Little Trough Creek Sediment TMDL

Huntingdon County, Pennsylvania

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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

"Total Maximum Daily Loads" (TMDLs) for sediment were developed for the Little Trough Creek Subwatershed (Figure 1) to address the siltation impairments noted in the 2018 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Grazing related 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 Little Trough Creek Subwatershed was estimated to be 2,892,402 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 23% to 2,234,466 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 streambanks should be reduced by 33% whereas loading from hay/pasture lands and croplands should be reduced by 28% each.

Table 1. Summary of Annual Average TMDL ($TMDL_{Avg}$) Variables for the Little Trough Creek Subwatershed

lbs/yr:						
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	2,234,466	223,447	25,083	1,985,936	33,144	1,952,793

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 Little Trough Creek Subwatershed was estimated to be 50,469 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 11% to 45,085 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 Little Trough Creek Subwatershed

lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	45,085	4,509	498	40,079	669	39,410

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

Little Trough Creek is a tributary of Great Trough Creek, with the confluence approximately four miles to the southeast of Trough Creek State Park (Figure 1). This Total Maximum Daily Load (TMDL) document has been prepared to address the siltation from grazing related agriculture impairments listed for the middle and lower valley mainstem, as well as for two tributaries, (Figure 1, Table 3) per the 2018 Final Integrated Report (see Appendix A for a description of assessment methodology). The Little Trough Creek Subwatershed was approximately 27 square miles and occurred entirely within Huntingdon County. It contained approximately 70 stream miles, all of which were designated for Trout Stocking (TSF) 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 2011 landcover data, as reported by Model My Watershed, land use in the study watershed was estimated to be 76% forest/naturally vegetated lands, 18% agriculture, and 5% mixed development. The vast majority of agricultural lands were hay/pasture lands (Appendix B, Table B1). There was one current NPDES permitted discharge in the watershed with load limits relevant to sedimentation, the wastewater treatment plant serving Cassville (Table 4). Analysis of its electronic discharge monitoring report data and its NPDES permit suggest it was a minor source of sediment.

Table 3. Aquatic-Life Impaired Stream Segments in the Little Trough Creek Subwatershed per the 2018 Final Pennsylvania Integrated Report

HUC: 02050303 – Raystown				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Grazing Related Agriculture	Siltation	11.1	TSF, MF	Aquatic Life

Grazing Related Agriculture	Other Habitat Alterations	4.2		Aquatic Life

HUC= Hydrologic Unit Code; TSF=Trout Stocking; MF= Migratory Fishes
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.

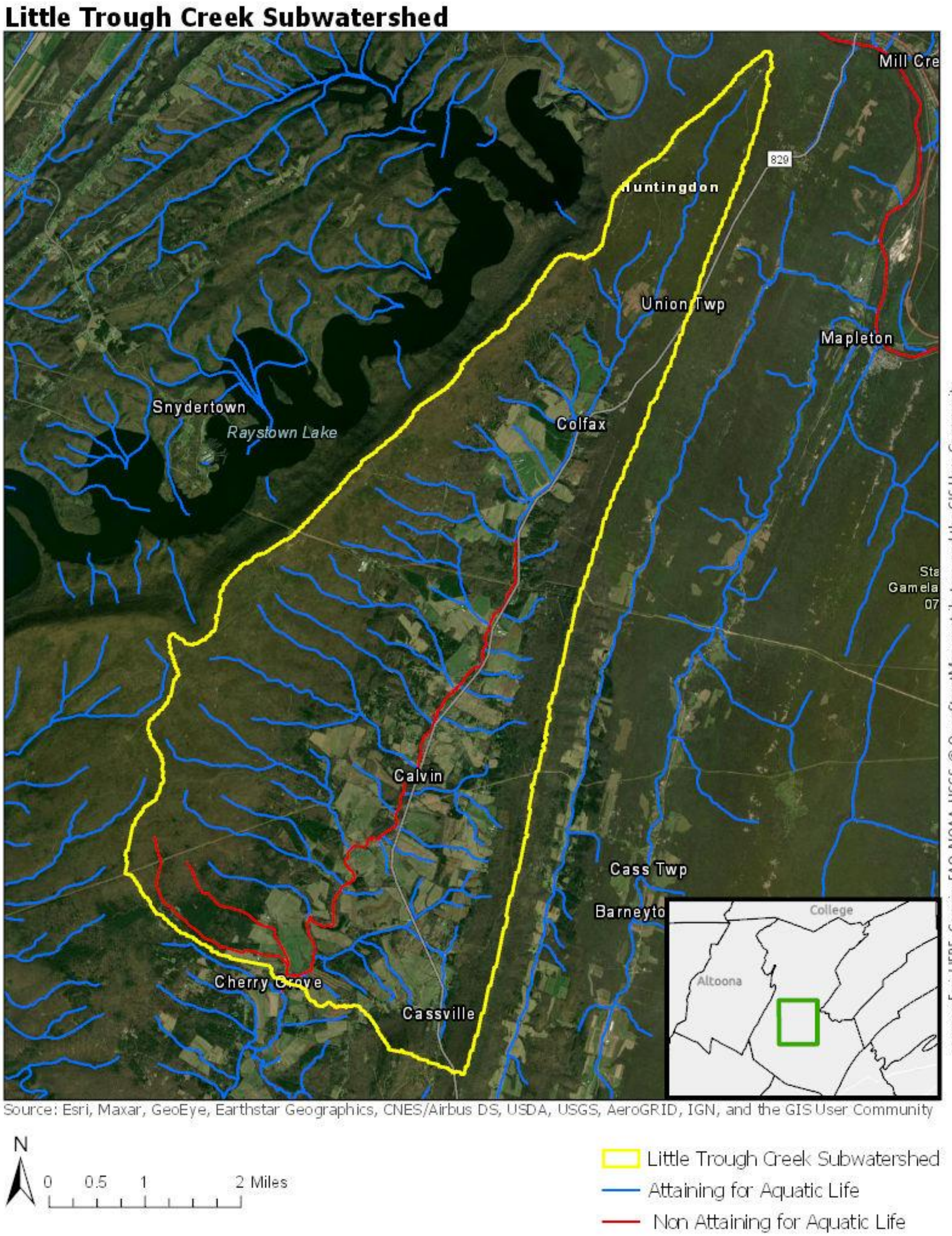

Figure 1. Little Trough Creek Subwatershed.

Table 4. Existing NPDES-Permitted Discharges in the Little Trough Creek Subwatershed 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
PA0087955	Cassville Water & Sewer Authority WWTP	2,738	45	501	47
PAG103570	Sunoco Pipeline LP (Expired)	NA	NA	NA	NA
PAG123658	Harley Bange CAFO	NA	NA	NA	NA
PAG123892	Cast Carowick Swine CAFO	NA	NA	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.

Cassville Water & Sewer Authority WWTP.
Permit based loads: Mean annual sediment load based on an average monthly loading limit of 7.5 lbs/d per their permit issued April 28, 2017. This value was multiplied by 365 days/yr. The maximum daily load was based off of an instantaneous maximum total suspended solids concentration limit of 60 mg/L and a flow value of 0.09 MGD (hydraulic design capacity times a peaking factor of 3) per their permit.

eDMR based values. During preparation of the initial draft of this TMDL, three full years of monthly reported eDMR data were available for this facility. For the average annual sediment load, the monthly average values in lbs/d were multiplied by the number of days in the month and all the months in a year were summed to create annual values. The three annual values were averaged to generate the number reported above. Maximum daily sediment load was calculated using the highest monthly reported daily maximum flow from December 2017 through January 2021. This value, along with the assumption that they discharged at their instantaneous maximum permitted TSS concentration limit of 60 mg/L was used to generate the maximum daily load reported above.

Sunoco Pipeline LP. Transient expired permit for hydrostatic testing of pipeline.

In Pennsylvania, routine, dry-weather discharges from concentrated animal feeding operations (CAFOs) are not allowed. Wet weather discharges are controlled through best management practices, resulting in infrequent discharges from production areas and reduced sediment loadings associated with lands under the control of CAFOs owner or operators, such as croplands where manure is applied. Although not quantified in this table, sediment loading from CAFOs is accounted for since the modelling program estimates loadings from croplands and hay/pasturelands.

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 to 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 Little Trough Creek Subwatershed, 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 fourteen miles to the southwest), 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 Sideling Hill Creek in Fulton County was considered for use as a reference (Figures 2 and 3, Table 5).

Table 5. Comparison of Little Trough and the Sideling Hill Creek Subwatersheds.		
	Little Trough	Sideling Hill
Phys. Province[1]	Appalachian Mountain Section of the Ridge and Valley Province	Appalachian Mountain Section of the Ridge and Valley Province
Land Area[2], ac	17,331	16,765
Land Use[2]	18% Agriculture 76% Forest/Natural Vegetation 5% Developed	11% Agriculture 84% Forest/Natural Vegetation 5% Developed
Soil Infiltration[3]	26% Group A 33% Group B 3% Group B/D 1% Group C 8% Group C/D 28% Group D	18% Group A 40% Group B 3% Group B/D 22% Group C 0.2% Group C/D 17% Group D
Dominant Bedrock[4]	54% Sandstone 46% Shale 0.4% Argillaceous Sandstone	60% Sandstone 38% Shale 1% Argilaceous Sandstone
Average Precipitation[5], in/yr	41.5	40.4
Average Surface Runoff[5], in/yr	1.7	1.6
Average Elevation[5] (ft)	1,366	1,465
Average Slope[5]	9%	14%
Stream Channel Slope[5]	1st order: 3.29% 2nd order: 0.85% 3rd order: 0.08%	1st order: 4.95% 2nd order: 0.99% 3rd order: 0.30%

[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 based on NLCD 2011.
[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 Appalachian Mountain Section of the Ridge and Valley Physiographic Province and had modest agricultural coverage, though the percentage of agricultural land area was almost twice as much in the Little Trough Creek Subwatershed versus the Sideling Hill Creek Subwatershed (18 versus 11%-Table 5). Both watersheds were dominated by naturally vegetated lands and developed lands were minimal (Table 5 and Appendix Tables B1 and B2.)

Both watersheds had sandstone and shale bedrocks (Table 5) and the average topographic slope in both watersheds was similar, though slightly higher in the Sideling Hill Creek Subwatershed versus the Little Trough Creek Subwatershed (14% vs 9%). A notable feature of both watersheds was the low gradient nature of their third order segments; 0.3% stream slope in the Little Trough Creek Subwatershed, and an exceptionally low 0.08% in the Little Trough Creek Subwatershed (Table 5). Both watersheds had a mixture or well and poorly drained soils, and estimated surface runoff rates were nearly the same (1.7 versus 1.6 inches per year) (Table 5).

A potentially concerning difference between the Little Trough Creek Subwatershed and the Sideling Hill Creek Subwatershed was that stream segments within the Sideling Hill Creek Subwatershed were attaining a High-Quality Cold-Water Fishes designation whereas stream segments within the Little Trough Creek Subwatershed were designated for Trout Stocking. Use of a watershed that is actually attaining a special protection status (high quality or exceptional value) as a reference for a non-special special protection watershed could cause prescribed pollution reductions to be unnecessarily stringent. However, this concern was dismissed because the Sideling Hill Creek Subwatershed was the best overall reference identified based on a combination of watershed characteristics and quality of assessment data, and the calculated reductions reported below were modest and determined to be appropriate for the Little Trough Creek Subwatershed based on site observations and professional judgement.

There were no NPDES permitted point source discharges with concentration limits relevant to sediment in the Sideling Hill Creek Subwatershed (Table 6).

Table 6. Existing NPDES-Permitted Discharges in the Sideling Hill 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 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. Both watersheds were visited during December 2020. However, since an area of the Sideling Hill Creek Subwatershed was used as a reference in a prior project, recent observations from February of 2020 were also used to evaluate this watershed.

Site observations in the Little Trough Creek Subwatershed indicated that the streambed was dominated by fine sediment, in part due to agricultural pollution but also due to natural sandy conditions (Figures 4 and 5). Indeed, some sites, particularly in the lower mainstem but also some tributaries, had high turbidity and deposits of finer fractions often associated with agriculture. However, the presence of sandy substrate in headwater areas where substantial agricultural pollution was not suspected along with sandstone bedrock suggested that sandy substrate was natural for this watershed, especially in the very low gradient reaches.

It is hypothesized that the noted impairments may be attributable to poor agricultural practices in a watershed that was especially vulnerable to sediment deposition. While there were substantial agricultural lands in the valley (Figure 6), the overall amount of agriculture in the watershed was modest (Table 5) and dominated by hay/pasture lands (Table B1) which tend to be lesser sediment sources than croplands. However, areas were observed where: pasture lands were trampled to the point of creating bare patches, cattle had direct access to the stream resulting in enhanced bank erosion and lack of riparian buffering, and barnyard areas drained towards streams (Figure 7). It should also be noted though that natural conditions, including an abundance of forest and wetlands (Figure 8) as well as good management practices such as allowances for riparian buffers and the use of cattle exclusion fencing (Figure 9) likely protected water quality in this watershed. Overall, conditions within the watershed did not appear to be particularly bad and perhaps would not have even resulted in impairments in many other watersheds. However, the middle and lower mainstem of the Little Trough Creek Subwatershed was so low gradient (Figures 4 and 10) that sediment deposition rather than export may be favored.

Part of the reason that the Sideling Hill Creek Subwatershed was selected as a potential reference was that like the Little Trough Creek Subwatershed, regions of its mainstem were also low gradient, yet the entire watershed was listed as attaining its aquatic life use (Figures 3 and 10). And, it also exhibited naturally sandy conditions in some reaches likely due to its low gradient and sandstone geology (Figure 11). Unlike the lower Little Trough Creek however, valley mainstem segments within the Sideling Hill Creek Subwatershed had exceptional water clarity (Figure 11). As for smaller tributaries, many appeared to be naturally sandy, some were primarily rocky, and some exhibited substantial deposition of finer fractions apparently due to wetland conditions or in some cases apparently localized agriculture impacts (Figure 12).

Like the Little Trough Creek Subwatershed, uplands within the Sideling Hill Creek Subwatershed were primarily forested whereas valleys had substantial hay and pasture lands but little croplands (Figure 13). The overall amount of agriculture within the Sideling Hill Creek Subwatershed was substantially less however, about half as what occurred within the Little Trough Creek Subwatershed. In addition to its lesser amount of agriculture, conditions that promoted stream health within the Sideling Hill Creek Subwatershed included that so many of its stream segments occurred within forested areas or had forested buffers (Figures 3 and 14). Other practices such as the use of herbaceous buffers and cattle exclusion fencing were observed as well (Figure 14). It should also be noted though that there were also areas where conditions clearly could have been improved in the Sideling Hill Creek Subwatershed, particularly through the use of riparian buffers.

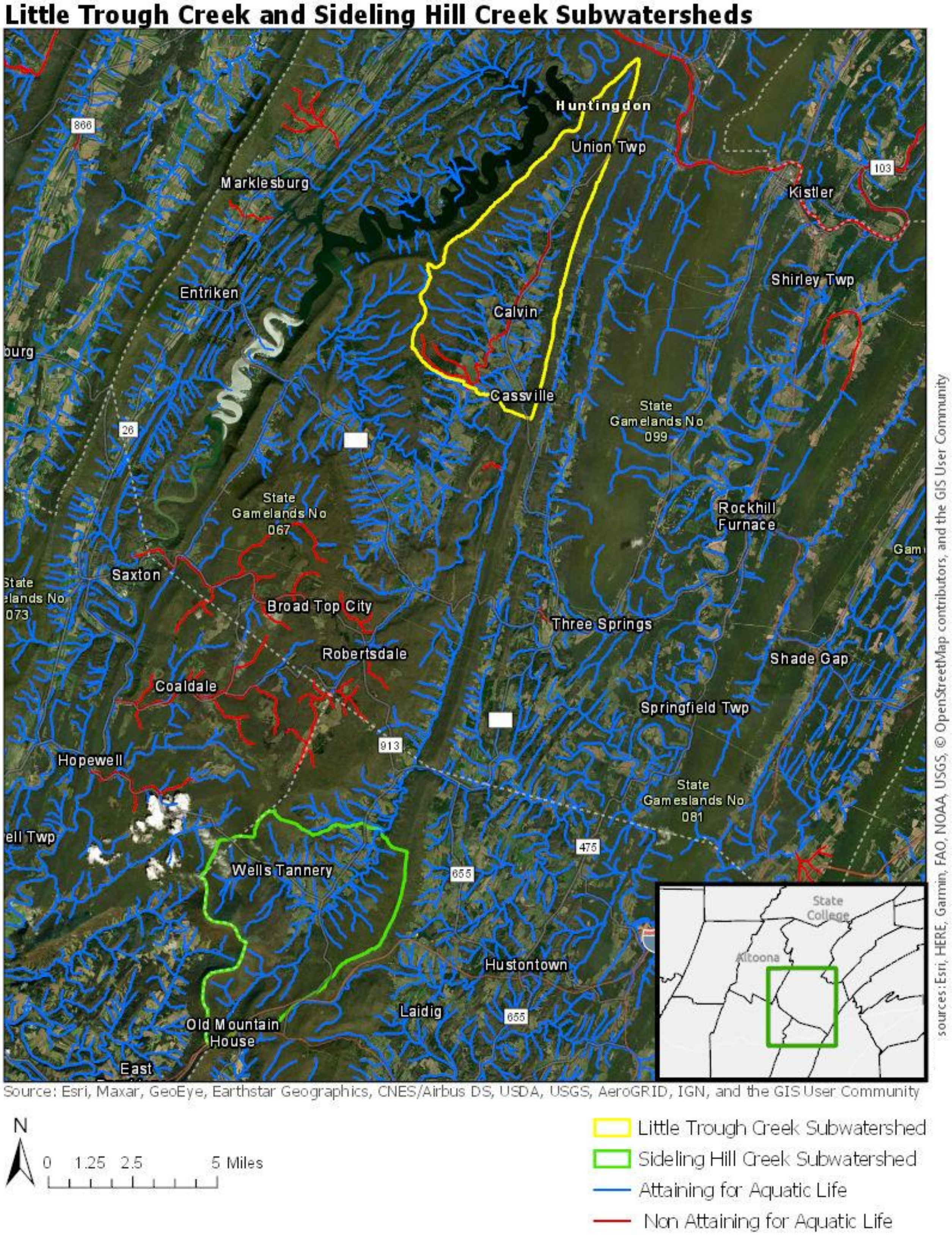

Figure 2. Little Trough Creek and Sideling Hill Creek Subwatersheds.

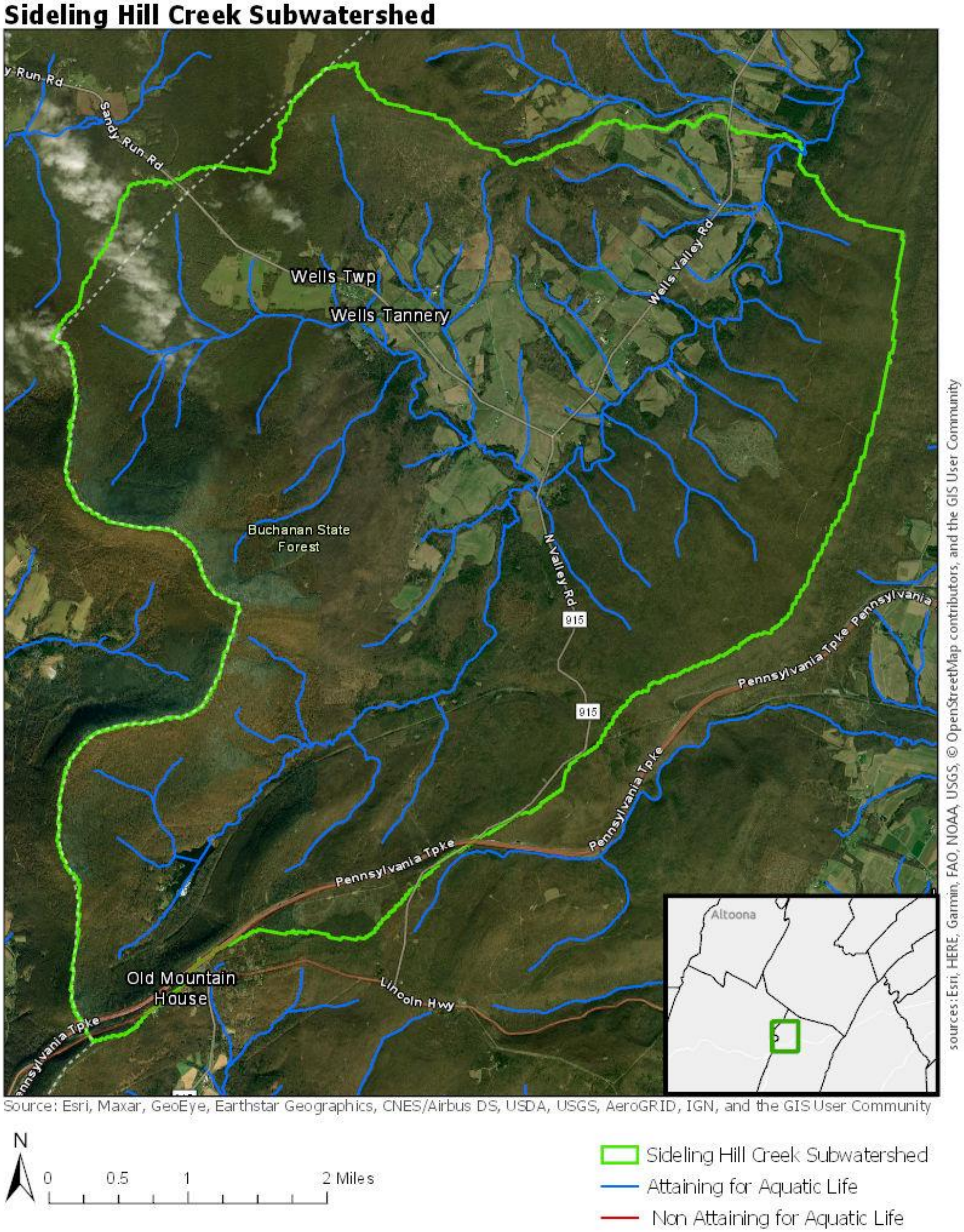

Figure 3. Sideling Hill Creek Subwatershed.

Figure 4. Photographs of stream substrate within the lower and middle reaches (Calvin area and downstream) of the Little Trough Creek mainstem. The upper row (A and B) shows the downstream most reaches while the lower photos (E and F) show more upstream reaches near Calvin. In most cases, the streambed was dominated by fine sediment. However, this was in part due to natural sandy conditions. Finer fractions and high turbidity in some cases suggested agricultural pollution as well. Some rockiness was observed in higher gradient areas (E and F).

Figure 5. Photographs of substrate conditions in the upper mainstem (upstream of Colfax) and tributaries in the Little Trough Creek Subwatershed. The upper mainstem occurring above the most intensive agricultural area was very sandy (photos A and B) which, along with the presence of sandstone bedrock, suggests this is a natural condition. Some tributaries had deposits of finer fractions suggesting anthropogenic pollution however (C and D). Photographs E and F show that other tributaries had rockier, healthier appearing substrate, though in many cases with natural sand deposits (F).

Figure 6. Example landscapes within the Little Trough Creek Subwatershed. Note the dominance of hay and pasture lands within the valleys and forested uplands along the margins of the watershed. Shrubby wetlands commonly occurred along valley stream segments.

Figure 7. In addition to the overall amount of agriculture, the most obvious reasons for impairment in the Little Trough Creek Subwatershed were cattle access to the stream and lack of riparian buffers. This resulted in bare areas and eroding banks, which leads to increased sediment and nutrient loading. Croplands, which appear to be in the background in photograph D comprised a small percentage of the overall land area in the watershed. However, they can be particularly important sediment sources when unbuffered and on slopes as in D.

Figure 8. Natural factors protecting water quality in the Little Trough Creek Subwatershed. Many upland tributaries were forested (A) and wetlands were common along much of the mainstem (B and C) and some tributaries (D).

Figure 9. Anthropogenic factors protecting the Little Trough Creek Subwatershed. Some stream segments had riparian buffers (A through C) and/or livestock exclusion fencing (D).

Figure 10. Map of channel slopes in the Little Trough Creek (left) and Sideling Hill Creek (right) watersheds. Slopes were reported as drop:length per USGS FACET output (see Hopkins et al. 2020)

Figure 11. Photographs of larger mainstem reaches within the Sideling Hill Creek Subwatershed. Note the abundance of sand, especially in lower gradient reaches of the watershed's mid section (B-D). The downstream most observed reach however was primarily rocky and higher gradient (E and F). Note the exceptional water clarity throughout.

Figure 12. Photographs of smaller tributary reaches within the Sideling Hill Creek Subwatershed. Some segments within the mountainous area were high gradient and sandy (A) or rocky with sand deposits (B). Low gradient reaches in the valley could be primarily rocky (C) or exhibit fines deposits associated with wetlands, as in D. Some apparent agricultural impacts were observed however, such as the fines deposition observed at the cattle crossing shown in E, or the turbidity occurring downstream of a pasture shown in F.

Figure 13. Photographs of landscapes within the Sideling Hill Creek Subwatershed. Note the forested mountainous margins of the watershed and valley area dominated by hay/pasture lands.

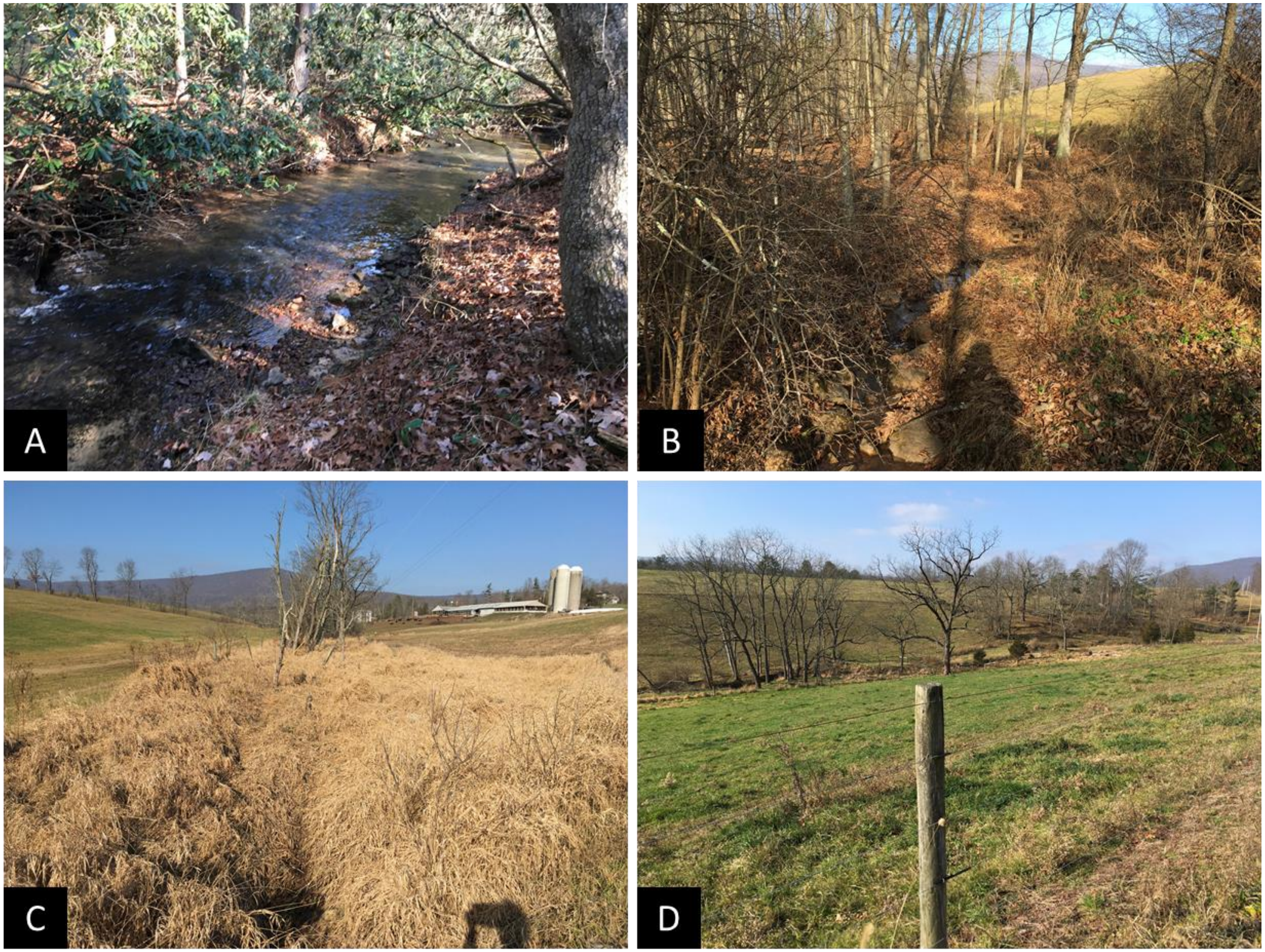

Figure 14. Conditions that may be protective of water quality within the Sideling Hill Creek Subwatershed. A major factor of the watershed's high quality was that so much of the land area was dominated by forest (A). Protective agricultural practices were also observed however, including forested and herbaceous riparian buffers (B and C), and livestock exclusion fencing along the stream (D).

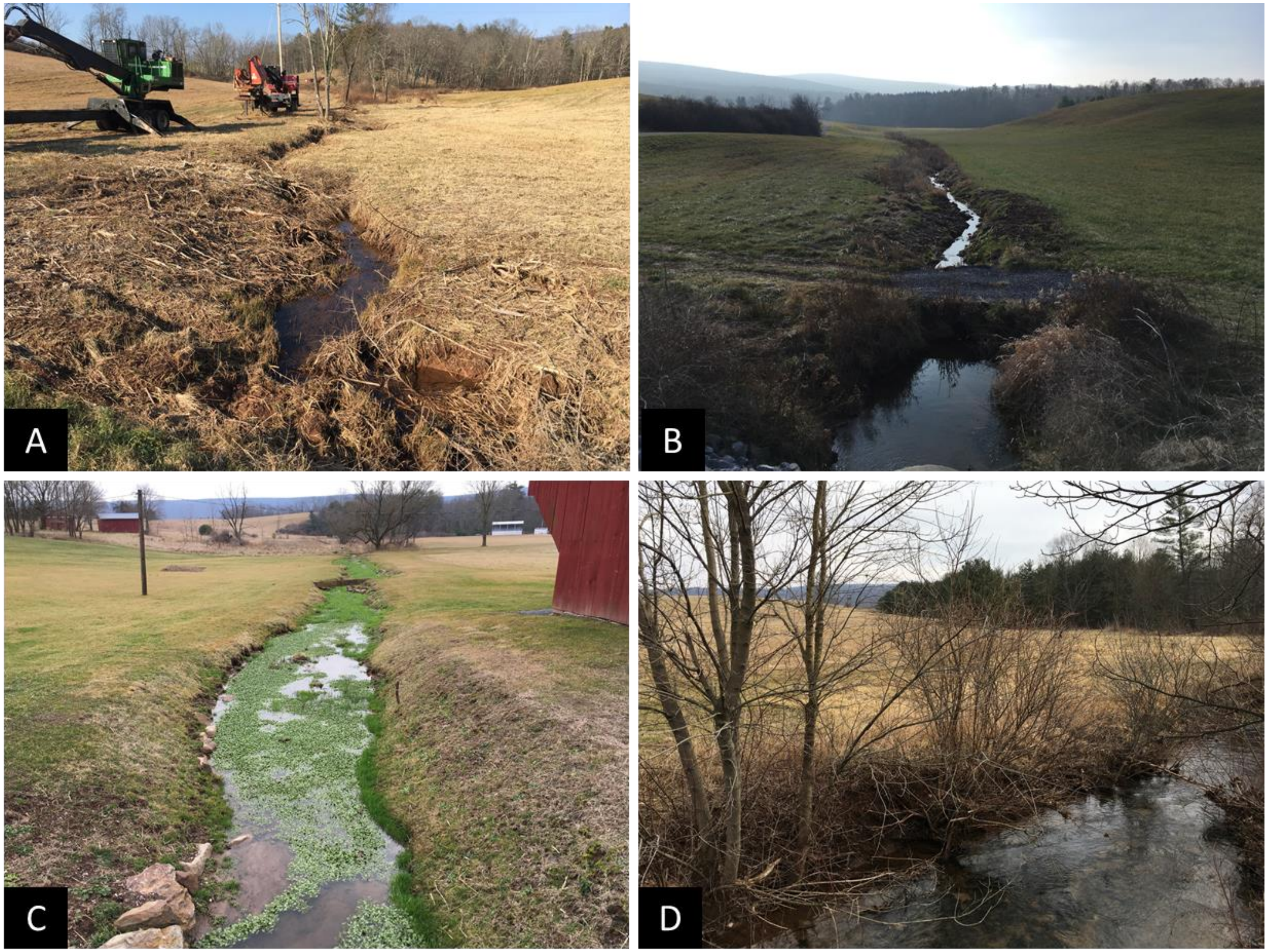

Figure 15. Conditions that may result in enhanced sediment loading in the Sideling Hill Creek Subwatershed. Note the lack of riparian buffers in A through C as well as apparent physical disturbance along the stream segments shown in A and B. While Figure D has at least some buffering, it is likely too narrow to be highly protective.

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 (note that only 28 years of data were available in the Sideling Hill Creek Subwatershed). 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 Cassville Wastewater Treatment Plant (63.92 m^3/d) was added as an input to the Little Trough Creek Watershed.

A correction for the presence of existing riparian buffers was made in the BMP Spreadsheet Tool provided by Model My Watershed following the model runs. The following paragraphs describe the riparian buffer correction methodology.

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. The selection polygons are shown in Figures 16 and 17. 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 55% in the agricultural area of the impaired watershed versus 67% in the reference watershed.

An additional reduction credit was given to the reference watershed to account for the fact it had more riparian buffers than the impaired watershed. 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 agricultural area of the reference watershed over the amount found in the impaired watershed, the length of NHD flowlines within the reference watershed was multiplied by the proportion of riparian pixels that were within the agricultural area selection polygon (see Figure 17) and then by the difference in the proportion of buffering between the agricultural area of the reference watershed versus that of 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 is 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.

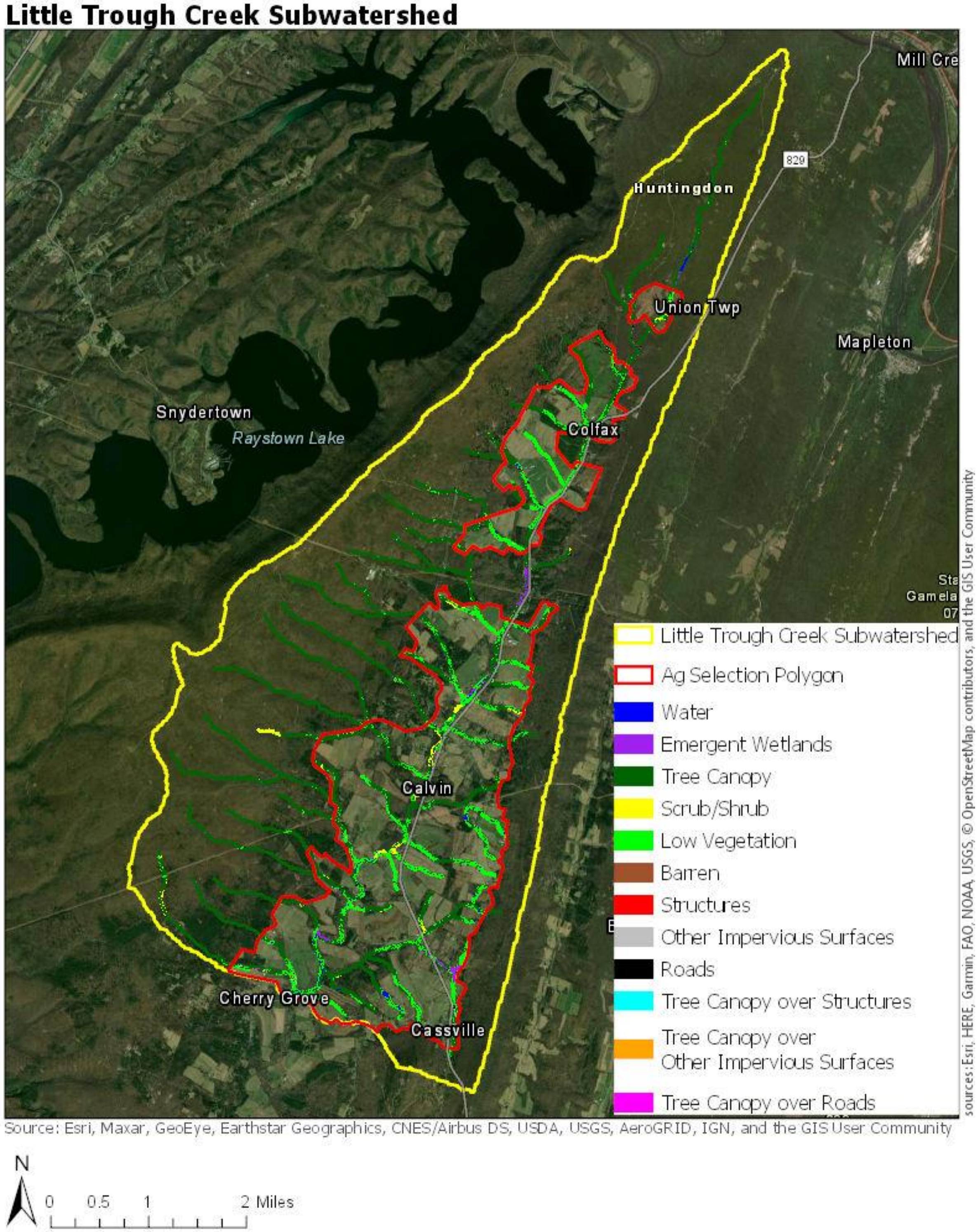

Figure 16. Riparian buffer analysis in the Little Trough Creek Subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The rate of riparian buffering within the agricultural selection polygons was estimated to be about 55%.

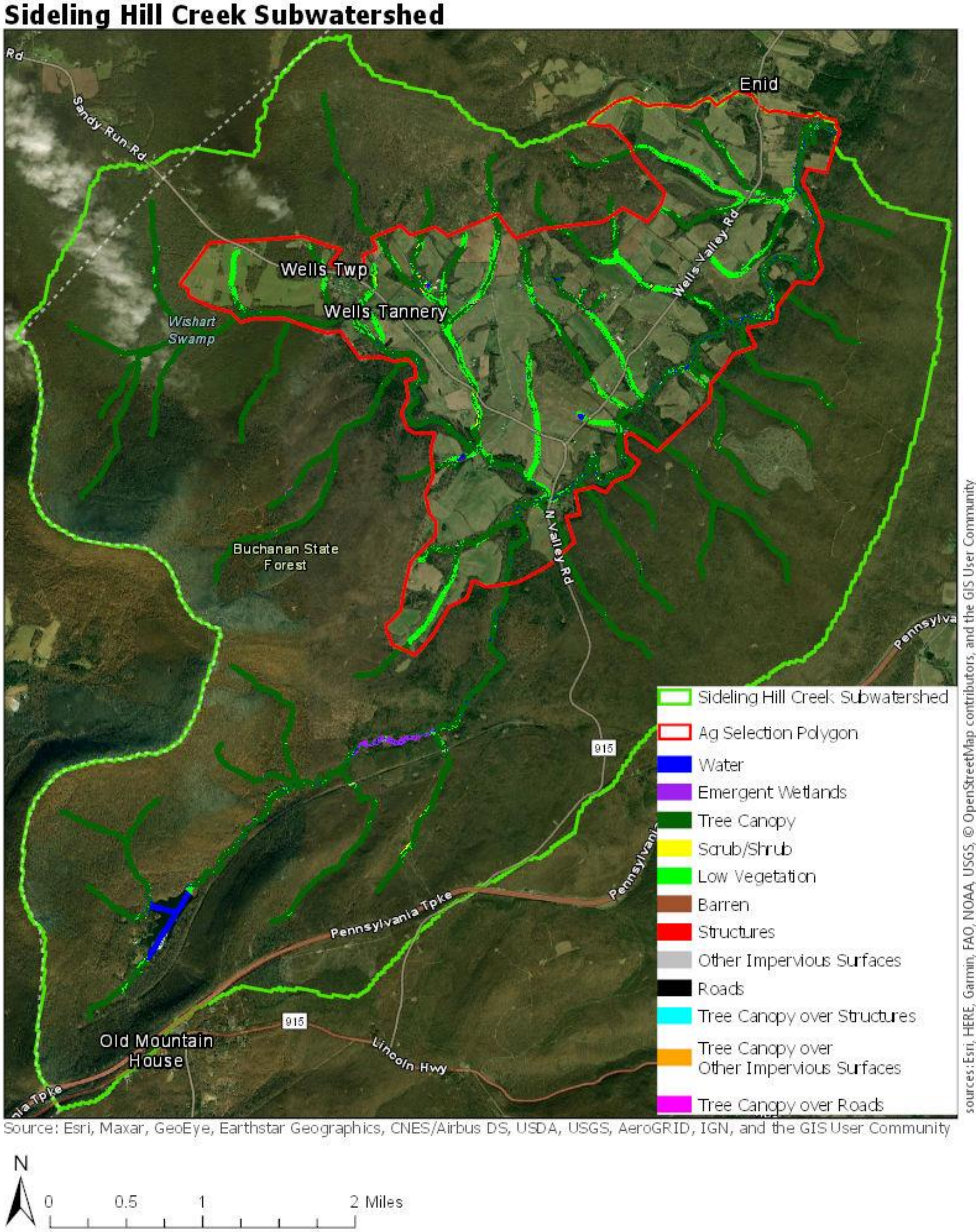

Figure 17. Riparian buffer analysis in the Sideling Hill Creek Subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The rate of riparian buffering within the agricultural selection polygon was estimated to be about 67%.

Calculation of the $TMDL_{Avg}$

The mean annual sediment loading rate for the unimpaired reference subwatershed (Sideling Hill Creek) was estimated to be 129 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired Little Trough Creek Subwatershed (167 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the Little Trough Creek Subwatershed should be reduced to 2,234,466 pounds per year or less (Table 9).

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

Source	Area ac	Sediment lbs/yr	Unit Area Load, lbs/ac/yr
Hay/Pasture	1,677	580,796	346
Cropland	212	216,218	1,018
Forest and Shrub/Scrub	13,975	17,781	1
Grassland/Herbaceous (Open Land)	2	47	19
Low Intensity Mixed Development	847	9,368	11
Medium Intensity Mixed Development	32	1,973	61
High Density Mixed Development	20	1,239	63
Streambank[1]		1,415,932	
Point Sources		0	
Additional Buffer Discount[2]		-81,789	
total	16,765	2,161,564	129

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

[2]Accounts for the amount of extra riparian buffering in the agricultural area of reference watershed versus the impaired watershed. For details on this calculation, see the "Hydrologic / Water Quality Modelling" section.

Table 8. Existing Annual Average Loading Values for the Little Trough Creek Subwatershed, Impaired			
Source	Area, ac	Sediment, lbs/yr	Unit Area Load, lb/ac/yr
Hay/Pasture	2,696	356,152	132
Cropland	491	395,185	804
Forest and Shrub/Scrub	13,160	18,822	1
Grassland/Herbaceous (Open Land)	74	4,363	59
Low Intensity Mixed Development	904	9,331	10
Medium Intensity Mixed Development	5	538	109
High Density Mixed Development	0	90	0
Streambank		2,107,420	
Point Sources		501	
total	17,331	2,892,402	167

"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 Little Trough Creek Subwatershed			
Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Avg}$ Value, lbs/yr
Sediment	129	17,331	2,234,466

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:

2,234,466 lbs/yr $TMDL_{Avg}$ * 0.1 = 223,447 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 was one existing NPDES permittee with loading limits relevant to sediment, the wastewater treatment plant serving Cassville. Based on an analysis of electronic discharge monitoring reports, it is estimated that they contributed approximately 501 lbs/yr of sediment to the watershed (Table 4). However, it they continuously discharged at their average monthly loading limit of 7.5 lbs/d per their NPDES permit, they would contribute approximately 2,738 lbs/yr. Either way they were a very minor sediment source to the watershed. Thus they will be given a wasteload allocation consistent with the existing loading limit of their permit.

In addition, the overall watershed wasteload allocation will contain a bulk reserve, which is a minor allowance for insignificant dischargers and new sources. The bulk reserve was defined as one percent of the targeted TMDL.

Thus, the WLA was calculated as:

2,234,466 lbs/yr $TMDL_{Avg}$ * 0.01 = 22,345 lbs/yr bulk $reserve_{Avg}$ + 2,738 lb/yr permitted loads = 25,083 lbs/yr WLA_{Avg}

Load Allocation

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

2,234,466 lbs/yr $TMDL_{Avg}$ – (223,447 lbs/yr MOS_{Avg} + 25,083 lbs/yr WLA_{Avg}) = 1,985,936 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, non-agricultural herbaceous/grasslands and developed lands within the Little Trough Creek Subwatershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 33,144 lbs/yr (Table 10).

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

1,985,936 lbs/yr LA_{Avg} – 33,144 lbs/yr LNR_{Avg} = 1,952,793 lbs/yr ALA_{Avg}

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

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**1,985,936**
Loads Not Reduced (LNR_{Avg}):	**33,144**
Forest	18,822

Open Land	4,363
Low Intensity Mixed Development	9,331
Medium Intensity Mixed Development	538
High Density Mixed Development	90
Adjusted Load Allocation (ALA_{Avg})	**1,952,793**

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, open lands (non-developed, non-agricultural grass/herbaceous lands) were considered natural sediment sources.

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 Little Trough Creek 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 streambanks exceeded the allocable load by itself. Thus, it received a 33% reduction whereas hay/pasture lands and croplandss each received a 28% reduction (Table 11).

Table 11. Average Annual Sediment Load Allocations for Source Sectors in the Little Trough Creek Subwatershed

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	491	285,384	395,185	28%
HAY/PASTURE	2,696	257,196	356,152	28%
STREAMBANK		1,410,213	2,107,420	33%
AGGREGATE		1,952,793	2,858,757	32%

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, 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 99^{th} percentiles (using the percentile.exc function) of estimated daily sediment loads in both the Little Trough Creek (impaired) and Sideling Hill 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 99^{th} 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)).

As with the average loading values reported previously (see the Hydrologic / Water Quality Modelling section), a correction was made for the additional amount of existing riparian buffers in the reference watershed versus the impaired watershed. This was calculated simply by reducing the 99^{th} percentile loading rate for the reference watershed by the same reduction proportion that was calculated previously for the average loading rate. After making this reduction, the estimated daily maximum loading from the Cassville Wastewater Treatment Plant (47 lbs/d, Table 4) was added to the total load in the Little Trough Creek Watershed.

Then, similarly to the $TMDL_{Avg}$ value reported in Table 9, $TMDL_{Max}$ was calculated as the 99^{th} 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 45,085 pounds per day (Table 12), which would be an 11% reduction from Little Trough Creek’s current 99^{th} percentile daily loading rate of 50,469 pounds per day.

Table 12. Calculation of $TMDL_{Max}$ for the Little Trough Creek Subwatershed

Pollutant	99^{th} Percentile Loading Rate in Reference, lbs/ac/d	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Max}$ Value, lbs/d
Sediment	2.6	17,331	45,085

Also, in accordance with the previous “Calculation of Load Allocations” section, the WLA_{Max} would consist of a bulk reserve defined as 1% of the $TMDL_{Max}$, plus an allocation for the wastewater treatment plant serving Cassville. For the latter, 47 lbs/yr per Table 4 was chosen. Currently there is no actual daily load limit per their NPDES permit, nor are daily loads reported in their discharge monitoring reports. This being the case, the daily values derived in Table 4 assumed that they continuously discharged at their instantaneous maximum total suspended solids concentration limit of 60 mg/l. This is probably an unrealistic assumption; actual concentrations throughout the day are likely much lower. Even so, their estimated sediment contribution is still small, and additional capacity of 451 lbs/yr would be available in the bulk reserve if needed.

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 Little Trough Creek Subwatershed

lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	45,085	4,509	498	40,079

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 71% of LA_{Avg} it was assumed that it was also 71% 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 Little Trough Creek Subwatershed

	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	1,985,936		40,079
Loads Not Reduced	33,144	0.02	669
Adjusted Loads Allocation	1,952,793	0.98	39,410
Croplands	285,384	0.14	5,759
Hay/Pasturelands	257,196	0.13	5,191
Streambanks	1,410,213	0.71	28,460

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 71% of LA_{Avg} it was assumed that it was also 71% 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 Little Trough Creek Subwatershed 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 Little Trough Creek Subwatershed would skyrocket to 16,456,060 lbs/yr, which almost six-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 Little Trough Creek Subwatershed. 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 for Little Trough Creek and 1963-1990 for Sideling Hill Creek. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations. Furthermore, this document calculates both annual average and 99th 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 23% reduction in annual average sediment loading for the Little Trough Creek Subwatershed. To achieve this goal while maintaining a margin of safety and minor allowance for point sources, annual average sediment loading should be reduced by 28% each from croplands and hay/pasture lands, and 33% from streambanks. The 99th percentile daily sediment loading should be reduced by 11%. 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.

The modest reductions proposed herein are consistent with site observations suggesting an abundance of forested land and fairly light agricultural land use within the watershed. Even so, the low gradient nature of the middle and lower mainstem suggest this stream is especially vulnerable to sediment deposition. Site observations from the watershed suggest water quality may improve greatly from repairing eroding banks, fencing cattle from the stream and establishing riparian buffers.

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

Development of a more detailed watershed implementation plan is 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 March 27, 2021 issue of the Pennsylvania Bulletin to foster public comment. A 30-day period was provided for the submittal of comments. No 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

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 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).

<u>Migration to National Hydrography Data (NHD)</u>

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

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.02	0.02
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	3.26	4.64
Developed, Low Intensity	22	0.4	0.57
Developed, Medium Intensity	23	0.02	0.03
Developed, High Intensity	24	0	0.01
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	46.84	66.71
Evergreen Forest	42	4.49	6.4
Mixed Forest	43	1.91	2.72
Shrub/Scrub	52	0.06	0.08
Grassland/Herbaceous	71	0.3	0.43
Pasture/Hay	81	10.92	15.56
Cultivated Crops	82	1.99	2.83
Woody Wetlands	90	0	0
Emergent Herbaceous Wetlands	95	0	0
Total		**70.21**	**100**

Table B1. Land Cover based on NLCD 2011 for the Little Trough Creek Subwatershed.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.18	0.27
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	2.75	4.04
Developed, Low Intensity	22	0.68	0.99
Developed, Medium Intensity	23	0.13	0.19
Developed, High Intensity	24	0.08	0.12
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	53.68	78.84
Evergreen Forest	42	0.91	1.34
Mixed Forest	43	1.97	2.89
Shrub/Scrub	52	0.04	0.06
Grassland/Herbaceous	71	0.01	0.02
Pasture/Hay	81	6.79	9.97
Cultivated Crops	82	0.86	1.27
Woody Wetlands	90	0	0
Emergent Herbaceous Wetlands	95	0	0
Total		**68.09**	**100**

Table B2. Land Cover based on NLCD 2011 for the for the Sideling Hill Creek Subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.63	0.56	5.06	0	0.33	7.15
Feb	6.36	0.71	5.65	0	0.52	7.31
Mar	7.46	0.31	7.15	0	1.83	8.36
Apr	6.25	0.08	6.16	0	4.51	8.41
May	4.25	0.06	4.19	0	8.54	10.51
Jun	3.33	0.75	2.57	0	12.09	10.58
Jul	1.25	0.11	1.15	0	11.67	9.86
Aug	0.37	0.07	0.3	0	9.31	8.64
Sep	0.72	0.58	0.14	0	6.16	9.04
Oct	1.17	0.39	0.77	0	3.57	8.06
Nov	2.32	0.24	2.08	0	1.77	9.38
Dec	5.09	0.39	4.69	0	0.69	8.11
Total	44.2	4.25	39.91	0	60.99	105.41

Table B3. “Model My Watershed” Hydrology Outputs for the Little Trough Creek Subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.59	0.53	5.07	0	0.49	6.99
Feb	6.21	0.52	5.69	0	0.75	7.05
Mar	6.51	0.2	6.31	0	2.3	8.11
Apr	5.39	0.03	5.36	0	5.2	7.97
May	3.52	0.13	3.39	0	9.64	10.69
Jun	2.65	0.77	1.88	0	12.29	9.93
Jul	0.83	0.16	0.67	0	10.45	9
Aug	0.31	0.17	0.14	0	8.87	9.19
Sep	0.8	0.55	0.26	0	5.97	8.94
Oct	1.36	0.4	0.96	0	3.86	7.94
Nov	1.72	0.21	1.51	0	2.06	8.57
Dec	4.63	0.41	4.23	0	0.97	8.2
Total	39.52	4.08	35.47	0	62.85	102.58

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

Sources	Sediment (kg)
Hay/Pasture	161,520.10
Cropland	179,222.40
Wooded Areas	8,536.10
Wetlands	0
Open Land	1,978.60
Barren Areas	0
Low-Density Mixed	461.8
Medium-Density Mixed	244.2
High-Density Mixed	40.7
Low-Density Open Space	3,769.80
Farm Animals	0
Stream Bank Erosion	955,746.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B5. Model My Watershed outputs for sediment in the Little Trough Creek Subwatershed.

Sources	Sediment (kg)
Hay/Pasture	263,399.50
Cropland	98,058.00
Wooded Areas	8,064.00
Wetlands	0
Open Land	21.2
Barren Areas	0
Low-Density Mixed	839.1
Medium-Density Mixed	894.9
High-Density Mixed	561.9
Low-Density Open Space	3,409.50
Farm Animals	0
Stream Bank Erosion	642,146.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

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

Appendix C: Stream Segments in the Little Trough Creek Subwatershed with Siltation Impairments for Aquatic Life Use

Stream Name:	Impairment Source:	Impairment Cause:	COMID:	Miles:
Wilson Run	Grazing Related Agric	Other Habitat Alterations	65840869	1.14
Little Trough Creek	Grazing Related Agric	Other Habitat Alterations	65840995	0.21
Wilson Run	Grazing Related Agric	Other Habitat Alterations	65840951	0.10
Wilson Run	Grazing Related Agric	Other Habitat Alterations	65840921	0.50
Unnamed Tributary to Wilson Run	Grazing Related Agric	Other Habitat Alterations	65840923	2.28
Wilson Run	Grazing Related Agric	Siltation	65840869	1.14
Little Trough Creek	Grazing Related Agric	Siltation	65840995	0.21
Little Trough Creek	Grazing Related Agric	Siltation	65840681	0.42
Little Trough Creek	Grazing Related Agric	Siltation	65840559	0.59
Little Trough Creek	Grazing Related Agric	Siltation	65840401	0.32
Little Trough Creek	Grazing Related Agric	Siltation	65840413	0.24
Little Trough Creek	Grazing Related Agric	Siltation	65840359	0.20
Little Trough Creek	Grazing Related Agric	Siltation	65840237	0.22
Wilson Run	Grazing Related Agric	Siltation	65840951	0.10
Little Trough Creek	Grazing Related Agric	Siltation	65840711	0.26
Little Trough Creek	Grazing Related Agric	Siltation	65840949	0.16
Little Trough Creek	Grazing Related Agric	Siltation	65840747	0.06
Little Trough Creek	Grazing Related Agric	Siltation	65840645	0.17
Little Trough Creek	Grazing Related Agric	Siltation	65840619	0.25
Little Trough Creek	Grazing Related Agric	Siltation	65840519	0.15
Little Trough Creek	Grazing Related Agric	Siltation	65840485	0.11
Unnamed Tributary to Wilson Run	Grazing Related Agric	Siltation	65840923	2.28
Little Trough Creek	Grazing Related Agric	Siltation	65840947	0.25
Little Trough Creek	Grazing Related Agric	Siltation	65840851	0.73
Little Trough Creek	Grazing Related Agric	Siltation	65840337	0.65
Wilson Run	Grazing Related Agric	Siltation	65840921	0.50
Little Trough Creek	Grazing Related Agric	Siltation	65840909	0.48
Little Trough Creek	Grazing Related Agric	Siltation	65840657	0.05
Little Trough Creek	Grazing Related Agric	Siltation	65840631	0.18
Little Trough Creek	Grazing Related Agric	Siltation	65840601	0.39
Little Trough Creek	Grazing Related Agric	Siltation	65840713	0.05
Little Trough Creek	Grazing Related Agric	Siltation	65840741	0.21
Little Trough Creek	Grazing Related Agric	Siltation	65840473	0.33
Little Trough Creek	Grazing Related Agric	Siltation	65840515	0.43

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	395,185	no	395,185		0.15	109,801	285,384	0.28
Hay/Pasture	356,152	no	356,152	751,337	0.13	98,956	257,196	0.28
Streambank	2,107,420	yes	1,952,793		0.72	542,580	1,410,213	0.33
sum	**2,858,757**		**2,704,130**		**1.00**	**751,337**	**1,952,793**	**0.32**

Table D1. Equal Marginal Percent Reduction calculations for the Little Trough Creek Subwatershed.

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 comments were received.