

**Total Maximum Daily Loads (TMDLs) Plan for
Conewago Creek Watershed**

Prepared for Pennsylvania Department of Environmental Protection

by

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TMDLs for Conewago Creek Watershed

EXECUTIVE SUMMARY

The Conewago Creek watershed is 53.2 square miles in size and covers areas in Dauphin, Lancaster and Lebanon counties. The protected uses of the watershed are water supply, recreation, and aquatic life. The aquatic use of Conewago Creek is trout stocking. This report focuses on the Total Maximum Daily Loads development for Subbasin A and Subbasin B that comprise Conewago watershed (see Figure 1). Conewago Subbasin A can be accessed from North via Pennsylvania Route 322 and from either East or West by Routes 23 and 743. Subbasin B can be reached from the South by Pennsylvania Route 441 to the south and from East or West via US Interstate 76 (Pennsylvania Turnpike), Interstate 283, Pennsylvania Route 23 and Route 743.

Total Maximum Daily Loads, or TMDLs, apply to Conewago Subbasins A and B, separately. TMDLs for Subbasin A target the upper part of main stem of Conewago Creek (Stream Code 9217) from the point where Little Conewago Creek drains into the main stem, Hoffer Creek, and another unnamed tributary located East of Hoffer Creek. TMDLs for Subbasin B includes the lower part of main stem of Conewago Creek to the point where it drains in the Susquehanna River and also an unnamed tributary located Dauphin county at about 5 miles from the Susquehanna River. These TMDLs were developed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water act Section 303(d) Lists. The impairments are primarily caused by excess nutrient and sediment loads from agriculture activities. The TMDL focuses on control of the nutrient phosphorus and sediments. Phosphorus is generally considered to be the limiting nutrient in a waterbody when the nitrogen/phosphorus ratio exceeds 10 to 1. In Conewago Creek, this ratio is 21 to 1.

Pennsylvania does not currently have water quality criteria for nutrients and sediments. For this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for nutrients and sediments in the impaired segments of the Conewago Creek watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the amount of phosphorus loading that will meet the water quality objectives for Conewago Creek is 4,522 pounds per year and 8,120 pounds per year for Subbasins A and B, respectively. Sediment loading must be limited to 3,123,517 pounds per year and 6,434,669 pounds per year for Subbasins A and B, respectively. Conewago Creek will support its aquatic life uses when these values are met. The TMDLs for Conewago Creek subbasins are allocated as shown in the table that follows.

Summary of TMDLs for Conewago Creek Subbasins (lb./yr)							
Pollutant	TMDL	MOS	WLA	LA	LNR	ALA	Reduction
SUBBASIN A							
Phosphorus	4,522	226	2103	2193	886	1307	40
Sediments	3,123,517	312,352	N/A	2,811,165	299,008	2,512,157	54
SUBBASIN B							
Phosphorus	8,120	406	1886	5828	446	5382	37
Sediments	6,434,669	643,467	N/A	5,791,202	112,362	5,678,840	34

The TMDLs are allocated to non-point source from agricultural activities, with 10% of the TMDL total load reserved as a margin of safety (MOS). The Wasteload Allocation (WLA) is that portion of the total load that is assigned to point sources. The allowable loading, or adjusted loading allocation (ALA), is that load attributed to agricultural land use and is computed by subtracting loads that do not need to be reduced (LNR) from the TMDL total values. The TMDLs cover a total of 36.30 miles of the main stem of Conewago Creek, its tributaries Lynch Run and Hoffer Run, and an unnamed tributary. The TMDL establishes a reduction for phosphorus loading of 40% and 37% from the current annual loading in Subbasin A (7131 lbs) and Subbasin B (12195 lbs), respectively. The reductions in sediment loading are respectively 54% from current loading of 6,154,085 lbs (Subbasin A) and 34% from current loading of 8,784,364 lbs (Subbasin B). A more complete discussion of Conewago Creek TMDLs and TMDLs in general are contained in the attached Information Sheet (Appendix A).

I. INTRODUCTION

Total Maximum Daily Loads or TMDLs were developed for the Conewago Creek watershed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water Act Section 303(d) Lists. It was first determined that Conewago Creek was not meeting its designated water quality uses for protection of aquatic life based on a 1994 aquatic biological survey, which included kick screen analysis and habitat surveys. In 1997, the Department again surveyed the stream and found the stream to still be impaired. As a consequence of these surveys, Pennsylvania listed Conewago Creek on the 1996 and 1998 Section 303(d) Lists of Impaired Waters. The 1996 303 (d) List reported 10 miles of Conewago Creek to be impaired by agricultural nutrients. The 1998 list includes 15.8 miles of the Main stem (Segment ID 6432), 3.6 miles of an unnamed tributary (Segment ID 970701-0745-SAW), 11.2 miles of Lynch Run (Segment ID 970626-1200-SAW), and 5.7 miles of Hoffer Creek (Segment ID 970701-1035-SAW) (Table 1). Hoffer Creek and Lynch Run are tributaries of Conewago Creek. These segments were listed on the 1998 303 (d) List because of impacts by nutrients and/or siltation due to agriculture.

The Pennsylvania approach to TMDL development involves comparing nutrient and sediment loads of the impacted watershed to those of a reference watershed. Based on the predominance of agricultural land use, nutrients and sediments are the most likely pollutants causing Conewago Creek to violate the aquatic life use. Therefore, the TMDLs propose reducing the phosphorus and sediment loadings in Conewago Creek Subbasins A and B to levels consistent with the Lehman-Muddy Run watershed and a portion of the Little Swatara Creek watershed (i.e. the reference watersheds). Because of the similarities in size and land use existing between the subbasins and the reference watersheds, achieving nutrient and sediment loadings in the Conewago Creek TMDL will ensure that the aquatic life use is achieved and maintained as evidenced in the reference watersheds.

Pennsylvania presently does not have water quality criteria for nutrients and sediments. It is for this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for nutrients and sediments in the impaired segments of the Conewago Creek watershed. The nutrient loading for this watershed only addresses phosphorus because it was determined that phosphorus was the limiting nutrient. Phosphorus is generally held to be the limiting nutrient in a waterbody when the nitrogen/ phosphorus ratio exceeds 10 to 1. This ratio in Conewago Creek is 21 to 1.

The Conewago Creek watershed TMDL Information Sheet that is attached to this document (Appendix A) provides a primer for TMDLs (*What are they and why are we doing them?*) and water quality standards (*What makes up a water quality standard?*). Appendixes B and C provide information on watershed hydrology and pollutant transport, and the method being used by Pennsylvania for establishing TMDLs for stream segments impaired by nutrients and sediments.

Table 1. 303(d) Sub-List								
State Water Plan (SWP) Subbasin: 7-Conewago Creek Watershed								
Year	SWP	Miles	Segment ID	DEP Stream Code	Stream Name	Designated Use	Data Source	EPA 305(b) Cause Code
1996	07-G	10.0		09217	Conewago	TSF	305(b) Report	Nutrients
1998		15.8	6432	09217	Conewago	TSF	305(b) Report	Nutrients
1998	07-G	0.9	6434*	09217	Conewago	TSF	305(b) Report	Organic enrichment/ Low D.O. and Suspended solids
1998	07-G	5.1	970626-0830-SAW	09217	Conewago	TSF	305(b) Report	Habitat alterations
1998	07-G	3.6	970701-0745-SAW	09217	Conewago	TSF	305(b) Report	Nutrients/Siltation
1998	07-G	5.7	970701-1035-SAW	09267	Hoffer Run	TSF	305(b) Report	Nutrients/Siltation/ Habitat alterations
1998	07-G	9.4	970626-1200-SAW	09232	Lynch Run	TSF	305(b) Report	Siltation/Turbidity

Trout Stocking = TSF

Hoffer Creek and Lynch Run are tributaries of Conewago Creek.

* Listing was for Municipal Point Source. TMDL completed for discharger in 1998.

II. BACKGROUND

The Conewago Creek watershed covers areas in Dauphin, Lancaster, and Lebanon counties and in the Piedmont Physiographic Province. It covers an area of 53.2 square miles. Conewago Creek drains in the Susquehanna River at about 11 miles South of the Town of Middletown. Its headwaters are in the southeastern part of Lebanon County, about 5 miles from the town of Palmyra. The watershed can be accessed via Pennsylvania Route 322 to the North and by Pennsylvania Route 441 to the South. It can also be reached from East or West via US Interstate 76 (Pennsylvania Turnpike), Interstate 283, Pennsylvania Route 23 and Route 743. The protected uses of the watershed are water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.0 (Commonwealth of PA, 1999), the designated aquatic life use for Conewago Creek, trout stocking fishes.

The primary land use in the Conewago Creek Watershed is agriculture (53%), with areas adjacent to the stream used for cropland and pasture. It was found also from a field survey that cattle have free access to some of the impaired stream segments in the watershed. Some stream segments also had no protected riparian zones.

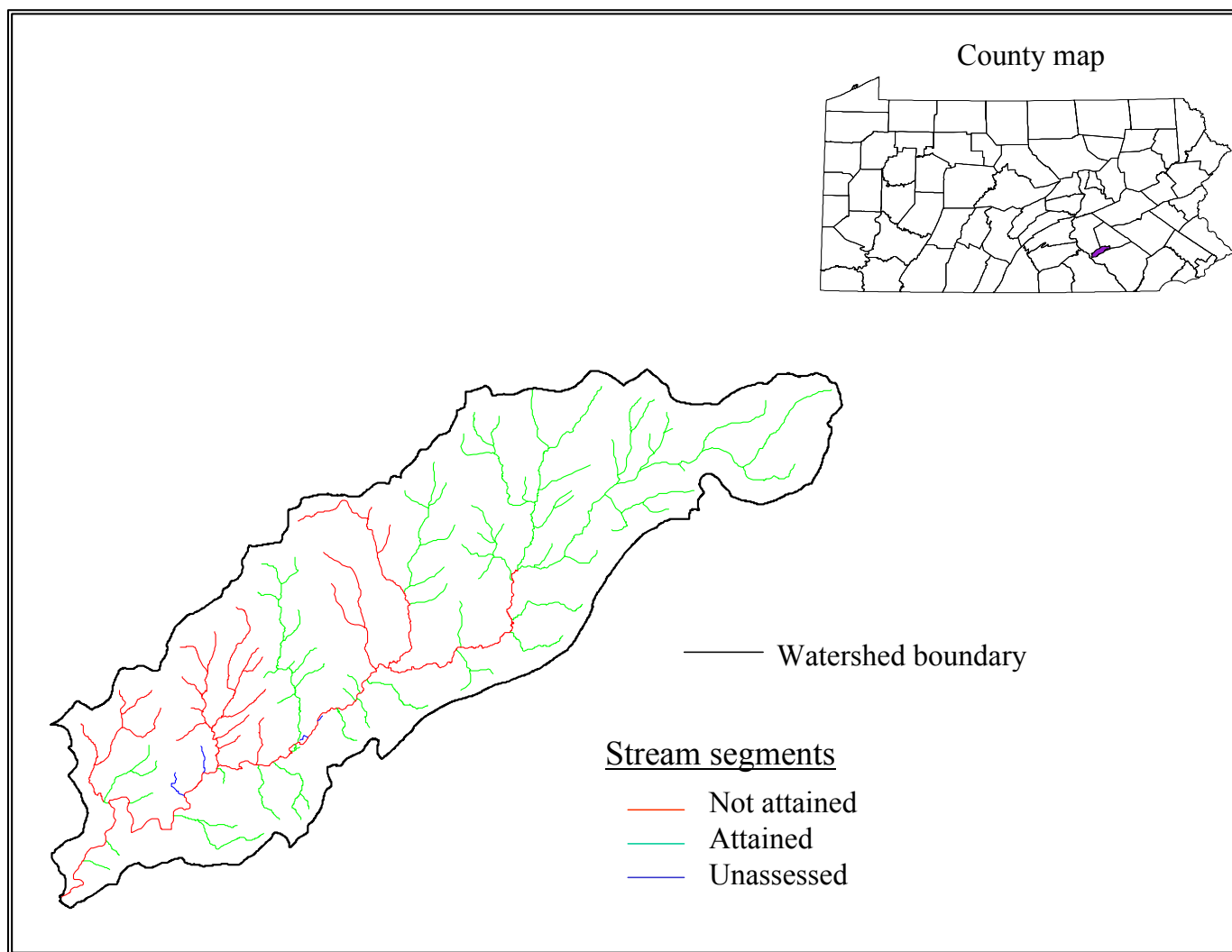


Figure 1. Conewago Creek Watershed.

III. TMDL ENDPOINTS

The TMDLs address phosphorus and sediments. Phosphorus was determined to be the nutrient limiting plant growth in Conewago Creek. Because neither Pennsylvania nor EPA has water quality criteria for phosphorus or sediments, we had to develop a method to determine water quality objectives for these parameters that would result in the impaired stream segments attaining their designated uses. The method employed for these TMDLs is termed the “Reference Watershed Approach.”

The Reference Watershed Approach pairs two watersheds, one attaining its uses and one that is impaired based on biological assessment. Both watersheds must have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible; however, most variations can be adjusted in the model. The objective of the process is to reduce the loading rate of nutrients and sediments in the impaired stream segment to a level equivalent to or slightly lower than the loading rate in the non-impaired, reference stream segment. This load reduction will allow the biological community to return to the impaired stream segments.

The TMDL endpoints established for this analysis were determined using Little Swatara Creek and Lehman-Muddy Run watersheds as the reference watersheds. These endpoints are discussed in detail in the TMDL section. The listing for impairment caused by nutrients and siltation is addressed through reduction to the phosphorus load. A detailed explanation of this process is included in the following section.

Nutrient Loads and Organic Enrichment in Stream Systems

As indicated earlier, Conewago Creek was listed as being impaired due to problems associated with nutrient loads and siltation. In stream systems, elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994).

Typically in aquatic ecosystems the quantities of trace elements are plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the *limiting nutrient* because its relative quantity affects the rate of production (growth) of aquatic biomass. If the nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem, 1994). In most efforts to control eutrophication processes in water bodies, emphasis is placed on the limiting nutrient. This is not always the case, however. For example, if nitrogen is the limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources such as nitrates in ground water.

In most fresh water bodies, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting. If the N/P

ratio is greater than 10, phosphorus is the limiting nutrient. In the case of Conewago Creek, the N/P ratio is approximately 21, which points to phosphorus as the limiting nutrient. Controlling the phosphorus loading to Conewago Creek will limit plant growth and result in raising the dissolved oxygen level.

IV. SELECTION OF THE REFERENCE WATERSHED

In general, three factors should be considered when selecting a suitable reference watershed. The first factor is to use a watershed that has been assessed by the Department using the Unassessed Waters Protocol and has been determined to be attaining water quality standards. The second factor is to find a watershed that closely resembles Conewago Creek watershed in physical properties such as land cover/land use, physiographic province, and geology. Finally, the size of the reference watershed should be within 20-30% of the impaired watershed area. The search for a reference watershed that would satisfy the above characteristics was done by means of a desktop screening using several GIS coverages including the Multi-Resolution Land Characteristics (MRLC) Landsat-derived land cover/use grid, the Pennsylvania's 305(b) assessed streams database, and geologic rock types.

A watershed that would satisfy all the characteristics mentioned above could not be found in the same physiographic province as Conewago Creek due to the following reasons:

- 1) Not all stream segments in the Piedmont Physiographic Province where Conewago Creek watershed is located have been assessed.
- 2) All watersheds that have similar levels of agricultural land use and geologic rock type distributions as Conewago Creek watershed are also impaired.

The watersheds selected for use as "References" are 24.6 and 22.2 square miles, whereas Conewago Creek Watershed is 53.1 square miles. As indicated above, a reference watershed is recommended to be within 20 to 30% of the area of the impaired watershed. It is for this reason Conewago Creek Watershed was subdivided into two subbasins, Subbasin A and Subbasin B, for model simulations of nutrients and sediments. The areas of these subbasins are respectively 28.7 and 24.4 square miles. Figure 2 shows the locations and boundaries of Subbasins A and B in the Conewago watershed.

All stream segments in the Lehman-Muddy Run and Little Swatara Creek watersheds used as references have been assessed and were not found to be attaining water quality standards. Figure 3 shows the location of these watersheds. There are several impaired stream segments 15-20 miles south of this watershed in Franklin County also called Muddy Run. These streams are not in the reference watershed.

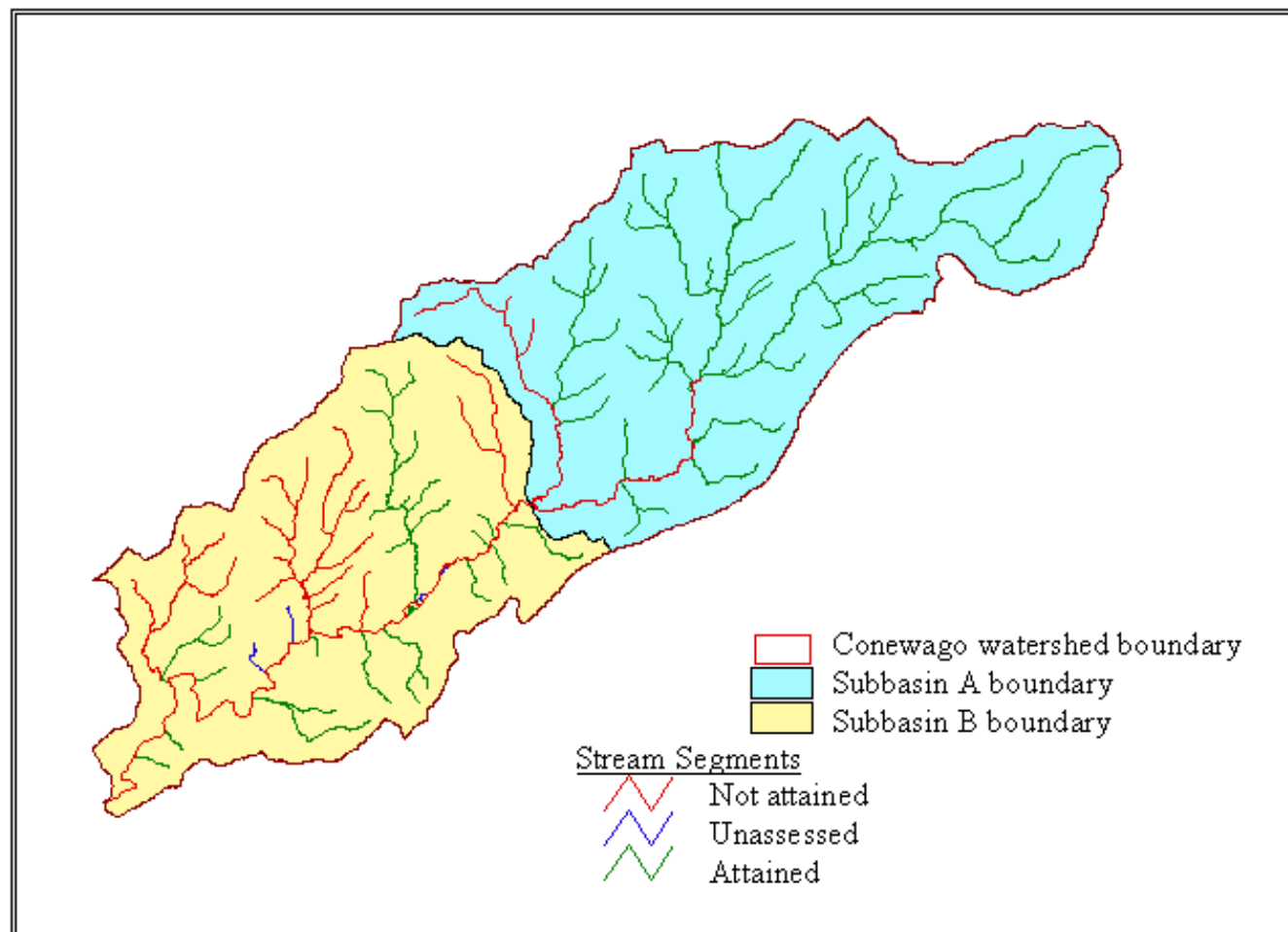


Figure 2. Conewago Creek Watershed showing Subbasin boundaries.

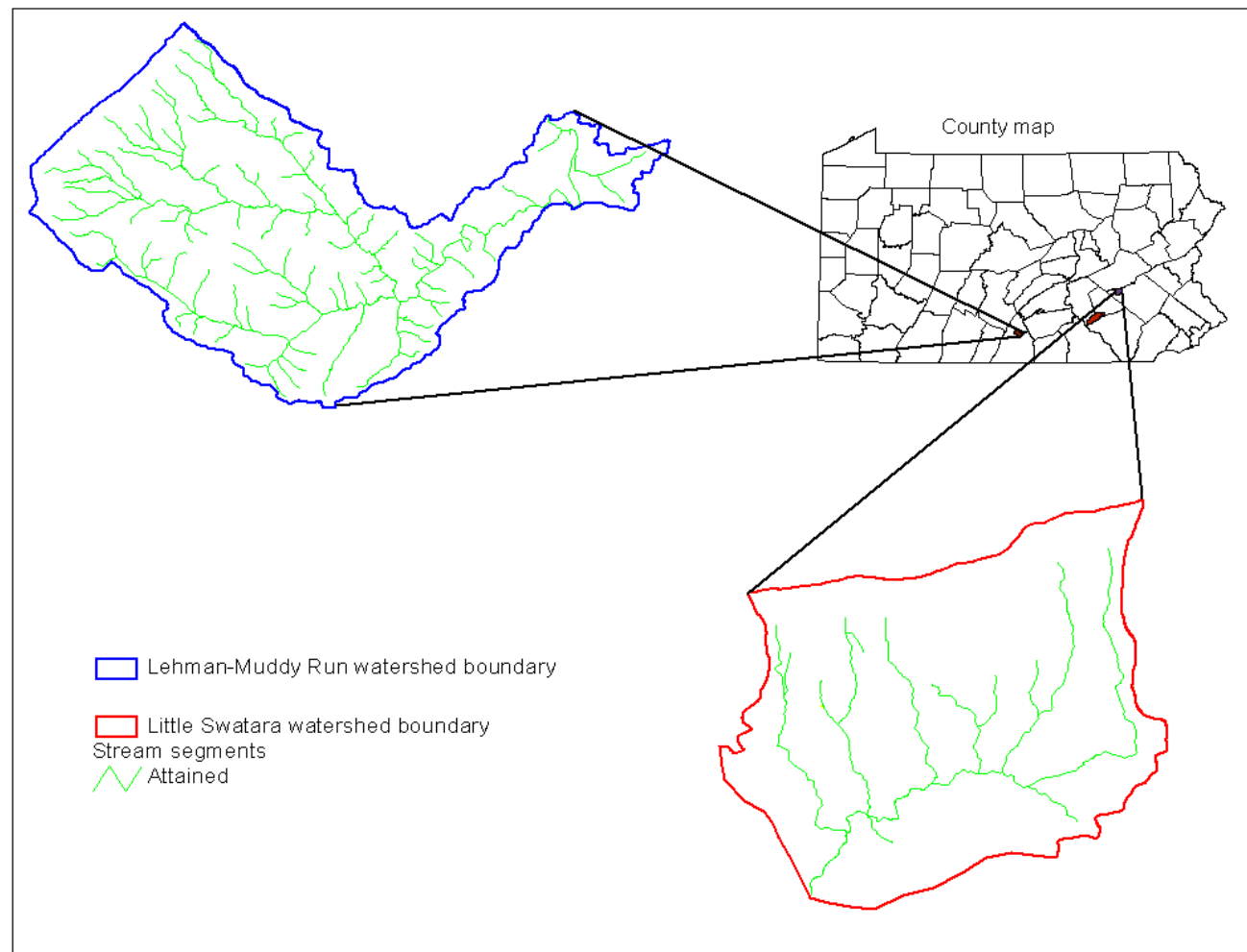


Figure 3. Location of Reference Watersheds

Table 2 compares Conewago subbasins to the reference watersheds in terms of their size, location, and other physical characteristics. The analysis of value counts for each pixel of the MRLC grid revealed that land cover/use distributions in both watersheds are similar. The agricultural land use, which is the source of impairment in Conewago Creek watershed, accounts for 48% and 59% of the total land area in Subbasin A and Subbasin B, respectively as compared to 52% in Lehman-Muddy Run watershed and 55% in the Little Swatara Creek watershed. The surficial geologies of the Conewago Subbasins and the reference watersheds were also compared and produced reasonably good matches. The geology of the 4 watersheds consists primarily of shale: 69% for Conewago Subbasin A, 74% for Conewago Subbasin B, 93% for Lehman-Muddy Run Watershed, and 80% for the Little Swatara Creek watershed. The bedrock geology affects primarily surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability.

Table 2. Comparison Between Conewago Subwatersheds and Reference Watersheds

ATTRIBUTE	CONEWAGO		REFERENCE	
	SUBBASIN A	SUBBASIN B	LEHMAN- MUDDY RUN	LITTLE SWATARA CREEK
Physiographic Province	Piedmont	Piedmont	Ridge and Valley	Ridge and Valley
Area (square miles)	27.8	24.4	24.6	22.2
Predominant Land Use				
Agriculture (%)	48	59	52	55
Predominant Geology				
Shale (%)	69	74	93	80

V. HYDROLOGIC/WATER QUALITY MODELING

5.1. Data Compilation and Model Overview

The TMDLs were developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) loadings from 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 a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For sub-surface 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 sub-surface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss erosion (K), the length slope factor (LS) the vegetation cover factor (C) and conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. 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. Point source discharges can also contribute to dissolved losses to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing 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. All of the equations used by the model can be viewed in Attachment E, GWLF Users Manual.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

5.2. GIS-Based Derivation of Input Data

The primary sources of data for this analysis were geographic information system (GIS) formatted databases. A specially designed interface was prepared by the Environmental Resources Research Institute of the Pennsylvania State University in ArcView (GIS software) to generate the data needed to run the GWLF model, which was developed by Cornell University. The new version of this model has been named AVGWLF (ArcView Version of the Generalized Watershed Loading Function)

In using this interface, the user is prompted to identify required GIS files and to provide other information related to “non-spatial” model parameters (e.g., beginning and end of the growing season, the months during which manure is spread on agricultural land and the names of nearby weather stations). This information is subsequently used to automatically derive values for required model input parameters which are then written to the TRANSPRT.DAT, NUTRIENT.DAT and WEATHER.DAT input files needed to execute the GWLF model (see Appendix B). For use in Pennsylvania, AVGWLF has been linked with statewide GIS data layers such as land use/cover, soils, topography, and physiography; and includes location-specific default information such as background N and P concentrations and cropping practices. Complete GWLF-formatted weather files are also included for eighty weather stations around the state. Table 3 lists the statewide GIS data sets and provides explanation of how they were used for development of the input files for the GWLF model.

Table 3. GIS Data Sets	
Censustr	Coverage of Census data including information on individual homes septic systems. The attribute <i>usew_sept</i> includes data on conventional systems, and <i>sew_other</i> provides data on short circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100 meter digital elevation model. This used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid which is classified into 15 different landcover categories. This dataset provides landcover loading rate for the different categories in the model.
Pasingle	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
Physprov	A shapefile of physiographic provinces. Attributes <i>rain_cool</i> and <i>rain_warm</i> are used to set recession coefficient
Pointsrc	Major point source discharges with permitted N and P loads.

Refwater	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
Soilphos	A grid of soil phosphorous loads which has been generated from soil sample data. Used to help set phosphorus and sediment values.
Smallsheds	A coverage of watersheds derived at 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
Statsgo	A shapefile of generalized soil boundaries. The attribute <i>mu_k</i> sets the k factor in the USLE. The attribute <i>mu_awc</i> is the unsaturated available capacity., and the <i>mu_hsg_dom</i> is used with landuse cover to derive curve numbers.
Strm305	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
Surfgeol	A shapefile of the surface geology used to compare watersheds of similar qualities.
T9sheds	Data derived from a DEP study conducted at PSU with N and P loads.
Zipcode	A coverage of animal densities. Attribute <i>aeu_acre</i> helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
Weather Files	Historical weather files for stations around Pennsylvania to simulate flow.

As described in the Data Compilation and Model Overview section, the GWLF model provides the ability to simulate surface water runoff, as well as sediment and nutrient loads from a watershed based on landscape conditions such as topography, land use/cover, and soil type. In essence, the model is used to estimate surface runoff and nonpoint source loads from different areas within the watershed. If point source discharges are identified, and the corresponding nutrient loads are quantified, these loads are summed to represent the total pollutant loads for the watershed.

In the GWLF model, the nonpoint source load calculated is affected by terrain conditions such as amount of agricultural land, land slope, and inherent soil erodibility. It is also affected by farming practices utilized in the area, as well as by background concentrations of nutrients (i.e., N and P) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized below:

Areal extent of different land use/cover categories: This is calculated directly from a GIS layer of land use/cover.

Curve number: This determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type, and is calculated directly using digital land use/cover and soils layers.

K factor: This factor relates to inherent soil erodibility, and affects the amount of soil erosion taking place on a given unit of land.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, the crops grown and the cultivation practices utilized largely control this factor. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

P factor: This factor is directly related to the conservation practices utilized in agricultural areas. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment that is delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This relates to the amount of water that can be stored in the soil and affects runoff and infiltration. It is calculated using a digital soils layer.

Dissolved nitrogen in runoff: This varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Dissolved phosphorus in runoff: Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Nutrient concentrations in runoff over manured areas: These are user-specified concentrations for N and P that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations.

Nutrient build-up in non-urban areas: In GWLF, rates of build-up for both N and P have to be specified. In Pennsylvania, this is estimated using historical information on atmospheric deposition.

Background N and P concentrations in groundwater: Subsurface concentrations of nutrients (primarily N) contribute to the nutrient loads in streams. In Pennsylvania, these concentrations are estimated using recently published data from USGS.

Background N and P concentrations in soil: Since soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. In Pennsylvania, this information is based on literature values as well as soil test data collected annually at Penn State University. These values can be adjusted locally depending upon manure loading rates and farm animal populations.

Other less important factors that can affect sediment and nutrient loads in a watershed are also included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF Users Guide provided in Appendix D of this document. Specific details in this guide that describe equations and typical parameter values used can be found on pages 15 through 41.

5.3. Watershed Assessment and Modeling

The AVGWLF model was run for both the Conewago Creek subbasins, the Little Swatara Creek watershed and the Lehman-Muddy Run watershed to establish existing loading conditions under existing land cover use conditions in each watershed.

General observations of watershed characteristics:

Conewago subwatersheds A and B are basically similar in terms of topographic relief, surface geology, and conservation practices (strip cropping, amount of residues left on the field, etc.) to their respective reference watersheds. The most significant difference is that stream banks in some areas of Conewago Subbasin A are trampled by cattle. Cattle have also free access to the stream.

Adjustment to Specific GWLF-related parameters

Conewago Creek Subbasin A: reset “P” factor to 0.54 for Hay/Pasture and Cropland land uses to account for trampled stream banks in some areas.

The 20-year (1979-1998) means for these parameters for each watershed are shown Table 4 (Conewago Subbasin A), Table 5 (Conewago Subbasin B), Table 6 (Lehman-Muddy Run Watershed), and Table 7 (Little Swatara Creek Watershed). The Unit Area Load for each pollutant in each watershed was estimated by dividing the mean annual loading (lbs/yr) by the total area (acres) resulting in an approximate loading per unit area for the watershed. Table 8 presents an explanation of the header information contained in Tables 4 to 7. Modeling output for the three watersheds are presented in Appendices D and E, respectively

Table 4. Existing Loading Values for Conewago Creek Subbasin A

Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/yr)
Hay/Past	3,064	450	0.15	5,166	1.69	352,346	114.99
Cropland	5,572	5,391	0.97	33,433	6.00	5,502,731	987.49
Coniferous For	275	2	0.01	20	0.07	1,909	6.93
Mixed For	346	2	0.01	23	0.07	1,943	5.62
Deciduous For	8,584	250	0.03	1,276	0.15	268,909	31.33
Lo Int Dev	185	8	0.04	106	0.59	14,162	76.63
Hi Int Dev	61	38	0.62	610	10.01	12,085	198.35
Groundwater		548		142,944			
Point Source		404					
Septic Systems		38		12,077			
Total	18,087	7,131	0.39	195,655	10.82	6,154,085	340.27

Table 5. Existing Loading Values for Conewago Creek Subbasin B

Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/yr)
Hay/Past	3,042	844	0.28	11,051	3.63	453,754	149.15
Cropland	6,078	10,701	1.76	62,134	10.22	8,218,248	1,352.15
Coniferous For	312	3	0.01	24	0.08	1,935	6.21
Mixed For	473	5	0.01	39	0.08	3,333	7.05
Deciduous For	4,891	102	0.02	544	0.11	81,701	16.70
Lo Int Dev	371	7	0.02	224	0.60	13,952	37.63
Hi Int Dev	154	40	0.26	1,424	9.25	11,441	74.35
Groundwater		255		145,556			
Point Source		204					
Septic Systems		34		14,192			
Total	15,321	12,195	0.80	235,188	15.35	8,784,364	573.35

Table 6. Existing Loading Values for Lehman-Muddy Run Watershed

Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/yr)
Hay/Past	3,409.88	498	0.15	10,260	3.01	269,840	79.13
Cropland	4,604.94	2,229	0.48	26,514	5.76	2,135,860	46..82
Coniferous For	160.49	1	0.01	20	0.13	819	5.10
Mixed For	217.28	2	0.01	28	0.13	1,239	5.70
Deciduous For	5,417.28	163	0.03	1,213	0.22	222,359	41.05
Transition	4.94	7	1.38	45	9.10	8,070	1,633.60
Lo Int Dev	1,506.17	128	0.08	959	0.64	12,802	7.57
Hi Int Dev	86.42	96	1.11	862	9.97	9,748	100.39
Groundwater		708		101,290			
Point Source		0					
Septic Systems		40		3,563			
Total	15,407.41	3,872	0.25	144,754	9.40	2,660,737	172.69

Table 7. Existing Loading Values for Little Swatara Reference

Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/yr)
Hay/Past	2471	379	0.15	5091	2.06	278,417	112.67
Cropland	5189.1	5042	0.97	28815	5.55	4,752,230	915.81
Coniferous For	86.5	0	0.01	1	0.02	446	5.16
Mixed For	205.1	2	0.01	6	0.03	1,825	8.90
Deciduous For	5779.7	785	0.14	2394	0.41	796,791	137.86
Lo Int Dev	113.7	11	0.09	79	0.70	12,645	111.25
Hi Int Dev	89.0	104	1.17	939	10.56	9,556	107.42
Groundwater		1010		144281			
Point Source		0		0			
Septic Systems		4		1212			
Total	13,934	7,338	0.53	182,819	13.12	5,851,910	420

Table 8. Header Information for Tables 4 to 6.

Land Use Category	The land cover classification that was obtained by from the MRLC database
Area (acres)	The area of the specific land cover/land use category found in the watershed.
Total P	The estimated total phosphorus loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area P Load	The estimated loading rate for phosphorus for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total N	The estimated total nitrogen loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area N Load	The estimated loading rate for nitrogen for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total Sed	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sed Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

VI. LOAD ALLOCATION PROCEDURE FOR PHOSPHORUS AND SEDIMENT TMDLS

The load allocation and reduction procedures will be applied to the entire Conewago Creek Subbasins and their associated subwatersheds. Subwatersheds in each subbasin were obtained by delineating contributing areas to each of the impacted segments previously shown in Tables 1 and 2. The subwatershed boundaries for Subbasin A and B are shown in Figure 4. In addition to subwatershed delineations, a GIS analysis was performed to determine land use distributions in each subwatershed, data needed for load reduction analyses.

The load reduction calculations in Conewago Creek subbasins are based on the current loading rates for phosphorus and sediments in Lehman-Muddy Run watershed, the reference watershed for this analysis. Based on biological assessment, it was determined that Lehman-Muddy Run was attaining its designated uses. The phosphorus and sediment loading rates were computed for Lehman-Muddy Run watershed using the AVGWLF model. These loading rates were then used as the basis for establishing the TMDLs for Conewago Creek subbasins. The equations defining TMDLs are as follows:

$$TMDL = MOS + LA + WLA \quad (1)$$

$$LA = ALA - LNR \quad (2)$$

TMDL is the TMDL total load. The LA (load allocation) is the portion of Equation (1) that is assigned to non-point sources. The MOS (margin of safety) is the portion of loading that is

reserved to account for any uncertainty in the data and computational methodology used for the analysis. The WLA (Waste Load Allocation) is the portion of this equation that is assigned to point sources. The adjusted load allocation (ALA) is load that originates from nonpoint sources (Equation 2) that need to be reduced for the Conewago Creek subbasins to meet water quality standards. Therefore, it is the load that originates from agricultural sources for water quality problems encountered in the watershed. Details of TMDL, MOS, LA, and ALA computations are presented below.

6.1. TMDL Total Load

The TMDL loads for both pollutants of concern were computed in the same manner. The first step is to determine the TMDL total target load for Conewago Creek, the impaired watershed. This value was obtained by multiplying each pollutant unit loading rate in Lehman-Muddy Run watershed by the total watershed area of Conewago Creek. This information is presented in Table 9.

Table 9. TMDL Total Load Computation			
Pollutant	Unit Area Loading Rate in Lehman-Muddy Run Creek and Little Swatara Creek (lbs/acre/yr)	Total Watershed Area in Subbasin A (acres)	TMDL Total Load (lbs/yr)
Subbasin A			
Phosphorus	0.25	18,087.42	4,522
Sediment	172.69	18,087.42	3,123,517
Subbasin B			
Phosphorus	0.53	15,320.64	8,120
Sediment	420	15,320.64	6,434,669

6.2. Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of each of the TMDLs was reserved as the MOS. Using ten percent of the TMDL load was based on professional judgement and provided an additional level of protection to the uses of the waterbody. The 2001 report was found to be in error by omitting several existing point sources. This revision of the 2001 report incorporates a portion of the associated loads from the omitted point sources by reducing the original ten percent MOS reserve for phosphorus to five percent. The resulting reduced MOS is as follows:

SUBBASIN A

$$\text{Phosphorus} - 4,522 \text{ lbs/yr} \times 0.05 = 226 \text{ lbs/yr} \quad (3)$$

$$\text{Sediment} - 3,123,517 \text{ lbs/yr} \times 0.1 = 312,352 \text{ lbs/yr} \quad (4)$$

SUBBASIN B

$$\text{Phosphorus} - 8,120 \text{ lbs/yr} \times 0.05 = 406 \text{ lbs/yr} \quad (5)$$

$$\text{Sediment} - 6,434,669 \text{ lbs/yr} \times 0.1 = 643,467 \text{ lbs/yr} \quad (6)$$

6.3. Wasteload Allocation

Point source contributions to the watershed for use in determining the loading rate in the reference watershed, and serving as the target loading rate for the impaired watershed, were determined using the Discharge Monitoring Records (DMR) data for each facility. DMR data are also used in assessing the existing point source contributions to the impaired watershed. There is no in-stream module in the GWLF model; therefore, in-stream phosphorus losses must be accounted for externally in order to accurately represent the existing load at the watershed outlet. The method used to estimate in-stream losses from point sources was taken from the USGS SPARROW (**SP**Atially **R**egressioned **R**egressions **on** **W**atershed **A**tttributes) model (Preston, 2000). SPARROW estimates in-stream nutrient losses using a decay function based on travel time and stream flow. Travel time to the watershed outlet is calculated for each facility using flow velocity, as determined by flow volume and a representative cross-sectional area of the stream based on field measurements at several sites along the reach, and distance traveled.

The WLA for the watershed is set to the sum of the permitted loads for each discharger in the watershed. In-stream losses are not applied to the permitted loads in setting the WLA. A TMDL was completed for the Cedar Manor Mobile Home Park for NH₃-N in 1998; however, the TP limit for this facility (located on stream segment with stream code 9243) remained at 2 mg/l. The discharger data for facilities in the Conewago Creek watershed is presented in Table 10. There are no active point source discharges in either reference watershed.

Table 10. Point Source Discharger Data in Conewago Creek Watershed

Conewago Sub-Basin	Discharger Name	NPDES Permit #	1999 Average DMR Flow (mgd)	1999 Average DMR TP (mg/l)	1999 Average TP load (lbs/yr)**	Perm. Flow (mgd)	Perm. TP (mg/l)	Perm. TP Load (lbs/yr)
A	Mt. Gretna Authority	PA0020591	0.098	Not Available	596*	0.2	2.0	1,217.2
A	Pa Turnpike Plaza	PA0081752	Unknown	Unknown	Na	0.05	2.0	304
A	Oliver MHP	PA0080527	0.018	1.2	66	0.029	2.0	177
A	South Londonderry Colebrook	PA0081311	0.01	1.5	46	0.044	2.0	268
A	South Londonderry Lawn	PA0081329	0.008	1.0	24	0.0225	2.0	137

B	Cedar Manor Mobile Home Park	PA0080721	0.06	0.56	116	0.072	2.0	438
B	Conewago Valley Motor Inn	PA0041220	0.028	1.04	89	0.048	2.0	292.1
B	Crowe Transportation	PA0081353	0.0025	0.7	5	0.007	2.0	43
B	Pine Manor MHP	PA0033391	Unknown	Unknown	na	0.02	2.0	122
B	David Over STP	PA0088552	Na	Na	Na	0.0032	8	78
B	Conewago Industrial Park	PA0080055	0.01	Not Available	61*	0.15	2.0	913

* Calculated using 1999 DMR Flow and permitted TP Conc.

** Represents edge-of-pipe load. Point source load presented in Tables 4, 5, 15, and 16 as Existing or Current Load are the load delivered to watershed outlet after in-stream losses described above are applied to edge-of-pipe loads.

6.4. Load Allocation

The Load allocation (LA), consisting of all nonpoint sources in the watershed, was computed by subtracting the margin of safety and the wasteload allocation (WLA) from the TMDL total load. Notice that sediments do not have waste load allocation. In this case, WLA equals to 0 lbs.

SUBBASIN A

$$LA \text{ (Phosphorus)} = 4,522 \text{ lbs/yr} - 226 \text{ lbs/yr} - 2,103 \text{ lbs/yr} = 2,193 \text{ lbs/yr} \quad (7)$$

$$LA \text{ (Sediments)} = 3,123,517 \text{ lbs/yr} - 312,352 \text{ lbs/yr} = 2,811,165 \text{ lbs/yr} \quad (8)$$

SUBBASIN B

$$LA \text{ (Phosphorus)} = 8,120 - 406 \text{ lbs/yr} - 1,886 \text{ lbs/yr} = 5,828 \text{ lbs/yr} \quad (9)$$

$$LA \text{ (Sediments)} = 6,434,669 \text{ lbs/yr} - 643,467 = 5,791,202 \text{ lbs/yr} \quad (10)$$

6.5. Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual load allocation for sources that will need reductions. It is computed by subtracting loads from non-point sources that are not considered in the reduction scenario (LNR). These are loads from all non-point sources in Table 5 except those from agricultural land uses (Hay/Past, Row Crops). Therefore, using data in Table 5,

SUBBASIN A

$$\begin{aligned} LNR \text{ (Phosphorus)} &= 2 \text{ lbs/yr} + 2 \text{ lbs/yr} + 250 \text{ lbs/yr} + 8 \text{ lb/yr} \\ &\quad + 38 \text{ lbs/yr} + 548 \text{ lbs/yr} + 38 \text{ lbs/yr} = 886 \text{ lbs/yr} \end{aligned} \quad (11)$$

$$ALA \text{ (Phosphorus)} = 2,193 \text{ lbs/yr} - 886 \text{ lbs/yr} = 1,307 \text{ lbs/yr} \quad (12)$$

$$\begin{aligned} \text{LNR (Sediments)} &= 1,909 \text{ lbs/yr} + 1,943 \text{ lbs/yr} + 268,909 \text{ lb/yr} + 14,162 \text{ lb/yr} \\ &\quad + 12,085 \text{ lbs/yr} = 299,008 \text{ lbs/yr} \end{aligned} \quad (13)$$

$$\text{ALA (Sediments)} = 2,811,165 \text{ lbs/yr} - 299,008 \text{ lbs/yr} = 2,512,157 \text{ lbs/yr}. \quad (14)$$

SUBBASIN B

$$\begin{aligned} \text{LNR (Phosphorus)} &= 3 \text{ lbs/yr} + 5 \text{ lbs/yr} + 102 \text{ lbs/yr} + 7 \text{ lbs/yr} \\ &\quad + 40 \text{ lbs/yr} + 255 \text{ lbs/yr} + 34 \text{ lbs/yr} = 446 \text{ lbs/yr} \end{aligned} \quad (15)$$

$$\text{ALA (Phosphorus)} = 5,828 \text{ lb/yr} - 446 \text{ lbs/yr} = 5,382 \text{ lbs/yr} \quad (16)$$

$$\begin{aligned} \text{LNR (Sediments)} &= 1,935 \text{ lbs/yr} + 3,333 \text{ lbs/yr} + 81,701 \text{ lb/yr} + 13,952 \text{ lb/yr} \\ &\quad + 11,441 \text{ lbs/yr} = 112,362 \text{ lbs/yr} \end{aligned} \quad (17)$$

$$\text{ALA (Sediments)} = 5,791,202 \text{ lbs/yr} - 112,362 \text{ lbs/yr} = 5,678,840 \text{ lbs/yr}. \quad (18)$$

Table 11 presents TMDLs for Conewago Creek watershed and corresponding subbasins.

Table 11. Summary of TMDLs for Conewago Creek Subbasins (lbs/yr)						
Pollutant	TMDL	MOS	WLA	LA	LNR	ALA
SUBBASIN A						
Phosphorus	4,522	226	2103	2193	886	1307
Sediments	3,123,517	312,352	N/A	2,811,165	299,008	2,512,157
SUBBASIN B						
Phosphorus	8,120	406	1886	5828	446	5382
Sediments	6,434,669	643,467	N/A	5,791,202	112,362	5,678,840

The ALA computed above is the portion of the load that is available to allocate among contributing sources (Hay/Past, Cropland) as described in the next step. Not all land use/source categories were included in the allocation because they are difficult to control, or provide an insignificant portion of the total load (e.g., transition land use). The following section shows the allocation process in detail for the entire watershed and subwatersheds.

6.6. Load Reduction Procedures

The P and sediment loads obtained in the previous step were allocated among the remaining land use/sources of the impaired watershed according to the Equal Marginal Percent Reduction (EMPR) method. EMPR is carried out using an Excel Worksheet in the following manner:

- 1) Each land use/source load is compared with the total allocable load to determine if any contributor would exceed the allocable load by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load to the receiving waterbody. If the contributor exceeds the allocable load, that contributor would be reduced to the allocable load. This is the baseline portion of EMPR.
- 2) After any necessary reductions have been made in the baseline the multiple analysis is run. The multiple analysis will sum all of the baseline loads and compare them to the total allocable load. If the allocable load is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analysis, the final reduction percentage for each contributor can be computed.
- 3) Now that the load allocation for each land use in the Conewago Creek subbasins has been calculated, portions of the whole watershed load can be allocated to each subwatershed. The TMDL total load for each subwatershed was computed as the product of the unit area load for that land use determined in the watershed analysis and the area covered by the land use/source in the subwatershed. The load allocation for each land use was determined by multiplying the allowable unit area loading rate for that land use (after EMPR) and the area of the land use in the impaired subwatersheds. Results of the load reduction procedure are load allocations to agricultural activities and associated percent reductions needed to reach water quality standards in Conewago Creek Subbasins A and B. They are presented for phosphorus and sediment in Table 10 and Table 11, respectively. The load allocation and EMPR procedures was performed using an Excel Worksheet and results are presented in Appendices F and G for P and sediments, respectively.

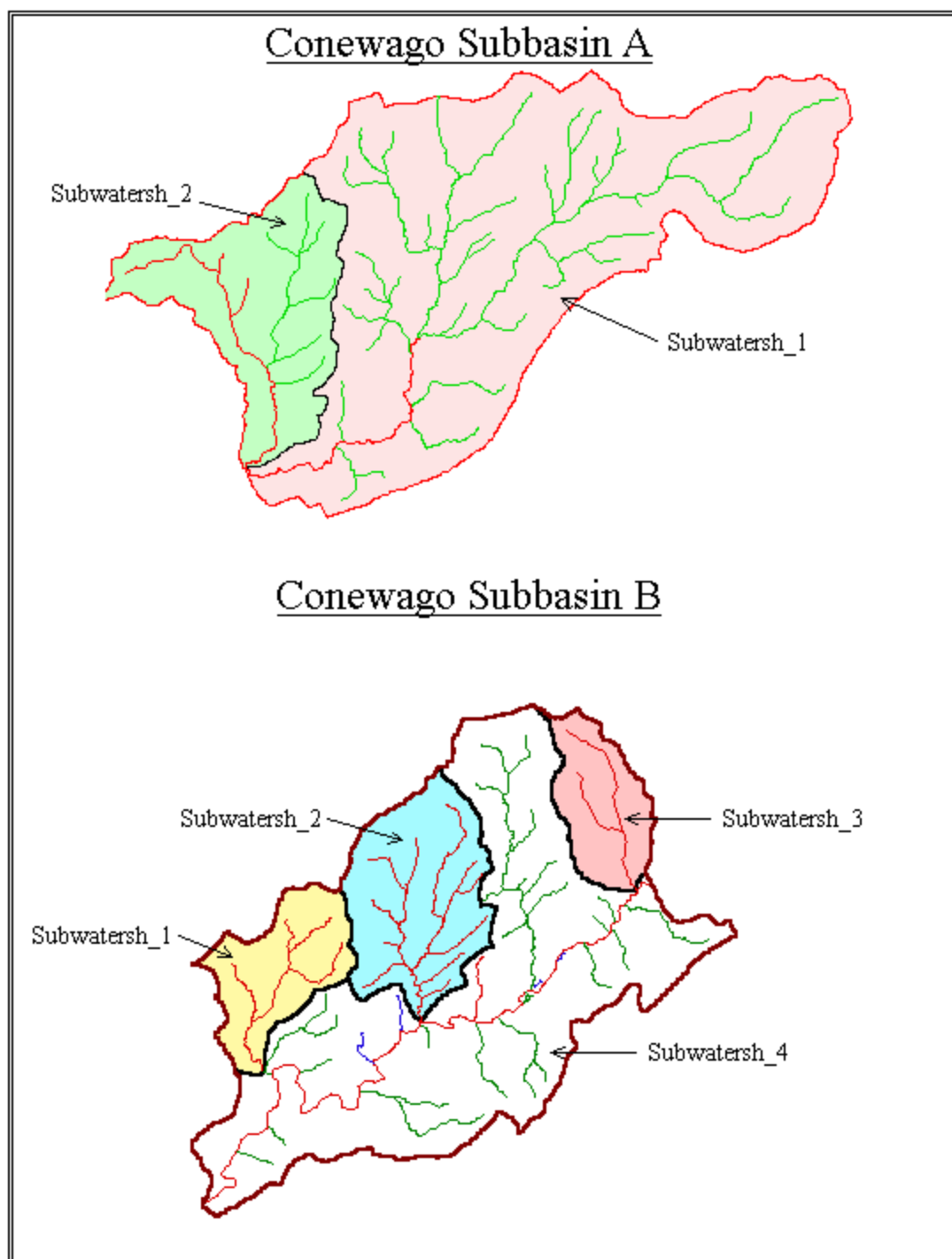


Figure 4. Locations of subwatersheds in Conewago Creek Subbasins.

Table 12. Load Allocation for Phosphorus by Agricultural Source

Stream Segment ID	Land Use/ Source	Area	Current Loading Rate	Current Annual Load	Annual ALA	Reduction
		Acres	Lbs/ac/yr	lbs/yr	lbs/yr	- % -
SUBBASIN A						
Subwatershed 1 1996 Listing Stream Code 09217	Hay/Past	1,843	0.11	271	148	45
	Cropland	3,813	0.97	3,689	726	80
	Subtotal	5,626	0.70	3,960	874	78
Subwatershed 2 ID 970701-1035- SAW	Hay/Past	1,221	0.15	179	98	45
	Cropland	1,760	0.97	1,703	335	80
	Subtotal	2981	0.63	1,882	433	77
SUBBASIN A TOTALS	Hay/Past	3,064	0.15	450	246	45
	Cropland	5,572	0.97	5,391	1061	80
	TOTAL	8,636	0.68	5,841	1307	78
SUBBASIN B						
Subwatershed 1 ID 970626-0830- SAW	Hay/Past	341	0.28	95	24	75
	Cropland	635	1.76	1,118	540	52
	Subtotal	976	1.24	1,213	564	54
Subwatershed 2 ID 970626-1200- SAW	Hay/Past	814	0.28	226	56	75
	Cropland	1,307	1.76	2,301	1112	52
	Subtotal	2,121	1.19	2,527	1168	54
Subwatershed 3 ID 970701-0745- SAW	Hay/Past	372	0.28	103	26	75
	Cropland	581	1.76	1,022	494	52
	Subtotal	953	1.18	1,125	520	54
Subwatershed 4 1996 Listing Steam Code 09217	Hay/Past	1,515	0.28	420	105	75
	Cropland	3,555	1.76	6,260	3025	52
	Subtotal	5,070	1.32	6,680	3130	53
SUBBASIN B TOTALS	Hay/Past	3,042	0.28	844	211	75
	Cropland	6,078	1.76	10,701	5171	52
	TOTAL	9,120	1.27	11,545	5382	53

Table 13. Load Allocation for Sediment by Agricultural Source

Stream Segment ID	Land Use/ Source	Area	Current Loading Rate	Current Annual Load	Annual ALA	Reduction
		Acres	lbs/ac/yr	lbs/yr	lbs/yr	- % -
SUBBASIN A						
Subwatershed 1 1996 Listing Stream Code 09217	Hay/Past	1,843	114.99	211,975	185,901	12
	Cropland	3,813	987.49	3,764,969	1,507,396	60
	Subtotal	5,626	703.13	3,976,944	1,693,297	57
Subwatershed 2 ID 970701-1035- SAW	Hay/Past	1,221	114.99	140,371	123,105	12
	Cropland	1,760	987.49	1,737,762	695,755	60
	Subtotal	2981	630.15	1,878,133	818,859	56
SUBBASIN A TOTALS	Hay/Past	3,064	114.99	342,346	309,006	12
	Cropland	5,572	987.49	5,502,731	2,203,151	60
	TOTAL	8,636	677.94	5,845,077	2,512,156	57
SUBBASIN B						
Subwatershed 1 ID 970626-0830- SAW	Hay/Past	341	149.15	50,915	47,148	7
	Cropland	635	1,352.15	858,521	549,347	36
	Subtotal	976	950.86	909,436	596,495	34
Subwatershed 2 ID 970626-1200- SAW	Hay/Past	814	149.15	121,433	112,448	7
	Cropland	1,307	1,352.15	1,766,949	1,130,628	36
	Subtotal	2,121	950.86	1,888,382	1,243,076	34
Subwatershed 3 ID 970701-0745- SAW	Hay/Past	372	149.15	55,492	51,386	7
	Cropland	581	1,352.15	785,140	502,392	36
	Subtotal	953	950.86	840,632	553,778	34
Subwatershed 4 1996 Listing Steam Code 09217	Hay/Past	1,515	149.15	225,914	209,199	7
	Cropland	3,555	1,352.15	4,807,638	3,076,292	36
	Subtotal	5,070	950.86	5,033,552	3,285,491	35
SUBBASIN B TOTALS	Hay/Past	3,042	149.15	453,754	420,181	7
	Cropland	6,078	1,352.15	8,218,248	5,258,659	36
	TOTAL	9,120	950.86	8,672,002	5,678,840	35

Table 14. Load Allocation by Each Land Use/Source in Conewago Subbasin A.

		Phosphorus					Sediment				
Source	Area	Unit Area Loading Rate	Current Annual Average Load	ALA (annual average)	Allowable Loading Rate (lb/ac/yr)	Reduction	Unit Area Loading Rate	Current Annual Average Load	ALA (annual average)	Allowable Loading Rate (lb/ac/yr)	Reduction
	(ac)	lbs/ac./yr	lbs/yr	lbs/year		- % -	lbs/ac/yr	lbs/yr	lbs/yr		- % -
Hay/Past	3,064	0.15	450	246	0.08	45	114.99	352,346	309,006	100.85	12
Cropland	5,572	0.97	5,391	1,061	0.19	80	987.49	5,502,731	2,203,151	395.40	60
Coniferous For	275	0.01	2	2	0.01	0	6.93	1,909	1,909	6.93	0
Mixed For	346	0.01	2	2	0.01	0	5.62	1,943	1,943	5.62	0
Deciduous For	8,584	0.03	250	250	0.03	0	31.33	268,909	268,909	31.33	0
Lo Int Dev	185	0.04	8	8	0.04	0	76.63	14,162	14,162	76.63	0
Hi Int Dev	61	0.62	38	38	0.62	0	198.35	12,085	12,085	198.35	0
Groundwater			548	548		0					
Point Source			404	2,103		0					
Septic Systems			38	38		0					
Total	18,087	0.39	7,131	4,296	0.24	40	340.27	6,154,085	2,811,165	155.42	54

Table 15. Load Allocation by Each Land Use/Source in Conewago Subbasin B.

		Phosphorus					Sediment				
Source	Area	Unit Area Loading Rate	Current Annual Average Load	ALA (annual average)	Allowable Loading Rate (lb/ac/yr)	Reduction	Unit Area Loading Rate	Current Annual Average Load	ALA (annual average)	Allowable Loading Rate (lb/ac/yr)	Reduction
	Acres	lbs/ac./yr	lbs/yr	lbs/year		- % -	lbs/ac/yr	lbs/yr	lbs/yr		- % -
Hay/Past	3,042	0.28	844	211	0.07	75	149.15	453,754	420,181	138.12	7
Cropland	6,078	1.76	10,701	5,171	0.85	52	1,352.15	8,218,248	5,258,659	865.20	36
Coniferous For	312	0.01	3	3	0.01	0	6.21	1,935	1,935	6.21	0
Mixed For	473	0.01	5	5	0.01	0	7.05	3,333	3,333	7.05	0
Deciduous For	4,891	0.02	102	102	0.02	0	16.70	81,701	81,701	16.70	0
Lo Int Dev	371	0.02	7	7	0.02	0	37.63	13,952	13,952	37.63	0
Hi Int Dev	154	0.26	40	40	0.26	0	74.35	11,441	11,441	74.35	0
Groundwater			255	255		0					
Point Source			204	1,886		0					
Septic Systems			34	34		0					
Total	15,321	0.80	12,195	7,714	0.50	37	573.35	8,784,364	5,791,202	378.00	34

VII. CONSIDERATION OF CRITICAL CONDITIONS

The AVGWLF model is a continuous simulation model which 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. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

VIII. CONSIDERATION OF SEASONAL VARIATIONS

The continuous simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season, and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these actions by the model accounts for seasonal variability.

IX. RECOMMENDATIONS

The pollutant reductions in the TMDLs are allocated entirely to agricultural activities in the watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of sediment reaching the streams can be made through the planting of riparian buffer zones, contour strips, and cover crops. These BMPs range in efficiency from 20% to 70% for sediment reduction. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus. Additional phosphorus reductions can be achieved through the installation of more effective animal waste management systems and stone ford cattle crossings. Other possibilities for attaining the desired reductions in phosphorus and sediment include streambank stabilization and fencing. Further ground truthing will be performed in order to assess both the extent of existing BMPs, and to determine the most cost-effective and environmentally protective combination of BMPs required to meet the nutrient and sediment reductions outlined in this report.

X. PUBLIC PARTICIPATION

A public meeting to discuss and accept comments on proposed TMDLs was held on January 25, 2001 beginning at 7:00 p.m., in the main auditorium of the Farm and Home Center in Lancaster . Public notice of the draft TMDL and the public meeting was published in the *Pennsylvania Bulletin* and the *Lancaster Intelligencer*. Notice of final plan approval will be published in the *Pennsylvania Bulletin*.

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