Unnamed Tributary to Cocolamus Creek Watershed Sediment TMDL

Perry County, Pennsylvania

Prepared by:

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

“Total Maximum Daily Loads” (TMDLs) for sediment were developed for the UNT Cocolamus Creek Watershed (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. Agriculture and grazing related agriculture were 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 UNT Cocolamus Creek Watershed was estimated to be 1,873,012 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 51% to 918,798 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 should be reduced by 62% whereas loading from hay/pasture lands and streambanks should be reduced by 27 each%.

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

lbs/yr:						
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	918,798	91,880	9,188	817,730	5,158	812,571

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 UNT Cocolamus Creek Watershed was estimated to be 74,065 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 56% to 32,900 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 UNT Cocolamus Creek Watershed

lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	32,900	3,290	329	29,281	185	29,097

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

The study watershed, an Unnamed Tributary to (UNT) Cocolamus Creek, flows into Cocolamus Creek approximately two miles northeast of Millerstown Borough in Perry County, Pennsylvania. This Total Maximum Daily Load (TMDL) document has been prepared to address the siltation from grazing related agriculture impairments listed for the entire watershed (Figure 1), per the 2018 Final Integrated Report (see Appendix A for a description of assessment methodology). The UNT Cocolamus Creek Watershed was approximately 5 square miles and occurred within Perry County, just south of the border with Juniata County. It contained approximately 7 stream miles, all of which are 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))*.

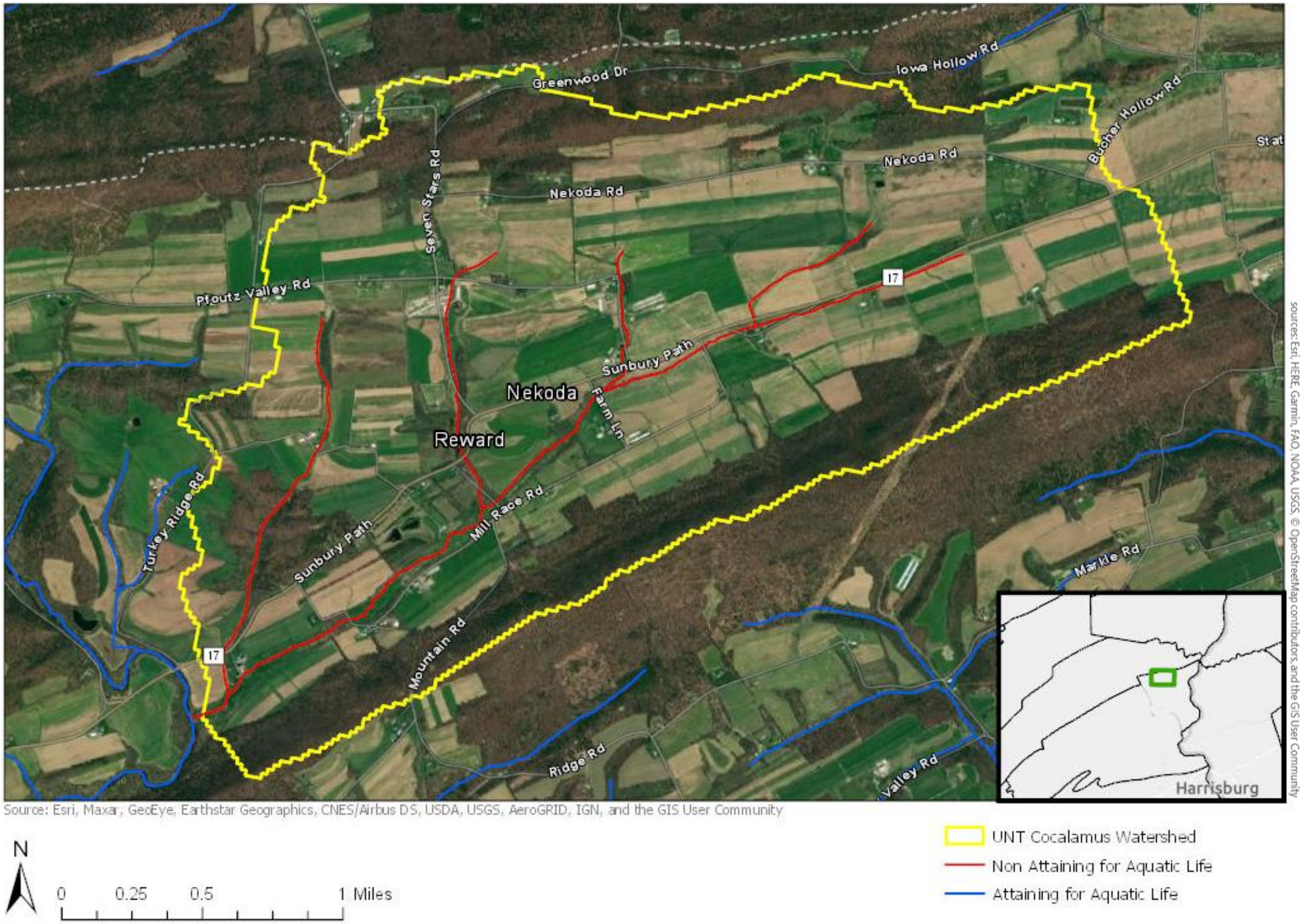
While grazing related agriculture has been identified as the source of the impairments, this TMDL document is applicable to all significant sources of solids that may settle to form deposits.

According to an analysis of NLCD 2016 landcover data, land use in the study watershed was estimated to be 31% forest/naturally vegetated lands, 62% agriculture, and 7% mixed development. The agricultural lands were dominated by croplands, which accounted for 47% of the watershed's land cover (Appendix B, Table B1). There were no NPDES permitted point source discharges in the watershed with concentration limits relevant to sedimentation.

Table 3. Aquatic-Life Impaired Stream Segments in the UNT Cocolamus Creek Watershed per the 2018 Final Pennsylvania Integrated Report

HUC: 02050304 – Lower Juniata				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Grazing Related Agriculture	Siltation	7.05	TSF, MF	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.



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Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. UNT Cocolamus Creek Watershed. All stream segments within the study watershed were listed as impaired for siltation per the approved 2018 Integrated Report. Note that UNT Cocalamus should have been spelled UNT Cocolamus in the figure legend.

Table 4. Existing NPDES-Permitted Discharges in the UNT Cocolamus Creek Watershed 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.

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 rates. 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 data layers consistent with the Integrated Report, was used to search for nearby watersheds that were of similar size as the UNT Cocolamus Creek 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 clearly attaining its aquatic life use and not impaired for sediment. 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 five miles to the northwest), in the same section of 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 Stony Run in Juniata County was considered for use as a reference (Figures 2 and 3, Table 5).

Table 5. Comparison of the Impaired UNT Cocolamus Creek Watershed and Reference Stony Run Subwatershed.

	UNT Cocolamus Creek	Stony Run
Phys. Province[1]	Susquehanna Lowland Section of the Ridge and Valley Province	Susquehanna Lowland Section of the Ridge and Valley Province
Land Area[2], ac	3,316	3,036
Land Use[2]	62% Agriculture 31% Forest/Natural Vegetation 7% Developed	33% Agriculture 58% Forest/Natural Vegetation 8% Developed
Soil Infiltration[3]	39% Group A 42% Group B 1% Group B/D 1% Group C 2% Group C/D 15% Group D	14% Group A 53% Group B 3% Group B/D 9% Group C 4% Group C/D 17% Group D
Dominant Bedrock[4]	47% Calcareous Shale 34% Limestone 19% Shale	46% Siltstone 43% Shale 10% Calcareous Shale

		0.5% Limestone
Average Precipitation[5], in/yr	41.5	41.5
Average Surface Runoff[5], in/yr	2.1	2.1
Average Elevation[5] (ft)	597	789
Average Slope[5]	11%	16%
Average Stream Channel Slope[5]	1st order: 0.84% 2nd order: 0.78%	1st order: 1.81% 2nd order: 0.40%

[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 corrected for 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 located in the Susquehanna Lowlands Section of the Ridge and Valley Physiographic Province and had significant agricultural coverage, though the amount of agricultural land area was nearly twice as much in the UNT Cocolamus Creek Watershed versus the Stony Run Subwatershed (62 versus 33%- Table 5). The greater amount of agricultural landcover in the UNT Cocolamus Creek Watershed was driven primarily by a far greater amount of cropland cover (47% of land area versus 23%, see Appendix Tables B1 and B2). There was substantially more natural lands cover in the Stony Run Subwatershed (58% versus 31%), whereas the amount of developed lands were nearly the same (8 and 7%).

Both watersheds were dominated by non-Karst sedimentary bedrocks (shales and/or siltstone), though UNT Cocolamus Watershed did have a significant amount of limestone (34%), whereas the Stony Run Subwatershed did not (0.5%) (Table 5). However, this is not expected to result in large differences in hydrology as the type of limestone present in the UNT Cocolamus Creek Watershed, Keyser and Tonoloway Limestone, does not have a strong tendency to form karst features, and no sinkholes or other Karst features were mapped in the watershed (see PA Department of Conservation and Natural Resource's Bureau of Topographic and Geologic Survey's "Digital data set of mapped karst features in south-central and southeastern Pennsylvania" GIS layer). The two watersheds had similar average slopes, though the reference watershed was somewhat steeper (11 versus 16%). However, 2nd order stream channel slopes were actually lower in the reference watershed (0.40% versus 0.78%). Estimated surface runoff rates were approximately the same (2.1 inches per year).

Like the UNT Cocolamus Creek Watershed, stream segments within the Stony Run Subwatershed were designated for trout stocking and there were no relevant NPDES permitted point source discharges with concentration limits for sediment (Table 6).

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

Permit No.	Facility Name	Load, mean lbs/yr	Load, max lbs/d
PAG123554	Erisman Farm CAFO (terminated)	NA	NA
PAG123660	Lauver Poultry Farm CAFO (terminated)	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

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.

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 August 2020 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 UNT Cocolamus Creek Watershed suggested there were some areas of substantial impairment, though conditions were highly variable (Figure 4). For instance, steeper tributaries originating near the mountainous margins of the watershed may have rocky substrate. In contrast mainstem reaches within the valley appeared to have substantial fines deposition and high turbidity, even during low summer flows.

According to site observations, the most obvious reasons for impairment appeared to be both the overall abundance of agricultural lands (Figure 5) as well as degrading agricultural practices (Figure 6). At about 62% of the land area, the amount of agriculture in the watershed was high to the extent that some impairment may be expected even if agricultural practices were exceptionally good. However, problematic practices were observed, such as the occurrence of large expanses of pasture where cattle accessed the stream. This resulted in obvious degradation, such as bare patches within the pasture and severe bank erosion. Furthermore, there were numerous stream segments that lacked expansive forested buffers and instances where croplands occurred in close proximity to streams (Figure 6). It should also be noted that good practices were observed as well, such as the allowance for forested riparian buffers, utilization of herbaceous buffers, and areas where livestock had been fenced out of the streams/drainageways (Figure 7). However, at present it appears that far more BMP implementation would be necessary to allow aquatic community health to improve to the point of aquatic life use attainment.

Stream substrate conditions and turbidity were typically noticeably better in the Stony Run Subwatershed, with some localized exceptions (Figure 8). This would be expected given that it had far less agricultural lands as the UNT Cocolamus Watershed (See Table 5, and Appendix Tables B1 and B2). The lesser amount of agricultural lands was likely in part due to its different topographic configuration. Rather than having one broad agricultural valley, the Stony Run Subwatershed had more forested hills that broke up the watershed into a series of smaller interconnected agricultural valleys (See Figures 1 and 3, also Figures 5 and 9). Forested riparian buffers appeared to be more common in the Stony Run Subwatershed, and BMPs such as livestock exclusion fencing, and drainageway protection were observed (Figure 10). However, like the impaired watershed, there were instances where agricultural practices could clearly be improved (Figure 11). Apparently however, these instances did not lead to widespread impairment.

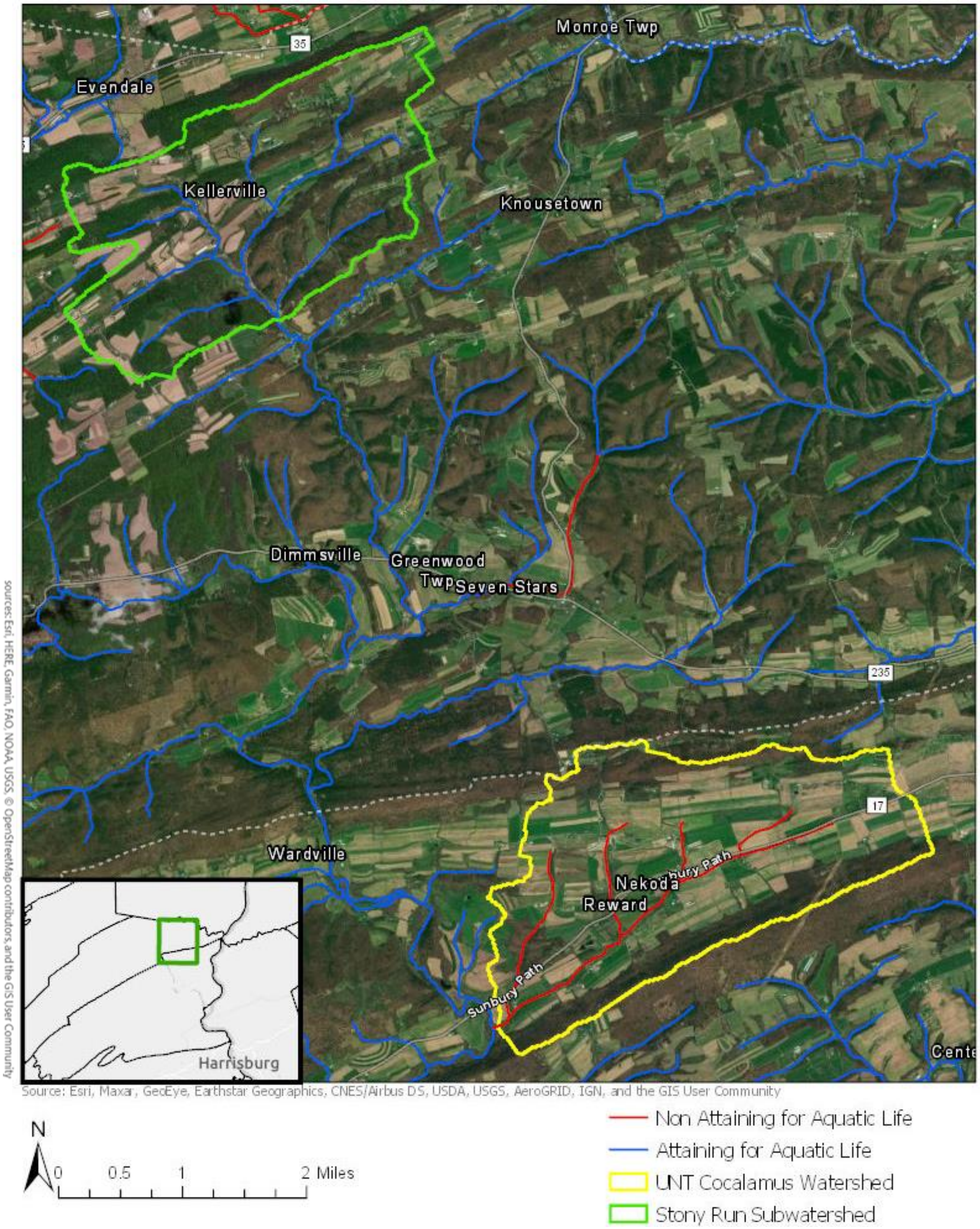

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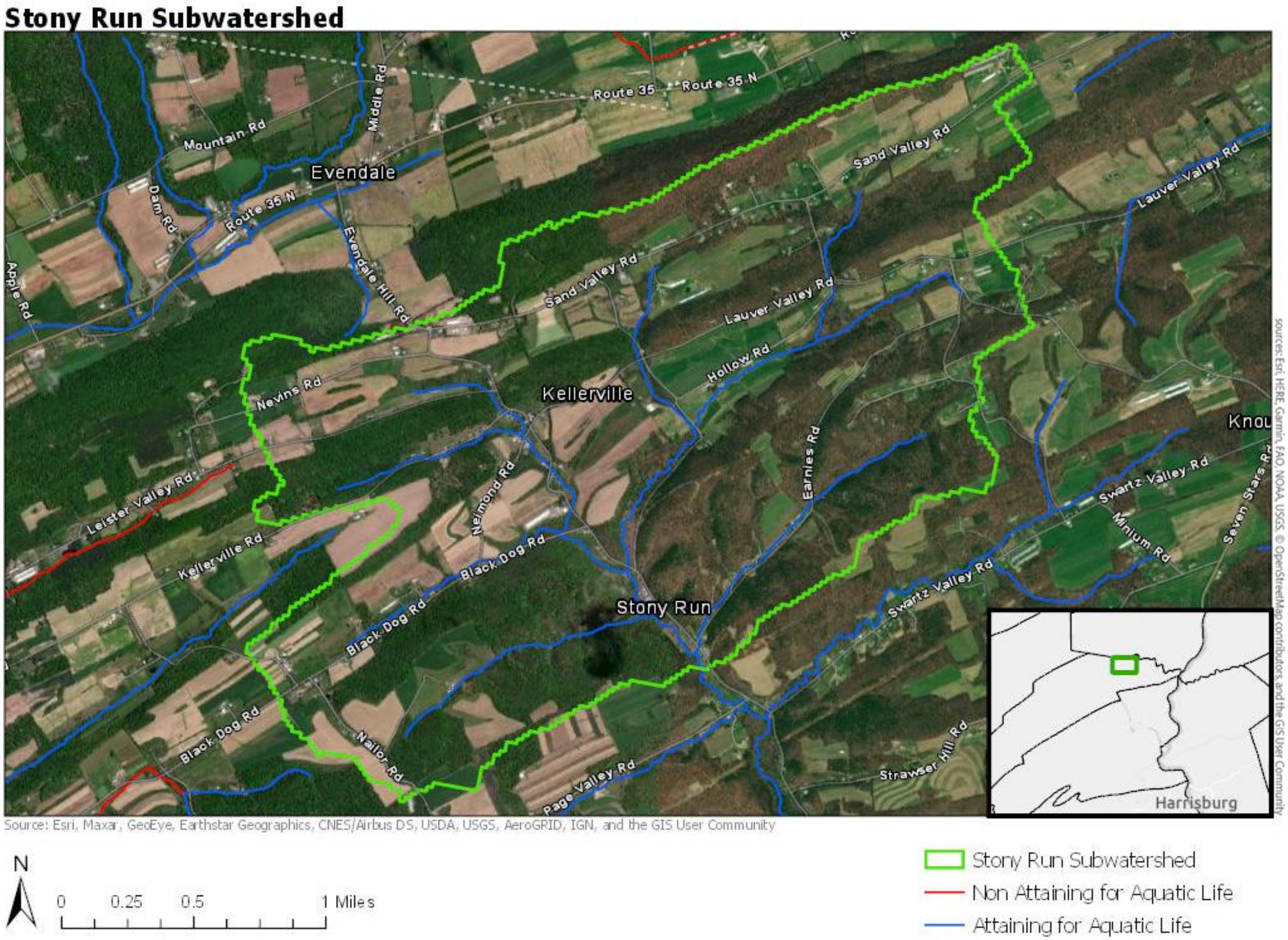
Figure 2. UNT Cocolamus and Stony Run Watersheds. Note that UNT Cocalamus should have been spelled UNT Cocolamus in the figure legend.



Stony Run Subwatershed

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

🟩	Stony Run Subwatershed
—	Non Attaining for Aquatic Life
—	Attaining for Aquatic Life

Figure 3. Stony Run Subwatershed. All stream segments within the subwatershed were listed as attaining per PA DEP's 2018 Integrated Report Viewer available at: https://www.depgis.state.pa.us/integrated_report_viewer/index.html.

Figure 4. Example stream substrate and turbidity conditions within the UNT Cocolamus Watershed. Near the watershed outlet (photographs A and B) the stream substrate appeared to be rocky particularly in the riffles, though there was obvious fine sediment deposition. Photographs C and D show the mainstem in the middle reaches. The water was so turbid, apparently due to cattle access to the stream, that it was difficult to distinguish sediment conditions in pools. However, some rockiness was apparent in riffles. Photographs E and F show example tributaries. The mountain tributary in E was primarily rocky, while the valley tributary in F exhibited heavy fine sediment deposition.

Figure 5. Photograph showing the agricultural dominated ridge and valley landscape of the UNT Cocolamus Watershed. Note that large forested patches were largely relegated to the mountainous margins of the watershed.

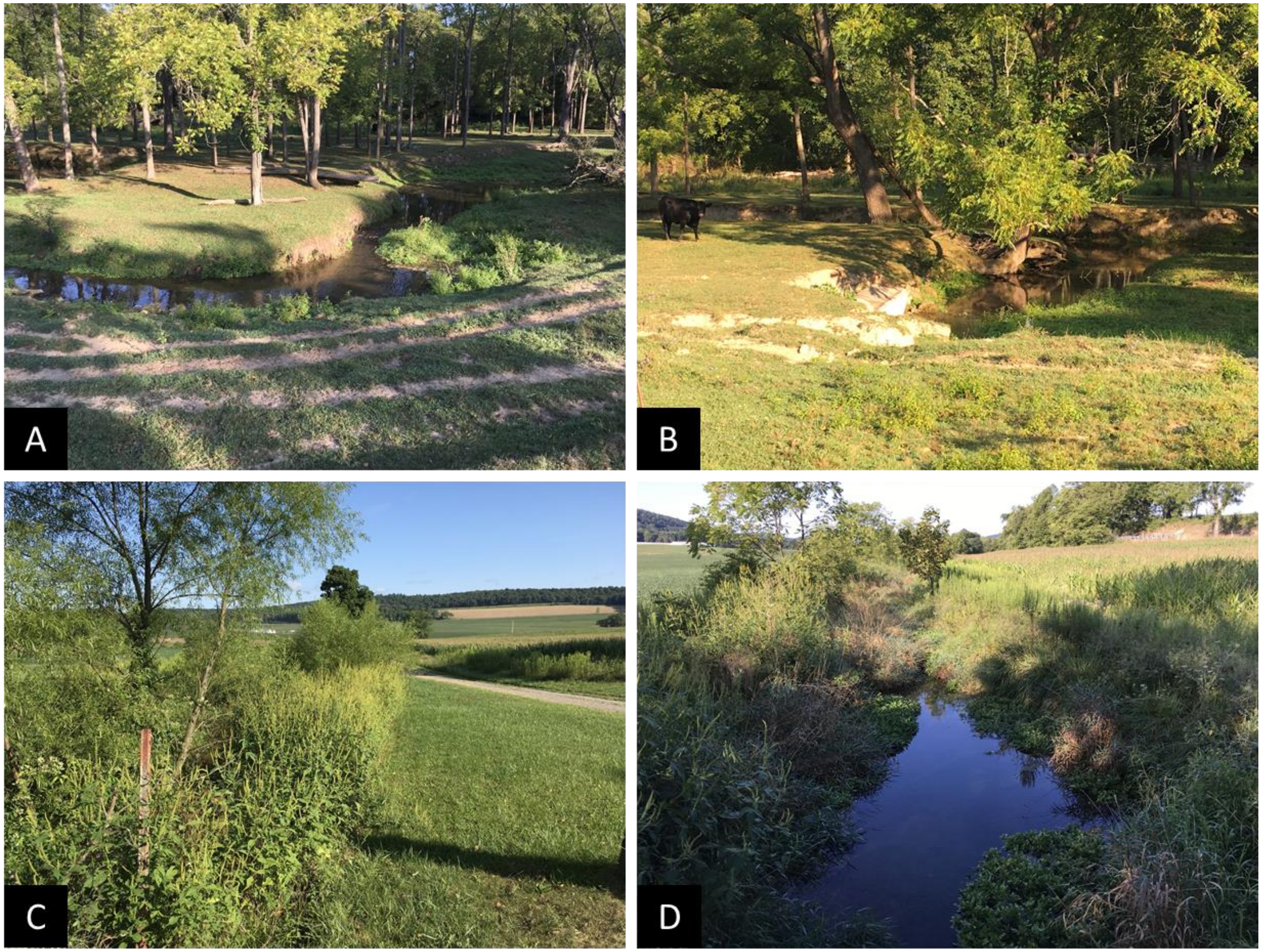


Figure 6. Stream segments and drainageways flowing through areas with conditions that may exacerbate sediment loading in the UNT Cocolamus Watershed. Photographs A and B show stream segments among degraded pasture lands where cattle directly accessed the stream. Note the bare patches and obvious bank erosion. Photographs C and D show areas where lawn and crops are in close proximity to stream segments. In these cases buffering was likely too narrow to be highly protective.

Figure 7. Example conditions and agricultural practices in the UNT Cocolamus Creek Watershed that may help prevent sediment loading. Photograph A shows an expansive forested riparian buffer. Photograph B shows cattle exclusion fencing and herbaceous buffers along a stream flowing through barnyard areas. Photograph C shows a grassy drainageway among croplands and photograph D shows a pasture where cattle have been fenced out of the stream/drainageway.

Figure 8. Example stream segments in the Stony Run Subwatershed. The stream was primarily rocky in riffles and runs, as in A, but some fine sediment deposition could be observed in pools (B). Forested and hilly areas tended to have very rocky substrates (C). Tributary reaches were typically primarily rocky, though some localized fine sediment could be observed in degraded reaches (D).

Figure 9. Example landscapes within the Stony Run Subwatershed. Like the UNT Cocolamus Watershed, the Stony Run Subwatershed had uplands with forest and agricultural dominated valleys. However, rather than existing as a single uniform valley, there was a series of interconnected valleys separated by forested hills. This resulted in greater patchiness and more overall forested area. There also tended to be more forested area along the streams.

Figure 10. Practices that may be protective against sediment loading in the Stony Run Subwatershed. Photograph A shows a stream segment with expansive forested buffers. Photograph B shows livestock exclusion fencing along a stream and recent buffer plantings. Photographs C and D show shrubby and herbaceous buffers protecting drainageways among hay and croplands.

Figure 11. Practices that may exacerbate pollutant loading in the Stony Run Subwatershed. Photograph A shows a pasture where livestock had direct access to the stream. Also, note the degradation from heavy livestock use on the hillslope in the background. Photograph B also appears to show a pasture where cattle had access to the stream, though it appears to be well vegetated. Photograph C shows a stream segment with a herbaceous buffer, though it may be too narrow to substantially protect it from the surrounding croplands. Photograph D shows a stream segment without adequate buffering along a road shoulder and croplands. Note the erosive banks.

Hydrologic / Water Quality Modeling

This section deals primarily with the $\mathrm{TMDL}_{\mathrm{Avg}}$ calculation, as use of annual average values was determined to be the most relevant way to express the "TMDL" variables. For information about the $\mathrm{TMDL}_{\mathrm{Max}}$ calculations, see the later "Calculation of a Daily Maximum '$\mathrm{TMDL}_{\mathrm{Max}}$'" 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 (2020).

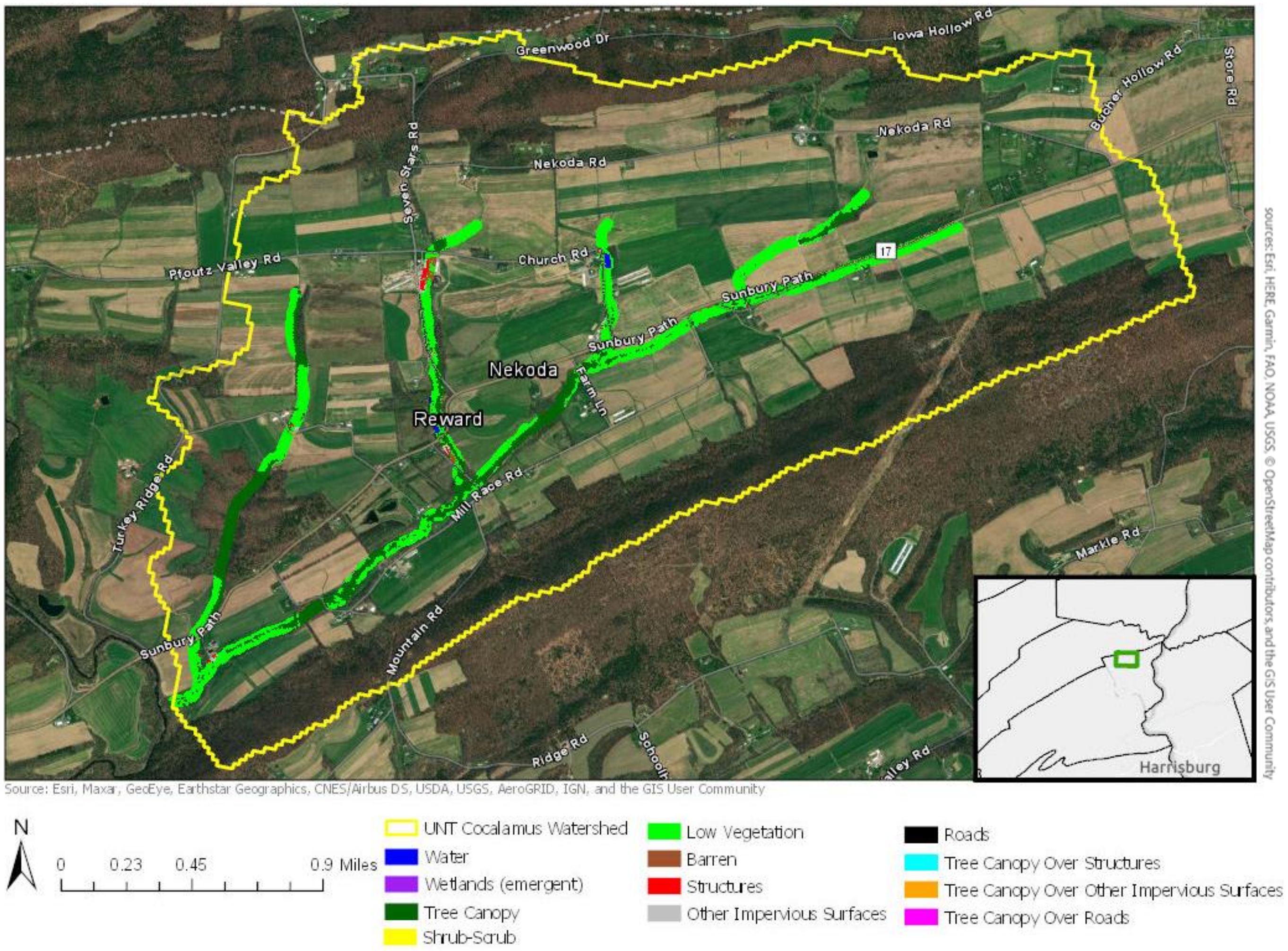
Model My Watershed allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling run, with the exception that landcover types 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 exact landcover area needed by the program for the UNT Cocolamus Watershed added up to 0.1 hectares less than the value calculated using the raster proportions. Thus, the input value for "wooded areas" was reduced by a negligible 0.1 hectares to get the exact number needed by the program.

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 12 and 13. 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 31% in the agricultural area of the impaired watershed versus 56% 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 polygons (see Figure 13) 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.



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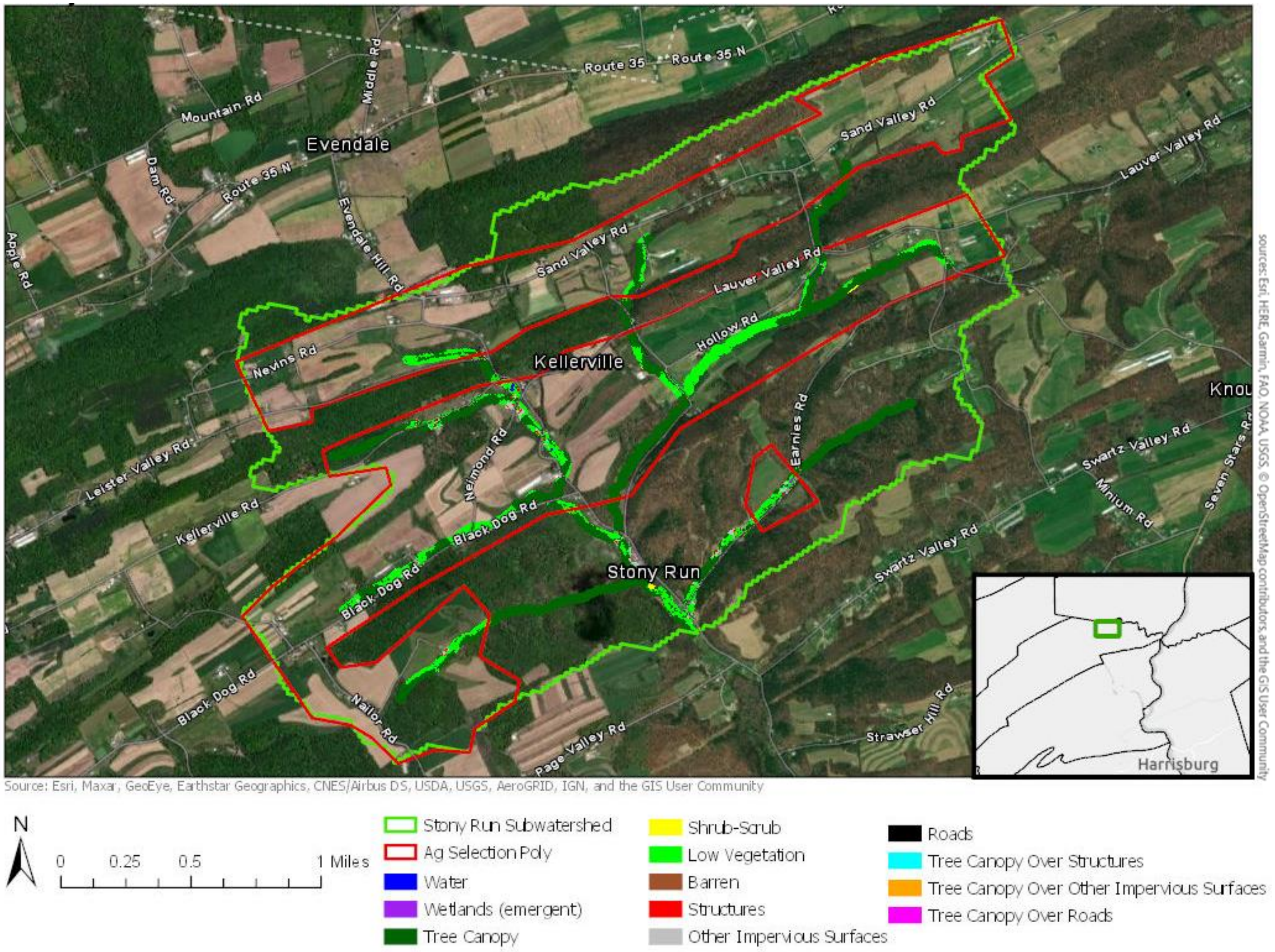
Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 12. Riparian buffer analysis in the UNT Cocolamus Watershed. 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. No agricultural area selection polygons were needed as all flowlines/buffers were considered to be in the agricultural area. The rate of riparian buffering was estimated to be about 31%. Note that UNT Cocalamus should have been spelled UNT Cocolamus in the figure legend.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 13. Riparian buffer analysis in the Stony Run 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 56%.

Calculation of the TMDL_{Avg}

The mean annual sediment loading rate for the unimpaired reference subwatershed (Stony Run) was estimated to be 277 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired UNT Cocolamus Watershed (565 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the UNT Cocolamus Creek Watershed should be reduced to 918,798 pounds per year or less (Table 9).

Table 7. Existing Annual Average Loading Values for the Stony Run Subwatershed, Reference

Source	Area ac	Sediment lbs/yr	Unit Area Load, lbs/ac/yr
Hay/Pasture	323	160,986	498
Cropland	686	541,119	789
Forest and Shrub/Scrub	1,766	8,206	5
Wetlands	6	0	0
Low Intensity Mixed Development	248	2,597	10
Medium Intensity Mixed Development	4	230	57
High Density Mixed Developmen	0.2	14	64
Streambank[1]		160,731	
Point Sources		0	
Additional Buffer Discount[2]		-32,658	
total	3,034	841,227	277

[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 UNT Cocolamus Creek Watershed, Impaired

Source	Area, ac	Sediment, lbs/yr	Unit Area Load, lb/ac/yr
Hay/Pasture	481	196,802	409
Cropland	1,565	1,564,525	1,000
Forest and Shrub/Scrub	1,032	2,741	3
Wetland	10	27	3
Grassland/Herbaceous	1	34	51
Low Intensity Mixed Development	224	2,314	10
Medium Intensity Mixed Development	1	42	32
Streambank		106,526	
Point Sources		0	
total	3,314	1,873,012	565

“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 UNT Cocolamus Creek Watershed

Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target TMDL_{Avg} Value, lbs/yr
Sediment	277	3,314	918,798

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:

918,798 lbs/yr TMDL_{Avg} * 0.1 = 91,880 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 National Pollutant Discharge Elimination System (NPDES) point source discharges with numeric limits for sediment (Table 4). Therefore, the wasteload allocation consisted solely of the bulk reserve, which was 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:

918,798 lbs/yr TMDL_{Avg} * 0.01 = 9,188 lbs/yr bulk $\text{reserve}_{\text{Avg}}$ + 0 lb/yr permitted loads = 9,188 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:

918,798 lbs/yr TMDL_{Avg} – (91,880 lbs/yr MOS_{Avg} + 9,188 lbs/yr WLA_{Avg}) = 817,730 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 and developed lands within the UNT Cocolamus Creek Watershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 5,158 lbs/yr (Table 10).

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

817,730 lbs/yr LA_{Avg} – 5,158 lbs/yr LNR_{Avg} = 812,571 lbs/yr ALA_{Avg}

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

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**817,730**
Loads Not Reduced (LNR_{Avg}):	**5,158**
Forest	2,741
Wetlands	27
Open Land	34
Low Intensity Mixed Development	2,314

Medium Intensity Mixed Development	42
Adjusted Load Allocation (ALA_{Avg})	**812,571**

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.

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 UNT Cocolamus 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 croplands exceeded the allocable load by itself. Thus, it received a 62% reduction whereas hay/pasture lands and streambanks each received a 27% reduction (Table 11).

Table 11. Average Annual Sediment Load Allocations for Source Sectors in the UNT Cocolamus Creek Watershed

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	1,565	591,695	1,564,525	62%
HAY/PASTURE	481	143,307	196,802	27%
STREAMBANK		77,570	106,526	27%
AGGREGATE		812,571	1,867,854	56%

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 99th percentiles (using the percentile.exc function) of estimated daily sediment loads in both the UNT Cocolamus (impaired) and Stony Run (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)).

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 99th percentile loading rate for the reference watershed by the same reduction proportion that was calculated previously for the average loading rate.

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 32,900 pounds per day (Table 12), which would be a 56% reduction from UNT Cocolamus Creek's current 99th percentile daily loading rate of 74,065 pounds per day.

Table 12. Calculation of $TMDL_{Max}$ for the UNT Cocolamus Creek 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	9.9	3,314	32,900

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 $TMDL_{Max}$. 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 UNT Cocolamus Creek Watershed

lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	32,900	3,290	329	29,281

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 9% of LA_{Avg} it was assumed that it was also 9% 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 UNT Cocolamus Creek Watershed

	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	817,730		29,281
Loads Not Reduced	5,158	0.006	185
Adjusted Loads Allocation	812,571	0.994	29,097
Croplands	591,695	0.72	21,187
Hay/Pasturelands	143,307	0.18	5,132
Streambanks	77,570	0.09	2,778

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 9% of LA_{Avg} it was assumed that it was also 9% 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 UNT Cocolamus Creek 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 UNT Cocolamus Creek Watershed would skyrocket to 12,008,636 lbs/yr, which is more than 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 UNT Cocolamus Creek

Watershed. Therefore, BMP implementation would ultimately be deemed adequate if the prescribed annual average reductions were satisfied.

Consideration of Critical Conditions and Seasonal Variations

“Model My Watershed” uses a continuous simulation model with daily time steps for weather data and water balance (precipitation, stream flow, surface runoff, subsurface flow, and evapotranspiration) calculations. The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990 (Stroud Water Research Center 2020). The evapotranspiration calculations also take into account the length of the growing season and changing day length. Monthly calculations are made for sediment loads based on daily water balance accumulated in monthly values. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations. 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 51% reduction in annual average sediment loading for the UNT Cocolamus Creek 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 62% each from croplands, and 27% each from hay/pasture lands and streambanks. Similarly, the 99th percentile daily sediment loading should be reduced by 56%. 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. Based on site observations, it appeared that grazing land management, streambank fencing, streambank stabilization, and forested riparian buffer BMPs were especially needed.

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 January 30, 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

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.

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).

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

Land Classication	**NLCD Code**	**hectares**	**%**
Developed, Open Space	21	82.4	6.1
Developed, Low Intensity	22	8.4	0.6
Developed, Medium Intensity	23	0.5	0.0
Deciduous Forest	41	347.1	25.9
Evergreen Forest	42	0.6	0.0
Mixed Forest	43	67.3	5.0
Shrub/Scrub	52	3.0	0.2
Open Land (Grassland/Herbaceous)	71	0.3	0.0
Hay/Pasture	81	194.7	14.5
Cultivated Crops	82	633.9	47.2
Woody Wetlands	90	2.9	0.2
Emergent Herbaceuous Wetlands	95	1.0	0.1
Sum		*1342.0*	*100.0*

Table B1. Land Cover based on NLCD 2016 for the UNT Cocolamus Creek Watershed. “Open Water” pixels were excluded from the analysis.

Land Classificaton	**NLCD Code**	**hectares**	**%**
Developed, Open Space	21	88.4	7.2
Developed, Low Intensity	22	12.2	1.0
Developed, Medium Intensity	23	1.6	0.1
Developed, High Intensity	24	0.1	0.0
Barren Land (Rock/Sand/Clay)	31	0.1	0.0
Deciduous Forest	41	616.1	50.1
Evergreen Forest	42	12.1	1.0
Mixed Forest	43	86.7	7.1
Shrub/Scrub	52	0.4	0.0
Hay/Pasture	81	130.9	10.7
Cultivated Crops	82	277.7	22.6
Emergent Herbaceuous Wetlands	95	2.5	0.2
Sum		*1228.7*	*100.0*

Table B2. Land Cover based on NLCD 2016 for the for the Stony Run Subwatershed. “Open Water” pixels were excluded from the analysis.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.77	0.77	5	0	0.28	7.15
Feb	6.46	0.96	5.5	0	0.43	7.31
Mar	7.54	0.46	7.09	0	1.54	8.36
Apr	6.4	0.13	6.28	0	4.2	8.41
May	4.45	0.1	4.35	0	8.4	10.51
Jun	3.47	0.85	2.62	0	11.98	10.58
Jul	1.29	0.15	1.14	0	11.72	9.86
Aug	0.4	0.1	0.3	0	9.32	8.64
Sep	0.83	0.7	0.12	0	6.18	9.04
Oct	1.21	0.51	0.7	0	3.41	8.06
Nov	2.42	0.36	2.06	0	1.58	9.38
Dec	5.25	0.55	4.7	0	0.61	8.11
Total	45.49	5.64	39.86	0	59.65	105.41

Table B3. “Model My Watershed” Hydrology Outputs for the UNT Cocolamus Creek Watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	6.09	0.73	5.35	0	0.31	7.15
Feb	6.46	0.92	5.55	0	0.47	7.31
Mar	7.45	0.42	7.03	0	1.68	8.36
Apr	6.35	0.11	6.23	0	4.32	8.41
May	4.47	0.09	4.38	0	8.42	10.51
Jun	3.54	0.83	2.71	0	10.96	10.58
Jul	1.4	0.14	1.27	0	10.37	9.86
Aug	0.57	0.09	0.48	0	8.5	8.64
Sep	1.13	0.68	0.45	0	5.8	9.04
Oct	1.89	0.49	1.4	0	3.46	8.06
Nov	3.24	0.33	2.91	0	1.65	9.38
Dec	6.05	0.52	5.53	0	0.65	8.11
Total	48.64	5.35	43.29	0	56.59	105.41

Table B4. “Model My Watershed” Hydrology Outputs for the Stony Run reference subwatershed

Sources	**Sediment (kg)**
Hay/Pasture	89,252.80
Cropland	709,535.30
Wooded Areas	1,243.00
Wetlands	12.4
Open Land	15.3
Barren Areas	0
Low-Density Mixed	97.1
Medium-Density Mixed	19.1
High-Density Mixed	0
Low-Density Open Space	952.5
Farm Animals	0
Stream Bank Erosion	48,311.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B5. Model My Watershed outputs for sediment in the UNT Cocolamus Creek Watershed.

Sources	**Sediment (kg)**
Hay/Pasture	73,009.60
Cropland	245,405.60
Wooded Areas	3,721.70
Wetlands	0
Open Land	0
Barren Areas	0
Low-Density Mixed	142.8
Medium-Density Mixed	104.3
High-Density Mixed	6.5
Low-Density Open Space	1,035.00
Farm Animals	0
Stream Bank Erosion	72,894.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B6. Model My Watershed Outputs for Sediment in the Stony Run reference subwatershed.

Appendix C: Stream Segments in the UNT Cocolamus Creek Watershed with Siltation Impairments for Aquatic Life Use

Stream Name:	**Impairment Source:**	**Impairment Cause:**	**COMID:**	**Miles:**
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204551	0.17
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204205	0.59
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204527	1.47
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204175	0.78
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204357	1.04
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204207	0.39
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204177	0.62
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204525	1.20
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204355	0.64
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204151	0.11
Unnamed Tributary to Cocolamus Creek	Grazing Related Agric	Siltation	66204167	0.06

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	1,564,525		yes		812,571				0.73		220,876		591,695		0.62
Hay/Pasture	196,802		no		196,802		303,328		0.18		53,496		143,307		0.27
Streambank	106,526		no		106,526				0.10		28,956		77,570		0.27
sum	**1,867,854**				**1,115,900**				**1.00**		**303,328**		**812,571**		**0.56**

Table D1. Equal Marginal Percent Reduction calculations for the UNT Cocolamus Creek 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

This section is reserved for public comments and responses. No public comments were received.