The surficial geology of the watershed consists of metamorphic/gneiss formations. The bedrock geology affects primarily surface runoff and background nutrient loads through its influences on soils and landscape as well as fracture density and directional permeability. Soils are mostly sandy and very erodible, as indicated by a high average K factor (0.35). Watershed characteristics are summarized in Table C10.1.

Table C10.1. Physical Characteristics of Neshaminy Creek Tributary #2 Watershed	
Physiographic Province	Piedmont
Area (square miles)	1.8
Predominant Land Uses	- Developed land (47%) - Forested (40%)
Predominant Geology	Metamorphic/Gneiss (100%)
Soils	
Dominant HSGs	C
Average K Factor	0.35
20-Year Average Rainfall (in)	41.5
20-Year Average Runoff (in)	3.4

C10.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for Neshaminy Creek Tributary #2 to address the impairments noted on Pennsylvania's 2002 Clean Water Act Section 303(d) List (see Table A1 in section A1.0). It was first determined that this stream was not meeting its designated water quality uses for protection of aquatic life in 2001 based on aquatic biological survey. As a consequence, Pennsylvania listed the stream on the 2002 Section 303(d) List of Impaired Waters.

The 2002 303 (d) List reported 1.5 miles of this stream (Stream Segment Id # 980514-1004-GLW) to be impaired by siltation and water/flow variability from land development. The stream segments is impacted by siltation as a result of "New Land Development" in the watershed. New Land Development is defined here as disturbed land at construction sites/new development. It appeared from our reconnaissance surveys and contacts in the watershed that siltation presently observed in this stream is the result of years of a build-up of sediments in the channel bottom that started in the early 1990's. These sediments originated from disturbed and unprotected soils at construction sites and increased channel bank erosion during periods of intense storm events. As indicated above, land development has increased by approximately 29% between 1992 and 2000.

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 causes 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 events were observed during a reconnaissance survey of the Neshaminy Creek Tributary #2 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 this stream. Without effective storm water management practices and sediment traps, build-up of sediments will likely continue to occur.

C10.1 APPROACH TO TMDL DEVELOPMENT

The present TMDL addresses impairment by sediments in the stream as reported on the 2002 303(d) Lists. The stream water flow variability impairment caused by urban runoff/storm sewer was not explicitly addressed by this TMDL because it is assumed that management practices that will be used to address storm water runoff and sediment production at new construction sites and other developed areas will reduce problems associated with flow variability as well. The TMDL was derived as follows:

C10.1.1 Water/Flow Variability Due to Urban Runoff/Storm Sewers

A TMDL was not explicitly determined for flow alterations. It was assumed that addressing sediment loads through the use of urban BMPs will at the same time reduce water flow alterations within the watershed.

C10.1.2 Siltation Caused by Urban Runoff/Storm Sewers

The 2001 survey showed that sediments generated by newly developed land in the watershed were the cause of impairment of stream segments in this watershed. Sediments deposited in large quantities on the streambed were degrading the habitat of bottom-dwelling macroinvertebrates. The TMDL for this watershed address sediments from construction sites or "Transitional" land uses, and from stream bank erosion. Because neither Pennsylvania nor EPA have 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 approach consists of:

Comparing simulated annual sediment loads for Year 1992 and Year 2000 land use conditions in the watershed. It appeared from several field visits in the watershed that most of the siltation and turbidity observed in the stream have accumulated during several years. This assumption is supported by the fact that siltation was not found as a cause of impairment during the 1994 survey and 1997 assessments. Year 1992 is considered here as the benchmark because (as indicated earlier) the analysis of classified satellite images showed that development in the watershed increased by about 29% between 1992 and 2000.

C10.1.3 Watershed Assessment and Modeling

The AVGWLF model was run for the Neshaminy Creek Tributary #2 watershed to establish sediment loadings under differing land use/cover conditions (see section A for model-specific details). First, the model was run using the 1992 land use distributions provided by the National Land Cover Data (NLCD) set. As indicated earlier, NLCD land uses were developed by the MRLC Consortium using primarily 1992-vintage Landsat TM imagery. Second, the model was performed for the Year 2000 land use conditions using an updated version of this earlier land use data set. SPOT imagery that was acquired in the summer of 2000 was used for the land use update. In this model, land in transition (transitional land use) was considered to be new development (built after 1992) or construction sites.

Prior to running the model for the two land use conditions as described, 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 re-run for the watershed. Based on the use of 20 years of historical weather data, the mean annual sediment loads for the 1992 and 2000 land use/cover conditions were simulated and are shown in Tables C10.2 and C10.3, respectively. The Unit Area Load for sediment in the watershed was estimated by dividing the mean annual loading (lbs/yr) by the total area (acres) resulting in an approximate loading per unit area for the watershed. Table C10.4 presents an explanation of the header information contained in Tables C10.2 and C10.3. Modeling output for this watershed for 1992 and 2000 land use conditions is presented in Appendix F.

Table C10.2. Loading Values for Neshaminy Creek Tributary #2 Watershed, Year 1992 Land Use Conditions			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sed Load (lbs/acre/yr)*
Hay/Past	12	198	16.50
Cropland	92	37,439	406.95
Coniferous Forest	20	88	4.40
Mixed Forest	40	154	3.85
Deciduous Forest	124	1,236	9.97
Transitional	0	0	0
Low Intensity Dev	151	10,795	71.49
High Intensity Dev	17	552	32.47
Stream Bank		11,920	
Groundwater			
Point Source			
Septic Systems			
Total	456	62,382	136.80

Table C10.3. Loading Values for Neshaminy Creek Tributary #2 Watershed, Year 2000 Land Use Conditions			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sed Load (lbs/acre/yr)*
Hay/Past	7	110	15.71
Cropland	52	16,600	319.23
Coniferous Forest	20	88	4.40
Mixed Forest	40	154	3.85
Deciduous Forest	121	1,170	9.67
Transitional	54	123,863	2,293.76
Low Intensity Dev	145	10,662	73.53
High Intensity Dev	17	552	32.47
Stream Bank		12,362	
Groundwater			
Point Source			
Septic Systems			
Total	456	165,561	363.02

Table C10.4. Header Information for Tables C10.2 and C10.3	
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

C10.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to the entire Neshaminy Creek Tributary #2 watershed. The load reduction calculations are based on sediment loads that were obtained using 1992 land use conditions. This assumes that the watershed was attaining its designated uses prior to 1992. As indicated earlier, land development, which is the source of stream impairment in the watershed, has increased considerably since 1992. These loads were then used as the basis for establishing the TMDL for the watershed.

The equations defining TMDL for sediment are 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 sub-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 sub-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.

C10.2.1 Sediment TMDL Total Load

As noted earlier, the TMDL total target load for this watershed is based on the sediment loads obtained using the 1992 land use conditions, and is equal to 62,382 lbs/year (see Table C10.2).

C10.2.2 Margin of Safety

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

MOS (Sediments) $\quad$ *62,382 lbs/yr x 0.1 = 6,238 lbs/yr* $\quad$ *(2)*

C10.2.3 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. 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) $\quad$ 62,382 *lbs/yr – 6,238 lbs/yr = 56,144 lbs/yr* $\quad$ *(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.

C10.2.4 Load Reduction Procedures

The allocation of sediment among contributing sources in the watershed was done by reducing each source equally on a percentage basis. Based on the target WLA of 56,144 lbs per year described above, the computed load allocations are as shown in Table C10.5.

Table C10.7. Sediment Load Allocation by Each Land Use/Source

Land Use Category	*Area (acres)*	*Unit Area Load (lbs/acre/yr)*	*Avg.Load (lbs/year)*	*WLA (lbs/year)*	*Reduction (%)*
Hay/Past	7	15.71	110	110	0
Cropland	52	319.23	16,600	16,600	0
Conifer Forest	20	4.40	88	88	0
Mixed Forest	40	3.85	154	154	0
Decid Forest	121	9.67	1,170	1,170	0
Transition	54	2,293.76	123,863	24,375	80
Low Int. Dev	145	73.53	10,662	10,662	0
High Int. Dev.	17	32.47	552	552	0
Stream Bank			12,362	2,433	80
Groundwater					
Point Source					
Septic Systems					
Total	456	363.02	165,561	56,144	66

The total allowable sediment load in the watershed when all sources are considered is 56,144 pounds per year. In order for this stream segment to attain its specific uses, total sediment load should be reduced from 165,561 pounds per year by a factor of 66%.

C10.3 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.

C10.4 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.

C10.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated primarily to transitional land uses and stream bank erosion in the watershed. Implementation of best urban 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 and ditches. . 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 Neshaminy Creek Tributary #2 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.

C10.6 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.

C11.0 Total Maximum Daily Load (TMDL) Development for Neshaminy Creek Tributary #3 Watershed

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EXECUTIVE SUMMARY

The Neshaminy Creek Tributary #3 watershed in Bucks County is about 2.9 square miles in size. The stream in the watershed are tributaries of 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.

Total Maximum Daily Loads (TMDLs) apply to 3.3 miles of streams in the watershed (Stream Segment ID#s 980515-1347-GLW and 980515-1348-GLW). They were developed to address the impairments noted on Pennsylvania’s 1996 and 2002 Clean Water act Section 303(d) List. The impairments are primarily caused by sediment loads from construction sites, and water/flow variability and other organics from a municipal point source in the watershed. The listing for other organics is addressed separately in the “point source” section of this document (i.e., Section D). The water/flow variability is not addressed in this TMDL because it is assumed that BMPs that will be implemented to control siltation from urbanized areas will also decrease this flow variability. Therefore, this TMDL focuses on control of sediments.

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 Neshaminy Creek Tributary #3 watershed. Based upon comparison to a similar, non-impaired watershed, it was estimated that the sediment loading must be limited to 292,667 pounds 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 Creek Tributary #3 is allocated as shown in the table below.

Summary of TMDL for Neshaminy Creek Tributary #3 (lbs/yr)						
Pollutant	**TMDL**	**MOS**	**WLA**	**LA**	**LNR**	**ALA**
Sediment	292,667	29,267	263,400	-	-	-

The TMDL is allocated primarily to non-point source loads from construction sites (transitional land use) 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 3.3 miles of the streams in this watershed, and establishes a reduction for sediment loading from land construction (transitional land use) and stream bank erosion of 75% from the current annual loading of 1,054,746 pounds.

C11.0 INTRODUCTION

C11.0.1 Watershed Description

The Neshaminy Creek Tributary #3 watershed is located in the Piedmont physiographic province and is in Bucks County. It covers an area of approximately 2.9 square miles. The streams in the watershed drain directly into the main stem of Neshaminy Creek. The watershed is located north of the town of Jamison and can be reached via Pennsylvania Route 263 from the east. Figure C11.1 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 Neshaminy Creek Tributary #3 is warm water fishes and migratory fishes.

The current land use distribution in the Neshaminy Creek Tributary #3 watershed was developed by updating the National Land Cover Data (NLCD) layer described by Vogelmann et al. (1998) using a recent 10-m colorized panchromatic SPOT (System Probatoire pour l'Observation de la Terre) satellite image. The NLCD layer was based primarily on 1992 Landsat Thematic Mapper (TM). SPOT imagery was acquired in 2000 and is available for the entire Commonwealth of Pennsylvania at the Pennsylvania Spatial Data Access (PASDA) site (http://spot.pasda.psu.edu) at no charge. The primary land uses in the watershed include developed land (38%), which includes low and high intensely developed and transitional land use, woodland (33%), and agricultural land (29%). It is important to note that development in the watershed increased from 10% to 38% from 1992 to 2000. The 1994 and 2001 surveys showed that sediment from construction sites deposited in large quantities on the streambed and was degrading the habitat of bottom-dwelling macroinvertebrates. Therefore, for the purposes of this watershed assessment, the amount of land in development during this time period (about 560 acres) was considered to be "transitional" land when modeling current conditions (see additional explanation below).

Figure C11.1. Neshaminy Creek Tributary #3 watershed.

The surficial geology of the Neshaminy Creek Tributary #3 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 C11.1.

Table C11.1. Physical Characteristic Comparisons between the Neshaminy Creek Tributary #3 and Reference Watersheds

Attribute	Neshaminy Creek Tributary #3	Reference Watershed
Physiographic Province	Piedmont	Piedmont
Area (square miles)	2.9	3.2
Predominant Land Uses	- Developed land (38%) - Agriculture (29%)	- Developed land (33%) - Agriculture (49%)
Predominant Geology	Sandstone (60%) Shale (40%)	Shale (100%)
Soils - Dominant HSG	C	C
- K Factor	0.37	0.38
20-Year Average Rainfall (in)	40.4	41.4
20-Year Average Runoff (in)	4.1	4.1

C11.0.2 Surface Water Quality

A Total Maximum Daily Load or TMDL was developed for the Neshaminy Creek Tributary #3 watershed 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 Creek Tributary #3 was not meeting its designated water quality uses for protection of aquatic life in 1994 based on an aquatic biological survey. The 2001 survey found that this stream segment was still impaired. As a consequence, Pennsylvania listed the stream segments in this watershed on the 1996 and 2002 Section 303(d) Lists of Impaired Waters.

The 1996 303 (d) List reported 2 miles of streams in the watershed (Stream Segment ID# 980515-1347-GLW) to be impaired by siltation from construction, and water/flow variability and other organics due to municipal point sources. The 2002 303 (d) List added 1.3 miles (Stream Segment ID# 980515-1348-GLW) to be impaired by siltation from construction.

Sediments, which are often the cause of stream impairment in urban and suburban areas, are primarily from two sources: 1) disturbed land and unprotected soils at construction sites, and 2) stream channel erosion. New construction sites are one of the main sources of sediments in streams. 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, 1990). 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 events were observed during a reconnaissance survey of the Neshaminy Creek Tributary #3 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 this watershed. Without effective storm water management practices and sediment traps, build-up of sediments will continue to occur in these stream segments.

C11.1 APPROACH TO TMDL DEVELOPMENT

C11.1.1 TMDL Endpoints

This particular TMDL 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 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 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. 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 were determined using a sub-area of the Ironworks Creek watershed at the lower end of Neshaminy Creek as the reference watershed. The listing for impairment caused by siltation is addressed through reduction to the sediment load. A detailed explanation of this process is included in the following sections.

Stream segments of the Neshaminy Creek Tributary #3 watershed were found to be impaired by siltation as a result of construction in 1994 and 2000. This TMDL considers that developed land (10% of the 1996 land use distribution) to be primarily construction sites/newly developed land and therefore an important source of sediments in the creek. The additional development between 1992 and 2000 was considered construction sites/newly developed land as well. Therefore, the cause of impairment, construction sites, consisted of "transitional" land uses. It appeared from our reconnaissance surveys in the watershed that siltation presently observed in Neshaminy Creek Tributary #3 is the result of years of a build-up of sediments in the channel bottom that started in the early 1990's. These sediments originated from disturbed and unprotected soils at construction sites and increased channel bank erosion during periods of intense storm events.

C11.1.2 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 attaining designated water uses. The second factor is to find a watershed that closely resembles the Neshaminy Creek Tributary #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 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 Tributary #3 watershed was obtained by screen-digitizing a sub-watershed of the Ironworks Creek watershed at the lower end of Neshaminy Creek. This watershed is also located in the Piedmont physiographic province and in State Water Plan (SWP) Basin 2F. Table C11.1 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 C11.2 shows the reference watershed boundary and its location in Bucks County.

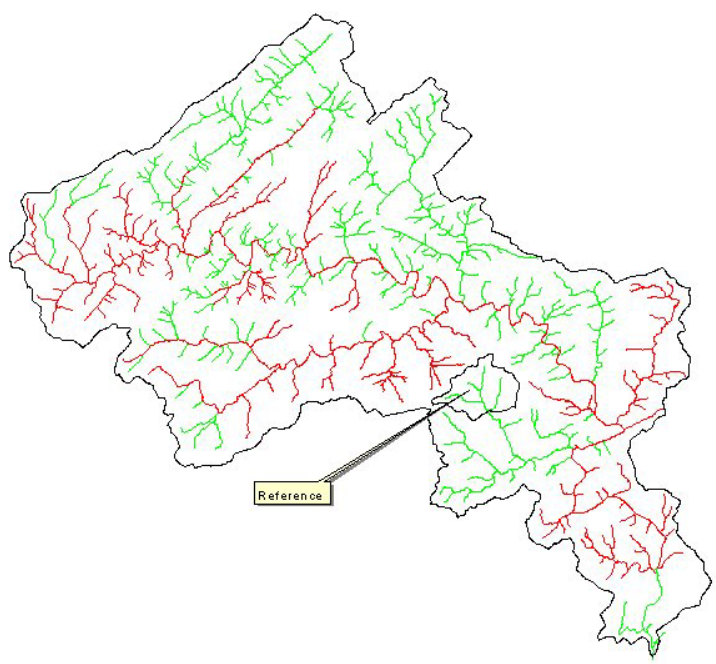

Figure C11.2. Reference watershed location.

An analysis of the MRLC land use/cover grid for the area revealed that land use distributions in both watersheds are somewhat similar. The surficial geology of the Neshaminy Creek Tributary #3 watershed is shale and sandstone, and it is primarily sandstone in the reference watershed. A look at the attributes in Table C11.1 indicates that these watersheds also compare very well in terms of average runoff, precipitation, and soil K factor.

C11.1.3 Water/Flow Variability due to Municipal Point Source

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

C11.1.4 Other Organics due to Municipal Point Source

The "other organics" listing refers to problems in this reach associated with nutrients and excessive aquatic plant growth. As discussed in Section D, it has been determined that nuisance aquatic plant growth problems are associated with excessive amounts of the limiting nutrient in this watershed (i.e., phosphorus). These specific problems are addressed separately in Section D of this document.

C11.1.5 Siltation from Construction Sites

The TMDL for the Neshaminy Creek Tributary #3 watershed addresses sediment from construction sites and from stream bank erosion. As indicated above, existing developed areas in the watershed were considered to be "transitional" land use for modeling purposes since sediment impairment from constructions sites were observed in 1994 and 2001. 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.

C11.1.6 Watershed Assessment and Modeling

The AVGWLF model was run for both the Neshaminy Creek Tributary #3 and reference watersheds to establish loading conditions under existing land cover use 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 loads for sediment for the impaired and reference watersheds were calculated as shown in Tables C11.2 and C11.3, respectively. Table C11.4 presents an explanation of the header information contained in Tables C11.2 and C11.3. Modeling output for both watersheds is presented in Appendix F.

Table C11.2. Loading Values for the Neshaminy Creek Tributary #3 Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	136	4,569	33.60
Cropland	395	102,539	259.59
Coniferous Forest	7	0	0.00
Mixed Forest	131	352	3.882.70
Deciduous Forest	467	1,832	3.92
Transition	560	870,839	1,555.07
Low Intensity Developed	89	3,642	40.92
High Intensity Developed	42	1,302	31.00
Stream Bank		69,536	
Groundwater			
Point Source			
Septic Systems			
Total	1,827	1,054,611	577.2

Table C11.3. Loading Values for the Reference Watershed			
Land Use Category	*Area (acres)*	*Sediment Load (lbs/year)*	*Unit Area Sediment Load (lbs/acre/yr)*
Hay/Pasture	622	36,490	58.67
Cropland	528	163,996	310.60
Coniferous Forest	25	44	1.76
Mixed Forest	210	662	3.15
Deciduous Forest	160	375	2.33
Transition	17	17,461	29.90
Low Intensity Developed	646	46,843	72.12
High Intensity Developed	106	4,636	43.74
Stream Bank		100,662	
Groundwater			
Point Source			
Septic Systems			
Total	2,317	371,169	160.19

Table C11.4. Header Information for Tables C11.2 and C11.3.	
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

C11.2 LOAD ALLOCATION PROCEDURE FOR SEDIMENT TMDL

The load allocation and reduction procedures were applied to the entire Neshaminy Creek Tributary #3 watershed. The load reduction calculations in the watershed are based on the current loading rates for sediment in the reference watershed. Based on biological assessment, it was determined that streams in the reference watershed were attaining their designated uses. The 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 Tributary #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 “construction” was listed as the primary source of sediment to impaired streams in this sub-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.

C11.2.1 Sediment TMDL Total Load

The first step was to determine the TMDL total target load for Neshaminy Creek Tributary #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 Tributary #3. This information is presented in Table C11.5.

Table C11.5. TMDL Total Load Computation			
Type of Pollutant	*Unit Area Loading Rate in Reference Watershed (lbs/acre/yr)*	*Watershed Area of Neshaminy Tributary #3 (acres)*	*TMDL Total Load (lbs/yr)*
Sediment	160.19	1,827	292,667

C11.2.2 Margin of Safety

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

Sediment = 292,667 lbs/yr x 0.1 = 29,267 lbs/yr (2)

C11.2.3 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. 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 (Sediments) = 292,667 lbs/yr – 29,267lbs/yr = 263,400 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.

C11.2.4 Load Reduction Procedures

The allocation of sediment among contributing sources in Neshaminy Creek Tributary #3 was done by reducing each source equally on a percentage basis. Based on the target WLA of 263,400 lbs/year described above, the computed load allocations are as shown in Table C11.6.

The total allowable sediment load in Neshaminy Creek Tributary #3 when all land use/cover sources are considered is 263,400 lb per year. In order for all stream segments to attain their specific uses, total sediment loads should be reduced from 1,054,746 pounds per year (i.e., sediment loads should be reduced by 75%).

Table C11.6. 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/Pasture	136	33.60	4,569	1,141	75
Cropland	395	259.59	102,539	25,610	75
Coniferous Forest	7	0.00	0	0	75
Mixed Forest	131	3.882.70	352	87	75
Deciduous Forest	467	3.92	1,832	456	75
Transition	560	1,555.07	870,839	217,515	75
Lo Intensity Dev	89	40.92	3,642	908	75
Hi Intensity Dev	42	31.00	1,302	323	75
Stream Bank			69,536	17,360	75
Groundwater					
Point Source					
Septic Systems					
Total	1,827	577.2	1,054,611	263,400	75

C11.3 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.

C11.4 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.

C11.5 REASONABLE ASSURANCE OF IMPLEMENTATION

Sediment reductions in the TMDL are allocated to transitional land uses and stream bank erosion in the watershed. Implementation of best urban 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 and ditches. 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 Neshaminy Creek Tributary #3 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.

C11.6 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.

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

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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.

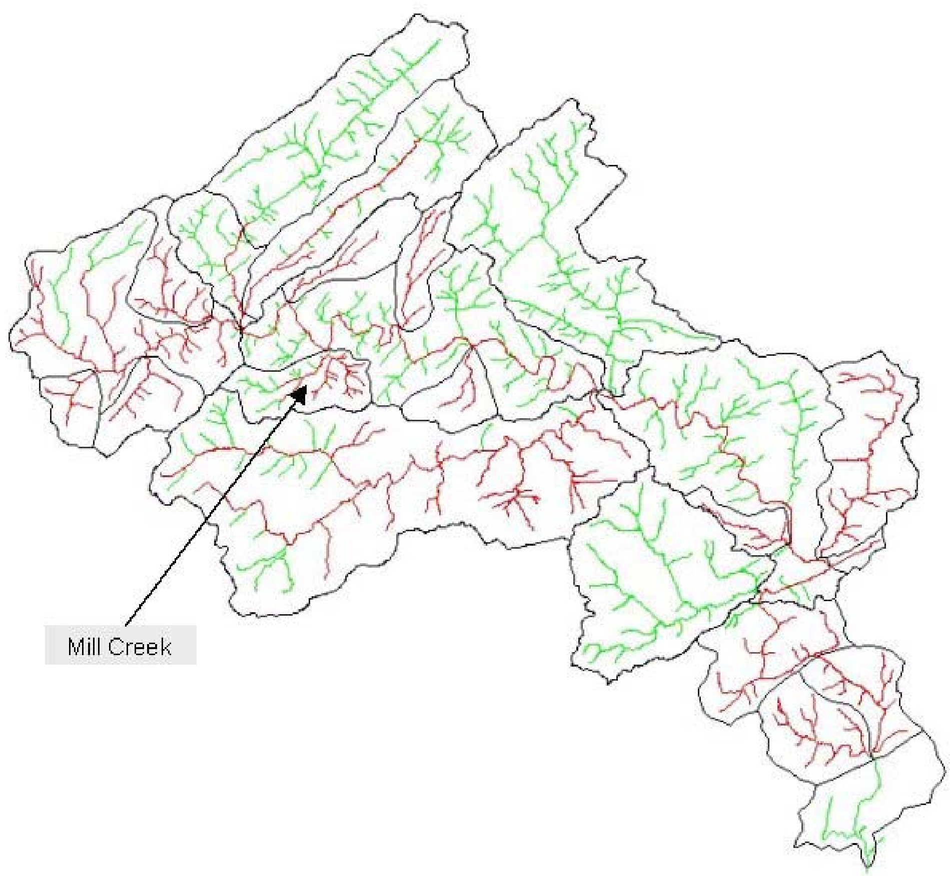

Figure C12.1. Location of Mill Creek sub-watershed.

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.

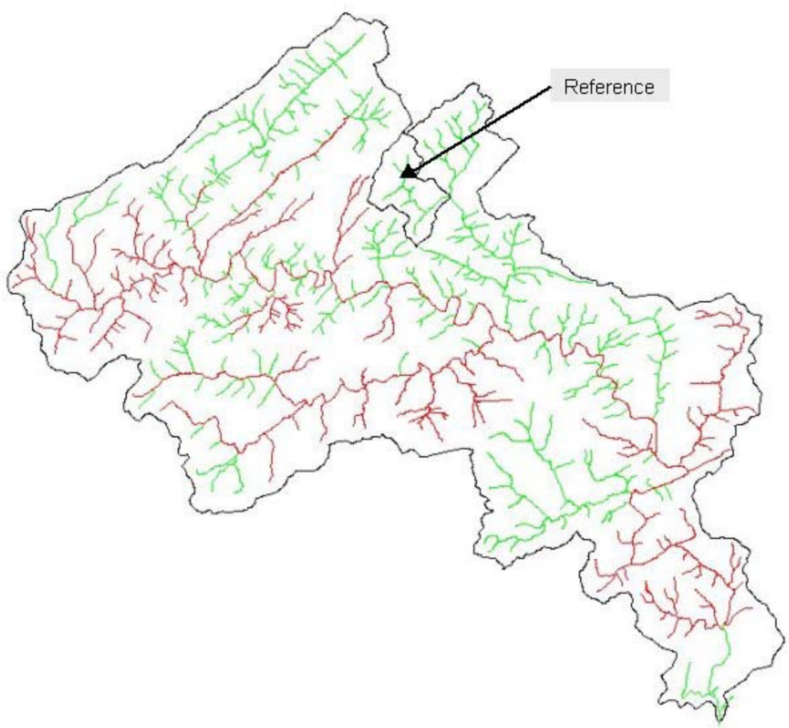

Figure C12.2. Reference watershed location.

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

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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.