Carpenters Run Sediment TMDL

Lycoming County, Pennsylvania

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

"Total Maximum Daily Loads" (TMDLs) for sediment were developed for the Carpenters Run Watershed (Figures 1 and 2) to address the siltation impairments noted in the 2020 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Agriculture was identified as the cause of these impairments. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from a similar unimpaired watershed were used to calculate the TMDLs.

"TMDLs" were calculated using both a long-term annual average value ($TMDL_{Avg}$) which would be protective under most conditions, as well as a 99th percentile daily value ($TMDL_{Max}$) which would be relevant to extreme flow events. Current annual average sediment loading in the Carpenters Run Watershed was estimated to be 2,603,651 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 49% to 1,339,381 pounds per year. Allocation of annual average sediment loading among the TMDL variables is summarized in Table 1. To achieve this reduction while maintaining a 10% margin of safety and minor allowance for point sources, annual average loading from croplands, hay/pasture lands and streambanks should be reduced by 55% each.

Table 1. Summary of Annual Average TMDL ($TMDL_{Avg}$) Variables for the Carpenters Run Watershed

lbs/yr:						
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	1,339,381	133,938	13,394	1,192,050	34,315	1,157,735

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Avg" indicates that these values are expressed as annual averages.

Current 99thpercentile daily loading in the Carpenters Run Watershed was estimated to be 102,288 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 45% to 56,069 pounds per day. Allocation of 99th percentile daily sediment loading among the TMDL variables is summarized in Table 2.

Table 2. Summary of 99th Percentile Daily Loading TMDL ($TMDL_{Max}$) Variables for the Carpenters Run Watershed

lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	56,069	5,607	561	49,902	1,436	48,465

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Max" indicates that these values are expressed as 99th percentile for daily loading.

Introduction

Carpenters Run is a tributary of the West Branch of the Susquehanna River, with the confluence approximately two miles northwest of the Borough of Muncy (Figure 1). Note that the mainstem is actually referred to as "Unnamed Tributary to West Branch Susquehanna River" in the Integrated Report, but it is labelled as "Carpenters Run" in USGS Topographic mapping and other sources. For specificity, "Carpenters Run" will be used in this document. This Total Maximum Daily Load (TMDL) document has been prepared to address the siltation from agriculture impairments listed for most of the watershed, (Figure 2, Table 3) per the 2020 Final Integrated Report (see Appendix A for a description of assessment methodology). Since the outlet is listed as impaired for sediment and this reach is affected by all upstream segments, this TMDL document will be relevant to all segments within the watershed, including those that were not listed as impaired for siltation.

The Carpenters Run Watershed was approximately 11 square miles and occurred entirely within Lycoming County. It contained approximately 21 stream miles, all of which were designated for Warm Water Fish (WWF) and Migratory Fishes (MF).

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 Chapter 93.6 (a)*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code, Chapter 93.6 (b))*.

While agriculture has been identified as the source of the impairments (Table 3), this TMDL document is applicable to all significant sources of solids that may settle to form deposits.

According to an analysis of NLCD 2016 landcover data, land use in the study watershed was estimated to be 52% forest/naturally vegetated lands, 37% agriculture, and 10% mixed development. The amount of hay/pasture lands in the watershed was approximately twice the amount of croplands (Appendix B, Table B1). There were no current NPDES permitted point source discharges in the watershed with significant load limits relevant to sedimentation, although there was a wastewater treatment plant serving a single-family residence (Table 4).

Table 3. Aquatic-Life Impaired Stream Segments in the Carpenters Run Watershed per the 2020 Final Pennsylvania Integrated Report
HUC: 02050206 – Lower West Branch Susquehanna

Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Agriculture	Siltation	14.3	WWF, MF	Aquatic Life
Urban Runnoff/Storm Sewers	Cause Unknown	0.76	WWF, MF	Aquatic Life
Habitat Modification-Other than Hydromodification	Habitat Alterations	2.51	WWF, MF	Aquatic Life

HUC= Hydrologic Unit Code; WWF=Warm Water Fish; MF= Migratory Fish
The use designations for the stream segments in this TMDL can be found in PA Title 25 Chapter 93.
See Appendix C for a listing of each stream segment and Appendix A for more information on the listings and listing process.

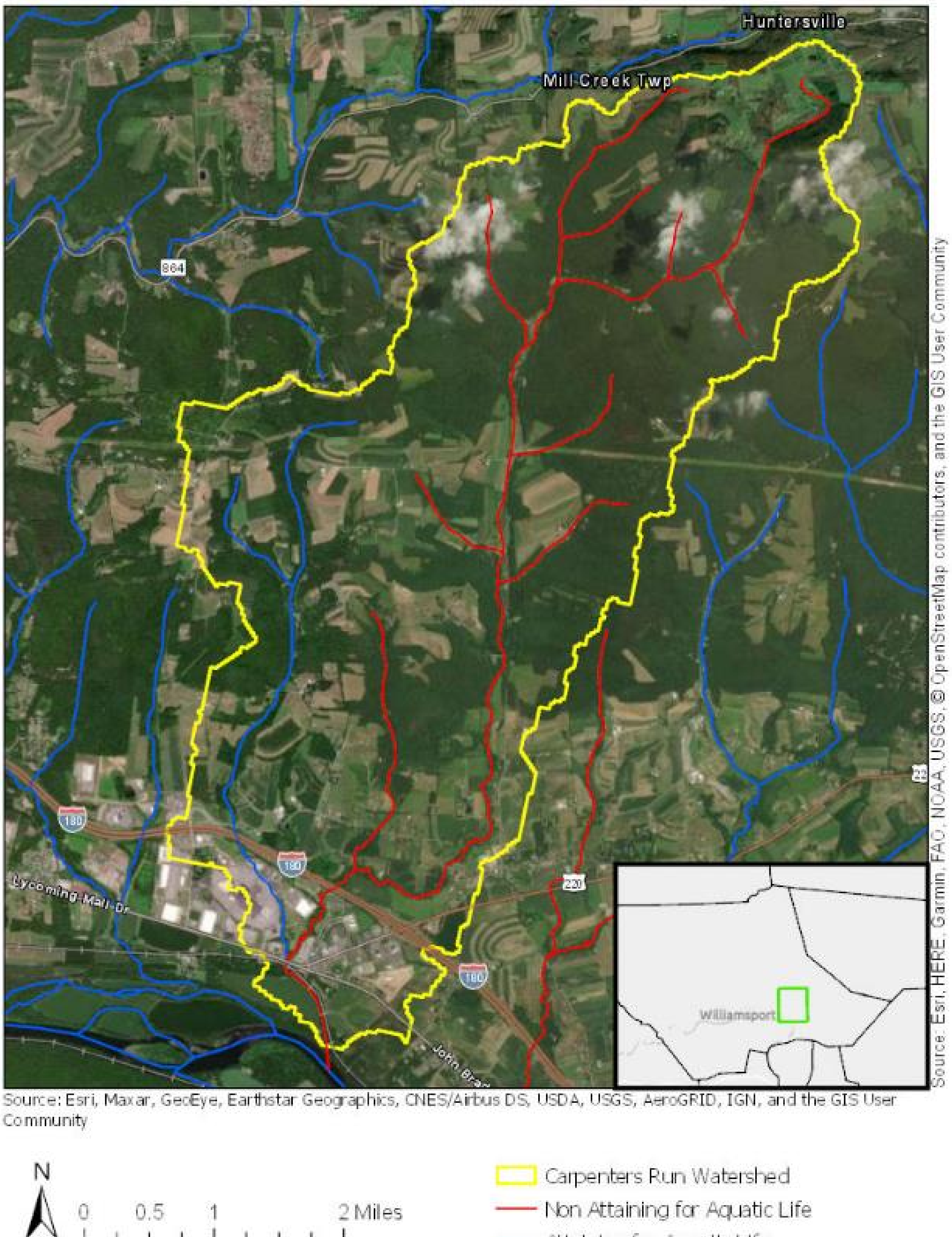

Figure 1. Carpenters Run Watershed. Stream segments are shown as either attaining or non-attaining per the 2020 Integrated Report viewer available at https://gis.dep.pa.gov/IRViewer2020/.

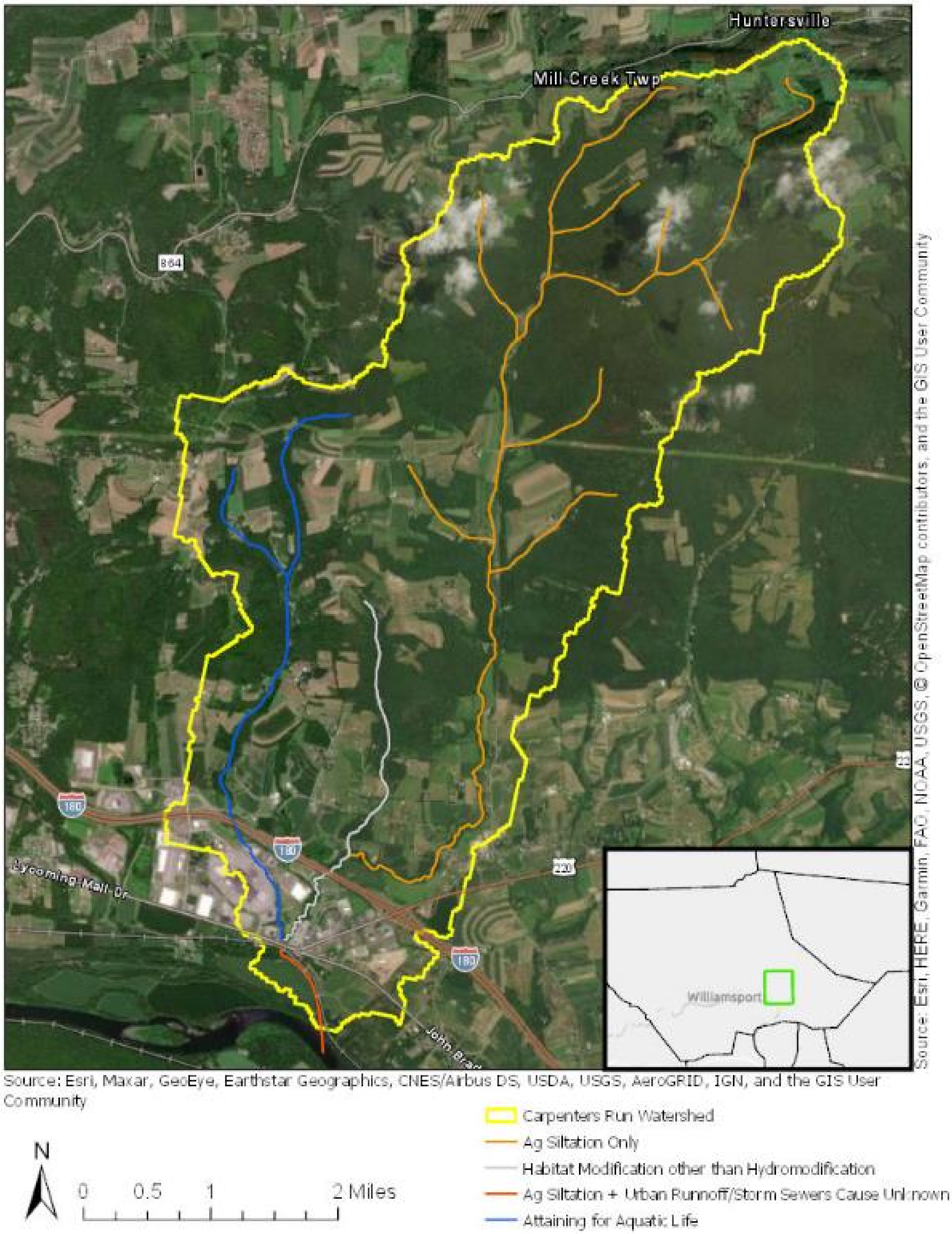

Figure 2. Carpenters Run Watershed with aquatic life impairments identified by source and cause per the 2020 Integrated Report. See https://gis.dep.pa.gov/IRViewer2020/.

Table 4. Existing NPDES-Permitted Discharges in the Carpenters Run Watershed and their Potential Contribution to Sediment Loading.					
		Permit Based Limits		DMR Based Loading	
Permit No.	Facility Name	Load, mean lbs/yr	Load, max lbs/d	Load, mean lbs/yr	Load, max lbs/d
PAG044862	Gregory Gilbert SFTF	8	0.07	NA	NA

Permits within the watershed were based on DEP's eMapPA available at http://www.depgis.state.pa.us/emappa/ and EPA's Watershed Resources Registry available at https://watershedresourcesregistry.org/map/?config=stateConfigs/pennsylvania.json

Note that given their transient nature, any stormwater construction permits were not included above. Furthermore, runoff and sediment loading from historic construction sites would be at least partially accounted for when modelling land use types.

Gregory Gilbert SFTF
Small flow wastewater treatment facility for a single-family residence. Assume an average daily flow of 262.5 gpd and a daily maximum flow of 400 gpd. The average flow with an average monthly TSS concentration of 10 mg/L was used to calculate the annual average loadings. A 20 mg/L TSS concentration along with an assumed peak daily flow of 400 gpd were used to calculate the daily max loads. No eDMR data were available.

TMDL Approach

Although watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes that apply to all cases. They include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of a TMDL that appropriately accounts for any 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. EPA approval of the TMDL.

Because Pennsylvania does not have numeric water quality criteria for sediment, the "Reference Watershed Approach" was used. This method estimates pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. Then, the loading rate in the unimpaired watershed is scaled to the area of the impaired watershed so that necessary load reductions may be calculated. It is assumed that reducing loading rates in the impaired watershed to the levels found in the 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 and accumulation rates in a watershed. Thus, selection of a reference watershed with similar natural characteristics as the impaired watershed is crucial. Failure to use an appropriate reference watershed could result in problems such as the setting of sediment reduction goals that are unattainable, or nonsensical TMDL calculations that suggest that sediment loading in the impaired watershed should be increased.

To find a reference, the Department's Integrated Report GIS-based website (available at https://www.depgis.state.pa.us/integrated_report_viewer/index.html), or GIS data layers consistent with the Integrated Report, were used to search for nearby watersheds that were of similar size as the Carpenters Run Watershed, but lacked stream segments listed as impaired for sediment. 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, bedrock geology, hydrology, soil drainage types, land use 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.

Considering that: it was nearby (only about eighteen miles to the southeast), within the same physiographic province, had similar topography and hydrologic characteristics, and there was good evidence that it was attaining its aquatic life use, a subwatershed of the Green Creek in Columbia County was considered for use as a reference (Figures 3 and 4, Table 5).

Table 5. Comparison of Carpenters Run and the Green Creek Watersheds.

	Carpenters Run	Green Creek
Phys. Province[1]	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province
Land Area[2], ac	7,164	6,580
Land Use[2]	37% Agriculture 52% Forest/Natural Vegetation 10% Developed	42% Agriculture 50% Forest/Natural Vegetation 8% Developed
Soil Infiltration[3]	14% Group A 31% Group B 3% Group B/D	2% Group A 41% Group B 4% Group B/D

	<1% Group C 6% Group C/D 45% Group D	4% Group C 2% Group C/D 48% Group D
Dominant Bedrock[4]	46% Mudstone 23% Sandstone 16% Shale 8% Siltstone 5% Calcareous Shale 3% Limestone	84% Siltstone 10% Sandstone 6% Shale
Average Precipitation[5], in/yr	41.5	39.3
Average Surface Runoff[5], in/yr	3.1	2.8
Average Elevation[5] (ft)	860	1,057
Average Slope[5]	17%	15%
Stream Channel Slope[5]	1st order: 2.96% 2nd order: 0.92%	1st order: 2.70% 2nd order: 0.96%

[1]Per PA_Physio_Sections GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[2]MMW output/input based on NLCD 2016.
[3]As reported by Model My Watershed's analysis of USDA gSSURGO 2016
[4]Per bedrock geology GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[5]As reported by Model My Watershed

Both watersheds were within the Susquehanna Lowland Section of the Ridge and Valley Physiographic, but near the transition to the Deep Valleys section of the Appalachian Plateaus Province (Table 5). Approximately half the land area of both watersheds was forested/natural vegetation landcover, while the bulk of the remaining area was agriculture lands (Table 5 and Appendix Tables B1 and B2). Furthermore, approximately one tenth of the land area in both watersheds were developed lands.

Both watersheds were dominated by non-karst sedimentary bedrocks, though siltstone was by far the dominant bedrock in the Green Creek Subwatershed whereas the Carpenters Run Watershed was dominated by mudstone and sandstone (Table 5). The average topographic slope in both watersheds was approximately the same (17% versus 15%, Table 5). Likewise, average stream channel slopes in the two watersheds were very similar (Table 5). Both watersheds were dominated by a mixture of slow (D) and moderate (B) infiltration soils, and estimated surface runoff rates were nearly the same (3.1 versus 2.8 inches per year) (Table 5).

Whereas the Carpenters Run Watershed was designated for Warm Water Fish (WWF), the Green Creek Subwatershed was designated for Trout Stocking (TSF). Neither watershed had stream segments designated for special protection (high quality or exceptional value). Also like the Carpenters Run Watershed there were no significant NPDES permitted point source discharges in the Green Creek Subwatershed (Table 6). Overall, the Green Creek Subwatershed appeared to be very similar to the Carpenters Run Watershed.

Table 6. Existing NPDES-Permitted Discharges in the Green Creek Subwatershed and their Potential Contribution to Sediment Loading.

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

Permits within the watershed were based on DEP's eMapPA available at http://www.depgis.state.pa.us/emappa/ and EPA's Watershed Resources Registry available at https://watershedresourcesregistry.org/map/?config=stateConfigs/pennsylvania.json

Note that given their transient nature, any stormwater construction permits were not included above.

After selecting the potential reference, the two watersheds were visited during the winter of 2021 to confirm the suitability of the reference as well as to explore whether there were any obvious land use differences that may help explain why one watershed was impaired for sediment while the other was attaining.

Site observations in the Carpenters Run Watershed indicated that streambed conditions changed drastically from the upper to lower watershed. The lower watershed was a relatively flat valley dominated by agriculture plus the Lycoming Mall plus surrounding development (Figures 1 and 2). Excessive fine sediment deposition and stream bed instability were obvious in this area (Figure 5). Fine sediment deposition was also apparent at some sites within the hillier valley area above the Lycoming Mall, though the problem was not as severe (Figure 6). In contrast, stream sites within the higher gradient middle and upper watershed appeared to be comparatively healthy in most cases (Figure 7).

Based on site observations, it was hypothesized that topographic conditions may make the lower watershed particularly vulnerable to anthropogenic sediment deposition. While the amount of agricultural land in the watershed was considerable (37% of total land area), it alone did not seem excessive to the point of creating the striking impairments noted in the lower watershed. Indeed, slightly more than half of the watershed was forested (Table 5). Rather, some agricultural lands within the watershed may be especially vulnerable to erosion because they occurred on very steep slopes (Figures 8 and 9), and sometimes without expansive riparian buffers (Figure 9). Even stream segments within the upper and middle watershed without obvious fine sediment deposition problems may be problematic sources of fine sediment to the lower watershed. While such high gradient streams might export fine sediment very efficiently, the sediment load may ultimately settle as stream slopes decrease in the downstream areas of the watershed.

It is suspected that a legacy of deforestation and agriculture in the watershed has led to the thick floodplain sediment deposits and resultant excessive bank erosion observed in the lower watershed (Figures 5 and 10). This may be exacerbated by high runoff rates associated with agriculture and the surrounding developed lands (Figure 10).

It should also be noted however that conditions within the watershed could be far worse if not for factors that were protective of water quality, including that: so much of the watershed remained forested, there was a high rate of riparian buffering, and stormwater BMPs were in use (Figure 11).

In contrast, streambed conditions appeared to be far better in the Green Creek Subwatershed (Figures 12 and 13). Like the Carpenters Run Watershed, most of the upper and middle Green Creek Subwatershed was hilly while the lower watershed occurred in a broad valley (Figures 4 and 14). And while many stream segments occurred in forested landscapes or had forested buffers (Figure 15), there were also agricultural lands on steep slopes (Figure 16). While there were some areas where conditions could have been improved (Figure 16), all stream segments within the watershed were listed as attaining their aquatic life use per the approved integrated report.

The Green Creek Subwatershed may have been healthier in part because it had a lesser amount of cropland cover, which tends to have the highest sediment loading rates. Furthermore, the spatial orientation of the land uses may also have been relevant. In the Carpenters Run Watershed, agricultural and developed lands tended to be concentrated in the lower valley along downstream segments whereas large forested tracts were more common in the upper watershed (Figure 1). In contrast, broad forested areas tended to follow stream segments in the Green Creek Subwatershed while anthropogenic land uses tended to be more distant from the stream segments (Figure 4). It should also be noted that the lower valley of the Green Creek Subwatershed tended to be not quite as broad and flat, and thus perhaps not as prone to deposition, as occurred in the Carpenters Run Watershed.

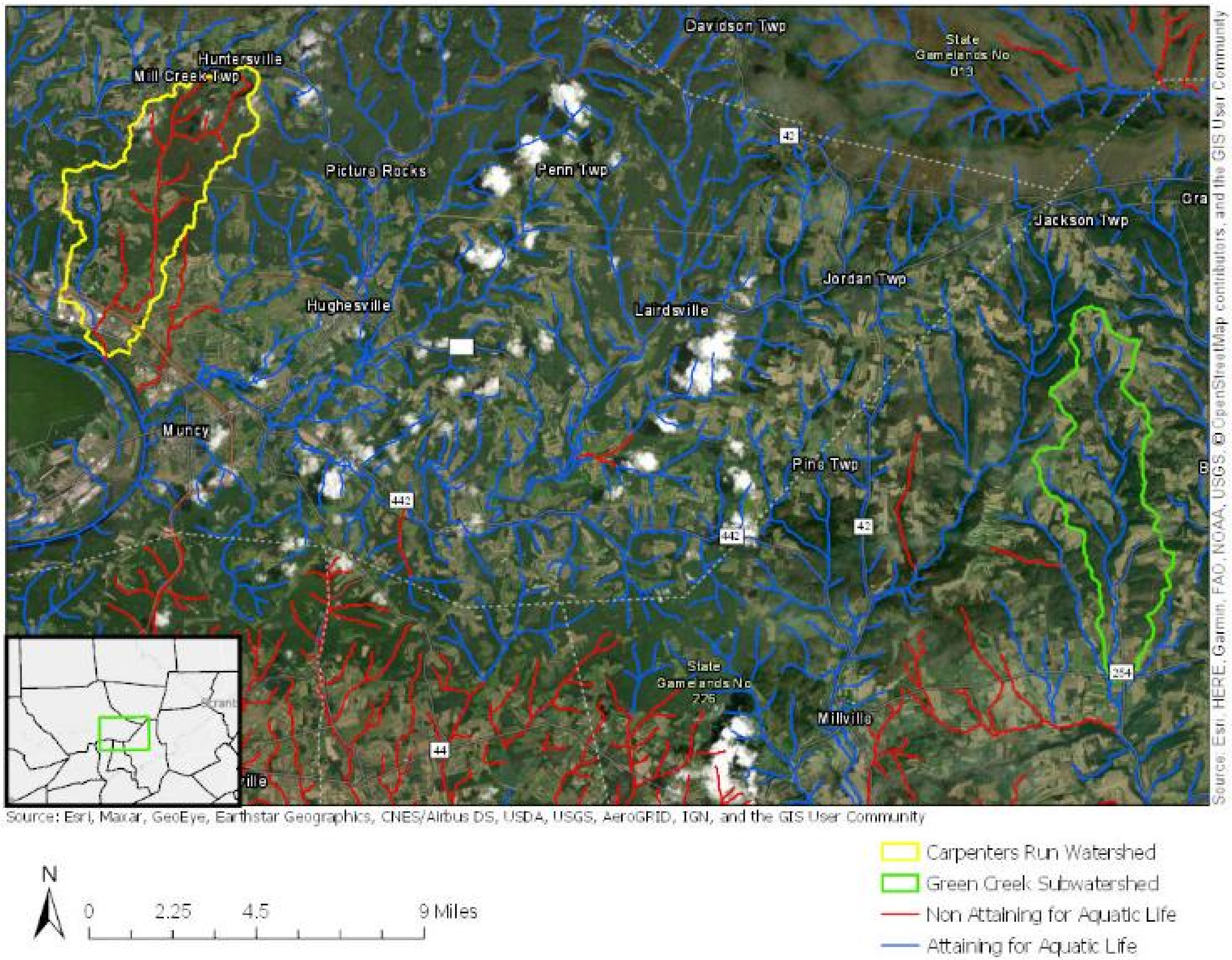

Figure 3. Carpenters Run and Green Creek Watersheds. Stream segments are shown as either attaining or non-attaining for aquatic life use per the 2020 Integrated Report viewer available at https://gis.dep.pa.gov/IRViewer2020/

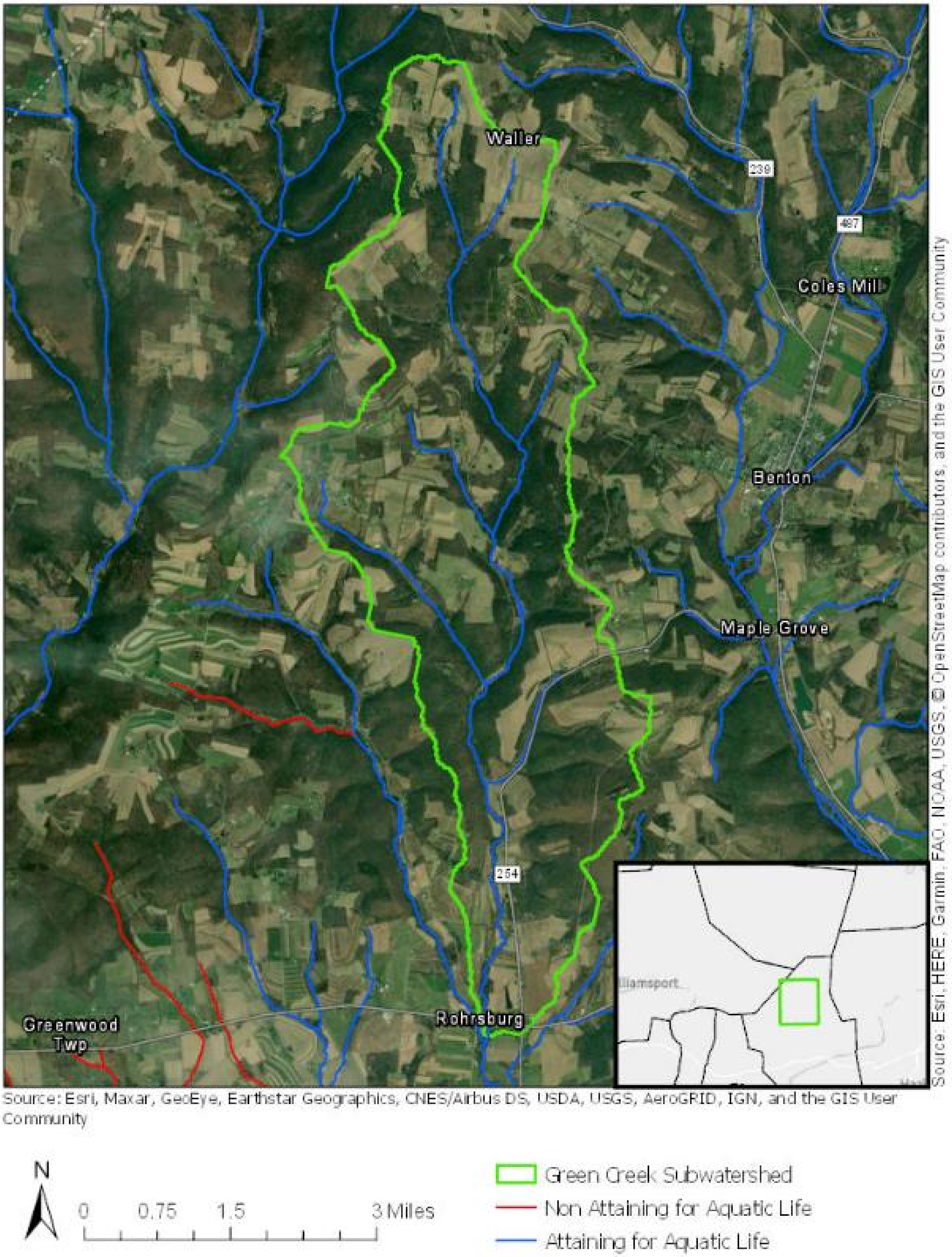

Figure 4. Green Creek Subwatershed. All of its stream segments were listed as attaining for aquatic life use per the Integrated Report viewer available at https://gis.dep.pa.gov/IRViewer2020//

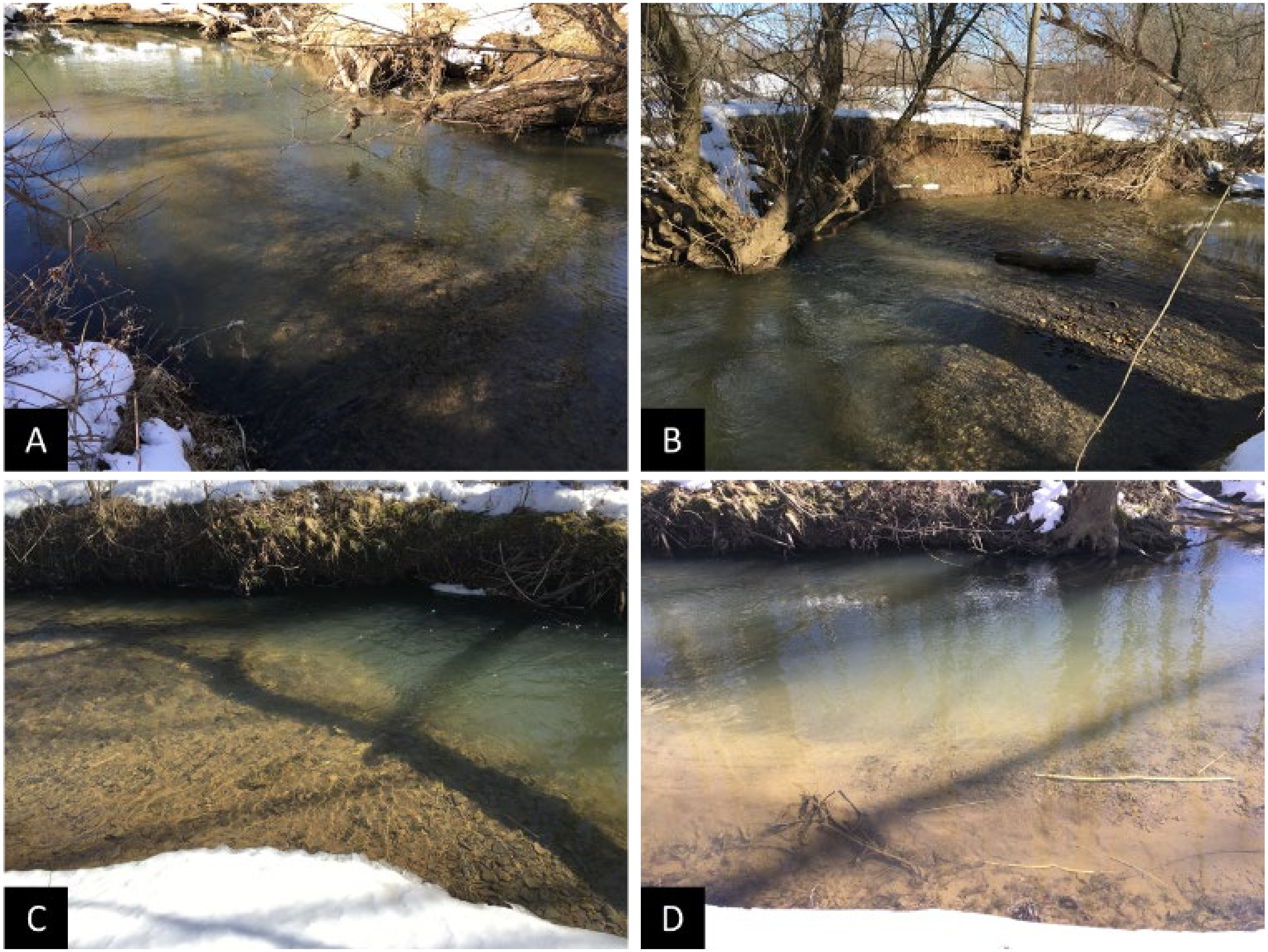

Figure 5. Sediment deposition in mainstem reaches of the Carpenters Run Watershed in the valley area near the Lycoming Mall. Note the high amounts of fines deposition and shifting bedload as evidenced by bar formation.

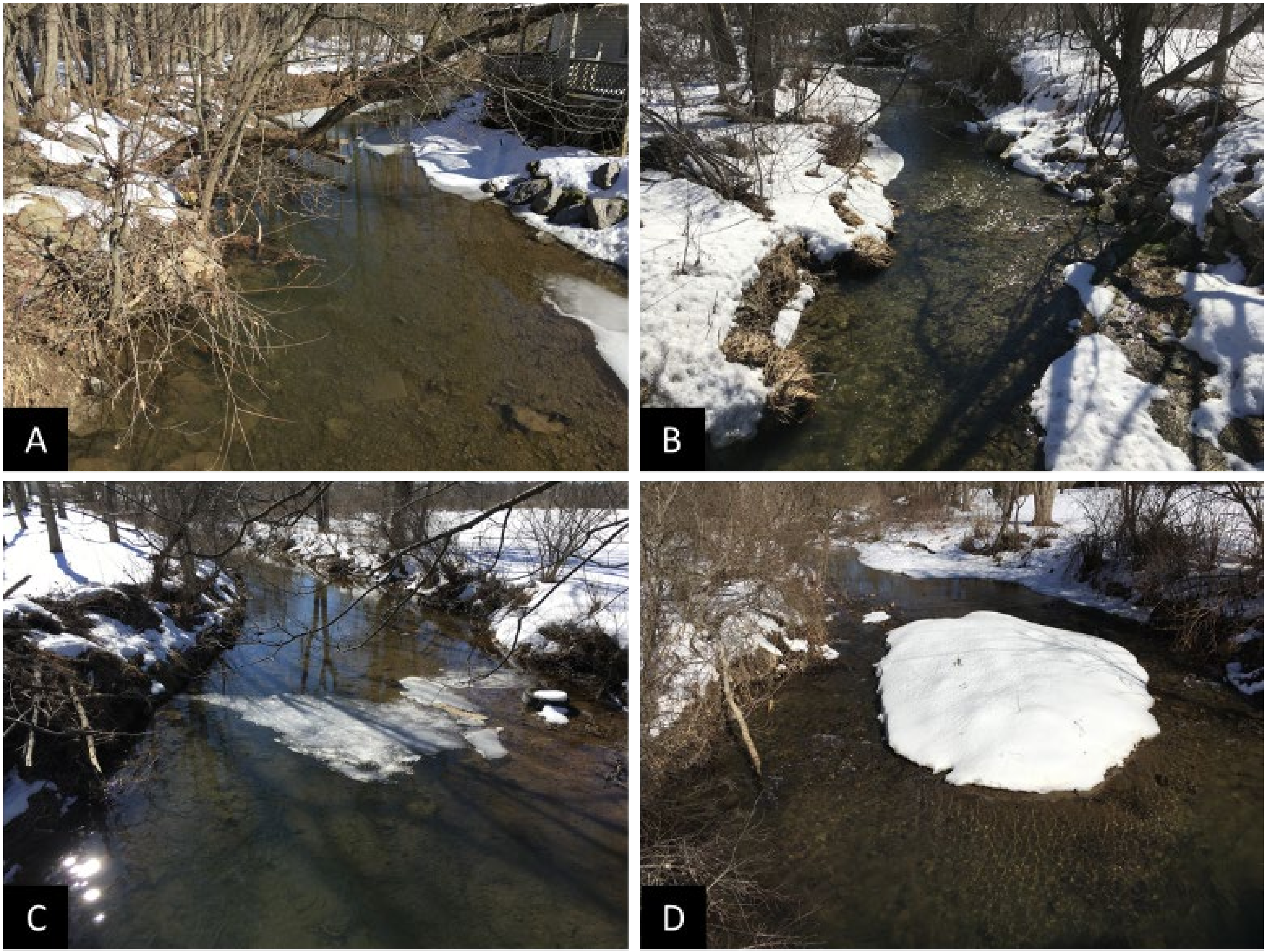

Figure 6. Sediment deposition in the valley area of the Carpenters Run Watershed upstream of the Lycoming Mall.

Figure 7. Stream segments in the upper more mountainous area of the Carpenters Run Wastershed. Stream substrate in this area may be largely rocky or exhibit some shifting bed load or fine sediment deposition.

Figure 8. Landscapes within the Carpenters Run Watershed. The upper watershed was mountainous/hilly with patches of forest and agriculture. Note that agricultural lands sometimes occurred on very steep slopes. The lower watershed was a large valley dominated by agriculture and development.

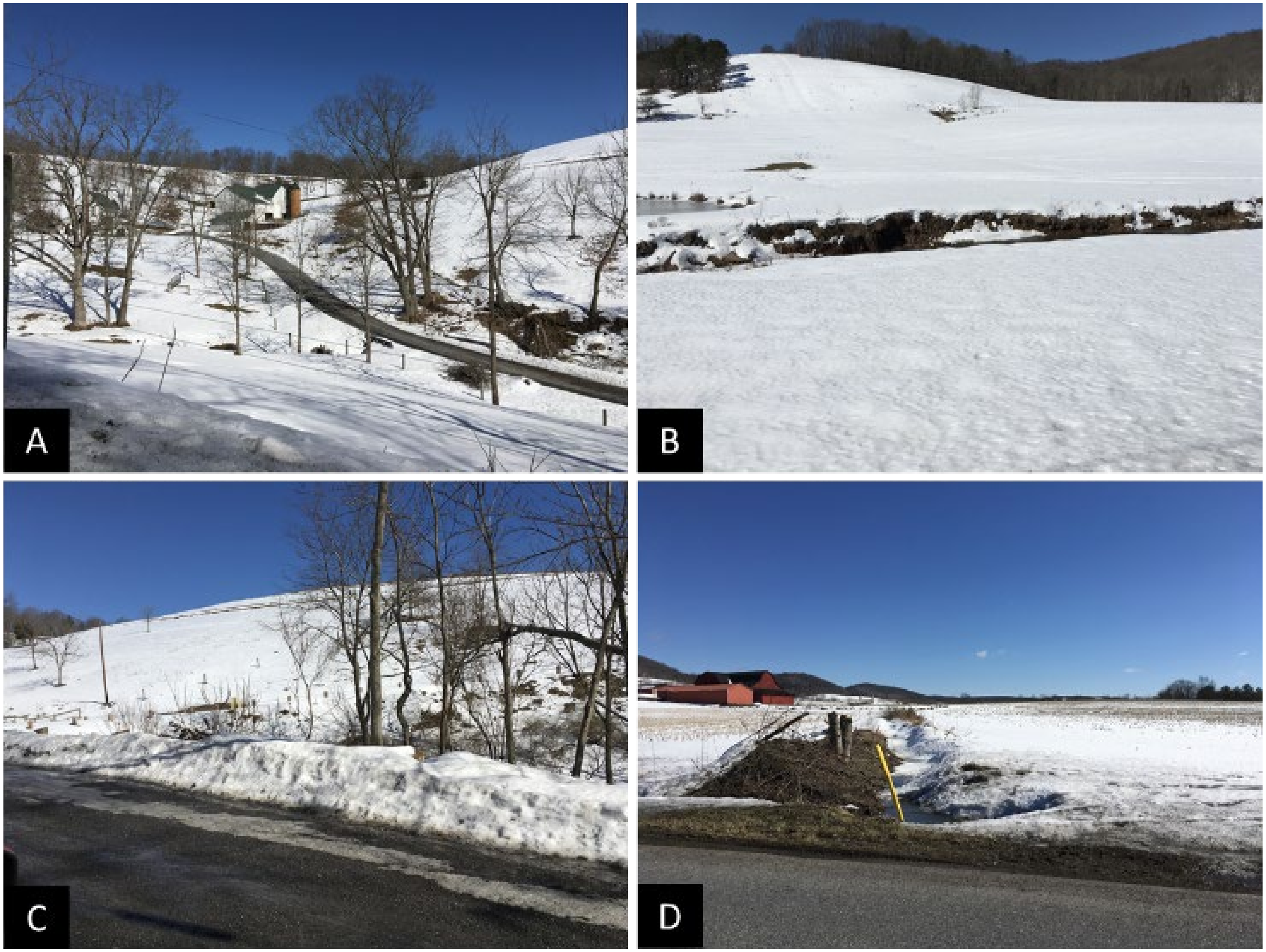

Figure 9. Agricultural conditions that may exacerbate sediment loading in the Carpenters Run Watershed. Note the presence of very steep agricultural lands that sometimes surrounded unbuffered streams or drainageways. Photograph D shows an unbuffered drainageway amongst croplands.

Figure 10. Additional factors that may exacerbate sediment loading in the Carpenters Run Watershed. Note the high amount of impervious area (A) and channelized drainageway (B) associated with the Lycoming Mall. Furthermore, the mainchannel in the area of the Lycoming Mall had highly erosive streambanks (C and D).

Figure 11. Factors that may be protective against sediment loading in the Carpenters Run Watershed. Much of the watershed was forested or had forested riparian buffers (A and B). Photographs C shows an area with recent riparian buffer plantings and photograph D shows a stormwater basin on the mall property.

Figure 12. Substrate conditions within larger mainstem segments of the Green Creek Subwatershed. Conditions were primarily rocky, especially in riffles. However, some fines deposition can be observed in the slower reach shown in photograph D.

Figure 13. Substrate conditions within smaller tributary reaches of the Green Creek Subwatershed. As with the mainstem, conditions were primarily rocky.

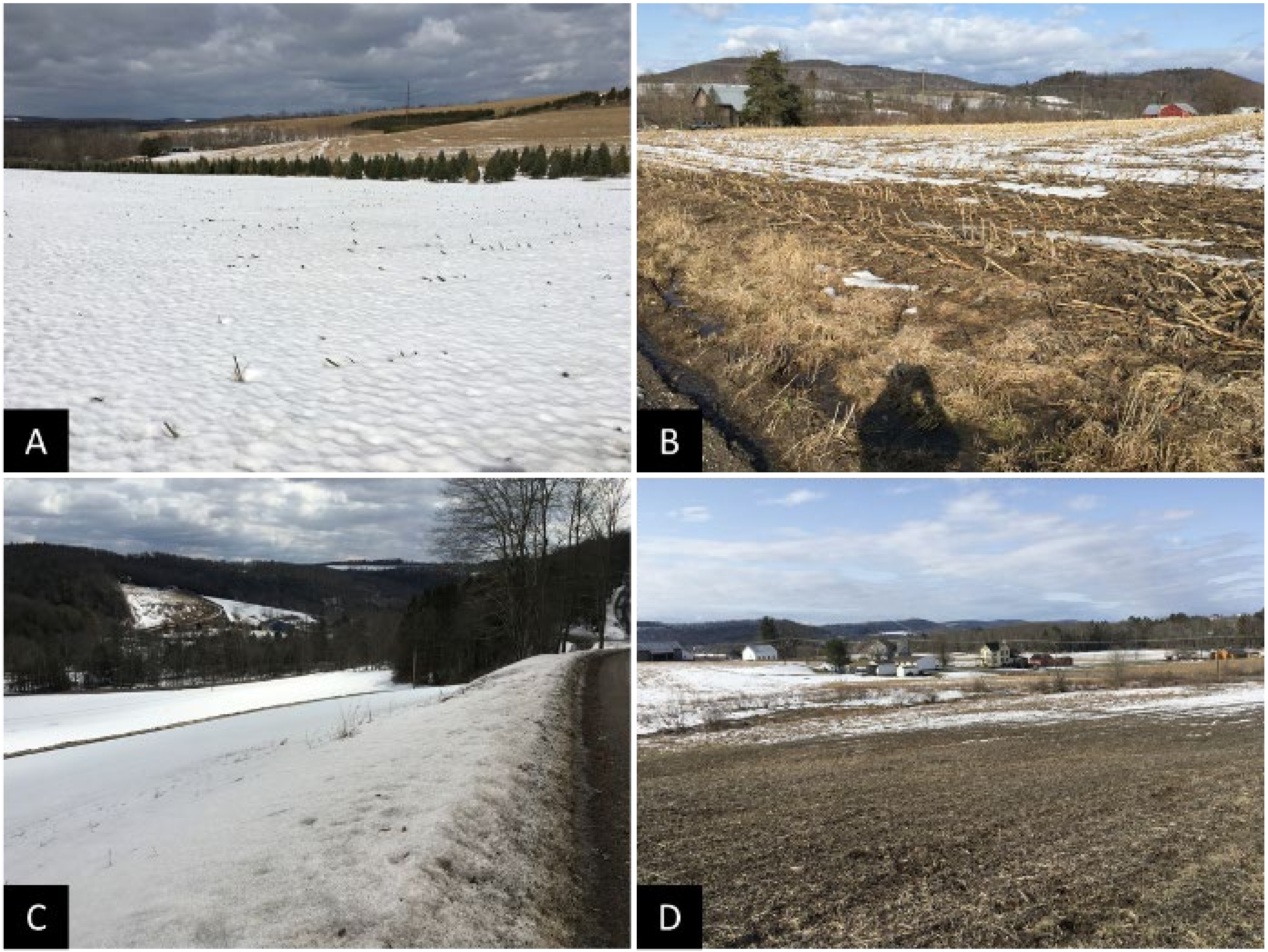

Figure 14. Example landscapes within the Green Creek Subwatershed. Photograph A shows a large expanse of agricultural lands, which commonly occurred in the upland areas. Photographs B and C shows examples of the hilly regions of the watershed which often occurred as a mix of agricultural and forest lands. Photograph D shows the broad agricultural valley typical of the downstream most reach of the watershed.

Figure 15. Examples of conditions that were protective of water quality in the Green Creek Subwatershed. Many reaches, both mainstem and tributary, occurred within forested landscapes (A and B). Furthermore, riparian buffers were common (C), and some sites contained new riparian buffer plantings (D).

Figure 16. Examples of conditions that may exacerbate sediment loading in the Green Creek Subwatershed. Photographs A and B show large expanses of croplands, and in some cases riparian buffers were lacking (B). Agricultural lands often occurred on steep slopes (C and D). Photograph C shows an area where land was being cleared, likely to create new agricultural fields. Photograph D shows a stream segment between steep agricultural fields. Note the lack of riparian buffers and livestock access to the stream.

Hydrologic / Water Quality Modeling

This section deals primarily with the $TMDL_{Avg}$ calculation, as use of annual average values was determined to be the most relevant way to express the "TMDL" variables. For information about the $TMDL_{Max}$ calculations, see the later "Calculation of a Daily Maximum '$TMDL_{Max}$'" section.

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

In the present study, watershed areas were defined using MMW's Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 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 Model My Watershed'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 EPA Center for Exposure Assessment Modeling (CEAM) meteorological data distribution. Erosion and sediment yield are

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

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

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

For a detailed discussion of this modelling program, including a description of the data input sources, see Evans and Corradini (2016) and Stroud Research Center (2019).

Model My Watershed allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling run, except that the flow from the small flow wastewater treatment plant noted in Table 4 (0.99 m^3/d) was added as an input to the Carpenters Run Watershed, and landcovers were adjusted to reflect newer NLCD 2016 landcover data. A raster dataset of NLCD 2016 landcover was opened in ArcGISPro and clipped to the shapefile of each subwatershed to determine the proportion of non-open water pixels accounted for by each landcover class. These proportions were then multiplied by the total area reported in Model My Watershed's landcover adjustment feature to readjust the inputs. Presumably due to rounding, the input value required by Model My Watershed for the Carpenters Run Watershed was 0.1 hectares greater than we calculated. Thus the input for "wooded areas" was increased by a negligible +/- 0.1 hectare to get the exact total needed by the program.

Some of Pennsylvania's recent sediment TMDLs have included a corrected loading to account for additional riparian buffering in the reference watershed. However, this was not done in the present study because it was determined that the rate of buffering along streams in the agricultural area of the impaired watershed was similar to that of the reference watershed. This was determined as follows. Riparian buffer coverage was estimated via a GIS analysis. Briefly, landcover per a high resolution landcover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of NHD flowlines. 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 be in an agricultural-dominated valley or have significant, obvious agricultural land on at least one side. This was not necessary for the Green Creek Subwatershed because the entire watershed was determined to be within the agricultural area. Then the sum of raster pixels that were classified as either "Emergent Wetlands", "Tree Canopy" or "Shrub/Scrub" was divided by the total number of non-water pixels to determine percent riparian buffer. Using this methodology, percent riparian buffer was determined to be 74% in the agricultural area of the impaired watershed versus 75% in the reference watershed.

Calculation of the $TMDL_{Avg}$

The mean annual sediment loading rate for the unimpaired reference subwatershed (Green Creek) was estimated to be 186 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired Carpenters Run Watershed (362 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the Carpenters Run Watershed should be reduced to 1,339,381 pounds per year or less (Table 9).

Table 7. Existing Annual Average Loading Values for the Green Creek Subwatershed, Reference

Source	Area ac	Sediment lbs/yr	Unit Area Load, lbs/ac/yr
Hay/Pasture	2,299	264,748	115
Cropland	491	504,155	1,027
Forest and Shrub/Scrub	3,232	8,826	3
Wetland	38	68	2
Grassland/Herbaceous (Open Land)	7	767	115
Bare Rock	8	11	1
Low Intensity Mixed Development	522	5,413	10
Medium Intensity Mixed Development	2	174	71
Streambank[1]		446,113	
Point Sources		0	
total	6,599	1,230,275	186

[1]"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.

Table 8. Existing Annual Average Loading Values for the Carpenters Run Watershed, Impaired

Source	Area, ac	Sediment, lbs/yr	Unit Area Load,

			lb/ac/yr
Hay/Pasture	1,814	782,589	431
Cropland	837	1,032,827	1,234
Forest and Shrub/Scrub	3,740	17,611	5
Wetland	20	45	2
Grassland/Herbaceous (Open Land)	9	736	79
Bare Rock	20	67	3
Low Intensity Mixed Development	579	6,403	11
Medium Intensity Mixed Development	85	4,941	58
High Density Mixed Development	78	4,511	58
Streambank		753,912	
Point Sources		8	
total	7,184	2,603,651	362

"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.

Table 9. Calculation of an Annual Average TMDL Value for the Carpenters Run Watershed.			
Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Avg}$ Value, lbs/yr
Sediment	186	7,184	1,339,381

Calculation of Load Allocations

In the TMDL equation, the load allocation (LA) is the load derived from nonpoint sources. The LA is further divided into the adjusted loads allocation (ALA), which is comprised of the nonpoint 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:

LA = ALA + LNR

Considering that the total maximum daily load (TMDL) is the sum of the margin of safety (MOS), the wasteload allocation (WLA), and the load allocation (LA):

TMDL = MOS + WLA + LA,

then the load allocation is calculated as follows:

LA = TMDL - MOS - WLA

Thus, before calculating the load allocation, the margin of safety and wasteload allocation must be defined.

Margin of Safety

The margin of safety (MOS) is a portion of pollutant loading that is reserved to account for uncertainties. Reserving a portion of the load as a safety factor requires further load reductions from the ALA to achieve the TMDL. For this analysis, the MOS_{Avg} was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

1,339,381 lbs/yr $TMDL_{Avg}$ * 0.1 = 133,938 lbs/yr MOS_{Avg}

Wasteload Allocation

The wasteload allocation (WLA) is the pollutant loading assigned to existing permitted point sources as well as future point sources.

There were no significant existing NPDES permittees with limits relevant to sediment. Thus, the wasteload allocation will consist solely of a 1% bulk reserve, which is a minor allowance for existing dischargers not assigned an individual wasteload allocation, and minor increases form point sources as a result of future growth of existing or new sources. In addition, the bulk reserve would likely contain more than sufficient capacity to cover any stormwaters construction permits.

Thus, the WLA was calculated as:

1,339,381 lbs/yr $TMDL_{Avg}$ * 0.01 = 13,394 lbs/yr bulk $reserve_{Avg}$ + 0 lb/yr permitted loads = 13,394 lbs/yr WLA_{Avg}

Since the wastewater treatment plant serving a single-family residence noted in Table 4 is only estimated to contribute a negligible 8 pounds of sediment per year, the bulk reserve will be more than sufficient to cover this facility.

Load Allocation

Now that the margin of safety and wasteload allocation have been defined, the load allocation (LA) is calculated as:

1,339,381 lbs/yr $TMDL_{Avg}$ – (133,938 lbs/yr MOS_{Avg} + 13,394 lbs/yr WLA_{Avg}) = 1,192,050 lbs/yr LA_{Avg}

Loads Not Reduced and Adjusted Load Allocation

Since the impairments addressed by this TMDL were for sedimentation due to agriculture, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands bare rock, and developed lands within the Carpenters Run Watershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 34,315 lbs/yr (Table 10).

The LNR is subtracted from the LA to determine the ALA:

1,192,050 lbs/yr LA_{Avg} – 34,315 lbs/yr LNR_{Avg} = 1,157,735 lbs/yr ALA_{Avg}

Table 10. Average Annual Load Allocation, Loads Not Reduced and Adjusted Load Allocation

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**1,192,050**
Loads Not Reduced (LNR_{Avg}):	**34,315**
Forest	17,611

Wetland	45
Open Land	736
Bare Rock	67
Low Intensity Mixed Development	6,403
Medium Intensity Mixed Development	4,941
High Density Mixed Development	4,511
Adjusted Load Allocation (ALA_{Avg})	**1,157,735**

Note, the ALA is comprised of the anthropogenic sediment sources targeted for reduction: croplands, hay/pasturelands and streambanks (assuming an elevated erosion rate). The LNR is comprised of both natural and anthropogenic sediment sources. While anthropogenic, developed lands were considered a negligible sediment source in this watershed and thus not targeted for reduction. Forests, wetlands, open lands (non-developed, non-agricultural grass/herbaceous lands) were considered natural sediment sources. Depending on its origin, bare tock may or may not be a natural sediment source, but either way it was a minor sediment source in the watershed.

Calculation of Sediment Load Reductions

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

In this evaluation no source sector exceeded the allocable load by itself. Thus, streambanks, hay/pasture lands and croplands all received the same prescribed reduction of 55% (Table 11).

Table 11. Average Annual Sediment Load Allocations for Source Sectors in the Carpenters Run Watershed.

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	837	465,390	1,032,827	55%
HAY/PASTURE	1,814	352,633	782,589	55%
STREAMBANK		339,711	753,912	55%
AGGREGATE		1,157,735	2,569,328	55%

Calculation of a Daily Maximum “$TMDL_{Max}$” Value

When choosing the best timescale for expressing pollutant loading limits for siltation, two major factors must be considered:

1) Sediment loading is driven by storm events, and loads vary greatly even under natural conditions.
2) Siltation pollution typically harms aquatic communities through habitat degradation as a result of chronically excessive loading.

Considering then that siltation pollution has more to do with chronic degradation rather than acutely toxic loads/concentrations, pollution reduction goals based on average annual conditions are much more relevant than daily maximum values. Nevertheless, a truer “Total Maximum Daily Load” ($TMDL_{Max}$) is also calculated in the following.

Model My Watershed currently does not report daily loading rates, but its predecessor program, “MapShed” does. Thus, for the calculation of a $TMDL_{Max}$ value, modelling was initially conducted in Model My Watershed as described above, and the “Export GMS” feature was used to provide an input data file that was run in MapShed. The daily output was opened in Microsoft Excel, and current “maximum” daily loads were calculated as the 99th percentiles (using the percentile.exc function) of estimated daily sediment loads in both the Carpenters Run (impaired) and Green Creek (reference) Watersheds. The first year of data was excluded to account for the time it takes for the model calculations to become reliable. The 99th percentile was chosen because 1) sediment loading increases with the size of storm events, so, as long as there could be an even larger flood, a true upper limit to sediment loading cannot be defined and 2) 99% of the time attainment of water quality criteria is prescribed for other types of pollutants per PA regulations (see PA Code Title 25, Chapter 96, Section 96.3(e)). The estimated daily maximum loading from the wastewater treatment plant serving the single-family residence shown in Table 4 was added to the total load in the Carpenters Run Watershed.

Then, similarly to the $TMDL_{Avg}$ value reported in Table 9, $TMDL_{Max}$ was calculated as the 99th percentile daily load of the reference watershed, divided by the acres of the reference watershed, and then multiplied by the acres of the impaired watershed. Thus, the $TMDL_{Max}$ loading rate was calculated as 56,069 pounds per day (Table 12), which would be an 45% reduction from Carpenter Run’s current 99th percentile daily loading rate of 102,288 pounds per day.

Table 12. Calculation of $TMDL_{Max}$ for the Carpenters Run Watershed

Pollutant	99th Percentile Loading Rate in Reference, lbs/ac/d	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Max}$ Value, lbs/d
Sediment	7.8	6,599	56,069

Also, in accordance with the previous “Calculation of Load Allocations” section, the WLA_{Max} would consist solely of a bulk reserve defined as 1% of the $TMDL_{Max}$.

The MOS_{Max} was defined as 10% of the $TMDL_{Max}$. The LA_{Max} was then calculated as the amount remaining after subtracting the WLA_{Max} and the MOS_{Max} from the $TMDL_{Max}$. See Table 13 for a summary of these $TMDL_{Max}$ variables.

Table 13. 99th Percentile of Daily Loading TMDL ($TMDL_{Max}$) Variables for the Carpenters Run Watershed.

lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	56,069	5,607	561	49,902

Mapshed did not break down daily loads by land use type. Thus, the daily maximum load allocation variables were calculated assuming the same distribution as occurred for the annual average load allocation variables. For instance, if the streambanks allocation was 28% of LA_{Avg} it was assumed that it was also 28% of LA_{Max}. While the distribution of sources likely changes with varying flow levels, this might be an acceptable assumption considering that the largest flow events may control the bulk of annual sediment loading (see Sloto et al. 2012). See Table 14 for a summary of the LA_{Max} variables.

Table 14. Allocation of the 99th Percentile Daily Load Allocation (LA_{Max}) for the Carpenters Run Watershed.

	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	1,192,050		49,902
Loads Not Reduced	34,315	0.03	1,436
Adjusted Loads Allocation	1,157,735	0.97	48,465
Croplands	465,390	0.39	19,482
Hay/Pasturelands	352,633	0.30	14,762
Streambanks	339,711	0.28	14,221

Because the modelling program did not break down daily loadings by land use types, the load allocations for $TMDL_{Max}$ were calculated by assuming the same distribution as occurred for the LA_{Avg} variables. For instance, if the streambanks allocation was 28% of LA_{Avg} it was assumed that it was also 28% of LA_{Max}.

Because sediment loading varies so greatly with discharge, the $TMDL_{Max}$ value would probably only be relevant on a handful of days each year with the highest flow conditions. And, while these times are especially important to overall annual sediment loading (see-Sloto and Olson 2011, Sloto et al. 2012), it is cautioned that reliance solely on a $TMDL_{Max}$ value may not be protective of the Carpenters Run Watershed because chronic excessive sediment inputs occurring at lower discharge levels may be ignored. Take for instance an extreme scenario where the $TMDL_{Max}$ was met every day but never exceeded. In this case, the annual sediment loading in the Carpenters Run Watershed would skyrocket to 20,465,222 lbs/yr, which almost eight-times the current annual average. The $TMDL_{Avg}$ value on the other hand is sensitive to typical conditions, extreme events, and long-term effects, and thus is the most relevant of the two TMDL targets for achieving restoration in the Carpenters Run Watershed. Therefore, BMP implementation would ultimately be deemed adequate if the prescribed annual average reductions were satisfied.

Consideration of Critical Conditions and Seasonal Variations

According to Model My Watershed's technical documentation (see Stroud Water Research Center 2019), Model My Watershed uses a "continuous simulation model that uses daily time steps for weather data and water balance. 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. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations. Furthermore, this document calculates both annual average and 99^{th} percentile daily TMDL values. See the discussion of the relevance of these values in the previous section. Seeking to attain both of these values will be protective under both long-term average and extreme flow event conditions.

Recommendations

This document proposes a 49% reduction in annual average sediment loading for the Carpenters Run Watershed. To achieve this goal while maintaining a margin of safety and minor allowance for point sources, annual average sediment loading should be reduced by 55% each from croplands, hay/pasture lands and streambanks. The 99^{th} percentile daily sediment loading should be reduced by 45%. Reductions in stream sediment loading due to agricultural activities can be made through the implementation of required Erosion and Sediment Control Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Chapter 102.4, see also Appendix E) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, etc.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. Furthermore, riparian buffers are also beneficial for many other reasons beyond just protecting from sedimentation and nutrients. For instance, riparian buffers may: filter out other pollutants such as pesticides; provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; and moderate stream temperature. Thus, use of forested riparian buffers should be encouraged wherever possible. While the Carpenters Run Watershed typically had a good rate of riparian buffering, some areas were noted where riparian buffers could have been improved. And, given that agriculture often occurred on steep topography, buffering may need to be especially wide to be highly protective. Furthermore, the extension of buffers up into ephemeral drainageways may be necessary to prevent the formation of concentrated flowpaths that can circumvent streamside buffers.

Improvements to stormwater BMPs within the Lycoming Mall and surrounding developed areas could also be used to prevent sediment pollution both directly and indirectly. Consider the stormwater basin shown in Figure 11. As evidenced by the largely unimpeded channel of snowmelt passing through the basin, it may do little to prevent pollution during smaller storm events. However, if retrofitted to promote infiltration, direct sediment removal from floodwaters may be enhanced and discharge volume during a wider range of storm events could be moderated, which may reduce streambank erosion.

Development of a more detailed watershed implementation plan is recommended. Further ground truthing should be performed to assess both the extent of existing BMPs and to determine the most cost effective and environmentally protective combination of BMPs required for meeting the prescribed sediment reductions. Key personnel from the regional DEP office, the County Conservation District, Susquehanna River Basin Commission (SRBC) and other state and local agencies and/or watershed groups should be involved in developing a restoration strategy. There are a number of possible funding sources for agricultural BMPs and stream restoration projects, including: The Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), PA DEP's Growing Greener Grant Program, United States Department of Agriculture's Natural Resource Conservation Service funding, and National Fish and Wildlife Foundation Grants.

Public Participation

Public notice of a draft of this TMDL was published in the May 15, 2021 issue of the Pennsylvania Bulletin to foster public comment. A 30-day period was provided for the submittal of comments. No public comments were received.

Citations

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Appendix A: Background on Stream Assessment Methodology

Integrated Water Quality Monitoring and Assessment Report, List 5, 303(d), Listing Process

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 2018 Assessment Methodology for Rivers and Stream, available at https://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Methodology/2015%20Methodology/Assessment_Book.pdf

Documentation of other historic methodologies are available upon request.

Assessment Methods:

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be listed 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 and found on List 5. Table A1. summarizes the changes to listing documents and assessment methods over time.

With guidance from EPA, the states have developed methods for assessing the waters within their respective jurisdictions. From 1996-2006, the primary method adopted by the Pennsylvania Department of Environmental Protection for evaluating waters found on the 303(d) lists (1998-2002) or in the Integrated Water Quality Monitoring and Assessment Report (2004-2006) was the Statewide Surface Waters Assessment Protocol (SSWAP). SSWAP was a modification of the EPA 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 land uses, 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 present 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 land uses, 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 EPA Rapid Bioassessment Protocol III (RPB-III) and provides a more rigorous and consistent approach to assessing Pennsylvania's streams than the SSWAP.

After these surveys (SSWAP, 1998-2006 lists or ICE, 2008-present lists) are completed, the biologist 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 was to be listed on the state's 303(d) List, or presently, the Integrated Water Quality Monitoring and Assessment Report 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 receives a separate and specific TMDL within that stream segment. Adjoining stream segments with the same source and cause listings are 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-Present	Integrated List	ICE

Integrated List= Integrated Water Quality Monitoring and Assessment Report
SSWAP= Statewide Surface Waters Assessment Protocol
ICE= Instream Comprehensive Evaluation Protocol

Justification of Mapping Changes to 303(d) Lists 1998 to Present

The following are excerpts from the Pennsylvania DEP Section 303(d) narratives that justify changes in listings between the 1996-2002 303(d) Lists and the 2004 to present Integrated Water Quality Monitoring and Assessment Reports. The Section 303(d) listing process has undergone an evolution in Pennsylvania since the development of the 1996 list.

In the 1996 Section 303(d) narrative, strategies were outlined for changes to the listing process. Suggestions included, but were not limited to, a migration to a Global Information System (GIS), improved monitoring and assessment, and greater public input.

The migration to a GIS was implemented prior to the development of the 1998 Section 303(d) list. Because of additional sampling and the migration to the GIS, some of the information appearing on the 1996 list differed from the 1998 list. Most common changes included:

1. mileage differences due to recalculation of segment length by the GIS;
2. slight changes in source(s)/cause(s) due to new EPA codes;
3. changes to source(s)/cause(s), and/or miles due to revised assessments;
4. corrections of misnamed streams or streams placed in inappropriate SWP subbasins; and
5. unnamed tributaries no longer identified as such and placed under the named watershed listing.

Prior to 1998, segment lengths were computed using a map wheel and calculator. The segment lengths listed on the 1998 Section 303(d) list were calculated automatically by the GIS (ArcInfo) using a constant projection and map units (meters) for each watershed. Segment lengths originally calculated by using a map wheel and those calculated by the GIS did not always match closely. This was the case even when physical identifiers (e.g., tributary confluence and road crossings) matching the original segment descriptions were used to define segments on digital quad maps. This occurred to some extent with all segments, but was most noticeable in segments with the greatest potential for human errors using a map wheel for calculating the original segment lengths (e.g., long stream segments or entire basins).

Migration to National Hydrography Data (NHD)

New to the 2006 report is use of the 1/24,000 National Hydrography Data (NHD) streams GIS layer. Up until 2006 the Department relied upon its own internally developed stream layer. Subsequently, the United States Geologic Survey (USGS) developed 1/24,000 NHD streams layer for the Commonwealth based upon national geodatabase standards. In 2005, DEP contracted with USGS to add missing streams and correct any errors in the NHD. A GIS contractor transferred the old DEP stream assessment information to the improved NHD and the old DEP streams layer was archived. Overall, this marked an improvement in the quality of the streams layer and made the stream assessment data compatible with national standards but it necessitated a change in the Integrated Listing format. The NHD is not attributed with the old DEP five-digit stream codes so segments can no longer be listed by stream code but rather only by stream name or a fixed combination of NHD fields known as reachcode and ComID. The NHD is aggregated by Hydrologic Unit Code (HUC) watersheds so HUCs rather than the old State Water Plan (SWP) watersheds are now used to group streams together. A more basic change was the shift in data management philosophy from one of “dynamic segmentation” to “fixed segments”. The dynamic segmentation records were proving too difficult to manage from an historical tracking perspective. The fixed segment methods will remedy that problem. The stream assessment data management has gone through many changes over the years as system requirements and software changed. It is hoped that with the shift to the NHD and OIT’s (Office of Information Technology) fulltime staff to manage and maintain SLIMS the systems and formats will now remain stable over many Integrated Listing cycles.

Appendix B: Model My Watershed Generated Data Tables

NLCD_Land_Cover_Class	proportion	Area (ha)
Developed, Open Space	0.06	177.0
Developed, Low Intensity	0.02	57.5
Developed, Medium Intensity	0.01	34.5
Developed, High Intensity	0.01	31.5
Barren Land	0.00	7.9
Deciduous Forest	0.29	837.9
Evergreen Forest	0.03	77.8
Mixed Forest	0.20	594.7
Shrub/Scrub	0.00	4.5
Herbaceuous	0.00	3.8
Hay/Pasture	0.25	734.8
Cultivated Crops	0.12	339.1
Woody Wetlands	0.00	6.9
Emergent Herbaceuous Wetlands	0.00	1.4

Table B1. Land Cover based on NLCD 2016 for the Carpenters Run Watershed. Note that when entered into Model My Watershed, wooded areas (forests + shrub/scrub) were increased by 0.1 ha to get the exact input total needed.

NLCD_Land_Cover_Class	proportion	Area (ha)
Developed, Open Space	0.07	193.7
Developed, Low Intensity	0.01	17.6
Developed, Medium Intensity	0.00	1.0
Barren Land	0.00	3.1
Deciduous Forest	0.22	577.2
Evergreen Forest	0.03	84.7
Mixed Forest	0.24	643.6
Shrub/Scrub	0.00	3.6
Herbaceuous	0.00	2.7
Hay/Pasture	0.35	930.9
Cultivated Crops	0.07	198.9
Woody Wetlands	0.00	13.1
Emergent Herbaceuous Wetlands	0.00	2.3

Table B2. Land Cover based on NLCD 2016 for the for the Green Creek Subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	6.24	1.09	5.15	0	0.35	7.15
Feb	6.63	1.35	5.29	0	0.54	7.31
Mar	7.4	0.7	6.7	0	1.91	8.36
Apr	5.9	0.2	5.7	0	4.74	8.41
May	3.8	0.17	3.63	0	8.84	10.51
Jun	2.98	0.98	2	0	10.51	10.58
Jul	0.97	0.21	0.76	0	9.8	9.86
Aug	0.46	0.16	0.3	0	8.29	8.64
Sep	1.41	0.88	0.54	0	5.81	9.04
Oct	2.24	0.69	1.55	0	3.72	8.06
Nov	3.75	0.56	3.19	0	1.83	9.38
Dec	6.54	0.8	5.74	0	0.72	8.11
Total	48.32	7.79	40.55	0	57.06	105.41

Table B3. “Model My Watershed” Hydrology Outputs for the Carpenters Run Watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.27	0.95	4.32	0	0.27	6.21
Feb	5.99	1.44	4.56	0	0.43	6.32
Mar	6.53	0.7	5.83	0	1.6	7.43
Apr	5.86	0.56	5.3	0	3.63	8.08
May	4.16	0.16	4	0	7.68	9.73
Jun	3	0.61	2.38	0	10.25	10.74
Jul	1.19	0.21	0.98	0	10.73	10.1
Aug	0.55	0.18	0.37	0	8.3	8.65
Sep	1.18	0.65	0.53	0	5.69	8.79
Oct	2.33	0.67	1.66	0	3.4	7.88
Nov	3.78	0.58	3.2	0	1.58	8.79
Dec	5.86	0.83	5.03	0	0.59	7.18
Total	45.7	7.54	38.16	0	54.15	99.9

Table B4. “Model My Watershed” Hydrology Outputs for the Green Creek Subwatershed.

Sources	Sediment (kg)
Hay/Pasture	354,915.70
Cropland	468,402.40
Wooded Areas	7,986.90
Wetlands	20.2
Open Land	333.8
Barren Areas	30.6
Low-Density Mixed	712
Medium-Density Mixed	2,240.90
High-Density Mixed	2,046.00
Low-Density Open Space	2,191.90
Farm Animals	0
Stream Bank Erosion	341,910.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B5. Model My Watershed outputs for sediment in the Carpenters Run Watershed.

Sources	Sediment (kg)
Hay/Pasture	120,066.90
Cropland	228,641.70
Wooded Areas	4,002.60
Wetlands	31
Open Land	347.7
Barren Areas	5.1
Low-Density Mixed	204.5
Medium-Density Mixed	79
High-Density Mixed	0
Low-Density Open Space	2,250.50
Farm Animals	0
Stream Bank Erosion	202,319.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B6. Model My Watershed Outputs for Sediment in the Green Creek Subwatershed.

Appendix C: Stream Segments in the Carpenters Run Watershed with Impairments for Aquatic Life Use

NHD Flowline COMID:	Length (miles):	ATTAINS ID:	Impairment Source:	Impairment Cause:	Date Listed As Impaired:
66914819	0.66	PA-SCR-66914819	URBAN RUNOFF/STORM SEWERS	CAUSE UNKNOWN	1998
66914923	0.10	PA-SCR-66914923	URBAN RUNOFF/STORM SEWERS	CAUSE UNKNOWN	1998
66914331	0.48	PA-SCR-66914331	HABITAT MODIFICATION - OTHER THAN HYDROMODIFICATION	HABITAT ALTERATIONS	1998
66914179	1.19	PA-SCR-66914179	HABITAT MODIFICATION - OTHER THAN HYDROMODIFICATION	HABITAT ALTERATIONS	1998
66914603	0.84	PA-SCR-66914603	HABITAT MODIFICATION - OTHER THAN HYDROMODIFICATION	HABITAT ALTERATIONS	1998
66914819	0.66	PA-SCR-66914819	AGRICULTURE	SILTATION	1998
66912851	0.28	PA-SCR-66912851	AGRICULTURE	SILTATION	1998
66913841	0.31	PA-SCR-66913841	AGRICULTURE	SILTATION	1998
66913351	0.67	PA-SCR-66913351	AGRICULTURE	SILTATION	1998
66913707	0.95	PA-SCR-66913707	AGRICULTURE	SILTATION	1998
66912801	0.23	PA-SCR-66912801	AGRICULTURE	SILTATION	1998
66913349	0.84	PA-SCR-66913349	AGRICULTURE	SILTATION	1998
66913023	0.43	PA-SCR-66913023	AGRICULTURE	SILTATION	1998
66912761	0.58	PA-SCR-66912761	AGRICULTURE	SILTATION	1998
66912853	0.71	PA-SCR-66912853	AGRICULTURE	SILTATION	1998
66912497	0.66	PA-SCR-66912497	AGRICULTURE	SILTATION	1998
66912411	0.67	PA-SCR-66912411	AGRICULTURE	SILTATION	1998
66914381	2.40	PA-SCR-66914381	AGRICULTURE	SILTATION	1998
66912877	0.47	PA-SCR-66912877	AGRICULTURE	SILTATION	1998
66913709	0.19	PA-SCR-66913709	AGRICULTURE	SILTATION	1998
66913025	0.96	PA-SCR-66913025	AGRICULTURE	SILTATION	1998
66912763	0.85	PA-SCR-66912763	AGRICULTURE	SILTATION	1998
66914923	0.10	PA-SCR-66914923	AGRICULTURE	SILTATION	1998
66913625	0.73	PA-SCR-66913625	AGRICULTURE	SILTATION	1998
66912803	0.40	PA-SCR-66912803	AGRICULTURE	SILTATION	1998
66913623	0.58	PA-SCR-66913623	AGRICULTURE	SILTATION	1998
66912759	0.61	PA-SCR-66912759	AGRICULTURE	SILTATION	1998

Appendix D: Equal Marginal Percent Reduction Method

Equal Marginal Percent Reduction (EMPR) (An Allocation Strategy)

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute the Adjusted Load Allocation (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 Adjusted Load Allocation based on TMDL, MOS, WLA and existing loads not reduced.

Step 3: Actual EMPR Process:

a. Each land use/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

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much 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	1,032,827	no	1,032,827		0.40	567,437	465,390	0.55
Hay/Pasture	782,589	no	782,589	1,411,593	0.30	429,956	352,633	0.55
Streambank	753,912	no	753,912		0.29	414,200	339,711	0.55
sum	**2,569,328**		**2,569,328**		**1.00**	**1,411,593**	**1,157,735**	**0.55**

Table D1. Equal Marginal Percent Reduction calculations for the Carpenters Run Watershed.

Appendix E: Legal Basis for the TMDL and Water Quality Regulations for Agricultural Operations

Clean Water Act Requirements

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support that use. Uses can include designations for drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be “fishable” and “swimmable.”

Additionally, the federal Clean Water Act and the United States Environmental Protection Agency’s (EPA) implementing regulations (40 CFR 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;
- States to submit the list of waters to EPA every two years (April 1 of the even numbered years);
- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and
- EPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Pennsylvania Clean Streams Law Requirements, Agricultural Operations

Pennsylvania farms are required by law to operate within regulatory compliance by implementing the applicable requirements outlined in the Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Part I Department of Environmental Protection, Subpart C Protection of Natural Resources, Article II Water Resources, Chapters: § 91.36 Pollution control and prevention at agricultural operations, § 92a.29 CAFO and § 102.4 Erosion and sediment control requirements. Water quality regulations can be found at following website: http://www.pacode.com/secure/data/025/025toc.html

Agricultural regulations are designed to reduce the amount of sediment and nutrients reaching the streams and ground water in a watershed.

Appendix F: Comment and Response

No public comments were received.