2	2,074	5	61,564	46,173
A-3	1,383	10	67,161	50,371
A-4	4,021	5	100,952	75,714
B-1	7,367	10	207,919	155,939
B-2	1,161	10	50,217	37,663
B-3	2,912	5	57,665	43,249
B-4	1,323	10	47,812	35,859
B-5	1,906	5	43,215	32,412
C-1	824	5	27,753	20,815
C-2	1,639	10	48,441	36,331
C-3	1,125	10	34,258	25,694
C-4	2,713	10	96,361	72,271
C-5	764	15	23,760	17,820
C-6	2,241	5	28,138	21,103
C-7	811	10	24,486	18,364
C-8	604	10	20,626	15,469
C-9	1,295	10	48,174	36,130
C-10	1,633	5	28,101	21,076
D-1	1,640	5	25,829	19,372
D-2	2,874	15	94,735	71,051
F-1	912	10	66,458	49,844
G-1	1,929	15	80,905	60,679
G-2	3,287	5	90,711	68,033
G-3	2,690	5	67,462	50,596

Note that width refers to distance from the centerline of the drainageway per side. Since a “5m” buffer would extend 5m in both directions, it would actually be 10m wide in total. Deviations from the configurations proposed herein will require additional modelling to calculate appropriate reductions.

Note that two crediting options are provided to solve a logical problem, the fact that implementation of agricultural erosion and sedimentation plans would already be estimated to reduce cropland loading by 25%, so when combined with the high percent reductions from filter strips reported in Table 22, calculated reductions for a drainageshed could exceed 100%. A simple solution to this "double counting" problem was to reduce each drainageshed's sediment load contribution to the watershed total by 25% before applying the filtration reduction (see above box). Note that this is conservative because an erosion and sedimentation plans' reduction of inputs to the buffer would likely result in a higher filtration efficiency by the buffer, and this was not even accounted for. Both crediting options are provided for different purposes. The uncorrected numbers are partially used in Table 14-20, relating to BMP opportunities; as well as Tables 21, 23 and 24 and Figure 43 which relate to costs, since these tables and figure are important to comparing the relative effectiveness and costs of BMPs. However, only the corrected figures are used in the forthcoming "Schedule and Milestones" section, since it is proposed to implement agricultural erosion and sedimentation plans as a first step.

Streambank Stabilization/Stream Restoration

Going forward, there appears to be a limited role for additional stream restoration work in the Fishing Creek watershed. For one, much of the problematic areas have already been addressed. It is estimated that about two miles of flowlines have been recently restored, and this includes some formerly highly problematic areas on the middle mainstem. And, much of the remaining mainstem passes through large forested areas which may have a protective effect against severe habitat degradation while making restoration with machinery impractical. With much of the middle and lower mainstem off the table, most of the remaining stream length is first order, and such streams may have lower bank erosion rates due to their less powerful flows. If so, habitat and bank erosion problems may be adequately addressed simply by establishing forested buffers.

With all of that said, there may be some stream segments that are sufficiently degraded to warrant restoration. Based on site observations, it is estimated that approximately 14,848 additional feet of stream may benefit from stabilization. It was conservatively assumed that streambanks in these areas loaded sediment at ten-times the rate as other areas.

This being the case, the normal erosion rate (X) was calculated as follows within each study subwatershed:

> (ft of flowlines with normal banks)*(X) + (ft of flowlines with degraded banks)*(10)*(X) = total streambank erosion

For instance, in the Fishing Creek Head watershed:

> (43,459 ft)*(X) + (2,237 ft)*(10X) = 156,985 lbs/yr

Thus, the normal streambank sediment loading rate was calculated to be 2.4 lbs/(ft*yr), in which case the credit given for stabilizing the eroding reaches was calculated to be 10X or 24 lbs/(ft*yr). It should be clearly stated that the above is intended as a very rough estimate due to factors such as uncertainties in modelling and mapping, and the above does not account for variability among sites.

Actual site measurements could be used to justify higher or lower credit claims. Using such methodology, stabilization of the proposed 14,848 ft of identified opportunities among all the study subwatersheds would reduce sediment loading by 93,387 lbs/yr (Tables 14-20). See below for the calculated crediting rate for each subwatershed. Note that further site inspections may reveal additional candidate areas for streambank stabilization.

In calculating the costs associated with streambank stabilization, it was assumed that simpler stabilization structures would be used rather than more complex comprehensive stream restoration methods. This seems appropriate given the modest problems suspected within these small streams. Such simple restoration utilizing general permit approved structures and only light equipment (S. McAdams, formerly of Trout Unlimited personal communication) is estimated to cost approximately $86 per foot (Table 21). Thus, at about $1.83 per pound of sediment removed per year (Table 21), basic stabilization projects appear to be very expensive (Figure 43). But, it still may be reasonable to use this BMP in limited cases, for instance, at sites where it can be demonstrated that the above simplified crediting scheme likely vastly underestimated the loading rate, and thus the cost effectiveness, of restoring a particular site. Furthermore, use of stream restoration may be further justified where fish habitat is of particular concern or due to its popularity with landowners.

For tracking, reductions associated with streambank stabilization/stream restoration may be calculated as:

Feet of streambank stabilized * estimated annual streambank loading rate for problematic areas
Where the estimated annual streambank loading rates for the problematic banks (lbs/ft*yr) are:

24.0 in Head
5.9 in A
2.2 in B
2.5 in C
5.8 in D
2.2 in F
7.0 in G

Alternatively, empirically derived values based on site specific measurements may be used as well.

CONSIDERATIONS OF COST EFFECTIVENESS

Note that the aforementioned analysis sought to identify BMP *opportunities*, and the total reduction associated with them exceeded the estimated reductions needed to achieve water quality standards in all cases. Showing more BMP opportunities than necessary is important, however, because implementation of most requires the voluntary cooperation of landowners. Plus, it allows for the selection of the most cost effective BMPs. While the total capital cost of all BMP opportunities was about three million dollars (Table 21), Table 23 shows how each reduction goal could be met, at least on paper, for about $250,000 capital cost. In this hypothetical analysis, agricultural erosion and sedimentation plans and conservation tillage were prescribed to be implemented fully relative to the identified opportunities due to their cost effectiveness. If more reductions were still needed, precision grass filter strips without fencing, then precision grass filter strips with fencing, and after that, riparian buffers without fencing were prescribed until reduction goals were achieved. Due to their expense per unit of sediment removed per year, bank stabilization, cover crops and riparian buffers with fencing were not prescribed.

However, this “cheapest” scenario is not recommended due to its avoidance of forested riparian buffers. While not the most cost effective BMP for sediment removal, forested riparian buffers are very important to stream health for factors beyond just sediment removal, such as the providing habitat and nutrition for aquatic organisms, filtering out other pollutants, providing shade and moderating stream temperature, etc. Thus, they should be implemented wherever possible. Otherwise, streams within the watershed may end up with a suitable sediment load while remaining impaired for Aquatic Life Use due to poor habitat. Therefore, we present a third cost scenario in Table 24, which is like the “cheapest” scenario but includes half the fenced and unfenced buffer opportunities. But to be clear, the assumption of half buffers is not to recommend that they only be implemented by half. Rather, it is recommended that they be implemented as much as feasible. But, half implementation was assumed because many farmers may be reluctant to devote agricultural lands to buffers. This “cheapest plus half buffers” scenario is estimated to cost a less than a million dollars (Table 24).

The primary purpose of these cost-effectiveness analyses was not to recommend against particular BMPs, but rather, to show how cost effectiveness may be taken into account. And, there may be good reason to implement BMPs that are less cost effective. For instance, while stream bank stabilization is expensive, its use would likely have positive habitat implications as well, and this BMP tends to be popular with landowners. And, cover crops may at least provide some benefit in situations where a farmer is unwilling or unable to use conservation tillage.

Table 23. Reduced estimates of project costs that take into account selective implementation based on cost effectiveness. All costs are reported as dollars. This table represents the minimum cost to implement the project.

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
Head	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~2,237~~	~~193,366~~	~~193,366~~	~~15,516~~	~~0.289~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	1,802	27,037	27,037	3,501	0.004	822,355	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~155~~	~~0~~	~~0~~	~~11,703~~	~~0.357~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	1092	0	0	0	0.000	829,990	Assume Full
	~~Riparian Buffer w/o Fence~~[3]	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~22~~	~~89,373~~	~~128,318~~	~~8,943~~	~~0.132~~	0	Assume None
	~~Riparian Buffer w/Fence~~[3]	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~42~~	~~303,092~~	~~343,887~~	~~31,792~~	~~0.245~~	0	Assume None
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	32	28,413	84,352	7,613	0.012	485,865	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	8	82,411	90,133	11,254	0.069	122,139	Assume Half
								Sum	***137,861***	***201,523***	***22,369***		2,260,349	**>2,252,375 target**
A	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,344~~	~~116,175~~	~~116,175~~	~~9,322~~	~~1.176~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	410	6,150	6,150	796	0.004	196,862	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~36~~	~~0~~	~~0~~	~~2,718~~	~~0.346~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	107	0	0	0	0.000	96,523	Assume Full
	~~Riparian Buffer w/o Fence~~[3]	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~2~~	~~7,312~~	~~10,499~~	~~732~~	~~0.141~~	0	Assume None
	~~Riparian Buffer w/Fence~~[3]	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~8~~	~~55,567~~	~~63,046~~	~~5,829~~	~~0.282~~	0	Assume None
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	6	5,305	15,749	1,421	0.009	121,268	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	2	16,586	18,140	2,265	0.051	33,029	Assume 25%
								sum	***28,041***	***40,039***	***4,483***		447,682	**>417,657 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
B	~~Bank Stabilization[1]~~	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~4,724~~	~~408,343~~	~~408,343~~	~~32,766~~	~~3.153~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	553	8,296	8,296	1,073	0.004	244,640	Assume Full
	~~Cover Crops[3]~~	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~44~~	~~0~~	~~0~~	~~3,299~~	~~0.339~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	131	0	0	0	0.000	119,596	Assume Full
	~~Riparian Buffer w/o Fence[3]~~	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~4~~	~~14,386~~	~~20,654~~	~~1,440~~	~~0.117~~	0	Assume None
	~~Riparian Buffer w/Fence[3]~~	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~26~~	~~188,774~~	~~214,183~~	~~19,801~~	~~0.248~~	0	Assume None
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	15	13,755	40,836	3,686	0.011	252,758	Assume Full
	~~Grass Filter Strips w/Fence[3]~~	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~3~~	~~32,852~~	~~35,931~~	~~4,486~~	~~0.064~~	0	Assume None
								sum	***22,051***	***49,132***	***4,759***		616,993	**>581,905 target**
C	~~Bank Stabilization[1]~~	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~3,795~~	~~328,040~~	~~328,040~~	~~26,323~~	~~2.774~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	531	7,963	7,963	1,030	0.004	250,048	Assume Full
	~~Cover Crops[3]~~	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~45~~	~~0~~	~~0~~	~~3,428~~	~~0.344~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	136	0	0	0	0.000	122,517	Assume Full
	~~Riparian Buffer w/o Fence[3]~~	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~9~~	~~35,140~~	~~50,452~~	~~3,516~~	~~0.138~~	0	Assume None
	~~Riparian Buffer w/Fence[3]~~	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~20~~	~~146,134~~	~~165,803~~	~~15,328~~	~~0.271~~	0	Assume None
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	16	14,207	42,176	3,807	0.011	255,666	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	0.5	4,665	5,102	637	0.065	7,352	Assume 25%
								sum	***26,834***	***55,241***	***5,474***		635,583	**>632,021 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
D	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,055~~	~~91,194~~	~~91,194~~	~~7,318~~	~~1.196~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	348	5,214	5,214	674	0.005	123,756	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~21~~	~~0~~	~~0~~	~~1,608~~	~~0.330~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	64	0	0	0	0.000	59,891	Assume Full
	~~Riparian Buffer w/o Fence~~[3]	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~12~~	~~47,937~~	~~68,825~~	~~4,797~~	~~0.145~~	0	Assume None
	~~Riparian Buffer w/Fence~~[3]	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~23~~	~~165,979~~	~~188,319~~	~~17,410~~	~~0.275~~	0	Assume None
	~~Grass Filter Strips w/o Fence~~[3]	~~ac~~	~~10~~	~~899~~	~~36~~	~~1,770~~	~~241~~	~~1~~	~~899~~	~~2,669~~	~~241~~	~~0.016~~	0	Assume None
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~7~~	~~69,453~~	~~75,961~~	~~9,485~~	~~0.090~~	0	Assume None
								sum	***5,214***	***5,214***	***674***		183,647	**>150,776 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
F	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,267~~	~~109,519~~	~~109,519~~	~~8,788~~	~~3.153~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	175	2,622	2,622	339	0.004	83,934	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~14~~	~~0~~	~~0~~	~~1,080~~	~~0.323~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	43	0	0	0	0.000	41,088	Assume Full
	~~Riparian Buffer w/o Fence~~[3]	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~2~~	~~9,344~~	~~13,415~~	~~935~~	~~0.217~~	0	Assume None
	~~Riparian Buffer w/Fence~~[3]	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~3~~	~~18,763~~	~~21,288~~	~~1,968~~	~~0.304~~	0	Assume None
	~~Grass Filter Strips w/o Fence~~[3]	~~ac~~	~~10~~	~~899~~	~~36~~	~~1,770~~	~~241~~	~~1~~	~~1,259~~	~~3,737~~	~~337~~	~~0.005~~	0	Assume None
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~917~~	~~1,416~~	~~0~~	~~0~~	~~0~~	~~0~~	~~N/A~~	0	Assume None
								sum	***2,622***	***2,622***	***339***		125,022	**>97,680 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
G	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~426~~	~~36,823~~	~~36,823~~	~~2,955~~	~~0.991~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	363	5,445	5,445	704	0.005	147,497	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~26~~	~~0~~	~~0~~	~~1,955~~	~~0.334~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	78	0	0	0	0.000	71,901	Assume Full
	~~Riparian Buffer w/o Fence~~[3]	~~ac~~	~~40~~	~~4,062~~	~~81~~	~~1,770~~	~~407~~	~~2~~	~~7,312~~	~~10,499~~	~~732~~	~~0.169~~	0	Assume None
	~~Riparian Buffer w/Fence~~[3]	~~ac~~	~~30~~	~~7,216~~	~~239~~	~~971~~	~~757~~	~~8~~	~~57,732~~	~~65,502~~	~~6,056~~	~~0.350~~	0	Assume None
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	1	1,034	3,070	277	0.009	23,382	Assume Half
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~7~~	~~67,380~~	~~73,694~~	~~9,202~~	~~0.052~~	0	Assume None
								sum	***6,479***	***8,515***	***981***		242,780	**>240,385 target**
								All Subwatersheds Total Costs	***229,103***	***362,286***	***39,079***		**4,512,056**	Total Sed Red

Where necessary, costs were annualized using CAST methodology. See https://cast.chesapeakebay.net/Documentation/CostProfiles.

[1] Current CAST methodology reports a much higher cost for "Non Urban Stream Restoration". However, per personal communication with Shaun McAdams formerly of Trout Unlimited, smaller projects using general permit type structures and restoration designs provided by government agencies tend to be much cheaper, approximately $50 per foot. Based on site observations, simpler projects are envisioned for the present study. To be conservative, $63.56 per foot was used in accordance with a prior version of the CAST methodology for Pennsylvania. This value however was multiplied by 1.36 to adjust for inflation from April 2010 to July 2022 per the CPI inflation calculator provided at https://data.bls.gov/cgi-bin/cpicalc.pl.

[2]Based in internal discussions at DEP, the most current CAST estimate of $24.91 per year for "Soil Conservation and Water Quality Plans" does not seem to reflect typical costs and longevity for agricultural erosion and sedimentation plans in Pennsylvania. Thus a prior CAST cost estimate was used.

[3]Based on most recent CAST methodology, except that cover crops were considered annual O&M costs rather than captial costs due to their 1yr lifespans.

*When assigning loads to with and without fenced categories, a simple method was used. The approximate proportion of buffer area with fencing and without fencing was calculated. These proportions were then multiplied by the total load associated with that BMP.

Table 24. Reduced estimates of project costs that take into account selective implementation based on cost effectiveness, but with half riparian buffer implementation due to the importance of this BMP for habitat. All costs are reported as dollars.

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
Head	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~2,237~~	~~193,366~~	~~193,366~~	~~15,516~~	~~0.289~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	1,802	27,037	27,037	3,501	0.004	822,355	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~155~~	~~0~~	~~0~~	~~11,703~~	~~0.357~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	1092	0	0	0	0.000	829,990	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	11	44,687	64,159	4,472	0.132	33,992	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	21	151,546	171,943	15,896	0.245	64,894	Assume Half
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	32	28,413	84,352	7,613	0.012	485,865	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	8	82,411	90,133	11,254	0.069	122,139	Assume Full
								Sum	***334,094***	***437,625***	***42,737***		2,359,235	**>2,252,375 target**
A	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,344~~	~~116,175~~	~~116,175~~	~~9,322~~	~~1.176~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	410	6,150	6,150	796	0.004	196,862	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~36~~	~~0~~	~~0~~	~~2,718~~	~~0.346~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	107	0	0	0	0.000	96,523	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	1	3,656	5,249	366	0.141	2,450	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	4	27,783	31,523	2,914	0.282	10,480	Assume Half
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	6	5,305	15,749	1,421	0.009	121,268	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	2	16,586	18,140	2,265	0.051	33,029	Assume 25%
								sum	***59,480***	***76,812***	***7,763***		460,611	**>417,657 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
B	~~Bank Stabilization[1]~~	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~4,724~~	~~408,343~~	~~408,343~~	~~32,766~~	~~3.153~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	553	8,296	8,296	1,073	0.004	244,640	Assume Full
	~~Cover Crops[3]~~	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~44~~	~~0~~	~~0~~	~~3,299~~	~~0.339~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	131	0	0	0	0.000	119,596	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	2	7,193	10,327	720	0.117	5,503	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	13	94,387	107,091	9,901	0.248	40,652	Assume Half
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	15	13,755	40,836	3,686	0.011	252,758	Assume Full
	~~Grass Filter Strips w/Fence[3]~~	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~3~~	~~32,852~~	~~35,931~~	~~4,486~~	~~0.064~~	0	Assume None
								sum	***123,631***	***166,550***	***15,379***		663,149	**>581,905 target**
C	~~Bank Stabilization[1]~~	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~3,795~~	~~328,040~~	~~328,040~~	~~26,323~~	~~2.774~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	531	7,963	7,963	1,030	0.004	250,048	Assume Full
	~~Cover Crops[3]~~	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~45~~	~~0~~	~~0~~	~~3,428~~	~~0.344~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	136	0	0	0	0.000	122,517	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	4	17,570	25,226	1,758	0.138	12,281	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	10	73,067	82,901	7,664	0.271	28,750	Assume Half
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	16	14,207	42,176	3,807	0.011	255,666	Assume Full
	Grass Filter Strips w/Fence[3]	ac	19	10,366	509	971	1,416	0.5	4,665	5,102	637	0.065	7,352	Assume 25%
								sum	***117,471***	***163,369***	***14,896***		676,614	**>632,021 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
D	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,055~~	~~91,194~~	~~91,194~~	~~7,318~~	~~1.196~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	348	5,214	5,214	674	0.005	123,756	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~21~~	~~0~~	~~0~~	~~1,608~~	~~0.330~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	64	0	0	0	0.000	59,891	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	6	23,968	34,413	2,398	0.145	16,332	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	12	82,989	94,159	8,705	0.275	31,833	Assume Half
	~~Grass Filter Strips w/o Fence~~[3]	~~ac~~	~~10~~	~~899~~	~~36~~	~~1,770~~	~~241~~	~~1~~	~~899~~	~~2,669~~	~~241~~	~~0.016~~	0	Assume None
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~7~~	~~69,453~~	~~75,961~~	~~9,485~~	~~0.090~~	0	Assume None
								sum	***112,172***	***133,786***	***11,778***		231,811	**>150,776 target**
F	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~1,267~~	~~109,519~~	~~109,519~~	~~8,788~~	~~3.153~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	175	2,622	2,622	339	0.004	83,934	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~14~~	~~0~~	~~0~~	~~1,080~~	~~0.323~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	43	0	0	0	0.000	41,088	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	1	4,672	6,708	467	0.217	2,533	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	1	9,381	10,644	984	0.304	2,863	Assume Half
	~~Grass Filter Strips w/o Fence~~[3]	~~ac~~	~~10~~	~~899~~	~~36~~	~~1,770~~	~~241~~	~~1~~	~~1,259~~	~~3,737~~	~~337~~	~~0.005~~	0	Assume None
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~917~~	~~1,416~~	~~0~~	~~0~~	~~0~~	~~0~~	~~N/A~~	0	Assume None
								sum	***16,675***	***19,974***	***1,791***		130,418	**>97,680 target**

	BMP	Unit	Lifespan (yrs)	Capital Cost/Unit	Annual O&M Cost/Unit	One Time Opportunity Cost/Unit	Total Annualized Cost/Unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost/ (lb of sediment* yr)*	Total Reductions lbs/yr	Relative to Opportunties
G	~~Bank Stabilization~~[1]	~~ft~~	~~20~~	~~86~~	~~0~~	~~0~~	~~7~~	~~426~~	~~36,823~~	~~36,823~~	~~2,955~~	~~0.991~~	0	Assume None
	E&S Plans[2]	ac	10	15	0	0	2	363	5,445	5,445	704	0.005	147,497	Assume Full
	~~Cover Crops~~[3]	~~ac~~	~~1~~	~~0~~	~~76~~	~~0~~	~~76~~	~~26~~	~~0~~	~~0~~	~~1,955~~	~~0.334~~	0	Assume None
	Conservation Tillage[3]	ac	1	0	0	0	0	78	0	0	0	0.000	71,901	Assume Full
	Riparian Buffer w/o Fence[3]	ac	40	4,062	81	1,770	407	1	3,656	5,249	366	0.169	1,984	Assume Half
	Riparian Buffer w/Fence[3]	ac	30	7,216	239	971	757	4	28,866	32,751	3,028	0.350	8,819	Assume Half
	Grass Filter Strips w/o Fence[3]	ac	10	899	36	1,770	241	1	1,034	3,070	277	0.009	23,382	Assume Half
	~~Grass Filter Strips w/Fence~~[3]	~~ac~~	~~19~~	~~10,366~~	~~509~~	~~971~~	~~1,416~~	~~7~~	~~67,380~~	~~73,694~~	~~9,202~~	~~0.052~~	0	Assume None
								sum	***39,001***	***46,515***	***4,375***		253,584	**>240,385 target**
								All Subwatersheds Total Costs	***802,525***	***1,044,631***	***98,718***		**4,775,421**	Total Sed Red

Where necessary, costs were annualized using CAST methodology. See https://cast.chesapeakebay.net/Documentation/CostProfiles.

[1] Current CAST methodology reports a much higher cost for "Non Urban Stream Restoration". However, per personal communication with Shaun McAdams of Trout Unlimited, smaller projects using general permit type structures and restoration designs provided by government agencies tend to be much cheaper, approximately $50 per foot. Based on site observations, simpler projects are envisioned for the present study. To be conservative, $63.56 per foot was used in accordance with a prior version of the CAST methodology for Pennsylvania. This value however was multiplied by 1.36 to adjust for inflation from April 2010 to July 2022 per the CPI inflation calculator provided at https://data.bls.gov/cgi-bin/cpicalc.pl.

[2]Based in internal discussions at DEP, the most current CAST estimate of $24.91 per year for "Soil Conservation and Water Quality Plans" does not seem to reflect typical costs and longevity for agricultural erosion and sedimentation plans in Pennsylvania. Thus a prior CAST cost estimate was used.

[3]Based on most recent CAST methodology, except that cover crops were considered annual O&M costs rather than captial costs due to their 1yr lifespans.

*When assigning loads to with and without fenced categories, a simple method was used. The approximate proportion of buffer area with fencing and without fencing was calculated. These proportions were then multiplied by the total load associated with that BMP.

FUNDING SOURCES

This project seeks funding under Section 319 of the Clean Water Act, as such funds are specifically allocated for addressing nonpoint source pollution. In addition to use of 319 funds, BMPs may also be paid for as described in the following.

In some cases, farmers may be able to write their own agricultural erosion and sedimentation plans. Where a consultant is utilized, funding assistance may be available from USDA-NRCS, Pennsylvania's Growing Greener Program, the National Fish and Wildlife Foundation, and the Resource Enhancement and Protection (REAP) Tax Credit.

There are many ways to fund the establishment of streamside buffers. In fact, there is an entire document describing funding opportunities. See "A Landowner's Guide to Conservation Buffer Incentive Programs in Pennsylvania" (Talbert 2009). In short, there are various programs that range from loan programs that provide funding assistance for designing and implementing buffers, all the way to programs that pay landowners more than the county's average agricultural land rental rate for the landuse associated with the buffers. Specific sources of such funding include the USDA Conservation Reserve Program (CRP), USDA-NRCS's Wetlands Reserve Program, Pennsylvania's Conservation Reserve Enhancement Program (CREP), USDA Environmental Quality Incentives Program (EQIP), USDA's Wildlife Habitat Incentives Program (WHIP), DEP's Stream Bank Fencing Program, USFWS's Partners for Fish and Wildlife Program, the State Treasury's AgriLink loan program, Pennsylvania's Growing Greener program, USEPA's 319 program, and the State Conservation Commission's Nutrient Management Plan Implementation Grant Program (NMPIGP). PA DCNR also gives grants for the establishment of riparian buffers. Given the complexities of potential funding sources, the County Conservation District should discern on a case by case basis the most appropriate funding options.

With regard to agriculture specific BMPs such as cover crops, conservation tillage, grazing land management, grass filter strips and streambank fencing, there may be numerous ways to fund such projects, especially through various programs administered through USDA's Natural Resources Conservation service. See https://www.nrcs.usda.gov/wps/portal/nrcs/main/pa/programs/financial/. Pennsylvania's Growing Greener program may also fund agricultural BMPs and farmers and businesses who install BMPs may be eligible for REAP tax credits.

Stream restoration specific BMPs may be paid for through various funding sources, such as Pennsylvania's Growing Greener program and the National Fish and Wildlife Foundation. In the past, organizations such as the PFBC and the USFWS have supported stream restoration projects, for instance by providing restoration design work.

The above paragraphs only list some of the major funding opportunities for BMP implementation as part of this project. Consultation with groups such as USDA-NRCS, and DEP grant administrators should be done on a case by case basis for choosing the best way to fund specific BMPs.

EVALUATION OF RECENT PROGRESS

Hypothetical progress towards each study watershed's reduction goal was estimated based on: an analysis of a non-public BMP tracking database (Practice Keeper), the final report from the prior "Adaptive Toolbox" project (Berger 2021), and site observations. It should be warned that the numbers shown in Table 25 are highly uncertain. For instance, credit was given simply because it was confirmed that a farmer *had* an agricultural erosion and sedimentation or conservation plan, but such credit could be removed if it is found that the plan is not being implemented. Furthermore, it appears that some BMPs were missing from Practice Keeper. And, grass waterways were modestly credited using the above formula for riparian buffers. More generous crediting using the methodology developed for precision grass filter strips could be used once details such as grass height and configuration are further evaluated. Despite these uncertainties, it appears that substantial progress might have been made in all study subwatersheds, ranging from about 41% to 121% of the reduction goals.

For the sake of privacy protection, the actual BMPs identified in each watershed will not be revealed in this public document. But with that said, most of this progress has to do with the presence of legally required agricultural erosion and sedimentation plans. The use of recently implemented (within the past 5 years) conservation tillage was also a major contributor in some watersheds. Conservation tillage implemented more than 5 years ago per Practice Keeper was not counted so that crediting would reflect recent improvements rather than historic conditions.

The ability to account for BMP crediting should improve over the course of the project as relationships with landowners develop, site visits are made, histories can better be constructed, and implementation of erosion and sedimentation plans can be confirmed.

Table 25. Hypothetical estimates of recent progress towards reduction goals. Specific BMPs are not listed in order to protect farmer confidentiality. Most of the reductions were due to agricultural erosion and sedimentation plans and conservation tillage. Conservation tillage was only credited if it was implemented in 2017 or later.

	Subwatershed						
	Head	**A**	**B**	**C**	**D**	**F**	**G**
Estimated Progress (lbs/yr)	924,033	187,808	340,609	275,222	182,185	74,549	135,064
Reductions Needed (lbs/yr)	2,252,375	417,657	581,905	632,021	150,776	97,680	240,385
Percent of goal	41%	45%	59%	44%	121%	76%	56%

STAKEHOLDER ROLES

Triennial Update Report

It is proposed that the Donegal Chapter of Trout Unlimited and DEP (Figure 47) collaborate to prepare a brief triennial (every 3 year) report over the nine-year project period (Figure 48) that, among other things, reports progress towards prescribed pollutant reduction goals, improvements in water quality, and any other updates on key activities. Furthermore, a public meeting is planned after the first two triennial reports to review the report, update the public, and encourage additional participation (Figure 48). It is proposed that the triennial reports be shared with USEPA's TMDL and 319 sections.

Education

With the exception of the Triennial Report, which would be a joint effort with DEP, the Donegal Chapter of Trout Unlimited would be primarily responsible for education, though DEP may be able to assist in these efforts. At the onset of the project, mailings, phone calls, and door-to door visits with landowners should be used to notify landowners of the project and to encourage farmers to adopt the BMPs called for in this document. Depending on interest, a public meeting could also be held around the time of project initiation. After this, it is planned at a minimum to have mailings to landowners, a public report, and a public meeting on a triennial basis to keep the public informed and involved in the project (Figure 48). The LancCo View 2.0 GIS website (Lancaster County Geographic Information System Division 2024) may be used to gather contact information from property owners. Also, more generally, Donegal Trout Unlimited maintains a website at https://www.donegaltu.org/. This website includes information on their projects, a calendar of events and is used to distribute a periodic newsletter. This website and newsletter will be used to inform the public about the ARP efforts. The Donegal Chapter of Trout Unlimited could cover necessary expenses associated with the aforementioned activities with their own funding, including grants from the Keith Campbell Foundation for the Environment.

In addition to these activities, it is proposed to construct signs informing the public of significant restoration sites in the watershed as well as more general educational signs. These signs would be paid for with grant money, with an estimated cost perhaps of $10,000 total over the life of the project. Depending on landowner willingness, the more general educational signs could be placed at one or more sites within Lancaster Conservancy's Fishing Creek Nature Preserve lands and within the Drumore Township Community Park.

Outreach beyond what is described herein may occur at the discretion of the implementation partners. More is not always better, as excessive outreach may wear on the patience of landowners. This can be especially true for busy farmers who are also being approached by various other groups for many reasons, such as DEP, USEPA, the County Conservation Districts, USDA-NRCS, the local municipality, business interests and other environmental groups. Thus, more discreet efforts to make inroads with particular members of the local community, and then allowing for growth via word of mouth and reputation building might be more advantageous than more generic outreach. Thus, much should be left to the discretion of the implementation partners in this matter.

Implementing BMPs

The Donegal Chapter of Trout Unlimited would ultimately be responsible for implementation of most of the BMPs called for in this plan (Figure 47). They would be responsible for day to day logistics, such as applying for funds, landowner outreach, acquiring site designs, hiring contractors, and assuring that work is done according to schedule. The Donegal Chapter of Trout Unlimited may partner with other organizations such as the Lancaster County Conservation District and USDA's

Natural Resources Conservation Service (NRCS), who can offer a great deal of expertise with agricultural BMPs, as well as the USFWS and PFBC who may assist with the development of stream restoration/bank stabilization designs. The Donegal Trout Unlimited may choose to involve contractors for various tasks as well.

Since this plan relies so heavily on agricultural BMPs that are beyond the Donegal Chapter of Trout Unlimited's expertise, and the Lancaster County Conservation District may have limited ability to devote extra resources specifically to this project, it is proposed to acquire grant funds for the purpose of using agricultural consultants. It is envisioned that such consultants would visit farms, help diagnose site specific needs, develop required agricultural plans, and promote the BMPs called for in this plan. The ability to adequately compensate consultants for their time and expertise may go a long way towards the successful promotion of the highly cost-effective BMPs called for in this plan, as such BMPs may not generate large consulting profits. It is estimated that $100,000 over the life of this project would be adequate, per the following rationale. In order to visit the various willing farmers in the watershed, it was estimated that approximately one month of work would be needed for six of the nine project years. Thus, a total of about six full months of work would be needed from such a consultant. If the salary for an agricultural consultant or environmental scientist in Pennsylvania is $85,000 per year, then $42,500 may cover their salary for those 6 months. However, this value was doubled to $85,000, and then rounded up to $100,000 to cover various additional expenses. Possible funding sources for this work may include 319 program funds, funds from DEP's Growing Greener program, and National Fish and Wildlife Foundation funds.

Considering that the total capital cost of all BMPs in this plan may range from about 350,000 to 3 million dollars, this $100,000 dollar estimated expense is modest, and may actually *save* money in the long run. The main purpose of this money is to employ an advocate for the most cost-effective BMPs. And, if lesser of these cost effective BMPs are used, then much more expensive BMPs will be needed to meet reduction goals. When compared with the six or seven figure price tags that are typical stream habitat restoration projects, this $100,000 spread over a nine-year project seems like a bargain.

Prescription and Tracking of Pollutant Reductions

The present document, largely drafted by the DEP, establishes a quantitative sediment reduction goal and includes an analysis of hypothetical BMPs that are estimated to achieve the prescribed reductions. Furthermore, this document provides simple ways to calculate the credit received for implementing most BMPs. Even so, DEP's TMDL section plans to be available over the life of the project to aid in additional modelling and the calculation of BMP reductions. It is proposed that the Donegal Chapter of Trout Unlimited and DEP collaborate in the preparation of a brief triennial update report every three years over the nine-year project period that, among other things, reports progress towards prescribed pollutant reduction goals (Figure 48). It will be important therefore for stakeholders and cooperating organizations to keep accurate records of all BMPs and report them to The Donegal Chapter of Trout Unlimited and/or DEP when possible for tracking. It is understood however that careful consideration must be given to landowner confidentiality agreements.

Assessment
DEP is responsible for assessing and monitoring Pennsylvania's waterways. Thus, even before the inception of this project, DEP had already assessed the Fishing Creek watershed using benthic macroinvertebrates and physical habitat screening to determine its impairment status. And, DEP would continue to assess the watershed even if this project did not go forward. However, given the interest in this project, it is expected that Fishing Creek will be the focus of additional assessment by DEP. These proposed measures will be detailed in the "Effectiveness Monitoring and Evaluation of Progress Section".

Disclaimer
It must be stated up front that the administrative and BMP implementation goals in this document cannot be firm commitments because among other things: 1) DEP and the Donegal Chapter of Trout Unlimited's ability to commit to the project may change with changing personnel, resources, funding and management goals and 2) most of the proposed BMPs require the voluntary consent of land owners. Since the bulk of the grant monies are allocated on a project by project basis, the funding organizations may choose to stop funding projects proposed in this document if satisfactory progress is not made. It should also be noted that even if implemented BMPs do not allow for the full amelioration of all impairments in the Fishing Creek watershed, water quality will almost assuredly improve both in this watershed and in downstream areas. If it becomes clear that the impairments will not be reversed as a result of this project, then a TMDL will be required (which could be developed by DEP but would not be a task for the implementation organization).

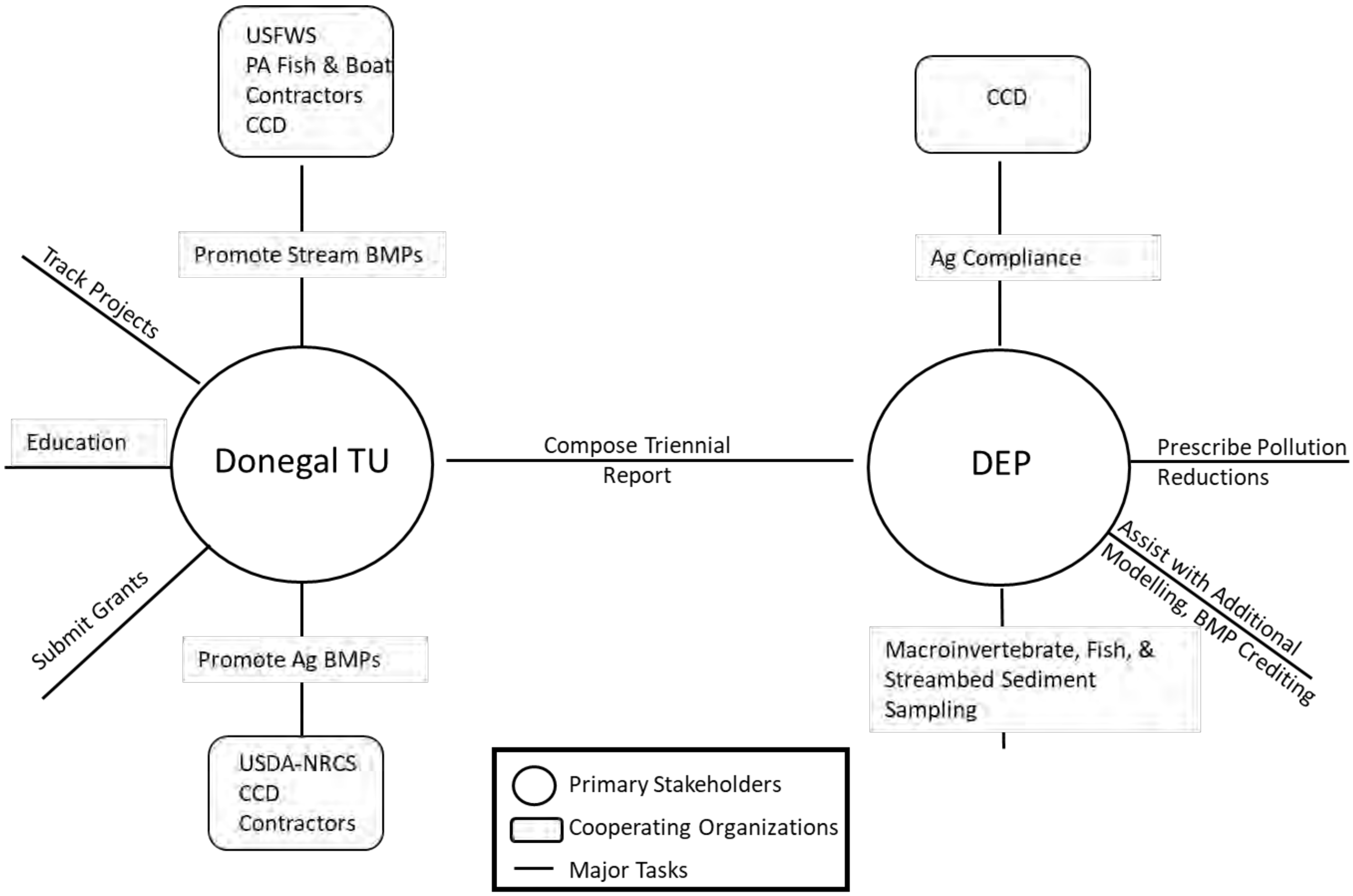


Figure 47. Proposed organizational structure for the Fishing Creek ARP. DEP = Pennsylvania Department of Environmental Protection, Donegal TU = Donegal Chapter of Trout Unlimited, USDA-NRCS = United States Department of Agriculture Natural Resources Conservation Service, USFWS = United States Fish and Wildlife Service, CCD = County Conservation District, PA Fish & Boat = Pennsylvania Fish and Boat Commission. NFWF = National Fish and Wildlife Foundation. The Donegal Chapter of Trout Unlimited and DEP would be the primary stakeholders but would require cooperation from landowners and assistance from cooperating organizations for completion of the major tasks shown above.

SCHEDULE AND MILESTONES

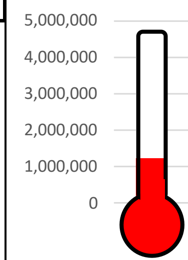
Figure 48 details a schedule of major goals and milestones for the restoration plan. The basic organizational unit of the schedule is a 3-year period after which there is proposed to be a "Triennial Report" that summarizes: progress made to date, updated assessment information, and makes needed adjustments to future goals. Depending on stakeholder interest, a public meeting may also be held at the onset of the project, as well as after preparation of the first two triennial reports. Such meetings would be used to solicit more stakeholder involvement and review the triennial reports. A public mailing would likely be used in advance of the meetings to solicit public involvement. The total active length of the project is anticipated to be nine years, plus additional assessment samplings around year twelve.

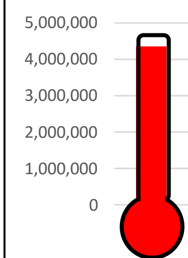
A subset of BMP opportunities that together are sufficient to satisfy the prescribed sediment reduction goals are divided among the three triennial periods (Figure 48). It is anticipated that the effort to achieve implementation of agricultural erosion and sedimentation plans will extend over the first two triennial periods. A focus of the first triennial period could be to visit farms, develop relationships with landowners, determine the status of plans, and develop plans where they are lacking. Confirmed implementation could then be the goal of the second triennial period. This might not take the full six years, as a review of non-public BMP implementation data suggests that many farms within the Fishing Creek subwatershed already at least have plans. But, nevertheless, six years was included to be conservative. It is hoped that implementation of these plans will spur the greater adoption of conservation tillage. Thus, half of the proposed additional conservation tillage was planned for the first three years. However, because it may take some time for farmers to more fully adopt this practice, the remaining half of the conservation tillage goal was placed within the second triennial period. Otherwise, the riparian buffer and precision grass filter strip goals were evenly divided among the three triennial periods.

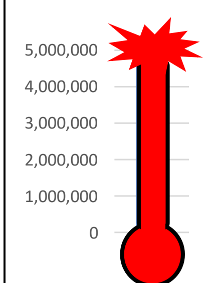
It must be clearly stated, however, that there will likely be substantial deviations from the schedule. Specific BMPs would be implemented as opportunity allows and there may be other BMPs that are not even on the schedule. These "goals" presented herein are not intended to limit other opportunities, nor is meeting all of the goals necessary to reach the reduction targets. Also, from prior experience, landowner involvement may ramp up over time as they see examples of successful projects on neighboring properties. But, in any case, the BMP implementation goals as well as the schedule presented herein cannot be firm commitments, as explained in the previous section.

Figure 48. Proposed timeline of major goals. The thermometer graphs indicate progress towards the overall sediment reduction goal (lbs/yr) during the three main triennial periods. Note that only a subset of BMP opportunities were chosen as goals.

Timeline	Administrative Goal	BMP Target Goal	Responsible Party	Expected Sediment Reductions (lbs/yr)
2025	*Approval of Restoration Plan*		DEP, EPA	
	Meeting (if sufficient public interest); Mailing; Site Visits		DTU, DEP	
	Biological and Sediment Sampling		DEP	
		100% Ag. E&S Plan Dev.	DTU, CCD	0
		857 acres conservation till	DTU, CCD	670,753
		29 acres precision grass filter strips[1]	DTU, CCD	474,533
		30 acres forested buffers	DTU	87,789
2028	*First Triennial Report; Meeting; Mailing*		DTU, DEP	
	Biological and Sediment Sampling		DEP	
		100% Implement Ag. E&S Plan	DTU, CCD	1,869,091
		857 acres more conservation till	DTU, CCD	670,753
		29 acres precision grass filter strips[1]	DTU, CCD	474,533
		30 acres forested buffers	DTU	87,789
	Outreach/Site visits to at least 40 farms		DTU	
	Cooperation by at least 20 farms		DTU	
2031	*Second Triennial Report; Meeting; Mailing; Signs*		DTU, DEP	
	Biological and Sediment Sampling		DEP	
		29 acres precision grass filter strips[1]	DTU, CCD	474,533
		30 acres forested buffers	DTU	87,789
2034	*Third Triennial Report*		DTU and DEP	
	Biological and Sediment Sampling		DEP	
2037	Macroinvertebrate, Fish and Sediment Sampling		DEP	







[1]Reductions for prescision grass filter strips used the corrected values that assumed prior agricultural erosion and sedimentation plan implementation.

Note-because most of these BMPs require the voluntary cooperation of the landowner; DEP and CCD priorities, personell and resources may change; and grant funds are allocated on a case by case basis; the above are "target goals" rather than firm commitments. Furthermore, other BMPs may be substituted in as opportunities arise. And, because potential reductions overshoot the target, failure to fully implement some of the BMPs listed above might still allow for the the pollutant reduction goal to be reached.

EFFECTIVENESS MONITORING AND EVALUATION OF PROGRESS

Evaluation of "progress" will include indicators of: whether the progress is being made on required tasks, landowner commitment, BMP implementation, and stream health improvements. It is proposed to summarize such progress for each triennial report.

Indicators of task completion in accordance with the timeframe proposed in Figure 48 will include things such as whether implementation of agricultural erosion and sediment plans is confirmed, whether landowners have been contacted about implementation of voluntary BMPs, and whether sampling is being done. If it is clear by the second triennial report that these tasks are not being completed, then a plan should be made to get the project back on track. For instance, based on an analysis of a confidential BMP database (Practice Keeper) as well as the LancCo View 2.0 GIS website (Lancaster County Geographic Information System Division 2024), it was estimated that there may be about 80 or so farms within the target subwatersheds that are at least 10 acres in size. If they have not been reached out to, or site visits have not occurred at at least half of these larger farms by the second triennial period, it may be concluded that outreach efforts are falling well short of what may be needed, and the cause of this problem would need to be diagnosed and corrected if possible. If there are substantial irreparable deviations from these tasks, say perhaps that at least 20 of these farms have not indicated at least some willingness to cooperate by the time of the second triennial report, the restoration plan approach should be abandoned in favor of TMDL development, unless there is some good reason to expect the problems will be corrected. Sediment loading reductions associated with BMP implementation can be estimated using the methodology described in the "An Analysis of Possible BMPs" section. If it becomes clear that there will be insufficient BMP implementation to result in restoration of any of the target subwatersheds, the restoration plan approach may also be abandoned in favor of TMDL development.

It is proposed to evaluate in-stream sediment pollution via measurements of streambed sediment deposits in accordance with the methodology discussed in Appendix G. Depending on access, it is hoped to collect such data within the thee reaches shown in Figure 48 at the onset of the project as well as approximately every three years over the expected duration of the project, and then again three years after the projected has ended. These sites were placed near the downstream reaches of the Head, B and C subwatersheds because these subwatersheds exhibited the highest sediment loads (Tables 7-10) and some of the highest reductions still needed (Table 25) within the larger Fishing Creek watershed. Additional sites were not chosen, as these measurements are very time consuming. Considering that there may be a lag time for benthic macroinvertebrate recolonization following restoration, or that other factors could continue to inhibit benthic communities once fine sediment loading has been reduced to an appropriate level, directly measuring fine sediment reductions will be important in demonstrating restoration progress.

The present Aquatic Life Use impairments listed for the Fishing Creek watershed were based on macroinvertebrate sampling and descriptive physical habitat screening. Thus, the Fishing Creek watershed should continue to be evaluated for these attributes in accordance with DEP's most current protocols. In order to be able to remove impairments on a watershed by watershed basis, it is proposed to conduct this conventional assessment sampling in the lower reaches of each of the seven study subwatersheds. In addition, a Fishing Creek mainstem site was chosen near the lower reaches of the impaired area in order to determine whether improvements within tributaries are having a positive effect on the mainstem. The most current versions of these protocols, along with criteria for making assessments and delisting's, are described in DEP's "Assessment Methodology for Rivers and Streams" (Shull and Whiteash 2021) and Water Quality Monitoring Protocols for Streams and Rivers (Lookenbill and Whiteash 2021). In addition to these major sites, such sampling may also occur at localized restoration sites. Since the most recent assessment samples were from 2018, it is suggested that new sampling should be conducted at the major sites around the time of project initiation in 2025, especially since the "Adaptive Toolbox" study has presumably led to improvements within the watershed. These major sites should continue to be sampled approximately every three years during the expected duration of the project, and then again three years after the project has ended to evaluate for impairment delistings (Figure 48).

As for benthic macroinvertebrate improvement goals, we suggest a possible benchmark for evaluation of progress would be that at least four of the eight proposed sampling sites (Figure 49) would demonstrate IBI score improvement of at least 10 points, while no sites would exhibit declines of greater than 10 points by the second triennial report. According to Shull (2017), score changes of more than 10 points suggest discernible changes to the benthic macroinvertebrate community, rather than temporal variation. Thus, if no sites exhibit a substantial decline, while at least half the sites appear to show substantial improvement, it could be concluded that water quality is likely trending in the right direction. Eventually it is hoped that the IBI scores would improve to ≥63, as scores below this value are suggestive of impairment for special protection streams such as Fishing Creek (see Shull 2017). However, it is cautioned that this might not be an appropriate metric of success. For one, the primary goal of this plan is resolving siltation impairments, and this could be achieved while some other factor, such as habitat or nutrients, may continue to depress macroinvertebrate communities. Furthermore, there may be a substantial lag time for the benthic macroinvertebrate community to recover following BMP implementation. Consider that it may take a newly planted riparian buffer decades to develop a canopy over the stream. Thus, while IBI scores may be an informative indicator of progress, achieving a specific IBI threshold should not be the primary indicator of project success or failure. Rather, direct evaluation of the pollutant of concern (siltation) may be more informative over the course of the project.

Demonstrating that sediment deposition is decreasing as a result of restoration may be difficult because the patterns of deposition may be subject to high spatial and temporal variability. Because the measurements described in Appendix G are so time-consuming, the gathering of baseline data is proposed to follow the acceptance of this plan by state and federal 319 programs and the formation of relationships with landowners. In the following, we speculate how these attributes might improve over the course of the project. An analysis was made of the sediment reduction goals of the "cheapest plus one-half buffer" scenarios shown in Table 24 for each subwatershed. It was assumed that, per Figure 48, half the conservation tillage, one third of the grass buffers and one third of the forested buffers would be implemented in the first 3 years. During the second triennial period, 100% agricultural erosion and sedimentation plan implementation, half the conservation till, one third of the grass buffers and one third of the forested buffers would be achieved. Finally, it was assumed that one third of the grass and one third of the forested buffers would be achieved during the third triennial period. If this were true for each subwatershed, it may be expected that sediment loads would be reduced by 6-18% after the first triennial period, 31-41% more relative to the original load after the second triennial period, and another 1-10% after the third triennial period. While these can serve as targeted expectations, we caution that there are many reasons why measurements might show different rates of change. For instance, many farms already have agricultural erosion and sedimentation plans and may be using conservation tillage, and some other BMPs have already been implemented (Table 25). If some of the expected declines have already occurred, reductions after the first three years would likely be smaller than predicted. Furthermore, additional factors such as uncertainty in our modelling and BMP crediting, environmental variability, and lag times will likely confound these results. Since the characteristics of individual storm events is a major driver of sediment loading, variability in sediment measurements is expected to be high and thus larger trends may only be elucidated with longer-term datasets. Also consider that it may take years for some BMPs to realize their maximum effectiveness. This especially true of new forested riparian buffer plantings, but may also even be true of BMPs like conservation tillage, where soil health improvements may increase this BMP's effectiveness over time. Those, the only realistic hope may be to show that the measurements are generally trending in the right direction over the course of the project.

Thus, while the above may serve as a hypothetical goals, the project should not be considered failing if these targets are not being achieved. Each triennial report should consider monitoring results in light of both expectations and such caveats, and take into account other measures of progress when interpreting this data. For instance, if the BMP implementation targets are meeting expectations but sediment measurements seem far too low, it may be concluded that confounding factors such as lag times or environmental variability may explain the diminished response. If however, the lack of water quality improvement is consistent with major failures in achieving BMP implementation targets, then it should be considered whether the restoration plan should be abandoned in favor of a TMDL, or whether the plan should be amended to include actions to get the project back on track. The decision to continue with the restoration plan should take into consideration the likelihood that the problem can be corrected. For instance, if landowners have been reached out to multiple times and it is clear that they have little interest in voluntary cooperation, the plan should be abandoned in favor of a TMDL. However, if there appears to be a high degree of landowner interest, but a correctable factor such as the ability of the implementation organization to commit to the project is limiting progress, then other remedies, such as soliciting the participation of additional implementation partners could be considered. In the unlikely scenario that sampling indicates that the Aquatic Life Use criteria improved to the point that the all subwatersheds are no longer impaired prior to the estimated completion date in 2032, a decision can be made to either: 1) end the project or 2) continue the project to overshoot prescribed reductions as a layer of protection and for the benefit of downstream aquatic resources.

It is expected that the earliest improvements will be noticed in physical habitat screening, sediment sampling and, if measured, fish populations at or near the local sites of restoration projects and then further downstream as progress is made throughout the watershed. Based on prior experience, it is expected that benthic macroinvertebrate communities may take the longest time to improve. Since the sampling design includes both individual subwatersheds, as well as a site on the lower mainstem (Figure 49), it is possible that individual subwatersheds could be delisted as impaired before the entire watershed is delisted.

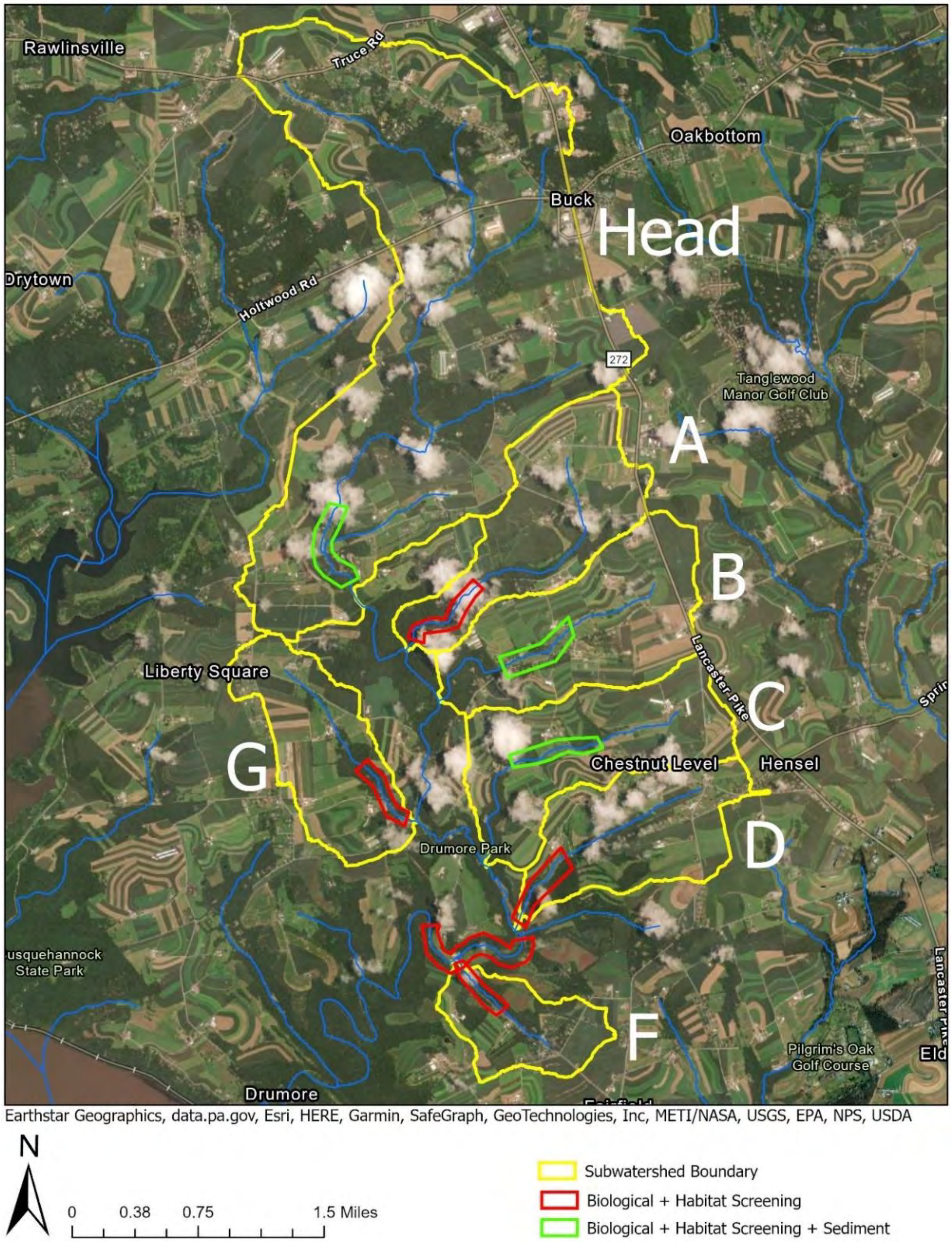


Figure 49. Proposed sampling reaches in the Fishing Creek watershed. One sampling event per time period per reach was envisioned. These reaches are longer than necessary; ultimate site selection will depend on willingness of landowners to grant access. Note that per Lookenbill 2021, macroinvertebrate sampling are to be done over a 100 m reach, while fish sampling may be done over a 100 to 400 m reach. Some physical habitat assessments parameters are considered over 100 m, while some are considered over the larger reach. Per Appendix G, Streambed sediment measurements are based on number of consecutive pools and riffles, rather than a defined reach length.

SUMMARY

This project proposes the remediation of siltation impairments within seven subwatersheds of Fishing Creek. Estimated siltation load reductions needed range from 20 to 61%. The present document proposes a nine-year restoration project to be administered by The Donegal Chapter of Trout Unlimited, with assistance from the Pennsylvania Department of Environmental Protection and with cooperation from landowners and other agencies. Critical BMPs proposed herein include agricultural erosion and sedimentation plan implementation, use of conservation tillage, precision grass filter strips and forested riparian buffers. The total capital cost of the proposed BMPs is expected to range from about $230,000 to about $3,000,000.

PUBLIC PARTICIPATION

Public notice of the Advance Restoration Plan was published in the Pennsylvania Bulletin on February 15, 2025 to foster public comment. A 30-day period will be provided for the submittal of comments. No public comments were received.

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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 around 2020 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 around 2018 to present were based on updated data collection protocols and Aquatic Life Use assessment methods that are specific to the use(s) being assessed.

After these surveys (SSWAP, 1998-2006 lists or ICE, 2008-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-around 2020	Integrated List	ICE
Around 2018 to present	Integrated List	ALU

APPENDIX B: MODEL MY WATERSHED GENERATED DATA TABLES

Table B1. "Model My Watershed" land cover inputs for the Fishing Creek subwatersheds based on NLCD 2019.

		Subwatershed															
		Head		A		B		C		D		E		F		G	
Type	NLCD Code	Area km²	%	Area km²	%	Area km²	%	Area km²	%	Area km²	%	Area km²	%	Area km²	%	Area km²	%
Open Water	11	0.000	0	0.000	0.07	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
Perennial Ice/Snow	12	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
Developed, Open Space	21	0.910	7.74	0.200	8.05	0.160	5.51	0.160	6	0.223	10.98	0.071	5.86	0.127	11.24	0.18	9.05
Developed, Low Intensity	22	0.330	2.78	0.030	1.33	0.050	1.9	0.040	1.5	0.047	2.3	0.003	0.22	0.010	0.87	0.02	1.05
Developed, Medium Intensity	23	0.140	1.22	0.010	0.47	0.020	0.67	0.020	0.7	0.015	0.75	0.000	0	0.001	0.08	0.01	0.46
Developed, High Intensity	24	0.040	0.37	0.000	0.14	0.000	0.1	0.000	0.2	0.004	0.18	0.000	0	0.000	0	0	0.05
Barren Land (Rock/Sand/Clay)	31	0.000	0.02	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
Deciduous Forest	41	2.400	20.37	0.480	19.27	0.280	9.72	0.180	6.8	0.233	11.51	0.282	23.31	0.227	20.03	0.21	10.79
Evergreen Forest	42	0.000	0	0.000	0.18	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
Mixed Forest	43	0.390	3.33	0.100	3.88	0.070	2.57	0.050	2	0.076	3.76	0.176	14.55	0.043	3.8	0.06	3.2
Shrub/Scrub	52	0.030	0.29	0.000	0.18	0.020	0.54	0.000	0	0.022	1.06	0.004	0.37	0.017	1.5	0.01	0.55
Grassland/Herbaceous	71	0.010	0.08	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
Pasture/Hay	81	1.010	8.54	0.210	8.45	0.470	16.44	0.310	12	0.545	26.87	0.260	21.53	0.127	11.24	0.42	21.17
Cultivated Crops	82	6.290	53.42	1.450	57.96	1.770	62.56	1.840	71	0.863	42.59	0.413	34.15	0.581	51.23	1.05	53.68
Woody Wetlands	90	0.210	1.79	0.000	0	0.000	0	0.010	0.3	0.000	0	0.000	0	0.000	0	0	0
Emergent Herbaceous Wetlands	95	0.000	0.03	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0	0
	Total	**11.77**	**100**	**2.5**	**100**	**2.83**	**100**	**2.6**	**100**	**2.03**	**100**	**1.21**	**100**	**1.13**	**100**	**1.96**	**100**

Table B2. "Model My Watershed" land cover inputs for the reference watersheds based on NLCD 2019.

		Subwatershed							
		Huber Run		**Trout Run 3km^2**		**Trout Run 2km^2**		**Trout Run 1km^2**	
	NLCD	**Area**		**Area**		**Area**		**Area**	
Type	**Code**	km²	%	km²	%	km²	%	km²	%
Open Water	11	0.000	0.02	0.000	0	0.000	0	0.000	0
Perennial Ice/Snow	12	0.000	0	0.000	0	0.000	0	0.000	0
Developed, Open Space	21	1.500	12.7	0.200	6.61	0.105	5.33	0.077	8.11
Developed, Low Intensity	22	0.510	4.33	0.040	1.44	0.032	1.64	0.025	2.64
Developed, Medium Intensity	23	0.100	0.87	0.010	0.47	0.013	0.68	0.008	0.85
Developed, High Intensity	24	0.040	0.3	0.000	0	0.000	0	0.000	0
Barren Land (Rock/Sand/Clay)	31	0.000	0.02	0.000	0	0.000	0	0.000	0
Deciduous Forest	41	4.480	37.81	1.570	51.47	0.956	48.52	0.353	37.08
Evergreen Forest	42	0.000	0.01	0.000	0	0.000	0	0.000	0
Mixed Forest	43	1.140	9.63	0.130	4.38	0.058	2.96	0.048	5.09
Shrub/Scrub	52	0.220	1.86	0.030	0.82	0.013	0.68	0.013	1.42
Grassland/Herbaceous	71	0.050	0.4	0.020	0.71	0.000	0	0.000	0
Pasture/Hay	81	1.540	13.03	0.090	3.09	0.031	1.55	0.015	1.6
Cultivated Crops	82	2.200	18.57	0.950	31.01	0.762	38.64	0.411	43.21
Woody Wetlands	90	0.040	0.36	0.000	0	0.000	0	0.000	0
Emergent Herbaceous Wetlands	95	0.010	0.11	0.000	0	0.000	0	0.000	0
	Total	**11.85**	**100**	**3.05**	**100**	**1.97**	**100**	**0.95**	**100**

Table B3. "Model My Watershed" hydrology outputs for the Fishing Creek Head watershed.

Month	Stream Flow (cm)	Surface Runoff	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.04	0.9	3.14	0	0.37	7.46
Feb	5.04	0.85	4.19	0	0.56	7.42
Mar	6.34	0.61	5.73	0	1.73	8.53
Apr	5.93	0.1	5.83	0	4.35	8.42
May	5.01	0.22	4.8	0	8.57	10.28
Jun	3.88	0.64	3.24	0	12.65	9.4
Jul	2.3	0.37	1.93	0	13.5	9.94
Aug	1.22	0.24	0.98	0	10.01	8.52
Sep	0.94	0.47	0.47	0	6.17	8.81
Oct	0.64	0.29	0.35	0	3.58	7.37
Nov	0.98	0.44	0.54	0	1.76	8.63
Dec	2.54	0.64	1.89	0	0.78	8.53
Total	38.86	5.77	33.09	0	64.03	103.31

Table B4. "Model My Watershed" hydrology outputs for the Fishing Creek watershed A.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.14	0.84	3.3	0	0.35	7.46
Feb	5.12	0.79	4.33	0	0.54	7.42
Mar	6.43	0.56	5.87	0	1.65	8.53
Apr	6.04	0.09	5.95	0	4.25	8.42
May	5.1	0.19	4.91	0	8.46	10.28
Jun	3.94	0.62	3.31	0	12.55	9.4
Jul	2.33	0.35	1.98	0	13.45	9.94
Aug	1.22	0.21	1.01	0	10	8.52
Sep	0.92	0.45	0.47	0	6.18	8.81
Oct	0.64	0.26	0.37	0	3.53	7.37
Nov	0.99	0.39	0.6	0	1.71	8.63
Dec	2.62	0.6	2.02	0	0.76	8.53
Total	39.49	5.35	34.12	0	63.43	103.31

Table B5. "Model My Watershed" hydrology outputs for the Fishing Creek watershed B.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	4.07	0.87	3.2	0	0.36	7.46
Feb	5.08	0.82	4.26	0	0.54	7.42
Mar	6.39	0.58	5.81	0	1.67	8.53
Apr	5.99	0.09	5.9	0	4.33	8.42
May	5.03	0.2	4.83	0	8.64	10.28
Jun	3.87	0.63	3.24	0	12.8	9.4
Jul	2.28	0.36	1.92	0	13.45	9.94
Aug	1.2	0.22	0.97	0	10.01	8.52
Sep	0.92	0.46	0.46	0	6.1	8.81
Oct	0.61	0.27	0.33	0	3.58	7.37
Nov	0.95	0.41	0.54	0	1.74	8.63
Dec	2.53	0.62	1.91	0	0.77	8.53
Total	38.92	5.53	33.37	0	63.99	103.31

Table B6. "Model My Watershed" hydrology outputs for the Fishing Creek watershed C.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	4.14	0.93	3.21	0	0.34	7.46
Feb	5.13	0.87	4.26	0	0.51	7.42
Mar	6.44	0.62	5.82	0	1.57	8.53
Apr	6.04	0.1	5.94	0	4.2	8.42
May	5.12	0.22	4.91	0	8.47	10.28
Jun	3.95	0.65	3.3	0	12.63	9.4
Jul	2.34	0.38	1.95	0	13.51	9.94
Aug	1.23	0.24	0.99	0	10.02	8.52
Sep	0.96	0.5	0.47	0	6.15	8.81
Oct	0.64	0.3	0.34	0	3.5	7.37
Nov	0.99	0.44	0.55	0	1.68	8.63
Dec	2.6	0.66	1.95	0	0.73	8.53
Total	39.58	5.91	33.69	0	63.31	103.31

Table B7. "Model My Watershed" hydrology outputs for the Fishing Creek watershed D.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	3.83	0.83	3	0	0.43	7.46
Feb	4.9	0.78	4.12	0	0.65	7.42
Mar	6.2	0.54	5.66	0	2.02	8.53
Apr	5.75	0.08	5.67	0	4.77	8.42
May	4.71	0.18	4.53	0	9.19	10.28
Jun	3.61	0.61	3	0	13.34	9.4
Jul	2.07	0.33	1.74	0	13.32	9.94
Aug	1.09	0.2	0.88	0	9.9	8.52
Sep	0.84	0.42	0.41	0	6.03	8.81
Oct	0.53	0.26	0.27	0	3.85	7.37
Nov	0.84	0.38	0.45	0	1.95	8.63
Dec	2.28	0.59	1.69	0	0.89	8.53
Total	36.65	5.2	31.42	0	66.34	103.31

Table B8. "Model My Watershed" hydrology outputs for the Fishing Creek watershed E.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	3.84	0.64	3.21	0	0.42	7.46
Feb	4.91	0.6	4.31	0	0.63	7.42
Mar	6.26	0.4	5.86	0	1.94	8.53
Apr	5.9	0.05	5.85	0	4.63	8.42
May	4.84	0.13	4.71	0	8.95	10.28
Jun	3.71	0.55	3.16	0	13.07	9.4
Jul	2.14	0.26	1.89	0	13.46	9.94
Aug	1.11	0.15	0.96	0	10.07	8.52
Sep	0.79	0.34	0.45	0	6.1	8.81
Oct	0.51	0.18	0.33	0	3.76	7.37
Nov	0.81	0.28	0.53	0	1.89	8.63
Dec	2.32	0.44	1.87	0	0.85	8.53
Total	37.14	4.02	33.13	0	65.77	103.31

Table B9. "Model My Watershed" hydrology outputs for the Fishing Creek watershed F.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	4.07	0.8	3.27	0	0.38	7.46
Feb	5.07	0.75	4.32	0	0.57	7.42
Mar	6.37	0.52	5.85	0	1.77	8.53
Apr	5.97	0.08	5.89	0	4.4	8.42
May	4.99	0.17	4.81	0	8.66	10.28
Jun	3.85	0.6	3.24	0	12.75	9.4
Jul	2.26	0.32	1.93	0	13.37	9.94
Aug	1.18	0.2	0.98	0	9.99	8.52
Sep	0.88	0.42	0.46	0	6.11	8.81
Oct	0.6	0.24	0.36	0	3.62	7.37
Nov	0.94	0.37	0.57	0	1.79	8.63
Dec	2.54	0.56	1.97	0	0.8	8.53
Total	38.72	5.03	33.65	0	64.21	103.31

Table B10. "Model My Watershed" hydrology outputs for the Fishing Creek watershed G.

Month	**Stream Flow** (cm)	**Surface Runoff** (cm)	**Subsurface Flow** (cm)	**Point Src Flow** (cm)	**ET** (cm)	**Precip** (cm)
Jan	3.81	0.82	2.98	0	0.39	7.46
Feb	4.86	0.77	4.09	0	0.59	7.42
Mar	6.21	0.54	5.67	0	1.83	8.53
Apr	5.84	0.08	5.76	0	4.53	8.42
May	4.88	0.18	4.7	0	8.9	10.28
Jun	3.77	0.61	3.16	0	13.09	9.4
Jul	2.21	0.34	1.87	0	13.64	9.94
Aug	1.17	0.21	0.96	0	10.12	8.52
Sep	0.89	0.43	0.46	0	6.12	8.81
Oct	0.56	0.25	0.3	0	3.71	7.37
Nov	0.84	0.38	0.46	0	1.84	8.63
Dec	2.29	0.58	1.71	0	0.82	8.53
Total	37.33	5.19	32.12	0	65.58	103.31

Table B11. "Model My Watershed" hydrology outputs for the Huber Run reference subwatershed.

Month	Stream Flow (cm)	Surface Runoff	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	3.75	0.7	3.04	0.02	0.45	7.46
Feb	4.78	0.66	4.1	0.02	0.69	7.42
Mar	6.08	0.45	5.61	0.02	2.11	8.53
Apr	5.73	0.07	5.64	0.02	4.77	8.42
May	4.77	0.14	4.61	0.02	9	10.28
Jun	3.74	0.55	3.17	0.02	13	9.4
Jul	2.24	0.27	1.95	0.02	13.36	9.94
Aug	1.22	0.16	1.03	0.02	10.03	8.52
Sep	0.87	0.34	0.51	0.02	6.09	8.81
Oct	0.61	0.21	0.38	0.02	3.83	7.37
Nov	0.88	0.32	0.54	0.02	1.97	8.63
Dec	2.29	0.5	1.78	0.02	0.91	8.53
Total	36.96	4.37	32.36	0.24	66.21	103.31

Table B12. "Model My Watershed" hydrology outputs for the UNT Trout Run-west 3 km^2 reference subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.1	0.65	3.46	0	0.39	7.46
Feb	5.07	0.61	4.46	0	0.58	7.42
Mar	6.38	0.41	5.98	0	1.79	8.53
Apr	6.04	0.06	5.98	0	4.35	8.42
May	5.06	0.13	4.93	0	8.46	10.28
Jun	3.92	0.55	3.38	0	12.4	9.4
Jul	2.33	0.26	2.07	0	13.36	9.94
Aug	1.22	0.15	1.07	0	9.96	8.52
Sep	0.86	0.34	0.53	0	6.2	8.81
Oct	0.65	0.19	0.47	0	3.59	7.37
Nov	0.97	0.29	0.68	0	1.78	8.63
Dec	2.6	0.45	2.14	0	0.8	8.53
Total	39.2	4.09	35.15	0	63.66	103.31

Table B13. "Model My Watershed" hydrology outputs for the UNT Trout Run-west 2 km^2 reference subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.2	0.69	3.51	0	0.36	7.46
Feb	5.14	0.65	4.49	0	0.55	7.42
Mar	6.45	0.44	6.01	0	1.69	8.53
Apr	6.1	0.06	6.04	0	4.23	8.42
May	5.14	0.14	5	0	8.32	10.28
Jun	3.98	0.56	3.42	0	12.26	9.4
Jul	2.37	0.28	2.09	0	13.38	9.94
Aug	1.24	0.17	1.08	0	9.96	8.52
Sep	0.89	0.36	0.53	0	6.23	8.81
Oct	0.68	0.2	0.48	0	3.52	7.37
Nov	1.01	0.31	0.7	0	1.72	8.63
Dec	2.67	0.48	2.19	0	0.76	8.53
Total	39.87	4.34	35.54	0	62.98	103.31

Table B14. "Model My Watershed" hydrology outputs for the UNT Trout Run-west 1 km^2 reference subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.3	0.76	3.54	0	0.37	7.46
Feb	5.23	0.72	4.51	0	0.55	7.42
Mar	6.48	0.5	5.99	0	1.7	8.53
Apr	6.08	0.08	6	0	4.25	8.42
May	5.13	0.17	4.97	0	8.36	10.28
Jun	3.98	0.59	3.4	0	12.31	9.4
Jul	2.38	0.3	2.07	0	13.07	9.94
Aug	1.26	0.19	1.07	0	9.83	8.52
Sep	0.92	0.39	0.52	0	6.08	8.81
Oct	0.71	0.23	0.48	0	3.53	7.37
Nov	1.09	0.35	0.74	0	1.73	8.63
Dec	2.79	0.54	2.25	0	0.77	8.53
Total	40.35	4.82	35.54	0	62.55	103.31

Table B15. Model My Watershed outputs for sediment in the Fishing Creek watershed. All values in are in kg.

	Subwatershed							
Sources	**Head**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Hay/Pasture	17,869	3,822	8,834	5,790	11,530	4,837	2,420	7,675
Cropland	1,486,000	355,874	441,075	451,987	220,996	101,054	151,869	265,338
Wooded Areas	883	245	133	68	161	224	149	98
Wetlands	73	0	0	2	0	0	0	0
Open Land	68	0	0	0	0	0	0	0
Barren Areas	0	0	0	0	0	0	0	0
Low-Density Mixed	403	39	66	45	55	3	11	23
Medium-Density Mixed	1,069	135	155	144	102	0	7	67
High-Density Mixed	327	45	24	32	27	0	0	8
Low-Density Open Space	1,118	236	192	178	262	81	139	199
Farm Animals	0	0	0	0	0	0	0	0
Stream Bank Erosion	71,195	5,949	5,078	4,864	4,782	1,286	1,610	3,305
Subsurface Flow	0	0	0	0	0	0	0	0
Point Sources	0	0	0	0	0	0	0	0
Septic Systems	0	0	0	0	0	0	0	0

Table B16. Model My Watershed outputs for sediment in the reference watersheds. All values in are in kg.

	Subwatershed			
Sources	**Huber Run**	**Trout Run 3km^2**	**Trout Run 2km^2**	**Trout Run 1km^2**
Hay/Pasture	26,533	1,695	559	268
Cropland	508,000	239,785	197,668	107,576
Wooded Areas	3,242	749	393	152
Wetlands	23	0	0	0
Open Land	604	223	0	0
Barren Areas	0	0	0	0
Low-Density Mixed	625	53	41	31
Medium-Density Mixed	717	153	132	50
High-Density Mixed	251	0	0	0
Low-Density Open Spa	1,833	242	133	95
Farm Animals	0	0	0	0
Stream Bank Erosion	81,129	4,781	3,104	1,113
Subsurface Flow	0	0	0	0
Point Sources	0	0	0	0
Septic Systems	0	0	0	0

APPENDIX C: STREAM SEGMENTS IN THE FISHING CREEK WATERSHED WITH AQUATIC LIFE USE IMPAIRMENTS FOR SILTATION PER THE 2020 INTEGRATED REPORT

Stream Name:	Length (miles):	ATTAINS ID:	Impairment Source:	Impairment Cause:
Unnamed Tributary to Fishing Creek	0.01	PA-SCR-57468575	AGRICULTURE	SILTATION
Fishing Creek	0.01	PA-SCR-57468581	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.51	PA-SCR-57468689	AGRICULTURE	SILTATION
Fishing Creek	1.41	PA-SCR-57468691	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.94	PA-SCR-57468823	AGRICULTURE	SILTATION
Fishing Creek	0.48	PA-SCR-57468825	AGRICULTURE	SILTATION
Fishing Creek	1.26	PA-SCR-57469229	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.99	PA-SCR-57469231	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.89	PA-SCR-57469637	AGRICULTURE	SILTATION
Fishing Creek	1.32	PA-SCR-57469639	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	1.95	PA-SCR-57469881	AGRICULTURE	SILTATION
Fishing Creek	1.03	PA-SCR-57469925	AGRICULTURE	SILTATION
Fishing Creek	0.38	PA-SCR-57469989	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	1.73	PA-SCR-57469991	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.47	PA-SCR-57470135	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.01	PA-SCR-57470137	AGRICULTURE	SILTATION
Fishing Creek	0.84	PA-SCR-57470309	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.77	PA-SCR-57470317	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	1.79	PA-SCR-57470413	AGRICULTURE	SILTATION
Fishing Creek	0.64	PA-SCR-57470415	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.63	PA-SCR-57470571	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.04	PA-SCR-57470581	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	1.50	PA-SCR-57470617	AGRICULTURE	SILTATION
Fishing Creek	0.53	PA-SCR-57470619	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.21	PA-SCR-57470627	AGRICULTURE	SILTATION
Fishing Creek	0.05	PA-SCR-57470629	AGRICULTURE	SILTATION
Fishing Creek	0.51	PA-SCR-57470709	AGRICULTURE	SILTATION
Fishing Creek	0.04	PA-SCR-57470727	AGRICULTURE	SILTATION
Fishing Creek	0.06	PA-SCR-57470729	AGRICULTURE	SILTATION
Unnamed Tributary to Fishing Creek	0.80	PA-SCR-57470997	AGRICULTURE	SILTATION

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 Fishing Creek Head watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	3,276,631	yes	1,220,642		0.86	169,169	1,051,473	0.68
Hay/Pasture	39,401	no	39,401	196,386	0.03	5,461	33,941	0.14
Streambank	156,985	no	156,985		0.11	21,757	135,228	0.14
sum	**3,473,017**		**1,417,028**		**1.00**	**196,386**	**1,220,642**	**0.65**

Table D2. Equal marginal percent reduction calculations for the Fishing Creek A watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	784,701	yes	388,588		0.95	20,412	368,176	0.53
Hay/Pasture	8,427	no	8,427	21,544	0.02	443	7,984	0.05
Streambank	13,118	no	13,118		0.03	689	12,428	0.05
sum	**806,245**		**410,133**		**1.00**	**21,544**	**388,588**	**0.52**

Table D3. Equal marginal percent reduction calculations for the Fishing Creek B watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	972,569	yes	421,341		0.93	28,594	392,747	0.60
Hay/Pasture	19,479	no	19,479	30,676	0.04	1,322	18,157	0.07
Streambank	11,197	no	11,197		0.02	760	10,437	0.07
sum	**1,003,245**		**452,017**		**1.00**	**30,676**	**421,341**	**0.58**

Table D4. Equal marginal percent reduction calculations for the Fishing Creek C watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	996,631	yes	388,101		0.94	22,150	365,951	0.63
Hay/Pasture	12,766	no	12,766	23,491	0.03	729	12,037	0.06
Streambank	10,725	no	10,725		0.03	612	10,113	0.06
sum	**1,020,123**		**411,592**		**1.00**	**23,491**	**388,101**	**0.62**

Table D5. Equal marginal percent reduction calculations for the Fishing Creek D watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	487,297	yes	372,489		0.91	32,800	339,688	0.30
Hay/Pasture	25,423	no	25,423	35,968	0.06	2,239	23,185	0.09
Streambank	10,544	no	10,544		0.03	929	9,616	0.09
sum	**523,265**		**408,456**		**1.00**	**35,968**	**372,489**	**0.29**

Table D6. Equal marginal percent reduction calculations for the Fishing Creek E watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	222,823	no	222,823		0.94	(16,523)	239,346	-0.07
Hay/Pasture	10,665	no	10,665	(17,524)	0.05	(791)	11,456	-0.07
Streambank	2,836	no	2,836		0.01	(210)	3,046	-0.07
sum	**236,323**		**236,323**		**1.00**	**(17,524)**	**253,847**	**-0.07**

Table D7. Equal marginal percent reduction calculations for the Fishing Creek F watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	334,870	yes	246,077		0.97	8,576	237,500	0.29
Hay/Pasture	5,336	no	5,336	8,886	0.02	186	5,150	0.03
Streambank	3,550	no	3,550		0.01	124	3,426	0.03
sum	**343,756**		**254,963**		**1.00**	**8,886**	**246,077**	**0.28**

Table D8. Equal marginal percent reduction calculations for the Fishing Creek G watershed.

	Current Load, lbs/yr	Any > ALA?	reduce to ALA	does sum exceed ALA?	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	585,069	yes	368,894		0.94	22,719	346,175	0.41
Hay/Pasture	16,922	no	16,922	24,210	0.04	1,042	15,880	0.06
Streambank	7,288	no	7,288		0.02	449	6,839	0.06
sum	**609,279**		**393,104**		**1.00**	**24,210**	**368,894**	**0.39**

APPENDIX E: INFORMATION ON USE OF THE CHESAPEAKE BAY PROGRAM'S BMP CREDITING

Calculated sediment reductions for many of the Best Management Practices (BMPs) proposed in this study were based on the logic used by the Chesapeake Bay Program's Chesapeake Assessment Scenario Tool (CAST). For more information, see "Chesapeake Bay Program Quick Reference Guide for Best Management Practices (BMPs): Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters" (Chesapeake Bay Program 2018). The following explains how both this information as well as other crediting logic were used for each major BMP type.

Agricultural Erosion and Sedimentation Plans

Chesapeake Bay Program:

"Soil Conservation and Water Quality Plans" (A-24): considers many types of agricultural lands. All croplands received a sediment reduction efficiency of 25%. Pasture lands received an 14% reduction efficiency and hay lands typically received an 8% efficiency.

This Study:

The 25% sediment reduction efficiency was used for croplands. Because landcover classifications didn't distinguish between hay and pasture lands, the 8% efficiency was used to be conservative.

Cover Crops

Chesapeake Bay Program:

CAST "Cover Crops-Traditional" A-4*:* has numerous different cover crop types and breaks them into low and high till landuses. When used in combination with low till, there is no additional sediment reduction. Sediment reductions range from 0-20% on high till lands.

CAST "Cover Crops-Commodity" A-5: when grown as a commodity, there are no sediment reductions.

This Study:

For simplicity, this study settled on a 10% reduction in all cases to account for the fact that sometimes it will be 0 and sometimes it will be 20%, depending on the cover crop type. It was also specified that the reductions are only to be applied to non-commodity cover crops used on high till lands.

Conservation Tillage

Chesapeake Bay Program:

"Conservation Tillage" A-3: % reductions vary based on "low residue" (15-29% crop residue immediately after planting) "conservation tillage" (30-59% crop residue) or "high residue" (at least 60% crop residue) categories. For sediment, low residue tillage gets an 18% reduction, conservation tillage gets a 41% reduction and high residue tillage gets a 79% reduction.

This Study

For simplicity, the middle "conservation tillage" reduction value of 41% was assumed in all cases. However, if more detailed information becomes available about pre and post residue cover conditions, different crediting options could be used in accordance with Chesapeake Bay Program methodology.

Riparian buffers
Chesapeake Bay Program:
"Forest Buffers and Grass Buffers" A12; Forest Buffers and Grass Buffers with Stream Exclusion Fencing A13. Riparian buffers are credited two ways: the land conversion effect and the upland filtration effect. For the upland sediment filtration effect, it is assumed that the loading from two acres of upland is reduced by an efficiency value of 40-60% depending on hydrogeomorphic region. Note that for buffers less than 35 feet wide average width, only the land conversion, and not the upslope filtration effect is credited. Buffers less than 10 feet wide get no credit.

This Study:
For simplicity, rather than using a different upland efficiency by region, the average efficiency value for the geomorphic regions that occur in Pennsylvania, 47%, was used for proposed buffers. Also, it was assumed that loading from two acres of *cropland* are filtered per acre of buffer created. Note that CAST assumes two acres of *uplands*, not necessarily croplands, are filtered per acre of buffer created. However, there was an abundance of croplands in the Fishing Creek watershed, and logic would suggest that if there is something else upslope that loads at a lower rate, the buffer may be capable of filtering more of it. The land conversion factor from croplands and hay/pasture lands to forests was also taken into account. The present study doesn't specify a minimum buffer width to receive filtration credit. If buffers are very narrow then they will be of low acreage and thus will not get much filtration credit.

Grazing Land Management
Chesapeake Bay Program:
"Pasture and Grazing Management Practices" A8: for sediment there is a 30% reduction efficiency, except in the case of horse pasture management where there is a 40% efficiency.

This Study:
Given that horse pastures are far less common and the difference is not that great, the 30% efficiency was assumed for all cases.

Precision Grass Filter Strips
Chesapeake Bay Program:
The Chesapeake Bay Program does not have crediting methodology specific to the "precision grass filter strips" as described herein, but it does recognize that that herbaceous riparian buffers can be credited similarly to forested riparian buffers.

This Study: See the above "Precision Grass Filter Strips" section under "An Analysis of Possible Best Management Practices" where this is described in detail.

Stream restoration
Chesapeake Bay Program:
Sites are credited using protocols that take into account site-specific measurements or using a single default value.

This Study: See the above “Streambank Stabilization/Stream Restoration under “An Analysis of Possible Best Management Practices” where this is described in detail.”

APPENDIX F: INFORMATION ON VFSMOD INPUTS

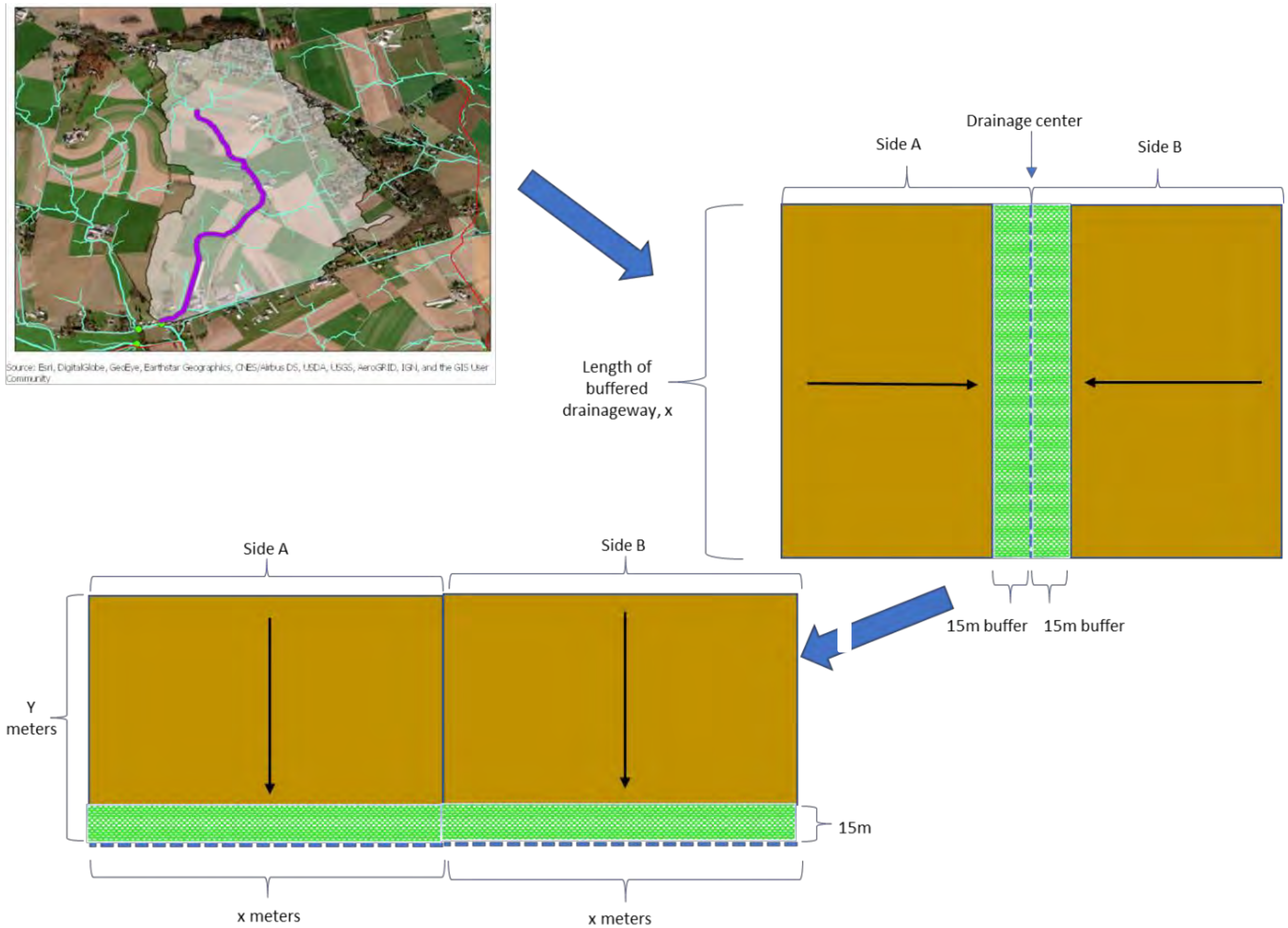

Figure F1. Conceptualization showing how site geometry was simplified for input into VFSMOD. Complex buffersheds were first assumed to be a uniform rectangle with a central buffered drainageway. The length of the rectangle (X) was assumed to be the length of the buffered drainageway. However, since VFSMOD only accepts inputs in one direction, from the source area to the buffer, the rectangle was split down the middle along the central drainageline and the two sides of the rectangle were laid end to end. Thus Y was solved by assuming that 2X * Y = total watershed area. The source area length along the slope was calculated as Y-(buffer width). Buffer width could be 5, 10 or 15m. The upland area was calculated as the total watershed area minus the area of the buffer. Note the image in the upper left corner is from the approved Hammer Creek 2021 ARP.

Table F1. VFSMOD inputs.

Drainageshed	**F-1**	**B-1**	**A-4**	**D-2**	**A-3**	**A-1**
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	75.1	74.3	75.0	72.2	74.7	71.9
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	290.9	110.1	88.4	168.8	233.3	131.9
watershed slope fraction[2]	0.037	0.038	0.056	0.061	0.04	0.048
upland area (ha)[4]	16.2	49.5	21.7	29.6	19.7	29.9
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0429	0.0443	0.0428	0.0433	0.0448	0.0446
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	3.2	3.0	3.0	3.1	3.0	3.0
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	10	10	5	15	10	10
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.065	0.054	0.080	0.088	0.047	0.057
double filter strip width in longest direction (m)[8]	556	4491	2451	1752	843	2264
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	No	Yes	No	Yes	No	No
Average depth to water table (cm)[10]	>200	175	>200	123	>200	>200
h_e(m)[11]		-0.1933		-0.1933		
Soil Water Characteristics Curve[11]		Brooks & Corey		Brooks & Corey		
Hydraulic Conductivity Curve[11]		Brooks & Corey		Brooks & Corey		
Theta Type Parameters[11]						
OR[11]		0		0		
BCALPHA, 1/m[11]		5.1741		5.1741		
BCLAMDA[11]		0.73		0.73		
KUN Type Parameters[11]						
BCETA[11]		5.8775		5.8775		
BCALPHA, 1/m[11]		5.1741		5.1741		
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	1.200E-05	1.070E-05	1.102E-05	1.043E-05	9.3907E-06	1.039E-05
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2690	0.2703	0.2680	0.2591	0.2635	0.2659
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.236	0.074	0.175	0.213	0.22	0.06

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster et al. 1981

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	C-6	C-4	H-14	H-15	C-2	H-13
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	76.3	73.8	73.8	75.1	73.5	73.2
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	35.7	152.8	166.4	90.0	128.7	115.3
watershed slope fraction[2]	0.033	0.035	0.051	0.079	0.065	0.039
upland area (ha)[4]	4.9	25.3	27.3	17.4	12.9	26.7
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0486	0.0478	0.0438	0.0422	0.0461	0.0450
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	2.5	2.6	3.0	3.0	2.6	2.9
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	5	10	15	10	10	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.073	0.051	0.067	0.083	0.083	0.067
double filter strip width in longest direction (m)[8]	1366	1654	1643	1933	999	2314
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	No	Yes	Yes	Yes	Yes	No
Average depth to water table (cm)[10]	>200	184	143	192	194	>200
h_e(m)[11]		-0.1933	-0.1933	-0.1933	-0.1933	
Soil Water Characteristics Curve[11]		Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	
Hydraulic Conductivity Curve[11]		Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	
Theta Type Parameters[11]						
OR[11]		0	0	0	0	
BCALPHA, 1/m[11]		5.1741	5.1741	5.1741	5.1741	
BCLAMDA[11]		0.73	0.73	0.73	0.73	
KUN Type Parameters[11]						
BCETA[11]		5.8775	5.8775	5.8775	5.8775	
BCALPHA, 1/m[11]		5.1741	5.1741	5.1741	5.1741	
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	9.170E-06	1.045E-05	9.855E-06	1.065E-05	1.117E-05	9.269E-06
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2637	0.2659	0.2603	0.2693	0.2669	0.2638
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.009	0.102	0.15	0.154	0.182	0.172

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster et al. 1981

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	H-12	H-11	G-3	H-7	G-2	H-1
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	75.8	75.9	75.0	71.1	72.9	73.9
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	90.0	309.1	71.1	224.3	130.6	95.4
watershed slope fraction[2]	0.035	0.029	0.044	0.065	0.034	0.04
upland area (ha)[4]	15.1	26.1	11.7	42.4	26.2	22.9
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0436	0.0426	0.0421	0.0444	0.0427	0.0468
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	3.1	3.2	3.1	2.8	3.2	2.8
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	5	10	5	15	5	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.053	0.068	0.065	0.080	0.069	0.069
double filter strip width in longest direction (m)[8]	1676	844	1640	1889	2004	2402
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	No	No	No	Yes	Yes	No
Average depth to water table (cm)[10]	>200	>200	>200	57	175	>200
h_e(m)[11]				-0.1933	-0.1933	
Soil Water Characteristics Curve[11]				Brooks & Corey	Brooks & Corey	
Hydraulic Conductivity Curve[11]				Brooks & Corey	Brooks & Corey	
Theta Type Parameters[11]						
OR[11]				0	0	
BCALPHA, 1/m[11]				5.1741	5.1741	
BCLAMDA[11]				0.73	0.73	
KUN Type Parameters[11]						
BCETA[11]				5.8775	5.8775	
BCALPHA, 1/m[11]				5.1741	5.1741	
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	1.085E-05	1.095E-05	1.048E-05	9.133E-06	1.079E-05	9.264E-06
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2667	0.2670	0.2674	0.2623	0.2647	0.2603
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.085	0.216	0.063	0.367	0.205	0.133

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and

[6]USDA WSS.

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	**G-1**	**H-5**	**B-5**	**D-1**	**A-2**	**H-2**
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	72.8	72.6	75.0	73.0	75.0	75.0
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	234.0	104.9	76.5	55.4	105.1	50.8
watershed slope fraction[2]	0.046	0.039	0.058	0.068	0.033	0.028
upland area (ha)[4]	27.5	25.3	8.9	5.54	13.3	10.7
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0431	0.0428	0.0460	0.0460	0.0470	0.0424
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	3.1	3.2	2.8	2.7	2.7	3.2
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	15	5	5	5	5	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.043	0.056	0.085	0.102	0.052	0.060
double filter strip width in longest direction (m)[8]	1176	2417	1162	1000	1264	2103
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	Yes	Yes	No	Yes	No	Yes
Average depth to water table (cm)[10]	79	151	>200	189	>200	178
h_e(m)[11]	-0.1933	-0.1933		-0.1933		-0.1933
Soil Water Characteristics Curve[11]	Brooks & Corey	Brooks & Corey		Brooks & Corey		Brooks & Corey
Hydraulic Conductivity Curve[11]	Brooks & Corey	Brooks & Corey		Brooks & Corey		Brooks & Corey
Theta Type Parameters[11]						
OR[11]	0	0		0		0
BCALPHA, 1/m[11]	5.1741	5.1741		5.1741		5.1741
BCLAMDA[11]	0.73	0.73		0.73		0.73
KUN Type Parameters[11]						
BCETA[11]	5.8775	5.8775		5.8775		5.8775
BCALPHA, 1/m[11]	5.1741	5.1741		5.1741		5.1741
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	9.302E-06	1.097E-05	9.957E-06	1.046E-05	9.170E-06	1.155E-05
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2537	0.2629	0.2654	0.2675	0.2637	0.2662
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.231	0.198	0.149	0.104	0.121	0.024

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	**H-16**	**H-8**	**H-6**	**H-3**	**H-4**	**H-9**
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	75.1	75.6	69.2	81.3	74.0	79.9
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	165.0	82.2	173.5	75.7	184.0	58.0
watershed slope fraction[2]	0.059	0.037	0.067	0.042	0.036	0.058
upland area (ha)[4]	16.9	5.4	16.4	9.2	17.8	7.0
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0449	0.0457	0.0394	0.0442	0.0409	0.0468
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	3.0	2.8	3.3	3.0	3.1	2.7
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	15	5	10	5	10	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.071	0.053	0.073	0.035	0.069	0.069
double filter strip width in longest direction (m)[8]	1025	659	948	1218	966	1213
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	Yes	Yes	No	No	Yes	No
Average depth to water table (cm)[10]	124	196	>200	>200	150	>200
h_e(m)[11]	-0.1933	-0.1933			-0.1933	
Soil Water Characteristics Curve[11]	Brooks & Corey	Brooks & Corey			Brooks & Corey	
Hydraulic Conductivity Curve[11]	Brooks & Corey	Brooks & Corey			Brooks & Corey	
Theta Type Parameters[11]						
OR[11]	0	0			0	
BCALPHA, 1/m[11]	5.1741	5.1741			5.1741	
BCLAMDA[11]	0.73	0.73			0.73	
KUN Type Parameters[11]						
BCETA[11]	5.8775	5.8775			5.8775	
BCALPHA, 1/m[11]	5.1741	5.1741			5.1741	
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	9.551E-06	9.603E-06	9.170E-06	1.121E-05	9.113E-06	1.038E-05
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2578	0.2655	0.2645	0.2676	0.2604	0.2659
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.251	0.094	0.128	0.143	0.149	0.131

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	H-10	C-9	C-8	C-1	C-5	C-7
Source Area Inputs						
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	81.1	74.7	75.0	75.2	75.0	74.2
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	103.8	130.6	100.9	132.4	110.9	96.3
watershed slope fraction[2]	0.068	0.066	0.062	0.033	0.079	0.076
upland area (ha)[4]	7.1	10.3	3.7	6.7	5.2	4.8
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0486	0.0410	0.0421	0.0486	0.0470	0.0474
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	2.5	3.0	3.0	2.5	2.4	2.6
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	10	10	10	5	15	10
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.072	0.116	0.203	0.033	0.101	0.096
double filter strip width in longest direction (m)[8]	684	790	368	502	466	494
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	No	No	No	Yes	Yes	No
Average depth to water table (cm)[10]	>200	>200	>200	172	69	>200
h_e(m)[11]		-0.1933	-0.1933	-0.1933	-0.1933	-0.1933
Soil Water Characteristics Curve[11]		Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey
Hydraulic Conductivity Curve[11]		Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey
Theta Type Parameters[11]						
OR[11]		0	0	0	0	0
BCALPHA, 1/m[11]		5.17411	5.17411	5.17411	5.17411	5.17411
BCLAMDA[11]		0.73	0.73	0.73	0.73	0.73
KUN Type Parameters[11]						
BCETA[11]		5.8775	5.8775	5.8775	5.8775	5.8775
BCALPHA, 1/m[11]		5.17411	5.17411	5.17411	5.17411	5.17411
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	1.017E-05	9.552E-06	9.170E-06	9.138E-06	9.021E-06	9.170E-06
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2658	0.2585	0.2614	0.2614	0.2524	0.2641
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.187	0.131	0.057	0.173	0.224	0.089

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

Drainageshed	**C-10**	**C-3**	**B-2**	**B-4**	**B-3**
Source Area Inputs					
rainfall (mm) for the five year storm[1]	99.4	99.4	99.4	99.4	99.4
storm duration (hrs)	24	24	24	24	24
curve no[2]	75.0	74.7	73.5	74.7	75.1
storm type[3]	II	II	II	II	II
length along slope (m)[4]	46.4	109.6	167.6	127.6	72.4
watershed slope fraction[2]	0.041	0.082	0.031	0.036	0.056
upland area (ha)[4]	4.6	7.5	11.9	10.3	12.8
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0445	0.0468	0.0473	0.0477	0.0436
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	2.8	2.5	2.7	2.6	3.1
dp particle class diam[3]	default	default	default	default	default
crop factor[2]	0.18	0.18	0.18	0.18	0.18
practice factor[2]	0.79	0.79	0.79	0.79	0.79
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs					
buffer length from input to output (m)	5	10	10	10	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.081	0.097	0.044	0.043	0.084
double filter strip width in longest direction (m)[8]	995	686	708	806	1775
kinematic wave parameters	default	default	default	default	default
Filter Strip Infiltration Inputs					
shallow water table[9]	No	Yes	No	Yes	Yes
Average depth to water table (cm)[10]	>200	181	>200	178	157
h_e(m)[11]	-0.1933	-0.1933	-0.1933	-0.1933	-0.1933
Soil Water Characteristics Curve[11]	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey
Hydraulic Conductivity Curve[11]	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey	Brooks & Corey
Theta Type Parameters[11]					
OR[11]	0	0	0	0	0
BCALPHA, 1/m[11]	5.1741	5.1741	5.1741	5.1741	5.1741
BCLAMDA[11]	0.73	0.73	0.73	0.73	0.73
KUN Type Parameters[11]					
BCETA[11]	5.8775	5.8775	5.8775	5.8775	5.8775
BCALPHA, 1/m[11]	5.1741	5.1741	5.1741	5.1741	5.1741
number soil layers[9]	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	9.170E-06	8.803E-06	9.170E-06	1.028E-05	1.020E-05
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2615	0.2683	0.2636	0.2638	0.2617
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0
Buffer Vegetation Properties					
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0
Outputs					
five year storm sediment delivery ratio	0.02	0.208	0.055	0.075	0.221

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed, per NLCD 2019 landcover

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster

[6]USDA WSS

[7]estimated from USGS Lidar Data and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

[10]USDA WSS. In cases were values were reported as >200 cm, 200 cm was used in calculating the average.

[11]Based on example (sampleWT.prj) provided with VFSMOD. The general effect of assuming an existing shallow water table during the 5-year storm is to decrease sediment retention in the filter strip, and thus makes BMP crediting more conservative.

APPENDIX G: DRAFT FINE SEDIMENT METHODOLOGY, JANUARY 2023

Introduction

DEP uses a modified version of the habitat data collection protocols included with USEPA's Rapid Bioassessment Protocols to make siltation impairment determinations (Lookenbill and Whiteash 2021, Shull and Whiteash 2021). These methods provide descriptions of optimal, suboptimal, marginal and poor habitat conditions, and the observer rates sites on a 1 to 20 scale. This rapid methodology was the basis for the existing siltation impairments listed for the impaired watershed.

To explore whether streambed fine sediment deposits are decreasing during and after the implementation of this restoration plan, we sought a more quantitative methodology of monitoring streambed fine sediment deposits that would better allow for statistical analysis. A secondary way that this methodology may be used is to compare conditions among sites, for instance, to confirm whether a reference site has lesser fine sediment deposits than an impaired site.

The methodology presented herein is preliminary, with the expectation that it will be revised following more rigorous testing. A major consideration in developing the protocol as it currently exists was to strike an appropriate balance between effort and data quality. Indeed, an earlier version was determined to take far too long, and thus sampling effort was streamlined to the point that this protocol is expected to take two experienced people one day, or one person two days at each site. The proposed protocol should be considered the minimum effort to produce sample sizes that may statistically distinguish between clearly impaired and clearly non-impaired sites in the case of reference confirmation, or poor versus good before and after conditions when exploring for improvements as a result of restoration. Elucidating more subtle differences may require increased effort, and thus researchers may increase sample sizes beyond what is described herein at their discretion.

Two variables were chosen for measurement: <2mm (sieve size) deposits in riffles (see Kusnierz and Kron 2013) and fine sediment deposits in pools (see Hilton and Lisle 1993). Both are easily measured and have biological relevance. Riffles are of particular concern because they are commonly sampled for benthic macroinvertebrates, and excessive fine sediment deposition may smother and embed the coarse substrate habitats that many species require. Pools were of interest because they are natural areas of fine sediment deposition, thus may be the most sensitive aquatic habitats for degradation by siltation. There are a number of ways that excessive fine sediment deposition in pools could adversely affect biota, but the most obvious is the loss of deep-water habitats as pools fill with sediment.

Choosing a study reach

Before choosing a sampling reach, consideration should be given to finding areas that may be conducive to the use of the methods described below. For instance, very small streams, streams that are too large to wade, stream types that lack riffles or pools, wetland reaches that may experience heavy fines deposition even under natural conditions, or streams that are dry for much of the year would likely not be good candidates for the use of the methodology described below.

Sampling should be done at base flow. The replicates for statistical analysis will be 5 separate riffles and 5 separate pools within each study reach. When comparing impaired and reference watersheds for TMDL/ARP studies, reaches with similar geomorphology should be chosen in the impaired and reference watersheds, and preference would typically be given to mainstem reaches near the downstream-most areas of the delineated watersheds. However, areas just upstream of a stream's mouth with a larger body of water might be avoided, as atypically large, slow pools with high sediment deposition can form in these areas. Other areas of atypical, localized effects such as bridges and culverts may also be avoided, unless they are the focus of the study. It is suggested that the study keep at least one riffle-run-pool sequence away from such atypical areas. Also, unless typical for the study stream, it is recommended that areas with high channel complexity (islands, side channels, etc.) be avoided as they may make identifying mainchannel features more difficult. For studies that seek to explore whether conditions are changing over time, for instance before and after BMP implementation, the same general reach should be sampled repeatedly, though it is not required to sample the exact same riffles and pools repeatedly, as geomorphology is expected to evolve, especially where restoration projects are occurring.

Once a reach is chosen, measurements should be made in a sequence of 5 consecutive, obvious, main-channel riffles. Likewise, a sequence of 5 consecutive, obvious, main-channel large scour pools should be measured (Figure G1). Riffles will be identified as areas where there is shallow, turbulent flow, a thalweg may be poorly defined, and the channel slope is steeper than normal (see Kusnierz and Kron 2013). Pools are the areas where depth is greater than normal, current is the slowest, the water surface is mostly non-turbulent. To qualify for measurement, pools must be at least two times deeper in their deepest part than the depth of water at the apex (highest point) of the tailout (or terminus of the pool, typically where it transitions to a riffle) (See Hilton and Lisle 1993). Furthermore, the pool must be a "large pool" defined as covering at least ½ of the wetted width of the stream (Hilton and Lisle 1993), and be a scour pool formed primarily by the shape of the bed substrate rather than debris jamming (Kusnierz and Kron 2013). Some debris jamming is acceptable, so long as it isn't the main reason the pool exists. Runs, which are not sought for measurement, can be distinguished from riffles in that they are less turbulent, deeper and often have a thalweg (Kusnierz and Kron 2013). Also, relative to pools, runs are swifter and shallower. It should be noted that riffles, runs and pools are not always discrete features; rather, they may transition into one another and different observers may disagree where they begin and end. Therefore, some field judgement will be required when choosing sampling units. However, to help ensure that riffles and pools are selected, areas where there is a high degree of doubt should be avoided.

Once a study reach is established, start at the tailout of the downstream-most qualifying pool, and work upstream to avoid turbidity. Standardized datasheets have been constructed to help ensure all necessary information is collected.

Spreadsheets that can be used with iPads have also been created for easy calculation of transect placement and sampling point spacing.

Pool measurements

1) Using the graduated measuring probe, measure water depth within the deepest parts of the apex of the pool tailout/crest of the riffle. The deepest measurement will be used to determine if the pool has sufficient depth to be qualifying.
2) Probe around the pool to find the deepest water depth. The deepest point must be at least two times the depth measured in the previous step to qualify the pool for measurement. If not, move upstream to find the next qualifying pool.
3) If of sufficient depth and also a large, mainchannel, scour pool (see above for definitions), take a GPS point near the center of the pool. If not, go upstream to find the next useable pool.
4) Using a large measuring tape, measure the length of the pool from the apex of the tailout up to the head of the pool, which may be a plunge point from a riffle, or perhaps a transition area from a run.
5) Three transects will be established perpendicular to the pool at approximately 25, 50 and 75% of the length of the pool. The provided spreadsheet calculator may be used for easy field calculation.
6) Measurements will be taken at 10, 20, 30, 40, 50, 60, 70, 80 and 90% of the wetted channel width along each perpendicular transect. The provided spreadsheet calculator may be used for easy field calculation.
7) At each sampling point, gently put the graduated probe down on the substrate to measure the depth of water. Record this number to the nearest cm.
8) Forcefully push the probe down into the substrate. Then record the water level to the nearest cm. This will be depth of sediment plus water. Subtract the water depth from the previous step from this value to calculate the depth of fine sediment.

   Note that what is being measured is the ability to drive a rod into the substrate comprised primarily of small gravels and smaller. Once large gravels and cobbles are reached, penetration will be greatly impeded. Thus, don't pound with a hammer or push so hard as to force the probe deep between cobbles. Also, if a large pointy rock is contacted on the substrate surface, the probe will tend to slide down its edge. If this is felt to be the case, record depth of fines as 0 cm. Also, where measurements are not possible due to an obstruction such as a log, take the measurements to the side of the obstruction.
9) Once measurements are complete for all 5 qualifying pools, enter the data into the provided data analysis spreadsheet (Figure G2). Summary statistics will be calculated, and a graph will be generated (Figure G3).
10) Statistical significance between the 5 pools of the impaired/before site and the 5 pools of a reference/after site can be determined using the non-parametric Wilcoxon Rank Sum Test/ Mann-Whitney U Test. Given the small sample sizes, an α level of 0.1 (for the two-sided test) is suggested.

Main-channel Riffle Measurements

1) Take a GPS point near the center of the riffle.
2) Using a large measuring tape, measure the length of the riffle.

3) Three transects will be established perpendicular to the riffle, at approximately 25, 50 and 75% of the length of the riffle. The provided spreadsheet calculator may be used for easy field calculation.
4) Particle size will be measured at 17 approximately equally spaced points across the wetted channel width along each perpendicular transect. The provided spreadsheet calculator may be used for easy sampling point calculation.
5) Sampling at each point is similar to a typical pebble count procedure, except that rather than measuring all particles, only the presence/absence of <2mm sieve size deposits will be recorded. Where feasible, the observer's foot is placed on the streambed at each location to be sampled. The observer reaches straight down with an index finger along the tip of their shoe next to their big toe to feel for a particle. Note whether the particle(s) that is/are felt could fit through a 2mm by 2mm square or not. In many cases this will be obvious. When not, use a gravelometer as an aid.

   A judgement call may be needed for cases where deposits contain particles less than and greater than 2mm sieve size. In these cases, take a pinch of the deposit and examine it visually to determine whether the smaller or larger particles comprise the bulk of the volume of the pinch.

   For a sampling point to count as <2mm sieve size, it needs to be a deposit that can be felt. Since light dustings of silt or clay on large rocks cannot be felt, they would not be recorded as <2mm. It is suggested that the sampler avoid looking directly at specific sampling points so that visible observations do not lead to bias. Also, if the observer feels a large rock with some occasional sand grains on top of it, it would be recorded as >2mm since the sparse individual sand grains are not a deposit.

   If necessary, gently remove vegetation or leaves that cover a sampling point. If a large obstruction such as a log prevents sampling at a point, sample next to it. Also note that sometimes it is not feasible to sample along one's toe, such as in cases of narrow stream width or irregular regular substrate. In such cases try to use the transect tape as a guide in finding sampling points.

   It would be very difficult to try to read sampling points off an iPad, sample, and then write with wet hands when working solo. In these situations, small binder clips may be put on the transect tape to mark all 17 points before sampling begins. A clicker-counter can then be used to keep track of how many of the 17 points were <2mm sieve size.
11) Once measurements are complete for all 5 mainchannel riffles, enter the proportion <2mm sieve size for each riffle in the data analysis spreadsheet (Figure G4). Summary statistics will be calculated, and a graph will be generated (Figure G5).
12) Statistical significance between the 5 riffles of the impaired/before site and the 5 riffles of a reference/after site can be determined using the non-parametric Wilcoxon Rank Sum Test/ Mann-Whitney U Test. Given the small sample sizes, an α level of 0.1 (for the two-sided test) is suggested.

Equipment List

pencils
data sheets
clipboard
yard/meter stick
300 ft measuring tapes
100 ft measuring tapes
short rebar
long rebar
hammer
streambed probe (metal tipped broom handle with cm graduations)
gravelometer, or 2mm X 2mm example hole.
Ipad with calculation spreadsheets downloaded
GPS
clicker counter (if doing by yourself)
small binder clips (if doing by yourself)
waders
sunscreen, bug repellent, drinking
water

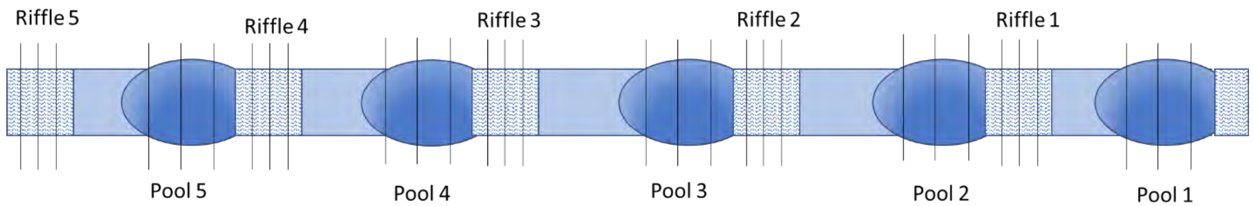

Figure G1. Cartoon of hypothetical stream reach showing data collection transects. Hypothetical stream would be flowing from left to right. Starting at the downstream end of the reach, five consecutive, large, mainchannel scour pools would be sampled and five consecutive mainchannel riffles would be sampled. Within each pool or riffle, three perpendicular transects would be established at approximately 25, 50 and 75% of the feature's length. Along each perpendicular riffle transect measurements would be taken at 17 "pebble count" sampling points, for a total of 51 sampling points per riffle. Along each perpendicular pool transect, fine sediment depth would be measured at 9 sampling points, for a total of 27 sampling points per pool. For statistical analysis, n=5 riffles and n=5 pools.

Ontelaunee Creek	enter fine sediment depth in cm														
	Pool 1			**Pool 2**			**Pool 3**			**Pool 4**			**Pool 5**		
	Tans 1	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*
10	0	2	13	8	1	2	5	7	1	9	5	32	4	0	0
20	0	0	2	2	5	3	5	0	0	9	4	4	3	1	0
30	0	0	0	5	1	3	2	5	2	0	5	3	5	1	5
40	0	0	0	0	4	1	0	4	0	5	2	0	1	0	0
50	0	0	5	0	1	4	0	2	0	0	3	4	0	5	1
60	0	0	0	1	0	0	0	0	0	3	1	0	4	0	2
70	0	0	0	0	0	0	3	1	0	0	0	0	0	4	6
80	0	0	0	6	0	1	5	5	2	0	0	7	0	6	4
90	0	1	0	0	0	0	8	5	5	4	2	9	0	7	0
transect mean (cm)	0.0	0.3	2.2	2.4	1.3	1.6	3.1	3.2	1.1	3.3	2.4	6.6	1.9	2.7	2.0
Pool mean (cm)	**0.9**			**1.8**			**2.5**			**4.1**			**2.2**		

Hammer Creek-Obie	enter fine sediment depth in cm														
	Pool 1			**Pool 2**			**Pool 3**			**Pool 4**			**Pool 5**		
	Tans 1	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*	*Tans 1*	*Trans 2*	*Trans 3*
10	29	0	0	0	2	3	22	15	17	13	19	17	37	38	15
20	28	41	0	5	2	19	13	23	7	9	18	12	39	28	13
30	25	37	0	6	21	37	8	21	3	6	12	11	25	18	22
40	11	40	13	9	18	17	4	3	0	13	7	9	14	0	15
50	12	50	11	10	12	7	2	1	1	5	2	10	4	15	6
60	9	44	12	11	12	8	0	4	1	2	6	5	3	1	9
70	8	32	6	0	11	13	3	2	7	6	1	9	2	14	5
80	4	14	2	17	11	8	4	6	5	25	2	3	0	5	7
90	29	22	3	9	24	22	8	1	10	32	21	4	12	0	19
transect mean (cm)	17.2	31.1	5.2	7.4	12.6	14.9	7.1	8.4	5.7	12.3	9.8	8.9	15.1	13.2	12.3
Pool mean (cm)	**17.9**			**11.6**			**7.1**			**10.3**			**13.6**		

Figure G2. Sample calculation spreadsheet for pool fine sediment depth

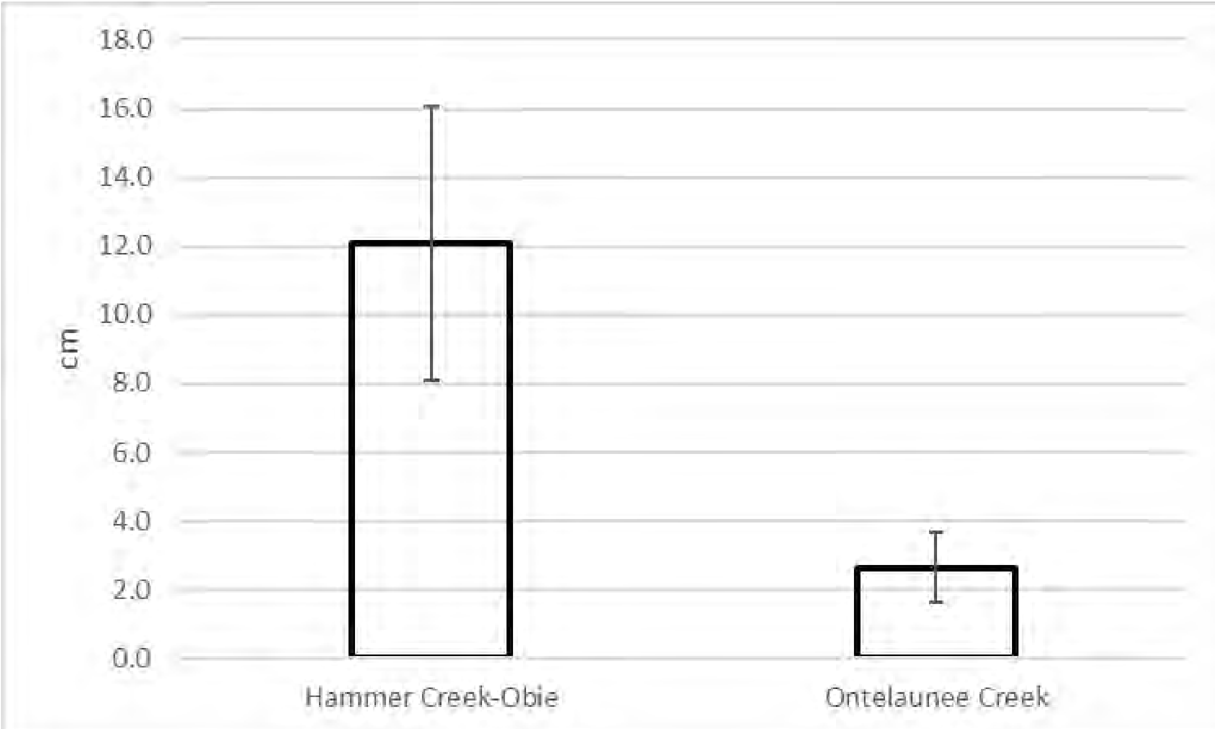

Figure G3. Example pool graph. Mean (+/-sd) depth of fine sediment deposits in pools of the Hammer Creek (impaired) and Ontelaunee Creek (reference) subwatersheds. Measurements were made in five consecutive, large mainchannel pools within each subwatershed. According to the Wilcoxon Rank Sum Test, pool sediment depth was significantly different between the two groups (p=0.0079)

Riffle	Hammer Creek-Obie Road proportion <2mm	Ontelaunee Creek proportion <2mm
1	0.647	0.020
2	0.569	0.235
3	0.490	0.039
4	0.510	0.176
5	0.294	0.137
mean	***0.50***	***0.12***
sd	***0.12***	***0.08***

Figure G4. Example calculation spreadsheet for riffle fine sediment.

Figure G5. Example riffle sampling graph. Mean (+/- sd) proportion of sampling points dominated by <2mm deposits within riffles of the Hammer Creek (impaired) and Ontelaunee Creek (reference) Subwatersheds. Measurements were made in five consecutive mainchannel riffles within each subwatershed. According to the Wilcoxon Rank Sum Test, the amount of fine sediment in riffles was significantly different between the two groups ($p=0.0079$).

Appendix G References

The following two references provided a good starting point for the exploration of the proposed methodology, and some of what has been included in this document was in-part derived from these sources. Ultimately however, the methodology proposed in this document was heavily customized.

Hilton, S. and T. E. Lisle. 1993. Measuring the fraction of pool volume filled with fine sediment. Research Note PSW-RN-414-WEB. United States Department of Agriculture, Pacific Southwest Research Station. Berkeley, CA. (Available online at: https://www.fs.usda.gov/psw/publications/documents/psw_rn414/psw_rn414.pdf)

Kusnierz, P., A. Welch and D. Kron. 2013. The Montana Department of Environmental Quality Western Montana sediment assessment method: Considerations, physical and biological parameters, and decision making. Draft, June 2013. Montana Department of Environmental Quality, Water Quality Planning Bureau. Helena, MT. (Available online at: http://deq.mt.gov/Portals/112/Water/SurfaceWater/UseAssessment/Documents/FINAL_Sediment_AM_V17.pdf)

APPENDIX H: COMMENT AND RESPONSE

No public comments were received.