Mummasburg Run Sediment and Phosphorus TMDLs

Adams County, Pennsylvania

Prepared by:

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

"Total Maximum Daily Loads" (TMDLs) for sediment and phosphorus were developed for the Mummasburg Run Watershed (Figure 1) to address the siltation and nutrient 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 was identified as the cause of these impairments. Because Pennsylvania does not have numeric water quality criteria for sediment or phosphorus, 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. Existing annual average sediment loading in the Mummasburg Run Watershed was estimated to be 1,995,664 pounds per year. Phosphorus loading was estimated to be 3,342 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 62% to 760,817 pounds per year, and phosphorus loading should be reduced by 63% to 1,252 pounds per year. Allocation among the annual average TMDL variables is summarized in Table 1. To achieve these reductions while maintaining 10% margins of safety and minor allowances for point sources, annual average sediment loading from croplands should be reduced by 72% whereas loading from hay/pasture lands and streambanks should be reduced by 28%. Annual average phosphorus loadings from croplands should be reduced by 81% whereas loadings from hay/pasture lands, streambanks, and farm animals should be reduced by 58% each.

Table 1. Summary of Annual Average $TMDL_{Avg}$ Variables for the Mummasburg Run Watershed

lbs/yr:						
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	760,817	76,082	7,608	677,127	8,500	668,626
Phosphorus	1,252	125	13	1,114	249	864

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 99th percentile daily loading in the Mummasburg Run Watershed was estimated to be 100,882 pounds per day of sediment and 168 pounds per day of phosphorus. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 72% to 28,509 pounds per day. 99th percentile daily phosphorus loading should be reduced by 71% to 48 pounds per day. Allocation of 99th percentile daily sediment and phosphorus loading among the TMDL variables is summarized in Table 2.

Table 2. Summary of 99th Percentile Daily Loading $TMDL_{Max}$ Variables for the Mummasburg Run Watershed						
lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	28,509	2,851	285	25,373	319	25,055
Phosphorus	48	5	0.5	43	10	33

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 99^{th} percentile for daily loading.

Introduction

Mummasburg Run is a tributary of Marsh Creek, with the confluence approximately 3 miles northwest of the Borough of Gettysburg in Adams County, PA. The study watershed (Figure 1) contains approximately 15.5 stream miles, all of which were designated for cold-water fishes (Table 3). With the exception of an approximately half-mile reach of the headwaters, all stream segments in the watershed were listed as impaired for siltation and nutrients due to agriculture per the 2018 Final Integrated Report (see Appendix A for a description of assessment methodology).

The removal of natural vegetation and disturbance of soils 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. Soil erosion, along with animal waste and fertilizer use, may lead to excessive phosphorus loading in streams and in turn eutrophication, which may lower dissolved oxygen concentrations, increase pH, change community composition, and degrade aesthetic value.

While Pennsylvania does not have numeric water quality criteria for sediment or phosphorus, 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));*
>
> *and,*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code, Chapter 93.6 (b))*.

While agriculture has been identified as the source of the impairments, this TMDL document is applicable to all significant sources of phosphorus that may contribute to eutrophication, as well as all significant sources of sediment and solids that may settle to form deposits.

A striking feature of the Mummasburg Run Watershed was that it has been nearly completely deforested and converted to agriculture, which accounted for about 75% of its total land area (see Figure 1 and Appendix B, Table B1). The agricultural lands were nearly evenly divided between croplands and pasture/hay lands (40% versus 35% of total land cover). About 6% of land area within the watershed was classified as mixed development. Another notable feature of the watershed is that it lies within the "Adams County Fruitbelt". Pennsylvania is the fourth largest apple producer in the nation (TCG 2018), and its greatest concentration of orchards occurs within a four to six-mile-wide, approximately 25 miles long swath along the eastern border of South Mountain within Adams County (PHMC 2015). Orchards were most common in the hilly areas of the upper watershed.

There were no NPDES permitted point source discharges in the watershed with numeric limits relevant to sediment or phosphorus (Table 4).

Table 3. Aquatic-Life Impaired Stream Segments in the Mummasburg Run Watershed per the 2018 Final Pennsylvania Integrated Report

HUC: 02070009 – Lower Susquehanna-Swatara				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Agriculture	Siltation	15.0	CWF, MF	Aquatic Life
Agriculture	Nutrients	15.0	CWF, MF	Aquatic Life

HUC= Hydrologic Unit Code; CWF=Cold Water Fishes; 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

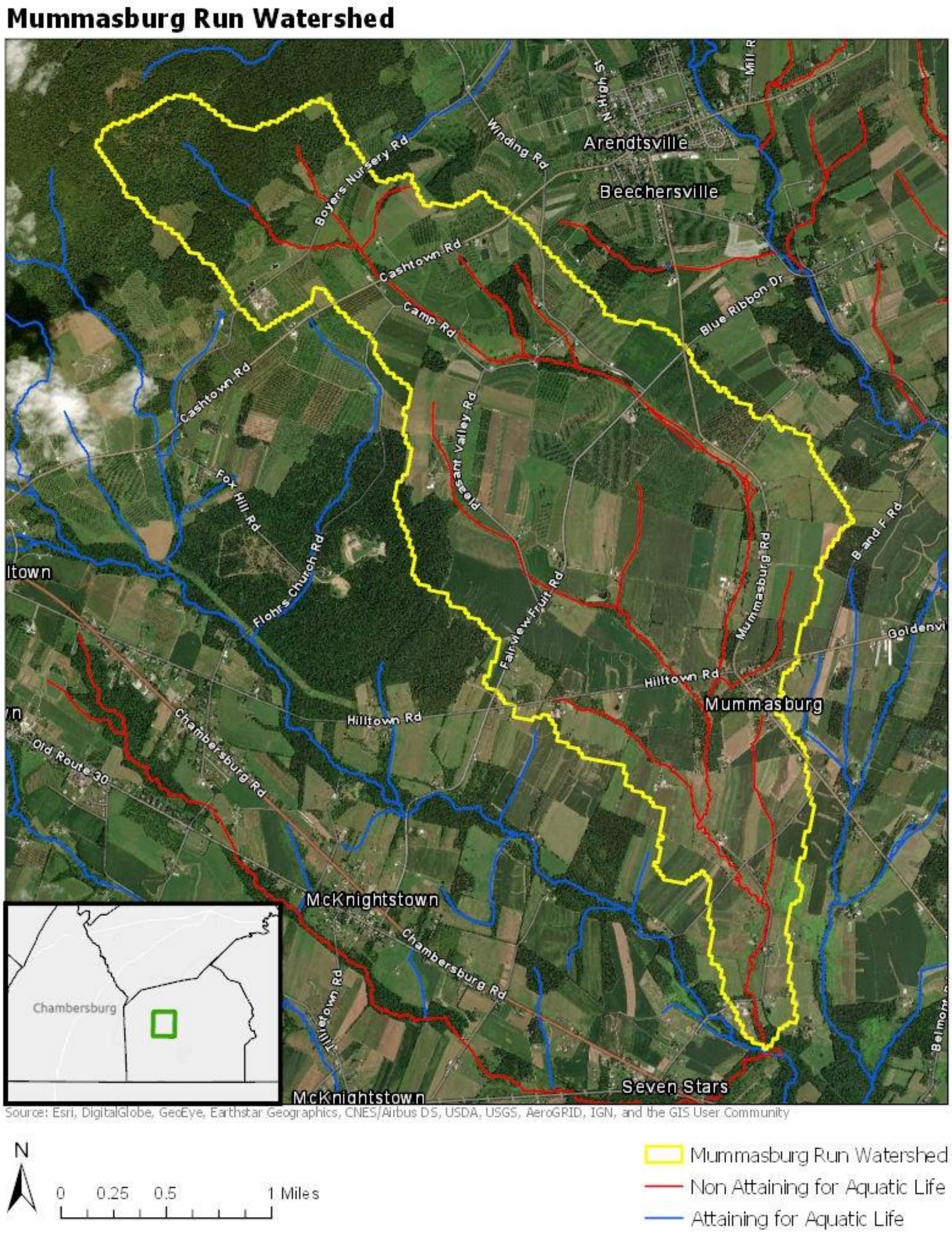

Figure 1. Mummasburg Run Watershed. Nearly all stream segments within the watershed were listed as impaired for siltation and nutrients per the 2018 final Integrated Report (see PA DEP's 2018 Integrated Report Viewer available at: https://www.depgis.state.pa.us/integrated_report_viewer/index.html)

Table 4. Existing NPDES Permitted Discharges in the Mummasburg Run Watershed and their Potential Contribution to Sediment and Phosphorus Loading.					
		Sediment Load		Phosphorus Load	
Permit No.	Facility Name	mean lb/yr	max lb/d	mean lb/yr	max lb/d
PAG123847	Wetzel Poultry Farm 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

NA – Not applicable. NPDES permit did not include numeric effluent limits relevant to sediment or phosphorus loading.

In Pennsylvania, routine, dry-weather discharges from concentrated animal feeding operations (CAFOs) are not allowed. Wet weather discharges are controlled through best management practices, which result in infrequent discharges from production areas and reduced sediment/nutrient 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, loadings from CAFOs are accounted for in the modeling of land uses, with the assumption of no additional CAFO-related BMPs.

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 or phosphorus, the "Reference Watershed Approach" was used. This method estimates loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired. Then, the loading rates in the unimpaired watershed are 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 unimpaired 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 and nutrient loading rates. Thus, selection of a reference watershed with similar natural characteristics as the impaired watershed is crucial. Failure to use an appropriate reference watershed could result in problems such as the setting of reduction goals that are unattainable, or nonsensical TMDL calculations that suggest that loadings in the impaired watershed should be increased.

To determine the suitability of the reference site, the Department's Integrated Report GIS-based website (available at http://www.depgis.state.pa.us/integrated_report/index.html) and internal GIS layers were used to search for nearby watersheds of similar size and characteristics of the Mummasburg Run Watershed, but lacked stream segments listed as impaired for sediment or nutrients. Potential watersheds were further scrutinized to confirm that they were clearly attaining based on assessment data, and preliminary modelling was done to confirm that use of a particular reference would result in reasonable pollutant reductions. No clearly suitable local references could be found, so the search was expanded to the entire Gettysburg-Newark Lowland Section of the Piedmont Physiographic province. Even so, a suitable reference still could not be found. Common problems with finding potential references included: that watersheds with similar physical characteristics tended to have similar pollution problems; lack of recent assessment data or the presence of data suggesting that the reference may contain impairments; and failure of the reference to produce reasonable pollutant reductions, which suggested that the impaired watershed may differ in some fundamental way. Thus, the search was expanded to other parts of the state.

Since the Mummasburg Run Watershed had a fairly low average slope (7%) and high surface runoff rate due in part to the presence of slow infiltration soils, the search for a reference focused on other areas of Pennsylvania with significant agricultural cover, low topographic relief and poorly drained soils. A subwatershed of Black Hole Creek (see Figure 2) in northcentral Pennsylvania (Lycoming County) was found to possess these key characteristics (Table 5). Furthermore, review of macroinvertebrate and physical habitat assessment data indicated that it was clearly attaining, and preliminary modelling suggested that its use would result in reasonable pollutant reductions.

Table 5. Comparison of the Impaired Mummasburg Run Watershed and Reference Black Hole Creek Subwatershed.

	Mummasburg Run	Black Hole Creek
Phys. Province[1]	89% Gettysburg-Newark Lowland Section of the Piedmont Province 11% South Mountain Section of the Blue Ridge Province	32% Appalachian Mountain Section of the Ridge and Valley Physiographic Province 68% Susquehanna Lowland Section of the Ridge and Valley Physiographic Province
Land Area[2], ac	3,543	3,940
Land Use[2]	75% Agriculture 19% Forest/Natural Vegetation 6% Developed	23% Agriculture 60% Forest/Natural Vegetation 16% Developed
Soil Infiltration[3]	19% Group A 29% Group B 0.2% Group B/D 13% Group C 16% Group C/D 22% Group D	29% Group A 23% Group B 1% Group B/D 4% Group C 28% Group C/D 15% Group D
Dominant Bedrock[4]	49% Silty Mudstone 34% Quartz Conglomerate 11% Metarhyolite 5% Diabase	12% Calcareous Shale 7% Limestone 14% Quartzite 14% Sandstone 43% Shale

	1% Metabasalt	10% Siltstone
Average Precipitation[5], in/yr	40.6	41.5
Average Surface Runoff[5], in/yr	3.3	2.6
Average Elevation[5] (ft)	741	904
Average Slope[5]	7.0%	10.1%
Stream Channel Slope[5]	1st order: 1.70% 2nd order 0.47%	1st order: 2.53% 2nd order: 0.55%

[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

The average slope in both watersheds was similar, though modestly greater in the Black Hole Creek Subwatershed (10.1 versus 7.0%, see Table 5). Based on an analysis of 2016 NLCD landcover, both watersheds had significant agricultural landcover, though percentage was far higher in the Mummasburg Run Watershed (75% versus 23%). Of the agricultural lands, the area of croplands was slightly greater than the area of hay/pasture lands in the Mummasburg Run Watershed whereas there were far more hay/pasture lands than croplands in the Black Hole Creek Subwatershed (See Appendix B, Tables B1 and B2). The percentage of naturally vegetated lands in the Black Hole Creek Subwatershed was more than three times the value found in the Mummasburg Run Watershed (60% versus 19%). Both watersheds had substantial amounts of both high and slow infiltration soils (Table 5), and the surface runoff rates of the two watersheds were similar (3.3 versus 2.6 in/yr).

Whereas stream segments in the Mummasburg Run Watershed were designated for cold-water fishes, all stream segments within the Black Hole Creek Subwatershed were designated for trout stocking. Neither watershed had any stream segments designated for special protection (high quality or exception value). Like the impaired watershed, there were no active NPDES permits with numeric limits relevant to phosphorus or sediment loading in the Black Hole Creek Subwatershed, though recently there was one relatively minor point source (Table 6).

Table 6. Existing NPDES Permitted Discharges in the Black Hole Creek Subwatershed and their Potential Contribution to Sediment and Phosphorus Loading.					
		Sediment Load		Phosphorus Load	
Permit No.	Facility Name	mean lb/yr	max lb/d	mean lb/yr	max lb/d
PAR604816	Robert Twigg[1] B&C Auto Wreckers	NA	NA	NA	NA
PA0010421	Moran Ind Inc. West Pharm Svc Montomery Plt.[2] (rescinded)	274	1.5	NA	NA
PAR234808	West Pharmaceutical Service[3]	NA	NA	NA	NA
PA0228311	Brady Township[4]	913	10	NA	NA
PAG045256	White Deer Hole Golf Course[5]	46	0.3	NA	NA
PA0041327	PA College of Technology WWTP[6]	183	1	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

[1]Industrial stormwater permit without sediment or phosphorus loading limits. Note that Model My Watershed accounts for loading from developed lands.

[2]This discharge has ceased and the permit has been rescinded. However, since the discharge was apparently active before and during the watershed's assessment, its pollutant loading was included in the watershed total. The amended permit, issued March 14, 2013, listed two outfalls but only one had limits relevant to sediment. Total suspended solids limits were 10 mg/l monthly average and 20 mg/l instantaneous maximum. A Pennsylvania Bulletin Notice listed a design flow of 0.009 MGD for this outfall. This flow, and the monthly average concentration limit was used to calculated mean lbs/yr. The instantaneous maximum concentration limit along with this flow was used to calculated max lbs/d. The other outfall had a design flow of 0.041 MGD. No limits were given for phosphorus.

[3]Industrial stormwater permit without sediment or phosphorus loading limits. Note that Model My Watershed accounts for loading from developed lands.

[4]Permit for a wastewater treatment plant. Based on the permit issued July 31, 2017, the total suspended solids load limit of 2.5 lbs/day monthly average was multiplied by 365 days per year to calculate the mean annual sediment load. The daily max sediment load was based on the 20 mg/l instantaneous maximum concentration limit for total suspended solids and a 0.06 MGD hydraulic design capacity for the wastewater treatment plant. No phosphorus limits were given.

[5]Permit for wastewater treatment plant expired 2013. According to EPA's Enforcement and Compliance History Online website, the facility had a design flow of 0.0015 MGD. A total suspended solids concentration limit of 10 mg/l monthly average was assumed when calculating the mean annual load and concentration limit of 20 mg/l instantaneous maximum was assumed when calculating the maximum daily load. No phosphorus limits were assumed.

[6]Permit for this WWTP has been terminated, but it was active during assessment sampling. The permit issued in 2016 had a 10 mg/l monthly average total suspended solids concentration limit as well as a 20 mg/l instantaneous maximum limit. The permit listed an effluent discharge rate of 0.006 MGD. This flow, along with the monthly average total suspended solids concentration was used to generate the monthly average load. This flow, along with the instantaneous maximum concentration was used to generate the daily maximum load. No phosphorus limits were assumed.

The Mummasburg Run Watershed was visited during the winter of 2019/2020 and the Black Hole Creek Subwatershed was visited during Spring 2020 to confirm the suitability of the reference as well as to explore whether there were any obvious land use differences that may help to explain why one watershed was impaired for sediment and nutrients while the other was attaining. Substantial fine sediment deposition was obvious in the Mummasburg Run Watershed (Figure 3). Based on site observations and GIS analysis, it is hypothesized that the Mummasburg Run Watershed's impairments were attributable to two key factors: 1) the extreme amount of landcover devoted to agriculture, and 2) the lack of expansive forested riparian buffers in many cases (see Figures 1, 4 and 5, though see also Figure 6). Aside from the lack of buffers, agricultural practices did not seem that bad. Crop fields typically had high levels of residue and grazing lands were well vegetated, at least at the time of the site visit (Figures 4 and 5). Even so, the nearly 77% agricultural coverage of the Mummasburg Run Watershed was comparable to watersheds of the most heavily farmed regions of the state, so impairment may be expected even if agricultural practices were good.

One area of uncertainty is the effect that orchards, which were common in the Mummasburg Run Watershed, may have on streams. Mature orchards typically had grassy swaths between tree rows, which would seem to prevent erosion. Furthermore, weed growth around trees appeared to be controlled with herbicides rather than mechanical soil disturbance. Thus, mature orchards did not appear to be an obvious cause of excessive pollution. However, based on a prior conversation with the Adams County Conservation District, orchard trees are periodically replaced, perhaps every 15 to 20 years or so. Indeed, a site was observed where orchard trees had been ripped out of the ground, and some soil disturbance was obvious (Figure 7). Furthermore, orchards are often replaced with crop fields for several years before tree replanting. This, combined with the fact that orchards of the region are often on steep slopes, suggests that these areas may experience episodic periods of high erosion.

Finally, it should be noted that site observations and the U.S. Fish & Wildlife Service's "National Wetlands Inventory" GIS Application indicated that wetlands were common along stream segments within the Mummasburg Run Watershed (Figure 8). Since wetlands are typically areas of natural sediment deposition, stream segments within the Mummasburg Run Watershed may be especially vulnerable to degradation resulting from enhanced upslope erosion.

Site observations within the Black Hole Creek Subwatershed indicated much healthier stream substrate conditions (see Figure 9). This was likely in large part due to its far lesser amount and intensity of agricultural landcover (compare Appendix Tables B1 and B2). As exemplified in Figures 10 and 4, agricultural lands within the Black Hole Creek Subwatershed tended to be intermixed with forested patches whereas the Mummasburg Run Watershed contained vast areas nearly devoid of trees. In addition, expansive forested riparian buffers were much more common in the Black Hole Creek Subwatershed (Figure 11, though see also Figure 12). According to a GIS analysis, approximately 72% of the land area within 100 feet of NHD flowlines was comprised of tree canopy vegetation, shrub/scrub lands or emergent wetlands in the agricultural valley area of the Black Hole Creek Subwatershed versus only about 33% in the Mummasburg Run Watershed (see the "Hydrologic / Water Quality Modelling" section). Furthermore, hay/pasture lands in the Black Hole Creek Subwatershed typically appeared as meadows that seemed to be mowed infrequently whereas such lands within the Mummasburg Run Watershed were more commonly large expanses of closely cropped grasses (Figures 10 and 14 versus Figure 5).

The far lesser amount and intensity of agricultural land uses within the Black Hole Creek Subwatershed was in large part due to the presence of the restricted Susquehanna Ordnance Depot military site, which along with the neighboring White Deer Golf Course, probably comprised more than half of the land area within the subwatershed that would have been suitable for agriculture (Figure 13). In fact, the land that is now the Susquehanna Ordnance Depot at one time contained numerous farms until the Federal Government acquired these lands in the early 1940s for the purpose of manufacturing and stockpiling munitions for World War II (Beauge 2019). At present, the site is fenced and posted against trespassing. And, according to satellite imagery, GIS land use classification, and observations from its perimeter, it appears to be mostly comprised of patches of forest, wetland, and areas of hay/mowed grass (Figure 14). Such grasslands and even developed lands associated with golf courses would be expected to be a far lesser sources of sediment than crop fields.

It should be noted that the Mummasburg Run and the Black Hole Creek watersheds were in different physiographic provinces, had different geologies, and experienced somewhat different climatic conditions (see Table 5). While the uncertainties resulting from such factors are not ideal, the Black Hole Creek Subwatershed was chosen as the most suitable reference candidate identified following a diligent search for potential references. And, as detailed in the “Calculation of the Load Allocations” section, the prescribed pollution reductions include a safety factor that helps account for such uncertainty.

Black Hole Creek Subwatershed

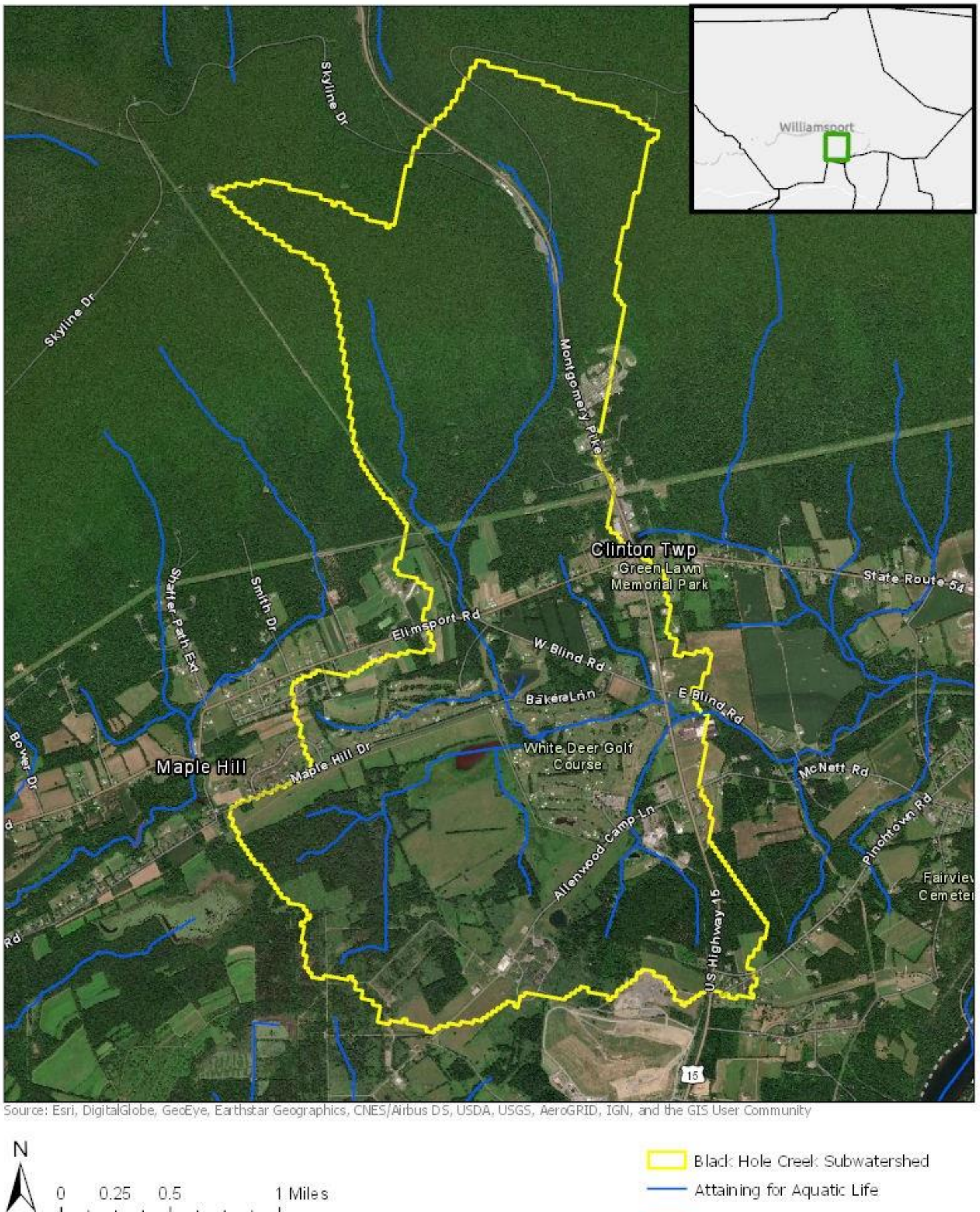

Figure 2. Black Hole Creek reference subwatershed. All stream segments were listed as attaining for aquatic life per the 2018 Final Pennsylvania Integrated Report. (see PA DEP's 2018 Integrated Report Viewer available at: https://www.depgis.state.pa.us/integrated_report_viewer/index.html)

Figure 3. Examples of fine sediment degradation within the Mummasburg Run Watershed.

Figure 4. Agricultural landscape within the Mummasburg Run Watershed. This photo shows hay and crop fields growing in the valley and orchards on the hill in the distance. Note the intensity of agriculture and lack of forested riparian buffers.

Figure 5. Stream segments among agricultural lands with minimal to no riparian buffers in the Mummasburg Run Watershed. These sites included streams among croplands (photos A and C) as well as hay or pasture lands (photos B and D). Lack of substantial riparian buffers may be especially problematic in areas with high slopes, as in photographs C and D. On a positive note, the croplands shown in photographs A and C had a high amount of crop residue and the pasturelands shown in photograph D lacked large areas of bare soils.

Figure 6. Photographs showing stream segments with forested or herbaceous/wetland riparian buffers within the Mummasburg Run Watershed. Note that in some cases buffers may have been too narrow to be highly protective (photograph D).

Figure 7. Orchard tree removal within the Mummasburg Run Watershed.

Figure 8. Large expanse of wetlands within the Mummasburg Run Watershed.

Figure 9. Example streambed conditions in the Black Hole Creek Subwatershed. Observed sites were typically very rocky with the exception of some minor fine sediment deposition in pools. All photographs were taken within the study subwatershed with the exception of D, which was taken approximately 0.6 miles downstream of the delineation point.

Figure 10. Landscape within the Black Hole Creek Subwatershed. Note the patchy light-intensity agriculture, sparse development and the presence of forested/wetland buffer along the stream.

Figure 11. Examples of conditions within the Black Hole Creek Subwatershed that may prevent sediment and nutrient pollution. Photographs A shows a drainageway within the mountainous headwaters area of the watershed near Route 15/Montgomery Pike. Runoff from along the highway appeared to infiltrate within boulder-fields in this forested area, which may remove sediment and nutrients. Photographs B through D show examples of forested/wetland riparian buffers that were common along valley reaches.

Figure 12. Stream segments/drainageways among lands with potentially inadequate riparian buffers in the Black Hole Creek Subwatershed. The stream shown in the upper photograph lacks a forested buffer on one side between the lawn and road shoulder. While there is some forested buffer along the drainageway in the lower photo, it appears to be too narrow to be adequately protective from the surrounding soy fields. Overall however, buffering within the watershed was common and these examples did not appear to be highly problematic. Note the relative flatness of the landscapes and high vegetative cover.

Black Hole Creek Subwatershed

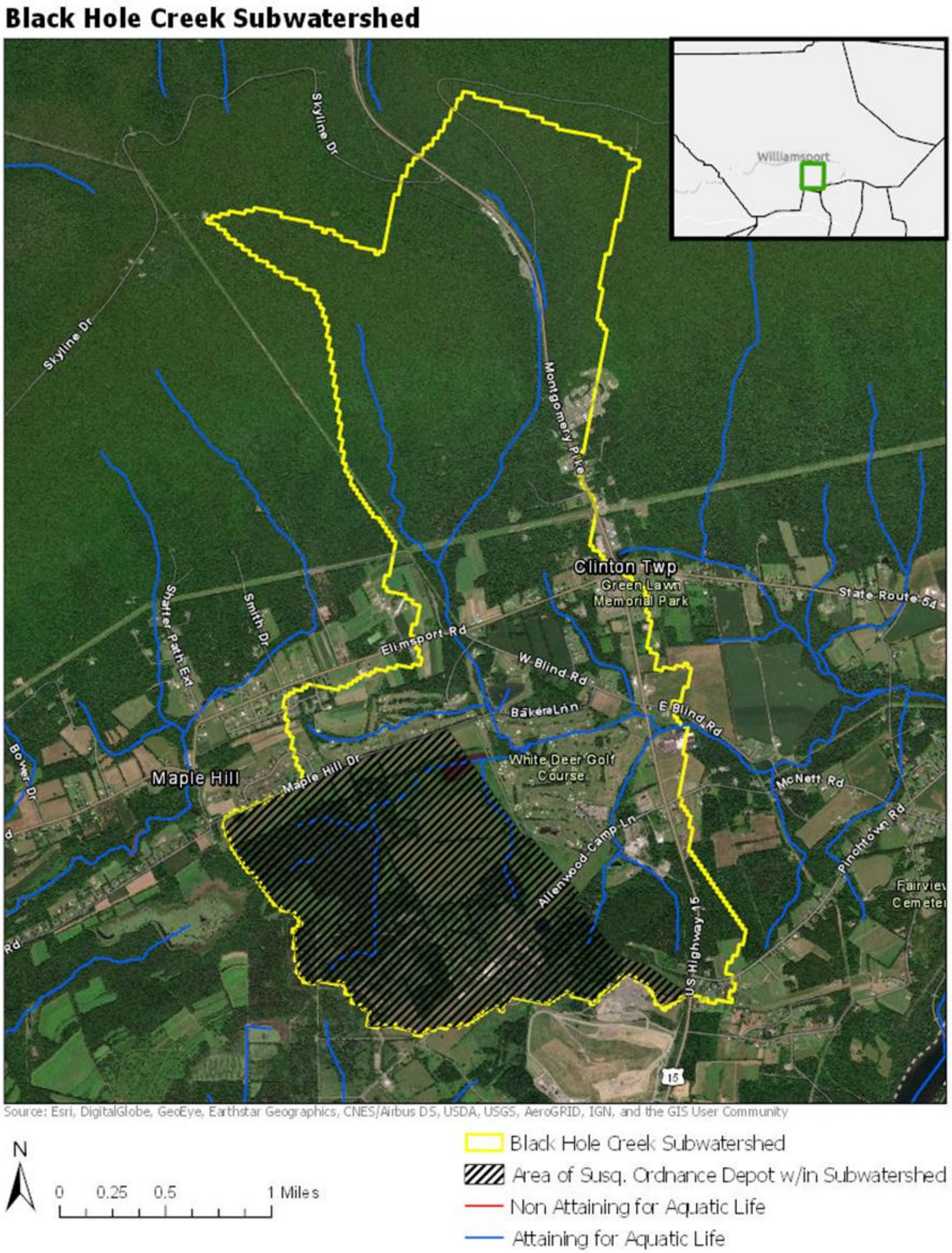

Figure 13. Approximate area of the Susquehanna Ordnance Depot within the Black Hole Creek Subwatershed. The location of the Depot's lands as shown in this figure is approximate and based on visual inspection of the Lycoming County Parcel Viewer. Also, be aware that only Depot lands within the watershed are shown; their lands actually extend well beyond the watershed boundary.

Figure 14. Photograph looking into the Susquehanna Ordnance Depot from the fenced periphery along Maple Hill Drive. Note the presence of mowed grass fields/hay and forested area down in the valley.

Hydrologic / Water Quality Modeling

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

Estimates of sediment and phosphorus 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 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 Version 1.27.0 allows the user to adjust model parameters, such as the area of land coverage types, the use of and efficiency of conservation practices, the watershed's sediment delivery ratio, etc. In the present study the area of landcover types were adjusted to reflect newer NLCD 2016 data because the current version of Model My Watershed based landcover on NLCD 2011 and substantial discrepancies were noted between these datasets. A raster dataset of NLCD 2016 landcover was opened in ArcGISPro and clipped to the shapefile of each watershed 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 inputs typically added up to 0.1 hectares greater or lesser than the exact landcover area needed by the program. Thus, whichever landcover class was closest to having been rounded in the other direction needed was changed by a negligible +/- 0.1 hectare to get the exact number needed. In addition, the average annual flow from the wastewater treatment plant listed in Table 6 was added as an input for the Black Hole Creek Subwatershed. Otherwise, default values were used for the modelling runs.

After the modelling run, corrections were made to account for the presence of existing riparian buffers using the BMP Spreadsheet Tool provided by Model My Watershed. The following paragraphs describe this 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 (geodesic) 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. Note that Susquehanna Ordnance Depot lands were included within the selection polygon due the presence of mowed grasslands, though it is uncertain whether these were actually used for hay production. Riparian buffer classifications are shown in Figures 15 and 16. 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 72% in the Black Hole Creek Subwatershed versus 33% in the reference watershed.

Additional pollution reductions were 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 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 within the agricultural area selection polygon, then by the difference in proportion 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 and phosphorus reductions 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 and phosphorus 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 or phosphorus loading rate calculated for croplands, and then by a reduction coefficient of 0.54 for sediment and 0.40 for phosphorus. The BMP spreadsheet tool is designed to account for the area of lost cropland and gained forest when riparian buffers are created. However, these parts of the reduction equations were deleted for the present study since historic rather than proposed buffers were being accounted for.

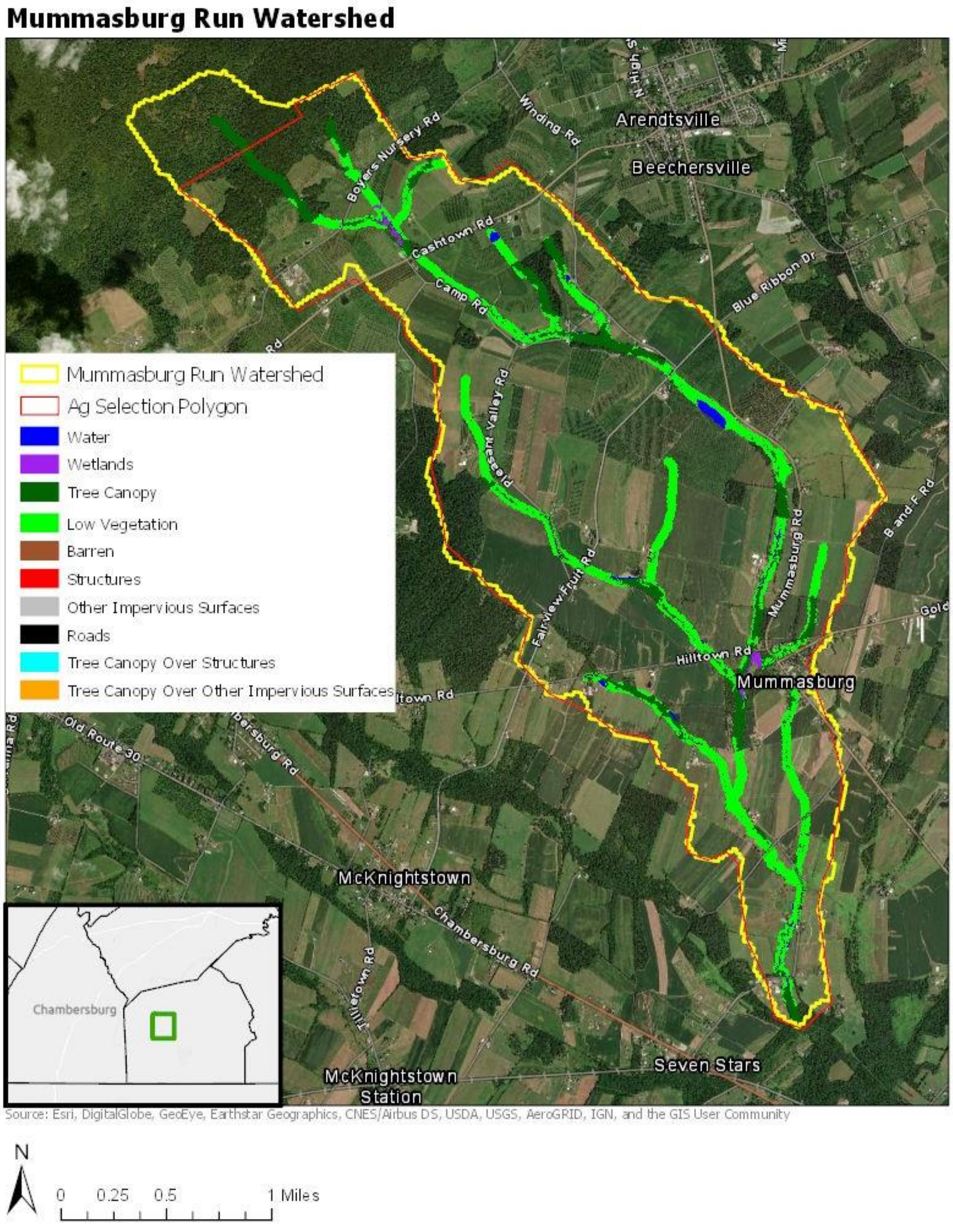

Figure 15. Riparian buffer analysis in the Mummasburg Run Watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The agricultural area selection polygon is shown in red. It was estimated that only about 33% of land area within 100 feet of NHD flowlines within the agricultural area selection polygon was comprised of forest, wetlands, or shrub/scrub lands.

Black Hole Creek Subwatershed

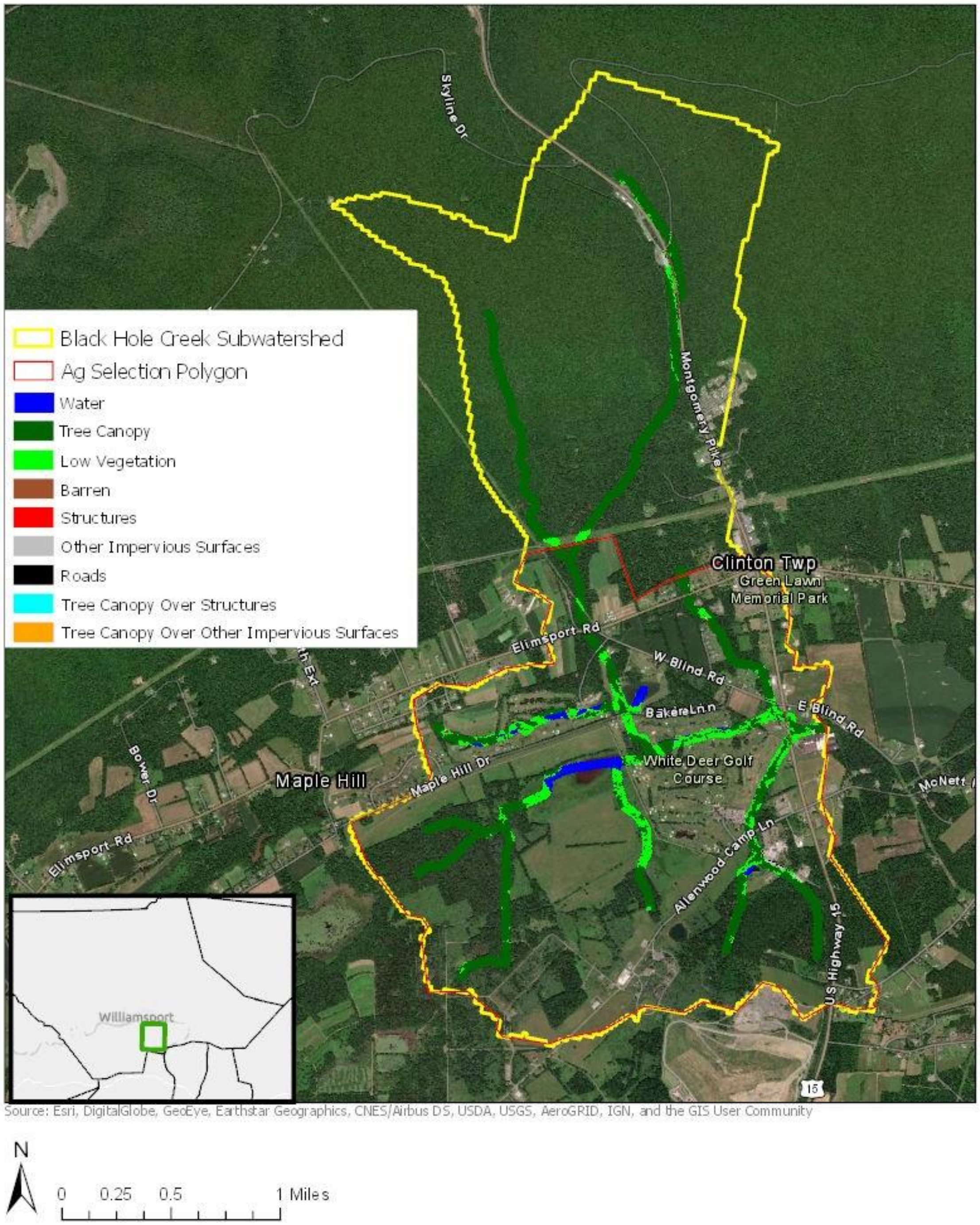

Figure 16. Riparian buffer analysis in the Black Hole Creek Subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The agricultural area selection polygon is shown in red. Note that the grass fields and other lands within the Susquehanna Ordnance Depot were included in the "agricultural area". It was estimated that about 72% of land area within 100 feet of NHD flowlines within the agricultural area selection polygon was comprised of forest, wetlands, or shrub/scrub lands.

Calculation of the TMDL

The mean annual loading rates for the unimpaired reference subwatershed (Black Hole Creek) were estimated to be 215 pounds per acre per year of sediment and 0.35 pounds per acre per year of phosphorus (Table 7). These were substantially lower than the estimated mean annual loading rates in the impaired Mummasburg Run Watershed: 565 pounds per acre per year of sediment and 0.95 pounds per acre per year of phosphorus (Table 8). To achieve the loading rates of the unimpaired watershed, loadings in the Mummasburg Run Watershed should be reduced to 760,817 pounds per year of sediment and 1,252 pounds per year of phosphorus, or less (Table 9).

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

Source	Area, ac	Sediment, lbs/yr	Sediment, lb/ac/yr	P lbs/yr	P lbs/ac/yr
Hay/Pasture	799	498,513	624	776	0.97
Cropland	120	201,956	1,682	280	2.33
Forest and Shrub/Scrub	2,297	5,019	2	17	0.007
Wetland	77	0	0	0	0
Open Land	1	43	33	0	0
Bare Rock	15	0	0	0	0
Low Intensity Mixed Development	584	6,113	10	15	0.03
Medium Intensity Mixed Development	39	2,585	66	5	0.13
High Density Mixed	7	458	65	1	0.12
Streambank[1]		284,222		79	
Farm Animals				182	
Groundwater				196	
Extra Buffer Discount[2]		-152,105		-156	
Point Sources		1,416			
total	3,940	848,220	215	1,395	0.35

[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 Mummasburg Run Watershed, Impaired					
Source	Area, ac	Sediment, lbs/yr	Sediment, lb/ac/yr	P lbs/yr	P lbs/ac/yr
Hay/Pasture	1,237	71,195	58	299	0.24
Cropland	1,422	1,728,674	1,216	1,893	1.33
Forest and Shrub/Scrub	513	1,638	3	2	0.005
Wetland	93	346	4	2	0.02
Open Land	59	4,107	69	4	0.07
Low Intensity Mixed Development	205	2,147	10	5	0.03
Medium Intensity Mixed Development	4	263	59	0.4	0.1
Streambank		187,295		40	
Farm Animals				861	
Groundwater				235	
total	3,534	1,995,664	565	3,342	0.95

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

Table 9. Calculation of Annual Average TMDL Values for the Mummasburg Run Watershed			
Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Avg}$ Value, lbs/yr
Sediment	215	3,534	760,817
Phosphorus	0.35	3,534	1,252

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 allocations, the margins of safety and wasteload allocations 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} for each TMDL was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

Sediment: 760,817 lbs/yr $TMDL_{Avg}$ * 0.1 = 76,082 lbs/yr MOS_{Avg}

Phosphorus: 1,252 lbs/yr $TMDL_{Avg}$ * 0.1= 125 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 in the impaired watershed with numeric limits for sediment or phosphorus (Table 4). Bulk reserves were included as part of the wasteload allocations to allow for insignificant dischargers and minor increases from point sources as a result of future growth of existing or new sources.

Since there were no permits with numeric effluent limits for sediment or phosphorus, the WLAs were simply comprised of the bulk reserves, which we defined as one percent of the targeted TMDLs. Therefore:

Sediment: 760,817 lbs/yr $TMDL_{Avg}$ * 0.01 = 7,608 lbs/yr bulk $reserve_{Avg}$ + 0 lb/yr permitted loads = 7,608 lbs/yr WLA_{Avg}

Phosphorus: 1,252 lbs/yr $TMDL_{Avg}$*0.01 = 13 lbs/yr bulk $reserve_{Avg}$ + 0 lbs/yr permitted loads = 13 lbs/yr WLA_{Avg}

It should be noted that the concentrated animal feeding operation (CAFO) listed in Table 4 was not provided individual wasteload allocations. Runoff from land application areas of CAFOs is typically considered nonpoint source pollution when permittees are operating in compliance with their permits.

Furthermore, Pennsylvania does not allow routine point source discharges from CAFO production areas. If, however, effluent limits are necessary in the future, capacity would be available in the bulk reserves.

Load Allocation

Now that the margins of safety and wasteload allocations have been defined, the load allocations (LA) are calculated as:

Sediment: 760,817 lbs/yr $TMDL_{Avg}$ – (76,082 lbs/yr MOS_{Avg} + 7,608 lbs/yr WLA_{Avg}) = 677,127 lbs/yr LA_{Avg}

Phosphorus: 1,252 lbs/yr $TMDL_{Avg}$ – (125 lbs/yr MOS_{Avg} + 13 lbs/yr WLA_{Avg}) = 1,114 lbs/yr LA_{Avg}

Loads Not Reduced and Adjusted Load Allocation

Since the impairments addressed by this TMDL are due to agriculture, sediment and phosphorus contributions from forests, wetlands, developed lands, and groundwater (for phosphorus) within the Mummasburg Run Watershed were considered loads not reduced (LNR). LNR_{Avg} were calculated to be 8,500 lbs/yr for sediment and 249 lbs/yr for phosphorus (Table 10).

The LNRs were subtracted from the LAs to determine the ALAs:

Sediment: 677,127 lbs/yr LA_{Avg} – 8,500 lbs/yr LNR_{Avg} = 668,626 lbs/yr ALA_{Avg}

Phosphorus: 1,114 lbs/yr LA_{Avg} – 249 lbs/yr LNR_{Avg} = 864 lbs/yr ALA_{Avg}

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

	Sediment lbs/yr	Phosphorus lbs/yr
Load Allocation (LA_{Avg})	**677,127**	**1,114**
Loads Not Reduced (LNR_{Avg}):	**8,500**	**249**
Forest	1,638	2
Wetlands	346	2
Low Intensity Mixed Development	2,147	5
Med. Intensity Mixed Dev.	263	0.4
Groundwater	0	235
Open Land	4,107	4
Adjusted Load Allocation (ALA_{Avg})	**668,626**	**864**

Note, the ALA is comprised of the anthropogenic sources targeted for reduction: croplands, hay/pasturelands, streambanks (assuming an elevated erosion rate) and farm animals. The LNR is comprised of both natural and anthropogenic sediment and phosphorus sources. While anthropogenic, developed lands were considered a negligible sediment and phosphorus source in this watershed and thus not targeted for reduction. Forests, wetlands and groundwater were considered natural sediment or phosphorus sources.

Calculation of Load Reductions

To calculate load reductions by source, the ALAs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although the Mummasburg Run TMDLs were developed to address impairments caused by agricultural activities, streambanks were also significant contributors to the sediment and phosphorus loadings 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 analysis, croplands exceeded the entire allocable load of sediment by itself, so it received a greater annual average reduction goal (72%) than hay/pasture lands or streambanks (28% each) (Table 11). Likewise for phosphorus, croplands received an 81% reduction whereas hay/pasture lands, streambanks and farm animals received the same prescribed annual average reduction of 58% (Table 12).

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

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	1,422	482,206	1,728,674	72%
HAY/PASTURE	1,237	51,345	71,195	28%
STREAMBANK		135,075	187,295	28%
AGGREGATE		668,626	1,987,163	66%

Table 12. Annual Average Phosphorus Load Allocations for Source Sectors in the Black Hole Creek Subwatershed

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	1,422	362	1,893	81%
HAY/PASTURE	1,237	125	299	58%
STREAMBANK		17	40	58%

FARM ANIMALS			361		861	58%
AGGREGATE			864		3,093	72%

Calculation of Daily Maximum "$TMDL_{Max}$" Values

When choosing the best timescale for expressing pollutant loading limits for siltation and phosphorus, several factors must be considered:

1) Sediment and nonpoint-source phosphorus 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.
3) Nonpoint-source phosphorus pollution typically harms aquatic communities through eutrophication degradation as a result of chronically excessive loading.

Considering then that siltation and nonpoint-source phosphorus 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, true "Total Maximum Daily Loads" ($TMDL_{Max}$) are 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 $TMDL_{Max}$ values, modelling was initially conducted in Model My Watershed, and the "Export GMS" feature was used to provide input data files that were run in MapShed. The daily output was opened in Microsoft Excel (Version 1902), and current maximum daily loads were calculated as the 99th percentiles (using the percentile.exc function) of estimated daily sediment and phosphorus loads in both the Mummasburg Run (impaired) and Black Hole Creek (reference) Watersheds. The first year of data were excluded to account for the time it takes for the model calculations to become reliable. 99th percentiles were chosen because 1) sediment and phosphorus loading increases with the size of storm events, so, as long as there could be an even larger flood, true upper limits to 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 agricultural area of 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 percentage that was calculated previously for the average loading rate. Then, any maximum daily point sources reported in Tables 4 or 6 were added to the watershed total.

Then, similarly to the $TMDL_{Avg}$ values reported in Table 9, $TMDL_{Max}$ values were calculated as the 99th percentile daily loads of the reference watershed, divided by the acres of the reference watershed, and then multiplied by the acres of the impaired watershed. The $TMDL_{Max}$ loading rate for sediment was calculated as 28,509 pounds per day (Table 13), which would be a 72% reduction from Mummasburg

Run's current 99th percentile daily loading rate of 100,882 pounds per day. For phosphorus, the $TMDL_{Max}$ loading rate was calculated as 48 pounds per day (Table 13), which would be a 71% reduction from Mummasburg Run's current 99th percentile daily loading rate of 168 pounds per day.

Table 13. Calculation of $TMDL_{Max}$ Values for the Mummasburg Run Watershed			
Pollutant	99th Percentile Loading Rate in Reference, lbs/ac/d	Total Area in Impaired Watershed, ac	Target $TMDL_{Max}$ Value, lbs/d
Sediment	8.1	3,534	28,509
Phosphorus	0.014	3,534	48

Also, in accordance with the previous "Calculation of Load Allocations" section, the WLA_{Max} would consist solely of a bulk reserve defined as 1% of the $TMDL_{Max}$ and the MOS_{Max} would be 10% of the $TMDL_{Max}$. The LA_{Max} would then be calculated as the amount remaining after subtracting the WLA_{Max} and the MOS_{Max} from the $TMDL_{Max}$. See Table 14 for a summary of these $TMDL_{Max}$ variables.

Table 14. 99th Percentile of Daily Loading TMDL ($TMDL_{Max}$) Variables for the Mummasburg Run Watershed				
lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	28,509	2,851	285	25,373
Phosphorus	48	5	0.5	43

The modelling program however 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 20% of LA_{Avg} it was assumed that it was also 20% 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 Tables 15 and 16 for a summary of these LA_{Max} variables.

Table 15. Allocation of the 99th Percentile Daily Sediment Load Allocation (LA_{Max}) for the Mummasburg Run Watershed			
	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)

Load Allocation	677,127		25,373
Loads Not Reduced	8,500	0.013	319
Adjusted Loads Allocation	668,626	0.987	25,055
Croplands	482,206	0.71	18,069
Hay/Pasturelands	51,345	0.08	1,924
Streambanks	135,075	0.20	5,061

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 20% of LA_{Avg} it was assumed that it was also 20% of LA_{Max}.

Table 16. Allocation of the 99th Percentile Daily Phosphorus Load Allocation (LA_{Max}) for the Mummasburg Run Watershed

	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	1,114		43
Loads Not Reduced	249	0.22	10
Adjusted Loads Allocation	864	0.78	33
Croplands	362	0.32	14
Hay/Pasturelands	125	0.11	5
Streambanks	17	0.01	1
Farm Animals	361	0.32	14

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 1% of LA_{Avg} it was assumed that it was also 1% of LA_{Max}.

Because both sediment and phosphorus loading vary so greatly with discharge, the $TMDL_{Max}$ values 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 and nutrient loading (see-Sloto and Olson 2011, Sloto et al. 2012), it is cautioned that reliance solely on a $TMDL_{Max}$ values may not be protective because chronic excessive inputs occurring at lower discharge levels may be ignored. Take for instance an extreme scenario where the $TMDL_{Max}$ value for sediment was met every day but never exceeded. In this case, annual sediment loading in the Mummasburg Run Watershed would skyrocket to 10,405,809 lbs/yr, which is more than five-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 Mummasburg Run Watershed. Therefore, while adherence with the loading requirements of this TMDL include meeting both the $TMDL_{Avg}$ and the $TMDL_{Max}$, 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 on 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.

Summary and Recommendations

This document proposes a 62% reduction in annual average sediment loading and 63% reduction in annual average phosphorus loading for the Mummasburg Run Watershed. To achieve these goals while maintaining margins of safety and minor allowances for point sources, it is proposed to reduce sediment loading from croplands by 72% and hay/pasture lands and streambanks by 28%. Annual average phosphorus loading from croplands should be reduced by 81% whereas loading from hay/pasture lands, farm animals and streambanks should be reduced by 58% each. In addition, 99th percentile daily sediment and phosphorus loading should be reduced by 72% and 71%, respectively.

Reductions in stream sediment and nutrient loading due to agricultural activities can be made through the implementation of required Erosion and Sediment Control and Nutrient Management Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Chapter 102.4) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, legacy sediment removal etc.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. However, 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.

As mentioned previously in the "Introduction" and "Selection of the Reference Watershed" sections, orchards were common in the upper portions of the watershed, and because they are often on sloping lands, they may be particularly prone to erosion, especially when orchards are cleared and periodically replaced with crops (see Figure 7, also Figure 17). Thus, we recommend that orchard management practices and the need for erosion and sedimentation controls be evaluated over the entire orchard rotation cycle.

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 new BMPs needed to achieve the prescribed sediment and phosphorus reductions. Key personnel from the regional DEP office, the County Conservation District, 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.

Figure 17. Example orchard management practices in Adams County. In mature orchards, weeds within the tree rows appeared to be managed with herbicides and the rows were separated by vegetated swaths (Photograph A). Photograph B shows new plantings on steep slopes within strips plowed on contour, but the tree rows were separated by vegetated strips. Photographs C and D show tree removal. In C, trees were uprooted, leaving only bare patches within the vegetated strips. Photograph D shows extensive bare soils on steep slopes where an old overgrown orchard was cleared. Note these photographs were taken as part of another study and were not within the Mummasburg Run Watershed.

Public Participation

Public notice of the draft TMDL document was published in the Pennsylvania Bulletin on July 11th and August 1st, 2020 to foster public comment. A public comment period ran until August 24, 2020. See Appendix F for public comments and responses.

Citations

Note: maps for this document were made with ArcGIS Pro 2.2.0 by Esri.

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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 sought to select 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 then 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) were completed, the biologist determined the status of the stream segment. The decision was based on the performance of the segment using a series of biological metrics. If the stream segment was classified as impaired, it was then 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 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 Data Tables

Land Class	Acres
Hay/Pasture	1237.0
Cropland	1422.1
Various Forest +Shrub/Scrub	513.0
Various Wetland	92.8
Open Land (grassland/herbaceous)	59.4
Bare Rock	0.0
Developed, Low-Density Mixed	205.3
Developed, Medium-Density Mixed	4.4
Developed-High Density Mixed	0.0

Table B1. Estimates of land uses in the Mummasburg Run Watershed based on NLCD 2016. A GIS analysis was conducted to determine the proportion of total non-open water NLCD 2016 raster pixels that were in each of the listed land classes. Then those proportions were multiplied by the total area of non-open water land reported by Model My Watershed.

Land Class	Acres
Hay/Pasture	798.9
Cropland	120.0
Various Forest +Shrub/Scrub	2297.4
Various Wetland	76.6
Open Land (grassland/herbaceous)	1.3
Bare Rock	15.1
Developed, Low-Density Mixed	584.3
Developed, Medium-Density Mixed	39.2
Developed-High Density Mixed	7.1

Table B2. Estimates of land uses in the Black Hole Creek Subwatershed based on NLCD 2016. A GIS analysis was conducted to determine the proportion of total non-open water NLCD 2016 raster pixels that were in each of the listed land classes. Then those proportions were multiplied by the total area of non-open water land reported by Model My Watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.4	1.34	4.06	0	0.49	7.48
Feb	6.1	1.25	4.85	0	0.76	7.68
Mar	6.71	0.73	5.98	0	2.23	8.46
Apr	5.48	0.14	5.34	0	5.18	8.04
May	3.91	0.32	3.59	0	9.84	10.14
Jun	2.78	0.79	1.99	0	12.96	9.55
Jul	1.25	0.4	0.86	0	10.54	9.26
Aug	0.67	0.37	0.29	0	8.54	9.17
Sep	1.14	1.02	0.12	0	5.8	8.79
Oct	0.95	0.52	0.43	0	3.91	7.51
Nov	1.62	0.67	0.94	0	2.08	8.7
Dec	3.65	0.92	2.73	0	0.98	8.44
Total	39.66	8.47	31.18	0	63.31	103.22

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

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.88	0.94	4.9	0.04	0.35	7.15
Feb	6.57	1.17	5.36	0.03	0.55	7.31
Mar	7.44	0.59	6.81	0.04	1.94	8.36
Apr	5.98	0.16	5.79	0.04	4.69	8.41
May	3.91	0.13	3.74	0.04	8.87	10.51
Jun	3.08	0.9	2.14	0.04	12.11	10.58
Jul	1.06	0.18	0.84	0.04	11.34	9.86
Aug	0.34	0.13	0.18	0.04	9.1	8.64
Sep	0.92	0.78	0.1	0.04	5.91	9.04
Oct	1.39	0.6	0.76	0.04	3.67	8.06
Nov	2.58	0.46	2.08	0.04	1.82	9.38
Dec	5.47	0.68	4.75	0.04	0.72	8.11
Total	44.62	6.72	37.45	0.47	61.07	105.41

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

Sources	Sediment (kg)	Total P (kg)
Hay/Pasture	32,287.90	135.8
Cropland	783,979.00	858.3
Wooded Areas	742.7	1.1
Wetlands	156.7	0.9
Open Land	1,862.70	2
Barren Areas	0	0
Low-Density Mixed	195.7	0.5
Medium-Density Mixed	119.2	0.2
High-Density Mixed	0	0
Low-Density Open Space	778	1.9
Farm Animals	0	390.6
Stream Bank Erosion	84,941.00	18
Subsurface Flow	0	106.5
Point Sources	0	0
Septic Systems	0	0

Table B5. Model My Watershed outputs for sediment and phosphorus in the Mummasburg Run Watershed.

Sources	Sediment (kg)	Total P (kg)
Hay/Pasture	226,082.80	352.1
Cropland	91,590.00	127.1
Wooded Areas	2,276.30	7.6
Wetlands	0	0
Open Land	19.7	0
Barren Areas	0	0
Low-Density Mixed	397.5	1
Medium-Density Mixed	1,172.40	2.3
High-Density Mixed	207.8	0.4
Low-Density Open Space	2,374.70	5.8
Farm Animals	0	82.6
Stream Bank Erosion	128,899.00	36
Subsurface Flow	0	88.8
Point Sources	0	0
Septic Systems	0	0

Table B6. Model My Watershed outputs for sediment and phosphorus in the Black Hole Creek Subwatershed.

Appendix C: Stream Segments in the Mummasburg Run Watershed with Aquatic Life Impairments

Stream Name:	Impairment Source:	Impairment Cause:	Date Listed:	COMID:	Miles:
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	134238611	0.42
Mummasburg Run	Agriculture	Nutrients	2002	53319398	0.27
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319448	0.41
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319394	0.59
Mummasburg Run	Agriculture	Nutrients	2002	53319424	0.33
Mummasburg Run	Agriculture	Nutrients	2002	53319614	0.65
Mummasburg Run	Agriculture	Nutrients	2002	53319534	0.21
Mummasburg Run	Agriculture	Nutrients	2002	53319502	0.92
Mummasburg Run	Agriculture	Nutrients	2002	53319436	0.39
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	134238614	1.09
Mummasburg Run	Agriculture	Nutrients	2002	134238609	1.05
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	134238618	0.61
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319396	0.60
Mummasburg Run	Agriculture	Nutrients	2002	53319778	0.94
Mummasburg Run	Agriculture	Nutrients	2002	53319674	0.68
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319378	0.05
Mummasburg Run	Agriculture	Nutrients	2002	53319416	0.10
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319672	0.95
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319434	0.20
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319384	0.67
Mummasburg Run	Agriculture	Nutrients	2002	53319412	0.40
Mummasburg Run	Agriculture	Nutrients	2002	53319380	0.58
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319616	1.02
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	134238616	0.84
Unnamed Tributary to Mummasburg Run	Agriculture	Nutrients	2002	53319518	0.76
Mummasburg Run	Agriculture	Nutrients	2002	53319426	0.05
Mummasburg Run	Agriculture	Nutrients	2002	134238607	0.02
Mummasburg Run	Agriculture	Nutrients	2002	53319422	0.18
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	134238611	0.42
Mummasburg Run	Agriculture	Siltation	2002	134238609	1.05
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319616	1.02
Mummasburg Run	Agriculture	Siltation	2002	53319412	0.40
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319434	0.20
Mummasburg Run	Agriculture	Siltation	2002	53319534	0.21
Mummasburg Run	Agriculture	Siltation	2002	53319436	0.39
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	134238614	1.09
Mummasburg Run	Agriculture	Siltation	2002	134238607	0.02
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	134238616	0.84
Mummasburg Run	Agriculture	Siltation	2002	53319614	0.65
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319384	0.67
Mummasburg Run	Agriculture	Siltation	2002	53319674	0.68
Mummasburg Run	Agriculture	Siltation	2002	53319426	0.05
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319448	0.41
Mummasburg Run	Agriculture	Siltation	2002	53319380	0.58
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319378	0.05
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319394	0.59
Mummasburg Run	Agriculture	Siltation	2002	53319416	0.10
Mummasburg Run	Agriculture	Siltation	2002	53319422	0.18
Mummasburg Run	Agriculture	Siltation	2002	53319424	0.33
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319672	0.95
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	134238618	0.61
Mummasburg Run	Agriculture	Siltation	2002	53319398	0.27
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319396	0.60
Mummasburg Run	Agriculture	Siltation	2002	53319778	0.94
Unnamed Tributary to Mummasburg Run	Agriculture	Siltation	2002	53319518	0.76
Mummasburg Run	Agriculture	Siltation	2002	53319502	0.92

Table C1. Listing of stream segments with aquatic life impairments in the Mummasburg Run Watershed.

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

	Non-MS4 Sewershed 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	1,728,674	yes	667,715		0.72	186,349	481,366	0.72
Hay/Pasture	71,195	no	71,195	258,490	0.08	19,869	51,325	0.28
Streambank	187,295	no	187,295		0.20	52,271	135,024	0.28
sum	**1,987,163**		**926,205**		**1.00**	**258,490**	**667,715**	**0.66**

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

	Non-MS4 Sewershed 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	1,893	yes	864		0.42	503	362	0.81
Hay/Pasture	299	no	299	1,200	0.15	174	125	0.58
Streambank	40	no	40		0.02	23	17	0.58
Farm Animals	861	no	861		0.42	501	361	0.58
sum	**3,093**		**2,065**		**1.00**	**1,200**	**864**	**0.72**

Table D2. Phosphorus Equal Marginal Percent Reduction calculations for the Mummasburg Run Watershed.

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

Clean Water Act Requirements

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

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

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

Pennsylvania Clean Streams Law Requirements, Agricultural Operations

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

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

Appendix F: Comment and Response

Note that comments appear in plain text while DEP responses appear in italics.

Received via email July 24, 2020:

Good Afternoon Mr. Morris:

I am involved with Adams County's Phase 3 WIP Planning, and I have a great interest in any efforts directed to our fruit growers in addressing watershed issues. We have identified fruit growing as a unique agricultural activity in our area deserving of its own recognition. With that said, we have also discovered that BMPs such as forested buffers may not work in this industry for various reasons. Therefore, I would like to encourage the Department to engage Penn State Extension, in a specialized approach to determine the most appropriate BMPs to achieve reductions of pollutants for this unique industry. This effort should have a scientific approach that quantifies reductions and qualifies water quality improvements. Thank you.

Bicky Redman, Senior Planner II– Environmental Services

Adams County Office of Planning & Development

670 Old Harrisburg Road, Suite 100

Gettysburg, PA 17325

Phone: (717) 337-9827

Email: bredman@adamscounty.us

DEP Response:

Forested riparian buffers are typically preferable in areas where forests would have occurred naturally. Not only are forested buffers effective at filtering pollutants, but they also provide many other benefits such as shade, habitat, bank protection and nutritional sources for aquatic and riparian organisms. However, it is understood that forested riparian buffers may be undesirable or difficult to implement in some agricultural operations. Fortunately, however, research suggests that simply from a pollution filtration standpoint, grass buffers can be very effective for sediment and phosphorus removal, which is the concern of this TMDL document. In fact, with regard to their ability to filter sediment and phosphorus from upland runoff, the current Chesapeake Assessment Scenario Tool currently assumes that grass buffers are just as effective as forested buffers, though it is acknowledged that more research on this *topic is needed (see Belt et al. 2014). Thus, it is recommended that buffer strips comprised of densely growing tall grasses/other herbaceous vegetation be used wherever forested buffers will not be accepted. It should be noted however that if such grass buffers were not the natural riparian conditions for this stream then their use may be less effective for promoting natural stream communities.*

To initiate further discussions on BMPs for Pennsylvania TMDL/alternate restoration plan development, you may email Michael Morris (michamorri@pa.gov)

To initiate further discussions on BMPs relevant to the Chesapeake Bay TMDL, you may email DEP's Chesapeake Bay Program Office (EP-WM-CBO@pa.gov) or more specifically, Kristen Wolf, Chesapeake Bay Program Coordinator (kwolf@pa.gov)

Reference:

Belt, K., P. Groffman, D. Newbold, C. Hession, G. Noe, J. Okay, M. Southerland, G. Speiran, K. Staver, A. Hairston-Strang, D. Weller, D. Wise. 2014. Recommendations of the Expert Panel to Reassess Removal Rates for Riparian Forest and Grass Buffers Best Management Practices. Prepared by Sally Claggett, USFS Chesapeake Bay Liason and Tetra Tech, Inc. Downloaded at: https://www.chesapeakebay.net/documents/Riparian_BMP_Panel_Report_FINAL_October_2014.pdf

Received via email on August 5, 2020:

Mr. Morris, I have prepared the following comments on the TMDL Plan for the Mummsaburg Run Watershed in Adams County.

1. The reference watershed is comprised of only 23% agriculture land. The Mummasburg Run watershed is comprised of 75% agricultural land. This does not seem to be a very representative reference watershed for this evaluation.
2. It is apparent that orchards are difficult to address in this plan as noted on Page 10 of the report. The nature of the orchards industry is difficult to capture within existing Chapter 102 regulations. Currently agricultural operations need to have a crop rotation that meets tolerable soil loss levels (T) over the entire rotation as determined by soil loss modeling such as RUSLE. A field that is in trees and grass for 15-20 years and row crops for 2 or 3 years will most likely meet T. What is the meaning of the last paragraph on page 38? What additional evaluation is being suggested?
3. On page 26 it is noted that streambank erosion is calculated based off of modelling. Why would visible streambank erosion not factor into this evaluation?
4. On page 38, paragraph 2 it is noted that sediment and nutrient load reduction in agricultural activities can be made through proper plans and BMP installation. The list of BMP's mentioned

include legacy sediment removal. How is legacy sediment removal regulated through Chapter 102?

5. The recommendations of this report point to the use of forested riparian buffers. While clearly desirable, it is worth noting that two USDA CREP (Conservation Reserve Enhancement Program) projects funded in this watershed which involved tree plantings along the Mummasburg Run failed due to the invasive nature of Reed's Canarygrass (RCG). One project dropped out completely due to tree mortality requirements in the program and the other removed large portions of the site from the program. RCG is prevalent along several areas of the stream. The RCG is very aggressive and smothers out nearly any other plant. Trees have very low survival rates when planted in RCG.

If you have any questions, feel free to contact me. Thank you for the opportunity to comment.

Brian M. Sneeringer

Agricultural Conservation Technician

Adams County Conservation District

670 Old Harrisburg Road, Suite 201

Gettysburg PA 17325

717-334-0636 Ext. 3050

Fax: 717-334-0786

www.adamscounty.us

bsneeringer@adamscounty.us

DEP Responses

1) *Page 10 of the draft TMDL document states that:*

Based on site observations and GIS analysis, it is hypothesized that the Mummasburg Run Watershed's impairments were attributable to two key factors: 1) the extreme amount of landcover devoted to agriculture, and 2) the lack of expansive forested riparian buffers in many cases (see Figures 1, 4 and 5, though see also Figure 6)…. Even so, the nearly 77% agricultural coverage of the Mummasburg Run Watershed was comparable to watersheds of the most heavily farmed regions of the state, so impairment may be expected even if agricultural practices were good.

It would be very unlikely, if not impossible, to find a reference with a comparably extreme amount of agricultural landcover yet with aquatic communities that were healthy enough to be attaining via our current assessment methodology. This is especially true considering that the relevant macroinvertebrate assessment methodology was in part based on relationships between landcover, as a surrogate for anthropogenic influence, and macroinvertebrate community indices (see PA DEP-Division of Water Quality Standards 2012). When answering this question, the author reviewed about 16 final and draft agricultural TMDL/restoration plan documents that he worked on over the past two years and found that none had a majority land coverage as agriculture.

Be assured that there was a diligent search for reference watersheds for Mummasburg Run. In fact, about 50 potential watersheds were explored via a GIS analysis. For more information, refer to pages 6 and 7 of the TMDL document. Part of the reason that Black Hole Creek was ultimately chosen was that, like the Mummasburg Run Watershed, it had significant amounts of slow infiltration soils and thus had a similarly high surface runoff rate. It also had a similar terrain slope and similar stream segment slopes. And, very importantly, there was substantial assessment evidence that it was attaining. Use of the Black Hole Creek Subwatershed resulted in reasonable pollutant reductions; indeed other references could be found that would have resulted in more drastic reductions, but remember that the goal is to try to find the "total maximum daily load". Finally, one interesting feature of the Black Hole Creek Subwatershed is that it could have supported more agriculture and perhaps been impaired as well, yet the unique history of the site involving federal land acquisition during World War II prevented it from experiencing more substantial agricultural pollution (see Page 11).

Reference:
PA DEP Division of Water Quality Standards (2012). A benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania. Available at: http://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Technical%20Documentation/freestoneIBImarch2012.pdf

2) *Mr. Sneeringer makes a good point that the unique circumstances of the orchard industry, having to do with the periodic conversion to crops on high slopes, may allow for episodes of high erosion rates while possibly still meeting the requirements of the erosion and sediment control plans. Therefore, BMPs beyond the minimum called for to satisfy the erosion and sediment control plans should be used, especially during the conversion to crops. Grass buffer strips along streams and drainageways immediately come to mind, especially where forested buffers would be undesirable. Other BMPs that should be considered might include use of conservation tillage, cover crops and strip-cropping. Significant financial incentives would likely be available for orchard owners seeking to implement such BMPs. Additional evaluation should occur on a site by site basis to choose the most effective BMPs for a particular situation. Such decisions should utilize the expertise of groups such as the Adams County Conservation District, NRCS, Penn State Cooperative Extension and representatives of the orchard industry.*

3) *The reason that the model isn't corrected based on site visit observations primarily has to do with the fact that converting observations into a quantifiable erosion rate would involve far more effort than can be invested in each TMDL. PA DEP employs two full time TMDL writers that are responsible for writing multiple TMDLs each year. Thus, the simplified, yet cost and time effective generalizations of models are necessary.*

   Given their uncertainty, model results in such complicated systems should be considered as hypotheses. In the scenario that future BMPs are implemented to the extent that prescribed pollution reductions are estimated to have been achieved, yet the impairments are not reversed, additional effort could be taken to improve the model to better account for streambanks and other factors for the purpose of developing a revised TMDL.

4) *The author has little experience in interpreting Chapter 102 regulations, thus if any legacy sediment removal projects are being considered, the responsible parties should reach out to the Southcentral Regional Office's Waterways and Wetlands Program, Phone #717-705-4802 to discuss Chapter 102 requirements.*

   However, based on a cursory review of Chapter 102, it would appear that significant (≥ 5,000 ft^2 total earth disturbance) legacy sediment removal projects in this watershed would require erosion and sediment BMPs and a written erosion and sediment control plan. If total earth disturbance were ≥ 1 acre then an NPDES permit, post construction stormwater management plan, and a preparedness, prevention and contingency plan (if certain materials were used) would be necessary under Chapter 102.

   The full Chapter 102 Regulations can be reviewed at: https://www.dep.pa.gov/Business/Water/CleanWater/StormwaterMgmt/Stormwater%20Construction/Documents/025_0102.pdf?Mobile=1&Source=%2FBusiness%2FWater%2FCleanWater%2FStormwaterMgmt%2FStormwater%20Construction%2F_layouts%2Fmobile%2Fdispform.aspx%3FList%3D3410853f-0390-4a35-bedc-bbdc3c7e7b3f%26View%3D48587e7e-e442-4559-bbdf-9534ba0aba5e%26ID%3D8%26CurrentPage%3D1

5) *There are likely situations where forested riparian buffers may not have been the natural riparian community, or, due to anthropogenic changes in the watershed, it may no longer be feasible to establish forested riparian buffers. Fortunately, however, research suggests that simply from a pollution filtration standpoint, grass buffers can be very effective for sediment and phosphorus removal, which is the concern of this TMDL document. In fact, with regard to their ability to filter sediment and phosphorus from upland runoff, the current Chesapeake Assessment Scenario Tool currently assumes that grass buffers are just as effective as forested buffers, though it is acknowledged that more research on this topic is needed (see Belt et al. 2014). Thus, it is recommended that buffer strips comprised of densely growing tall grasses/other herbaceous vegetation be used wherever forested buffers will cannot be used. There are many different ways that riparian buffers may be funded (See Talbert 2009). It is suggested that various funding programs be contacted to determine funding opportunities for herbaceous buffers.*

References:

Belt, K., P. Groffman, D. Newbold, C. Hession, G. Noe, J. Okay, M. Southerland, G. Speiran, K. Staver, A. Hairston-Strang, D. Weller, D. Wise. 2014. Recommendations of the Expert Panel to Reassess Removal Rates for Riparian Forest and Grass Buffers Best Management Practices. Prepared by Sally Claggett, USFS Chesapeake Bay Liason and Tetra Tech, Inc. Downloaded at: https://www.chesapeakebay.net/documents/Riparian_BMP_Panel_Report_FINAL_October_2014.pdf

Talbert, G.F. 2009. A Landowner's Guide to Conservation Buffer Incentive Programs in Pennsylvania. Prepared for the American Farmland Trust. Accessed at: https://pacd.org/wp-content/uploads/2009/09/LandownerGuide-1.pdf