C12.0 Total Maximum Daily Load (TMDL) Development Plan for Mill Creek

Table of Contents **Page**

List of Tables **Page**

List of Figures **Page**

EXECUTIVE SUMMARY

The Mill Creek sub-watershed is located in Bucks County and is about 4.7 square miles in size. The protected uses of the watershed are water supply, recreation, and aquatic life. Its aquatic use is cold water fishes and migratory fishes.

Total Maximum Daily Loads (TMDLs) apply to 8.7 miles of streams in this sub-basin (Stream Segment ID#s 20000525-1017-GLW, 20010417-GLW, 20010426-1512-GLW, and 980609-1425-GLW). They were developed to address the impairments noted on the Pennsylvania's 2002 Clean Water act Section 303(d) List. The listed impairments include siltation and flow alterations from surface mining, siltation and flow alterations from urban runoff/storm sewers, siltation and flow alterations from small residential runoff, and nutrients from a municipal point source. This TMDL focuses on control of sediments. A TMDL for flow alterations was not developed because neither the U.S. Environmental Protection Agency (EPA) or PaDEP currently have water quality criteria for this impairment. Furthermore, quantitative measures for water flow variability or alterations as "impairments" are not currently available. However, it was assumed for these segments that addressing sediment loads through the use of urban BMPs will at the same time reduce water flow variability or alterations within the watershed. The nutrient impairment from the municipal point source is dealt with in another section (Section D).

Pennsylvania does not currently have water quality criteria for sediment. For this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for sediment in the impaired segments of the Mill Creek sub-watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the sediment loading that will meet the water quality objectives for the Mill Creek sub-watershed is 1,735,682 pounds per year. It is assumed that the streams in this sub-basin will support designated aquatic life uses when this value is met. The TMDL for the sub-watershed is allocated as shown in the table below.

Summary of TMDL for the Mill Creek Sub-Watershed (lbs/yr)

Pollutant	TMDL	MOS	WLA	LA	LNR	ALA
Sediment	1,735,682	173,568	1,562,114	-	-	-

The TMDL has been allocated to all non-point sources of upland and stream bank erosion, with 10% of the TMDL total load reserved as a margin of safety (MOS). In this case, all sediment loads were assigned to the waste load allocation (WLA) category. The TMDL covers a total of 8.7 miles of streams within the Mill Creek sub-watershed, and establishes a reduction for total sediment loading of 28% from the current annual loading of 2,181,460 pounds/year.

C12.0 INTRODUCTION

C12.0.1 Watershed Description

The Mill Creek sub-watershed is located in the Piedmont physiographic province, is situated in Bucks County, and covers an area of approximately 4.7 square miles. The sub-watershed is located south of the town of Tradesville and north of Warrington in eastern Pennsylvania. It is bounded by Pennsylvania Route 611 to the south and Route 152 to the west. Figure C12.1 shows the watershed boundary, its location, and water quality status of stream segments as reported on the 2002 303(d) List. The designated uses of the watershed include water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.o (Commonwealth of PA, 1999), the designated aquatic life use for Mill Creek and its tributaries is cold water fishes and migratory fishes.

The primary land uses in the sub-basin are agriculture (62%), forested land (35%), and development (11%). It was found from a field survey of the watershed that sediment was being deposited in large quantities on the streambed and was degrading the habitat of bottom-dwelling macroinvertebrates.

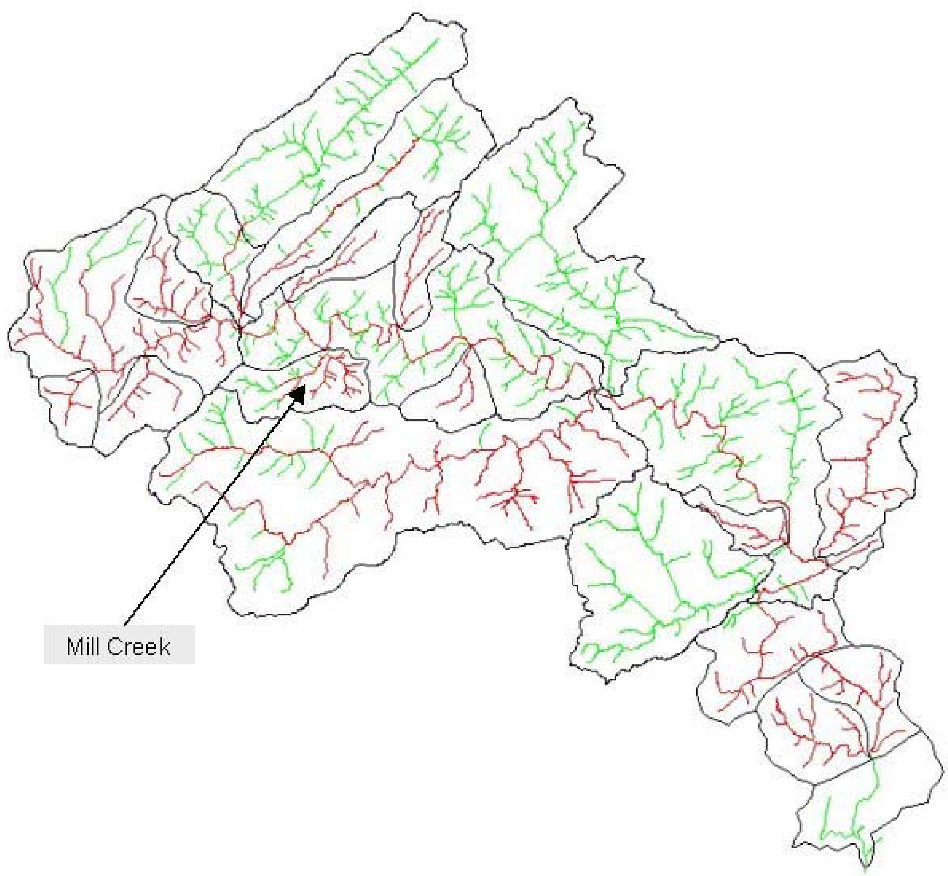

Figure C12.1. Location of Mill Creek sub-watershed.

The surficial geology of the Mill Creek sub-watershed consists of a shale formation. The bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability. Soils are mostly sandy and very erodible, as indicated by a high average K factor (0.37). Watershed characteristics are summarized in Table C12.1.

Table C12.1. Physical Characteristic Comparisons between the Mill Creek and Reference Watersheds

Attribute	Mill Creek Watershed	Reference Watershed
Physiographic Province	Piedmont	Piedmont
Area (square miles)	4.7	2.6
Predominant Land Uses	-Agriculture (62%) -Forested land (20%) -Developed (11%)	-Agriculture (48%) -Forested land (37%) -Developed (8%)
Predominant Geology	Shale (100%)	Sandstone (100%)
Soils - Dominant HSG	C	C
- K Factor	0.37	0.37
20-Year Average Rainfall (in)	40.4	40.4
20-Year Average Runoff (in)	3.7	3.3

C12.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for the Mill Creek sub-watershed to address the impairments noted on the Pennsylvania's 2002 Clean Water Act Section 303(d) List (see Table A1 in section A1.0). It was previously determined that Mill Creek and its tributaries were not meeting their designated water quality uses for protection of aquatic life in 2001. As a consequence, Pennsylvania listed 6.9 miles of streams in this sub-watershed (Stream Segment ID#s 20000525-1017-GLW, 20010426-1512-GLW, and 980609-1425-GLW) on the 2002 Section 303(d) List of Impaired Waters as being impaired by siltation and flow alteration from mining operations, urban runoff/storm sewers, and small residential development.

Sediments, which are often the cause of stream impairment in urban and suburban areas, are primarily from two sources: disturbed land and unprotected soils at construction sites, and stream channel erosion. Transitional land uses, mainly new construction sites, are one of the main sources of sediments in streams draining newly developed areas. Sediment production and sedimentation in streams are typically important during the construction phase because soils are disturbed and exposed to detachment by raindrops and transported during storm events. Construction also renders landscapes unstable and cause soil to move in "sheets" and localized landslides during storm events.

Channel erosion and scour that occur in waterways and receiving waters located in urban and suburban areas may also be an important source of sediments. Channel erosion is primarily the result of elevated storm water runoff during storm events caused by increased impervious surfaces from residential, commercial and industrial areas; construction sites; roads; highways; and bridges in the watershed (Horner, 1994). Basically, impervious areas and disturbed land restrict water infiltration thus converting more rainfall into runoff during storm events. The visible impact of elevated storm runoff includes fallen trees, eroded and exposed stream banks, siltation, floating litter and debris, and turbid conditions in streams. All these conditions were observed during a reconnaissance survey of the watershed. In conclusion, addressing storm water runoff and sediment production at new construction sites through the use of management practices will assure that aquatic life use is achieved and maintained in the watershed. Without effective storm water management practices and sediment traps, build-up of sediments will continue to occur.

C12.1 APPROACH TO TMDL DEVELOPMENT

C12.1.1 TMDL Endpoints

The TMDL discussed herein address sediment. Because neither Pennsylvania nor EPA have water quality criteria for sediment, 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 this TMDL is termed the “reference watershed approach.” With the reference watershed approach, two watersheds are compared, with 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 greatest 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. The underlying assumption is that 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 Watson Creek as the reference watershed. These endpoints are discussed in detail in the TMDL section. The listing for impairment caused by siltation is addressed through reduction of the sediment load. A detailed explanation of this process is included in the following section.

C12.1.2 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 sufficient water quality to satisfy designated uses. The second factor is to find a watershed that closely resembles the Mill Creek subwatershed in terms of 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.

The watershed used as a reference for the Mill Creek sub-watershed was obtained by screen-digitizing the Watson Creek sub-watershed. This sub-watershed is located in the north-central part of the Neshaminy Creek watershed. An analysis of the MRLC land use/cover grid revealed that land cover/use distributions in both watersheds are similar. Characteristics of both watersheds are summarized in Table C12.1, and appear to compare favorably in terms of average runoff, precipitation, and soil K factor. All reference watershed stream segments have been assessed and were found to be unimpaired. Figure C12.2 shows the reference watershed boundary and its location.

C12.1.3 Flow Alterations Due to Mining Activities and Small Residential Runoff

A TMDL was not determined for water/flow variability. It was assumed that addressing sediment loads through the use of various BMPs in this area will at the same time reduce water flow variability within the watershed.

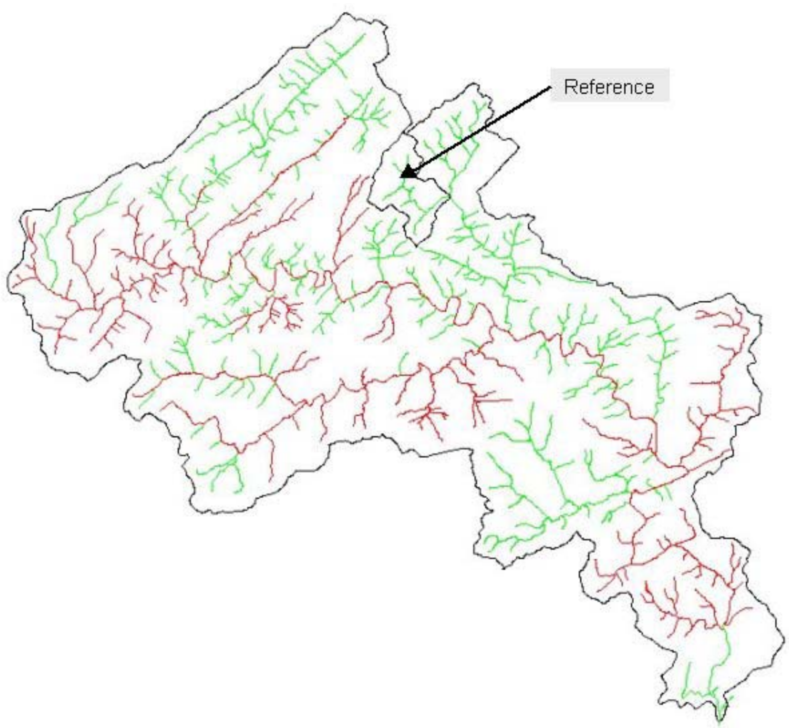

Figure C12.2. Reference watershed location.

C12.1.4 Siltation Due to Mining Activities, Urban Runoff/Storm Sewers, and Small Residential Runoff.

The 2001 survey showed that siltation originating from mining activities, urban runoff/storm sewers, and small residential runoff in the watershed was the cause of impairment to stream segments in the Mill Creek sub-watershed. Sediments deposited in large quantities on the streambed were degrading the habitat of bottom-dwelling macro-invertebrates. Because neither Pennsylvania nor EPA has water quality criteria for sediments, we had to develop a method to determine water quality objectives for this parameter that would result in the impaired stream segments attaining their designated uses.

The objective of the TMDL process for this sub-watershed is to reduce the average loading rate of sediment to the impaired stream segments to levels equivalent to or slightly lower than the average loading rate in the reference watershed. It is assumed that this load reduction will allow the biological community to return to the impaired stream segments. The TMDL endpoints established for this analysis are discussed in detail in the TMDL section. The listing for impairments caused by siltation is addressed through reduction of the sediment loads.

C12.1.5 Nutrients from Municipal Point Source

Nutrient impairments due to a municipal point source in the sub-watershed are not addressed in this section. Rather, they are dealt with in a following section on point source impairments (Section D).

C12.1.6 Watershed Assessment and Modeling

The AVGWLF model was run for both the Mill Creek and reference watersheds to establish loading conditions under existing land use/cover conditions in each watershed using the refined parameter estimates based on the calibration results. Based on the use of 20 years of historical weather data, the mean annual sediment loads for the impaired and reference watersheds were calculated as shown in Tables C12.2 and C12.3, respectively. Table C12.4 presents an explanation of the header information contained in Tables C12.2 and C12.3. Modeling output for Mill Creek Sub-basin #1 and the reference watershed is presented in Appendix F.

Table C12.2. Existing Loading Values for Mill Creek Watershed.			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	428	21,980	51.4
Cropland	1,446	1,426,580	986.6
Coniferous Forest	153	620	4.1
Mixed Forest	180	700	3.9
Deciduous Forest	282	1,240	4.4
Unpaved Road	3	1,240	413.3
Quarries	27	10,040	371.9
Transitional Land	180	150,120	834.0
Low Intensity Developed	329	6,220	18.9
Stream Bank		562,720	
Groundwater			
Point Source			
Septic Systems			
Total	3,027	2,181,460	720.7

Table C12.3. Existing Loading Values for Reference Watershed.			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	351	19,820	56.5
Cropland	944	991,620	1,050.4
Coniferous Forest	190	1,440	7.6
Mixed Forest	203	1,660	8.2
Deciduous Forest	601	6,120	10.2
Unpaved Road	0	0	0
Quarries	0	0	0
Transitional Land	198	310,240	1,566.9
Low Intensity Developed	218	5,940	27.2
Stream Bank		212,980	
Groundwater			
Point Source			
Septic Systems			
Total	2703	1,549,810	573.4

Table C12.4. Header Information for Tables C12.2 and C12.3.	
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.
Sediment Load	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sediment Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

C12.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to the entire area of the Mill Creek sub-watershed. The load reduction calculations in this area are based on the current loading rates for sediment in the reference watershed. Based on biological assessment, it was determined that the reference watershed was attaining its designated uses. Sediment loading rates were computed for the reference watershed using the AVGWLF model. These loading rates were then used as the basis for establishing the TMDL for the Mill Creek sub-watershed.

The basic equation defining a TMDL for sediment is as follows:

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

TMDL is the TMDL total load. The LA (load allocation) is the portion of Equation (1) that is typically 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 typically assigned to point sources. However, as described below, this category was used to reflect sediment loads from all sources in this particular watershed. This was done for two primary reasons: 1) because “urban runoff/storm sewers” and “small residential runoff” were listed as primary sources of sediment to impaired stream segments in this watershed, and 2) to be consistent with EPA guidance on how to handle sediment loads in urbanized watersheds. Details of how specific components of the overall TMDL calculation were derived are presented below.

C12.2.1 Sediment TMDL Total Load

The first step was to determine the TMDL total target load for the impaired watershed. This value was obtained by multiplying the sediment unit area loading rate of the reference watershed by the total area of the Mill Creek sub-watershed. This information is presented in Table C12.5.

Table C12.5. TMDL Total Load Computation			
Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Total Watershed Area in Mill Creek Sub-basin #1 (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	573.4	3027	1,735,682

C12.2.2 Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of the TMDL was reserved as the MOS.

MOS (Sediment): 1,735,682 lbs/yr x 0.1 = 173,568 lbs/yr (2)

C12.2.3 Waste Load Allocation

For the purposes of this TMDL assessment, sediment loads from all sources have been assigned to the waste load allocation (WLA) category to be consistent with EPA guidance on how to handle sediment loads in urbanized watersheds to which MS4 regulations apply. Therefore, the load allocation (LA) in this caser is equal to zero. Allowing for an explicit 10% MOS, the target WLA is recomputed as:

WLA (Sediment) = 1,735,682 lbs/yr – 173,568 lbs/yr = 1,562,114 lbs/yr (3)

Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix.

C12.2.4 Load Reduction Procedures

The allocation of sediment among contributing sources in the Mill Creek sub-watershed was done by reducing each source equally on a percentage basis. Based on the target WLA of 1,562,114 lbs/year described above, the computed load allocations are as shown in Table C12.4.

The total allowable sediment loads to stream segments in the Mill Creek sub-watershed when all sources are considered is 1,562,114 pounds per year. In order for the stream segments to attain their specific uses, total sediment loads should be reduced from 2,181,460 pounds per year by a factor of 28%.

Table C12.5. Load Allocation by Each Land Use/Source					
		Sediment			
Source	*Area* Acres	*Unit Area Loading Rate* lbs/ac/yr	*Annual average load* lbs/yr	*WLA* lbs/yr	*Reduction* - % -
Hay/Past	428	51.4	21,980	15,739	28
Cropland	1,446	986.6	1,426,580	1,021,556	28
Coniferous	153	4.1	620	444	28
Mixed For	180	3.9	700	501	28
Deciduous	282	4.4	1,240	888	28
Unpaved Roads	3	413.3	1,240	888	28
Quarries	27	371.9	10,040	7,189	28
Transitional Land	180	834.0	150,120	107,497	28
Low Intensity Dev	329	18.9	6,220	4,454	28
Stream Bank			562,720	402,958	28
Groundwater					
Point Source					
Septic Systems					
Total	3,027	720.7	2,181,460	1,562,114	**28**

C12.3 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 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 to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

C12.4 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.

C12.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated to all sources of upland and stream bank erosion in the watershed. Implementation of best management practices (BMPs) in the affected areas to increase infiltration and sediment control measures should achieve the loading reduction goals established in the TMDL. Substantial reductions in the amount of sediment reaching the streams can be made through the installation of drainage controls such as detention ponds, sediment ponds, infiltration pits, dikes, riparian buffers, stream bank stabilization and ditches in the watershed . These BMPs range in efficiency from **20% to 70%** for sediment reduction.

The implementation of such BMPs will likely occur in the watershed as a result of PaDEP's Proposed Comprehensive Stormwater Management Policy. When approved, this new policy will require affected communities to implement BMPs to address stormwater control that will "reduce pollutant loadings to streams, recharge groundwater tables, enhance stream base flow during times of drought and reduce the threat of flooding and stream bank erosion resulting from storm events." Over the next year and one-half, PaDEP will be developing a "Phase II" program for NPDES discharges from small construction sites, additional industrial activities, and for the 700 municipalities subject to the requirements for separate storm sewer systems (MS4). All of the municipalities located within the Mill Creek watershed will be affected by this policy, which has been included in Appendix E. Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus originating from transitional land uses and stream bank erosion.

C12.6 PUBLIC PARTICIPATION

Notice of the draft TMDL will be published in the *PA Bulletin* and local newspapers with a 30-day comment period provided. A public meeting with watershed residents will be held to discuss the TMDL. Notice of final TMDL approval will be posted on the Department website.

C13.0 Total Maximum Daily Load (TMDL) Development Plan for Core Creek

Table of Contents **Page**

List of Tables **Page**

List of Figures **Page**

EXECUTIVE SUMMARY

The Core Creek watershed is about 9.9 square miles in size, is located in Bucks County, and drains into the main stem of Neshaminy Creek. The protected uses of the watershed are water supply, recreation, and aquatic life. Its aquatic use is cold water fishes in the upper part of the stream, warm water fishes in the lower part and migratory fishes.

This Total Maximum Daily Load (TMDL) applies to 15.8 miles of Core Creek (Stream Segment ID# 980602-0954-GLW). It was developed to address the impairments noted on Pennsylvania's 2002 Clean Water Act Section 303(d) List. This particular segment was deemed to be impaired due to sediment from agricultural activities. Since Pennsylvania does not currently have water quality criteria for sediment, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for sediment in the impaired segments of the Core Creek watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the sediment loading that will meet the water quality objectives for Core Creek is 1,474,723 pounds per year. The TMDL for Core Creek is allocated as shown in the table below.

Summary of TMDL for Core Creek (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediment	1,474,723	147,472	-	1,327,251	603,112	724,139

The TMDL for sediment is allocated to non-point source loads from agricultural land, with 10% of the TMDL total load reserved as a margin of safety (MOS). The waste load allocation (WLA) is that portion of the total load that is assigned to point sources, which was zero for sediment. The allowable loading, or adjusted loading allocation (ALA), is that load attributed to agricultural land, and is computed by subtracting loads that do not need to be reduced (LNR) from the TMDL total values. The sediment TMDL covers a total of 15.8 miles of streams. The TMDL establishes a reduction for total sediment loading of 25% from the current annual loading of 1,775,981 pounds.

C13.0 INTRODUCTION

C13.0.1 Watershed Description

The Core Creek watershed is located in the Piedmont Physiographic Province, and is located in Bucks County. It covers an area of approximately 9.9 square miles. Core Creek drains into the main stem of Neshaminy Creek from the east (see Figure C13.1). The watershed is located east of the town of Newtown and north of Langhorne. It is bounded by Pennsylvania Route 632 to the north, and Route 432 to the east. The designated uses of the watershed include water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.o (Commonwealth of PA, 1999), the designated aquatic life use for Core Creek is warm water fishes in the upper part of the stream, warm water fishes in the lower part of the stream, and migratory fishes.

The primary land use in the Core Creek watershed is agriculture (57%), with areas adjacent to the stream used for cropland and pasture. The majority of the streams have no protected riparian zone. Based on the aquatic survey conducted in the area, it was found that sediment being deposited in large quantities on the streambed was degrading the habitat of bottom-dwelling macroinvertebrates.

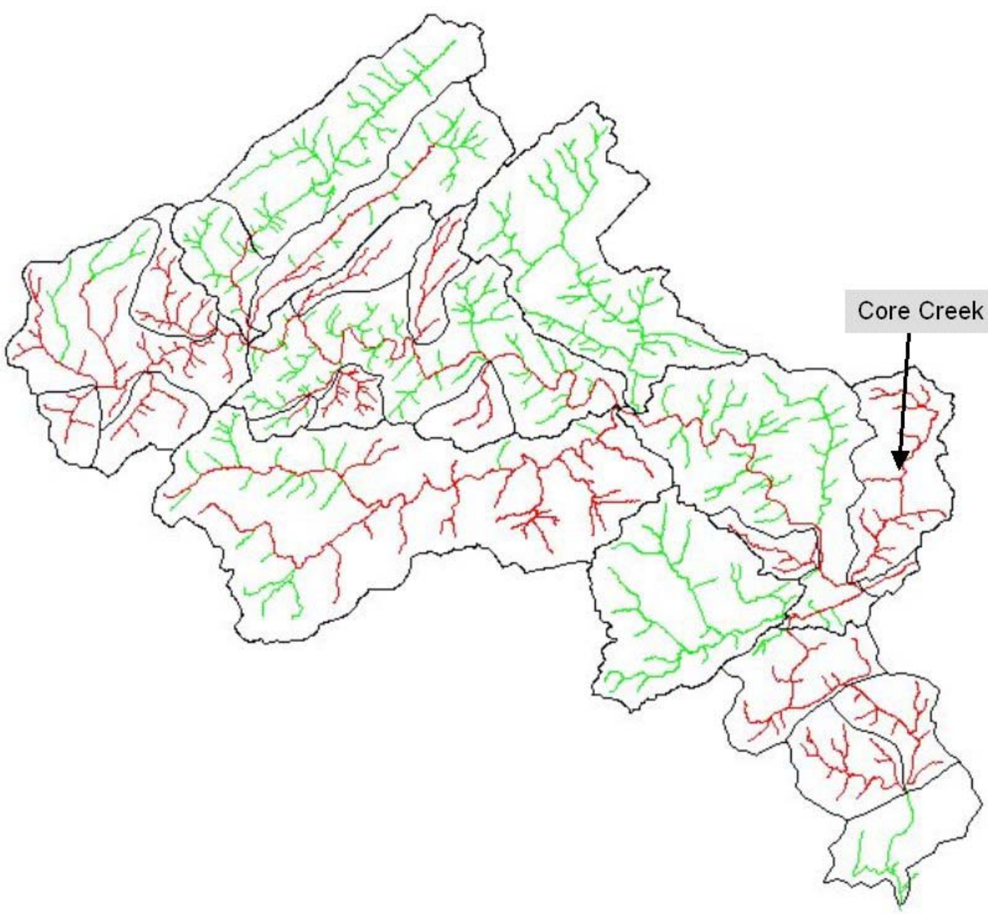

Figure C14.1. Core Creek watershed.

The surficial geology of Core Creek watershed consists of a sandstone formation. The bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability. Soils are mostly sandy and very erodible, as indicated by a high average K factor (0.38). Watershed characteristics are summarized in Table C13.1.

Table C13.1. Physical Characteristic Comparisons between the Core Creek and Reference Watersheds

Attribute	Core Creek Watershed	Reference Watershed
Physiographic Province	Piedmont	Piedmont
Area (square miles)	9.9	8.4
Predominant Land Uses	Agriculture (57%)	Agriculture (50%)
Predominant Geology	Sandstone (90%) Shale (10%)	Shale (90%) Carbonate (10%)
Soils - Dominant HSG	C	C
- K Factor	0.38	0.37
20-Year Average Rainfall (in)	40.5	40.6
20-Year Average Runoff (in)	4.1	4.3

C13.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for the Core Creek watershed to address the impairments noted on the Pennsylvania's 2002 Clean Water Act Section 303(d) List (see Table A1 in section A1.0). The 2001 survey found that that the stream was impaired. As a consequence, Pennsylvania listed Core Creek on the 2002 Section 303(d) List of Impaired Waters. The 2002 303 (d) List reported 15.8 miles of Core Creek (Stream Segment ID# 980602-0954-GLW) to be impaired by siltation from agricultural activities in the watershed.

C13.1 APPROACH TO TMDL DEVELOPMENT

C13.1.1 TMDL Endpoints

The TMDL described herein addresses sediment impairments. Because neither Pennsylvania nor EPA has water quality criteria for sediments, we had to develop a method to determine water quality objectives for this parameter that would result in the impaired stream segments attaining their designated uses. The method employed for this TMDL is termed the "reference watershed approach."

With the reference watershed approach, two watersheds are compared, with 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 greatest extent possible; however, most variations can be adjusted in the model. The objective of the process is to reduce the loading rate of 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. The underlying assumption is that this load reduction will allow the biological community to return to the impaired stream segments.

C13.1.2 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 attain water quality standards. The second factor is to find a watershed that closely resembles the Core 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 data layers 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.

The reference used for the Core Creek watershed is the Mill Creek watershed located in the north-central part of Neshaminy Creek (not to be confused with the other Mill Creek located farther upstream as discussed in the previous section). Both watersheds are located in the same physiographic Province and State Water Plan, and are tributaries of Neshaminy Creek. Table C13.1 compares the two watersheds in terms of their size, location, and other physical characteristics. All reference watershed stream segments have been assessed and were found to be unimpaired. Figure C13.2 shows the reference watershed boundary and its location in Bucks County. An analysis of the landuse/cover layer revealed that land cover/use distributions in both watersheds are similar. The surficial geology of the Core Creek and reference watersheds is somewhat different, but it is not expected that this would significantly affect sediment loads in either case.

C13.1.3 Siltation Due to Agricultural Sources

The 2001 survey showed that siltation originating from agricultural activities in the watershed was the cause of impairment of Core Creek stream segments. Sediments deposited in large quantities on the streambed were degrading the habitat of bottom-dwelling macroinvertebrates. This TMDL addresses sediments from agricultural activities.

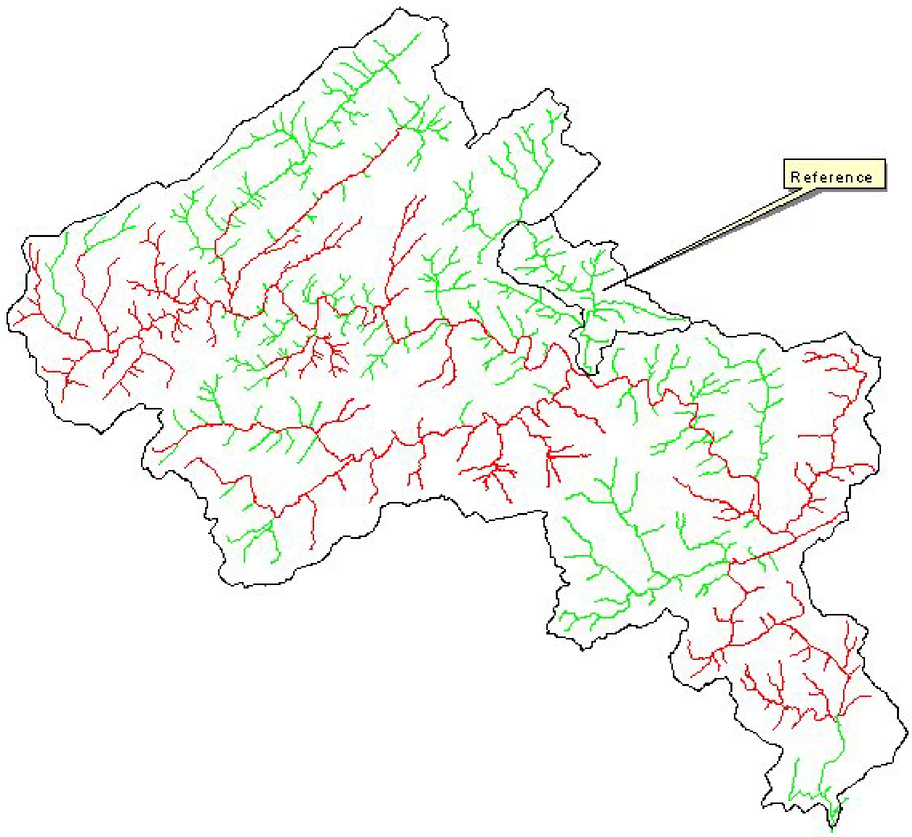

Figure C13.2. Reference watershed location.

C13.1.4 Watershed Assessment and Modeling

The AVGWLF model was run for both the Core Creek and reference watersheds to establish existing loading conditions under existing land cover use conditions in each watershed.

Adjustments to Specific GWLF-related parameters in the Reference Watershed:

-reset "C" factor to 0.18 for Cropland to account for use of more continuous cover crop.

-reset "P" factor to 0.35 for Cropland land use to account for use of riparian forest and grasses along streams, strip cropping, and buffer strips.

Using the refined parameter estimates based on the calibration results, AVGWLF was re-run for the Core Creek watershed. Based on the use of 20 years of historical weather data, the mean annual loads for sediment for the impaired and reference watersheds were calculated as shown in Tables C13.2 and C13.3, respectively. Table C13.4 presents an explanation of the header information contained in Tables C13.2 and C13.3. Modeling output for the Core Creek and reference watersheds is presented in Appendix F.

Table C13.2. Loading Values for Core Creek Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	956	28,079	29.37
Cropland	2,415	1,144,790	474.03
Coniferous Forest	30	22	0.73
Mixed Forest	437	728	1.67
Deciduous Forest	1,022	2,230	2.18
Lo Intensity Developed	825	24,106	29.22
Hi Intensity Developed	205	4,503	21.97
Stream Bank		571,523	
Groundwater			
Point Source			
Septic Systems			
Total	5,889	1,775,981	301.58

Table C13.3. Loading Values for the Reference Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	464	18,168	39.16
Cropland	2,202	729,669	331.37
Coniferous Forest	12	110	9.17
Mixed Forest	336	1,015	3.02
Deciduous Forest	2,057	10,574	5.14
Transition	2	1,766	883
Lo Intensity Developed	136	4,790	35.22
Hi Intensity Developed	18	287	15.94
Stream Bank		557,616	
Groundwater			
Point Source			
Septic Systems			
Total	5,287	1,323,995	250.42

Table C13.4. Header Information for Tables C13.2 and C13.3.	
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.
Sediment Load	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sediment Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

C13.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to the entire Core Creek watershed. The watershed was too small to subdivide it into meaningful sub-watersheds. Therefore, sub-watershed load allocations were not performed.

The load reduction calculations for the Core Creek watershed are based on the current loading rates for sediment in the reference watershed. Based on the biological assessment, it was determined that the reference watershed was attaining its designated uses. The sediment loading rate was computed for the reference watershed using the AVGWLF model. This loading rate was then used as the basis for establishing the TMDL for the Core Creek watershed.

The equations defining TMDLs for sediment 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 the load originating from sources (Equation 2) that needs to be reduced by the non-contributing sources (LNR) for Core Creek to meet water quality goals. Therefore, it is the load that originates from agricultural sources that have contributed to water quality problems encountered in the watershed. Details of TMDL, MOS, LA, LNR, and ALA computations are presented below.

C13.2.1 Sediment TMDL Total Load

The first step was to determine the TMDL total target load for Core Creek, the impaired watershed. This value was obtained by multiplying the sediment unit area loading rate in the reference watershed by the total watershed area of the Core Creek watershed. This information is presented in Table C13.5.

Table C13.5. TMDL Total Load Computation

Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Total Watershed Area for Core Creek (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	250.42	5,889	1,474,723

C13.2.2 Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of the TMDL was reserved as the MOS.

MOS (Sediment): 1,474,723 lbs/yr x 0.1 = 147,472 lbs/yr (4)

C13.2.3 Load Allocation

The load allocation (LA), consisting of all nonpoint source loads in the watershed, was computed by subtracting the margin of safety and the waste load allocation (WLA) from the TMDL total load. (Note that sediments do not have a waste load allocation in this case).

LA (Sediments): 1,474,723 lbs/yr – 147,472 lbs/yr = 1,327,251 lbs/yr (5)

C13.2.4 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 C13.2 except those from agricultural land uses (Hay/Pasture, Row Crops). Therefore, using data in Table C13.2,

LNR (Sediments) = 22 lbs/yr + 728 lbs/yr 2230 lb/yr + 24,106 lb/yr
+ 4,503lbs/yr + 571,523 lbs/yr
= 603,112 lbs/y r (6)

ALA (Sediments) = 1,327,251 lbs/yr – 603,112 lbs/yr = 724,139 lbs/yr (7)

Table C13.6 below presents TMDL results for the Core Creek watershed.

Table C13.6. Summary of TMDL for Core Creek (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediment	1,474,723	147,472	-	1,327,251	603,112	724,139

The ALA computed above is the portion of the load that is available to allocate among contributing sources (Hay/Pasture, 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., transitional land use). The following section shows the allocation process in detail for the entire watershed.

C13.2.5 Load Reduction Procedures

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:

3) 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.

4) 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.

The load allocation and EMPR procedures were performed using an Excel Worksheet, and results are presented in Appendix G. Results of the load allocation by contributing sources are presented in Table C13.7. Table C13.8 provides load allocation by considering all land uses in the Core Creek watershed. In this case, land uses/sources that were not part of the allocation are carried through at their existing loading values. (Again, it is important to note that Core Creek only has one stream segment. Therefore, sub-watersheds could not be delineated. As a result, load allocation by sub-watersheds was not performed.)

Table C13.7. Load Allocation by Each Contributing Source in the Core Creek Watershed.				
Land Use/Source	**Sediments**			
	Loading Rate Lbs/ac/yr	*Average Load Lbs/yr*	*Average ALA lbs/yr*	*Reduction - % -*
Hay/Past	28,079	29.37	27,031	4
Cropland	1,144,790	474.03	697,108	39
Sub-total	1,172,869	347.93	724,139	38

Table C13.8. Load Allocation by Each Land Use/Source					
		Sediment			
Source	*Area (acres)*	*Unit Area Loading Rate (lbs/ac/yr)*	*Annual average load (lbs/yr)*	*ALA (annual average) (lbs/yr)*	*Reduction (%)*
Hay/Past	956	28,079	29.37	27,031	4
Cropland	2,415	1,144,790	474.03	697,108	39
Coniferous	30	22	0.73	22	0
Mixed For	437	728	1.67	728	0
Transition	1,022	2,230	2.18	2,230	0
Lo Int Dev	825	24,106	29.22	24,106	0
Hi Int Dev	205	4,503	21.97	4,503	0
Stream Bank		571,523		571,523	0
Groundwater					
Point Source					
Septic Systems					
Total	5,889	1,775,981	301.58	1,327,251	**25**

The total allowable sediment load to Core Creek when all land use/cover sources are considered is 1,327,251 pounds per year. In order for all stream segments to attain their specific uses, total sediment load should be reduced from 1,775,981 pounds per year by 25%.

C13.3 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 to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

C13.4 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.

C13.5 REASONABLE ASSURANCE OF IMPLEMENTATION

The pollutant reductions in the TMDL 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 TMDL. 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. Other possibilities for attaining the desired reductions in sediment include streambank stabilization and fencing. Further field verification 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 sediment reductions outlined in this section.

C13.6 PUBLIC PARTICIPATION

Notice of the draft TMDL will be published in the *PA Bulletin* and local newspapers with a 30 day comment period provided. A public meeting with watershed residents will be held to discuss the TMDL. Notice of final TMDL approval will be posted on the Department website.

C14.0 Total Maximum Daily Load (TMDL) Development Plan for Neshaminy Creek South #1 Watershed

Table of Contents **Page**

List of Tables **Page**

List of Figures **Page**

EXECUTIVE SUMMARY

The Neshaminy Creek South #1 watershed is approximately 7.6 square miles in size. It is in Bucks County, and includes a portion of the main stem of Neshaminy Creek in the lower part of the Neshaminy Creek watershed, as well as several smaller tributaries that flow into it. The protected uses of streams in the watershed are water supply, recreation, and aquatic life. Their aquatic uses include warm water fishes and migratory fishes.

The Total Maximum Daily Load (TMDL) applies to 7.6 miles of streams in this watershed (Stream Segment ID#s 20010525-1250-GLW). A TMDL was developed to address the impairments noted on Pennsylvania's 2002 Clean Water Act Section 303(d) List. In this case, this segment was deemed to be impaired by siltation from development ("urban runoff/storm sewers") in the watershed. Since Pennsylvania does not currently have water quality criteria for sediment, it was necessary to develop a reference watershed approach to identify the TMDL endpoints or water quality objectives for sediment in the impaired segments of the watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the amount of sediment loading to the watershed that will meet the water quality objectives for streams therein is 2,394,456 pounds per year. The TMDL for the Neshaminy Creek South #1 watershed is allocated as shown in the table below.

Summary of TMDLs for Neshaminy Creek South #1 (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediments	2,394,456	239,446	2,155,010	-	-	-

The TMDL for sediment is allocated to all non-point sources of upland and stream bank erosion, with 10% of the TMDL total load reserved as a margin of safety (MOS). In this case, all sediment loads were assigned to the waste load allocation (WLA) category. The sediment TMDL covers a total of 7.6 miles of stream, and establishes a reduction for total sediment loading of 30% from the current annual loading of 3,073,400 pounds.

C14.0 INTRODUCTION

C14.0.1 Watershed Description

The watershed contains part of the main stem of Neshaminy Creek (Stream Segment ID# 467), as well as several small tributaries that flow into it. The watershed is located in the Piedmont Physiographic Province, is situated in Bucks County, and is approximately 7.4 square miles in size. The watershed covers the towns of South Hampton, Langhorne, and Middletown. It is bounded by Pennsylvania Route 213 to the north and Route 1 to the south. Figure C14.1 shows the watershed boundary and its location. The designated uses of the watershed include water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.o (Commonwealth of PA, 1999), the designated aquatic life use for the Neshaminy Creek South #1 watershed is warm water fishes and migratory fishes. The primary land use in the watershed is development (65%). As a result of aquatic surveys completed in the area, it was found that sediment deposited in large quantities on the streambed was degrading the habitat of bottom-dwelling macroinvertebrates.

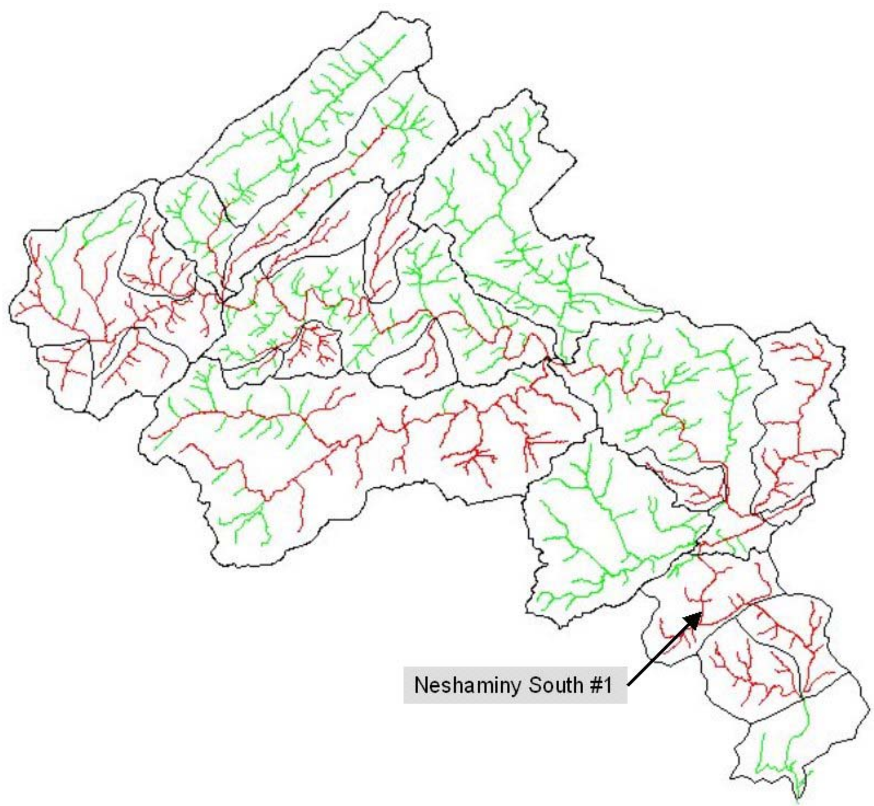

Figure C14.1. Neshaminy Creek South #1 watershed.

The surficial geology of the watershed consists of sandstone and metamorphic/gneiss formations. The bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability. Soils are mostly sandy and very erodible, as indicated by a high average K factor (0.32). Watershed characteristics are summarized in Table C14.1.

Table C14.1. Physical Characteristic Comparisons Between Neshaminy Creek South #1 and Reference Watersheds		
Attribute	**Neshaminy Creek South #1**	**Reference Watershed**
Physiographic Province	Piedmont	Piedmont
Area (square miles)	7.4	8.3
Predominant Land Uses	Development (65%)	Development (63%)
Predominant Geology	Sandstone (50%) Metamorphic/Gneiss (45%)	Metamorphic/Gneiss(95%)
Soils - Dominant HSG	C	C
- K Factor	0.32	0.34
20-Year Average Rainfall (in)	41.5	41.5
20-Year Average Runoff (in)	3.3	3.5

C14.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for the Neshaminy Creek South #1 watershed to address the impairments noted on the Pennsylvania's 2002 Clean Water Act Section 303(d) List (see Table A1 in section A1.0). The 2001 survey found that that stream segments in this sub-watershed that are tributaries to the main stem of Neshaminy Creek were impaired. As a consequence, Pennsylvania listed stream segments in this watershed on the 2002 Section 303(d) List of Impaired Waters. In particular, the 2002 303 (d) List reported 7.6 stream miles (Stream Segment ID# 20010525-1250-GLW) to be impaired by siltation from development in the watershed.

This sub-watershed also contains a portion of the Neshaminy Creek main stem (ID# 467) that was listed as being impaired by various municipal point sources. This particular impairment is not addressed here. Rather, it is dealt with in Section D.

C14.1 APPROACH TO TMDL DEVELOPMENT

C14.1.1 TMDL Endpoints

The TMDL discussed herein addresses sediment loads in the watershed. Because neither Pennsylvania nor EPA have water quality criteria for sediment, 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 this TMDL is termed the "reference watershed approach."

With the reference watershed approach, two watersheds are compared, with 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 greatest extent possible; however, most variations can be adjusted in the model. The objective of the process is to reduce the loading rate of 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. The underlying assumption is that this load reduction will allow the biological community to return to the impaired stream segments.

C14.1.2 Selection of the Reference Watershed

In general, three criteria should be considered when selecting a suitable reference watershed. The first criterion is to use a watershed that has been assessed by the Department using the Unassessed Waters Protocol and has been determined to attain water quality standards. The second criterion is to find a watershed that closely resembles impaired 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.

The watershed used as a reference for the Neshaminy Creek South #1 watershed is the Mill Creek watershed located in the lower part of the larger Neshaminy Creek watershed (not to be confused with the Mill Creek watershed located farther upstream discussed earlier in Sections 12.0 and 13.0). Both the impaired and reference watersheds are located in the same physiographic province and State Water Plan, and are tributaries of Neshaminy Creek. Table C14.1 compares the two watersheds in terms of their size, location, and other physical characteristics. All reference watershed stream segments have been assessed and were found to be unimpaired. Figure C14.2 shows the reference watershed boundary and its location in Bucks County. An analysis of the MRLC land use/cover GIS layer revealed that land cover/use distributions in both watersheds are similar. The major surficial geology in the two watersheds is somewhat different, but it is believed that this likely does not significantly affect sediment loads in either case.

C14.1.3 Siltation Due to Development

The 2001 survey showed that siltation originating from development was the cause of impairment of stream segments in this watershed. During the stream assessment, it was found that sediment deposited in large quantities on the streambed was degrading the habitat of bottom-dwelling macroinvertebrates. Stream bank erosion also occurred as a result of excess flow in the watershed due to a substantially high percentage of impervious areas (the watershed is 65% developed). Consequently, the TMDL discussed herein addresses sediment loads from development and from stream bank erosion.

C14.1.4 Watershed Assessment and Modeling

The AVGWLF model was run for both the Neshaminy Creek South #1 watershed and the reference watershed to establish existing loading conditions under existing land cover use conditions in each case. Prior to running the model, historical stream water quality data for the period 4/89 to 3/96 were first used to calibrate various key parameters within the GWLF model. Such data sets are typically not available in AVGWLF-based TMDL assessments done elsewhere in Pennsylvania. In this case, however, it was felt that model calibration would provide for better simulation of localized watershed processes and conditions. A description of the calibration procedure used can be found in section B1.4 of this document.

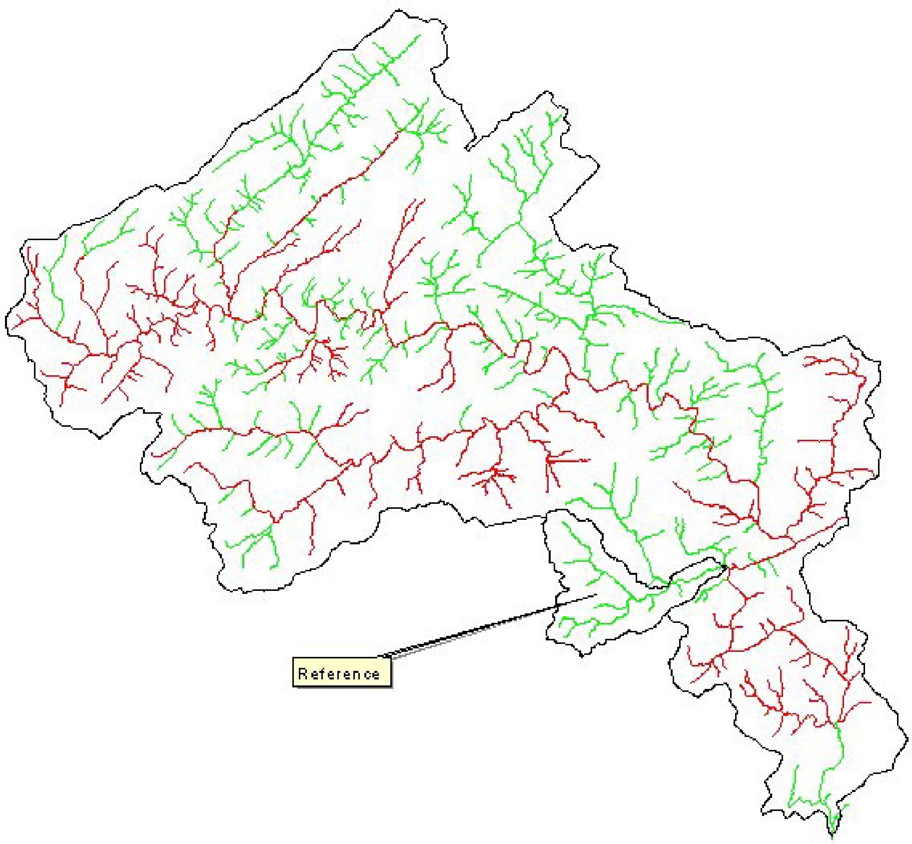

Figure C14.2. Reference watershed location.

Using the refined parameter estimates based on the calibration results, AVGWLF was run for the both watersheds. Based on the use of 20 years of historical weather data, the mean annual sediment loads for the impaired and reference watersheds were calculated as shown in Tables C14.2 and C14.3, respectively. Table C14.4 presents an explanation of the header information contained in Tables C14.2 and C14.3. Modeling output for Neshaminy Creek South #1 watershed and the reference watershed is presented in Appendix F.

Table C14.2. Loading Values for Neshaminy Creek South #1 Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	62	3,040	49.0
Cropland	220	233,840	1,062.9
Coniferous Forest	269	2,080	7.7
Mixed Forest	267	2,760	10.3
Deciduous Forest	699	8,600	12.3
Transition	126	158,180	1,255.4
Lo Intensity Develop	2,355	154,220	65.5
Hi Intensity Develop	723	18,980	26.3
Stream Bank		2,491,660	
Groundwater			
Point Source			
Septic Systems			
Total	4,720	3,073,400	651.1

Table C14.3. Loading Values for the Reference Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	101	5,060	50.1
Cropland	336	295,020	878.0
Coniferous Forest	381	3,620	9.5
Mixed Forest	264	2,080	7.9
Deciduous Forest	754	7,580	10.1
Unpaved Roads	3	1,920	640.0
Transitional Land	126	168,280	1,335.6
Lo Intensity Dev	3,077	221,240	71.9
Hi Intensity Dev	267	8,140	30.5
Stream Bank		1,979,660	
Groundwater			
Point Source			
Septic Systems			
Total	5,308	2,692,600	507.3

Table C14.4. Header Information for Tables C14.2 and C14.3.	
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 Sediment	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sediment Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

C14.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to the entire Neshaminy Creek South #1 watershed. The load reduction calculations in the watershed are based on the current loading rates for sediment in the reference watershed. As discussed earlier, the Neshaminy Creek South #1 watershed also contains a portion of the main stem of Neshaminy Creek that is listed as being impaired due to municipal point sources (Stream Segment ID #467). This particular impairment is not addressed here, however, since it has been discussed in another section of this document (see Section D). Based on biological assessment, it was determined that the reference watershed was attaining its designated uses. Sediment loading rates were computed for the reference watershed using the AVGWLF model. These loading rates were then used as the basis for establishing the TMDL for the Neshaminy Creek South #1 watershed.

The basic equation defining the TMDL for sediment is as follows:

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

TMDL is the TMDL total load. The LA (load allocation) is the portion of Equation (1) that is typically assigned to non-point sources. The MOS (margin of safety) is that portion of the 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 typically assigned to point sources. However, as described below, this category was used to reflect sediment loads from all sources in this particular watershed. This was done for two primary reasons: 1) because “urban runoff/storm sewers” was listed as the primary source of sediment to impaired streams in this watershed, and 2) to be consistent with EPA guidance on how to handle sediment loads in urbanized watersheds. Details of how specific components of the overall TMDL calculation were derived are presented below.

C14.2.1 Sediment TMDL Total Load

The first step was to determine the TMDL total target load for the Neshaminy Creek South #1 watershed. This value was obtained by multiplying the pollutant unit loading rate in the reference watershed by the total watershed area of the Neshaminy Creek South #1 watershed. This information is presented in Table C14.5.

Table C14.5. TMDL Total Load Computation

Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Total Watershed Area of Neshaminy South #1 (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	507.3	4,720	2,394,456

C14.2.2 Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of the TMDL was reserved as the MOS.

MOS (Sediment): 2,394,456 lbs/yr x 0.1 = 239,446 lbs/yr (2)

C14.2.3 Waste Load Allocation

For the purposes of this TMDL assessment, sediment loads from all sources have been assigned to the waste load allocation (WLA) category to be consistent with EPA guidance on how to handle sediment in urbanized watersheds. Therefore, the load allocation (LA) in this case is equal to zero. Allowing for an explicit 10% MOS, the target WLA is re-computed as:

WLA (Sediment): 2,394,456 lbs/yr – 239,446 lbs/yr = 2,155,010 lbs/yr (3)

Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix.

C14.2.4 Load Reduction Procedures

The allocation of sediment among contributing sources in Neshaminy Creek South #1 was done by reducing each source equally on a percentage basis. Based on the target WLA of 2,155,010 lbs/year described above, the computed load allocations are as shown in Table C14.

The total allowable sediment load in Neshaminy South #1 when all sources are considered is 2,155,010 pounds per year. In order for all stream segments to attain their specific uses, total sediment load should be reduced from 3,073,400 pounds per year by a factor of 30%.

Table C14.6. Load Allocation by Each Land Use/Source					
		Sediment			
Source	*Area* (*acres*)	*Unit Area Loading Rate* (*lbs/ac/yr*)	*Annual average load* (*lbs/yr*)	*WLA (annual average)* (*lbs/yr*)	*Reduction* (*%*)
Hay/Pasture	62	49.0	3,040	2,130	30
Cropland	220	1,062.9	233,840	163,964	30
Coniferous Forest	269	7.7	2,080	1,459	30
Mixed Forest	267	10.3	2,760	1,934	30
Deciduous Forest	699	12.3	8,600	6,030	30
Transitional	126	1,255.4	158,180	110,136	30
Low Intensity Dev	2,355	65.5	154,220	108,136	30
High Intensity Dev	723	26.3	18,980	13,307	30
Stream Bank			2,491,660	1,747,137	30
Groundwater					
Point Source					
Septic Systems					
Total	4,720	651.1	3,073,400	2,155,010	**30**

C14.3 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.

C14.4 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.

C14.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated to all sources of upland and stream bank erosion in the watershed. Implementation of best management practices (BMPs) in the affected areas to increase infiltration and sediment control measures should achieve the loading reduction goals established in the TMDL. Substantial reductions in the amount of sediment reaching the streams can be made through the installation of drainage controls such as detention ponds, sediment ponds, infiltration pits, dikes, riparian buffers, stream bank stabilization and ditches in the watershed . These BMPs range in efficiency from **20% to 70%** for sediment reduction.

The implementation of such BMPs will likely occur in the watershed as a result of PaDEP's Proposed Comprehensive Stormwater Management Policy. When approved, this new policy will require affected communities to implement BMPs to address stormwater control that will "reduce pollutant loadings to streams, recharge groundwater tables, enhance stream base flow during times of drought and reduce the threat of flooding and stream bank erosion resulting from storm events." Over the next year and one-half, PaDEP will be developing a "Phase II" program for NPDES discharges from small construction sites, additional industrial activities, and for the 700 municipalities subject to the requirements for separate storm sewer systems (MS4). All of the municipalities located within the Mill Creek watershed will be affected by this policy, which has been included in Appendix E. Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus originating from transitional land uses and stream bank erosion.

C14.6 PUBLIC PARTICIPATION

Notice of the draft TMDL will be published in the *PA Bulletin* and local newspapers with a 30 day comment period provided. A public meeting with watershed residents will be held to discuss the TMDL. Notice of final TMDL approval will be posted on the Department website.

C15.0 Total Maximum Daily Loads (TMDL) Development Plan for Neshaminy Creek South #2 Watershed

Table of Contents **Page**

List of Tables **Page**

List of Figures **Page**

EXECUTIVE SUMMARY

The Neshaminy South #2 sub-basin is about 5.4 square miles in size, and is located in southern Bucks County. This particular sub-basin consists of several unnamed tributaries to Neshaminy Creek. The protected uses of the watershed are water supply, recreation, and aquatic life. Its aquatic use is warm water fishes and migratory fishes.

The Total Maximum Daily Load (TMDL) applies to about 9.9 miles of streams within this basin (Stream Segment ID# 980713-1351-GLW). It was developed to address the impairments noted on Pennsylvania's 1996 and 2002 Clean Water Act Section 303(d) Lists. The impairment addressed in this particular section is caused by sediment-related nutrient loads from agriculture in the watershed. A TMDL for the listed impairment of water/flow variability was not developed because neither the U.S. Environmental Protection Agency (EPA) nor PaDEP currently have water quality criteria for this impairment. Furthermore, quantitative measures for water flow variability or alterations as "impairments" are not currently available. However, it is assumed for these segments that addressing sediment loads through the use of urban BMPs will at the same time reduce water flow variability or alterations within the watershed. As discussed previously, all municipalities within the Neshaminy Creek watershed will be affected by PaDEP's new stormwater management policy (MS4), a copy of which has been included in Appendix E.

Pennsylvania does not currently have water quality criteria for sediment and nutrients. For this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for sediment and non-point source nutrients in the impaired segments of Neshaminy South #2. Since most of the phosphorus reaching impaired segments appears to be attached to sediment originating from eroded agricultural areas, it was determined that a reduction in sediment loads would also reduce phosphorus loads in this watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the sediment loading that will meet the water quality objectives for this watershed is 1,205,913 per year. It is assumed that streams in the watershed will support their aquatic life uses when this value is met. The TMDL for Neshaminy South #2 is allocated as shown in the table below.

Summary of Sediment TMDLs for Neshaminy South #2 (lbs/yr)

Pollutant	TMDL	MOS	WLA	LA	LNR	ALA
Sediment	1,205,913	120,591	-	1,085,322	98,580	986,742

The TMDL for sediment is allocated to agricultural land and stream bank erosion, with 10% of the TMDL total load reserved as a margin of safety (MOS). The adjusted load allocation (ALA) is that load attributed to agricultural land and streambank erosion, and is computed by subtracting loads that do not need to be reduced (LNR) from the TMDL total values. The TMDL covers a total of 9.9 stream miles, and establishes a 39% reduction from the current sediment load of 1,780,400 pounds per year (which also accounts for the 10% MOS).

C15.0 INTRODUCTION

C15.0.1 Watershed Description

The following discussion provides information on the physical characteristics of the Neshaminy South #2 sub-basin, including its location, land use distribution, and geology. Neshaminy South #2 is located in the Piedmont physiographic province, and is situated in the southern end of Bucks County. It covers an area of approximately 5.4 square miles, and drains into the lowermost portion of the mainstem of Neshaminy Creek from the west. Figure C15.1 shows the watershed boundary and its location. The designated uses of the watershed include water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.o (Commonwealth of PA, 1999), the designated aquatic life use for streams in this sub-basin is warm water fishes and migratory fishes.

The primary land uses in the Neshaminy South #2 sub-basin are high and low density urban development (59%) and agriculture (21%). The 1994 survey showed that nutrients from agricultural activities were causing increased algae growth. It also found that sediment deposited in large quantities on the streambed was degrading the habitat of bottom-dwelling macroinvertebrates. Various characteristics of Neshaminy South #2, as well as those of the reference watershed chosen for further analysis (see later discussion), are summarized in Table C15.1.

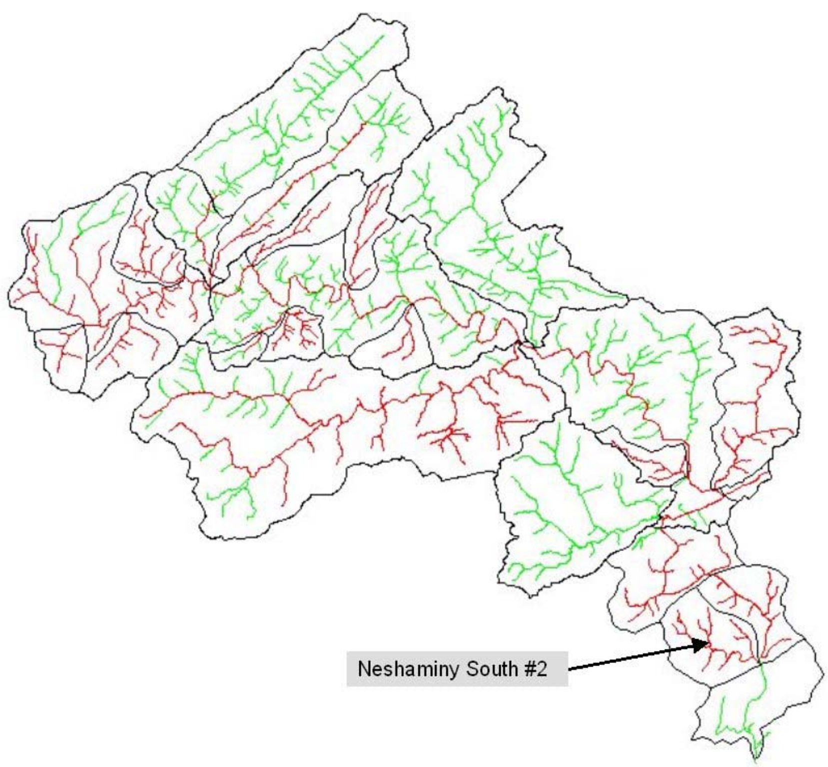

Figure C15.1. Neshaminy South #2 Watershed.

Table C15.1. Physical Characteristic Comparisons between the Neshaminy South #2 and Reference Watersheds		
Attribute	**Neshaminy South #2**	**Reference Watershed**
Physiographic Province	Piedmont	Piedmont
Area (square miles)	5.4	4.0
Predominant Land Uses	Agriculture (21%) Developed (59%) Forested (17%)	Agriculture (8%) Developed (69%) Forested (21%)
Predominant Geology	Unconsolidated (50%) Metamorphic/Gneiss (50%)	Shale (95%)
Soils - Dominant HSG	B and D	C
- K Factor	0.22	0.37
20-Year Average Rainfall (in)	40.6	40.6
20-Year Average Runoff (in)	4.9	4.3

C15.0.2 Surface Water Quality

Total Maximum Daily Loads or TMDLs were developed for Neshaminy South #2 to address the impairments noted on Pennsylvania's 1996 and 2002 Clean Water Act Section 303(d) Lists (see Table A1 in section A1.0). It was first determined that Neshaminy South #2 was not meeting its designated water quality uses for protection of aquatic life in 1994 based on aquatic biological survey. The 2001 survey found that that the stream was still impaired. As a consequence, Pennsylvania listed stream segments in Neshaminy South #2 on the 1996 and 2002 Section 303(d) List of Impaired Waters.

The 1996 303 (d) List reported 9.8 miles of stream segments in this sub-basin (Stream Segment ID# 980713-1352-GLW) to be impaired by nutrients from agricultural activities. The 2002 303(d) List reported an additional impairment in these segments of water/flow variability due to urban runoff/storm sewers.

C15.1 APPROACH TO TMDL DEVELOPMENT

C15.1.1 TMDL Endpoints

The TMDL described herein addresses the nutrient impairment due to agricultural activities. Because neither Pennsylvania nor EPA have water quality criteria for nutrients, we had to develop a method to determine water quality objectives for this parameter that would result in the impaired stream segments attaining their designated uses. The method employed for this TMDL is termed the "reference watershed approach." With the reference watershed approach, a pair of watersheds is compared; with one attaining its uses and one that is impaired based on biological assessment. Both watersheds should have similar land use/cover distributions. Other features such as base geologic formation should be matched to the greatest 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/or sediments in the watershed containing the impaired stream segment(s) to a level equivalent to or slightly lower than the loading rate in the watershed with the non-impaired, reference stream segment(s). The underlying assumption is that this load reduction will allow biological health to return to the impaired stream segments. The TMDL to be addressed in this section relates to the stream impairments found in the 1996 and 2002 303(d) Lists, and is described in greater detail below.

As discussed previously in Section B1.5, elevated nutrient loads to streams (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). As also described in Section D2.1, phosphorus was determined to be the limiting nutrient in the Neshaminy Creek watershed as a whole. Given that, phosphorus was the nutrient of focus in developing the TMDL for this sub-basin as well. Based on the field work undertaken as part of the initial aquatic biological surveys, it was determined that agricultural activities were the primary cause of non-point source-related impairments to streams in this watershed. Since most phosphorus transported from agricultural land is in the form of sediment-bound phosphorus, it is believed that the reduction of sediment from such areas will help mitigate problems with excessive algal growth and organic enrichment caused by elevated phosphorus levels. Consequently, the reduction of sediment was the focus of this particular TMDL.

C15.1.2 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 attain water quality standards. The second factor is to find a watershed that closely resembles the watershed being assessed (i.e., Neshaminy Creek South #2) with respect to 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 be similar to Neshaminy South #2 in terms of land use distribution could not be found due to the fact that other watersheds that have similar levels of agricultural land use and land development are typically also impaired. Therefore, the watershed used as a reference for Neshaminy South #2 has somewhat less agricultural land and urban development. The watershed used as a reference for the West Branch Sub-basin #4 is comprised of the Lashaka/Mill Creek watershed. This watershed is located in the same physiographic province and State Water Plan as Neshaminy South #2, and is in fact a sub-watershed of the Neshaminy Creek watershed. Table C15.1 compares the two watersheds in terms of their size, location, and other physical characteristics. All reference watershed stream segments have been assessed and were found to be unimpaired. Figure C15.2 shows the reference watershed boundary and its location in Bucks County.

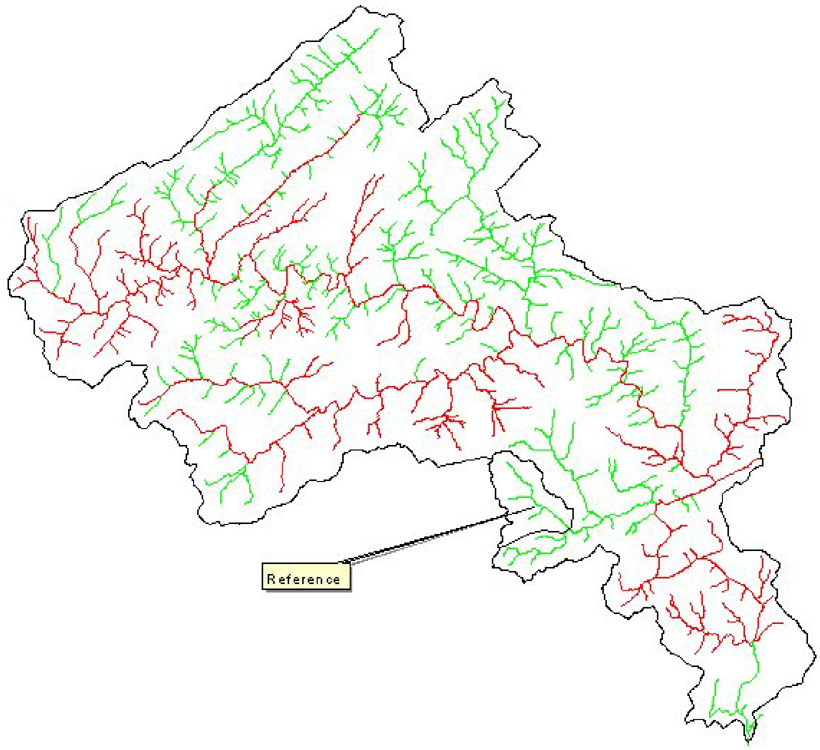

Figure C15.2. Reference Watershed Location.

C15.1.3 Water/Flow Variability Resulting from Urban Runoff/Storm Sewers

TMDLs were not determined for water/flow variability. It was assumed that addressing sediment loads through the use of various BMPs will at the same time reduce water flow variability/alterations within the watershed.

C15.1.4 Nutrients from Agricultural Sources

The 1994 and 2001 surveys showed that nutrients originating from agricultural activities in the watershed was a primary cause of impairment of stream segments in the Neshaminy South #2 sub-basin. Since most phosphorus transported from agricultural land is in the form of sediment-bound phosphorus, it is believed that the reduction of sediment from such areas will help mitigate problems with excessive algal growth and organic enrichment caused by elevated phosphorus levels. Consequently, the reduction of sediment was the focus of this particular TMDL.

C15.1.5 Watershed Assessment and Modeling

Using the refined parameter estimates based on the calibration results, the AVGWLF model was run for both Neshaminy South #2 and the reference watershed to establish sediment loads under existing land cover use conditions in each watershed. Based on the use of 20 years of historical weather data, the mean annual sediment loads for the impaired and reference watersheds are shown Tables C15.2 and C15.3, respectively. Table C15.4 presents an explanation of the header information contained in Tables C15.2 and C15.3. Modeling output for Neshaminy South #2 and the reference watershed is presented in Appendix F.

Table C15.2. Loading Values for Neshaminy South #2

Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	148	4,861	32.8
Cropland	576	283,509	492.2
Coniferous For	101	361	3.6
Mixed Forest	158	501	3.2
Deciduous For	321	1,205	3.7
Transitional Land	87	56,580	650.3
Lo Intensity Dev	1,421	27,469	19.3
Hi Intensity Dev	610	12,485	20.5
Stream Bank		1,393,429	
Groundwater			
Point Source			
Septic Systems			
Total	3,422	1,780,400	520.3

Table C15.3. Loading Values for the Reference Watershed

Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	52	3,520	67.7
Cropland	153	106,620	696.9
Coniferous Forest	104	520	5.0
Mixed Forest	84	680	8.1
Deciduous Forest	329	2,380	7.2
Transitional Land	64	72,920	1,139.4
Low Intensity Devel	1,698	135,120	79.6
High Intensity Devel	69	1,180	17.1
Stream Bank		576,680	
Groundwater			
Point Source			
Septic Systems			
Total	2,553	899,620	352.4

Table C15.4. Header Information for Tables C15.2 and C15.3.	
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 Sediment	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sediment Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

C15.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to all of Neshaminy South #2. The load reduction calculations in this watershed are based on the current sediment loading rate in the reference watershed. Based on biological assessment, it was determined that the reference watershed was attaining its designated uses. This loading rate was then used as the basis for establishing the sediment TMDL for Neshaminy South #2.

The basic equation defining TMDLs for sediments and nutrients 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 typically 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 typically assigned to point sources. The adjusted load allocation (ALA) is the load originating from sources (Equation 2) that needs to be reduced by the non-contributing sources (LNR) for Neshaminy South #2 to meet water quality goals. Therefore, it is the load that originates from agricultural sources that have contributed to water quality problems identified in this watershed. Details of how specific components of the overall TMDL calculation were derived are presented below.

C15.2.1 TMDL Total Load

The first step was to determine the TMDL total target load for Neshaminy South #2, the impaired watershed. This value was obtained by multiplying the unit area loading rate for sediment in the reference watershed by the total watershed area of Neshaminy South #2. This information is presented in Table C15.5.

Table C15.5. TMDL Total Load Computation

Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Total Watershed Area in Neshaminy South #2 (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	352.4	3,422	1,205,913

C15.2.2 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.

MOS (Sediment): 1,205,913 lbs/yr x 0.1 = 120,591 lbs/yr (3)

C15.2.3 Load Allocation

The load allocation (LA), consisting of all nonpoint source loads in the watershed, was computed by subtracting the margin of safety and the waste load allocation (which was zero for sediment in this case) from the TMDL total load.

LA (Sediment): 1,205,913 lbs/yr – 120,591 lbs/yr = 1,085,322 lbs/yr (4)

C15.2.4 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 C15.2 except those from agricultural land uses (Hay/Pasture, Row Crops, and Streambank Erosion). (Note: Streambank erosion was included in the load allocation in this case since this problem typically occurs in agricultural areas, and is a source that can be controlled via the use of BMPs in agricultural areas). Therefore, using data in Table C15.2,

LNR (Sediments) = 360 lbs/yr + 500 lbs/yr + 1,200 lb/yr + 56,580 lb/yr
+ 27,460 lbs/yr + 12,480 lbs/yr = 98,580 lbs/yr (6)

ALA (Sediments) = 1,085,322 lbs/yr – 98,580 lbs/yr = 986,742 lbs/yr (7)

Table C15.6 below presents TMDL results for the Neshaminy South #2 sub-basin.

Table C15.6. Summary of TMDL for Neshaminy South #2 (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediment	1,205,913	120,591	-	1,085,322	98,580	986,742

The ALA computed above is the portion of the load that is available to allocate among contributing sources (Hay/Pasture, Cropland, and streambank erosion) 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., forested areas). The following section shows the allocation process in detail for the entire watershed.

C15.2.5 Load Reduction Procedures

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:

5) 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.

6) 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.

The load allocation and EMPR procedures were performed using an Excel Worksheet, and results are presented in Appendix G. Table C15.7 provides load allocation by considering all land uses in the watershed. In this case, land uses/sources that were not part of the allocation are carried through at their existing loading values.

The total allowable sediment load in Neshaminy South #2 and its tributaries when all sources are considered (and including the 10% MOS) is 1,085,322 pounds per year. In order for all stream segments to attain their specific uses, the total sediment load should be reduced from 1,780,400 pounds per year by a factor of 39%.

Table C15.7 Load Allocation by Each Land Use/Source					
		Sediment			
Source	*Area (acres)*	*Unit Area Loading Rate (lbs/ac/yr)*	*Annual average load (lbs/yr)*	*ALA (lbs/yr)*	*Reduction (%)*
Hay/Pasture	148	32.8	4,861	2,852	41
Cropland	576	492.2	283,509	166,336	41
Coniferous Forest	101	3.6	361	360	0
Mixed Forest	158	3.2	501	500	0
Deciduous Forest	321	3.7	1,205	1,200	0
Transitional	87	650.3	56,580	56,580	0
Lo Intensity Dev	1,421	19.3	27,469	27,460	0
Hi Intensity Dev	610	20.5	12,485	12,480	0
Stream Bank			1,393,429	817,533	41
Groundwater					
Point Source					
Septic Systems					
Total	3,422	520.3	1,780,400	1,085,322	**39**

C15.3 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.

C15.4 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.

C15.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated to agricultural areas and sources of stream bank erosion in the watershed. Implementation of agricultural best management practices (BMPs) in the affected areas to increase infiltration and sediment control measures should achieve the loading reduction goals established in the TMDL. 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, and conservation tillage. 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, which is contributing to algal growth in the streams. Other possibilities for attaining the desired reductions in sediment include streambank stabilization and fencing. Further field verification 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 sediment reductions outlined in this section.

C15.6 PUBLIC PARTICIPATION

Notice of the draft TMDLs will be published in the *PA Bulletin* and local newspapers with a 30-day comment period provided. A public meeting with watershed residents will be held to discuss the TMDLs. Notice of final TMDL approval will be posted on the Department website.

C16.0 Total Maximum Daily Load (TMDL) Development Plan for Neshaminy Creek South #3

Table of Contents **Page**

List of Tables **Page**

List of Figures **Page**

EXECUTIVE SUMMARY

The Neshaminy Creek South #3 watershed is approximately 4.6 square miles in size. It is situated in Bucks County and is comprised of a portion of the lower part of the main stem of Neshaminy Creek and several small tributaries that flow into it. The protected uses of the watershed are water supply, recreation, and aquatic life. Its aquatic use is warm water fishes and migratory fishes.

Total Maximum Daily Loads (TMDLs) apply to 5.4 miles of stream (Stream Segment ID# 20010525-1330-GLW). This watershed is actually comprised of the main stem and several smaller segments (i.e., tributaries) located in the lower Neshaminy Creek watershed. A TMDL was developed to address the sediment impairments noted on Pennsylvania's 2002 Clean Water act Section 303(d) List. In particular, the impaired segments noted above were listed as being impaired due to siltation from development in the watershed. Nutrient impairments to the main stem are addressed in Section D. Pennsylvania does not currently have water quality criteria for sediment. For this reason, a reference watershed approach was used to identify the TMDL endpoints or water quality objectives for sediment in the impaired segments of the Neshaminy Creek South #3 watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the sediment loading that will meet the water quality objectives for this watershed is 999,759 pounds per year. The TMDL for Neshaminy Creek South #3 is allocated as shown in the table below.

Summary of TMDL for Neshaminy Creek South #3 (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediments	999,759	99,976	899,783	-	-	-

The TMDL for sediment is allocated to all non-point sources of upland and stream bank erosion, with 10% of the TMDL total load reserved as a margin of safety (MOS). In this case, all sediment loads were assigned to the waste load allocation (WLA) category. The sediment TMDL covers a total of 5.4 stream miles, and establishes a reduction for total sediment loading of 36% from the current annual loading of 1,414,300 pounds per year.

C16.0 INTRODUCTION

C16.0.1 Watershed Description

The watershed contains part of the lower main stem of Neshaminy Creek (Stream Segment ID# 467) as well as several small tributaries that flow into it (Stream Segment ID 20010525-1330-GLW). The watershed is located in the Piedmont Physiographic Province and is situated in Bucks County. It covers an area of approximately 4.5 square miles. The watershed is south of the towns of South Hampton, Langhorne, and Midletown. It is bounded by Pennsylvania Route 213 to the west and Route 1 to the east. Figure C17.1 shows the watershed boundary and its location. The designated uses of the watershed include water supply, recreation and aquatic life. As listed in the Title 25 PA Code Department of Environmental Protection Chapter 93, Section 93.o (Commonwealth of PA, 1999), the designated aquatic life use for the Neshaminy Creek South #3 watershed is warm water fishes and migratory fishes. The primary land use in the watershed is high and low intensity development (70%). During the stream assessment, it was found that sediment deposited in large quantities on the streambed was degrading the habitat of bottom-dwelling macroinvertebrates.

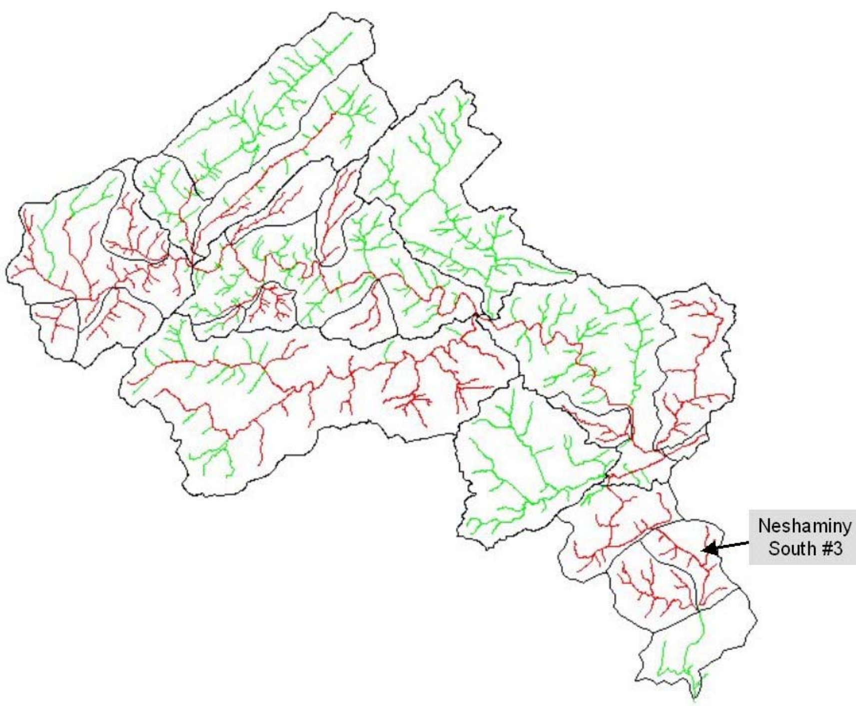

Figure C16.1. Neshaminy Creek South #3 watershed.

The surficial geology of the watershed consists of unconsolidated and metamorphic/gneiss formations. The bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability. Soils are mostly sandy and very erodible, as indicated by a predominantly high average K factor (0.32). Watershed characteristics are summarized in Table C16.1.

Table C16.1. Physical Characteristic Comparisons Between the Neshaminy Creek South #3 and Reference Watersheds		
Attribute	**Neshaminy Creek South #3**	**Reference Watershed**
Physiographic Province	Piedmont	Piedmont
Area (square miles)	4.5	4.0
Predominant Land Uses	Development (70%)	Development (69%)
Predominant Geology	Unconsolidated (50%) Metamorphic/Gneiss (50%)	Sandstone (95%)
Soils - Dominant HSG	C	C
- Dominant K Factor	0.32	0.32
20-Year Average Rainfall (in)	41.4	41.4
20-Year Average Runoff (in)	4.4	4.3

C16.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for the Neshaminy Creek South #3 watershed to address the impairments noted on the Pennsylvania's 2002 Clean Water Act Section 303(d) List (see Table A1 in section A1.0). The 2001 survey found that that the tributaries were impaired by siltation from development in the watershed. As a consequence, Pennsylvania listed these stream segments on the 2002 Section 303(d) List of Impaired Waters. The List reported 5.4 miles of stream in the Neshaminy Creek South #5 watershed (Stream Segment ID# 20010525-1330-GLW) to be impaired

This sub-watershed also contains a portion of the Neshaminy Creek main stem (ID# 467) that was listed as being impaired by various municipal point sources. This particular impairment is not addressed here. Rather, it is dealt with in Section D.

C16.1 APPROACH TO TMDL DEVELOPMENT

C16.1.1 TMDL Endpoints

The TMDL discussed herein addresses sediment. Because neither Pennsylvania nor EPA has water quality criteria for sediment, 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 this TMDL is termed the "reference watershed approach."

With the reference watershed approach, two watersheds are compared, with 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 greatest extent possible; however, most variations can be adjusted in the model.

The objective of the process is to reduce the loading rate for sediment in the impaired stream segment to a level equivalent to or slightly lower than the loading rate in the non-impaired, reference stream segment. The underlying assumption is that this load reduction will allow the biological community to return to the impaired stream segments.

C16.1.2 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 designated uses. The second factor is to find a watershed that closely resembles the Neshaminy Creek South #3 watershed in terms of 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 data layers 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.

The reference watershed used in this case is a part of the Mill Creek watershed located at the lower end of Neshaminy Creek. Both watersheds are located in the same physiographic province and State Water Plan, and include tributaries of Neshaminy Creek. Table C16.1 compares the two watersheds in terms of their size, location, and other physical characteristics. All reference watershed stream segments have been assessed and were found to be unimpaired. Figure C16.2 shows the reference watershed and its location within the larger Neshaminy Creek watershed.

An analysis of the land use/cover grid revealed that land cover/use distributions in both watersheds are similar. The surficial geology in the two watersheds is different, but it is not expected that this would significantly affect the sediment loads in either case.

C16.1.3 Siltation Due to Development

The 2001 survey showed that siltation originating from development in the watershed was the cause of impairment to Neshaminy Creek South #3 stream segments. Sediments deposited in large quantities on the streambed were found to be degrading the habitat of bottom-dwelling macroinvertebrates. This TMDL addresses sediment from development ("urban runoff/storm sewers") and from stream bank erosion. Stream bank erosion occurs as a result of excess flow in the watershed due to a significantly high percentage of impervious surface area (the watershed is 70% developed).

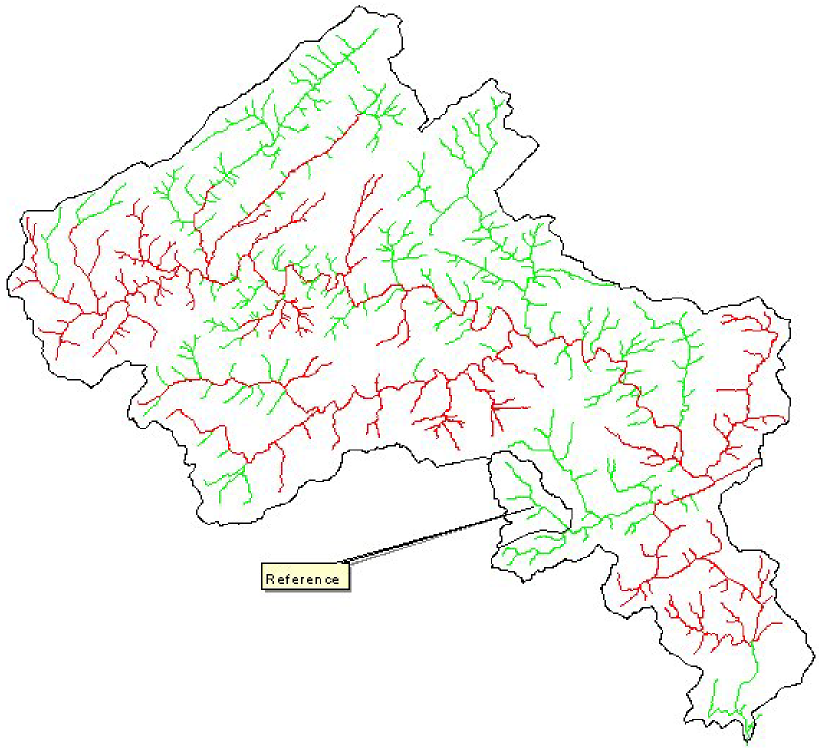

Figure C16.2. Reference watershed location.

C16.1.4 Watershed Assessment and Modeling

The AVGWLF model was run for both the Neshaminy Creek South #3 and reference watersheds to establish existing loading conditions under existing land use/cover conditions. Prior to running the model, historical stream water quality data for the period 4/89 to 3/96 were first used to calibrate various key parameters within the GWLF model. Such data sets are typically not available in AVGWLF-based TMDL assessments done elsewhere in Pennsylvania. In this case, however, it was felt that model calibration would provide for better simulation of localized watershed processes and conditions. A description of the calibration procedure used can be found in section B1.4 of this document.

Using the refined parameter estimates based on the calibration results, AVGWLF was run for both watersheds. Based on the use of 20 years of historical weather data, the mean annual loads for sediments for the impaired and reference watersheds were calculated as shown Tables C16.2 and C16.3, respectively. Table C16.4 presents an explanation of the header information contained in Tables C16.2 and C16.3. Modeling output for both watersheds is presented in Appendix F.

Table C16.2. Existing Loading Values for the Neshaminy Creek South #3 Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	59	960	16.3
Cropland	158	44,320	280.5
Coniferous Forest	121	420	3.5
Mixed Forest	124	300	2.4
Deciduous Forest	321	1000	3.1
Transitional	57	18,520	324.9
Low Intensity Developed	1,643	34,120	20.8
High Intensity Developed	353	2,300	6.5
Stream Bank		1,312,360	
Groundwater			
Point Source			
Septic Systems			
Total	2,837	1,414,300	498.5

Table C16.3. Loading Values for the Reference Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	52	3,520	67.7
Cropland	153	106,620	696.9
Coniferous Forest	104	520	5.0
Mixed Forest	84	680	8.1
Deciduous Forest	329	2,380	7.2
Transitional	64	72,920	1,139.4
Low Intensity Developed	1,698	135,120	79.6
High Intensity Developed	69	1,180	17.1
Stream Bank		576,680	
Groundwater			
Point Source			
Septic Systems			
Total	2,553	899,620	352.4

Table C16.4. Header Information for Tables C16.2 and C16.3.	
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.
Sediment Load	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sediment Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

C16.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

Load allocation and reduction procedures were applied to the entire Neshaminy Creek South #3 watershed. The load reduction calculations are based on the current loading rates for sediment in the reference watershed. (Note: This watershed also contains Stream Segment ID# 467, a portion of the main stem of Neshaminy Creek that is listed as being impaired due to municipal point sources. However, since municipal point sources are addressed in a different section of this document (see Section D), they are not discussed here). Based on biological assessment, it was determined that the reference watershed was attaining its designated uses. Sediment loading rates were computed for the reference watershed using the AVGWLF model. These loading rates were then used as the basis for establishing the TMDL for the Neshaminy Creek South #3 watershed.

The basic equation defining the TMDL for sediment is as follows:

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

TMDL is the TMDL total load. The LA (load allocation) is the portion of Equation (1) that is typically 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 typically assigned to point sources. However, as described below, this category was used to reflect sediment loads from all sources in this particular watershed. This was done for two primary reasons: 1) because “urban runoff/storm sewers” was listed as the primary source of sediment to impaired streams in this watershed, and 2) to be consistent with EPA guidance on how to handle sediment loads in urbanized watersheds. Details of how specific components of the overall TMDL calculation were derived are presented below.

C16.1.1 Sediment TMDL Total Load

The first step was to determine the TMDL total target load for Neshaminy Creek South #3, the impaired watershed. This value was obtained by multiplying the sediment unit area loading rate in the reference watershed by the total watershed area of Neshaminy Creek South #3. This information is presented in Table C16.5.

Table C16.5. TMDL Total Load Computation			
Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Total Watershed Area of Neshaminy South #3 (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	352.4	2,837	999,759

C16.2.2 Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of the TMDL was reserved as the MOS.

MOS (Sediment): 999,759 lbs/yr x 0.1 = 99,976 lbs/yr (2)

C16.2.3 Waste Load Allocation

For the purposes of this TMDL assessment, sediment loads from all sources have been assigned to the waste load allocation (WLA) category to be consistent with EPA guidance on how to handle sediment in urbanized watersheds. Therefore, the load allocation (LA) in this case is equal to zero. Allowing for an explicit 10% MOS, the target WLA is re-computed as:

WLA (Sediment): 999,759 lbs/yr – 99,976 lbs/yr = 899,783 lbs/yr (3)

Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix.

C16.2.4 Load Reduction Procedures

The allocation of sediment among contributing sources in Neshaminy Creek South #3 was done by reducing each source equally on a percentage basis. Based on the target WLA of 899,783 lbs/year described above, the computed load allocations are as shown in Table C2.6.

The total allowable sediment load in Neshaminy Creek South #3 when sources are considered is 899,783 pounds per year. In order for all stream segments to attain their specific uses, total sediment load should be reduced from 1,414,300 pounds per year by a factor of 36%.

Table C16.6. Load Allocation by Each Land Use/Source					
		Sediment			
Source	*Area (acres)*	*Unit Area Loading Rate (lbs/ac/yr)*	*Annual average load (lbs/yr)*	*WLA (annual average) (lbs/yr)*	*Reduction (%)*
Hay/Pasture	59	16.3	960	611	36
Cropland	158	280.5	44,320	28,196	36
Coniferous	121	3.5	420	267	36
Mixed Forest	124	2.4	300	191	36
Deciduous Forest	321	3.1	1000	636	36
Transition	57	324.9	18,520	11,783	36
Low Intensity Dev	1,643	20.8	34,120	21,708	36
High Intensity Dev	353	6.5	2,300	1,463	36
Stream Bank			1,312,360	834,928	36
Groundwater					
Point Source					
Septic Systems					
Total	2,837	498.5	1,414,300	899,783	**36**

C16.3 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 this TMDL using average annual conditions is protective of the waterbody.

C16.4 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.

C16.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated to all sources of upland and stream bank erosion in the watershed. Implementation of best management practices (BMPs) in the affected areas to increase infiltration and sediment control measures should achieve the loading reduction goals established in the TMDL. Substantial reductions in the amount of sediment reaching the streams can be made through the installation of BMPs such as detention ponds, sediment ponds, infiltration pits, dikes, riparian buffers, stream bank stabilization and ditches in the watershed . These BMPs range in efficiency from **20% to 70%** for sediment reduction.

The implementation of such BMPs will likely occur in the watershed as a result of PaDEP's Proposed Comprehensive Stormwater Management Policy. When approved, this new policy will require affected communities to implement BMPs to address stormwater control that will "reduce pollutant loadings to streams, recharge groundwater tables, enhance stream base flow during times of drought and reduce the threat of flooding and stream bank erosion resulting from storm events." Over the next year and one-half, PaDEP will be developing a "Phase II" program for NPDES discharges from small construction sites, additional industrial activities, and for the 700 municipalities subject to the requirements for separate storm sewer systems (MS4). All of the municipalities located within the Mill Creek watershed will be affected by this policy, which has been included in Appendix E. Tables that can be used to cross-reference sub-areas with municipalities in the Neshaminy Creek basin, as well as a summary of sediment-related WLAs, can be found in Appendix E. A map showing the overlap between sub-basin and municipal boundaries within the entire Neshaminy Creek basin is also included in this same appendix. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus originating from transitional land uses and stream bank erosion.

C16.6 PUBLIC PARTICIPATION

Notice of the draft TMDL will be published in the *PA Bulletin* and local newspapers with a 30 day comment period provided. A public meeting with watershed residents will be held to discuss the TMDL. Notice of final TMDL approval will be posted on the Department website.